ANALYTICAL MODELING OF FOUNDATIONS FOR SEISMIC ANALYSIS OF BRIDGES

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16. ABSTRACT

The response of bridges when subjected to seismic excitation may be significantly influenced by the dynamic properties of their foundations. With current design practice, foundation elements are typically considered as elastic springs without consideration of material and radiation damping.

The objectives of this research were to identify general foundation models that are suitable for modeling soil-structure interaction in seismic bridge analysis, to modify an existing nonlinear seismic bridge analysis computer program to include a new element capable of representing such models, and to conduct a parametric study to assess the effect of the increased energy dissipation mechanisms on the response of bridge substructures.

For spread footing foundations, three different models were identified and applied to a typical two-column bridge bent. For pile foundations, four models were derived and applied to a five-column bent. The seismic response for each model was compared with conventional elastic and fixed-base models. Several soil stiffness values and earthquake records were considered for analysis. Maximum values of displacement, plastic hinge rotation, and cumulative plastic hinge rotations were noted and compared.

It was concluded that the use of the foundation models can produce an important change in the bridge response when compared to that of the fixed-base model, depending on the frequency content of the earthquake and the stiffness of the soil. The effects of radiation damping were observed to be insignificant for foundations on stiff soil, but important for those on soft soil. In addition, the performance of the simpler damped foundation models was found to be quite similar to that of the more complex models.

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Summary

The response of bridges when subjected to seismic excitation may be significantly influenced by a number of mechanisms that are not currently incorporated into typical analysis methods. In particular, the dynamic interaction of the bridge foundations with the founding soil is the subject of the research presented in this report.

The objectives of the research were to determine foundation models suitable for incorporation into the seismic analysis of highway bridges, to modify the nonlinear seismic bridge analysis computer program NEABS to include a new element capable of representing the foundation models, and to conduct a parametric study to assess the performance of the foundation models relative to conventional fixed-base analysis in terms of their effects on the seismic response of two bridge bents.

Four models applicable to modeling spread footing foundations and four models applicable to modeling pile foundations were identified. A new element to represent these foundation models and other nonlinear soil reaction mechanisms, the "Discrete Foundation element," was designed and implemented within NEABS.

Two bents from Washington bridges were selected to be the subjects of the parametric study, one supported on the spread footing models, the other on the pile foundation models. Various seismic records were applied

to the bents in the transverse direction and the response of each bent was studied.

It was concluded that inclusion of the foundation models can produce a significant difference in predicted bridge response, depending on the frequency content of the earthquake and the stiffness of the soil. In some cases, the fixed-base bent models resulted in column demands that were unconservative compared with those obtained using the foundation models. Relatively simple models were found to be adequate for modeling both spread footing and pile foundations. NEABS, equipped with the Discrete Foundation element, is capable of being used to further explore the effects of soil–foundation interaction on the seismic response of bridges.

Chapter 1

Introduction

1.1 Context and Problem Statement

The response of bridges when subjected to seismic excitation may be significantly influenced by a number of mechanisms that are not currently incorporated into typical analysis methods. The interaction of the bridge superstructure with the abutments has been the cause of significant damage in past earthquakes [1 and 2]. Although damage to other foundation elements, such as spread footings and pile caps, has been shown to be minimal, the dynamic characteristics of these components have important effects on the behavior of the bridge [3, 4, 5, and 2], especially when the founding soil is soft [6]. Current design practice does not consider the effects of soil–structure interaction [7], and little emphasis is placed upon studying the role of foundations in the seismic analysis of bridges [2 and 8]. Current design guidance is simplistic in that the foundation elements are considered to behave as linear springs [9 and 2], although research has shown that a significant amount of seismic energy is dissipated through the material and radiation damping associated with

the founding material [10]. The effects of expansion joint gaps and the material nonlinearity of the soil at the abutments are approximated by manually varying the support spring constants such that the soil strength is not exceeded. However, important additional nonlinearities at abutments result from the force developed in the abutment key [5] and the energy loss due to impact during expansion joint gap closure [11]. The assumption of elastic springs at the abutments has been reported to be unconservative [12].

The influence of pile foundations has been included through the use of coupled translational and rotational springs. Nonlinearities arise from inelastic soil behavior and connection details at the pile cap [3]. Other important effects include the dissipation of energy due to outward propagation of waves induced in the soil by the vibration of the structure (referred to as "radiation" damping), the degradation of soil stiffness that occurs during cyclic loading [13], the loss of strength in the soil due to liquefaction, and the influence of pile group behavior. In addition, hysteretic damping may be intentionally included in the bridge design through the use of base isolation techniques [14, 15, and 16].

For certain bridge configurations, the assumption that the seismic excitation is uniform at all supports is not valid [17]. Differential movements may be introduced that tend to alter, and possibly amplify, the response [18]. Typically, asynchronous ground motion, or ground motion which is not uniform at all supports, is important for long bridges, such as

suspension and some arch bridges [19, 20, 21, and 22]. However, this effect can also be significant for foundations in which soil properties vary greatly between supports.

Currently, Washington State Department of Transportation (WSDOT) engineers use the computer program, SEISAB–I [23], to perform the seismic analysis of bridges. SEISAB–I is convenient because it was developed specifically for bridges with features that correspond directly to field data and to design guidance documents. However, this program has the capability to perform elastic analyses only. Energy dissipation is accomplished through "Rayleigh", or "proportional" damping, in which a unique damping coefficient is assigned to each of the structure's modes of vibration. Concentrated dampers, such as those that would occur at foundations, are not documented.

As an alternative to SEISAB–I for the seismic analysis of bridges, the computer program NEABS [24] was obtained for this research project. As delivered, it has the ability to incorporate into the analysis plastic column end hinging, elastic supports, a nonlinear expansion joint element, and multiple support excitations.

1.2 Research Objectives

The capability to more realistically model soil–foundation interaction mechanisms in the analysis of bridge seismic response is desired. Toward

that end, the objectives of this research were as follows:

1. To review and evaluate techniques that are employed to model soil–structure interaction and to identify models appropriate for representing typical bridge foundations.

2. To modify the nonlinear bridge analysis program NEABS, adding a new element capable of representing the foundation models and nonlinear soil mechanisms.

3. To evaluate the foundation models in terms of their effects on the predicted seismic response of bridges.

This report documents the findings of the research. Chapter Two, "Research Approach," discusses proposed foundation models, and describes the modification of NEABS to include the new "discrete foundation" (DF) element. A parametric study of the effects of the foundation models, using the DF element, on the predicted seismic response of two Washington bridges is presented in Chapter Three, "Findings and Interpretation." Based on the results of the parametric study, conclusions and recommendations pertinent to seismic bridge analysis needs of the Washington Department of Transportation (WSDOT) are developed in Chapter Four "Conclusions", as well as guidance on the implementation of NEABS for the seismic analysis of bridges.

Chapter 2

Research Approach

2.1 Introduction

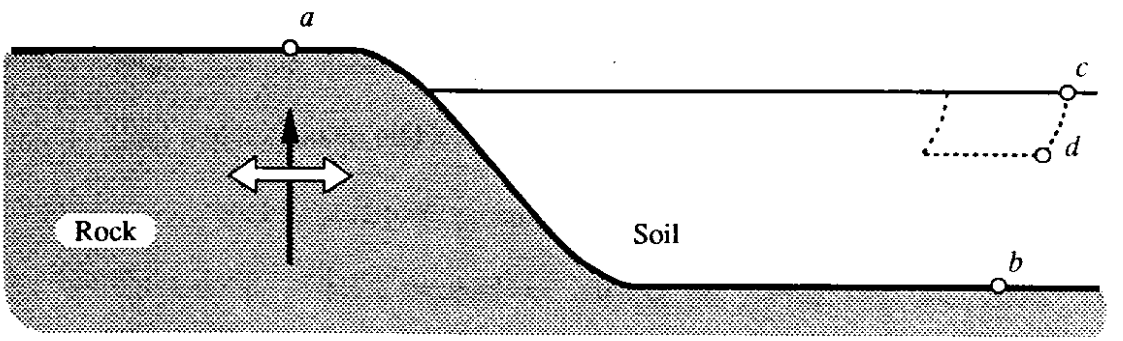
In this chapter, analytical models of foundations that have been used by various researchers are presented, and the modification of the bridge analysis program NEABS to accommodate these methods is described. First, the dynamic interaction of a structure and its founding soil is discussed qualitatively. Next, the soil–foundation modeling concept of the "half-space" is introduced. Various researchers have used this concept to construct discrete foundation models applicable to the dynamic analysis of structures founded on spread footing or pile foundations. The analysis program NEABS was used in the present research project to investigate the effects of these models on the seismic response of bridges. In order to incorporate the foundation models in NEABS analyses, the program was modified to include a new element capable of representing the models' behavior. The NEABS program and the new element that was added are described, as well as the testing program undertaken to verify the new element's performance.

2.1.1 *Soil–Structure Interaction*

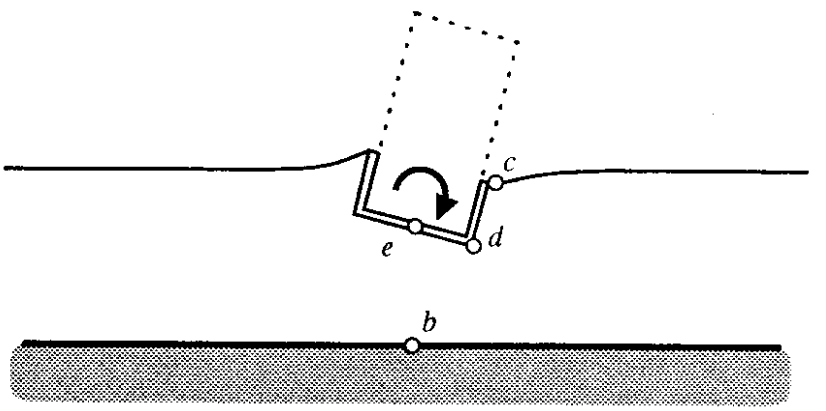
The influence of a bridge's foundations on the dynamic response of the bridge is an example of what is termed "soil–structure interaction." This phenomenon has been the subject of research dating from the early 1900's, but it has received increasing attention since the 1970's. To gain a general understanding of the issues involved in soil–structure interaction, the following discussion focuses on three component mechanisms of soil–structure interaction, following Wolf [25].

Figure 2.1 shows a structure founded on a soil layer which overlies bedrock. The bedrock, assumed to be essentially rigid, is subjected to vertically propagating horizontal excitations, which are recorded at point a of Figure 2.1(a). Point b, which lies on the bedrock–soil layer interface directly underneath the structure, may be expected to experience the same motions as point a. However, because of the response of the soil layer to the bedrock excitation, the ground motions at points c and d that would be recorded at the structure site without the presence of the structure, called the site "free-field" motions, would in general be different from each other, and often greater than those recorded at point a. Because it is the site free-field motions which are relevant to determining the response of the structure, recorded earthquake motions may not be applicable as seismic input to a discrete analysis of the structure if the structure's founding conditions are significantly different from those at the location of the

(a) Site Free-Field Motions



(b) Kinematic Interaction



(c) Inertial Interaction

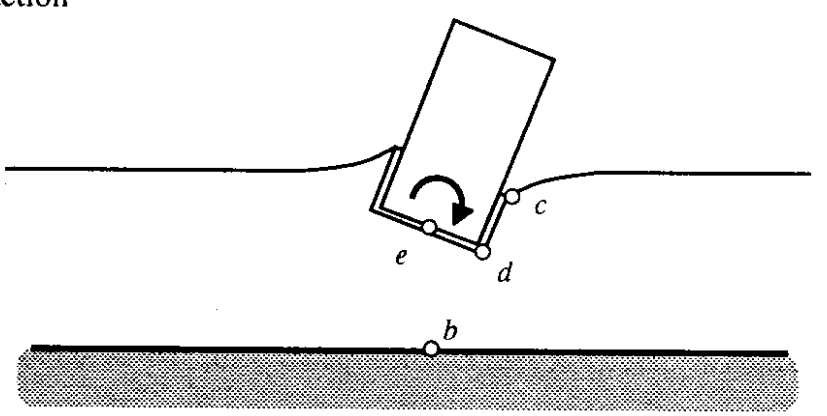


Figure 2.1: Soil–structure interaction mechanisms: (a) modification of the site free-field motions due to the response of the soil layer; (b) kinematic interaction of the soil layer and foundation stiffness; (c) inertial response of the structure causing further interaction. Adapted from [25].

recording instrument. As an example, in the study by McLean and Cannon of the seismic response of the westbound Interstate 90 bridge over the Mercer Slough [26], it was found necessary to use input excitation records obtained by a seismic analysis of the slough itself [27].

Kinematic interaction is caused by coupling the structure foundation with the soil layer, as shown in Figure 2.1(b). The stiffness of the foundation will modify the site free-field motions at points c and d, causing some averaging of the translational component and the introduction of a rotational component, as shown at point e. It is seen that this causes a different vertical distribution of lateral forces on the structure than would be experienced had the structure been founded on bedrock. Inertial interaction, shown in Figure 2.1(c), arises when the structure, with its stiffness, damping, and mass characteristics, is introduced. As the structure reacts to the imposition of the kinematic interaction-modified motions, forces are transmitted to the soil through the foundation, causing deformation of the soil and further modification of the motion at points c, d, and e.

Three commonly exhibited effects of these mechanisms may be identified [25]. First, the site free-field translational response is amplified and a rocking component is introduced. Second, the flexibility of the total dynamic system (which includes both the structure and the founding soil), and the corresponding natural period, is increased. Third, damping in the total system is increased, due to both the material hysteretic action of the

soil and to what is termed "radiation," or "geometric" damping. This refers to the apparent damping of the system caused by the radiation of energy away from the structure in the form of outward-propagating waves.

To obtain the seismic response of a structure, it is common to employ analysis techniques that mathematically discretize the structure, such as computer programs using the finite element method. Two general approaches are available for rationally incorporating soil–structure interaction, or at least its effects, into this type of structural analysis [25]. In the "direct method," the structure and the founding soil, or at least as much of the soil as is feasible, are incorporated into the finite element mesh. Conceptually, this is the simplest approach, but several drawbacks make its use prohibitive for all but the most extreme analysis demands. Because both the soil and the structure are modeled, the system may contain many more degrees-of-freedom than the structure alone, making the analysis computationally expensive. Developing appropriate soil elements based on available soil data may also be difficult. Additionally, the finite soil–structure system model restricts the outward propagation of soil waves that occurs in the essentially infinite real system, unless "boundary elements" or "infinite elements" are used at the system boundary to artificially model this effect. Failure to compensate for this boundary problem has the effect of unrealistically reducing the effective damping of the system model.

An approach more amenable for common structural analysis is the "substructure method." In this method, the structure and the soil are analyzed separately. First, the soil is analyzed alone, loaded dynamically at the interface between the soil and the structure. This system is analyzed in terms of the response of the interface to determine the effective dynamic characteristics of the soil that the structure will experience. Next, a simplified model is used to reproduce, or approximate, the behavior of the soil at the interface. This simplified model is then coupled with the structure model at the interface, and the structure–simplified model system is analyzed.

Rather than developing simplified soil–structure interface models for every structure to be analyzed, it is more practical to use models that have already been developed for this purpose. A number of these models will be presented in the following sections.

2.1.2 Half-Space Analogy

In order to create a simplified soil–structure interface model, the response of the soil at the interface must first be obtained. One of the most common analytical methods of doing this is to model the soil as an elastic or visco-elastic "half-space" continuum. The half-space continuum is a mathematical idealization of the soil as a medium with a flat surface extending horizontally in all directions to infinity, and having infinite depth. The half-space is assumed to have mechanical properties which

correspond to those of the soil; the elastic half-space is assigned a mass density, ρ, a shear modulus, G, and a Poisson's ratio, ν. The half-space may be made visco-elastic (corresponding to an effective viscous soil material damping) by also giving it a viscous damping ratio, ξ.

The response of the half-space may be analyzed using continuum mechanics, as will be discussed. Since the half-space continuum is a semi-infinite model, it does not have the energy reflecting boundary problem inherent in a finite element discretization of the soil. Thus, the elastic half-space correctly models radiation damping, given the assumption of soil linear elasticity. However, the constraint to elastic behavior renders the half-space continuum model more applicable for representing the soil away from the immediate vicinity of the structure (the soil "far-field"), since the behavior of the soil near the structure (the soil "near-field") is often nonlinear under seismic conditions.

2.1.3 Spread Footing Foundation Models

The method in which the half-space continuum model is used to create simplified discrete interface models applicable to representing spread footing foundations is illustrated in Figure 2.2. As shown, a rigid disk of radius r, representing the structure foundation, is assumed to be bonded to the surface of the half-space. The half-space, or soil, is assigned

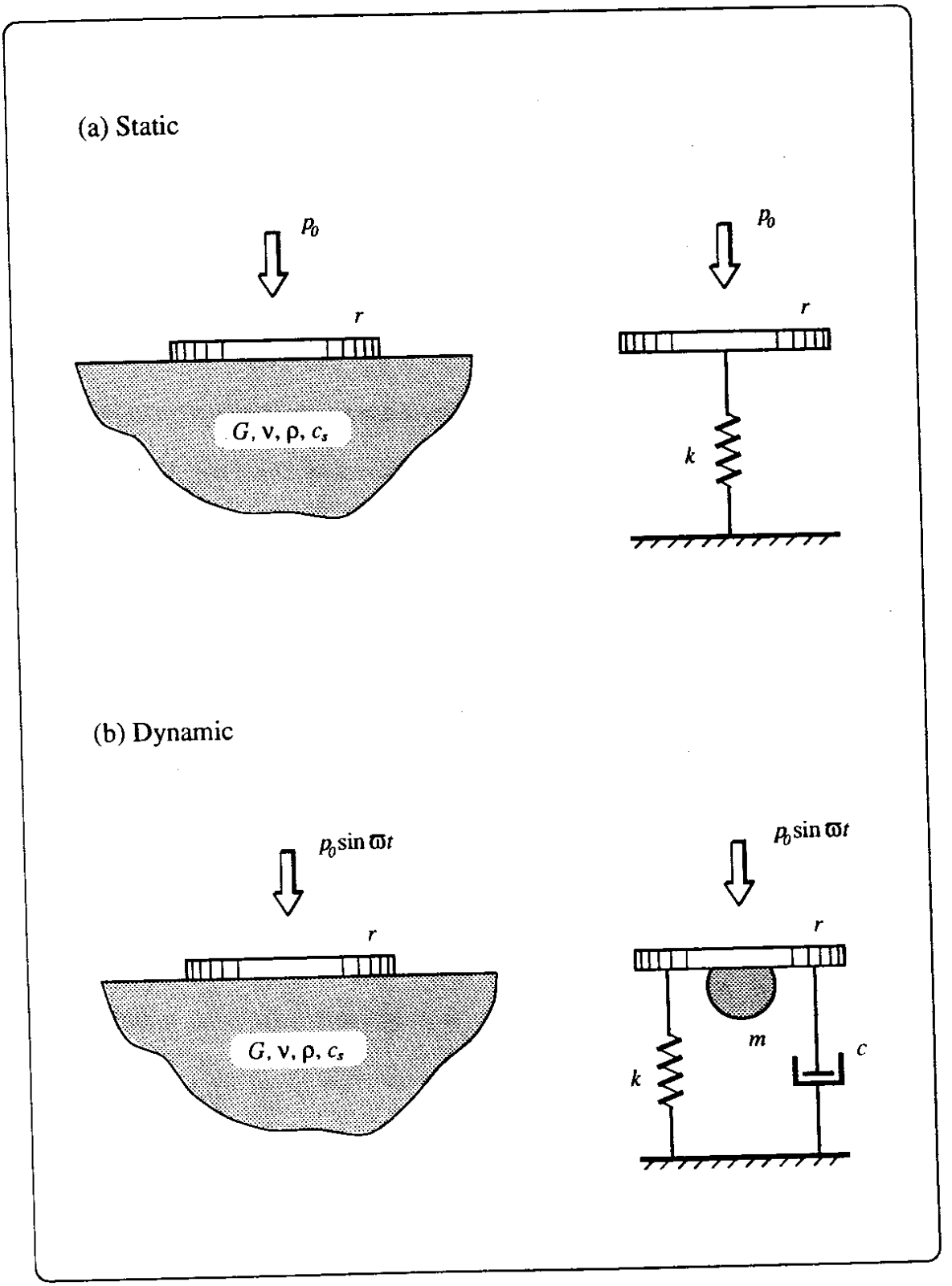


Figure 2.2: Modeling the disk–half-space continuum system as a discrete system: (top) equivalent static spring produces the same static displacements; (bottom) selection of parameters k, c, and m to produce the same displacement response to harmonic loading.

the properties discussed earlier, as well as a shear wave velocity, c_s, which is related to the soil mass density and shear modulus as follows:

$$c_s = \sqrt{\frac{G}{\rho}} \tag{2.1}$$

The disk–half-space system is subjected to either a static or a dynamic load, and the disk response is obtained using continuum mechanics. The parameters of a discrete system are then selected to produce the same response. The discrete system serves as the interface model in the analysis of the structure itself, incorporating the effects of soil–structure interaction. This approach was used as early as 1904, as documented by Richart *et al.* [28]. This reference provides an excellent review of the development of the half-space model, as well as other soil–structure interaction issues, prior to 1970.

When the applied loading is static, the equivalent discrete model uses springs to represent the half-space static stiffness. Because the disk and the half-space are axially symmetric, the disk has four degrees-of-freedom: horizontal and vertical translation, rocking (rotation about a horizontal axis), and torsional rotation (rotation about the vertical axis). Four uncoupled springs are used to represent the half-space static stiffness, one spring being applied to each degree-of-freedom. Such a static discrete model is represented in Figure 2.2. The figure shows the vertical spring only, it being understood that the model's configuration is the same in each

of the four degrees-of-freedom. The stiffness of the springs are selected to produce the same static displacements as those experienced by the disk on the half-space. These static stiffnesses are well established in the literature as follows:

$$
\begin{aligned}
k^s_x &= \frac{8G}{2-\nu} r && \textit{horizontal translation} \\
k^s_z &= \frac{4G}{1-\nu} r && \textit{vertical translation} \\
k^s_{\theta x} &= \frac{8G}{3(1-\nu)} r^3 && \textit{rocking rotation} \\
k^s_{\theta z} &= \frac{16}{3} G r^3 && \textit{torsional rotation}
\end{aligned}
\tag{2.2}
$$

where k^s_i ≡ equivalent static spring stiffness for the i^{th} degree-of-freedom

r ≡ radius of disk

G ≡ shear modulus of the half-space (soil)

ν ≡ Poisson's ratio of the half-space (soil)

When the loading is dynamic, a more complicated discrete model is required. Because the continuum mechanics analysis of the dynamically loaded disk–half-space is typically carried out in the frequency domain, the dynamic load is formed as the superposition of a series of harmonic loads. Figure 2.2 shows a harmonic load being applied to the disk–half-space system and to a simple discrete system utilizing a spring, mass, and dashpot acting in the vertical degree-of-freedom. Again, the model's

configuration in the other three degrees-of-freedom is the same as in the vertical degree-of-freedom. Values for these three discrete model parameters are selected to produce the same displacement response as that experienced by the disk–half-space system. Veletsos and Verbič report that only two of these three discrete model parameters are independent, so the spring stiffness may arbitrarily, but conveniently, be set to the value of the static spring stiffness [29]. They then express the discrete system parameters as follows:

$$\begin{aligned} k_i &= k^s{}_i \\ c_i &= \beta_i k^s{}_i \left(\frac{r}{c_s}\right)^2 \\ m_i &= \gamma_i k^s{}_i \left(\frac{r}{c_s}\right)^2, \qquad \gamma_i \equiv \left(\frac{1 - \alpha_i}{a_0{}^2}\right) \end{aligned} \tag{2.3}$$

where c_s ≡ shear wave velocity of the half-space (soil)

a_0 ≡ dimensionless loading frequency parameter; $a_0 \equiv \varpi r / c_s$

k_i, c_i, m_i ≡ stiffness, damping, and mass parameters for the equivalent discrete system

α_i, β_i ≡ dimensionless coefficients

The value of the coefficients α_i and β_i depend upon Poisson's ratio of the soil and upon the frequency of the loading. As an example of this dependency, Figure 2.3 shows plots of α_i and β_i versus the dimensionless loading frequency parameter, a_0, as determined by Veletsos and Wei [30],

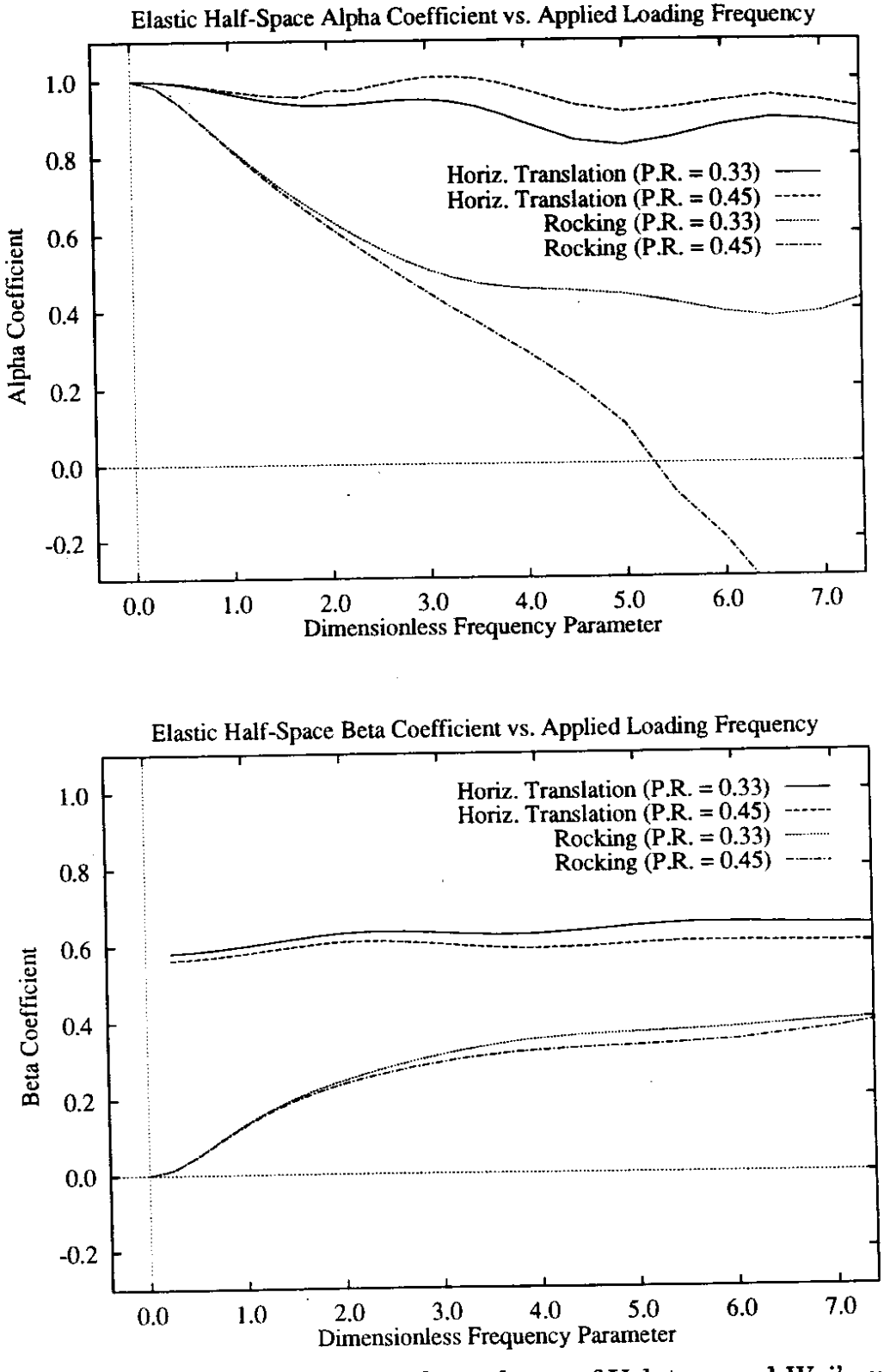


Figure 2.3: Graphs showing the dependence of Veletsos and Wei's α and β parameters (ordinates) on the applied harmonic loading frequency parameter, a_0 (abscissae). Graphs show α and β for horizontal translation and rocking d.o.f. for two Poisson ratios (P.R. $\equiv \nu = 0.33$ and $\nu = 0.45$).

for two degrees-of-freedom at two different values of Poisson's ratio. Note also that a_o appears directly in the equation for m_i.

Veletsos and Verbič [29] report the following approximate analytical expressions for the coefficients β_i and γ_i appearing in equations (2.3):

$$\begin{aligned} \beta_i &= \rho_{i_4} q_2 + \rho_{i_1} \rho_{i_3}{}^3 s_i a_o{}^2 + 2\frac{\xi}{a_o} \\ \gamma_i &= \rho_{i_3} + \rho_{i_1} \rho_{i_2}{}^2 t_i + \rho_{i_4} q_1 \frac{1}{a_o} \end{aligned} \tag{2.4}$$

where

$$\begin{aligned} s_i &\equiv \frac{q_2}{(q_1 + \rho_{i_2} a_o)^2 + q_2{}^2} \\ t_i &\equiv \frac{q_1(q_1 + \rho_{i_2} a_o) + q_2{}^2}{(q_1 + \rho_{i_2} a_o)^2 + q_2{}^2} \\ q_1 &\equiv \left[\frac{1}{2}(R - 1)\right]^{\frac{1}{2}} \\ q_2 &\equiv \left[\frac{1}{2}(R + 1)\right]^{\frac{1}{2}} \\ R &\equiv \left[1 + (2\xi)^2\right]^{\frac{1}{2}} \end{aligned} \tag{2.5}$$

and $\xi \equiv$ equivalent viscous damping ratio of the half-space (soil)

$\rho_{ij} \equiv$ coefficient j for degree-of-freedom i; function of Poisson's ratio, ν, of the half-space

$\beta_i, \gamma_i \equiv$ coefficients for use in equations (2.3)

Veletsos and Verbič report values for the coefficients ρ_{ij} for half-space Poisson's ratios of $\nu = 0.00, 0.33, 0.45$, and 0.50.

If the equivalent viscous damping ratio is set to zero, ($\xi = 0$), then the visco-elastic half-space becomes an elastic half-space, and equations (2.4) reduce to the following:

$$\beta_i = \rho_{i_4} + \rho_{i_1}\rho_{i_2}\frac{\left(\rho_{i_2}a_0\right)^2}{1+\left(\rho_{i_2}a_0\right)^2}$$
$$\gamma_i = \rho_{i_3} + \frac{\rho_{i_1}\rho_{i_2}^{\,2}}{1+\left(\rho_{i_2}a_0\right)^2} \qquad (2.6)$$

The dependency of the discrete model's parameters on the frequency of the applied loading introduces an analysis problem for nonharmonic loading, such as seismic excitation: a harmonic loading frequency must be chosen to determine the parameter values, and this is the only loading frequency at which the discrete model correctly reproduces the response of the half-space. This problem could be solved by performing the analysis in the frequency domain, expressing the seismic loading as a Fourier series, and using different parameter values for the discrete model in each component harmonic frequency. However, such an analysis relies upon the superposition of component responses, and therefore implicitly assumes linearity. To incorporate important nonlinearities in the system arising from the near-field soil behavior, yielding of structural members, gap development and closure, or other mechanisms, the analysis must be performed in the time domain. This restricts the analysis to a single set

of discrete model parameters; essentially, a loading frequency must be chosen for which the model is assumed to primarily respond.

One approach is to set this frequency to be equal to the fundamental frequency of the structure. The most damaging response of a structure frequently occurs when the fundamental mode of vibration is excited, and choosing this frequency as the basis for determining the discrete model parameter values ensures that the model is working best at this critical condition.

Another approach is to develop a more complicated discrete model. By incorporating more parameters in a model, more complicated response behavior can be achieved. This enables the model to acceptably reproduce the behavior of the half-space over a wider loading frequency range, thus reducing its frequency dependence. If a good fit can be achieved between the response of the discrete model and the half-space over the range of structure periods excited by earthquakes, then the model could be incorporated into analysis as though it was independent of frequency.

Figure 2.4 shows four such discrete models. It should again be pointed out that the figure shows the components of the model that appear in each degree-of-freedom. In a general three-dimensional analysis, incorporation of one of the models would require six of the component configurations shown for that model. It should also be noted that individual components do not necessarily represent real physical quantities. For example, the masses do not represent activated soil mass,

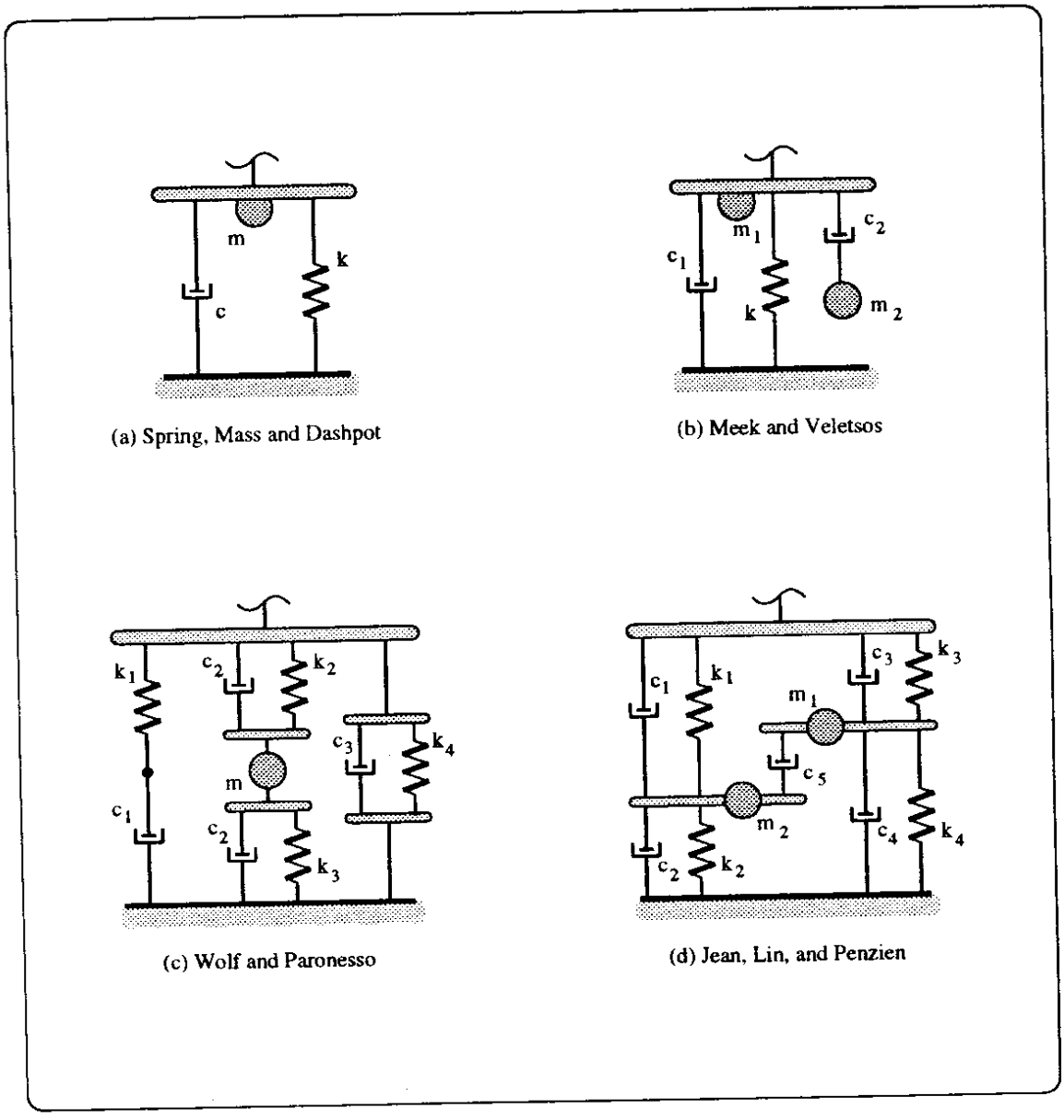


Figure 2.4: Four discrete models of the elastic half-space system: (a) spring–mass–dashpot model, three parameters; (b) Meek and Veletsos model, five parameters [31]; (c) Wolf and Paronesso model, nine parameters [32]; and (d) Jean *et al.* model, eleven parameters [33].

but are present simply to allow the model's behavior to better approximate the response of the half-space, and are thus called "virtual" masses. Additionally, springs and dampers with negative coefficients are sometimes utilized.

The first model shown, Figure 2.4(a), is the spring, mass, and dashpot model already discussed. It connects two nodes, one fixed, the other at the foundation–structure interface. This model will be referred to as a "three-parameter" model because it requires the specification of three parameters per degree-of-freedom. Of the three parameters, two are independent. This model has been used by numerous researchers, but the version presented by Veletsos and Verbič [29] was the one considered in this research. The second model shown was presented by Meek and Veletsos, and its inclusion in the report follows Wolf's discussion of this model [31]. This five-parameter model uses three nodes, one of the nodes being internal to the model. The third model, presented by Wolf and Paronesso [32], is a nine-parameter model, of which six parameters are independent. It uses two internal nodes, requiring four nodes total. The fourth model, presented by Jean, Lin, and Penzien [33], is an eleven-parameter model (ten independent parameters). This model also uses two internal nodes.

The number of independent parameters is directly related to the model's ability to reproduce the behavior of the half-space over a wide frequency band. On the other hand, the number of internal nodes and the

number of parameters that must be specified indicate the complexity involved in incorporating the model in analysis. The methods of determining the values of the discrete model parameters are relatively simple, and require such soil characteristics as mass density, shear modulus, Poisson's ratio, and shear wave velocity. In all cases, the parameter determination method for each model is specified in the reference cited.

Another required characteristic of the soil–foundation system is the disk radius. A foundation, such as a spread footing, may be rectangular rather than circular. For such cases, one approach is to use an effective radius, r^{eff}. Lam, Martin, and Imbsen [34] recommend using the radius of a disk having the same area as the actual foundation as the equivalent radius for the translational degrees-of-freedom, and the radius of a disk with the same spatial moment of inertia as the actual foundation as the equivalent radius for the rotational degrees-of-freedom. (Note that different degrees-of-freedom require different equivalent radii). These radii are additionally modified by "shape" factors. The change in the dynamic characteristics of the foundation due to embedment is also accounted for by modifying the effective radii. This is accomplished by applying "embedment" factors to the radii.

In another approach, Wolf [31] presents static spring stiffnesses developed by Pais and Kausel for the embedded rigid prismatic foundation shown in Figure 2.5. Spring stiffnesses for each of the six degrees-of-

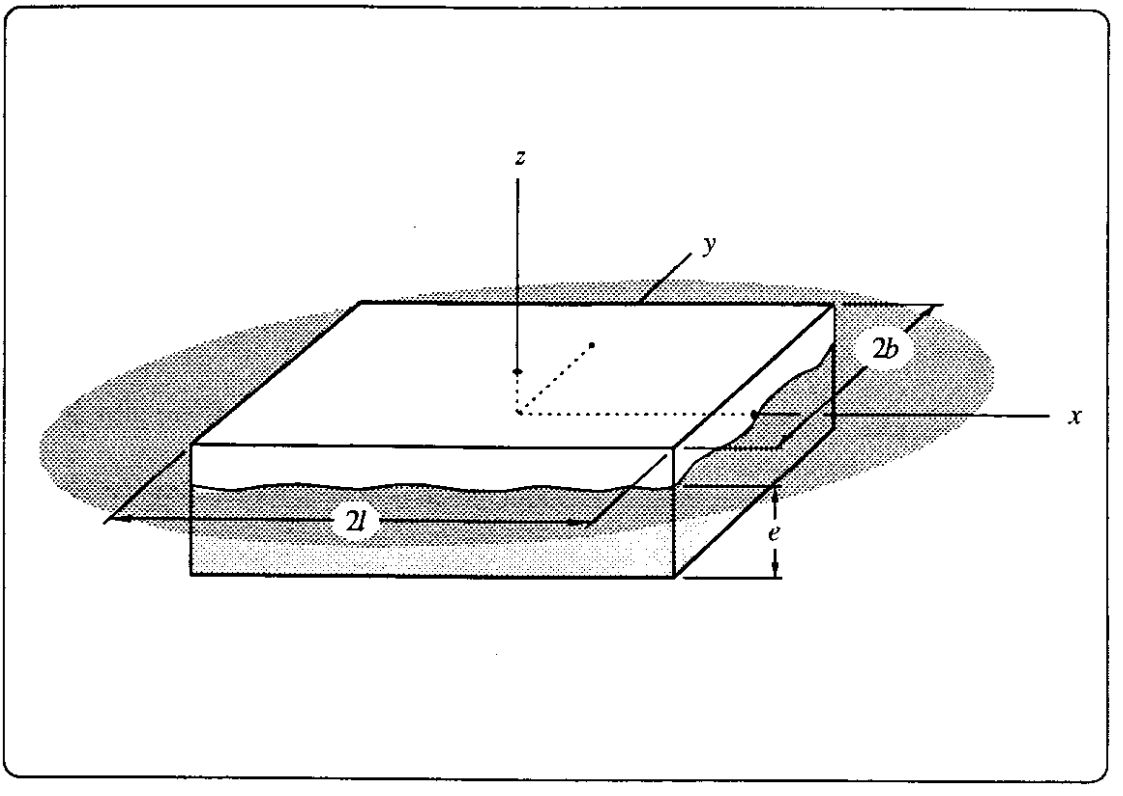


Figure 2.5: Pais and Kausel embedded prismatic foundation [31].

freedom of the foundation are given directly in terms of the dimensions of the foundation. Wolf also shows how the five-parameter Meek and Veletsos model may use these stiffnesses, and he gives values for the model parameters in terms of the foundation width b, instead of an effective radius. However, since most other models use a radius as their characteristic foundation dimension, it is useful to combine the Pais and Kausel stiffnesses with those stiffnesses presented in equations (2.2), and solve for the effective radii. In this manner, analytical expressions for the effective radii are obtained based implicitly on the Pais and Kausel stiffnesses. This allows the effects of foundation shape and embedment, as determined by Pais and Kausel, to be incorporated into each of the discrete models in a manner consistent with the model's development.

The approach presented by Lam *et al.* and the modified Pais and Kausel approach appear to yield comparable equivalent radii, at least over the common range of spread footing foundation dimensions and embedment depths. The Pais and Kausel equivalent radii are determined by the following equations, which assume that $l \geq b$, and that the x-axis is parallel

to the orientation of l, as shown in Figure 2.5:

$$r_i^{equiv} = q_i s_i h_i b \tag{2.7}$$

where

$$\begin{aligned}
q_x &= 1.150 & s_x &= 0.739\left(\frac{l}{b}\right)^{0.65} + 0.261 \\
q_y &= q_x & s_y &= 0.739\left(\frac{l}{b}\right)^{0.65} + 0.087\left(\frac{1}{b}\right) + 0.174 \\
q_z &= 1.175 & s_z &= 0.660\left(\frac{l}{b}\right)^{0.75} + 0.340 \\
q_{\theta x} &= 1.145 & s_{\theta x} &= \left\{ 0.800\left(\frac{l}{b}\right) + 0.200 \right\}^{\frac{1}{3}} \\
q_{\theta y} &= q_{\theta x} & s_{\theta y} &= \left\{ 0.993\left(\frac{l}{b}\right)^{2.40} + 0.068 \right\}^{\frac{1}{3}} \\
q_{\theta z} &= 1.159 & s_{\theta z} &= \left\{ 0.511\left[\left(\frac{l}{b}\right)^{2.45} + 0.955\right] \right\}^{\frac{1}{3}}
\end{aligned} \tag{2.8}$$

$$\begin{aligned}
h_x &= 1 + \left[0.33 + \frac{1.34}{1 + \left(\frac{l}{b}\right)} \right]\left(\frac{e}{b}\right)^{0.8} \\
h_y &= h_x \\
h_z &= 1 + 0.25\left[1 + \frac{1}{\left(\frac{l}{b}\right)} \right]\left(\frac{e}{b}\right)^{0.8} \\
h_{\theta x} &= \left\{ 1 + \left(\frac{e}{b}\right) + \left[\frac{1.6}{0.35 + \left(\frac{l}{b}\right)} \right]\left(\frac{e}{b}\right)^2 \right\}^{\frac{1}{3}} \\
h_{\theta y} &= \left\{ 1 + \left(\frac{e}{b}\right) + \left[\frac{1.6}{0.35 + \left(\frac{l}{b}\right)^4} \right]\left(\frac{e}{b}\right)^2 \right\}^{\frac{1}{3}} \\
h_{\theta z} &= \left\{ 1 + \left[1.3 + \frac{1.32}{\left(\frac{l}{b}\right)} \right]\left(\frac{e}{b}\right)^{0.9} \right\}^{\frac{1}{3}}
\end{aligned}$$

The shape and embedment functions, s_i and h_i, are plotted in Figure 2.6.

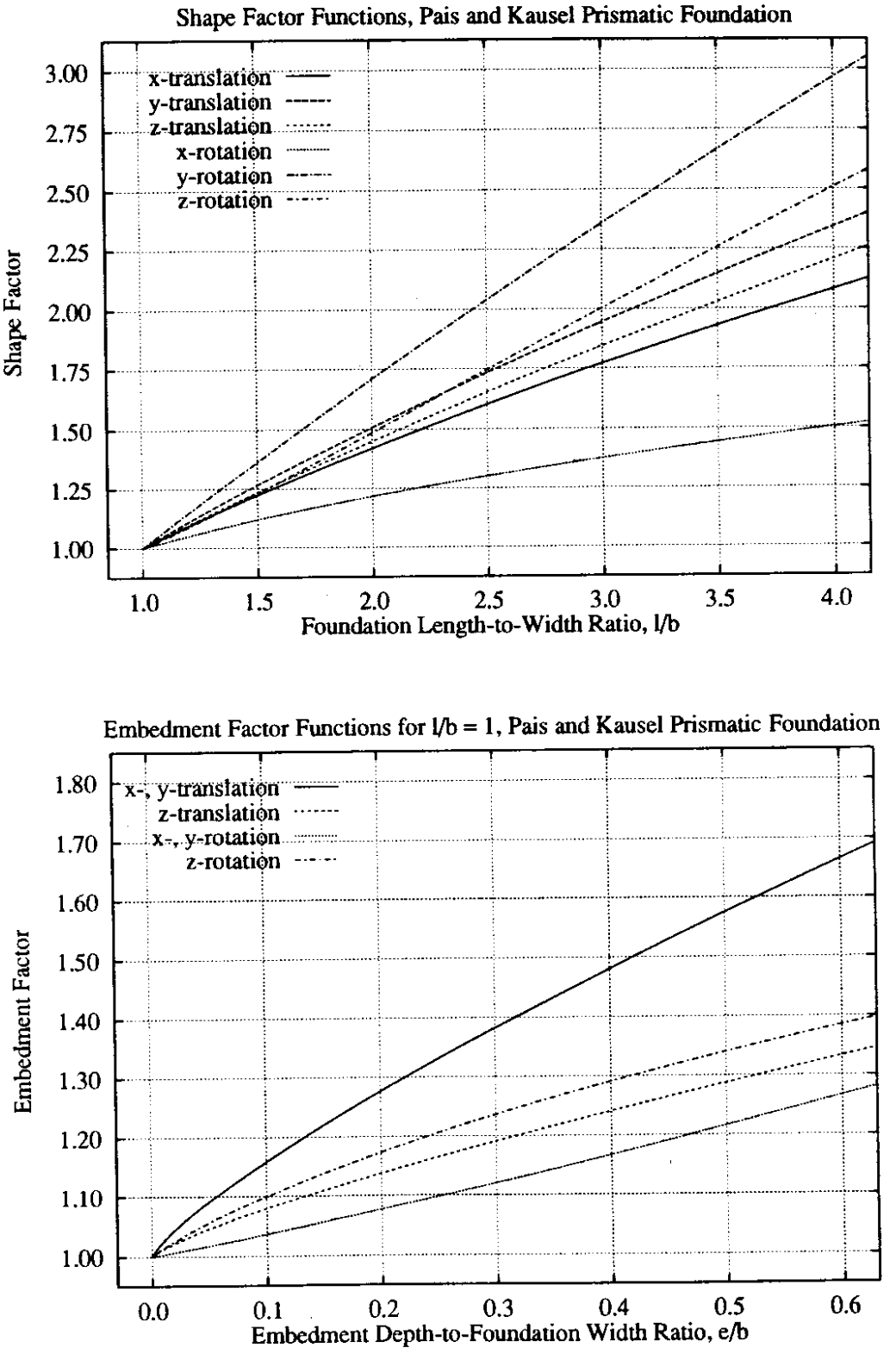


Figure 2.6: Shape factor and embedment factor functions, s_i and h_i, for the Pais and Kausel prismatic foundation model.

2.1.4 *Pile Foundation Models*

The discrete models discussed thus far are based on the disk–half-space system shown in Figure 2.2, where the "foundation" is a rigid member bonded to the surface of the half-space. These discrete models are useful for modeling spread footing foundations, but the concept of representing the soil as a half-space has also been used to develop discrete models applicable for modeling pile foundations. Nogami and Konagai [35] represented the soil as a vertically-stratified series of plane-strain elastic layers to develop Winkler-type discrete models that could be applied along the length of pile models embedded in the soil. The concept was later extended by Nogami *et al.* [36] to include in the soil reaction model a nonlinear soil near-field sub-model, and a sub-model capable of representing the development of a gap between the pile shaft and the soil. This model is illustrated in Figures 2.7 and 2.8.

The Nogami far-field submodel consists of three linear spring–dashpot combinations placed in series, as shown in Figure 2.7. The

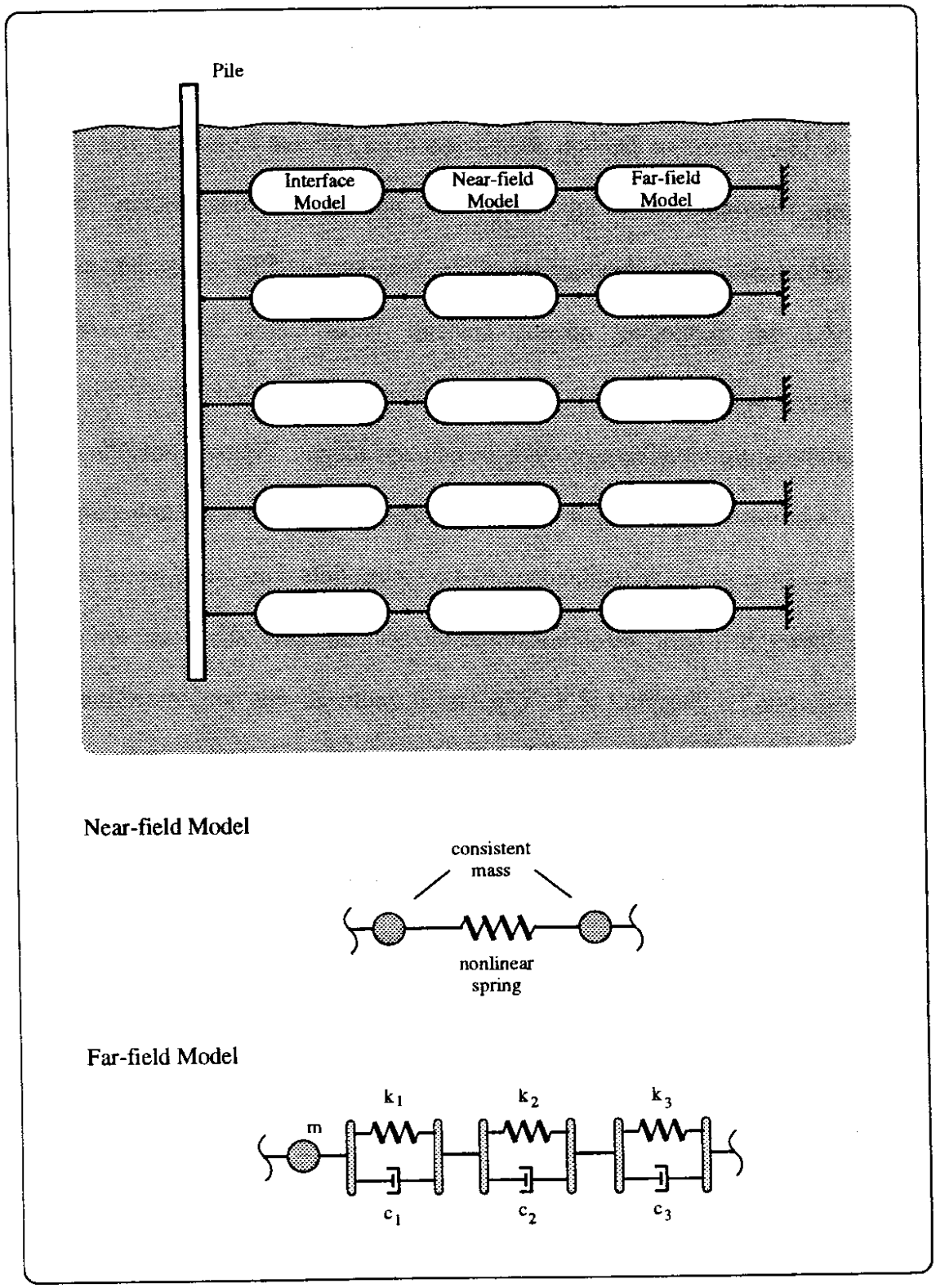


Figure 2.7: Soil–pile model proposed by Nogami *et al.* [37]: (top) Winkler foundation with three soil reaction models at each level: (bottom) soil far-field and near-field models.

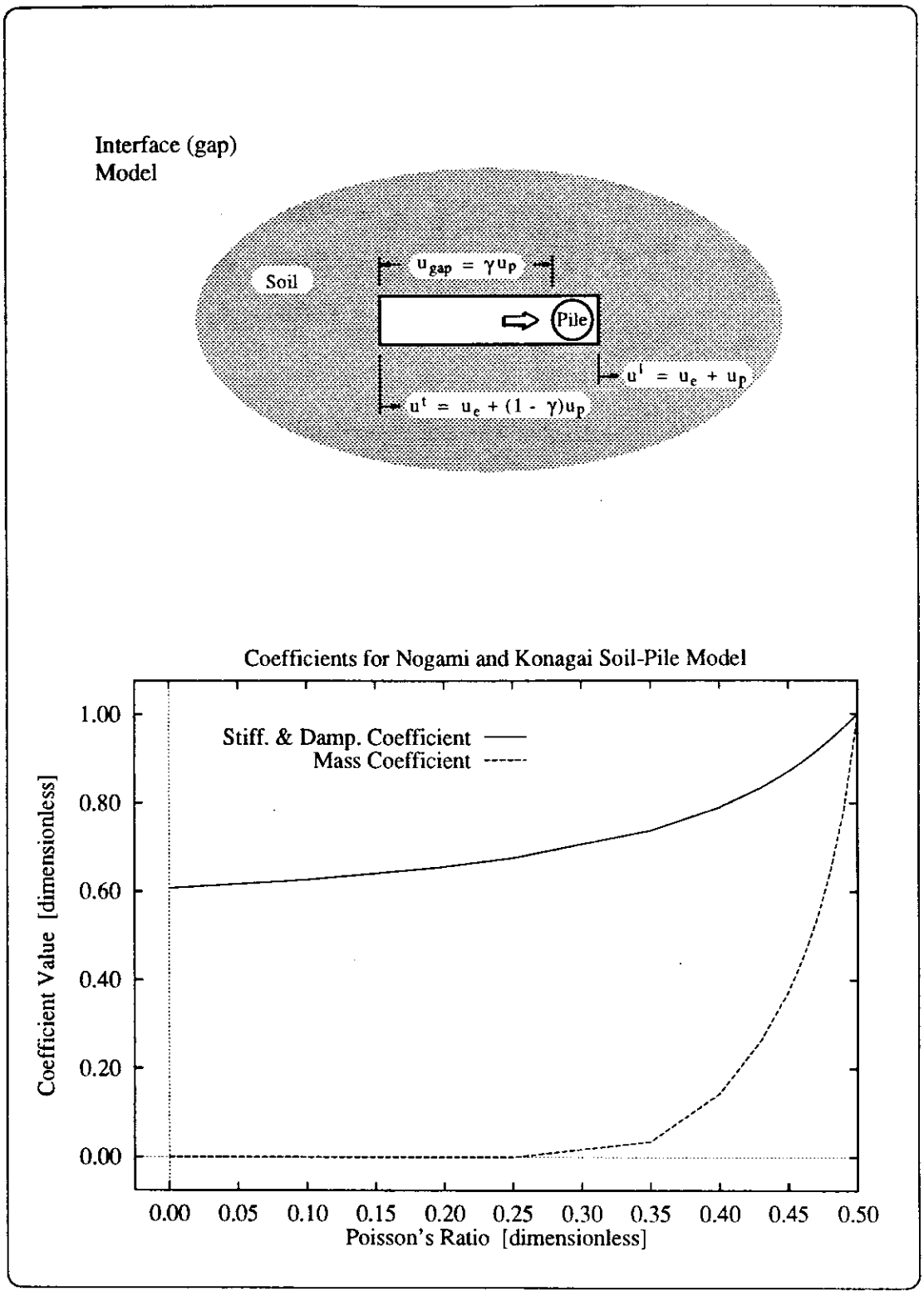


Figure 2.8: Nogami and Konagai soil–pile model: (top) soil–pile interface mechanism to model gap development; (bottom) variation of the model stiffness/damping and mass parameters, ξ_{sd} and ξ_m, with Poisson's ratio.

parameters of the far-field sub-model are determined by applying the following equations:

$$k_i = q_i \xi_{sd} G$$

$$c_i = d_i \xi_{sd} G \left(\frac{r_n}{c_s} \right) \qquad \begin{cases} q_1 = 7.036, & d_1 = 226.1946 \\ q_2 = 7.162, & d_2 = 50.266 \\ q_3 = 11.058, & d_3 = 18.724 \end{cases} \qquad (2.9)$$

$$m_i = \pi \xi_m G \left(\frac{r_n}{c_s} \right)^2$$

where r_n ≡ radius of the soil near-field

ξ_{sd}, ξ_m ≡ dimensionless coefficients; functions of Poisson's ratio, ν, of the soil, as shown in Figure 2.8

q_i, d_i ≡ dimensionless coefficients

The far-field sub-model is intended to represent the reaction of the soil at a sufficient distance from the pile to ensure linear behavior of the soil. It also models radiation damping. Nogami *et al.* [37] report that this sub-model accurately reproduces the behavior of the plane-strain elastic half-space over a wide frequency range.

The near-field sub-model is intended to represent the nonlinear, hysteretic action of the soil in the immediate vicinity of the pile. A method is presented to determine the required behavior of the nonlinear spring; however, using standard "*p–y*" load–deflection curves as the backbone curve of a bilinear hysteretic spring would be consistent with the intended

function of this sub-model. The consistent mass matrix prescribed for the near-field sub-model is given by the following equation:

$$m_n = \frac{1}{6}\pi \rho_s r_p^2 \left(\frac{r_n}{r_p} - 1\right) \begin{bmatrix} \frac{r_n}{r_p} + 3 & 3\frac{r_n}{r_p} + 1 \\ 3\frac{r_n}{r_p} + 1 & \frac{r_n}{r_p} + 1 \end{bmatrix} \qquad (2.10)$$

where r_p ≡ radius of the pile

ρ_s ≡ mass density of the soil

m_{ij} ≡ inertial force at node i caused by a unit acceleration at node j; node 1 is the "pile" end of near-field model, and node 2 is the "far-field" end of the near-field model.

The interface sub-model models the development of a gap between the pile and the surrounding soil. Referring to Figure 2.8, the displacement of the gap "leading" edge, u^l, is composed of an elastic component, u_e, and an accumulated plastic component, u_p. The gap displacement, u_{gap}, is taken to be a portion of u_p, and is controlled by the parameter γ. A gap parameter value of $\gamma = 0$ corresponds to not developing any gap, in which case the pile remains in contact with the soil at all times. The displacement of the gap "trailing" edge, u^t, is the displacement of the leading edge, u^l, less the gap displacement, u_{gap}.

Nogami *et al.* [37] illustrate the use of this soil–pile discrete model and the selection of model parameters with several examples.

2.2 Modification of NEABS

The bridge analysis computer program NEABS (*Nonlinear Earthquake Analysis of Bridge Systems*) was chosen to be used in implementing the proposed methods to model mechanisms not currently incorporated into standard seismic analysis. The public domain source coding for NEABS was obtained and modified for this purpose [24]. As will be explained, it was already capable of modeling differential support excitation, nonlinear expansion joint behavior, and linear elastic spring supports. In order to implement the models discussed above to represent bridge spread footing and pile foundation interaction with the soil, NEABS was modified to include a new, discrete foundation element. In this section, NEABS is described and the development of the new foundation element is discussed.

2.2.1 Description of NEABS

The computer program NEABS was originally developed by Tseng and Penzien in 1973 as part of a study of the seismic performance of long, multiple-span bridges [38]. Using the finite element method (FEM), NEABS may be used to model a bridge by mathematically idealizing the structure as a discrete parameter system subjected to nodal dynamic loadings and/or to prescribed support motions. The discrete parameter system is composed of both linear and nonlinear elements. The program

was later modified in 1976 by Kawashima and Penzien, and again in 1978 by Imbsen, Nutt, and Penzien [38].

Four element types are available to model the structural members of a bridge. Deck sections and columns are modeled with a beam element that may be either elastic or elasto-plastic. In the case of the elasto-plastic beam, the ends are allowed to develop perfectly-plastic hinges. To define the beam's yield surface, axial force–bending moment strength interaction curves may be specified for bending about both principal axes, and biaxial bending moment strength interaction is included by using Bresler's "load contour" method. An elastic curved-beam element is available. Structure supports may be specified as fixed or free in each of the six degrees-of-freedom associated with a support node. Free supports may be given elastic stiffnesses (support springs) with the boundary spring element. A nonlinear expansion joint is included, which can model the opening and closing of the joint gap, the impact at gap closure, and elasto-plastic joint tie bars. An elastic truss element was originally included in the coding, but has since been discontinued.

Lumped masses, or mass moments of inertia for rotational degrees-of-freedom, may be assigned to structure nodes directly, or by specifying mass densities for both the straight- and the curved-beam elements. In the latter case, the total mass of the beam is computed and distributed equally to the two end nodes.

Energy dissipation not inherent in the material damping of the elasto-plastic elements is accomplished globally by using two-parameter Rayleigh damping. Rayleigh damping is a form of viscous damping (i.e., velocity-proportional damping force) in which the global damping matrix is assumed to be a linear combination of the global mass and stiffness matrices. For an elastic structure, this has the effect of assigning a unique damping ratio to each of the structure's modes of vibration; selection of desired damping ratios for two of the modes of vibration will uniquely determine the values of the two global damping parameters.

Both static and dynamic nodal loadings may be prescribed, as well as support motion. Dynamic nodal loads and support motions are specified by supplying load and acceleration time histories, respectively. Multiple dynamic load and/or support acceleration time histories can be applied, allowing NEABS to model differential support motions.

The equations of motion are solved in the time domain to allow nonlinear response, and they are numerically integrated directly at each time step using the Newmark method. Either constant or linear acceleration between successive time steps may be assumed in the integration, allowing for two numerical accuracy/stability tradeoff combinations. At each time step, the out-of-balance force vector (i.e., the difference between the applied equivalent force and the sum of the structure's restoring, damping, and inertial forces) from the previous time step is added to the current applied equivalent force to minimize the

accumulation of integration errors. Additionally, NEABS will iterate and/or subdivide the time step used in integration, using linear interpolation of applied load and acceleration time histories as necessary, to ensure that the Euclidean norm of the out-of-balance force vector is within prescribed tolerances. Output consists of both the forces and displacements of the initial static response and of time histories of the dynamic response. These time histories may consist of nodal displacements, nodal accelerations, member forces, and, for nonlinear elements, member "nonlinear" (plastic) displacements.

2.2.2 Discrete Foundation Element Capabilities

The discrete foundation element (DF element) was designed and implemented within NEABS for this research project. It is intended to be a general purpose element to be used in incorporating a variety of discrete foundation models into NEABS analyses. These models may range in complexity from simple linear elastic spring supports to those employing a number of internal nodes, masses, dampers, and nonlinear springs.

A pictorial representation of the DF element may be seen in Figure 2.9. The DF element connects two nodes, nodes i and j. These two end nodes may actually occupy the same location, as in a simple foundation model using elastic supports, where node i might be fixed, and node j the connection point of a soil spring to the bridge foundation. Because of the possibility of having element lengths that are small, or even

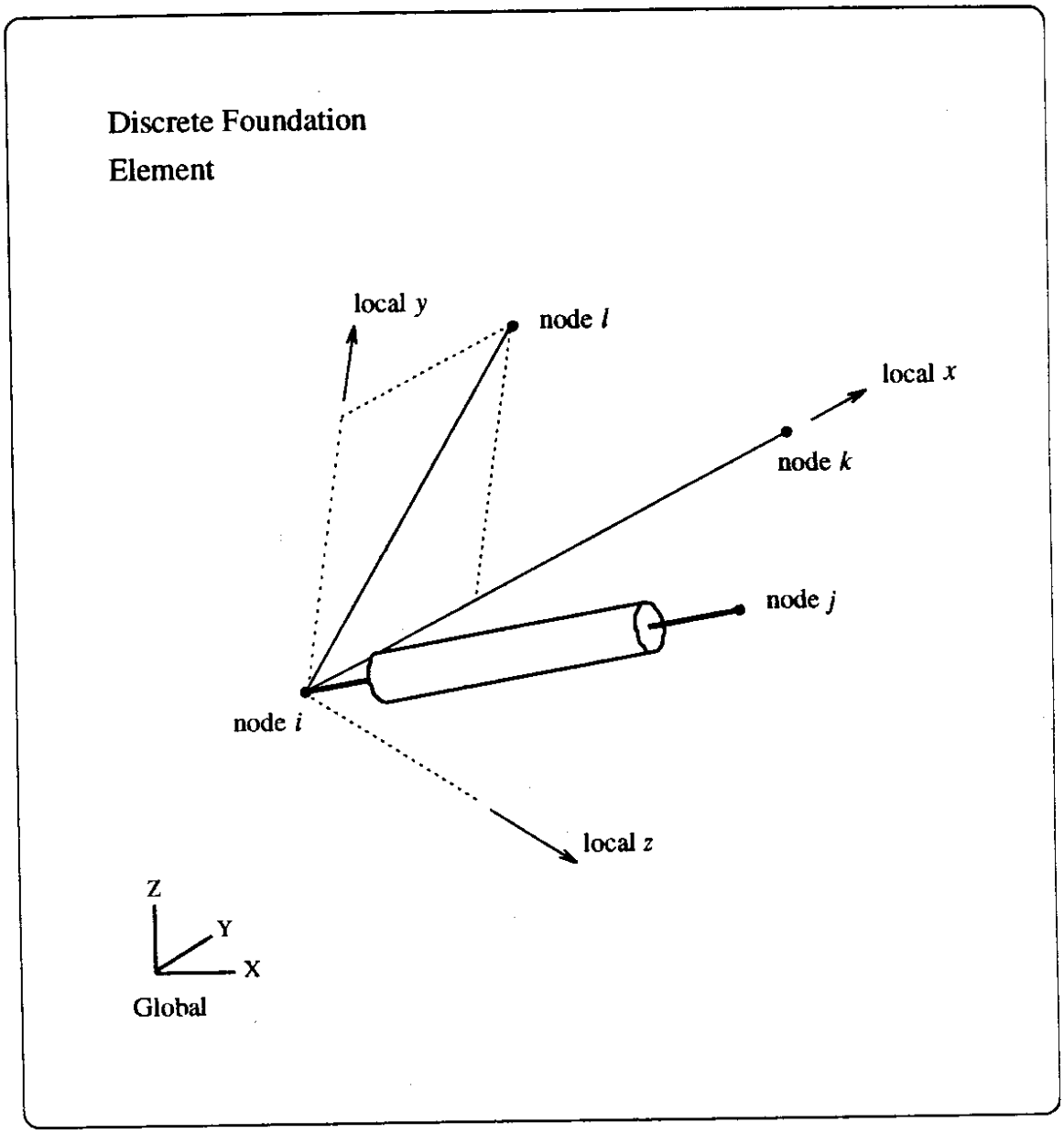


Figure 2.9: Pictorial representation of the DF element.

zero, the orientation of the local x-axis is determined by a vector originating at node i and terminating at node k (vector $\overline{ik}$). The local y-axis is determined by specifying node l; the component of the vector $\overline{il}$ perpendicular to the vector $\overline{ik}$ and lying in the plane defined by these vectors determines the direction of the local y-axis. The local z-axis is determined from the x- and y-axes, consistent with the requirements of a right-handed coordinate system. Nodes k and l serve only to determine the orientation of the local coordinate system, and need not be located on the structure.

The DF element connects the two end nodes with a spring and damper, or "dashpot," for each of the six local degrees-of-freedom. There is no stiffness or damping coupling; thus, the response in each degree-of-freedom is independent. Mass and mass moments of inertia may be lumped to each end node and each degree-of-freedom independently. The dashpot is a linear viscous damper, while the spring may be nonlinear.

The spring incorporates a number of features to facilitate modeling many of the nonlinear characteristics of soil. These features may or may not be utilized, depending on the requirements of the foundation model and the availability of necessary input parameters. The spring stiffness is bilinear, to allow elastic-plastic behavior and hysteretic material damping. Referring to Figure 2.10(a), an initial elastic stiffness k_{e_i}, a plastic stiffness k_p, and an initial yield force f_{y_i} may be specified. The elastic stiffness may be allowed to degrade on the basis of strain, as shown in

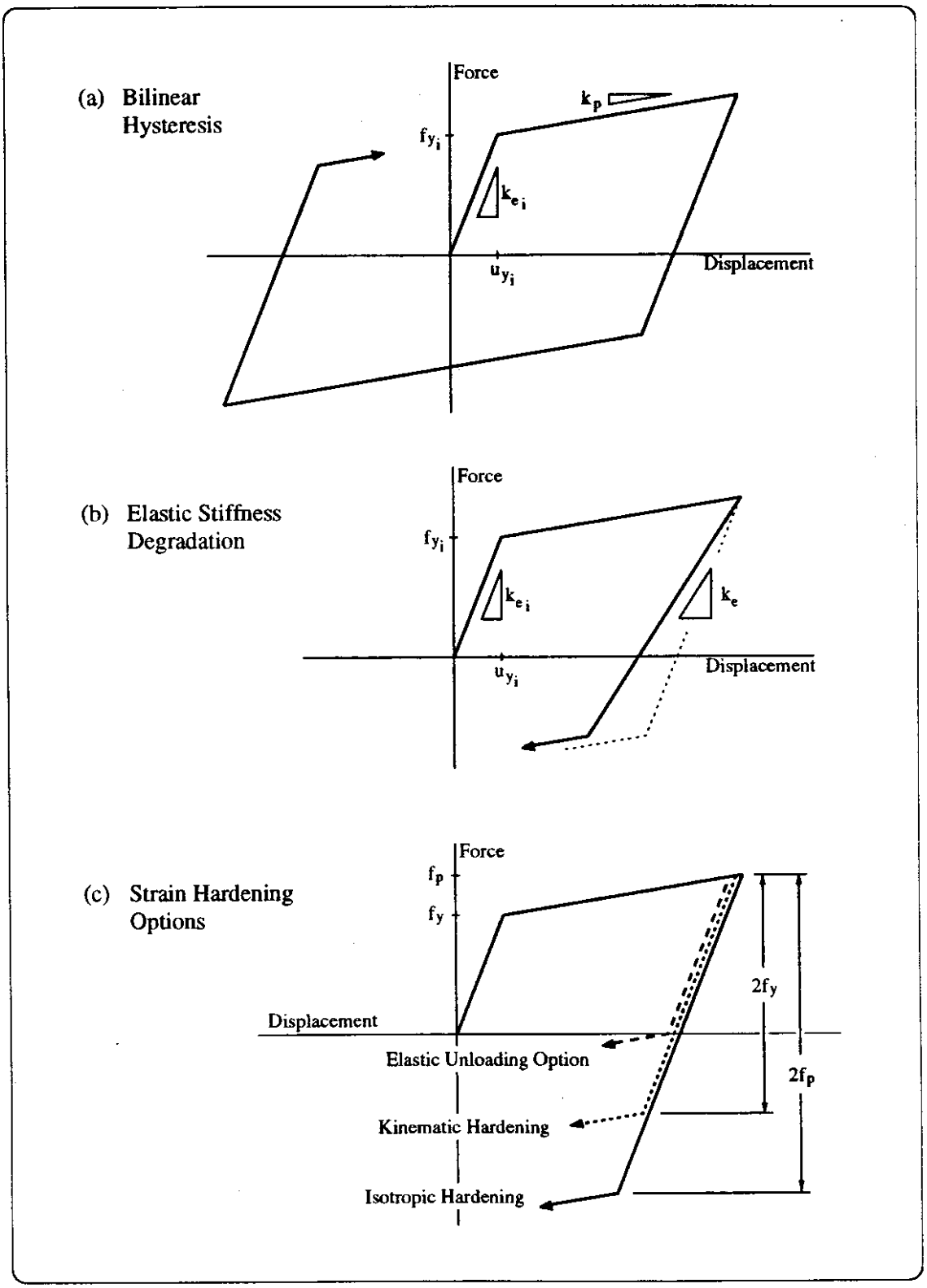


Figure 2.10: DF element nonlinear stiffness capabilities: (a) bilinear hysteresis; (b) elastic stiffness degradation; (c) strain hardening options.

Figure 2.10(b), according to the following equation, used by Loh and Lee [17]:

$$k_e = k_{e_i}\left(\frac{|u|_{max}}{u_{y_i}}\right)^{-\alpha} \leq k_{e_i} \qquad (2.11)$$

where k_e ≡ current elastic stiffness

k_{e_i} ≡ initial elastic stiffness

$|u|_{max}$ ≡ maximum absolute displacement during plastic response that has been attained thus far; $|u|_{max} \geq u_{y_i}$

u_{y_i} ≡ initial positive yield displacement

α ≡ stiffness degradation parameter

Different forms of strain hardening may be incorporated, as illustrated in Figure 2.10(c). The DF element defaults to kinematic hardening (yield force limits remain at their initial values), but isotropic hardening (yield force limits expand to previously attained maximum force), or an intermediate combination of the two may be specified. Additionally, an option is supported to force yielding to occur if the element has elastically unloaded to zero force prior to attainment of the yield force in the opposite direction consistent with the prescribed strain hardening rule. The use of this option has the effect of preventing the positive and negative yield force envelopes from "crossing" the zero-force axis, as can happen at large strains with kinematic strain hardening.

The DF element can incorporate a gap, which is useful for modeling the soil reaction on a pile. This gap model is the one proposed by

Nogami *et al.* [37], discussed earlier. Referring to Figure 2.11(a), a gap can develop according to the equation:

$$u_{gap} = \gamma u_p \tag{2.12}$$

where u_{gap} ≡ gap width, difference between displacements of gap "leading" and "trailing" edges, u^l and u^p

u_p ≡ accumulated plastic component of displacement at gap "leading" edge, u^l

γ ≡ parameter governing gap development rate

Thus, if $\gamma = 0$, no gap can develop, while a gap will develop for $\gamma > 0$. For the case of $\gamma = ½$, once the yield displacement is reached, the pile shown in Figure 2.11(a) will continue to "push" the "leading edge", while the "trailing" edge will be "dragged" along at half the rate of the leading edge until the pile reverses direction (point *c* of Figure 2.11(b)). At that time, the pile may unload the leading edge to zero force (point *d*); during the elastic portion of the unloading, both edges will translate back in unison. The pile may now traverse the gap, contact the former trailing edge (point *e*), and load this side elastically up to the yield force consistent with the prescribed hardening rule (point *f*). When the elastic unloading option, discussed earlier, is used in conjunction with the gap option, the pile of Figure 2.11(a) will always unload elastically to zero force, whereupon it enters the gap.

Although a true gap, such as illustrated in Figure 2.11(b), has no stiffness, hysteretic bilinear behavior may be specified for the gap. As

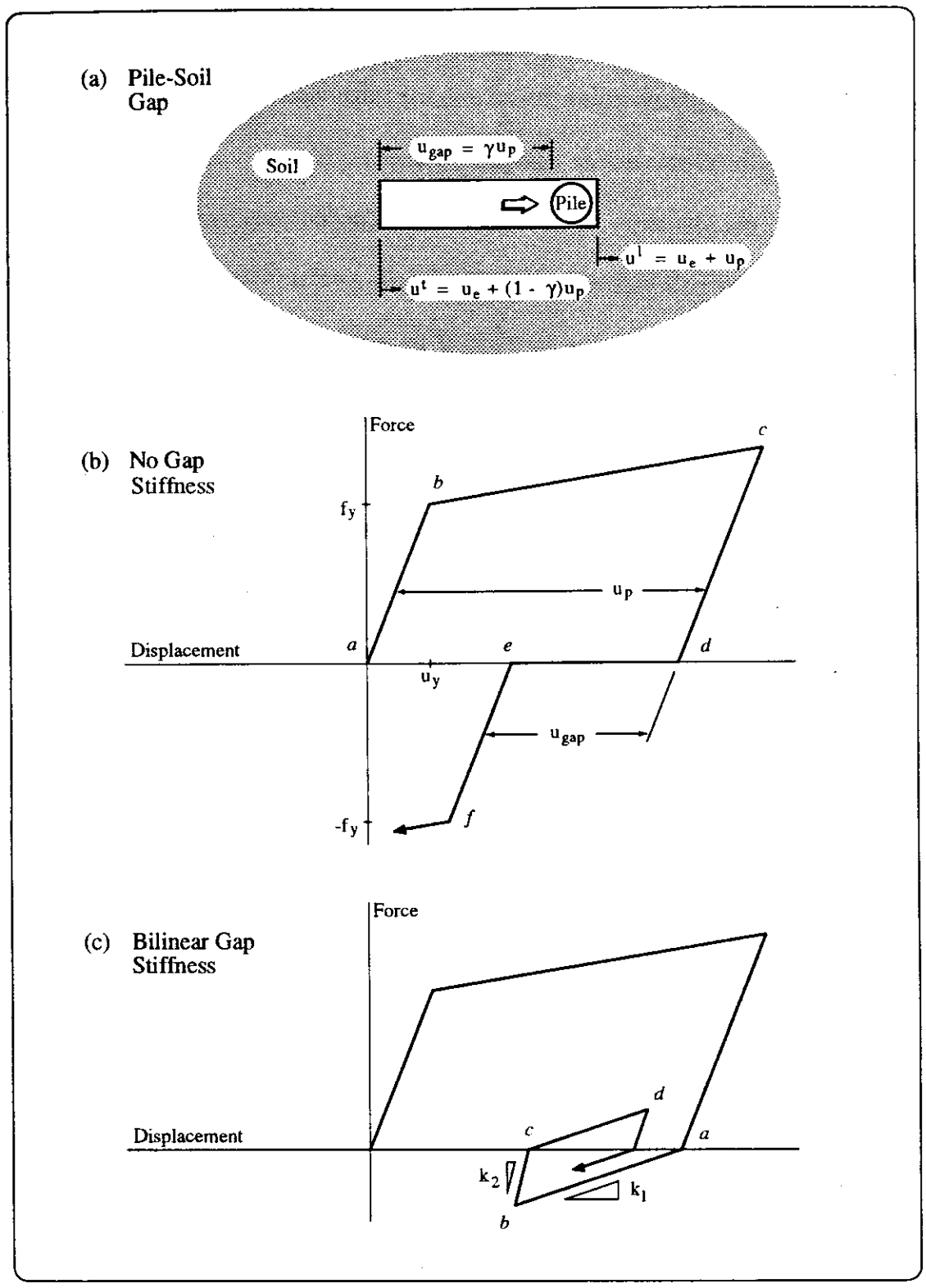


Figure 2.11: DF element nonlinear stiffness capabilities: gap development and in-gap hysteretic behavior.

illustrated in Figure 2.11(c), two stiffnesses may be specified. The first stiffness, k_1, applies when the gap is initially entered (point a). If the pile reverses direction within the gap (point b), it may unload at the second stiffness, k_2, to zero force (point c). Continuing on in the reversed direction, the pile will start loading again at the first stiffness. Thus, the in-gap behavior is similar to that of an elasto-plastic material, where the first stiffness is the plastic stiffness, and the second stiffness is the elastic stiffness. This feature is intended to provide versatile and rational behavior that may be utilized in modeling friction or other mechanisms which may give rise to stiffness within the gap.

The dashpot is a linear viscous damper. The coefficient of damping may be specified in all degrees-of-freedom independently, allowing concentrated dampers to be included in a foundation model. The DF element viscous damping is independent of the global Rayleigh viscous damping; the contribution of the DF element to the system's global mass and stiffness matrix is not considered when determining the Rayleigh damping contribution to the global damping matrix. Thus the Rayleigh damping concept may continue to be used for the majority of a bridge structure's components without affecting concentrated dampers present in the foundation models. The option of allowing the global damping parameters to apply to the DF element is supported, in which case the Rayleigh damping from the DF element is added to any specified dashpot damping in determining the element's total damping matrix.

2.2.3 *Discrete Foundation Element Implementation*

Six main subroutines were added to the NEABS coding to include the DF element in the NEABS element family, as shown in Figure 2.12. The architecture of the DF element subroutines is similar to that of the existing elements. The coding for these subroutines is given in Appendix C. The form of the equation of motion that NEABS integrated had to be changed to accommodate the concentrated damping capability of the DF element. Since NEABS originally used only Rayleigh damping, in which the global damping matrix is a linear combination of the global mass and stiffness matrices, the equation of motion was cast in terms of the mass and stiffness matrices only without explicitly formulating the damping matrix. To prevent the DF element from (necessarily) including Rayleigh damping, and to allow it to include concentrated dampers, it was necessary to formulate the global damping matrix. The equation of motion was then recast to include the global damping matrix directly.

2.2.4 *Discrete Foundation Element Verification*

Once the necessary coding was implemented in NEABS, verification tests were performed to ensure that the DF element behavior was correct; i.e., that the DF element response was sufficiently close numerically to the equations chosen to govern its behavior. These verification tests are described in this section. Static loading conditions were applied to test the DF element's elastic stiffness, the invariance of the elastic stiffness to

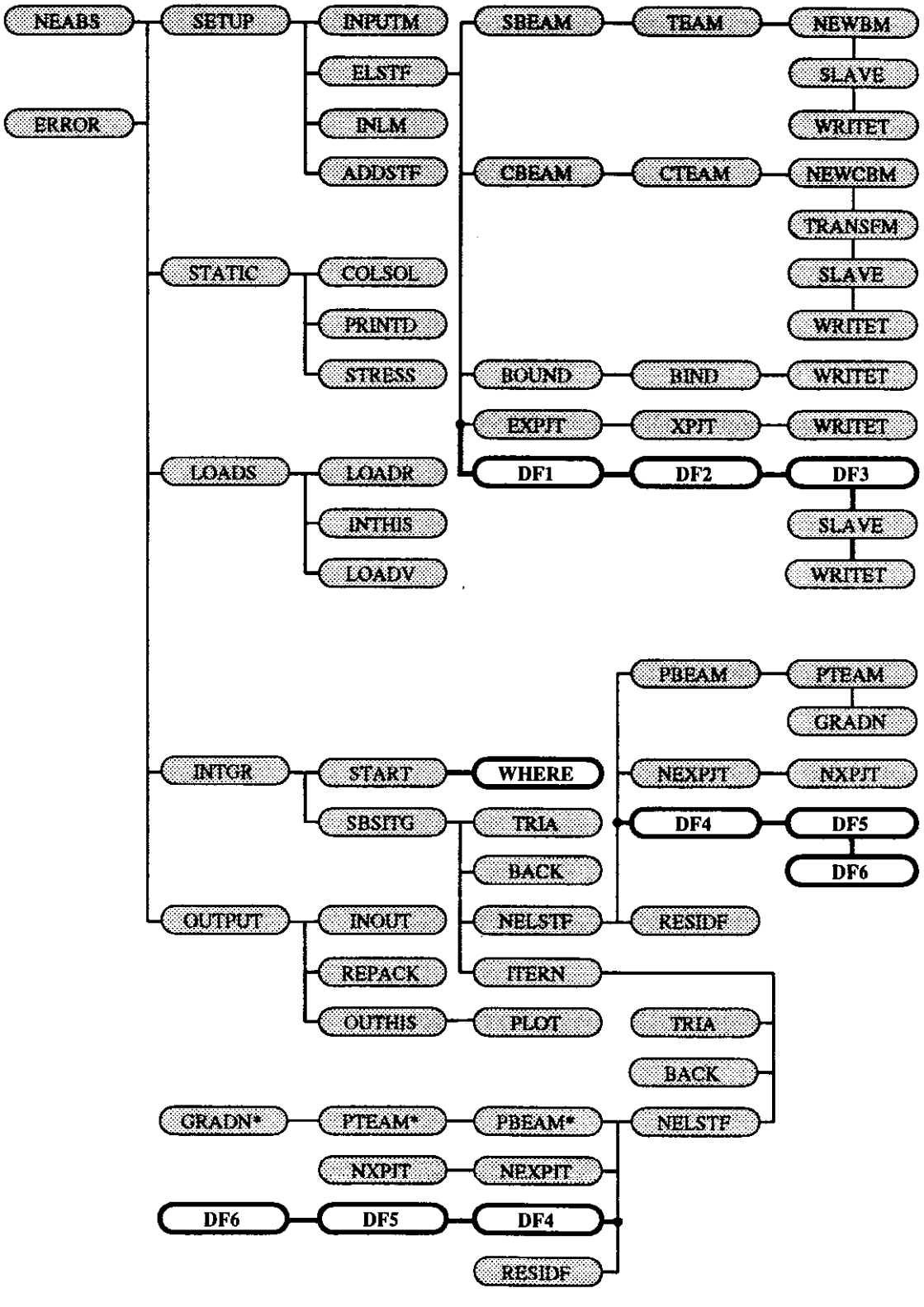


Figure 2.12: NEABS subroutine organization diagram: shaded bubbles indicate the subroutines present in the code as-delivered; open bubbles indicate the subroutines added.

spatial orientation, the DF element's ability to model weight (mass in a gravitational field), and its connectivity. Dynamic loading conditions were imposed to test the DF element's undamped and damped response, elastic stiffness degradation, strain hardening options, gap development, and in-gap hysteretic behavior.

To verify the DF element's correct elastic stiffness response, a single element was statically loaded as shown in Figure 2.13. The element was oriented such that its local coordinate system coincided with the global coordinate system. Different elastic stiffnesses were assigned to each translational degree-of-freedom. The element was fixed at one end, while the other was loaded in each translational degree-of-freedom. A variety of load force levels were applied, and the element forces and nodal displacements were recorded. The resulting load-displacement curves have slopes equal to the assigned stiffnesses, indicating correct static response. Figure 2.14 shows the setup and results of a corresponding test of the elastic response to moment loading applied to the rotational degrees-of-freedom.

To verify the invariance of the DF element behavior to its orientation relative to the global coordinate system, a test similar to the one above was performed, but with the element oriented as shown in Figure 2.15. Thus, a force applied in the local x-axis direction, acting against the element's x-axis translational stiffness, would produce nodal displacements in the global negative y-axis direction. Element stiffnesses were assigned

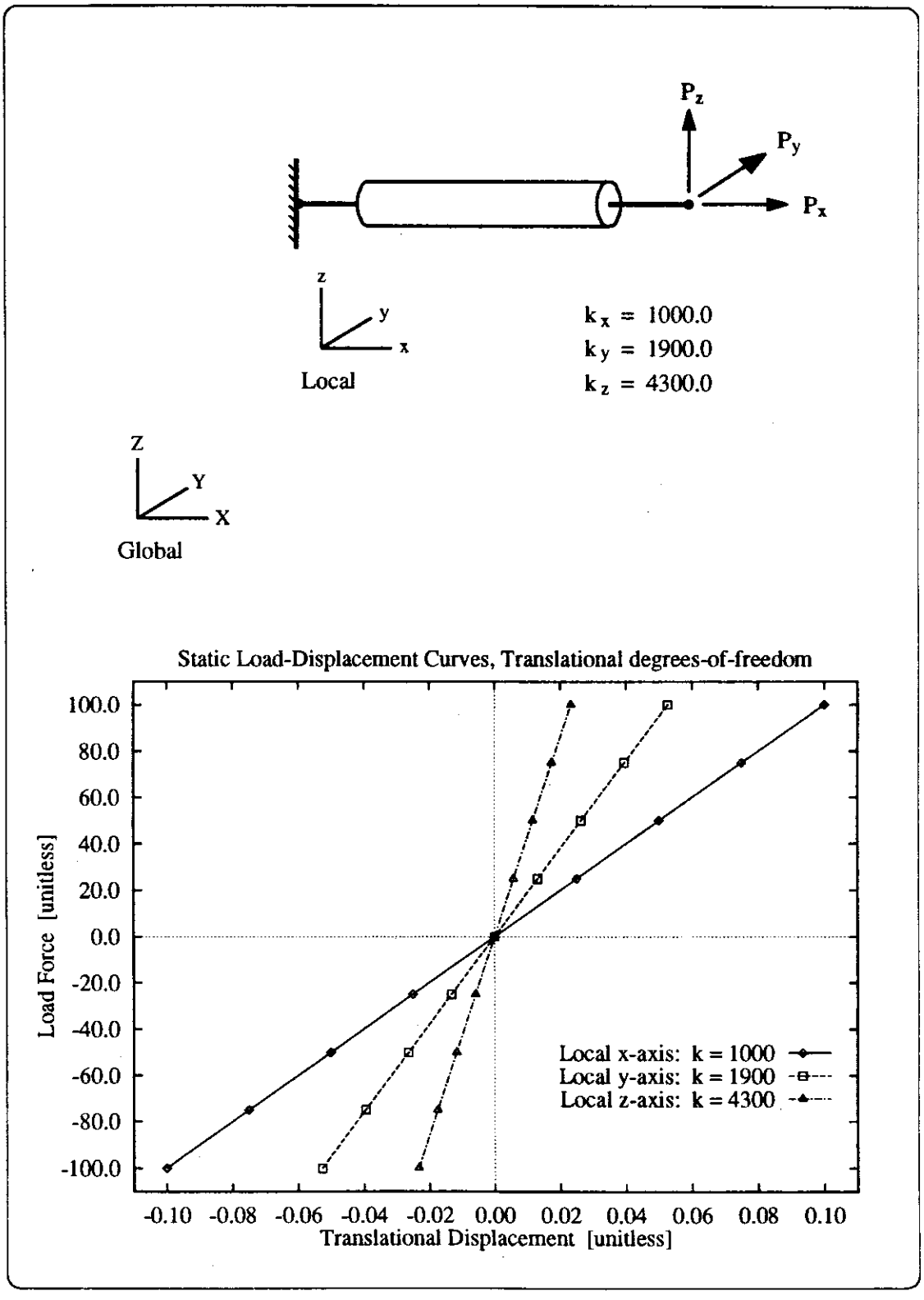


Figure 2.13: Elastic stiffness response verification test, force loads.

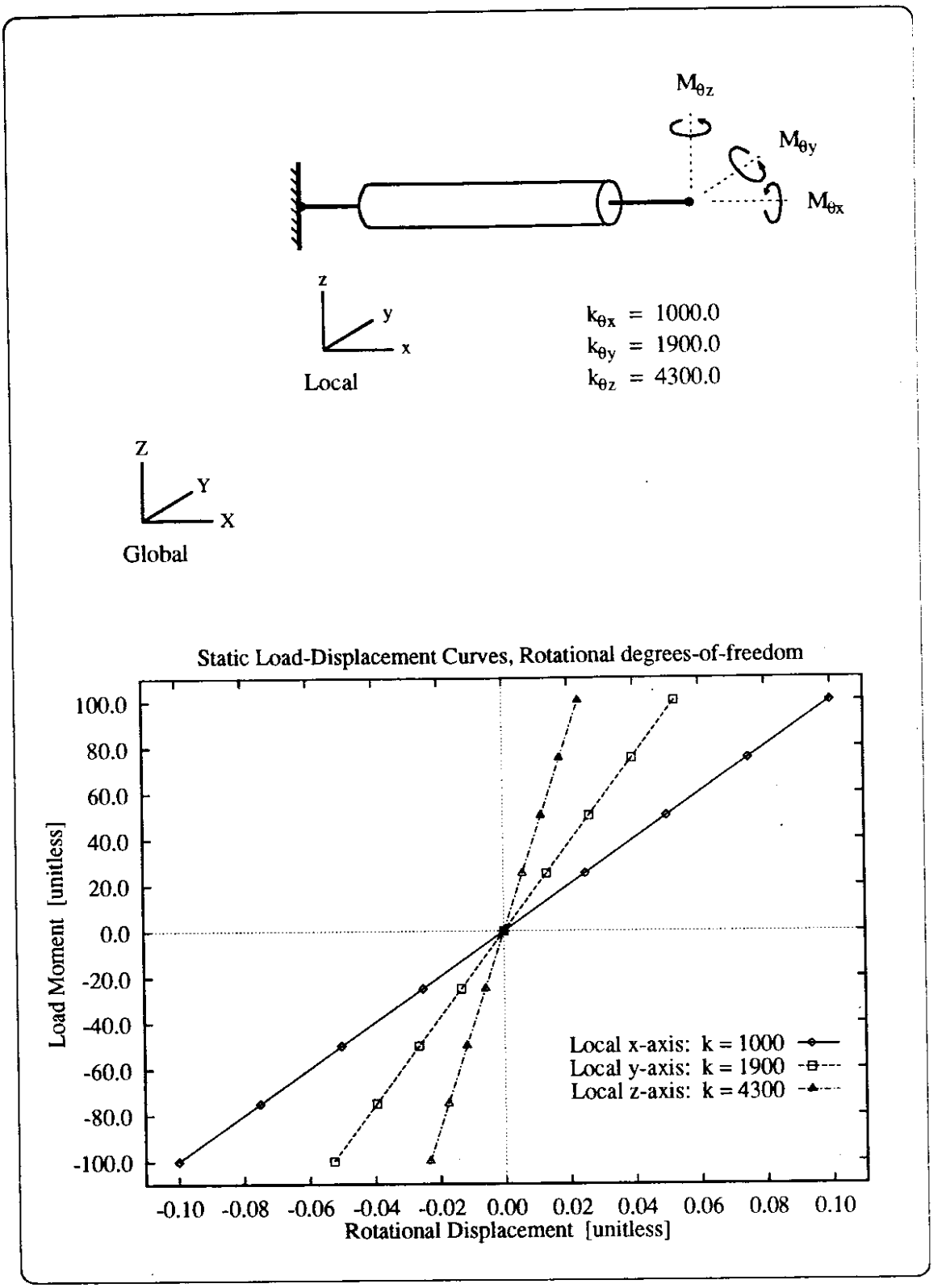


Figure 2.14: Elastic stiffness response verification test, moment loads.

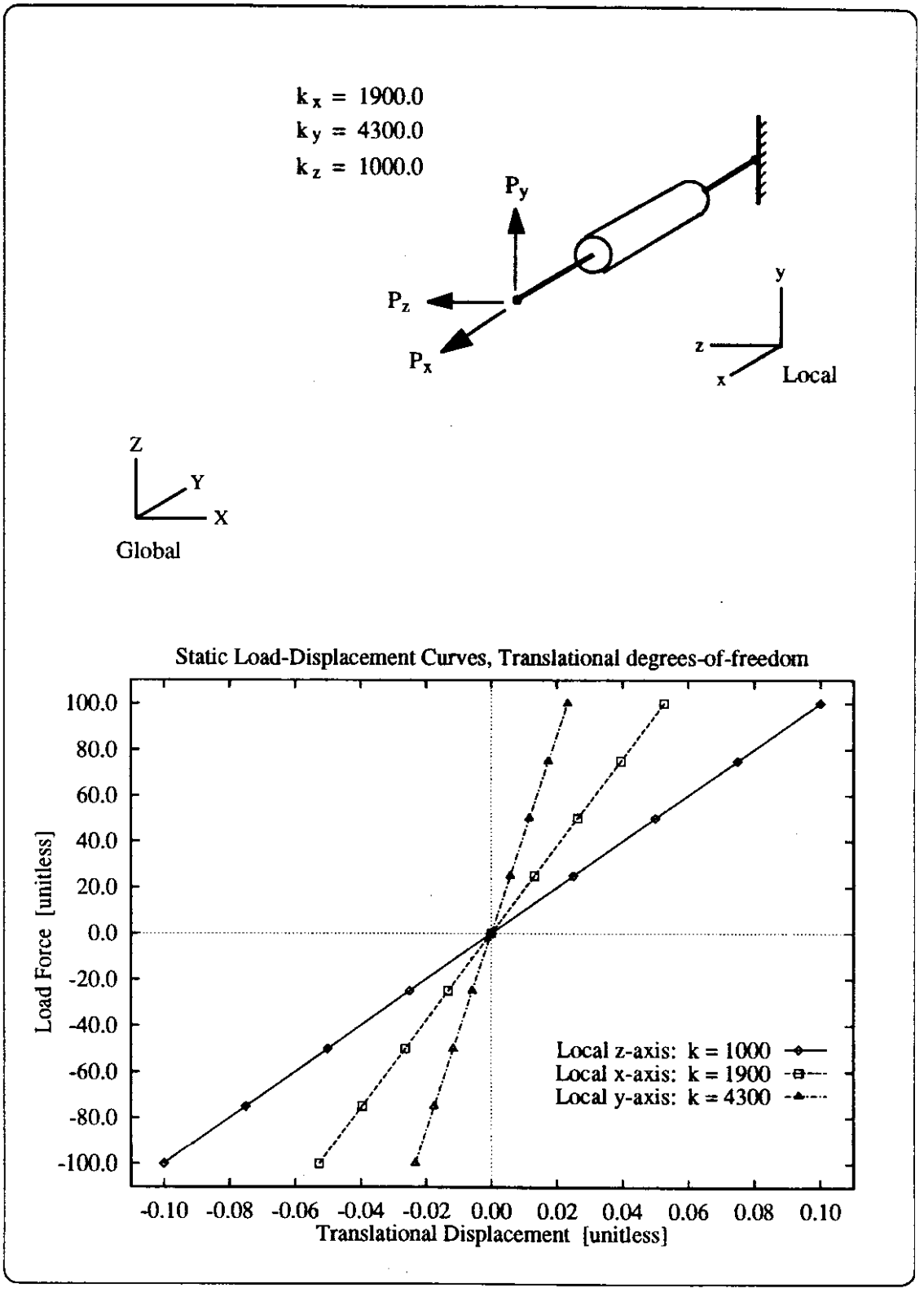


Figure 2.15: Spatial orientation response invariance verification test, force loads.

(specified relative to the local coordinate system), nodal loads were applied (assigned relative to the global system), and the resulting nodal displacements (reported relative to the global system) and element forces (reported relative to the local system) were recorded. Again, the load-displacement curve slopes corresponded directly with the stiffnesses assigned to each of the element's translational degrees-of-freedom. Figure 2.16 shows the setup and results of a corresponding test of the elastic response to loading applied to the rotational degrees-of-freedom.

Mass and mass moments-of-inertia may be assigned to each of the DF element's end nodes' translational and rotational degrees-of-freedom, respectively. Gravitational acceleration components in the global x-, y-, and z-axis directions may also be specified. These accelerations act on the nodal masses, resulting in static nodal forces. To verify the element's ability to model weight, which depends on its ability to apply a gravitational acceleration field to specified mass, the test illustrated in Figure 2.17 was conducted. A gravitational acceleration was applied in the global negative y-axis direction, which acted on the mass assigned to the free end of the element. The element was given a stiffness in the local x-axis direction, giving rise to a resisting force equal and opposite to the gravitational force, or weight. The mass was varied and plotted against the resulting resisting force, yielding a mass-weight curve with a slope equal to the gravitational acceleration.

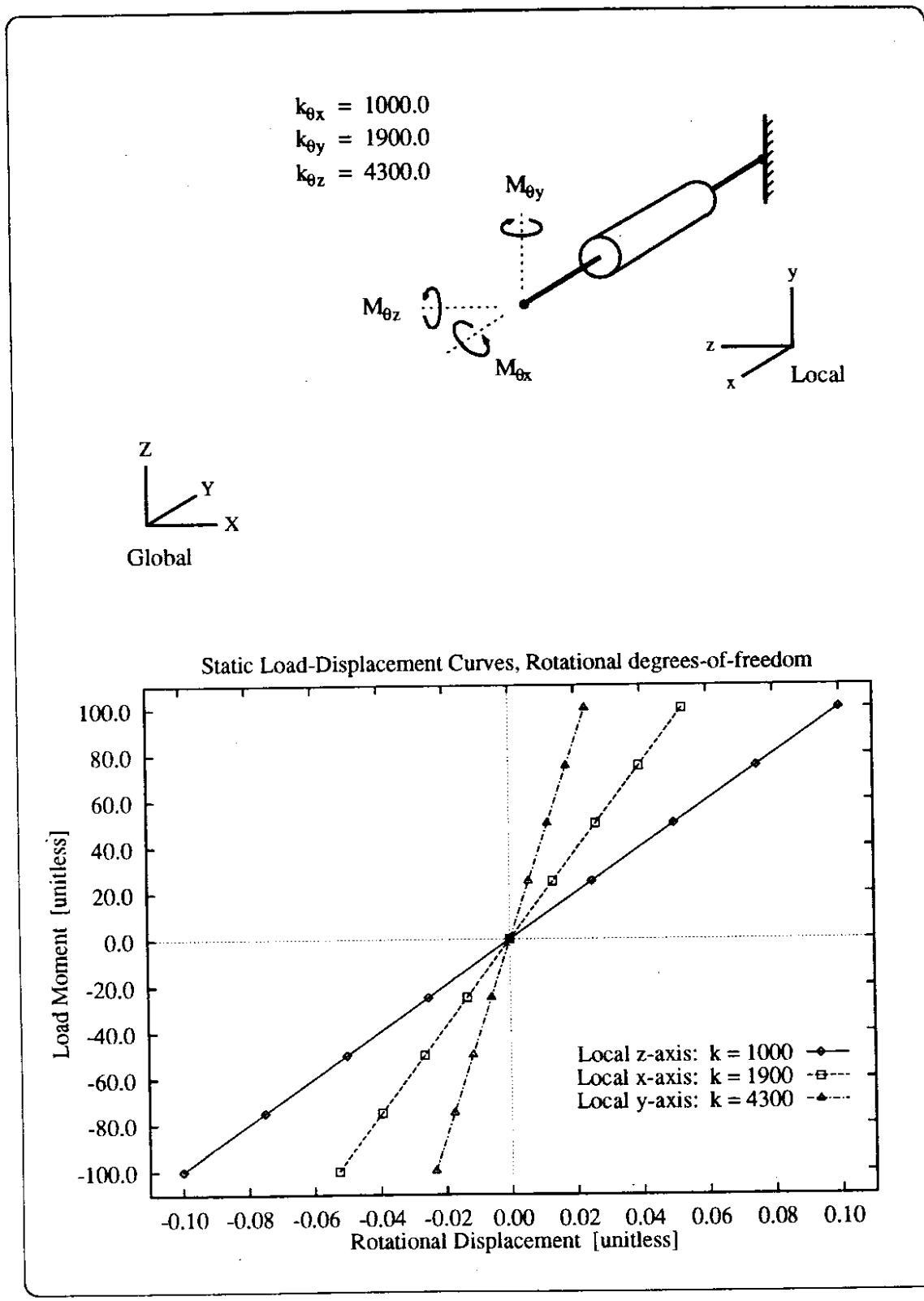


Figure 2.16: Spatial orientation response invariance verification test, moment loads.

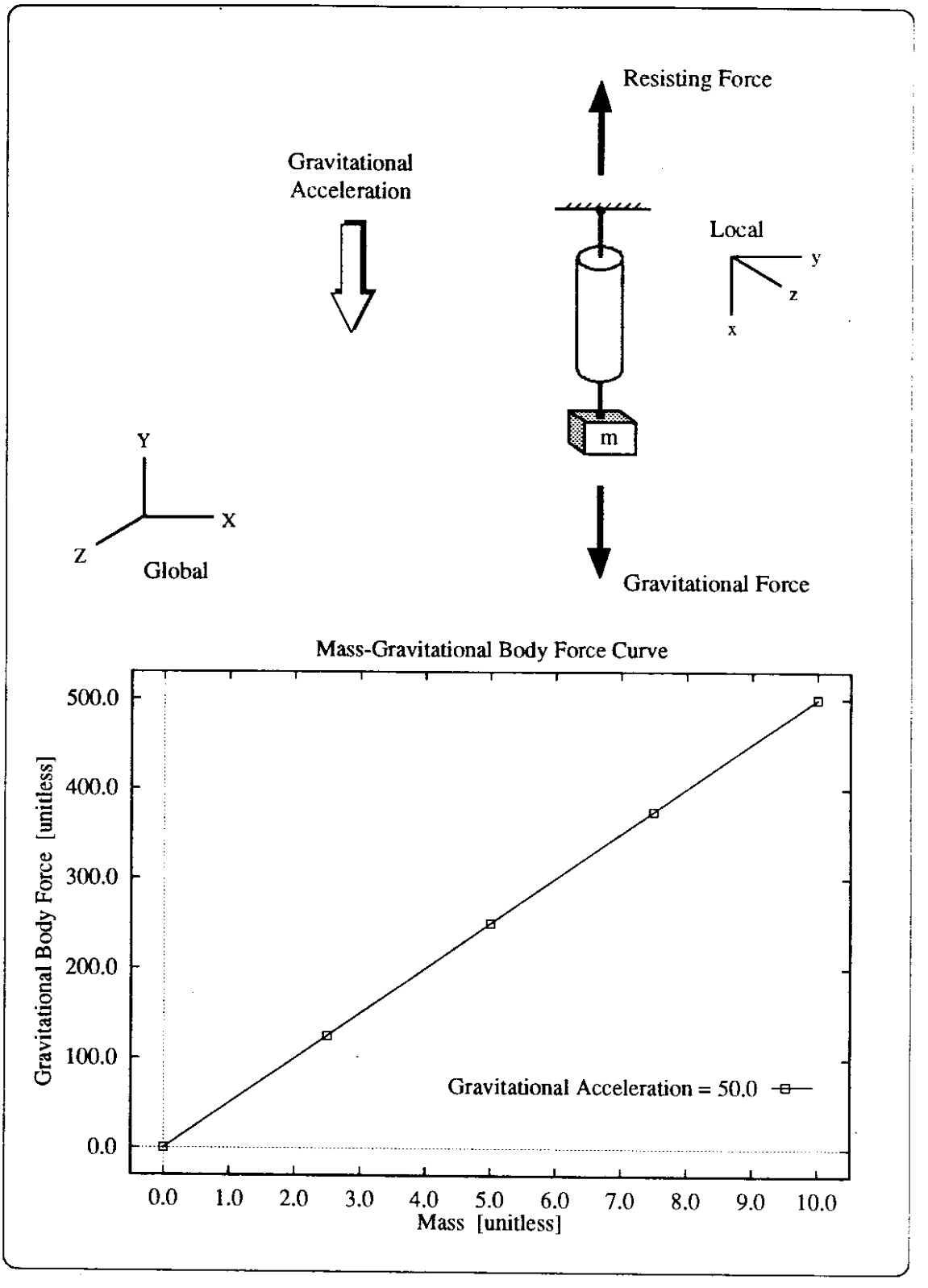


Figure 2.17: Mass–Gravitational field modeling verification test.

To verify the correct response of several DF elements interacting as a system, the "connectivity" test shown in Figure 2.18 was conducted. Two DF elements, having unitless stiffnesses $k_1 = 1800$ and $k_2 = 2250$, were connected in both a series and a parallel arrangement. The effective stiffnesses of these systems are given by the following equation:

$$k_{eff}^{series} = \frac{1}{\frac{1}{k_1} + \frac{1}{k_2}} = 1000 \qquad (2.13)$$

$$k_{eff}^{parallel} = k_1 + k_2 = 4050$$

The two systems were subjected to varying loads and the displacement ofthe end node was recorded. The slopes of the resulting load-displacement curves were found to be equal to their predicted values, providing verification of correct system behavior. Additionally, the distribution of the end node displacement to the elements in series, and the distribution of the load force to the elements in parallel, was found to be correct (inversely and directly proportional to element stiffness, respectively).

Correct undamped and damped dynamic response was verified by subjecting the DF element to resonant harmonic loading—sinusoidal loading at the natural period of the element. Without damping present,

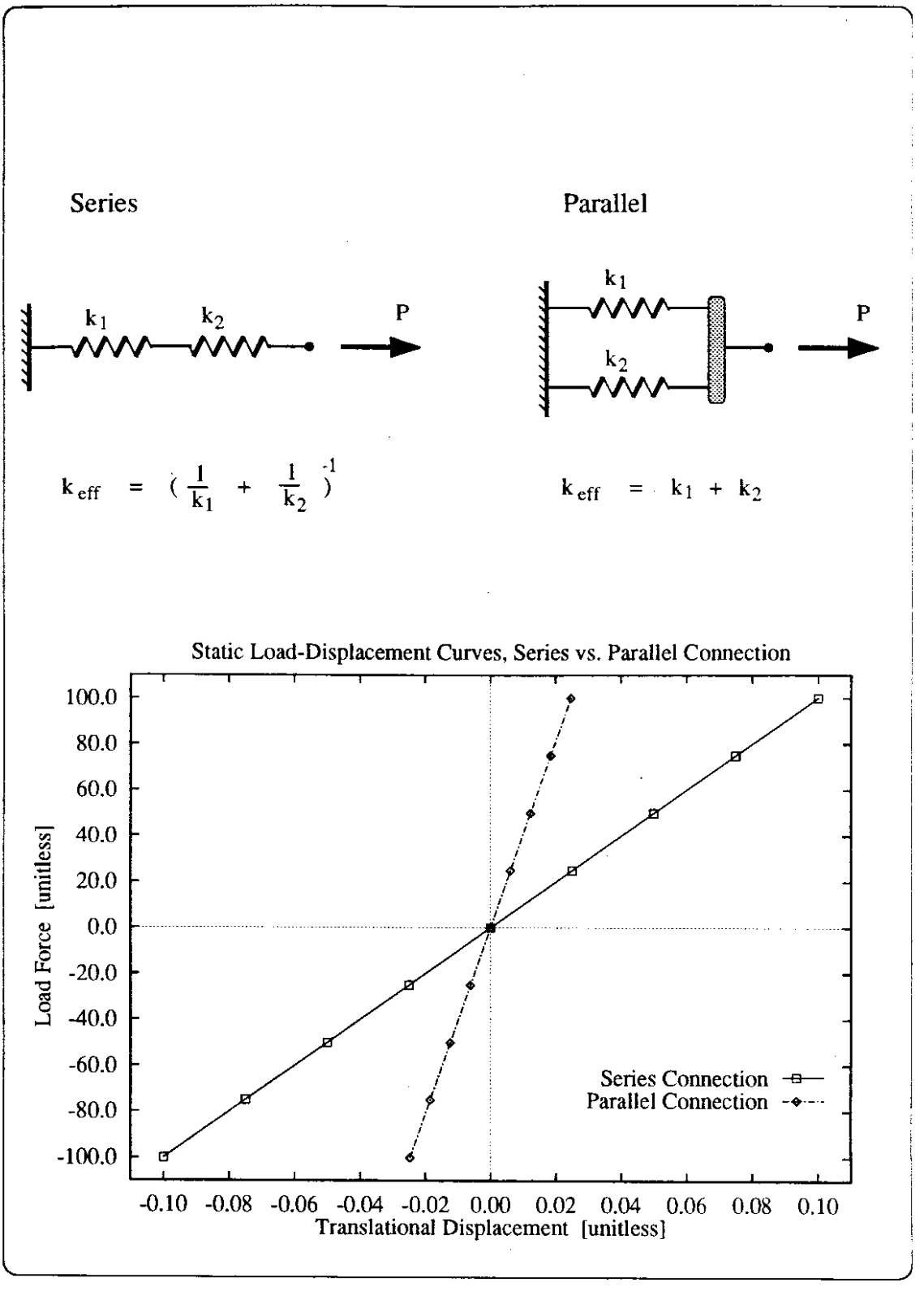


Figure 2.18: Connectivity verification test.

the displacement response should grow without bounds according to the equation:

$$u(t) = \frac{1}{2}\frac{p_0}{k}(\sin\omega t - \omega t\cos\omega t) \tag{2.14}$$

where $u(t)$ ≡ displacement at time t

p_0 ≡ amplitude of resonant sinusoidal loading; load at time t is: $p(t) \equiv p_0\sin(\omega t)$

k ≡ elastic stiffness of DF element

ω ≡ natural circular frequency of DF element, which is assumed to have mass m

With damping present, the response will reach a steady-state amplitude, Q_0, according to the equation:

$$u(t) = Q_0\left[e^{-\xi\omega t}\left(\frac{\xi}{\sqrt{1-\xi^2}}\sin\omega_d t + \cos\omega_d t\right) - \cos\omega t\right] \tag{2.15}$$

$$Q_0 = \frac{1}{2}\frac{p_0}{k}\frac{1}{\xi}$$

where Q_0 ≡ steady-state response amplitude

ξ ≡ damping ratio; fraction of system critical damping

ω_d ≡ damped natural circular frequency; $\omega_d \equiv \omega(1-\xi^2)^{1/2}$

Figure 2.19 shows the response plots of an undamped and a damped DF element subjected to resonant harmonic loading. They are numerically identical to equations (2.4) and (2.5) for the system/loading parameters chosen for the test, indicating correct element dynamic elastic behavior.

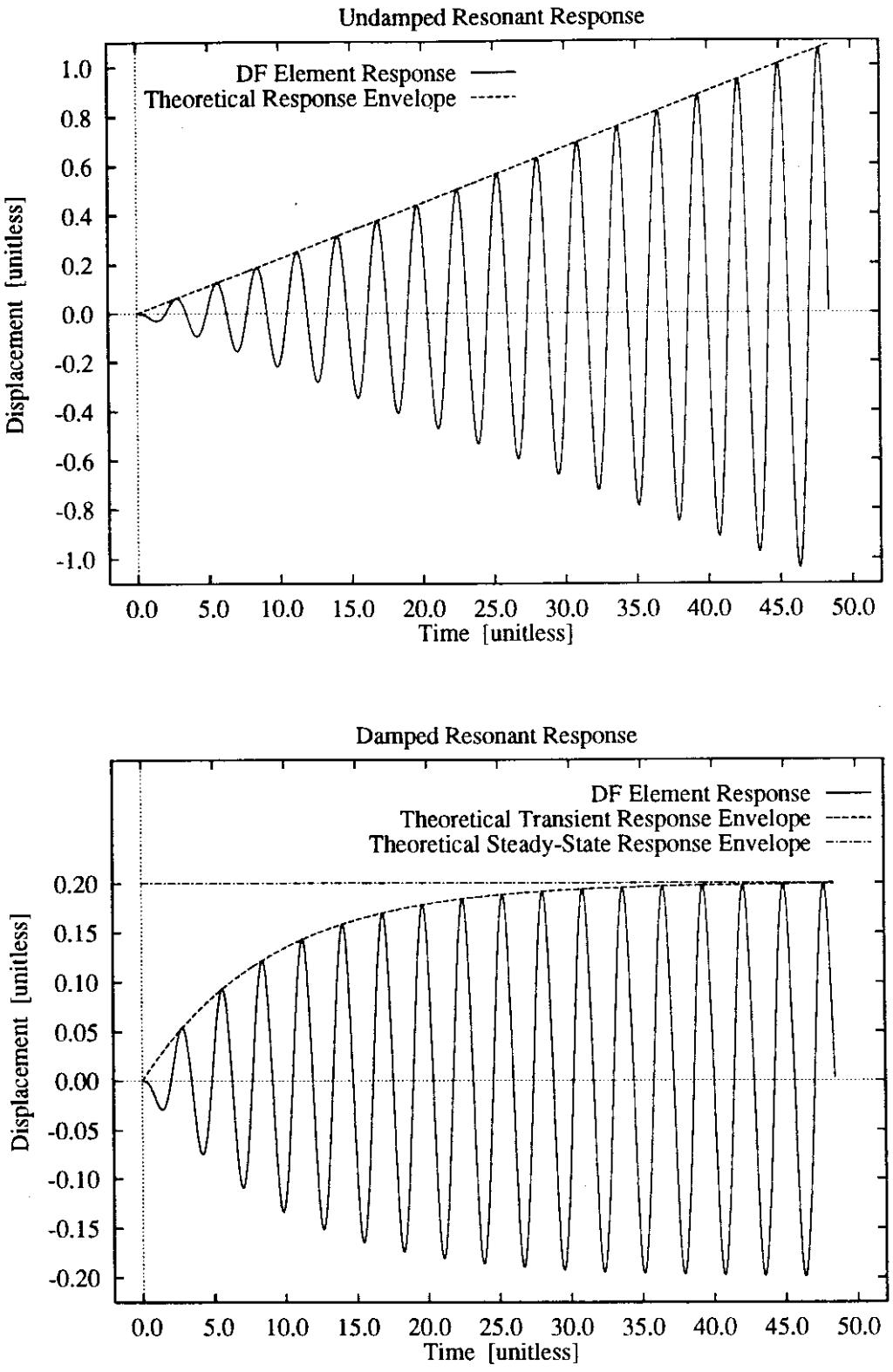
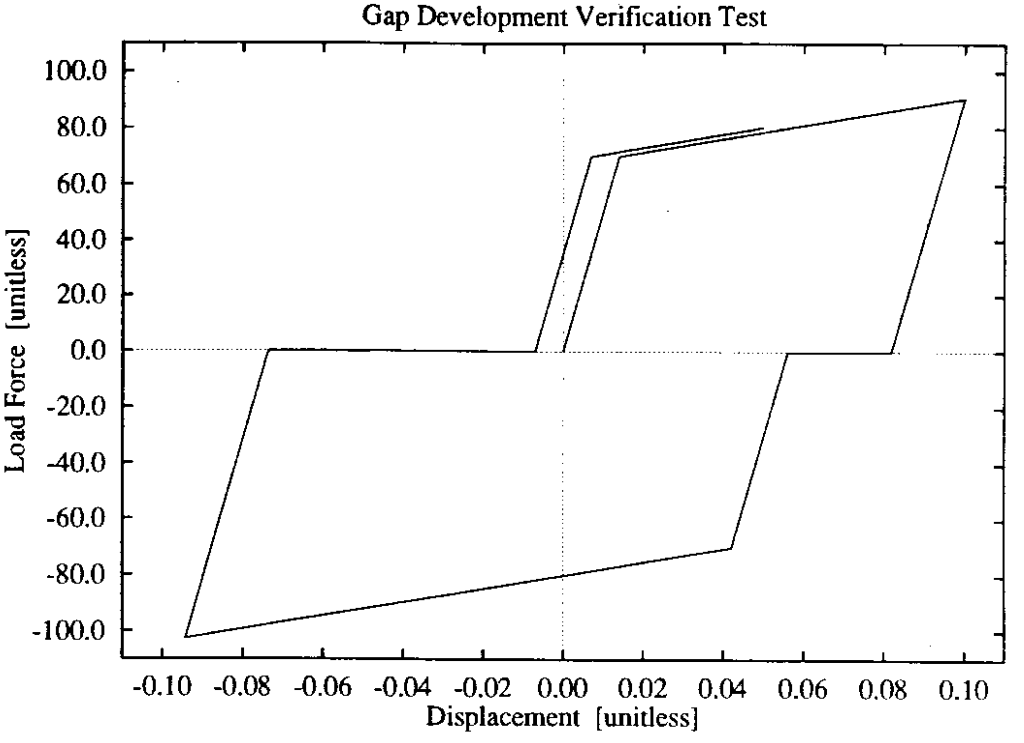


Figure 2.19: Resonant harmonic excitation dynamic response verification test.

Note also that the value of the steady-state response amplitude, Q_o, is dependent on the damping ratio ξ, providing a simple numerical check on the element's ability to correctly model viscous damping.

Sinusoidal loading was also used to test the DF element's nonlinear stiffness capabilities: bilinear hysteresis, elastic stiffness degradation, strain hardening options, gap development, and in-gap bilinear hysteresis. The results of these tests are presented in the four graphs of Figures 2.20 and 2.21. For these tests, no mass was assigned to the DF element, making the load quasi-static. In each of the four tests, the unitless elastic and plastic stiffnesses were $k_{e_i} = 5000$ and $k_p = 240$, respectively. The first graph of Figure 2.20 shows the results of a test of the elastic stiffness degradation capability; here the parameter α of equation (2.11) was taken to be $\alpha = 0.12$. Kinematic strain hardening, the default strain hardening rule, was used. In the second test, an identical sinusoidal load was applied to two DF elements, one using kinematic strain hardening, the other using isotropic strain hardening. The results of this test are shown in the second graph of Figure 2.20. The first graph of Figure 2.21 depicts the results of a test in which the DF element was allowed to develop a gap. No in-gap stiffness was specified (the default condition); the value of the γ parameter of equation (2.12) was $\gamma = 0.30$. In the fourth test, the same DF element was used, but with in-gap unitless stiffnesses of $k_1 = 300$ and $k_2 = 10100$, where k_1 and k_2 are as defined in Figure 2.11(c). The results of this test are given in the second graph of Figure 2.21.



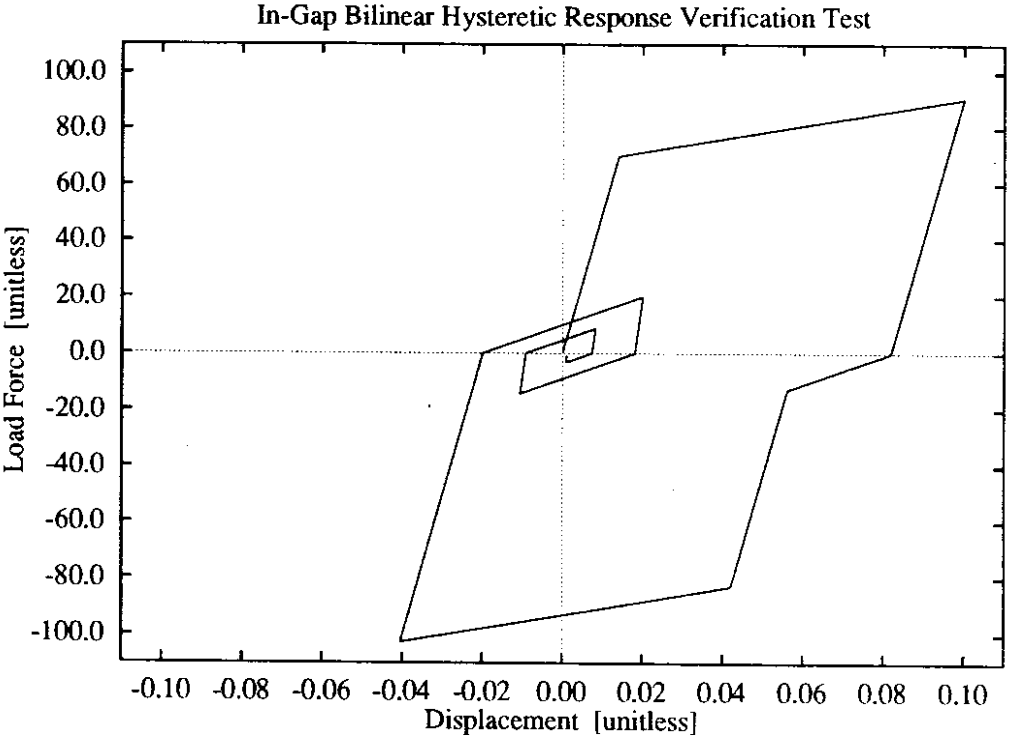


Figure 2.20: Nonlinear stiffness properties verification tests: (top) bilinear hysteresis with elastic stiffness degradation; (bottom) strain hardening options.

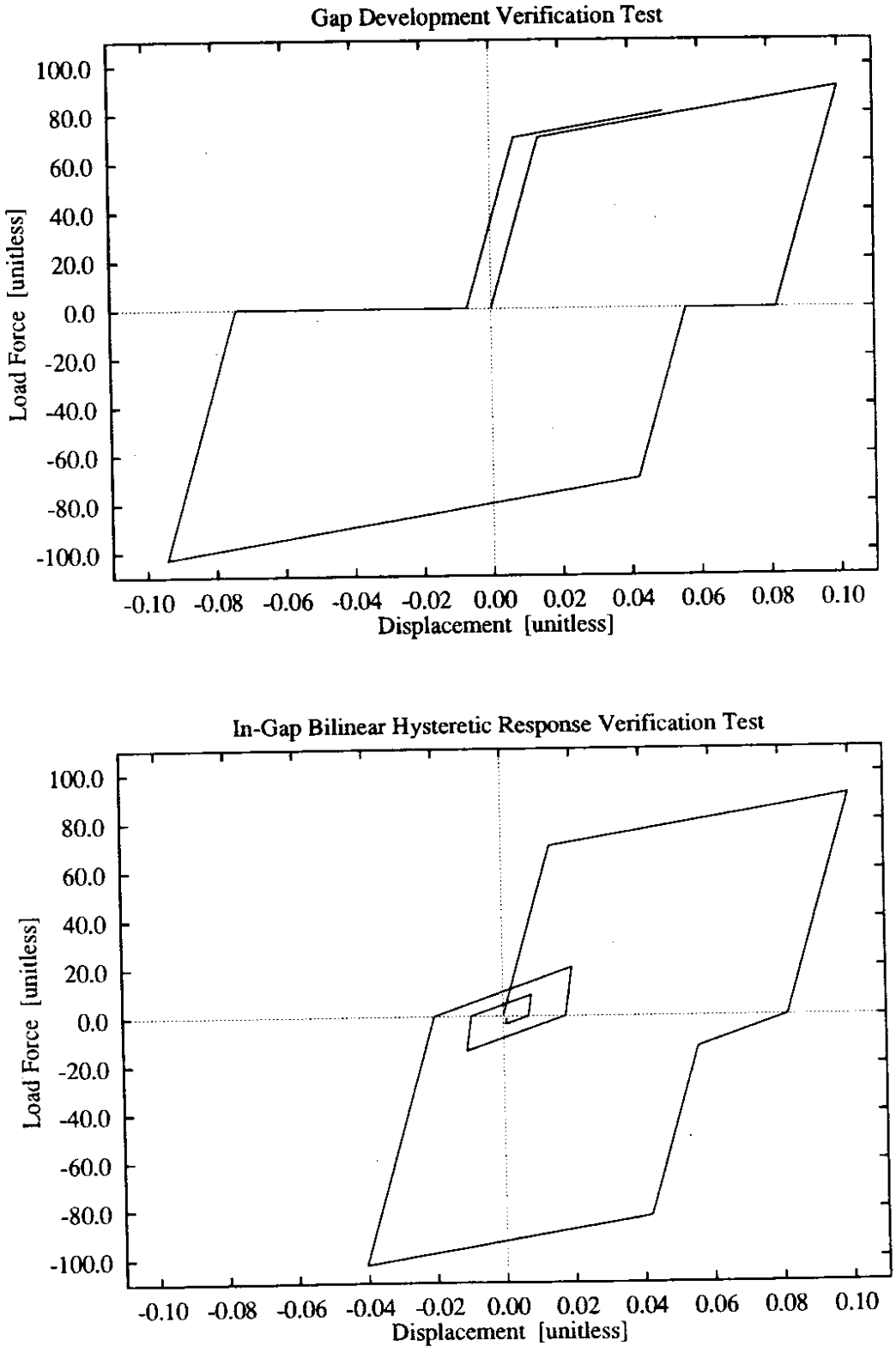


Figure 2.21: Nonlinear stiffness properties verification tests: (top) bilinear hysteresis with gap development; (bottom) bilinear hysteresis within gap.

Chapter 3

Findings and Interpretation

3.1 Parametric Study Approach and Objectives

A parametric study was undertaken to investigate the effects of incorporating foundation models of varying complexity into the seismic analysis of a bridge. Specifically, models relevant to representing soil–structure interaction at spread footing foundations and pile foundations were analyzed. The purpose was to compare the various foundation models with each other and with standard support conditions, such as fixed or elastic supports, in terms of the effects on bridge structural response. It should be noted that since the study results were not correlated with experimental response data, the study does not constitute a verification test of these models' accuracy in modeling bridge supports. Rather, it is an exploration of the structural response effects of incorporating these models in seismic bridge analysis. The identified effects are consistent with the assumptions made in the models themselves; establishing consistency between these assumptions and real bridge–foundation–soil behavior is outside the scope of this project.

However, these are in general well accepted assumptions for rationally incorporating soil–structure interaction in analysis.

The parametric study was conducted in two portions, one addressing spread footing foundation modeling, and the other addressing pile foundation modeling. Two Washington State highway bridges were chosen to provide bridge design guidance for the development of NEABS structural analysis models: a three-span overpass on Interstate 90 near Moses Lake (now dismantled), and the multispan westbound Interstate 90 bridge over Mercer Slough near Seattle. Bridge design, soil parameters, and other pertinent data was readily available for both bridges, both having been the subject of previous WSDOT research projects.

The bent columns of the Moses Lake bridge were founded on spread footings, while the Mercer Slough bridge bents' columns are supported by a pile–pile cap foundation. As will be described, a bridge bent from both of these bridges was analyzed with NEABS using a variety of foundation models. These bridge bent–foundation systems were subjected to lateral seismic excitation, transverse to the long axis of the bridge. Several key parameters of the resulting bent responses were chosen to characterize different aspects of the overall bent response, and the effects of the different foundation models on these response parameters were compared.

In this chapter, the two studies are considered; first the spread footing foundation study for the Moses Lake bridge, and then the pile

foundation study for the Mercer Slough bridge. The approach used in each study is discussed in detail, and the results are presented.

3.2 Spread Footing Foundation Study

The study using the Moses Lake bridge employed four different spread footing foundation models, along with a fixed-support "foundation." The NEABS model of the bent was based on the actual bridge bent, but a selected variation of founding soil properties was assumed in developing the foundation models, and thus the properties do not represent the soil conditions particular to the bridge. Descriptions of the bridge and site, the NEABS model of the bridge bent, the foundation models employed, the seismic excitation applied, and the observed results are presented in the subsequent sections.

3.2.1 Description of Bridge and Site

The bridge was located on Interstate 90, about 13 miles east of Moses Lake, and it was recently the subject of a WSDOT research project [39 and 40]. It was one of a pair of reinforced concrete bridges constructed in 1966 to span a now-abandoned railroad line. Figure 3.1 shows a photograph of the bridge, along with a plan-view drawing of the bridge and the site topography. The three-span bridge was 142 feet long. Two bents, skewed at 12.8°, supported the center span of 60 feet. The adjoining end spans

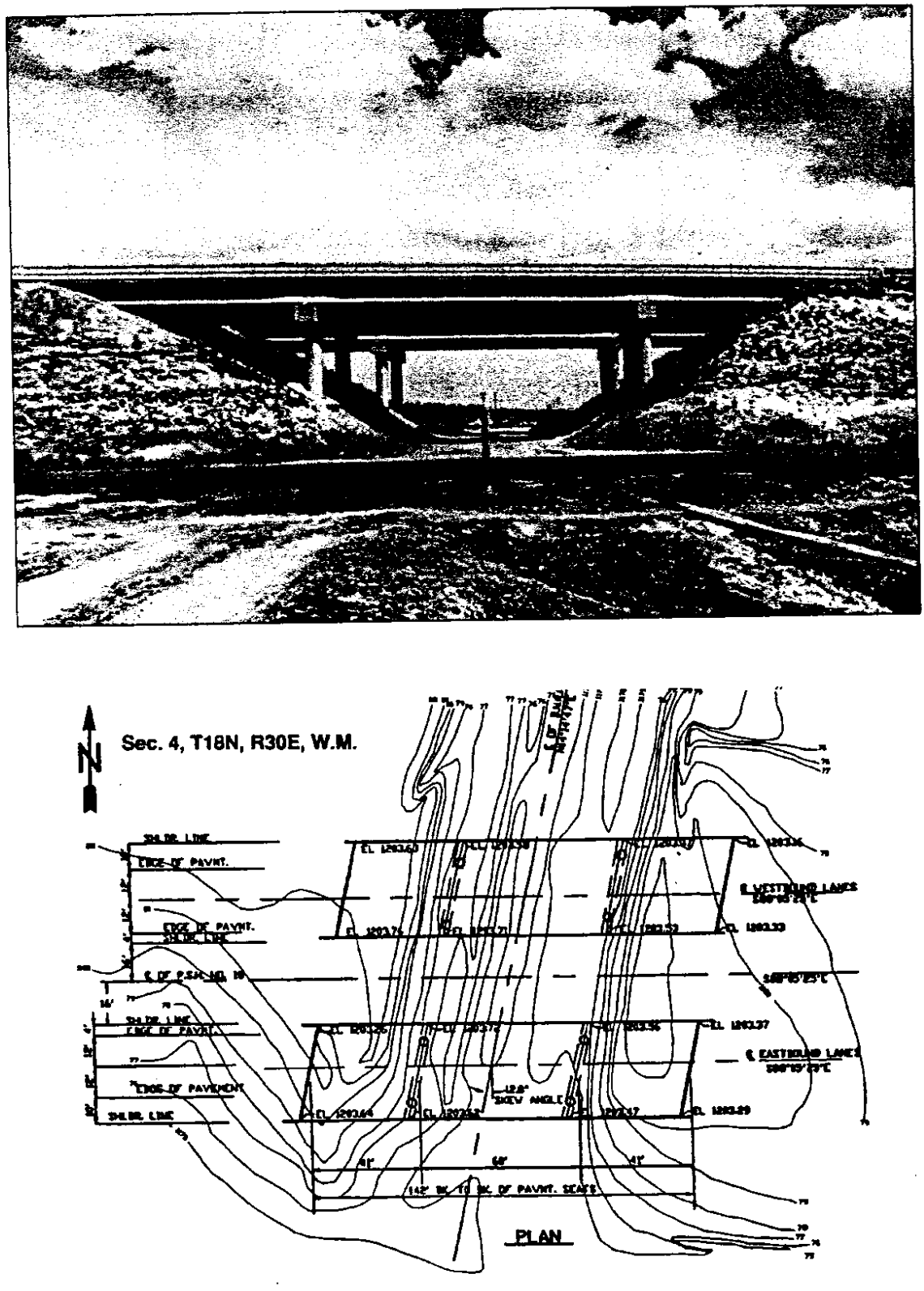


Figure 3.1: Interstate 90 three-span bridge near Moses Lake: (top) photograph showing elevation view of bridge; (bottom) plan view drawing of bridge and site. Adapted from [40] and [39].

were each 41 feet long, supported by the bents at one end and abutments at the other.

The reinforced concrete deck, 40 feet wide and 6.5 inches thick, was continuous over the two bents. The deck was supported by six prestressed concrete I-girders, 3 feet 6 inches deep and spaced at 6 feet 10 inches on center. These girders extended 2 inches into the 12-inch thick diaphragms at the bents and the cast-in-place abutments. At the bents, the heavily-reinforced diaphragm was cast monolithically with the slab and connected to the underlying bent crossbeam with No. 10 dowels. Eberhard *et al.* [39] report that, because of the heavy reinforcement and monolithic construction, the bridge was able to effectively transfer the high lateral test loading of the deck to the bents and the abutments. The abutments in particular were very stiff and strong. The bridge as a whole was therefore stiff and strong in the lateral direction, and tended to respond as a unit to lateral loads.

Figure 3.2 shows a detail of the bridge bents. The 42-inch wide, 36-deep crossbeam was reinforced longitudinally with ten No. 11 bars on the bottom and four No. 10 and six No. 11 bars on the top. Shear reinforcement was provided by No. 5 stirrups spaced at 12 inches. The crossbeam length was 39.5 feet, and it supported a static load of about 472 kips. The two supporting columns both had clear heights of about 25 feet, and their centerlines were spaced 24 feet apart. The circular columns had outside diameters of 36 inches. Eleven No. 9 bars provided

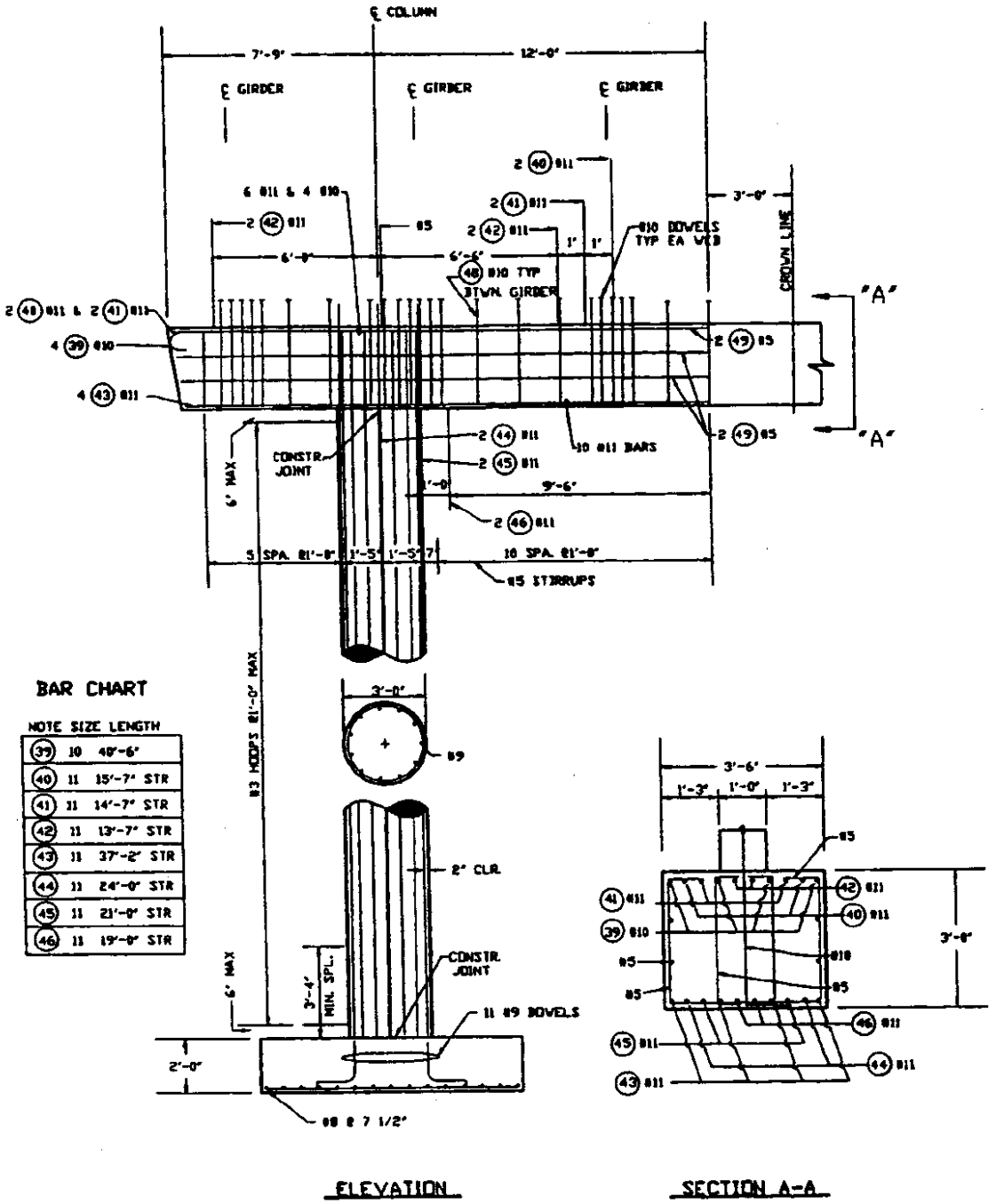


Figure 3.2: Moses Lake bridge bent column, crossbeam, and spread footing foundation details. Adapted from [39].

longitudinal reinforcement. The bars were spaced evenly around the cross-section perimeter and extended into the crossbeam with no splice. However, load transfer between the column bottom and the spread footing depended on a 40 inch lap splice (35 bar diameters). Column transverse reinforcement consisted of No. 3 hoops spaced at 12 inches; the hoops were closed with a 14-inch lap splice, but had no hooks into the column core. The spread footings were 9.5 feet square in plan and 24 inches deep. They were reinforced only at the bottom, by fourteen #8 bars in each direction. The footings and lower portions of the columns were embedded in compacted fill up to about half the column height, as shown in Figure 3.1.

The majority of the concrete used in the bridge was WSDOT class AX mix, which had a specified compressive strength at 28 days, f'_c, of 4000 psi. Eberhard *et al.* reports a measured in-situ compressive strength, f_c, of 6400 ± 300 psi, and a measured modulus of elasticity, E_c, of 4700 ± 200 ksi, for twelve cores taken from the columns [39]. Two samples of the longitudinal steel were also taken from the column, and found to have a modulus of elasticity, E_s, of 29,500 ksi, a yield stress, f_y, of 50.6 ksi, and an ultimate strength, f_u, of 86.3 ksi. The spread footings and the abutment wall were constructed of WSDOT class B mix with a specified compressive strength of f'_c = 3000 psi.

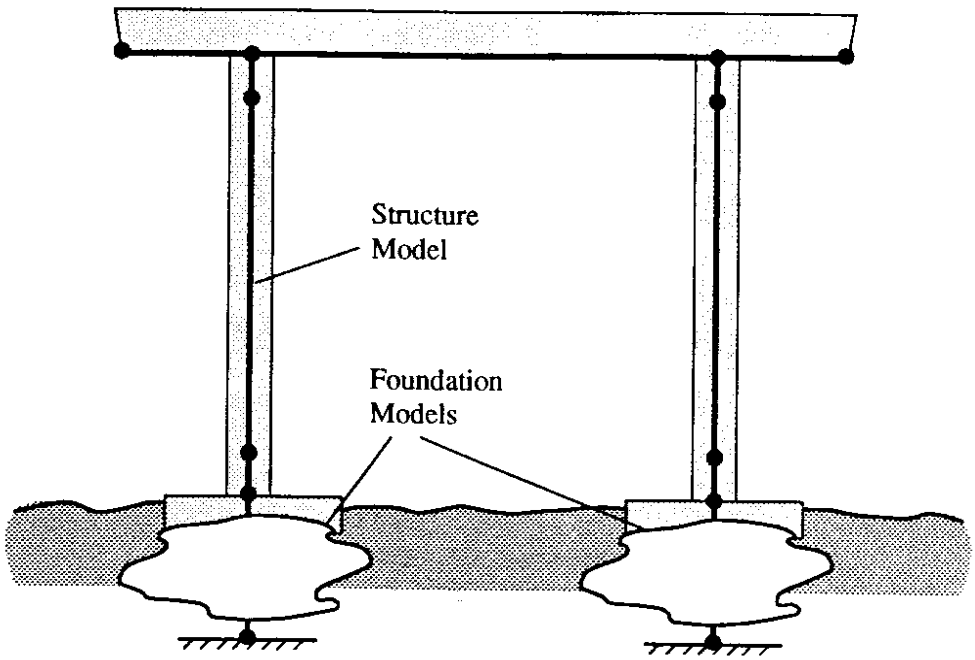
3.2.2 Structure Model

It was anticipated that the strength and stiffness of the bridge superstructure and abutments would minimize the dynamic participation of the soil-spread footing foundation in the overall seismic response of the bridge. To obtain a clearer understanding of the contribution to the structural response of the various foundation models, the spread footing study was confined to the analysis of an isolated bent. Additionally, the fill material surrounding the lower half of the columns was neglected. A schematic of the bent and foundation models used in the NEABS analyses is given in Figure 3.3. Note that the springs and dampers that are shown correspond to equivalent elastic half-space models for spread footings, as described in Section 2.1.3.

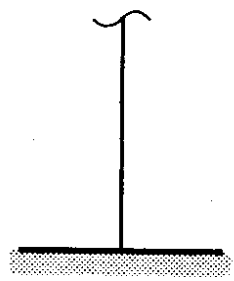
The bent structure itself was modeled with nine beam elements. This bent structure model was supported on various foundation models, which were comprised of DF elements. The crossbeam was modeled with elastic beam elements, while the columns used elasto-plastic beam elements. The modulus of elasticity used for the columns was E = 4600 ksi, as used by Eberhard *et al.* in their analyses [39]. The moment of inertia, I, that was used was half of that of the gross column cross-section, as suggested by Buckle *et al.* [1]. Thus, for the columns, the elastic stiffness was proportional to $EI_{eff} = 1/2E_cI_g$.

To define the yield surface for the elasto-plastic beam column elements, NEABS requires that an axial force-yield moment interaction curve be specified for bending about both of the beam element's local axes.

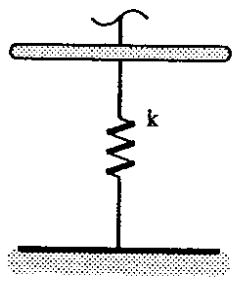
(a) Structure Model



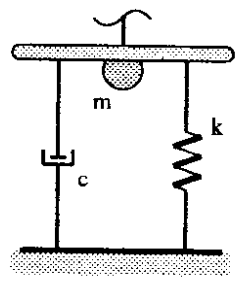
(b) Support Models



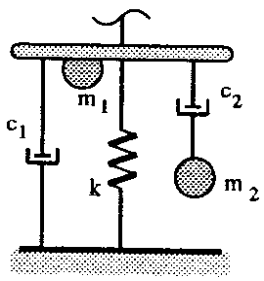
(i) Fixed Support (FX0)



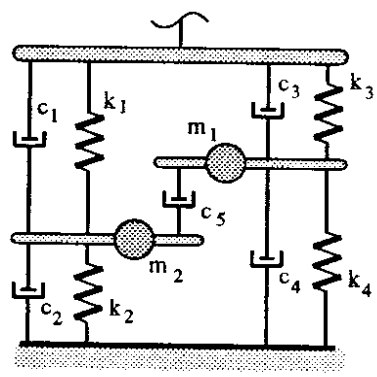
(ii) One Parameter (D01)



(iii) Three Parameter (D03)



(iv) Five Parameter (D05)



(v) Eleven Parameter (D11)

Figure 3.3: Schematic of the NEABS models of the Moses Lake bridge bent and supports employed: (a) model of the bent structure, with beam elements forming columns and crossbeam; (b) five support models—fixed supports and four models representing spread footing foundations.

NEABS uses the following cubic equation to represent these interaction curves:

$$M_y(P) = M_0\left[a_0 + a_1\left(\frac{P}{P_0}\right) + a_2\left(\frac{P}{P_0}\right)^2 + a_3\left(\frac{P}{P_0}\right)^3 \right] \qquad (3.1)$$

where P ≡ axial force on beam element (tension positive)

M_y ≡ yield moment under axial force P

M_0 ≡ yield moment in pure bending ($P = 0$)

P_0 ≡ ultimate axial compressive capacity, defined to be positive

a_0, a_1, a_2, a_3 ≡ required input coefficients

The required coefficients were determined by fitting a cubic curve to axial force–bending moment strength interaction data computed for the actual columns upon attainment of a maximum concrete strain of $\varepsilon_{cu} = 0.003$. The computed interaction data was generated by a computer program developed by Marsh [41], which discretizes the column cross-section and utilizes material constitutive laws developed by Burns and Seiss for steel and by Park and Kent for concrete, as reported in Park and Paulay [42], in its force equilibrium calculations. To facilitate this curve

fitting, the following equations were developed, which force the curve to pass through M_0 and P_0, and cause it to "peak" at M_m, as defined below:

$$
\begin{aligned}
a_0 &= 1 \\
a_1 &= \frac{1}{\alpha}\left[r^4 - qr(2-3r)\right] \\
a_2 &= \frac{1}{\alpha}\left[2r^3 - q(1-3r^2)\right] \\
a_3 &= \frac{1}{\alpha}\left[r^2 - q(1-2r)\right] \\
s &= \frac{1}{2a_3}\left[1 - a_1 - \sqrt{a_1^2 - 2a_1 - 4a_3 + 1}\,\right]
\end{aligned}
\tag{3.2}
$$

where M_m ≡ maximum yield moment

P_m ≡ compressive axial force at maximum yield moment (positive); M_m and P_m would typically occur at the balance point of an axial force–bending moment curve for a square cross-section

q ≡ $(M_m - M_0)/M_0$

r ≡ P_m/P_0, $r \neq ½$

α ≡ $r^2(1-r)^2$

s ≡ ratio P_t/P_0, required by NEABS, where P_t is the ultimate axial tensile capacity; in this method, s, and thus P_t also, are curve-dependent parameters

Figure 3.4 shows a comparison of the axial force–bending moment strength interaction data calculated for the column and the cubic curve used in the NEABS model, obtained by the above procedure; the fit is quite close. Since the column is axially symmetric, these curves apply to column

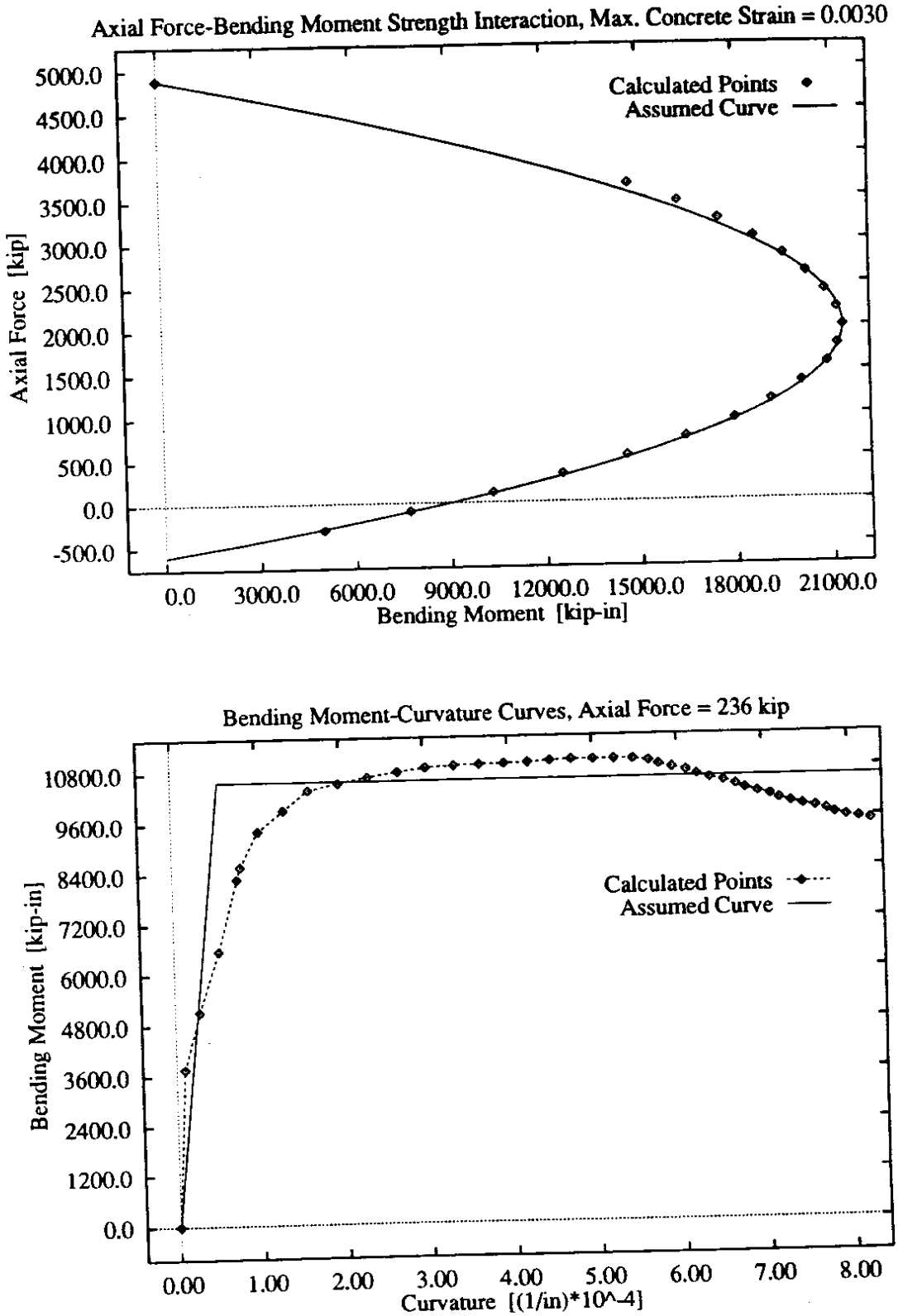


Figure 3.4: Calculated and assumed strength characteristics of Moses Lake bridge bent columns. Axial force–bending moment strength interaction curve taken at attainment of concrete strain of 0.003 in./in., and bending moment–curvature curve taken at static axial load of 236 kips.

bending about any axis. As another indication of this beam's accuracy in modeling the column's behavior, Figure 3.4 also shows a comparison of the bending moment–curvature relation calculated for the column under the static dead load of 236 kips and of the elasto-plastic curve used in the NEABS model. The bending moment–curvature data was calculated by a version of the computer program developed by Marsh [41] discussed earlier. The slope of the elastic portion of the NEABS curve is again $EI_{eff} = \frac{1}{2}E_cI_g$. The yield moment is determined by equation (3.1), the parameters of which were again determined by fitting a curve to the column's axial force–bending moment strength interaction diagram taken at attainment of a maximum concrete strain of $\varepsilon_{cu} = 0.003$. This fit is also close.

The stiffness of the crossbeam was deemed to be quite high relative to that of the column because of the heavy reinforcement and its secure connection with the monolithic diaphragm–deck structure. The crossbeam was therefore modeled as an essentially rigid member, having a stiffness that was approximately four orders of magnitude larger than that of the columns. The mass supported by the bent was applied by specifying an appropriate density for the three beam elements forming the crossbeam. Because NEABS lumps beam mass to the nodes at the beam element ends, the mass supported by the bent was therefore distributed to four lumped masses, two larger masses at the column tops, and two smaller masses at the crossbeam ends. The mass moment of inertia of the crossbeam used

in the NEABS model was calculated to be sufficiently close to that of the actual crossbeam assuming a uniform distribution of the supported mass.

To apply damping to the bent structure, the following rationale was used. If the crossbeam was truly rigid, and the bent columns were fixed at their bases, the bent would be a single-degree-of-freedom system. Further, if the columns remained elastic, then the natural period of transverse vibration of this system may be calculated to be 0.53 seconds. Damping was applied to the members forming the columns and the crossbeam by assuming damping in this mode of vibration to be 5 percent of critical ($\xi = 0.05$), and forcing damping in vibrational modes of all other periods to be higher. These constraints led to the following form of the Rayleigh damping coefficients:

$$\alpha = \xi\omega$$

$$\beta = \frac{\xi}{\omega} \qquad (3.3)$$

where $\omega \equiv$ frequency of the uncoupled vibrational mode assumed to have minimum Rayleigh damping (taken here to be $\omega = 2\pi/t$, where $t = 0.53$ seconds)

$\xi \equiv$ fraction of critical damping to be applied to vibration at the above frequency, ω (here $\xi = 0.05$)

$\alpha \equiv$ Rayleigh damping coefficient; fractional multiplier to apply to the system mass matrix

$\beta \equiv$ Rayleigh damping coefficient; fractional multiplier to apply to the system stiffness matrix

The NEABS models supported on the various foundation models are not single-degree-of-freedom systems, and their fundamental frequencies of vibration do not, in general, match the frequency used in the above method for determining the Rayleigh damping coefficients for the column–crossbeam portion of the system. However, by using these same α and β coefficients for all the NEABS analyses, and by not allowing Rayleigh damping to apply to the DF elements forming the foundation models, the contribution to the system damping from the column–crossbeam structure's Rayleigh damping was consistent for all of the analyses.

3.2.3 Foundation Models

As previously discussed, four foundation models were compared, as well as fixed-base supports. The four foundation models were all discrete approximations of the elastic half-space continuum model, but incorporated varying levels of complexity. These five support conditions are shown in Figure 3.3.

The spring stiffnesses for the spring-only model were taken from the equivalent static stiffnesses of an elastic half-space, which are given in equations (2.2). It will be referred to as a "one parameter" model because it requires the specification of one parameter, the spring stiffness, in each degree-of-freedom. The three-parameter spring-mass-dashpot model was presented by Veletsos and Verbič [29]. The five-parameter model was

presented by Meek and Veletsos; here the parameters were taken from Wolf's discussion of this model [31]. The eleven-parameter model was presented by Jean *et al.* [33]. A nine-parameter model, presented by Wolf and Paronesso [32], was also tried, but it was not pursued because of apparent numerical instabilities when applied within NEABS, probably due to the model's numerous negative stiffness and damping parameters. As shown in Figure 3.3, these models are also assigned a name of the form "D*nn*," where *nn* refers to the number of required parameters per degree-of-freedom. As discussed in Chapter Two, the more complex discrete models yield greater accuracy in representing the assumed half-space continuum soil model over a wider range of frequencies.

Since these discrete foundations are models of an *elastic* half-space, the damping present in those foundations incorporating dashpots models radiation damping only. Energy dissipation due to material damping, or to nonlinear action of the soil, is not modeled. These mechanisms would be expected to be significant only in the region of the soil in the immediate vicinity of the structure, the soil near-field. The elastic half-space foundation models are therefore better suited for capturing the effects of the far-field response than the near-field response. However, in the absence of applicable near-field models, the foundation models were applied directly to the bent base.

To obtain the equivalent radii for the square footings, the method discussed in conjunction with the Pais and Kausel prismatic foundation in

Chapter Two was used for all of the foundation models. Unlike the actual bridge bents, the footings and the columns were not assumed to be embedded, so no modification of the models to account for embedment was necessary.

Three soil stiffnesses were used in testing each model, making a total of twelve individual foundations in addition to the fixed-base bent. The stiffnesses were selected to span a range of soil stiffnesses commonly encountered. Based on soil tests reported by Eberhard *et al.* [39], the unit weight of the soil, γ_s, was taken to be 110 pcf. Three shear wave velocities, c_s, of 300, 700, and 1300 fps were selected to produce the three soil stiffnesses; for the given soil density, these corresponded to soil shear modulii, G, of 2140, 11,650, and 40,170 psi, respectively. These soils are identified as "soft," "intermediate," or "stiff," referring to their relative stiffnesses. Poisson's ratio for the soil was taken to be $\nu = 0.33$.

3.2.4 Seismic Excitation

Acceleration histories from actual earthquakes formed the basis of the seismic excitation applied to the bridge bent–foundation system. Two earthquake acceleration records were chosen to provide different frequency contents, and both records were scaled to two different intensities, providing four different frequency content–intensity combinations to be used as seismic input.

The two earthquake records chosen were the S00E component of the El Centro record of the 1940 Imperial Valley Earthquake (referred to as the "El Centro" record) and the N86E component of the Olympia record of the 1949 Western Washington earthquake (or "Olympia" record). The 1940 Imperial Valley earthquake was of 6.7 Richter magnitude, and the peak ground acceleration of the El Centro record was 0.35g. The 1949 Western Washington earthquake registered a magnitude 7.1 on the Richter scale, and 0.28g was the peak ground acceleration of the Olympia record. Acceleration history plots of the complete records are given in Figure 3.5.

As can be seen in Figure 3.5, it was not necessary to use the entire duration of either record. The method proposed by Trifunac and Brady (reported in [36]) for determining the strong-motion duration was employed to limit the record durations used as seismic input. The Trifunac and Brady duration lies between the accumulation of the first 5 and 95 percent of the quantity $\int a^2 dt$, where a is the earthquake acceleration and t is time. The duration used in this study began at the beginning of the record and ended at end of the Trifunac and Brady strong-motion duration (at 26.10 seconds and 24.42 seconds from the beginning of the record for the El Centro and Olympia records, respectively, as reported in [36]). Acceleration plots of the record durations that were modeled and elastic single-degree-of-freedom acceleration response spectra for the two records are given in Figures 3.6 and 3.7.

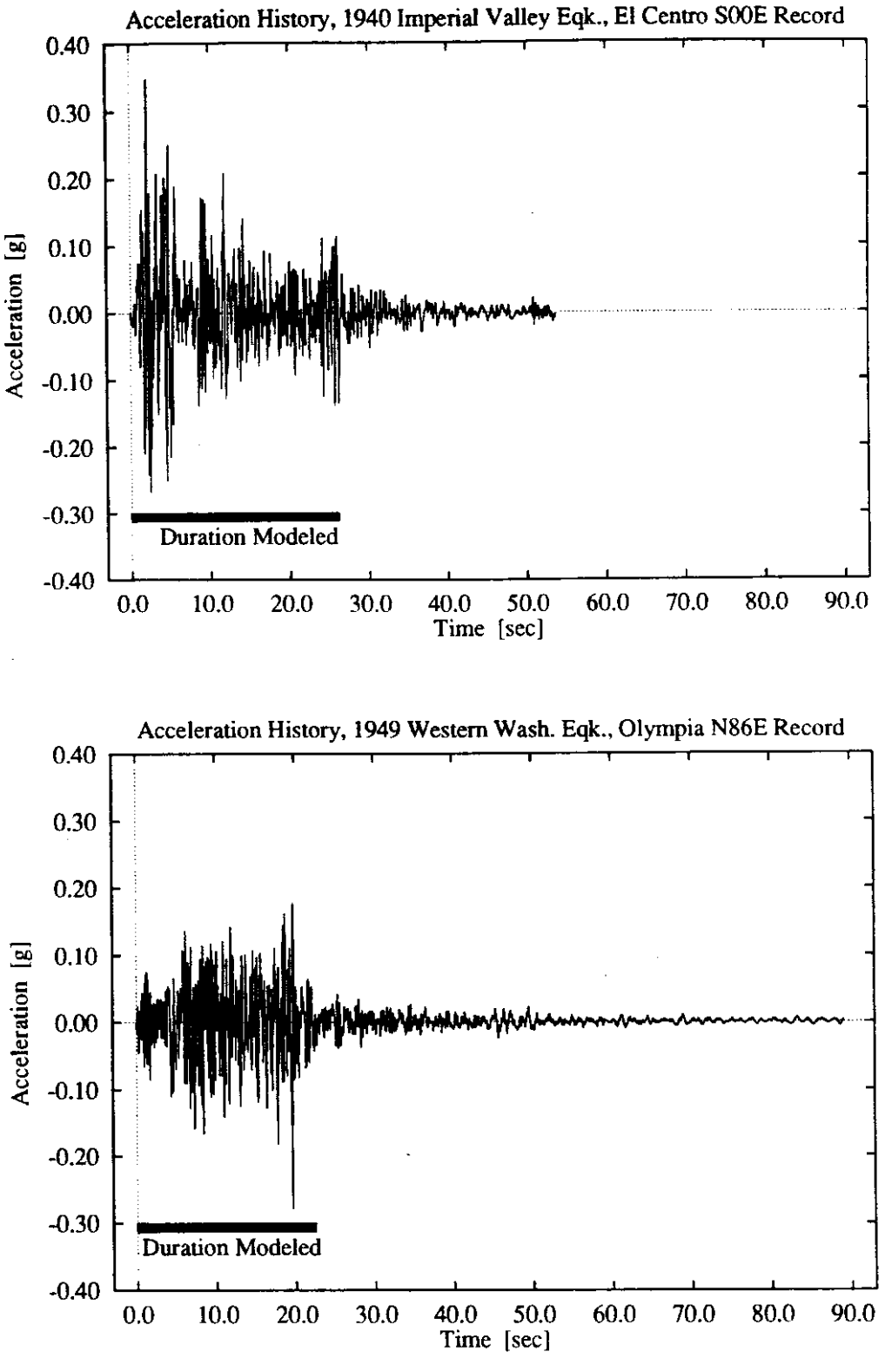


Figure 3.5: Complete acceleration history plots of the El Centro and Olympia records.

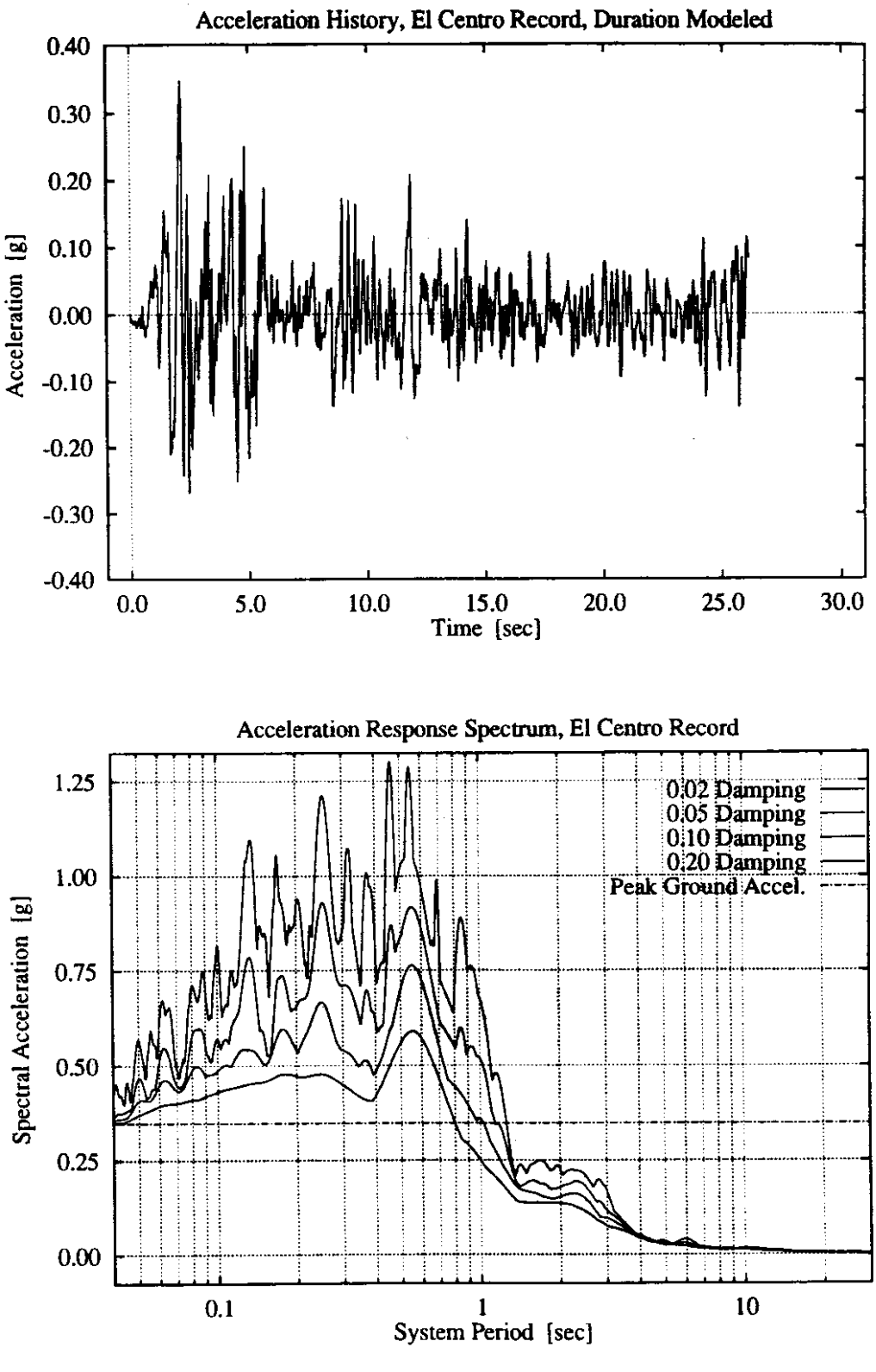


Figure 3.6: El Centro record: acceleration plot of duration modeled and acceleration response spectra.

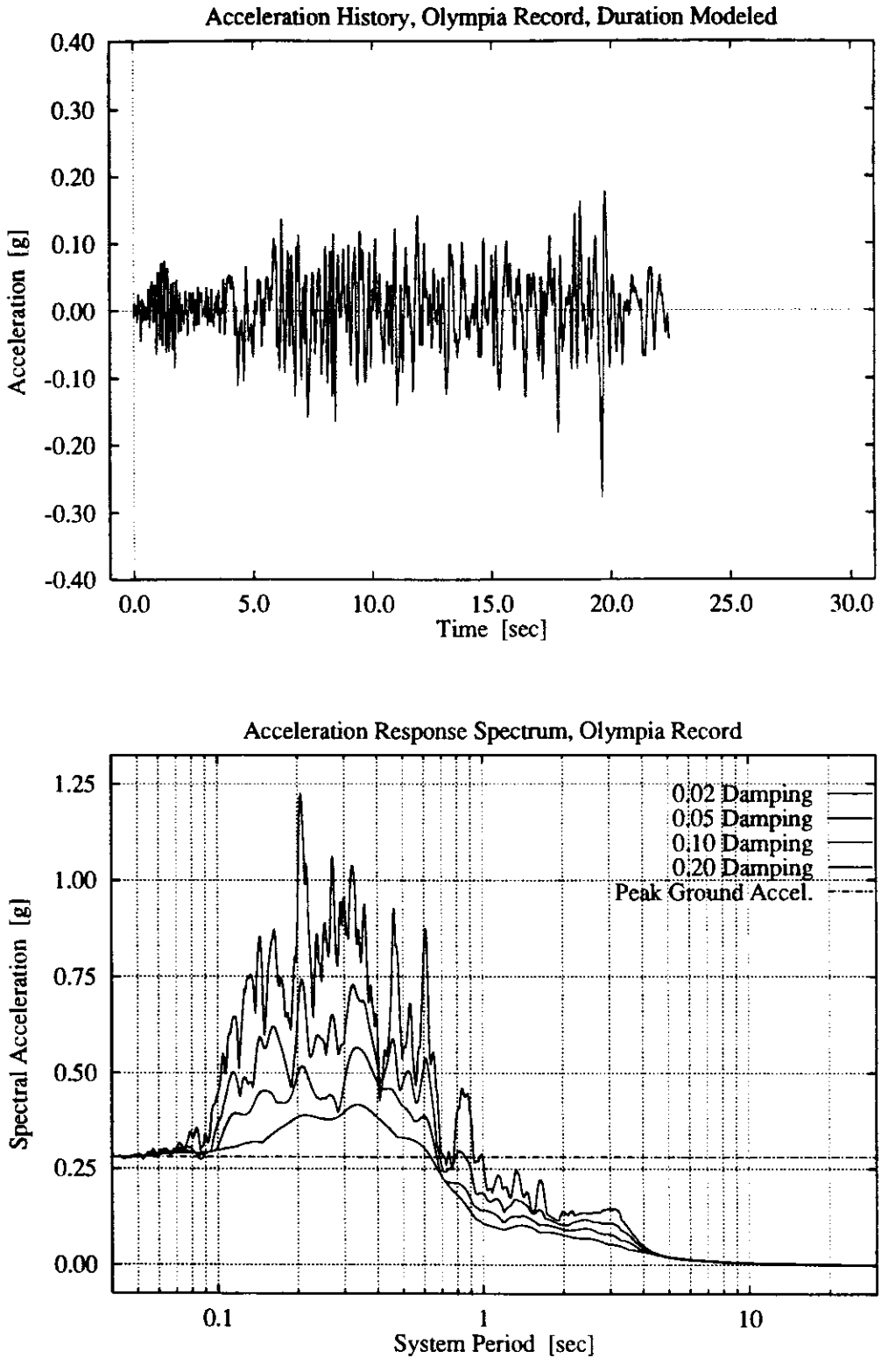


Figure 3.7: Olympia record: acceleration plot of duration modeled and acceleration response spectra.

The differences in the two acceleration response spectra are indicative of the different frequency content of these two records. To incorporate variations in record intensity in the study, both records were scaled to two different intensities, referred to as "lower" and "higher" intensities. The effective peak acceleration, or EPA, of each record was selected as the relevant intensity indicator. The EPA of a record is related to the average spectral acceleration the record produces over a certain system period range rather than to the ground motion itself. Thus, for engineering purposes, it is a more characteristic measure of intensity than peak ground acceleration [43]. The records were scaled such that the lower intensity El Centro and Olympia seismic inputs both had an intensity of 0.25g EPA, while the higher intensity inputs had an intensity of 0.40g EPA.

3.2.5 Discussion of Results

The performance of the various foundation models was assessed in terms of their effects on the response of the bent structure. Specifically, three aspects of the bent's response were selected to be studied: column drift (the displacement of the column top relative to the bottom), the internal moment at the column top, and the rotation of the plastic hinge at the column top. NEABS provided this information in the form of time histories. The results were then interpreted in terms of their implications for column ductility and energy dissipation demands.

A total of 52 NEABS analyses were performed. As discussed, there were five supports modeled (four foundation models plus the fixed-base bent); three soil stiffnesses were applied to each of the four foundation models (thirteen individual support conditions); and each support condition was subjected to the four seismic input records. Figure 3.8 displays this information in a matrix form, and indicates the "name" by which each of the 52 runs is identified. The nomenclature used in Figure 3.8 to identify the foundation model, the soil, and the applied seismic record, is discussed in the previous sections.

To facilitate the study of these three response parameters, four different graphs of the data from each NEABS analysis were created. Figure 3.9 shows a typical example of the first two graphs, which are time histories of the column drift and of the column top moment. It should be noted that the moment reported by NEABS appears to be the sum of the internal moments produced by the column stiffness and damping actions. The third graph, shown in Figure 3.10, depicts column moment–drift hysteresis. If it is assumed that the column drift is roughly proportional to the rotation of the column top (it is exactly proportional only for the fixed-base model, which does not allow rotation at the column base), then the area enclosed by this hysteresis curve is roughly proportional to the energy dissipation demand. The fourth graph, also shown in Figure 3.10, is a time history of the plastic rotation of the column top. Horizontal lines on this graph indicate that the column top joint is elastic; vertical

Spread Footing Parametric Study
Matrix of NEABS runs

		El Centro Record		Olympia Record	
		Lower Intensity	Higher Intensity	Lower Intensity	Higher Intensity
Fixed		SF01-FX0._EL	SF02-FX0._EH	SF03-FX0._OL	SF04-FX0._OH
D01 Model (Springs only)	Soft	SF05-D01.FEL	SF06-D01.FEH	SF07-D01.FOL	SF08-D01.FOH
	Intermediate	SF09-D01.IEL	SF10-D01.IEH	SF11-D01.IOL	SF12-D01.IOH
	Stiff	SF13-D01.SEL	SF14-D01.SEH	SF15-D01.SOL	SF16-D01.SOH
D03 Model (Springs, Mass, & Dashpot)	Soft	SF17-D03.FEL	SF18-D03.FEH	SF19-D03.FOL	SF20-D03.FOH
	Intermediate	SF21-D03.IEL	SF22-D03.IEH	SF23-D03.IOL	SF24-D03.IOH
	Stiff	SF25-D03.SEL	SF26-D03.SEH	SF27-D03.SOL	SF28-D03.SOH
D05 Model (Meek & Veletsos)	Soft	SF29-D05.FEL	SF30-D05.FEH	SF31-D05.FOL	SF32-D05.FOH
	Intermediate	SF33-D05.IEL	SF34-D05.IEH	SF35-D05.IOL	SF36-D05.IOH
	Stiff	SF37-D05.SEL	SF38-D05.SEH	SF39-D05.SOL	SF40-D05.SOH
D11 Model (Jean et al.)	Soft	SF41-D11.FEL	SF42-D11.FEH	SF43-D11.FOL	SF44-D11.FOH
	Intermediate	SF45-D11.IEL	SF46-D11.IEH	SF47-D11.IOL	SF48-D11.IOH
	Stiff	SF49-D11.SEL	SF50-D11.SEH	SF51-D11.SOL	SF52-D11.SOH

Figure 3.8: Matrix of the 52 NEABS analysis runs for the study of spread footing models. Each run is identified by a name of the form "SF*nn–fff.see*," where *nn* is the run number, *fff* is the foundation model code, *s* is the soil stiffness code, and *ee* is the applied seismic record code.

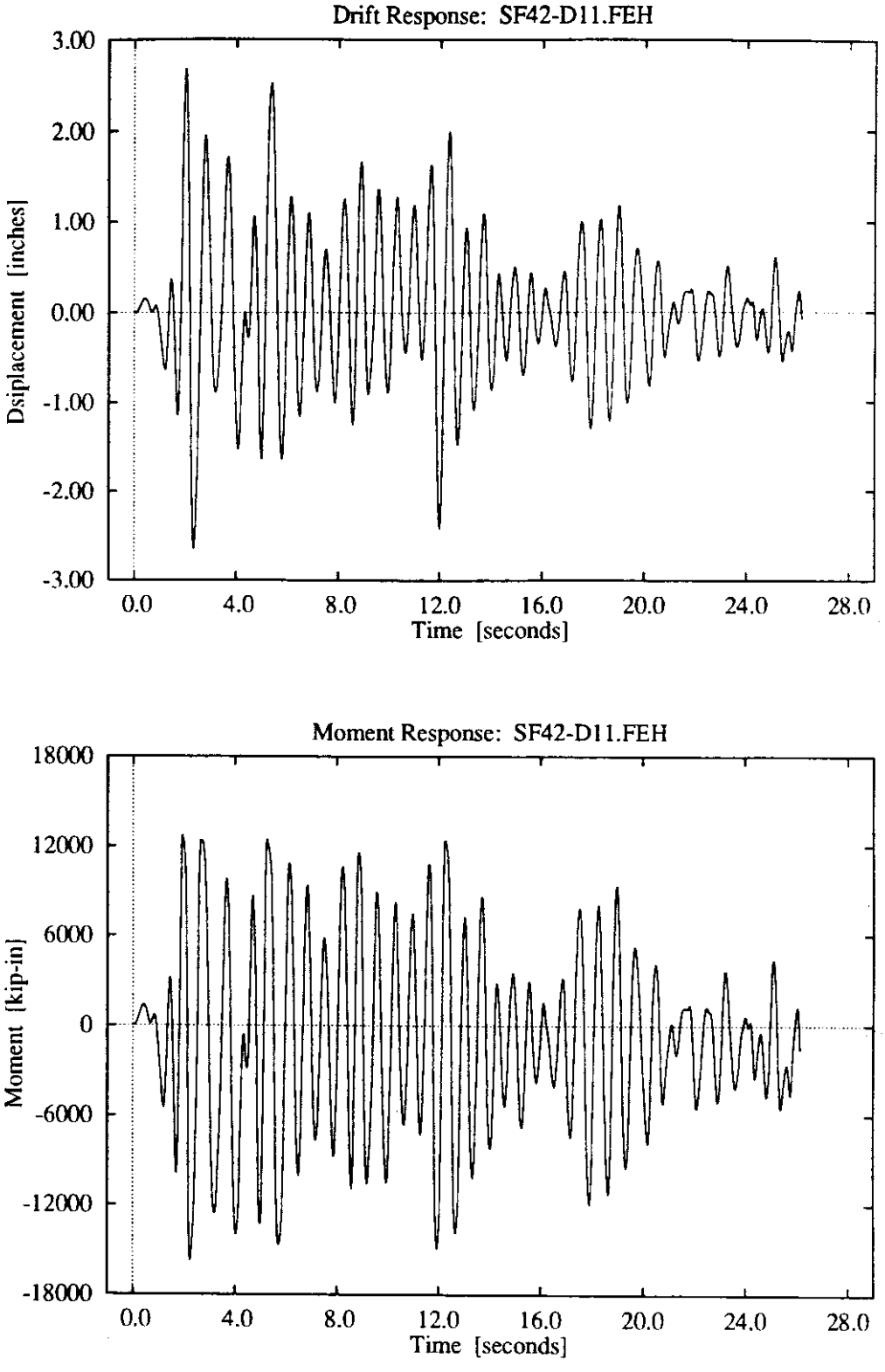
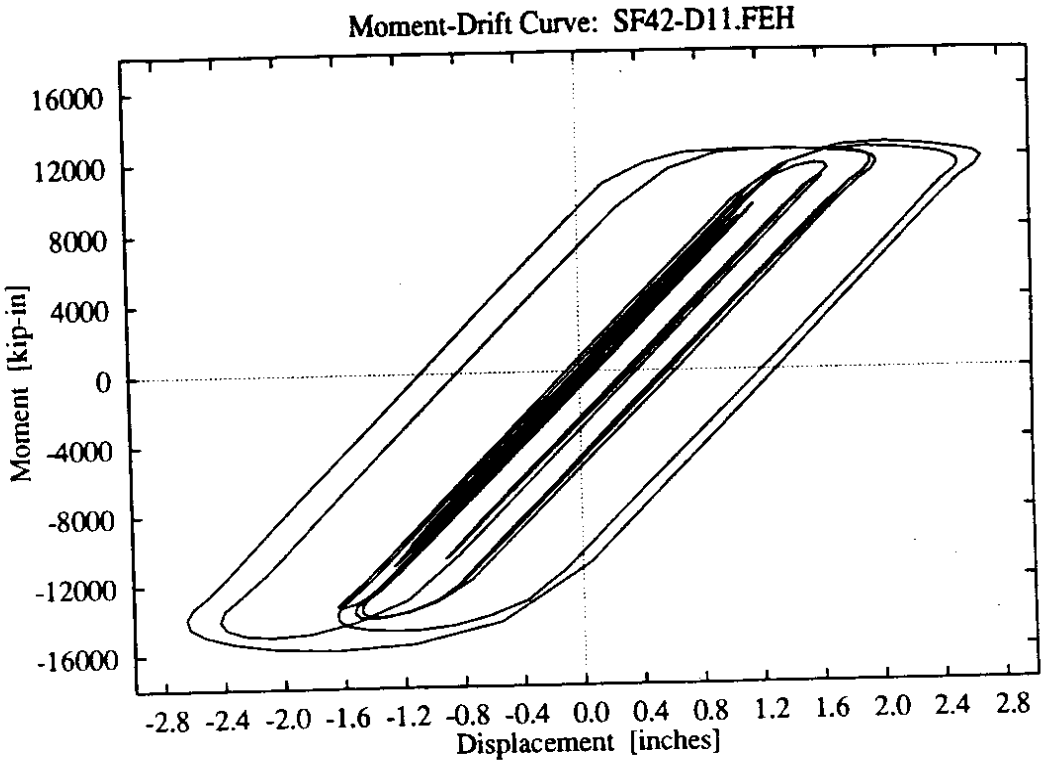


Figure 3.9: Typical results: time histories of column drift (relative lateral displacement between column top and bottom) and of the internal moment at the column top.



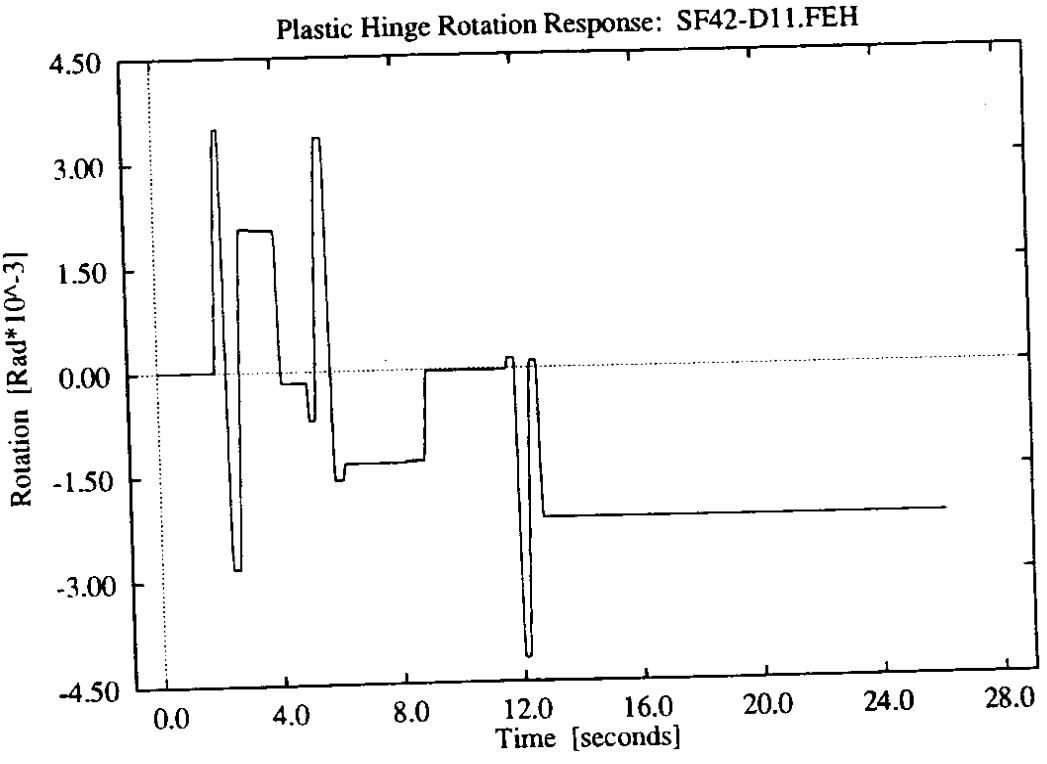


Figure 3.10: Typical results: Column moment–drift hysteresis and time history of the rotation of the plastic hinge at the column top.

movement indicates that a plastic hinge has formed at the column top, and it is being rotated by the internal moment. The lengths of these plastic rotation excursions are indicative of rotational ductility demand. Also, if the axial force on the columns is assumed to be constant, or nearly so, over the duration of the excitation, then the moment required to yield the column top will also be constant. If this is the case, then the work done on the column top over the excitation duration will be the yield moment multiplied by the sum of the vertical (absolute) lengths of all the plastic excursions indicated in the fourth graph (again, the second graph of Figure 3.10). Thus, for constant axial force, this plastic rotation "sum" is proportional to the energy dissipation demand of the column upper plastic hinge zone.

The column axial force observed in the analyses, however, was not nearly constant. The range of axial forces observed in the analyses with the more severe response resulted in a range of column top yield moments, as per equation (3.1), which varied approximately 20 percent from the median yield moment. Within the accuracy of assuming this varying yield moment to be constant, the plastic rotation sum obtained from the fourth graph provides an approximate indication of the energy dissipation demand of the upper plastic hinge zone. The four graphs discussed were compiled for all of the analyses and are given in Appendix D, along with the foundation model parameter values used in the analyses.

To summarize and compare these results, the maximum plastic rotation (measured from the initial orientation of the hinge) and the sum of all the plastic rotation was recorded for each run. As explained, these quantities are related to ductility and energy dissipation demands. This data is given in the form of bar charts in Figures 3.11 through 3.14. Each figure displays the bar charts of both the rotation maxima and rotation sums for the given seismic excitation record. Each chart shows the results of the four foundation models for each soil stiffness, and references them to the fixed-base results.

The response of the bridge bent to the two earthquakes is somewhat different, although the intensity of each record resulted in plastic hinge formation at the column top for almost all analyses. For the El Centro record, the models representing stiff and intermediate soil stiffness led to nearly the same ductility and energy dissipation demands at the column top as those observed for the fixed-base model. The models representing soft soil resulted in a significant increase in energy dissipation demand for both intensities, and they led to increased ductility demand for the lower intensity record. The ductility demand for the higher intensity El Centro record was approximately the same for all the foundation models.

As noted, the soft soil models caused an increase rather than a reduction in column demands. Comparing the El Centro record acceleration trace of Figure 3.6 with the plastic hinge rotation history of Figure 3.10 (D11 model of the soil, subjected to the higher intensity

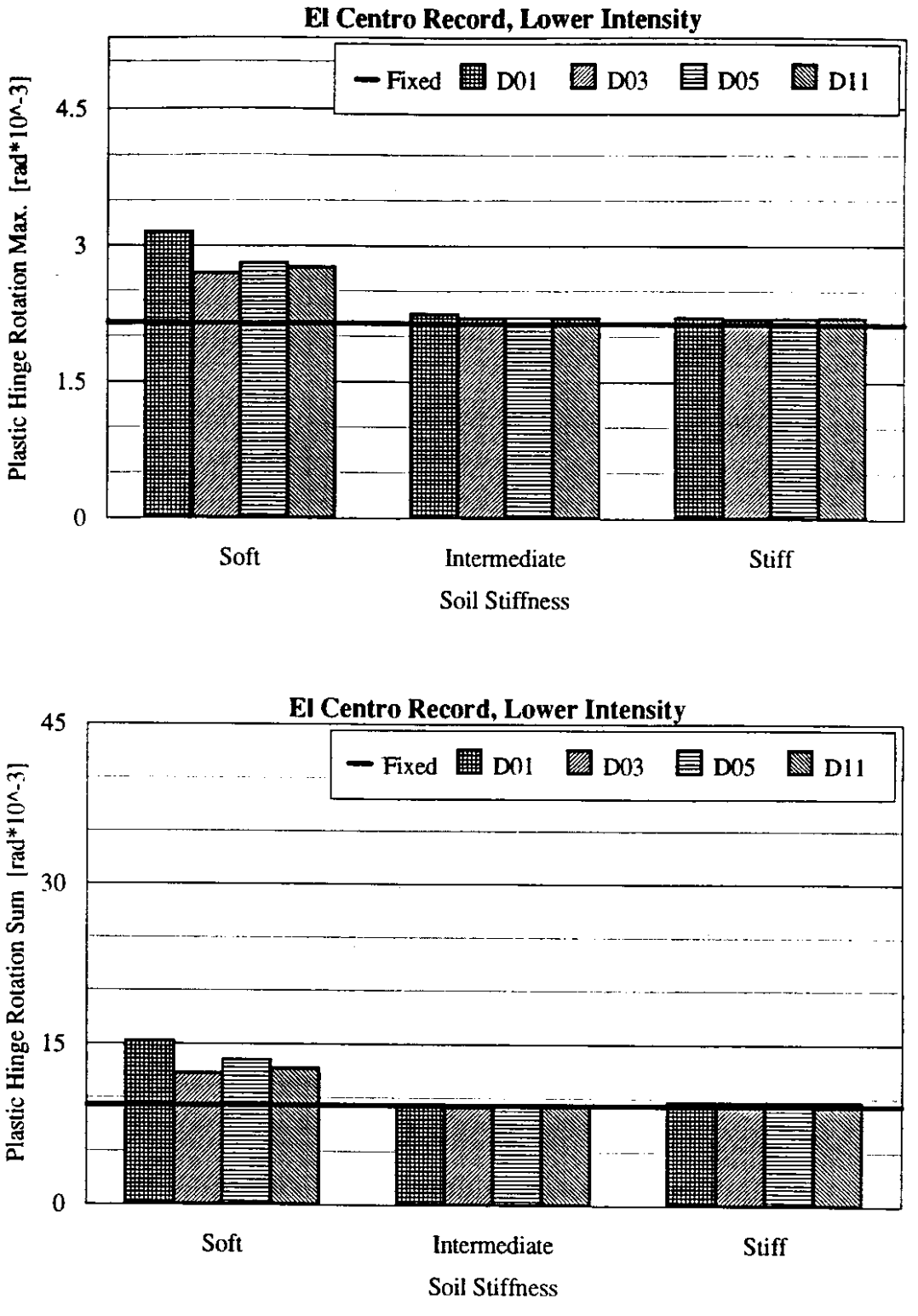


Figure 3.11: Comparison of effect of foundation model and soil stiffness on response of plastic hinge at column top during lower intensity El Centro record excitation: (top) maximum rotation attained (related to ductility demand); (bottom) total rotation sustained (related to energy demand).

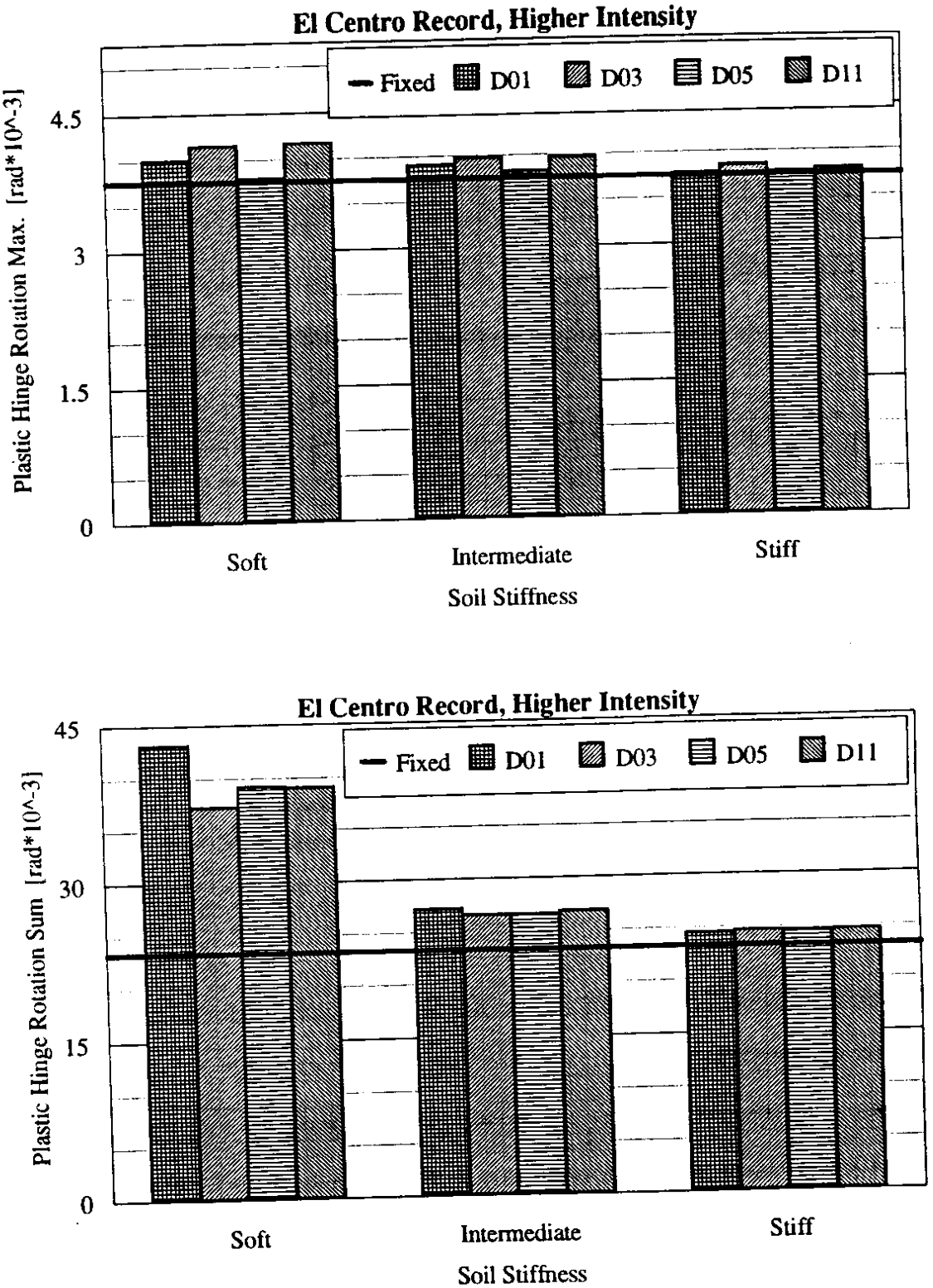


Figure 3.12: Comparison of effect of foundation model and soil stiffness on response of plastic hinge at column top during higher intensity El Centro record excitation: (top) maximum rotation attained (related to ductility demand); (bottom) total rotation sustained (related to energy demand).

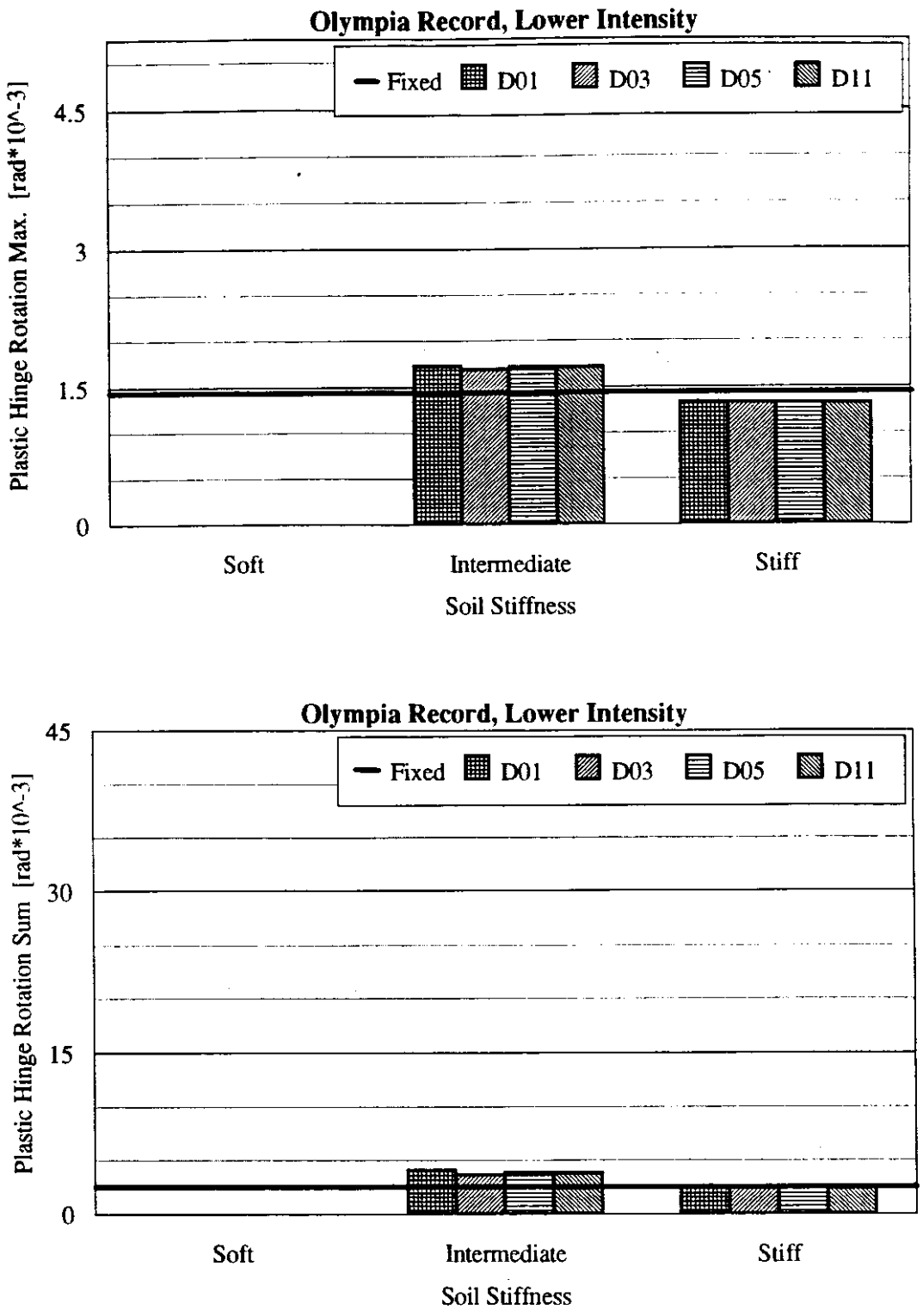


Figure 3.13: Comparison of effect of foundation model and soil stiffness on response of plastic hinge at column top during lower intensity Olympia record excitation: (top) maximum rotation attained (related to ductility demand); (bottom) total rotation sustained (related to energy demand).

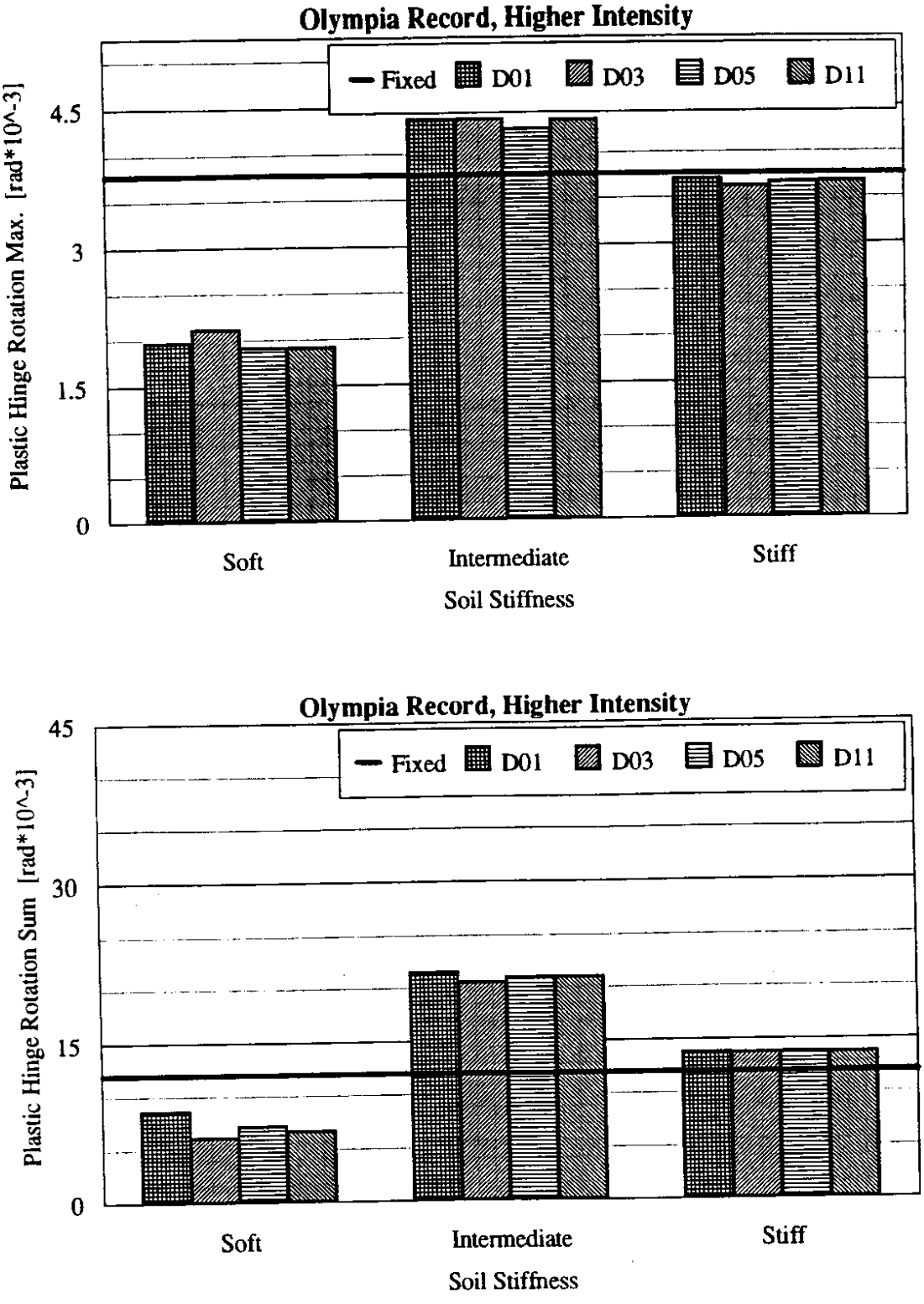


Figure 3.14: Comparison of effect of foundation model and soil stiffness on response of plastic hinge at column top during higher intensity Olympia record excitation: (top) maximum rotation attained (related to ductility demand); (bottom) total rotation sustained (related to energy demand).

El Centro record), it may be observed that much of the damage results from record acceleration peaks occurring at approximately 2 seconds, 5 seconds, and 12 seconds. The peak at 12 seconds is a major source of the increase in demand over the bents with the intermediate and stiff soil foundations. This may be caused by more excitation near the fundamental period of the soft soil-founded bent.

If only the lateral and rocking half-space static springs are applied to the column bases, neglecting the vertical springs, the equivalent lateral bent elastic stiffness may be calculated with the following equation:

$$k^{equiv} = \left[\frac{1}{k_x} + \left\{ k_c \left[1 - \frac{3}{4} \left(1 + 3 \frac{k_{\theta x}}{k_c} \right)^{-1} \right] \right\}^{-1} \right]^{-1} \qquad (3.4)$$

where k_x ≡ lumped stiffnesses of half-space translational springs

$k_{\theta x}$ ≡ lumped stiffnesses of half-space rocking springs

k_c ≡ lumped equivalent lateral stiffness of columns with ends fixed

From this equivalent stiffness, the fundamental period of bent translational vibration may be approximated. It was calculated that this period was increased by 27 percent over the fixed-base period of 0.53 seconds for the bent founded on soft soil, as opposed to period increases of 6 and 2 percent for the other soil stiffnesses. The predominant period of excitation at the 12 second acceleration peak appears to be about

0.7 seconds, which is close to the soft soil-founded bent's approximate shifted period of 0.68 seconds.

Another possible reason for the increased column top response observed for the soft soil is the redistribution of column moment which occurs as the resistance to rotation of the column base is made more flexible. Even if the column moment experienced by a column with a flexible base was somewhat lower than that experienced by a column with a stiff base (and assuming the columns are responding elastically), proportionally more moment in the flexible-base column would be concentrated at the top, and a net increase in column top moment may be observed.

For the Olympia records, the column ductility demands were of the same order as those of the El Centro records for the bents using the intermediate and stiff foundation models, but much less for the soft soil-founded bent. Indeed, no column yielding was indicated for the bent when founded on the soft soil models and subjected to the lower intensity Olympia records. The energy dissipation demand, however, was significantly less for all foundations when compared to that of the El Centro records. The two earthquakes were scaled to the same effective peak accelerations, but from Figure 3.7, it is apparent that the Olympia record is dominated by a single peak occurring at approximately 20 seconds. Because the majority of the column damage is caused by this

peak, as opposed to several different peaks in the El Centro records, the total amount of plastic hinge rotation is reduced.

The results portrayed in Figures 3.11 through 3.14 indicate that the bent response, considered in terms of ductility and energy dissipation demands of the column top, are sensitive to the combination of frequency content of the seismic excitation and stiffness of the founding soil. The variation of response trends noted previously with soil stiffness was typically consistent between the higher and lower intensity records of either earthquake, but were not consistent between the two earthquakes.

If it is assumed that the elastic half-space represents the actual foundation conditions more realistically than a fixed-base model, and that the D11 foundation model most accurately represents the half-space, then the closeness of the response when using a given foundation model to that produced by the D11 model is a measure of the relative accuracy of that model. Using this criteria, the fixed-base model was at times significantly unconservative. Additionally, reasonably close agreement was observed between the three simpler foundation models and the D11 model. Of these three models, the most significant deviations from the response produced by the D11 model occurred when using the D01 (springs only) model to represent soft soil. In this case, the response produced by the D01 model was greater; otherwise it was in close agreement with the other foundation models. Since this trend was observed for all four records, it would appear

to indicate that radiation damping, which the D01 model neglects, is significant only for modeling soils considerably softer than the bridge structure, and that neglecting it is usually a conservative assumption.

The close agreement between the responses produced by the four foundation models indicates that relatively simple models are likely to be adequate for representing the soil as a half-space. The D01 model was in good agreement with the D11 model for the intermediate and stiff soils, and the D03 model agreed closely for all soil stiffnesses. Further, the response produced by the half-space models appeared to approach that of the fixed-base model for stiff soil, as expected, since the fixed-base model may be thought of as representing a soil of infinite stiffness.

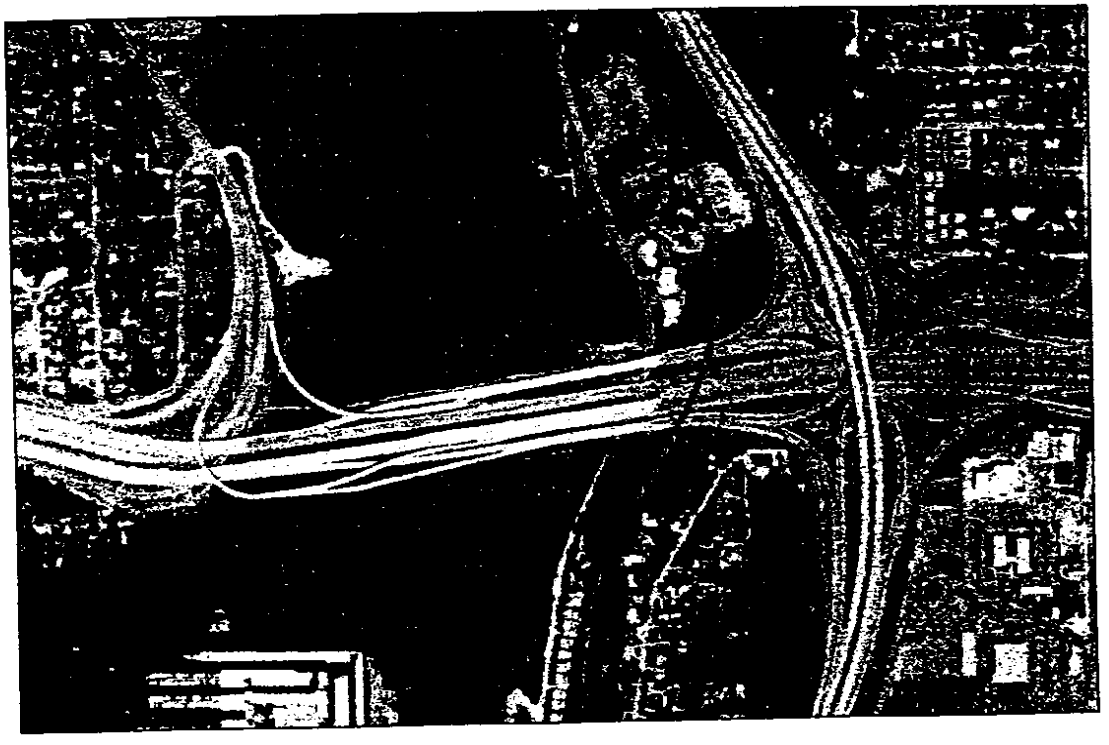
3.3 Pile Foundation Study

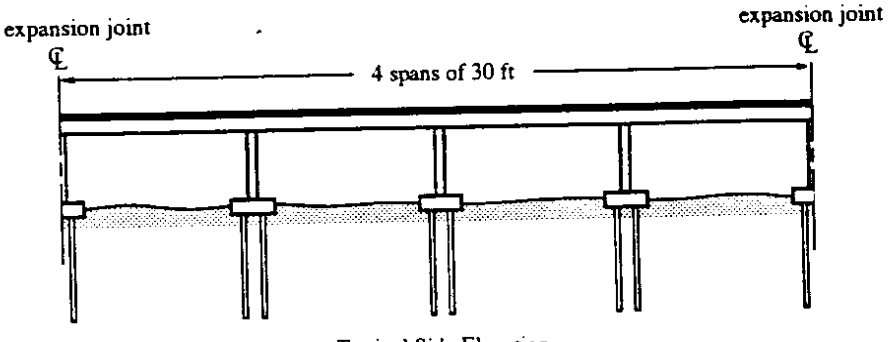
The study using the Mercer Slough bridge employed four different pile foundation models, along with a fixed-support "foundation." The bridge bent model and pile foundation models used in NEABS were based on the dimensions and material properties of the actual bridge. Additionally, the applied seismic excitation incorporated the effects of the founding soil conditions unique to Mercer Slough. Descriptions of the bridge and site, the NEABS model of the bridge bent, the foundation models employed, the seismic excitation applied, and the observed results are presented in the subsequent sections.

3.3.1 Description of Bridge and Site

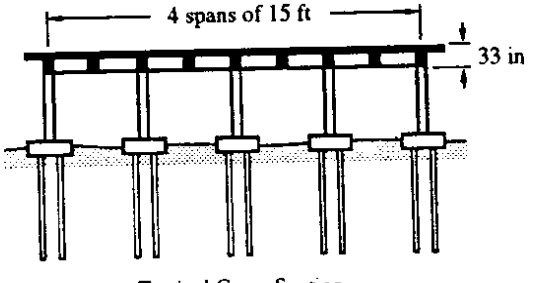
Interstate 90 crosses Mercer Slough in south Bellevue by means of four bridges, which carry two major roadways—one eastbound and one westbound—and several ancillary collectors and distributors. The structure carrying the westbound lanes was constructed in 1939, and it was recently the subject of a WSDOT research project [26 and 44]. This structure, referred to as the "Mercer Slough bridge", is approximately 2800 feet long and contains 85 spans. The spans are typically supported on pile-founded, five column, reinforced concrete bents. Except for the longer end spans, the spans are 30 feet in length. The superstructure consists of reinforced concrete T-girders, which are continuous over four spans and separated by an expansion joint at every fourth bent. The span typically has a width of 60 feet, and incorporates a 6-inch thick slab and nine 16-inch wide T-girder webs at 7.5-foot centers. The section depth is typically 33 inches from the bottom of the web to the top of the slab. The bent caps form diaphragms between the T-girder webs. Figure 3.15 shows an aerial photograph of the Interstate 90 Mercer Slough crossing and drawings of typical bridge longitudinal- and cross-sections.

Mercer Slough is a marshy, peat-filled extension of Lake Washington. Figure 3.16 shows an approximate subsurface soil profile of Mercer Slough along the Interstate 90 alignment. In a WSDOT study of the slough by Kramer [27] conducted in parallel with the bridge studies cited above, the





Typical Side Elevation



Typical Cross Section

Figure 3.15: Interstate 90 bridge over Mercer Slough (top) Aerial photograph showing the west- and eastbound Interstate 90 bridges and collector bridges; (bottom) Typical westbound bridge longitudinal- and cross-sections. Adapted from [26] and [44].

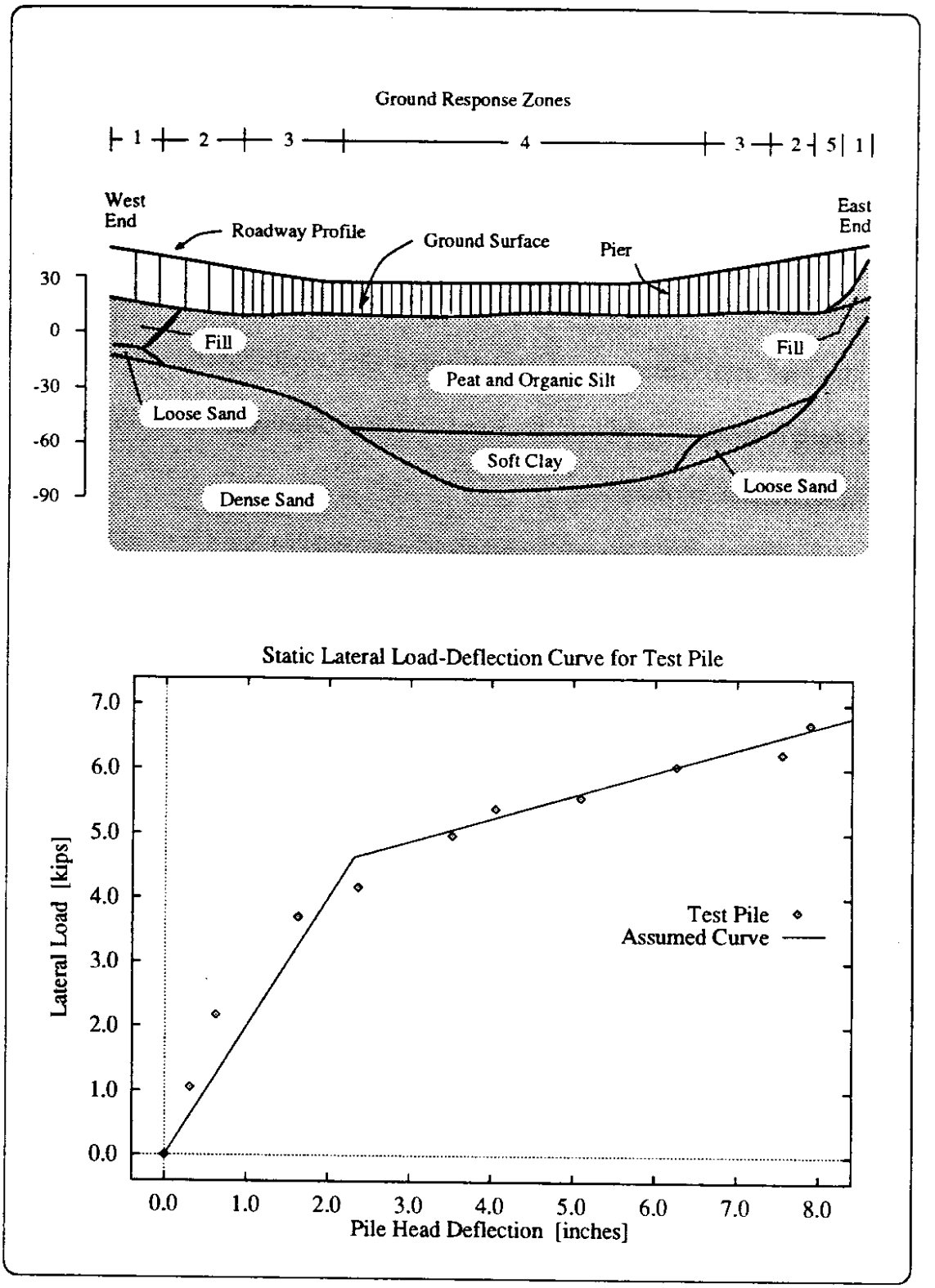


Figure 3.16: Mercer Slough: (top) approximate soil profile of Mercer Slough along alignment of Interstate 90, with seismic response zones as identified by Kramer [27]; (bottom) static pile head stiffness diagram for 8-inch diameter test pile as reported by Kramer [27].

soil was found, in general, to be very weak and soft. Because the seismic response of soft soils can change, and often amplify, ground free-field motions, free-field motions likely to occur at the Mercer Slough site were determined by Kramer. In addition to potentially amplifying ground motion, soft soils also provide little resistance to lateral bridge movement. McLean and Cannon [26] investigated the seismic response of the Mercer Slough bridge, applying as input seismic excitation the ground motions determined by Kramer.

Figure 3.17 shows a detail of a typical bridge bent column and pile cap. The column cross-section is 20 inches square, and contains eight No. 7 bars spaced evenly about the perimeter. The columns frame monolithically into both the foundation and the superstructure. The longitudinal reinforcement continues into the cross-beam or diaphragm at the column top, but it is lap spliced at the bottom with reinforcement from the pile cap. Column transverse reinforcement consists of No. 4 stirrups spaced 12 inches on center, which is insufficient to allow for the formation of a ductile plastic hinge [26]. The expected in-situ material strengths are f_c = 4500 psi for the concrete and f_y = 45 ksi for the steel [26].

Each of the five bent columns are supported on concrete pile caps, as shown for the column of Figure 3.17. Eight No. 8 bars in each direction provide the cap reinforcement. The pile cap, in turn, is supported on four timber piles. No mechanical connection is provided between the piles and the pile cap.

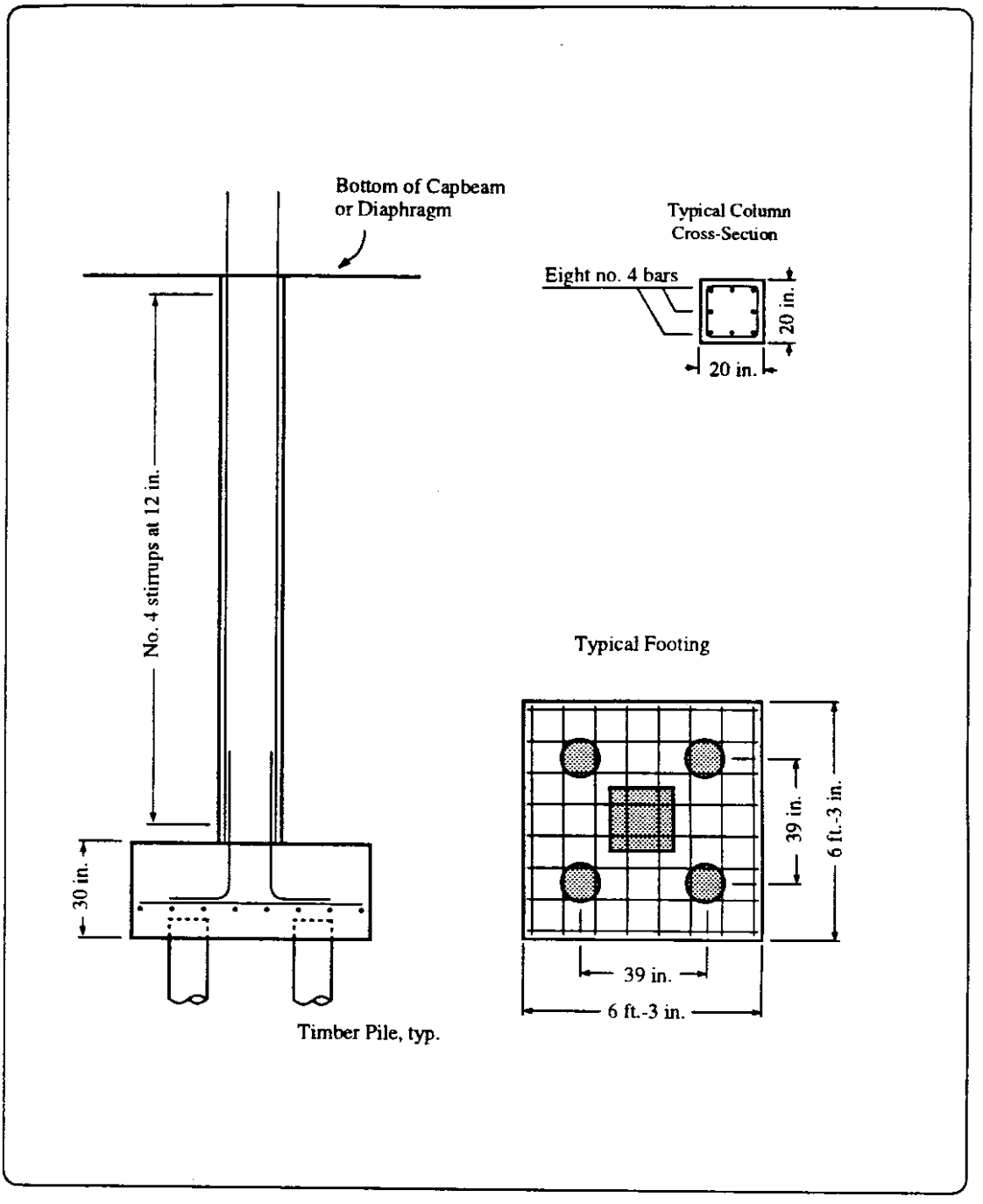


Figure 3.17: Mercer Slough bridge bent columns and pile cap details. Adapted from [44].

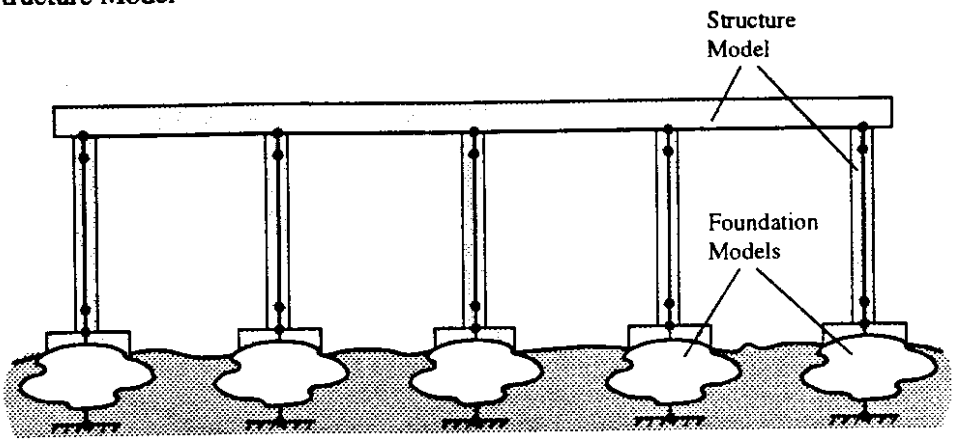
3.3.2 Structure Model

In the study by McLean and Cannon [26], it was observed that, away from the ends of the bridge, each four-span bridge section between expansion joints responded nearly independently to lateral seismic excitation. Therefore, as with the spread footing study on the Moses Lake bridge, the pile foundation study was confined to the analysis of an isolated bridge bent. A schematic of the bent and foundation models used in the NEABS analyses is given in Figure 3.18.

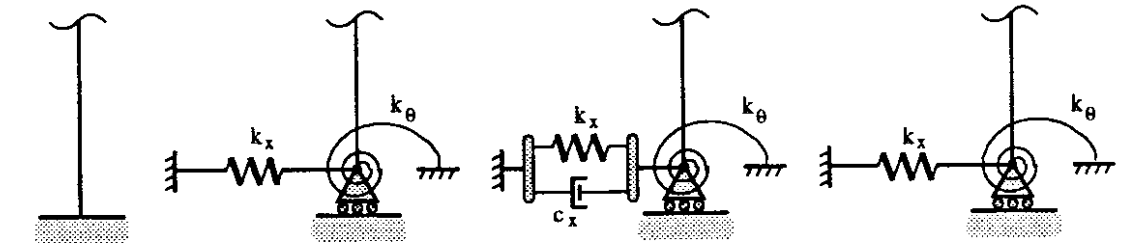
The bent structure was modeled with beam elements and the various foundation models with DF elements. The crossbeam was modeled with elastic beam elements, while the columns used elasto-plastic beam elements. The modulus of elasticity used for the columns was $E = 3800$ ksi $\approx 57\ f_c^{1/2}$, as per ACI 318-89 §8.5.1 [45]. The moment of inertia, I, that was used was half of that of the gross column cross-section [1]. Thus, for the columns, the elastic stiffness was proportional to $EI_{eff} = 1/2 E_c I_g$.

The same procedure described in the discussion the spread footing study was used for determining the NEABS yield surface of the columns. This procedure fits a cubic curve to the column's axial force-bending moment strength interaction diagram taken at attainment of a maximum concrete strain of $\varepsilon_{cu} = 0.003$. Figure 3.19 shows a comparison of the axial force-bending moment strength interaction data calculated for the column

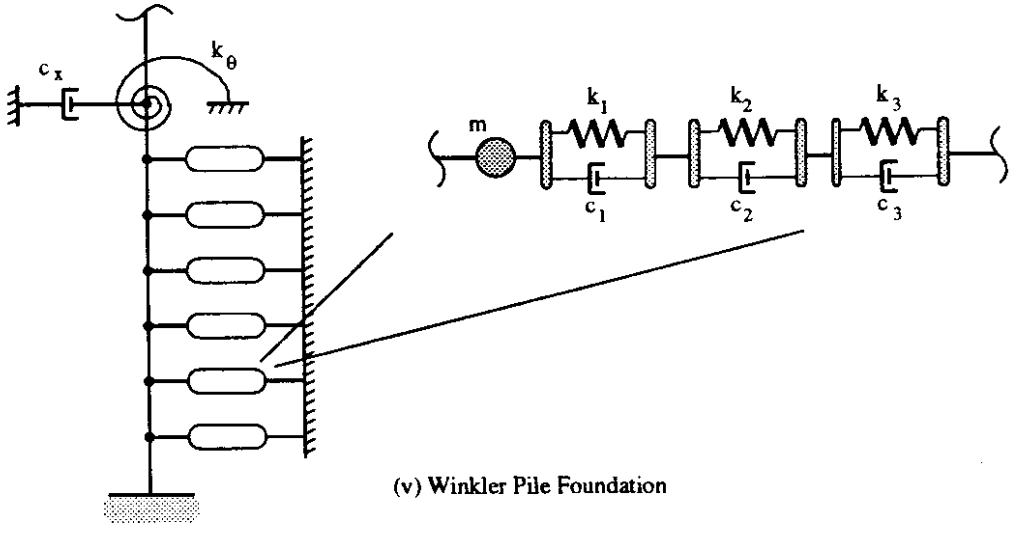
(a) Structure Model



(b) Support Models



(i) Fixed Support (ii) DF1 (iii) DF2 (iv) DF3



(v) Winkler Pile Foundation

Figure 3.18: Schematic of NEABS models of Mercer Slough bridge bent and supports employed: (a) model of bent structure, with beam elements forming columns and crossbeam; (b) five support models—fixed supports and four models representing pile foundations.

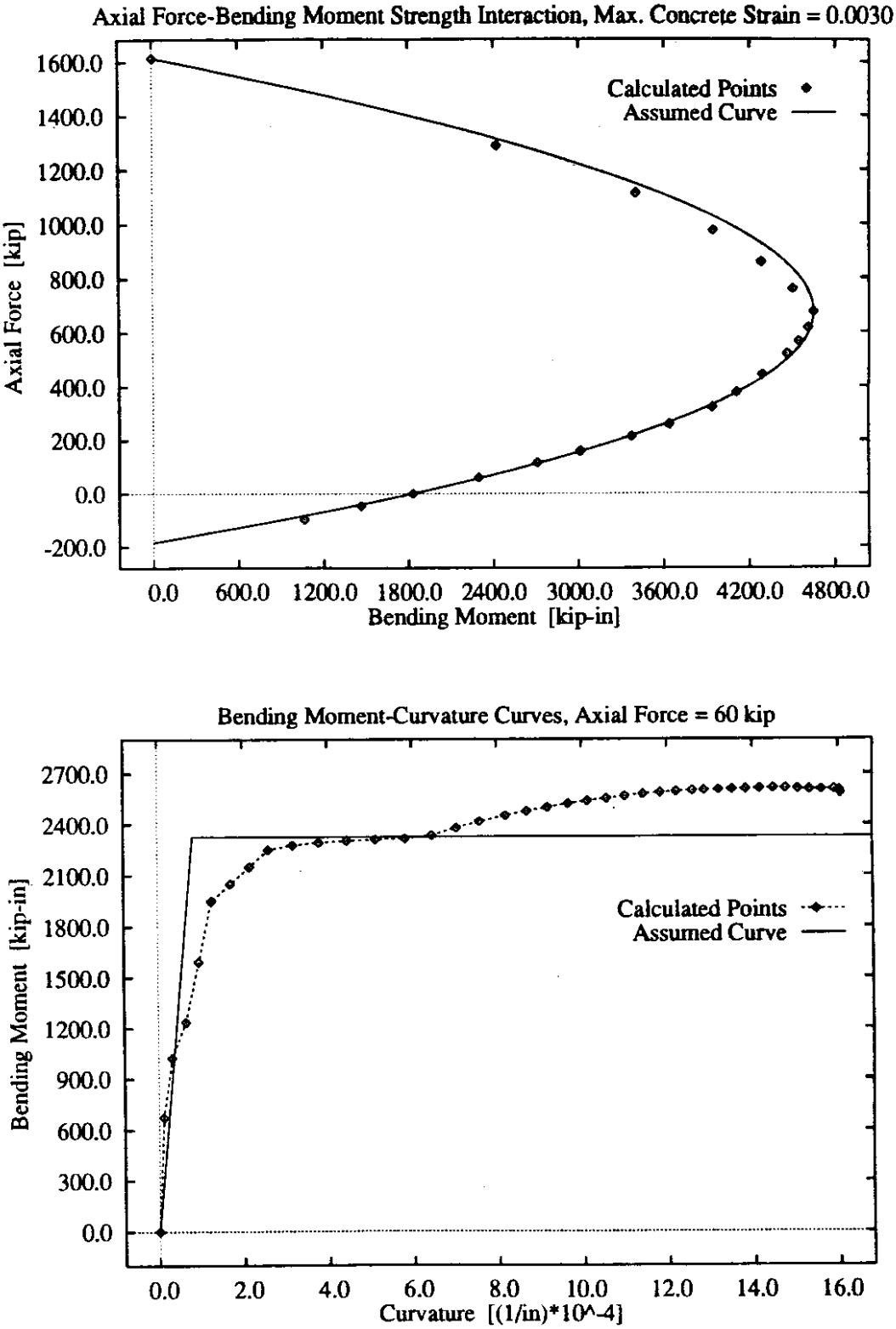


Figure 3.19: Calculated and assumed strength characteristics of Mercer Slough bridge bent columns. Axial force–bending moment strength interaction curve taken at attainment of concrete strain of 0.003 in./in., and bending moment–curvature curve taken at static axial load of 60 kips.

and the cubic curve used in the NEABS models. Also shown is a comparison of the bending moment–curvature relation calculated for the column under the static dead load of 60 kips. The slope of the elastic portion of the NEABS curve, again, is $EI_{eff} = \frac{1}{2}E_cI_g$. Both graphs show close agreement between calculated and assumed column strength characteristics.

Because the diaphragm forming the bent cap is constrained by the bridge T-girder superstructure, the stiffness of the crossbeam was deemed to be high relative to that of the column. As with the Moses Lake bridge model, the crossbeam was therefore modeled as an essentially rigid member. The mass supported by the bent was applied by specifying an appropriate density for the four crossbeam elements.

To apply consistent material damping to the bent elements, the same procedure described in the discussion of the spread footing study was used. The Rayleigh damping coefficients determined by this procedure are those necessary to produce a damping ratio of 5 percent of critical in a single-degree-of-freedom system having the same mass as the bridge bent and a stiffness equal to the total elastic stiffness of the columns, assuming the columns were fixed at the base and framed into a rigid crossbeam. The calculated period of this system is 0.33 seconds. The calculated coefficient values were used for all of the analyses.

3.3.3 *Foundation Models*

As previously discussed, four foundation models were compared, as well as fixed-base supports. Three of the four foundation models were discrete springs or spring/dashpot systems which modeled the pile cap behavior experienced by the column bases. The fourth foundation model was a Winkler-type pile foundation. These five support conditions are shown in Figure 3.18.

The first discrete pile cap model, referred to as the "DF1" model, used a lateral spring with a linear stiffness of k = 8.2 kips/inch. This pile head stiffness was used by McLean and Cannon [26] in their modeling of the Mercer Slough bridge. A simplified half-space modeling procedure, used in conjunction with static pile head stiffness data obtained from the testing of an 8-inch diameter steel tube pile driven into Mercer Slough [27], was used to determine this stiffness. The pile head stiffness data for the 8-inch test pile is given in Figure 3.16.

Additionally, a rotational pile head spring was applied. The stiffness of this spring was determined by calculating the resistance to rotation of the center of the pile cap about a horizontal axis perpendicular to the plane of the bent which was afforded by the eccentric axial reaction of the piles. The piles were assumed to be elastic and end-bearing for this calculation. This rotational spring was used for all four foundation models.

The second discrete pile cap model, or "DF2" model, utilized a hysteretic bilinear lateral spring in conjunction with a viscous lateral damper. The DF2 model's stiffnesses were obtained by first modeling the 8-inch test pile with six Winkler-type soil reaction springs. Stiffnesses for the soil springs were determined by assuming values for the modulus of horizontal subgrade reaction, r_h, in the following equation:

$$p(z) = r_h z \tag{3.5}$$

where $p(z)$ ≡ soil reaction stiffness per unit length of the pile at subsurface depth z.

r_h ≡ modulus of horizontal subgrade reaction, [force/length^3]

By subdividing the pile length and integrating equation (3.5) over the pile sublengths, discrete lateral soil spring stiffnesses were obtained. These soil springs were then applied to the pile at the depths of the "center-of-pressure" of the reaction $p(z)$ on the pile sublengths to create a Winkler-type foundation.

Six such springs were applied to a fixed-base, beam element model of the 8-inch test pile. The value of r_h was then varied until the lateral pile head static stiffness, as determined by applying a static unit lateral load at the pile top, matched the elastic portion of the assumed bilinear stiffness curve shown in Figure 3.16. Pile head rotation was not constrained, as it was anticipated that little moment could be transferred between the actual piles and the pile cap. Similarly, the plastic stiffnesses

of the soil springs were determined by varying r_k until the pile head stiffness matched the plastic portion of the assumed bilinear stiffness curve. These six bilinear soil springs were then coupled to a fixed-base beam element model of a typical Mercer Slough bridge pile group (four Douglas fir timber piles of 12-inch diameter and 50-foot length), first scaling the stiffnesses up by a factor of 1.5, and then again by 4, to account for the larger diameter of the bridge piles and the lumping of the four piles into one pile model, respectively. This model of the bridge pile group was then analyzed statically, applying lateral loads at the pile head. The yield forces for the soil springs were obtained by requiring the soil springs to all yield simultaneously upon attainment of a lateral pile head deflection of 2.3 inches, the yield displacement of the bilinear stiffness curve assumed for the 8-inch test pile, under a laterally applied load at the pile head. By enforcing this yielding criteria, a bilinear pile head stiffness was obtained which has the same yield displacement as shown in Figure 3.16 for the 8-inch test pile, but with different elastic and plastic stiffnesses, and a different yield force. The bridge pile group model's pile head lateral elastic stiffness, yield force, and plastic stiffness were thus attained analytically, based on the 8-inch test pile data, but by an alternate method to that used by McLean and Cannon, and used as the lateral foundation spring for the DF2 model.

A lateral viscous damper was also used in the DF2 model. The damping coefficient was based on the lateral pile head damping coefficients

obtained by Kramer for the 8-inch test pile [27]. The damping coefficients reported by Kramer were obtained from a dynamic test conducted at low soil-strain amplitudes, so these coefficients account primarily for radiation damping. The damping was observed to be relatively independent of the frequency of applied vibration. Because radiation damping is a far-field phenomenon, and because it was deemed unlikely that the far-field effects would vary significantly between an 8-inch and a 12-inch pile, the damping coefficient used was obtained by multiplying the average coefficient reported by Kramer by four piles.

The third discrete pile head model, or "DF3" model, was not strictly a unique model, since it used a simple lateral spring like the DF1 model. However, it used a linear secant stiffness based on the results of the seismic analysis of the bridge bent utilizing the DF2 model, and in this respect, it represents a model of intermediate sophistication. It was employed to test the use of an elastic secant stiffness to approximate nonlinear pile head stiffness, and by comparison with the DF1 model results, to test the sensitivity of the bridge bent response to the elastic stiffness of the lateral pile head foundation spring. The secant stiffness was determined by recording the maximum pile head lateral deflection of the DF2 model under each of the applied seismic excitation records. The internal force of the bilinear spring used in the DF2 model at these recorded maximum pile head deflections, divided by these maximum deflections, defined the secant stiffness used in the DF3 model. However,

a practical secant stiffness could also be obtained without first performing an analysis using the more complicated DF2 model by iterating to a maximum pile head deflection on a standard pile "*p–y*" curve. Like the DF1 model, no foundation damping was included in the DF3 model.

The fourth foundation model was a Winkler-type pile foundation, and it is referred to as the "WPF" model. The pile groups were each modeled as a single "pile" using beam elements coupled to the column bases. Six lateral soil reaction models were used with each of the pile group models. The soil reaction models that were used were based on the soil far-field sub-model proposed by Nogami and Konagai [35], illustrated in Figures 2.7 and 2.8. As discussed in Chapter Two, this model is derived from the representation of the soil as a vertically-stratified series of plane-strain elastic layers. The parameters of this model may be determined by use of equations (2.9) and Figure 2.8. For the Mercer Slough pile–soil foundation, the radius of the near field was taken as the timber pile radius, r_n = 6 inches, and the resulting values of c_i and m_i of equations (2.9) were multiplied by four piles. The value of Poisson's ratio was taken to be ν = ½, and the value of the shear modulus, G = 149 psi, was determined from average values of the soil weight density and shear wave velocity, γ_s = 69 pcf and c_s = 100 fps respectively, as measured by Kramer [27].

3.3.4 Seismic Excitation

Six different acceleration time histories were applied to the bent models as seismic excitation. Four were ground motions determined by Kramer [27], which were obtained by applying recorded earthquake acceleration time histories to the base of the soil models of Mercer Slough. As the soft soil models responded to the seismic excitation, the ground motion changed, and thus these ground motions will be referred to as "filtered" records. The two "unfiltered" records are the lower and higher intensity El Centro records previously presented in the discussion of the spread footing foundation study. Since the unfiltered records are quite different from expected ground motions at the Mercer Slough site, using these records serves more as an exploratory exercise of the effects of the foundation models than as a study of the performance of the actual Mercer Slough bridge under probable seismic conditions.

The four filtered records were determined by Kramer by first scaling the El Centro and Lake Hughes earthquake acceleration records to a peak acceleration of 0.25g and a predominant period of 0.36 seconds [27]. Then these scaled record were applied to the base of soil models representing Mercer Slough soil profiles at various positions along the length of the bridge, and the resulting surface ground motions were obtained. Based on similarities of the soil profiles and of the seismic response, the cross-section of Mercer Slough along the alignment of Interstate 90 shown in

Figure 3.16 was divided into five zones. The ground motions chosen to be used as seismic excitation for the pile foundation study were those resulting from applying the El Centro earthquake acceleration to zones three and four, and applying the Lake Hughes earthquake acceleration to zones one and two. These ground motions will be referred to as the "El Centro Z3," "El Centro Z4," "Lake Hughes Z1," and the "Lake Hughes Z2" records, respectively. They were chosen on the basis of the greater relative severity of their elastic spectral acceleration response spectra as compared with the other ground motions determined by Kramer.

As before, the beginning of the seismic excitation applied to the bent models was taken to be at the start of each record, and the end at the termination of the Trifunac and Brady duration for each record. These times were 20.77 seconds, 18.25 seconds, 32.68 seconds, and 33.05 seconds from the record beginnings for the El Centro Z3, El Centro Z4, Lake Hughes Z1, and the Lake Hughes Z2 records, respectively. Figures 3.20 through 3.23 show the acceleration time histories used in the pile foundation study, as well as the resulting elastic spectral acceleration response spectra.

3.3.5 Discussion of Results

As with the spread footing study, the performance of the various foundations was assessed in terms their effects on the response of the bent structure. The same three aspects of the bent response were selected to

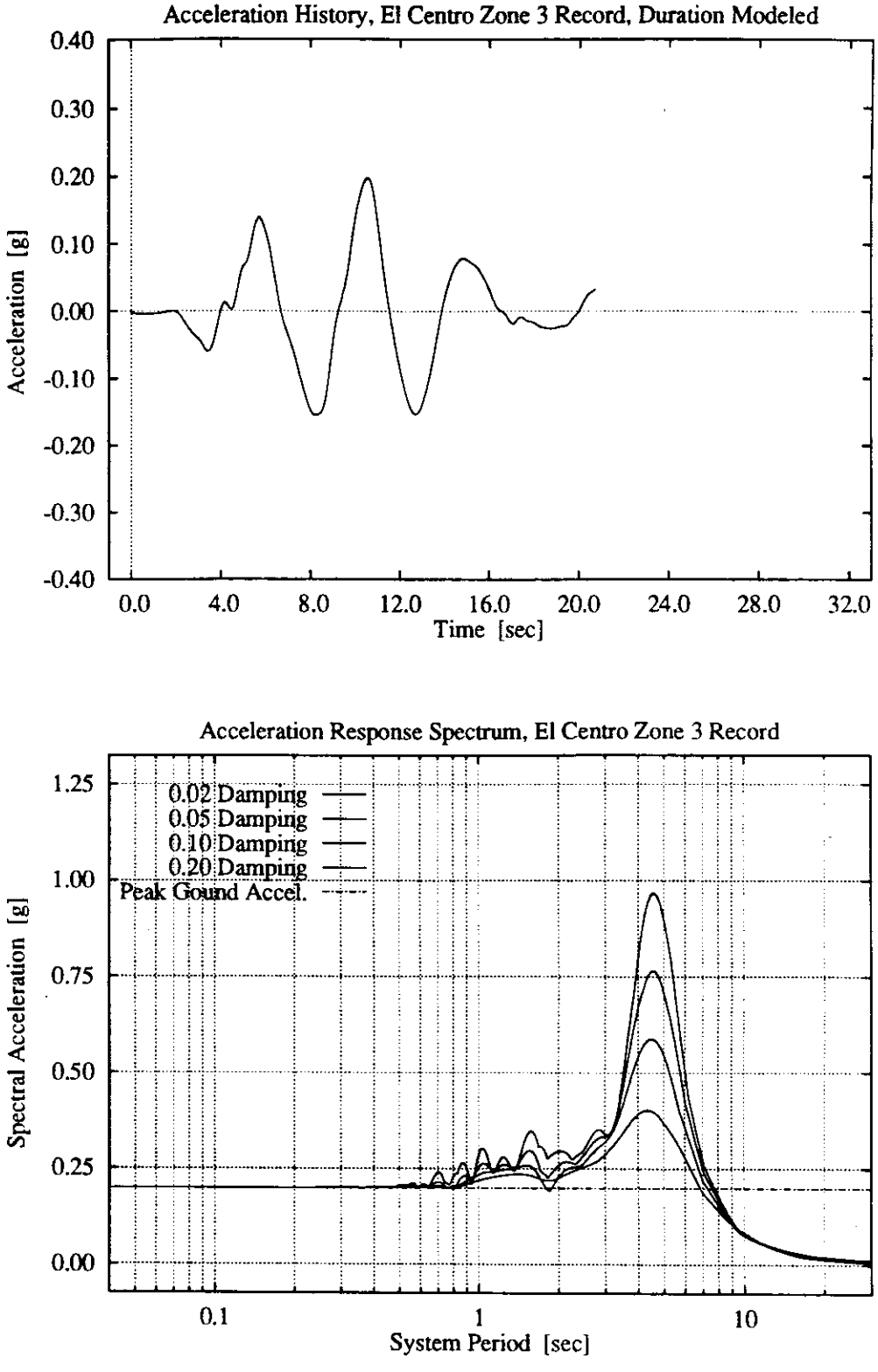


Figure 3.20: El Centro, Zone 3 record: acceleration plot of duration modeled and acceleration response spectra.

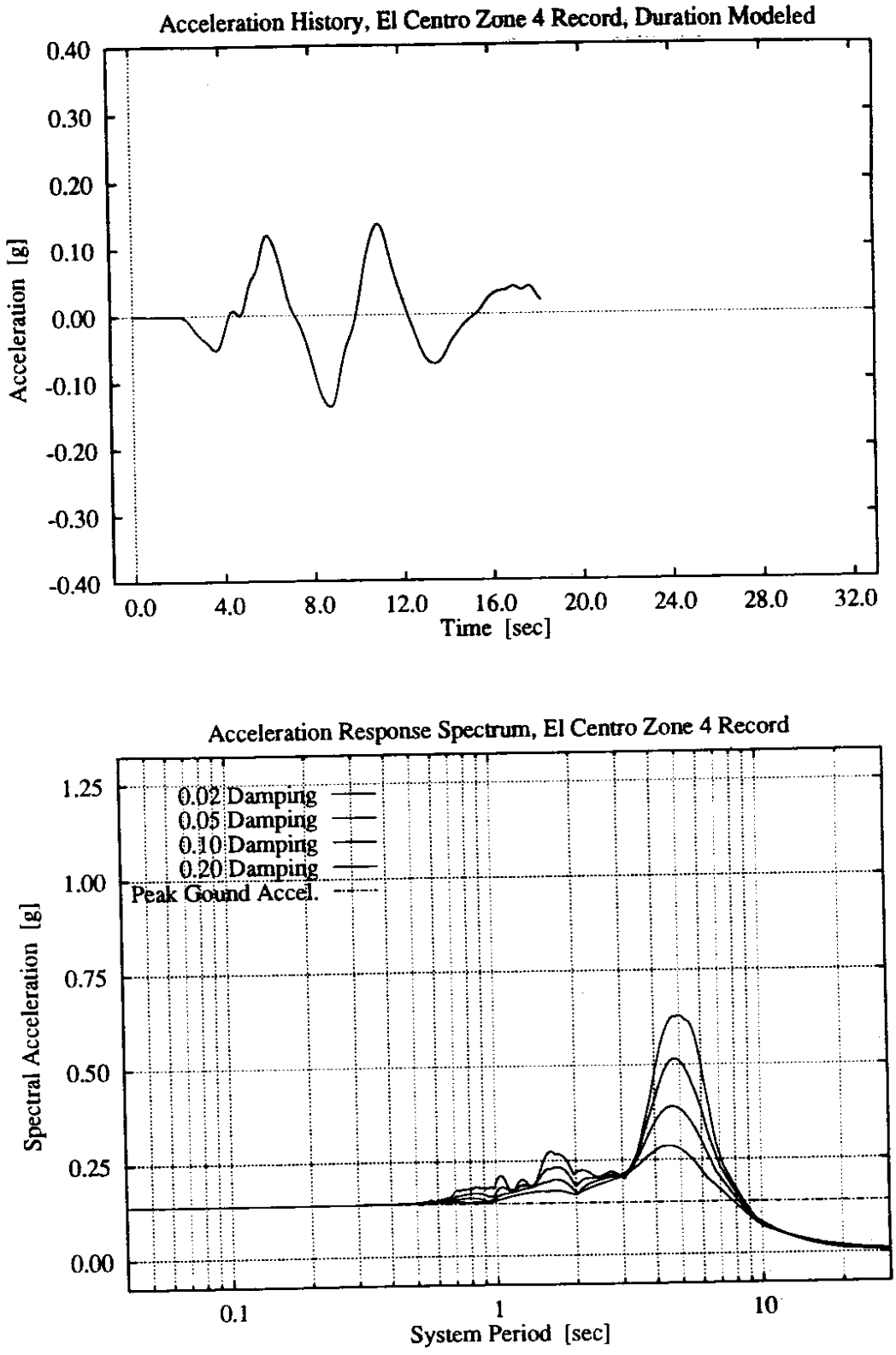


Figure 3.21: El Centro, Zone 4 record: acceleration plot of duration modeled and acceleration response spectra.

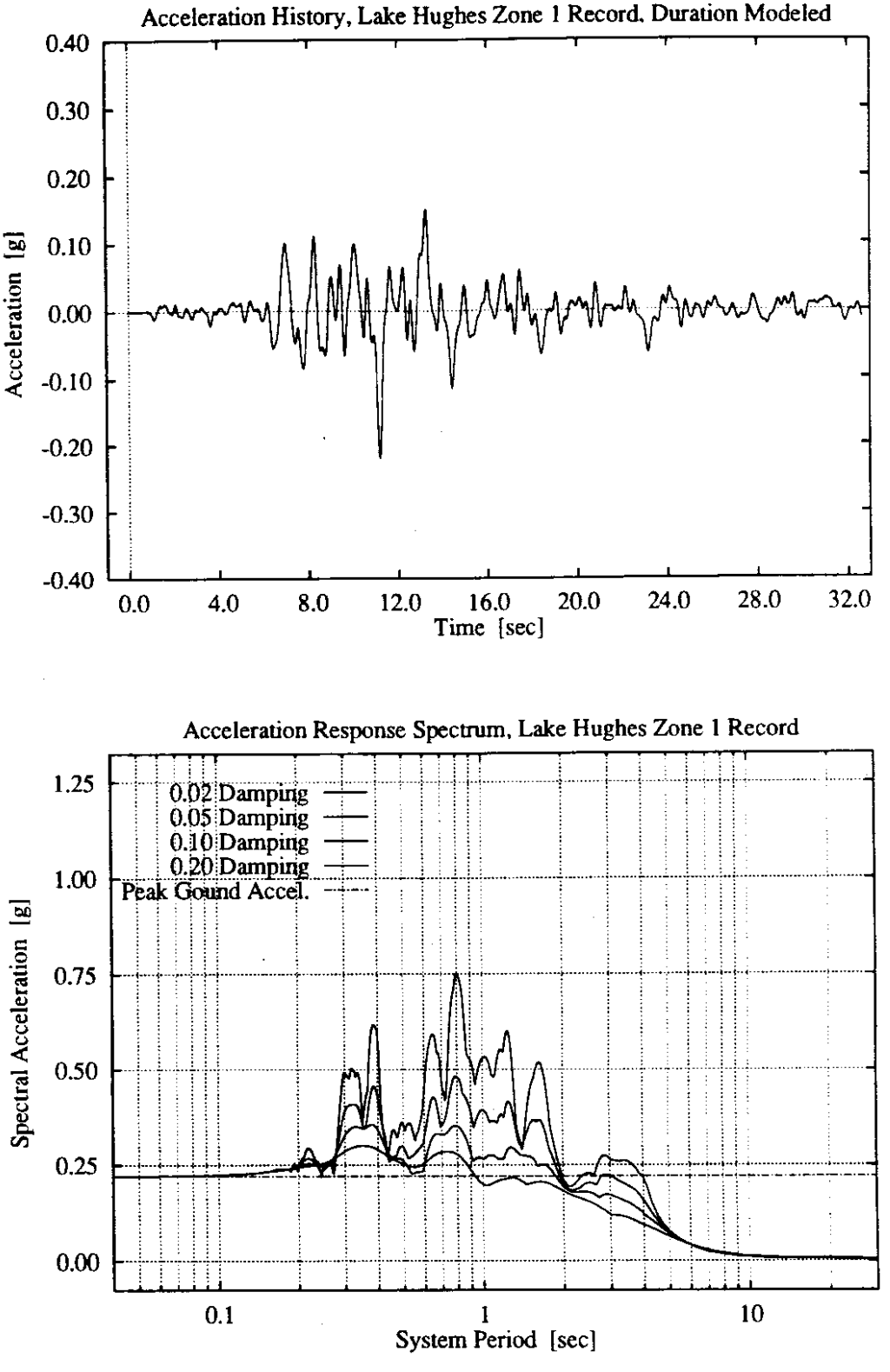


Figure 3.22: Lake Hughes, Zone 1 record: acceleration plot of duration modeled and acceleration response spectra.

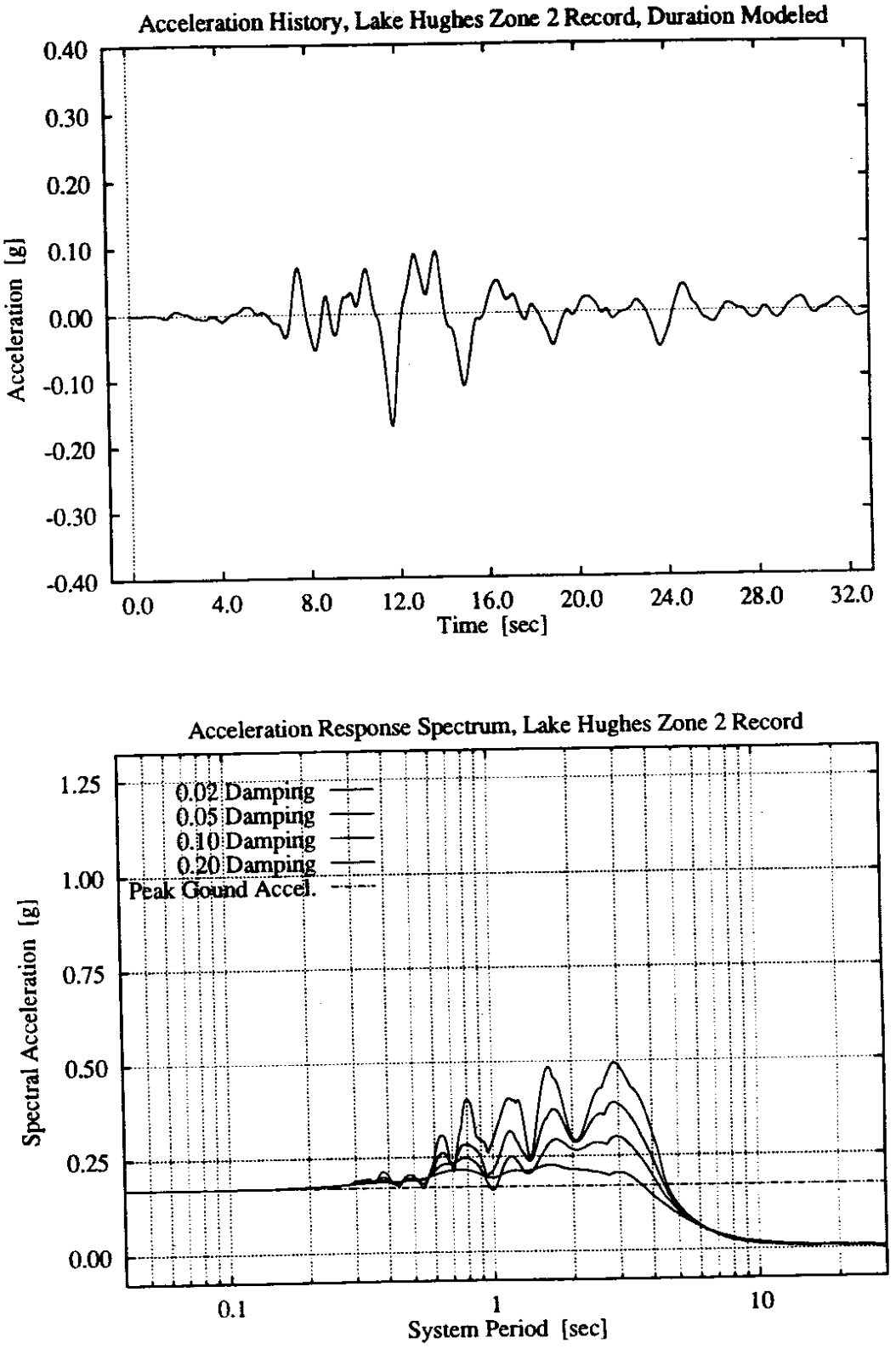


Figure 3.23: Lake Hughes, Zone 2 record: acceleration plot of duration modeled and acceleration response spectra.

be studied: column drift (the displacement of the column top relative to the bottom), the internal moment at the column top, and the rotation of the plastic hinge at the column top. Time histories of these parameters were obtained and studied in terms of their implications for column strength, ductility, and energy dissipation demands.

A total of 25 NEABS analyses were performed. As discussed, five supports were modeled, including the fixed-base bent. Four of these were subjected to all six ground motion records, while only the higher intensity El Centro record was applied to the fifth. Figure 3.24 displays this information in a matrix form, and indicates the "name" by which each of the 25 runs may be identified. The nomenclature used in Figure 3.24 to identify the foundation model and the applied seismic record is discussed in the previous sections.

Similar to the spread footing study, the three response parameters discussed were investigated by displaying the results of each analysis in up to four different graphs. The first two graphs are time histories of the column drift and the internal moment at the column top. These two graphs were created for each of the 25 runs. The second two graphs are a plot of the column moment–drift hysteresis and a time history of the plastic rotation of the column top. Examples of these four graphs are given in Figures 3.9 and 3.10, and interpretation of the physical significance of the type of data contained in these graphs may be found in the discussion of the spread footing study. The latter two graphs contain significant data

Pile Foundation Parametric Study
Matrix of NEABS runs

	Filtered Records				Unfiltered Records	
	El Centro		Lake Hughes		El Centro	
	Zone 3	Zone 4	Zone 1	Zone 2	Lower Inten.	Higher Inten.
Fixed	PF01-FX_.3EL	PF02-FX_.4EL	PF03-FX_.1LH	PF04-FX_.2LH	PF05-FX_.LEL	PF06-FX_.HEL
DF1	PF07-DF1.3EL	PF08-DF1.4EL	PF09-DF1.1LH	PF10-DF1.2LH	PF11-DF1.LEL	PF12-DF1.HEL
DF2	PF13-DF2.3EL	PF14-DF2.4EL	PF15-DF2.1LH	PF16-DF2.2LH	PF17-DF2.LEL	PF18-DF2.HEL
DF3						PF19-DF3.HEL
WPF	PF20-WPF.3EL	PF21-WPF.4EL	PF22-WPF.1LH	PF23-WPF.2LH	PF24-WPF.LEL	PF25-WPF.HEL

Figure 3.24: Matrix of the 25 NEABS analysis runs for the study of pile foundation models. Each run is identified by a name of the form "PF*nn–fff.eee*," where *nn* is the run number, *fff* is the foundation model code, and *eee* is the applied seismic record code.

only when a plastic hinge forms at the column top. With one exception, the column remained elastic for the fixed-base bent model and for the three discrete pile head foundation models when subjected to the four filtered records. Because the plastic rotation of the one exception was very small, the second two graphs were not compiled for these runs. However, these graphs were created for all the analyses using the two unfiltered El Centro records, and for the six analyses using the Winkler-type pile foundation model. These graphs are presented in Appendix E, along with the foundation model parameter values used in the analyses.

To summarize and compare these results, the maxima of the three response parameters, column drift, column top internal moment, and column top plastic rotation, were recorded for each run. Additionally, as with the spread footing study, the sum of the absolute values of the plastic hinge rotations occurring over the duration of the seismic excitation were also recorded. It may be recalled that the plastic hinge rotation maxima and plastic rotation sums are related to ductility and energy dissipation demands, respectively. This data is presented in Figures 3.25 and 3.26. Each chart summarizes one of the four response parameters discussed above, the three maxima and the hinge rotation sum, for either the filtered or the unfiltered seismic records. For the four filtered records, bar charts are provided for drift and column top moment, while for the two unfiltered records, bar charts are given for the hinge rotation maxima and sums.

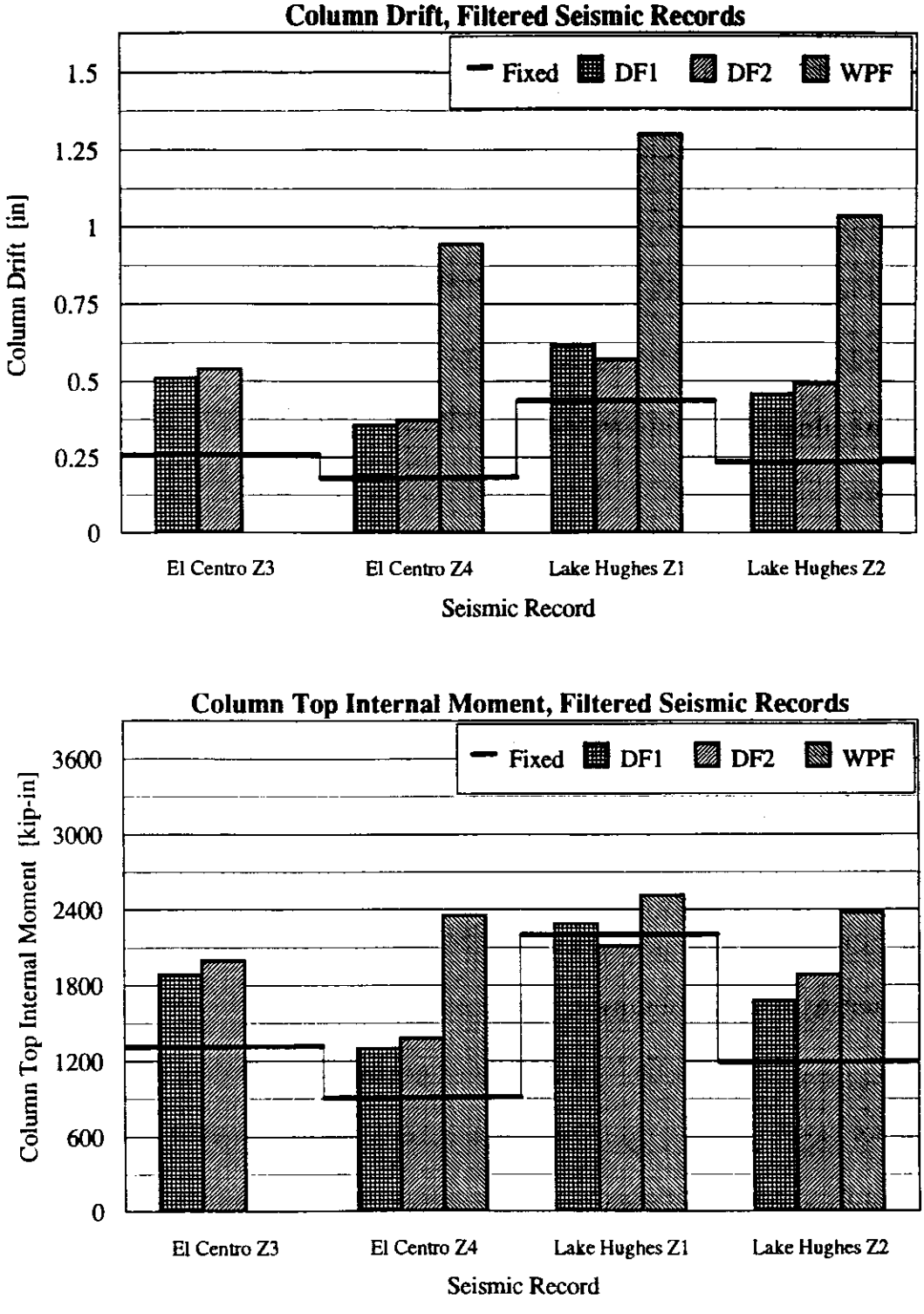
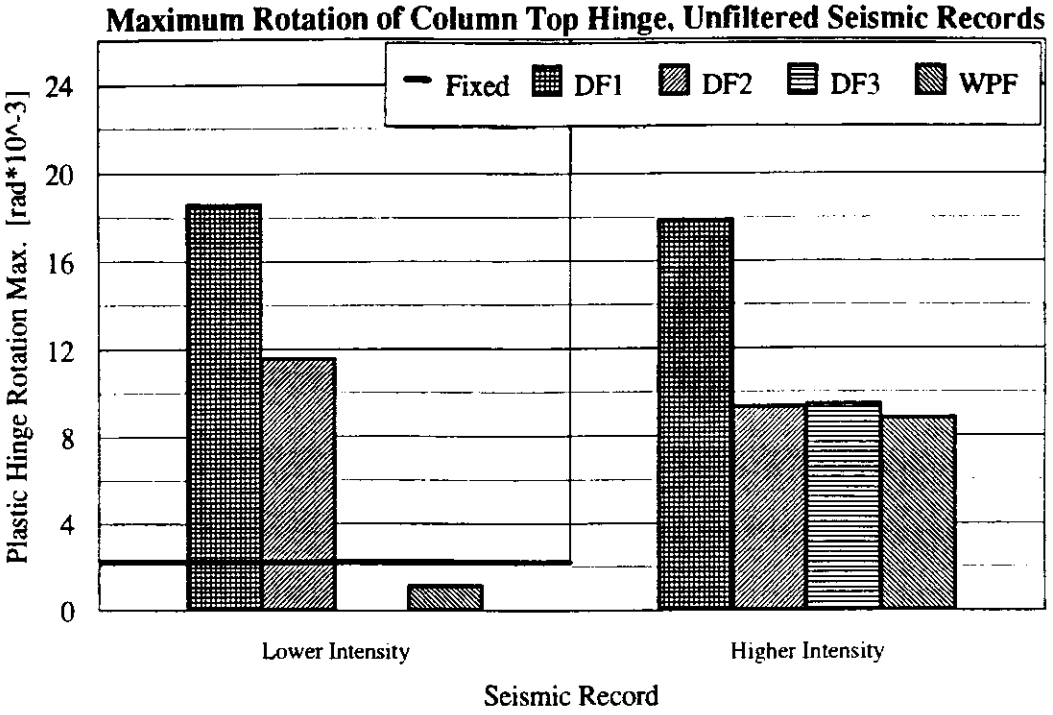


Figure 3.25: Comparison of the effect of the foundation models on the response of the column when the subjected to the filtered seismic records: (top) column drift maxima; (bottom) column top internal moment maxima.



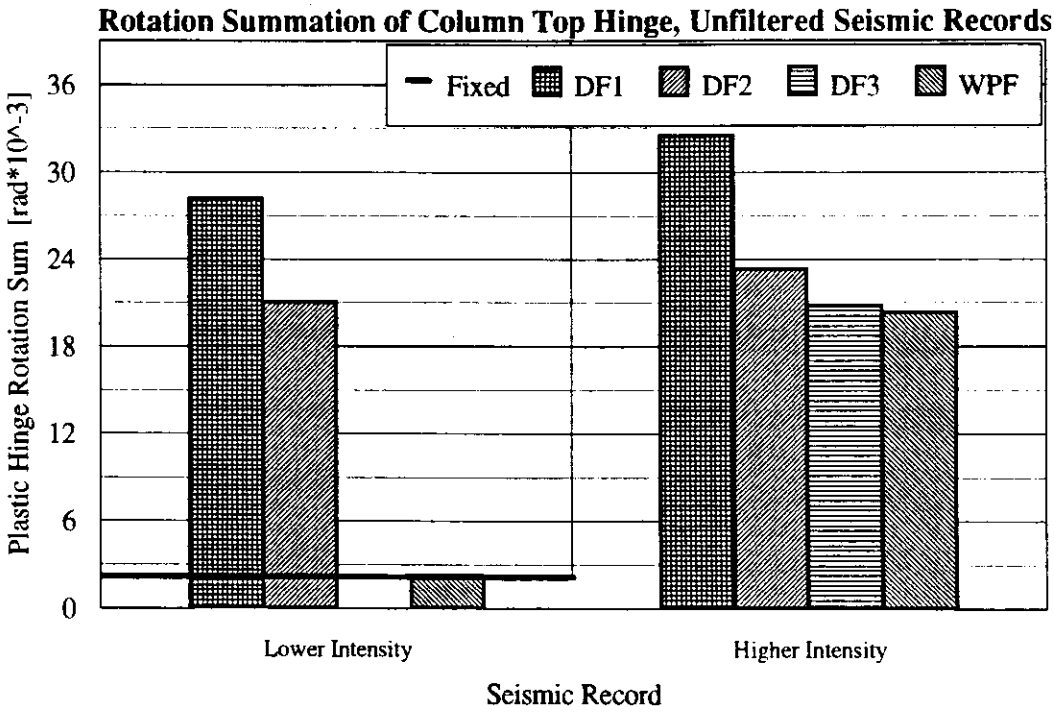


Figure 3.26: Comparison of the effect of foundation models on the response of the column top plastic hinge when subjected to the unfiltered seismic records: (top) maximum rotation attained (related to ductility demand); (bottom) total rotation sustained (related to energy demand).

Of the filtered records, the Lake Hughes Z1 record produced the highest values of all the measured response parameters for the fixed-base model, followed by the El Centro Z3 and Lake Hughes Z2 records (which produced very close results) and then by the El Centro Z4 record. This same ordering of response severity was observed for the bents using the DF1 and the DF2 foundation models. The column drift and column top moment response of these two models, as shown in Figure 3.25, were in close agreement with each other, and were both significantly more severe than the fixed-base response to each of these records. The DF1 model's response was slightly greater than the DF2 model's response for the Lake Hughes Z1 record, while the opposite was true for the other three records.

In no case was the response great enough to produce a maximum lateral pile head displacement in excess of 2.3 inches for the DF2 model, the yield displacement of the DF2 model's lateral spring. The only differences between the DF1 and the DF2 models were therefore the higher elastic stiffness of the DF2 model (approximately 40 percent stiffer) and the additional laterally-acting damper (which, as previously discussed, modeled primarily radiation damping). The closeness of the results of these two models appears to indicate that the column top moment is not especially sensitive to the stiffness of the pile head equivalent elastic springs, at least not in the stiffness range spanned by the DF1 and DF2 models. Further, the column top moment is not appreciably affected by radiation damping at the structure/excitation frequency combinations

analyzed, even though the Mercer Slough soil is very soft. Also, because the DF2 model's lateral spring did not yield during any of the analyses using the filtered records, the DF3 model's secant stiffness, as determined by the procedure described earlier, is the same as the elastic stiffness of the DF2 model's spring. Therefore, no unique DF3 model was created for these analyses.

The column top response is significantly more severe for the DF1 and the DF2 models than for the fixed-base model, contrary to the typical assumption that including the effects of soil–structure interaction in seismic analysis tends to reduce the predicted response. One probable reason for this increase is the redistribution of column moment, as was previously discussed for the spread footing study, which occurs when the fixed-base rotation constraint is removed for the addition of the foundation models. Even if the maximum column moment experienced by the column with the elastic base was somewhat lower than that experienced by the fixed-base column, proportionally more moment in the elastic base column would be concentrated at the top, and a net increase in column top moment may be observed.

The softest foundation model, in terms of lateral pile head stiffness, is the WPF model. The response it produced was significantly more severe than the DF1 or DF2 models, and yielding of the column top was observed for all the seismic records. This increased severity was most noticeable for the El Centro Z4 record. No results are reported for the WPF model

subjected to the El Centro Z3 record; an apparent numerical instability developed during this analysis, and caused the response to grow unreasonably.

It may also be noted that the increase in column drift between the bents with the fixed supports and those incorporating the WPF foundations is proportionally greater than the increase in column top moments between these models. This is consistent with the argument previously advanced regarding the redistribution of column moment between columns with fixed and elastic bases. In the limiting case of comparing elastic columns with fixed and pinned bases (and recalling that the column top is essentially fixed, since it frames into the crossbeam of very high relative stiffness), the proportional increase in column drift of the pinned base column relative to the fixed-base column is twice the proportional increase in column top moment.

The observed response of the bent models subjected to the two unfiltered records was more severe than that produced by the filtered records, and yielding of the column top was observed in all the analyses. The higher intensity El Centro record was the only record to produce yielding of the lateral pile head spring used in the DF2 model; thus, only one DF3 secant stiffness model was created. Using the procedure described earlier, based on the maximum pile head displacement observed in the DF2 model analysis, the secant stiffness was determined to be 9.0 kip/inch.

The responses of the column top plastic hinge for the DF1 and DF2 models, as shown in Figure 3.25, were quite different from each other. However, they were similar for each model between the lower and higher intensity records, despite the 60 percent greater EPA of the higher intensity record relative to that of the lower intensity record. For the lower intensity record, both the DF1 and the DF2 model produced much more severe response than did the fixed-base model. An apparent numerical instability developed during the analysis of the fixed-base model subjected to the higher intensity record, and caused the response to grow unreasonably at approximately 15 seconds.

The response of the DF1 model was significantly higher than the DF2 model for both records. The response of the one DF3 secant stiffness model was much closer to the response of the DF2 model (from which the DF3 model's stiffness is derived) than to the DF1 model, even though the DF3 model has an elastic spring stiffness only approximately 10 percent greater than the DF1 model. The DF3 model is apparently able to adequately reproduce the response of the bilinear DF2 model. The results of the analyses using the unfiltered records appear to indicate that the response is sensitive to the stiffness of elastic spring models of the pile cap lateral stiffness, contrary to the trend observed for the filtered records. However, this may again indicate that the effect of incorporating foundation models on the predicted response is very dependent on the

natural frequencies of the structure and the frequency content of the earthquake.

Also unlike the trend observed for the filtered record analyses, the response of the WPF model was the lowest of all the foundation models for the unfiltered record analyses. In examining the response histories given in Appendix E, the fundamental period of transverse vibration of the bent using the WPF model appears to be approximately 1.5 seconds. Comparing this period with the spectral acceleration response spectra of Figure 3.6, it appears probable that the lower predicted response for the WPF models is due to the lack of significant excitation of this period inherent in the El Centro record.

Chapter 4

Conclusions

4.1 Summary and Conclusions

The seismic response of bridges may be significantly influenced by the dynamic interaction of the bridge foundations with the founding soil. This phenomenon, known as "soil–structure interaction," is currently neglected, or included simplistically, in typical seismic analyses. Assuming a bridge to be fixed at its bases ignores the flexibility of the soil, while the use of elastic supports neglects energy dissipation which occurs through the soil's material damping, "radiation" damping, and nonlinear response of the soil.

More sophisticated foundation models have been proposed to account for these mechanisms. For foundations in contact with the soil primarily at the soil surface, such as spread footings, the analogy of the foundation to a disk bonded to an elastic half-space has been used by researchers to develop discrete foundation models. Such models are expected to capture the effects of the soil far-field, away from the nonlinear action of the soil in the immediate vicinity of the structure, in a simple model which can be coupled with the structure at the soil–foundation interface. This approach

can also be extended further to develop discrete models which represent soil layers of finite depth and soil material viscous damping.

Enhanced soil–structure interface models have also been developed which can be used in Winkler-type pile foundations. These include models of the soil far-field (developed in a manner similar to the procedure for the spread footing far-field models), and the soil near-field (including soil nonlinear stiffness, inertial effects of mobilized soil, and the development of a gap between the pile and the soil).

In order to implement these foundation models in the seismic analysis of bridges, the computer program NEABS was modified to include a new element. NEABS performs time history analyses of bridges, using earthquake acceleration records as input. As delivered, NEABS provided four elements, which included nonlinear beam and expansion joint elements, as well as elastic foundations. The new element, called the "discrete foundation," or "DF" element, can be used to incorporate the foundation models developed by previous research that were identified as appropriate for including soil–structure interaction in NEABS analyses. The element has the properties required by these models, as well as nonlinear stiffness capabilities intended to make it versatile in modeling other nonlinear soil mechanisms. These nonlinear properties include bilinear hysteretic stiffness, elastic stiffness degradation, variable strain hardening rules, and gap development. The nonlinear characteristics may also be useful for modeling abutments and base isolation devices.

Two bridge bents were analyzed using several of the foundation models. The first bent used four spread footing foundation models of each of three soil stiffnesses (corresponding to shear wave velocities of c_s = 300, 700 and 1300 fps), and was subjected to four different seismic records. All four foundation models were discrete representations of a linear elastic half-space; three of the models included radiation damping. No near-field effects such as nonlinear soil stiffness or soil material damping were included in these models.

The second bridge bent used four models of piles embedded in very soft soil. Three of the models were variations of a simple equivalent pile head model, while the fourth was a Winkler-type pile foundation. The three pile head models were assigned properties based on the results of a pile test conducted at the site, while the Winkler pile foundation's properties were assigned in accordance with an analytical method proposed by Nogami and Konagai [35]. Seismic excitation included both acceleration records of relatively low intensity developed specifically for the soft soil (referred to as "filtered" records), and unmodified, or "unfiltered" records.

The foundation models were incorporated into the NEABS analyses of these bents using the DF element, and they exercised the bilinear stiffness with kinematic strain hardening, viscous damping, and mass features of the element. The elastic stiffness degradation, gap development, and alternate strain hardening options were not utilized in the parametric study, although their correct performance was verified during the development of the element.

The analysis results of the bents founded on spread footings were interpreted in terms of their implications for column top ductility and energy dissipation demands. The greatest change in these aspects of the bent response, compared with the fixed-base analyses, were observed for the spring-only model. However, all the models indicated that the fixed-base assumption was, occasionally, significantly unconservative in estimating column top demands. Except for the soft soil (c_s = 300 fps), the spring-only foundation modeled the elastic half-space closely, using agreement with the response of the eleven parameter foundation model as a measure of adherence to the half-space soil representation. Models including radiation damping are probably warranted only for soft soil. The three-parameter model (spring-mass-dashpot) adequately modeled radiation damping, and the use of the more complex models does not appear to be justified. All the foundation models indicate that the response of the bent is very dependent on the frequency content of the earthquake. For the El Centro records, the soft soil models produced the highest column top demands, while the intermediate soil (c_s = 700 fps) was critical for the Olympia records. As previously discussed, no soil near-field nonlinearities were included in these models. The behavior of the near-field is unknown, but could conceptually be accounted for by including a near-field model connected in series with the models based on the half-space, provided the appropriate model properties could be specified.

The analysis results of the bents founded on the pile foundations were also interpreted in terms of the response of the column top. For the analyses using the records filtered for the actual bridge conditions, the response was primarily elastic, and the column drift and column top moment were the aspects of the response that were considered. All the foundation models indicated higher column top moment demands than predicted for the fixed-base bent. The frequency content of the filtered records made the effective dynamic loading nearly quasi-static, so the higher demands predicted for the bents with the foundation models are likely the result of the redistribution of column moment caused by the inclusion of support flexibility. The quasi-static nature of the loading is probably also the reason that the inclusion of radiation damping in the pile head model did not appear to appreciably affect the response. The two pile head foundation models were in close agreement, even though the effective lateral spring stiffness of the model with the higher stiffness was approximately 40 percent greater than that of the lower stiffness model. This appears to indicate a relative insensitivity of the response to the selected pile head stiffness, at least in the stiffness range spanned by these two models.

The Winkler pile model, which had a much more flexible effective lateral pile head stiffness, predicted significantly higher column demands. In the one test using a secant pile head stiffness to approximate a bilinear pile head stiffness, the predicted responses were in close agreement.

Finally, the predicted response was again dependent on the intensity and frequency content of the earthquake, based on the differences in the results of the analyses using the filtered and unfiltered records.

4.2 Recommendations and Implementation

In view of these conclusions, it is recommended that the interaction of bridge foundations with the founding material be rationally included in seismic analysis. For spread footings, this can usually be accomplished (at least to account for soil far-field effects) by employing simple spring-only foundation models, with spring stiffnesses based on the static stiffness of an elastic half-space. For foundations that are soft in comparison with the bridge, however, neglecting radiation damping may cause an over-estimation of the response. The three parameter spring-mass-dashpot adequately models radiation damping, and may be used for soft soils, such as those with shear wave velocities in the vicinity of c_s = 300 fps. Procedures for determining the three parameter model properties are presented by Veletsos and Verbič [29] and Wolf [31].

For pile foundations, either the Winkler pile or pile head models may be used, but the pile head models are recommended. The required properties may be determined from either field testing or finite element analysis data. Since they use far fewer elements than a Winkler pile foundation, the pile head models are particularly advantageous for large bridge models.

A few items may be suggested for future investigation. Additional parametric studies of the foundation models examined in the present study would prove useful in further identifying parameter sensitivity and bridge response trends. If undertaken, a greater number of earthquakes should be used to ensure a wide variety of frequency contents and to provide statistical significance to the observed results. However, they should be scaled to consistent intensities to better isolate frequency content-related effects.

Although the nonlinear stiffness properties of the DF element should make it versatile in soil–foundation modeling, these features should be further exercised to gain a better understanding of how they might realistically be employed in seismic analysis.

NEABS, equipped with the DF element, may be useful in developing and assessing new foundation models to represent the soil near-field, other bridge foundation substructures such as abutments and wall piers, and more refined pile models. One approach would be to identify the mechanisms that are exhibited in the response of these soil–foundation elements and determine if the DF element's features are appropriate for their modeling. Another approach, similar to the method used to develop the spread footing foundation models, would be to determine the response of these elements by either experimental testing or detailed finite element analysis, and use NEABS as part of a curve-fitting procedure to obtain relatively simple models that can reproduce the observed behavior.

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Appendix A

NEABS User's Guide Supplement

This appendix, "NEABS User's Guide Supplement", contains instructions for the use of NEABS, as modified to include the DF element (12/10/92). These instructions are supplementary to the instructions given in the user's guide provided with the program source code [24].

Changes / Additions to the required input data:

1. The Rayleigh damping coefficients are no longer specified with Card VIII-A, but with Card II. The format of Card II has been changed to include the following:

Columns		
36–45	ALFA	damping factor proportional to mass
46–45	BETA	damping factor proportional to stiffness

The format of Card VIII-A has been changed to the following:

Columns		
1–10	DT	Time interval for integration in seconds
11–15	INTG	Integration method indicator

2. The following cards, which follow the expansion joint Card D and preceed Card V, are required to specify DF element input data:

TYPE 6—Discrete Foundation (DF) Elements

A. Control Data Card
One card is required

Columns		
1–5	MTYPE	The number "6" for DF elements
6–10	NUMSSI	Number of DF elements
11–15	NPSET	Number of different element property sets

B. Element Stiffness Parameter Cards

Supply one card for each degree-of-freedom for each element property set

Columns		
1–5	NP	Element property set identification number (1 to NPSET)
6–10	IDOF	Local degree-of-freedom for which the following stiffness parameters apply (1 to 6)
11–20	RKEI	Initial elastic yield stiffness, as defined in Figure 2.10
21–30	FYI	Initial yield force, as defined in Figure 2.10
31–40	RKPI	Post-yield stiffness, as defined in Figure 2.10
41–50	RKG1	First in-gap stiffness, as defined in Figure 2.11
51–60	RKG2	Second in-gap stiffness, as defined in Figure 2.11
61–65	SD	Elastic stiffness degradation parameter; SD $\equiv \alpha$, where α is as defined in equation (2.11)
66–70	RIK	Strain hardening parameter; RIK = 0.0 results in kinematic hardening (see Figure 2.10), RIK = 1.0 results in isotropic hardening. Intermediate values of RIK are permitted.
71–75	RHOP	gap development parameter; RHOP $\equiv \gamma$, where γ is as defined in equation (2.12)
76–80	RIZ	Elastic unloading option parameter, as defined in Figure 2.10; RIZ = 1 turns option "on," RIZ $\neq$ 1 leaves option "off"

C. Element Damping Cards

Supply one card for each degree-of-freedom for each element property set

Columns		
1–5	NP	Element property set identification number (1 to NPSET)
6–10	IDOF	Local degree-of-freedom for which the following damping parameter applies (1 to 6)
11–20	C	Linear viscous damping coefficient

D. Element Mass Parameter Cards

Supply one card for each degree-of-freedom for each element property set

Columns		
1–5	NP	Element property set identification number (1 to NPSET)
6–10	IDOF	Local degree-of-freedom for which the following mass parameters applies (1 to 6)
11–20	RMI	Mass to be lumped to node *i* of element
21–30	RMJ	Mass to be lumped to node *j* of element

E. Element Data Cards

Supply one card for each DF element

Columns		
1–5	NE	Element number (1 to NUMSSI)
6–10	INI	Node *i* of element, as defined in Figure 2.9
11–15	INJ	Node *j* of element
16–20	INK	Node *k* of element
21–25	INL	Node *l* of element
26–30	PSNUM	Element property set number (1 to NPSET)
31–40	INELKI	End force release code at node *i* (works the same as for the NEABS beam element); using "000000" is recommended
41–50	INELKJ	End force release code at node *j*
51–55	*-blank-*	No data should be put in this field
56–60	IRD	Option to apply Rayleigh damping to element; IRD = 1 turns option "on," IRD ≠ 1 leaves option "off"

Additional Notes:

1. NEABS assumes input data to be contained in two files, "INPUT" and "RECORD". File INPUT contains all of the data specified by the users guide, including the changes/additions noted in this appendix, except for Cards VIII-F. These cards, which contain seismic acceleration and/or dynamic load data, are contained in file RECORD.

2. Results will be written to the file "OUTPUT". An execution error will result if a file named "OUTPUT" already exists when NEABS is executed.

3. If no input ground motion is to be specified, a blank line in the input should occupy the position of Card VIII-D. Failure to include a blank line will result in an execution error.

4. In the specification of requested element stress output (Cards IX-B-ii), output should be requested of at least one nonlinear element (elasto-plastic beam, expansion joint, or DF elements). Failure to do so will result in an execution error.

5. Appendix B contains the "INPUT", "RECORD", and "OUTPUT" files of an example NEABS analysis (specifically, the first 16 seconds of the SF42–D11.FEH analysis).

Appendix B

Example NEABS Analysis Incorporating DF Element

System Model and Analysis Control Input File, "INPUT"

```
0        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

Spread Footinge, Penzien 11 model, soft soil, El Centro, high intensity
   19    2   19    1    1  800    2 0.5869031 0.0042596
    1    1    1    1    1    1    1       0.0       0.0       0.0
    2    1    1    1    1    1    1     288.0       0.0       0.0
    3         1         1         1       0.0       0.0       0.0
    4         1         1         1     288.0       0.0       0.0
    5         1         1         1       0.0       0.0       0.0
    6         1         1         1     288.0       0.0       0.0
    7         1         1         1       0.0       0.0       0.0
    8         1         1         1     288.0       0.0       0.0
    9         1         1         1       0.0       0.0      36.0
   10         1         1         1     288.0       0.0      36.0
   11         1         1         1       0.0       0.0     264.0
   12         1         1         1     288.0       0.0     264.0
   13         1         1         1       0.0       0.0     300.0
   14         1         1         1     288.0       0.0     300.0
   15         1         1         1     -92.0       0.0     300.0
   16         1         1         1     380.0       0.0     300.0
   17    1    1    1    1    1    1       0.0       0.0     600.0
   18    1    1    1    1    1    1     288.0       0.0     600.0
   19    1    1    1    1    1    1     576.0       0.0     600.0
    2    9    2    0    2    1
    1  4600.0      0.18       0.0
    2 460000.0      0.18 1.000E-06
    1  1076.0    968.0     968.0   82400.0   41200.0   41200.0
    2  2590.0  96800.0   96800.0 8240000.0 4120000.0 4120000.0
      0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0
 -386.04        0.0       0.0       0.0
    1  4884.0    9000.0    9000.0    0.1226
      1.0   -6.9732   -9.4420   -1.4688       1.0   -6.9732   -9.4420   -1.4688
    1    7    9   18    1    1                                              1
    2    9   11   18    1    1                                              1
    3   11   13   18    1    1                                              1
    4    8   10   19    1    1                                              1
    5   10   12   19    1    1                                              1
    6   12   14   19    1    1                                              1
    7   13   14   19    2    2                                              0
    8   15   13   19    2    2                                              0
    9   14   16   19    2    2                                              0
    6   10    5
    1    1 1392.526  1.0E+10       0.0       0.0       0.0  0.0  0.0  0.0  0.0
    1    2 1699.802  1.0E+10       0.0       0.0       0.0  0.0  0.0  0.0  0.0
    1    3 1699.802  1.0E+10       0.0       0.0       0.0  0.0  0.0  0.0  0.0
    1    4  9458823  1.0E+10       0.0       0.0       0.0  0.0  0.0  0.0  0.0

12345678901234567890123456789012345678901234567890123456789012345678901234567890
0        1         2         3         4         5         6         7         8
```

1	5	5071944	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	6	5071944	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	1091.646	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2	591.1233	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3	591.1233	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	2214651	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	5	1306509	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	6	1306509	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	1777.904	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2	1798.386	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3	1798.386	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	4	6646334	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	5	3263418	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	6	3263418	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1	450.1618	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2	571.5546	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3	571.5546	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	4	7384009	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	5	4552660	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	6	4552660	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1	0.0	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	2	0.0	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	3	0.0	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	4	0.0	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	5	0.0	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	6	0.0	1.0E+10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1	31.43207								
1	2	36.01573								
1	3	36.01573								
1	4	119823.6								
1	5	64412.38								
1	6	64412.38								
2	1	13.66794								
2	2	13.11395								
2	3	13.11395								
2	4	-32320.1								
2	5	-16789.4								
2	6	-16789.4								
3	1	24.47924								
3	2	24.75835								
3	3	24.75835								
3	4	7672.424								
3	5	3164.212								
3	6	3164.212								
4	1	7.306419								
4	2	1.983106								
4	3	1.983106								
4	4	65682.8								
4	5	39968.27								
4	6	39968.27								
5	1	27.95565								
5	2	30.38705								
5	3	30.38705								
5	4	63747.98								
5	5	33788.29								
5	6	33788.29								
1	1	0.0	0.0							
1	2	0.0	0.0							
1	3	0.0	0.0							
1	4	0.0	0.0							
1	5	0.0	0.0							
1	6	0.0	0.0							
2	1	0.0	0.0							
2	2	0.0	0.0							
2	3	0.0	0.0							
2	4	0.0	0.0							
2	5	0.0	0.0							
2	6	0.0	0.0							
3	1	0.0	0.0							
3	2	0.0	0.0							
3	3	0.0	0.0							
3	4	0.0	0.0							

```
0        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
    3     5        0.0       0.0
    3     6        0.0       0.0
    4     1        0.0       0.0
    4     2        0.0       0.0
    4     3        0.0       0.0
    4     4        0.0       0.0
    4     5        0.0       0.0
    4     6        0.0       0.0
    5     1   0.253735  0.393096
    5     2   0.297489   0.05269
    5     3   0.297489   0.05269
    5     4   790.8962  2420.943
    5     5   392.4067  1228.482
    5     6   392.4067  1228.482
       0.0        0.0       0.0       0.0
       0.0        0.0       0.0       0.0
   -386.04        0.0       0.0       0.0
    1     1     5    17    18     1    000000    000000    0    0    0
    2     5     7    17    18     2    000000    000000    0    0    0
    3     1     3    17    18     3    000000    000000    0    0    0
    4     3     7    17    18     4    000000    000000    0    0    0
    5     3     5    17    18     5    000000    000000    0    0    0
    6     2     6    18    19     1    000000    000000    0    0    0
    7     6     8    18    19     2    000000    000000    0    0    0
    8     2     4    18    19     3    000000    000000    0    0    0
    9     4     8    18    19     4    000000    000000    0    0    0
   10     4     6    18    19     5    000000    000000    0    0    0


      1.0
   .02000     0
    5      0.050
   10     1       0.010     0.005
    1               1.433963

    1
    7     1     5
   13     1     5

    1
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Applied Seismic Excitation File, "RECORD"

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 -.041995 -.031496 -.023914 -.012248 -.019248 -.038204 -.055410 -.057160  $   3
 -.019248  .008749  .041120 -.014290 -.037329 -.041995 -.059201 -.075824  $   4
 -.094780 -.089239 -.050160 -.057451 -.047536 -.047827 -.019539  .007291  $   5
  .043745  .068825  .073491  .097988  .135025  .143482  .122193  .104695  $   6
  .079032  .068533  .098863  .120152  .154564  .186352  .213473  .190143  $   7
  .174686  .116652  .116652  .018373 -.150190 -.229513 -.175853 -.141149  $   8
 -.072908 -.017206  .039078  .089822  .145523  .207057  .290172  .355497  $   9
  .445903  .422572  .336833  .272674  .260134  .270050  .244678  .262759  $  10
  .289589  .352581  .095655 -.430155 -.602508 -.580052 -.593176 -.529600  $  11
 -.503062 -.510936 -.511228 -.526393 -.475357 -.392826 -.317002 -.228055  $  12
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.069116	-.195392	-.577428	-.478565	-.491397	-.431904	-.358997	-.291922	$	17
-.219014	-.152523	-.079032	-.012832	.054826	-.027705	-.126276	-.244386	$	18
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.071449	.169146	.091572	.068825	.141441	.171770	.153106	.103529	$	78
.057451	.058034	.143482	.100029	.083990	.125984	.069700	.025663	$	79
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-.080198	-.078740	.021581	.124818	-.067367	-.112861	-.024205	.040537	$	84
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0	1	2	3	4	5	6	7	8

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-.027122 -.027997 -.028288 -.025663 -.023622 -.020706 -.019831 -.019831  $ 303
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-.009915 -.006707 -.003791 -.000583  .002916  .004958  .002625  .000875  $ 305
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-.013415 -.012540 -.011082 -.009332 -.007582 -.005833 -.005541 -.005249  $ 310
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-.034704 -.027705 -.017498 -.006999  .009332  .011082  .004083 -.000292  $ 324
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-.016040 -.024497 -.027122 -.017789 -.010499 -.000583  .009624  .010790  $ 326
-.004083 -.013123 -.030038 -.022456 -.006707  .009041  .011957  .007582  $ 327
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-.040828 -.035287 -.027997 -.021581 -.013415 -.009915 -.012248 -.013123  $ 335
-.016040 -.018373 -.020997 -.023330 -.021289 -.015165 -.010790 -.007582  $ 336
-.004083                                                                 $ 337
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0        1         2         3         4         5         6         7         8
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Analysis Results File, "OUTPUT"

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0        1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
Spread Footinge, Penzien 11 model, soft soil, El Centro, high intensity

 number of nodal points     =   19
 number of element types    =    2
 number of total elements   =   19
 number of time functions   =    1
 ground motion input code   =    1
 number of time steps (dt)  =  800
 dt multiplier for output   =    2
 damping factor alpha       =  5.869E-01
 damping factor beta        =  4.260E-03

 1nodal point data as input.....

 0node      boundary condition codes              nodal point coordinates
  number  x    y    z   xx   yy   zz          x            y            z

12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0        1         2         3         4         5         6         7         8         9         10        11
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0        1         2         3         4         5         6         7         8
123456789012345678901234567890123456789012345678901234567890123456789012345678
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.129775	.007874	-.203266	-.232138	-.073199	-.039370	.023039	-.033537	$ 85
-.073199	-.097113	-.078449	-.087781	-.058326	-.019539	-.011082	.030621	$ 86
.086323	.100321	.279090	.261884	.052202	-.105570	-.289880	-.235346	$ 87
-.216973	-.157189	-.096238	-.037329	.009041	.043161	.148148	-.006416	$ 88
-.142607	-.104404	-.201516	-.150481	-.108195	.025663	.184310	.245261	$ 89
.372120	.404783	.347915	.219014	.065617	-.025663	-.066200	.021581	$ 90
.052785	.158647	.116360	.013123	-.023914	-.053952	-.005833	.001750	$ 91
-.034121	-.061242	-.088364	-.149315	-.212015	-.168854	-.077574	-.051910	$ 92
.011665	.028580	.039953	.064450	.127442	.026538	-.159813	-.161855	$ 93
-.070866	-.023622	.072908	.119568	.053077	-.007874	-.070866	-.004374	$ 94
.072033	.140566	.228346	.181394	.096530	-.004083	-.056868	-.072033	$ 95
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-.056868	-.005249	.049577	-.023330	.001458	.067075	.109070	.175270	$ 97
.150481	.125984	.100321	.147273	.190435	.199183	.050160	-.049577	$ 98
-.153689	-.193642	-.112861	-.064742	-.009624	.034704	-.037329	-.102362	$ 99
-.149898	-.097696	-.063575	-.003500	.041411	.020414	-.018373	-.034998	$ 100
-.093905	-.100904	-.026538	.021289	.090114	.137649	.175853	.167979	$ 101
.096238	-.021289	-.226597	-.177311	-.127734	-.060951	.009041	.102071	$ 102
.085448	.035287	.098571	.092447	.074074	.060076	.057743	.050744	$ 103
.006124	-.041995	-.100029	-.098863	-.042286	-.008166	.049577	-.027997	$ 104
-.074366	-.081365	-.113153	-.070575	-.062700	-.053077	-.050744	-.011082	$ 105
-.007874	-.053952	-.035871	.025372	.100029	.202683	.265383	.248761	$ 106
.221639	.149606	.054243	.004374	-.055410	-.044036	-.021289	.006124	$ 107
.037620	.062700	.006999	-.036162	-.095946	-.151356	-.206474	-.168854	$ 108
-.134733	-.089530	-.042286	-.002625	-.052493	-.092738	-.135608	-.114027	$ 109
-.100612	-.092155	-.126859	-.143190	-.138524	-.122485	-.105279	-.080782	$ 110
-.075241	-.040537	-.019831	.147857	.210557	.256051	.228055	.223097	$ 111
.128026	.023330	.003791	-.036745	-.004374	.008749	.030330	.030330	$ 112
.056285	.059784	.021581	-.016331	-.020997	.020414	.030913	.042870	$ 113
-.002625	-.046369	-.054535	-.002041	.045203	.030621	-.033537	-.088672	$ 114
-.090114	-.027705	-.016915	.001167	.005833	.014582	.016623	.028288	$ 115
.039078	.051619	.063575	.076115	.088072	.100904	.112569	.138233	$ 116
.114611	.069408	.033537	-.023039	-.036162	.015748	.007874	-.072908	$ 117
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.027413	.097696	.167979	.123651	.041703	-.002041	-.039370	-.078740	$ 123
-.099446	-.104112	-.115486	-.117235	-.142316	-.139983	-.118402	-.118693	$ 124
-.102362	-.054535	-.016623	.012832	-.005541	-.020997	-.049286	-.033537	$ 125
.036745	.104404	.190726	.208807	.222222	.215515	.183144	.141149	$ 126
.076990	-.012832	-.083990	-.111986	-.143482	-.124818	-.121318	-.080490	$ 127
-.015165	.069116	.124234	.176145	.131817	.082823	.036745	-.015748	$ 128
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.120443	.053660	-.013998	-.088364	-.154856	-.206474	-.270633	-.251677	$ 130
-.184019	-.109653	.025372	.090114	.171770	.179061	.112278	.102362	$ 131
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.118985	.164188	.154856	.091572	.048119	-.006999	-.055118	-.080490	$ 133
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-.046369	-.034704	-.015456	.000583	.017206	-.006707	-.032663	-.059784	$ 135
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-.187810	-.161855	-.130067	-.002333	.073782	.119860	.187810	.168854	$ 137
.138233	.111986	.112278	.099154	.104112	.002333	-.074074	-.134150	$ 138
-.137358	-.064742	-.018956	.047827	.103529	.146982	.108195	.081656	$ 139
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.016915	.006416	-.009041	-.009041	.001167	-.007291	-.036162	-.068533	$ 141
-.118402	-.154564	-.204433	-.094197	-.015165	.027413	.095655	.139399	$ 142
.148440	.104404	.099738	.089239	.083115	.076699	.048994	-.001458	$ 143
-.061826	-.106445	-.090405	-.086614	-.081656	-.069116	-.077574	-.089822	$ 144
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.040828	.032079	.031496	.026830	.025955	.005541	-.038204	-.072033	$ 146
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.050452	.022747	-.016915	-.062700	-.068241	.017498	.076407	.078449	$ 148
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.076115	.035287	.002333	-.048994	-.111403	-.165063	-.227763	-.180519	$ 151
-.074657	.012832	.132983	.228346	.321668	.277924	.142607	.035579	$ 152
-.112861	-.246719	-.357539	-.251969	-.179644	-.066492	.043745	.139108	$ 153
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.160980	.173520	.179936	.172937	.135900	.046078	-.022456	-.067075	$ 155
-.088364	-.095946	-.106153	-.142899	-.192476	-.210849	-.228638	-.246719	$ 156

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123456789012345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7         8
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0	1	2	3	4	5	6	7	8	
1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	
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-.083406	-.110819	-.133275	-.147273	-.226597	-.183144	-.055118	.055118	$ 159	
.148440	.216973	.218431	.163896	.132692	.153106	.185185	.213182	$ 160	
.248177	.270341	.284339	.270924	.237387	.076990	-.084281	-.262759	$ 161	
-.397784	-.250510	-.136483	.023622	.173228	.240012	.162146	.087781	$ 162	
-.003208	-.110819	-.101196	-.005833	.052493	.184602	.295421	.327209	$ 163	
.322835	.274132	.234762	.177311	.148148	.060076	-.058618	-.166812	$ 164	
-.297754	-.388451	-.357247	-.351998	-.293380	-.222222	-.159813	-.142607	$ 165	
-.118110	-.084864	-.051327	-.041120	-.028580	-.014582	.005541	.023330	$ 166	
.010207	-.008457	-.017789	-.009915	-.003791	.022164	.059784	.095363	$ 167	
.131234	.168271	.163896	.135316	.087489	.031204	-.001167	-.009624	$ 168	
-.020122	-.029455	-.058618	-.054826	.007291	.039078	.070866	.077574	$ 169	
.077282	.045203	-.005541	-.027705	-.062992	-.048702	-.034996	-.018664	$ 170	
-.037620	-.047536	-.056285	-.070575	-.068825	-.051035	-.036162	-.053952	$ 171	
-.077282	-.094197	-.097988	-.132400	-.125401	-.097404	-.062117	-.020122	$ 172	
.008749	.000875	-.027122	-.025955	-.043745	-.047827	-.069408	-.094197	$ 173	
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.088072	.114611	.118402	.112278	.095946	.053368	.036454	.020414	$ 181	
-.000292	-.019831	-.037912	-.037329	-.033537	-.029746	-.024497	-.041120	$ 182	
-.059784	-.078449	-.102071	-.104695	-.086614	-.066200	.005249	.028871	$ 183	
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.041120	.016040	-.019248	-.028288	-.007582	.004666	.029163	.027413	$ 185	
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.041703	.031788	.037329	.044328	.039953	.034121	.028288	.017498	$ 188	
-.008166	-.014582	-.024497	-.051910	-.093613	-.122485	-.151064	-.137649	$ 189	
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.074366	.096530	.095655	.073491	.050452	.013123	-.024789	-.055410	$ 191	
-.066783	-.088656	-.080782	-.066200	-.050744	-.035287	-.036745	-.037620	$ 192	
-.023330	-.007582	.011374	.018956	.016040	.014582	.018664	.036745	$ 193	
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.068241	.082240	.087781	.057160	.030913	-.011374	-.047536	-.093905	$ 195	
-.097696	-.063867	-.043161	-.002916	.003208	-.015456	-.029455	-.036745	$ 196	
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.069700	.093030	.099446	.092738	.062117	.021289	.002625	-.004374	$ 198	
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.050160	.058326	.074657	.092447	.083698	.067367	.030621	-.000292	$ 201	
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.045203	.059784	.041703	.021289	.006124	-.006416	-.020414	-.029163	$ 203	
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.038204	.029746	.016331	.001750	-.011665	-.028580	-.027997	-.013415	$ 206	
-.002041	.009041	.013123	.019831	.015165	.013123	.005249	-.000583	$ 207	
-.008457	-.008166	-.004958	-.001750	-.001458	-.004958	-.006416	-.010499	$ 208	
-.009332	-.002041	.004083	.011957	.018956	.018373	.015165	.001750	$ 209	
-.013123	-.022164	-.018664	-.018956	-.031204	-.046952	-.050744	-.034121	$ 210	
-.020414	-.010499	-.007291	-.000583	.001167	.010499	.023914	.033537	$ 211	
.020414	.011082	-.002916	-.007291	-.009915	-.011957	-.013123	-.018956	$ 212	
-.034996	-.034121	-.031496	-.028580	-.023622	-.022164	-.032079	-.040245	$ 213	
-.048411	-.041995	-.037912	-.032371	-.031496	-.028580	-.028580	-.018373	$ 214	
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-.078449	-.079907	-.063284	-.051910	-.033829	-.017789	.000000	.015748	$ 217	
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-.065908	-.052202	-.039662	-.023914	-.004083	.012832	.025955	.028288	$ 220	
.029163	.029163	.030330	.039662	.035287	.029163	.020997	.005541	$ 221	
-.008166	-.024205	-.038204	-.055410	-.056576	-.040537	-.029163	-.012832	$ 222	
-.012832	-.011665	-.013123	-.014290	-.011374	-.006124	-.006416	-.004666	$ 223	
-.004666	-.003500	-.003500	.008166	.019831	.033537	.027997	.016331	$ 224	
.004958	-.009041	-.022747	-.026830	-.026830	-.027705	-.026830	-.025080	$ 225	
-.015165	-.006416	.004083	.011082	.009915	.009915	.008457	.011665	$ 226	
.015748	.019539	.024789	.025372	.022456	.020414	.017789	.021872	$ 227	
.025372	.029746	.032371	.026247	.021872	.015456	.018081	.023039	$ 228	

1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890
0	1	2	3	4	5	6	7	8

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0         1         2         3         4         5         6         7         8
123456789012345678901234567890123456789012345678901234567890123456789012345678901
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-.078740	-.081073	-.083698	-.081073	-.078740	-.075241	-.073199	-.068867	$ 231
-.050452	-.037620	-.031788	-.030621	-.027705	-.026538	-.020997	-.017206	$ 232
-.011665	-.006707	.005249	.010207	.012248	.013998	.012540	.012540	$ 233
.011082	.010499	.009332	.013707	.018373	.024789	.032079	.039078	$ 234
.046661	.052785	.050452	.048994	.046369	.042870	.031496	.019831	$ 235
.009332	.002625	.005541	.008166	.011665	.015748	.020122	.027705	$ 236
.034121	.041703	.041703	.036454	.035579	.036162	.036745	.037912	$ 237
.038787	.030913	.023039	.013415	.005833	.001458	-.003208	-.007291	$ 238
-.003208	.005249	.012540	.022164	.030038	.038787	.029455	.018081	$ 239
.005249	-.007874	-.023330	-.025955	-.015748	-.008749	.001750	.003500	$ 240
.006416	.007874	.009332	.013998	.020122	.025955	.032663	.038787	$ 241
.040828	.039953	.040828	.039370	.040537	.029746	.008749	-.009332	$ 242
-.018373	-.024789	-.032663	-.045786	-.057451	-.054826	-.053077	-.049577	$ 243
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-.018664	-.006124	.000583	-.001167	-.001167	-.004083	-.005541	-.002333	$ 245
.003208	.007874	.014582	.015456	.012248	.008749	.003208	-.001458	$ 246
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.018956	.021581	.023622	.026538	.037037	.049286	.041995	.030621	$ 248
.020414	.010207	.000583	-.009332	-.018664	-.027705	-.026538	-.024205	$ 249
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-.022747	-.019831	-.018373	-.016623	-.014582	-.011957	-.009624	-.006999	$ 254
-.004083	-.001458	.001167	.003791	.006124	.000292	-.005249	-.011665	$ 255
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-.056576	-.058909	-.062117	-.057743	-.050452	-.039370	-.018956	-.004083	$ 257
.005833	.016040	.023914	.025955	.029746	.027122	.023330	.017789	$ 258
.009624	.000875	-.006999	-.016623	-.013123	-.003791	.003791	.009624	$ 259
.013998	.015748	.016915	.018081	.018956	.020122	.020997	.021872	$ 260
.022456	.021289	.020122	.018664	.016915	.015748	.013998	.017789	$ 261
.023039	.027997	.033246	.036745	.040537	.038204	.035871	.033246	$ 262
.030038	.025372	.020997	.016331	.011665	.006999	.002041	.001167	$ 263
.002333	.002625	.006707	.012248	.015165	.017789	.020997	.023039	$ 264
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.000000	-.000292	-.001167	-.002041	-.001750	-.000292	.000875	.002041	$ 273
-.000292	-.002041	-.004374	-.006999	-.008457	-.008166	-.008166	-.007291	$ 274
-.006999	-.006124	-.007874	-.012832	-.016915	-.022164	-.024497	-.023914	$ 275
-.024205	-.021872	-.014582	-.008166	-.000583	.005249	.005249	.006124	$ 276
.006124	.006124	.009041	.012540	.014290	.014290	.014290	.013998	$ 277
.013707	.015165	.019539	.023039	.027705	.028288	.027997	.027997	$ 278
.027122	.026538	.025955	.025372	.024497	.023914	.023330	.022456	$ 279
.018081	.013707	.010207	.010499	.009915	.010207	.010499	.009332	$ 280
.005541	.004374	.004083	.003500	.003500	.003208	.000000	-.002916	$ 281
-.005833	-.007291	-.008457	-.009624	-.010790	-.013998	-.018373	-.022456	$ 282
-.026830	-.031204	-.035579	-.040245	-.041703	-.034996	-.030038	-.022747	$ 283
-.019539	-.018373	-.016915	-.016331	-.015456	-.014582	-.013998	-.013123	$ 284
-.012248	-.011374	-.009041	-.007582	-.003208	.002916	.009041	.013415	$ 285
.013998	.015748	.016040	.018373	.024497	.029455	.024497	.020706	$ 286
.015456	.009624	.008166	.008457	.008166	.007874	.003500	-.000292	$ 287
-.002916	-.003208	-.004666	-.004374	-.009041	-.019831	-.028871	-.029746	$ 288
-.030621	-.030913	-.028871	-.025955	-.023039	-.021581	-.020997	-.019831	$ 289
-.019539	-.018373	-.011665	-.003791	.003791	.012540	.020706	.028871	$ 290
.025080	.018373	.011957	.003791	-.004083	-.010207	-.010790	-.012832	$ 291
-.013415	-.014290	-.014873	-.015748	-.016331	-.016915	-.013415	-.008457	$ 292
-.003791	.002041	.004958	.005541	.007291	.007291	.010207	.014582	$ 293
.018664	.023330	.027413	.028288	.029746	.030621	.031496	.032079	$ 294
.030330	.028871	.027122	.025080	.023039	.020997	.018373	.016040	$ 295
.013415	.011082	.009041	.007874	.006124	.004958	.003500	.002041	$ 296
.000875	.002333	.003791	.005541	.006416	.002625	-.000875	-.004958	$ 297
-.009041	-.013707	-.015456	-.013998	-.012540	-.011082	-.007291	-.002625	$ 298
.002041	.004958	.006416	.010207	.017789	.024205	.032663	.031204	$ 299
.025372	.020706	.013707	.007874	.001167	-.004666	-.006999	-.009624	$ 300

```
123456789012345678901234567890123456789012345678901234567890123456789012345678901
0         1         2         3         4         5         6         7         8
```

```
0         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
-.013415 -.020122 -.024497 -.025663 -.027122 -.027705 -.028288 -.028871  $ 301
-.029455 -.029746 -.028580 -.027705 -.026247 -.025372 -.025955 -.026538  $ 302
-.027122 -.027997 -.028288 -.025663 -.023622 -.020706 -.019831 -.019831  $ 303
-.019539 -.019539 -.019248 -.019248 -.018664 -.016331 -.014582 -.012540  $ 304
-.009915 -.006707 -.003791 -.000583  .002916  .004958  .002625  .000875  $ 305
-.001458 -.004083 -.002041  .001750  .004666  .003791  .003500  .002333  $ 306
 .001458  .000000  .000583  .002625  .004083  .006124  .006416  .002916  $ 307
 .000000 -.003500 -.006999 -.006999 -.005541 -.004666 -.005249 -.006416  $ 308
-.007874 -.008749 -.007582 -.006416 -.006416 -.009332 -.011957 -.014873  $ 309
-.013415 -.012540 -.011082 -.009332 -.007582 -.005833 -.005541 -.005249  $ 310
-.004374  .003791  .011957  .019539  .020414  .022164  .022747  .023330  $ 311
 .023622  .024497  .022747  .017789  .013998  .009041  .008457  .008749  $ 312
 .009332  .010207  .010790  .006999  .002041 -.002333 -.008166 -.010207  $ 313
-.006416 -.003791  .000292  .000875  .000292 -.000292 -.001458 -.002333  $ 314
-.003208 -.004374 -.003500 -.002333 -.001167  .000292  .001458  .002333  $ 315
 .002333  .002625  .002916  .006416  .009624  .013415  .017206  .020997  $ 316
 .023039  .018081  .014582  .009332  .004666 -.001167  .000000  .008749  $ 317
 .015165  .025372  .023914  .009041 -.000583 -.018081 -.008166  .016915  $ 318
 .037912  .064450  .053952  .027413  .026538  .022456  .026247  .004666  $ 319
-.024497 -.058326 -.043161 -.002041  .031204  .028871  .013998  .000875  $ 320
-.020122 -.031204 -.004374  .020122  .040245  .019539  .005833  .010207  $ 321
 .026247  .025080  .015165  .006999  .004666  .003791 -.003208 -.009915  $ 322
-.019539 -.015748 -.005833  .004083  .013998  .028288  .016915 -.013998  $ 323
-.034704 -.027705 -.017498 -.006999  .009332  .011082  .004083 -.000292  $ 324
-.002041  .001750  .002916  .006999  .003791  .001167 -.002333 -.007874  $ 325
-.016040 -.024497 -.027122 -.017789 -.010499 -.000583  .009624  .010790  $ 326
-.004083 -.013123 -.030038 -.022456 -.006707  .009041  .011957  .007582  $ 327
 .003791  .004374  .017789  .021289  .021581  .022164  .021289  .020706  $ 328
 .016623  .011082  .006124 -.000583 -.009624 -.018664 -.019831 -.014873  $ 329
-.015748 -.015748 -.016623 -.009624  .000000  .009624  .020414  .027997  $ 330
 .024789  .023330  .019831  .021872  .022456  .024789  .017789  .010790  $ 331
 .002041 -.000292  .001167  .001458 -.002916 -.008457 -.013415 -.020122  $ 332
-.018956 -.012832 -.008166 -.002041 -.006707 -.009624 -.014873 -.017498  $ 333
-.016331 -.015748 -.014582 -.019248 -.026538 -.033246 -.040828 -.040245  $ 334
-.040828 -.035287 -.027997 -.021581 -.013415 -.009915 -.012248 -.013123  $ 335
-.016040 -.018373 -.020997 -.023330 -.021289 -.015165 -.010790 -.007582  $ 336
-.004083                                                                 $ 337
```

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
0         1         2         3         4         5         6         7         8
```

Analysis Results File, "OUTPUT"

```
0         1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
```

```
 Spread Footinge, Penzien 11 model, soft soil, El Centro, high intensity

  number of nodal points     =   19
  number of element types    =    2
  number of total elements   =   19
  number of time functions   =    1
  ground motion input code   =    1
  number of time steps (dt)  =  800
  dt multiplier for output   =    2
  damping factor alpha       =   5.869E-01
  damping factor beta        =   4.260E-03

 1nodal point data as input.....

 0node       boundary condition codes              nodal point coordinates
  number  x    y    z   xx   yy   zz          x            y            z
```

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0         1         2         3         4         5         6         7         8         9         10        11
```

```
0        1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
```

1	1	1	1	1	1	1	.000	.000	.000	0
2	1	1	1	1	1	1	288.000	.000	.000	0
3	0	1	0	1	0	1	.000	.000	.000	0
4	0	1	0	1	0	1	288.000	.000	.000	0
5	0	1	0	1	0	1	.000	.000	.000	0
6	0	1	0	1	0	1	288.000	.000	.000	0
7	0	1	0	1	0	1	.000	.000	.000	0
8	0	1	0	1	0	1	288.000	.000	.000	0
9	0	1	0	1	0	1	.000	.000	36.000	0
10	0	1	0	1	0	1	288.000	.000	36.000	0
11	0	1	0	1	0	1	.000	.000	264.000	0
12	0	1	0	1	0	1	288.000	.000	264.000	0
13	0	1	0	1	0	1	.000	.000	300.000	0
14	0	1	0	1	0	1	288.000	.000	300.000	0
15	0	1	0	1	0	1	-92.000	.000	300.000	0
16	0	1	0	1	0	1	380.000	.000	300.000	0
17	1	1	1	1	1	1	.000	.000	600.000	0
18	1	1	1	1	1	1	288.000	.000	600.000	0
19	1	1	1	1	1	1	576.000	.000	600.000	0

lcomplete nodal point data.....

0node number	boundary condition codes x	y	z	xx	yy	zz	nodal point coordinates x	y	z
1	1	1	1	1	1	1	.000	.000	.000
2	1	1	1	1	1	1	288.000	.000	.000
3	0	1	0	1	0	1	.000	.000	.000
4	0	1	0	1	0	1	288.000	.000	.000
5	0	1	0	1	0	1	.000	.000	.000
6	0	1	0	1	0	1	288.000	.000	.000
7	0	1	0	1	0	1	.000	.000	.000
8	0	1	0	1	0	1	288.000	.000	.000
9	0	1	0	1	0	1	.000	.000	36.000
10	0	1	0	1	0	1	288.000	.000	36.000
11	0	1	0	1	0	1	.000	.000	264.000
12	0	1	0	1	0	1	288.000	.000	264.000
13	0	1	0	1	0	1	.000	.000	300.000
14	0	1	0	1	0	1	288.000	.000	300.000
15	0	1	0	1	0	1	-92.000	.000	300.000
16	0	1	0	1	0	1	380.000	.000	300.000
17	1	1	1	1	1	1	.000	.000	600.000
18	1	1	1	1	1	1	288.000	.000	600.000
19	1	1	1	1	1	1	576.000	.000	600.000

lequation number of nodal degrees of freedom....

0node number	equation number x	y	z	xx	yy	zz	node number	equation number x	y	z	xx	yy	zz
1	0	0	0	0	0	0	2	0	0	0	0	0	0
3	1	0	2	0	3	0	4	4	0	5	0	6	0
5	7	0	8	0	9	0	6	10	0	11	0	12	0
7	13	0	14	0	15	0	8	16	0	17	0	18	0
9	19	0	20	0	21	0	10	22	0	23	0	24	0
11	25	0	26	0	27	0	12	28	0	29	0	30	0
13	31	0	32	0	33	0	14	34	0	35	0	36	0
15	37	0	38	0	39	0	16	40	0	41	0	42	0
17	0	0	0	0	0	0	18	0	0	0	0	0	0
19	0	0	0	0	0	0							

l.....three dimensional beam elements

number of beams = 9

number of geometric property sets= 2

number of fixed end force sets = 0

number of materials = 2

number of beam n/l property sets = 1

lmaterial properties....

material number	young's modulus	poisson's ratio	mass density
1	4600.	.18000	.00000
2	460000.	.18000	.00000

beam geometric properties....

element type	area x	area y	area z	inertia x	inertia y	inertia z
1	1076.000	968.000	968.000	82400.000	41200.000	41200.000
2	2590.000	96800.000	96800.000	8240000.000	4120000.000	4120000.000

element load multipliers.....

	a	b	c	d
x-dir	.000000E+00	.000000E+00	.000000E+00	.000000E+00
y-dir	.000000E+00	.000000E+00	.000000E+00	.000000E+00
z-dir	-.386040E+03	.000000E+00	.000000E+00	.000000E+00

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0        1         2         3         4         5         6         7         8         9         10        11
```

```
0        1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
```

1

beam element nonlinear parameters

npar no	axial pu	moment mu/y	moment mu/z	axial tu	yield function constants a0	a1	a2	a3	b0	b1	b2	b3
1	.488E+04	.900E+04	.900E+04	.123E+00	1.000	-6.973	-9.442	-1.469	1.000	-6.973	-9.442	-1.469

1beam element data.....

0beam no	nodes i	j	k	matl no	geom no	elem loads a	b	c	d	end codes i	j	l/nl ind
1	7	9	18	1	1	0	0	0	0	0	0	1
2	9	11	18	1	1	0	0	0	0	0	0	1
3	11	13	18	1	1	0	0	0	0	0	0	1
4	8	10	19	1	1	0	0	0	0	0	0	1
5	10	12	19	1	1	0	0	0	0	0	0	1
6	12	14	19	1	1	0	0	0	0	0	0	1
7	13	14	19	2	2	0	0	0	0	0	0	0
8	15	13	19	2	2	0	0	0	0	0	0	0
9	14	16	19	2	2	0	0	0	0	0	0	0

.....DF elements (Type 6)

number of DF elements: 10
number of element property sets: 5

STIFFNESS PARAMETER DATA

np	dof	rkei	fyi	rkpi	rkg1	rkg2	sd	rik	rhop	riz
1	1	.139E+04	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
1	2	.170E+04	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
1	3	.170E+04	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
1	4	.946E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
1	5	.507E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
1	6	.507E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
2	1	.109E+04	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
2	2	.591E+03	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
2	3	.591E+03	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
2	4	.221E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
2	5	.131E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
2	6	.131E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
3	1	.178E+04	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
3	2	.180E+04	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
3	3	.180E+04	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
3	4	.665E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
3	5	.326E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
3	6	.326E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
4	1	.450E+03	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
4	2	.572E+03	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
4	3	.572E+03	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
4	4	.738E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
4	5	.455E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
4	6	.455E+07	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
5	1	.000E+00	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
5	2	.000E+00	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
5	3	.000E+00	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
5	4	.000E+00	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
5	5	.000E+00	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000
5	6	.000E+00	.100E+11	.000E+00	.000E+00	.000E+00	.000	.000	.000	.000

DAMPING PARAMETER DATA

np	dof	c
1	1	.3143E+02
1	2	.3602E+02
1	3	.3602E+02
1	4	.1198E+06
1	5	.6441E+05
1	6	.6441E+05
2	1	.1367E+02
2	2	.1311E+02
2	3	.1311E+02
2	4	-.3232E+05
2	5	-.1679E+05
2	6	-.1679E+05
3	1	.2448E+02
3	2	.2476E+02
3	3	.2476E+02
3	4	.7672E+04
3	5	.3164E+04
3	6	.3164E+04
4	1	.7306E+01
4	2	.1983E+01
4	3	.1983E+01
4	4	.6568E+05
4	5	.3997E+05
4	6	.3997E+05
5	1	.2796E+02
5	2	.3039E+02
5	3	.3039E+02
5	4	.6375E+05
5	5	.3379E+05

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0        1         2         3         4         5         6         7         8         9         10        11
```

```
0        1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
```

```
 5  6  .3379E+05

 MASS PARAMETER DATA

np dof  mi          mj
 1  1  .0000E+00   .0000E+00
 1  2  .0000E+00   .0000E+00
 1  3  .0000E+00   .0000E+00
 1  4  .0000E+00   .0000E+00
 1  5  .0000E+00   .0000E+00
 1  6  .0000E+00   .0000E+00
 2  1  .0000E+00   .0000E+00
 2  2  .0000E+00   .0000E+00
 2  3  .0000E+00   .0000E+00
 2  4  .0000E+00   .0000E+00
 2  5  .0000E+00   .0000E+00
 2  6  .0000E+00   .0000E+00
 3  1  .0000E+00   .0000E+00
 3  2  .0000E+00   .0000E+00
 3  3  .0000E+00   .0000E+00
 3  4  .0000E+00   .0000E+00
 3  5  .0000E+00   .0000E+00
 3  6  .0000E+00   .0000E+00
 4  1  .0000E+00   .0000E+00
 4  2  .0000E+00   .0000E+00
 4  3  .0000E+00   .0000E+00
 4  4  .0000E+00   .0000E+00
 4  5  .0000E+00   .0000E+00
 4  6  .0000E+00   .0000E+00
 5  1  .2537E+00   .3931E+00
 5  2  .2975E+00   .5269E-01
 5  3  .2975E+00   .5269E-01
 5  4  .7909E+03   .2421E+04
 5  5  .3924E+03   .1228E+04
 5  6  .3924E+03   .1228E+04

 ELEMENT LOAD FACTORS

   Load Case:          a              b              c              d
   Global X-dir:      .000000E+00    .000000E+00    .000000E+00    .000000E+00
   Global Y-dir:      .000000E+00    .000000E+00    .000000E+00    .000000E+00
   Global Z-dir:     -.386040E+03    .000000E+00    .000000E+00    .000000E+00

 ELEMENT DATA

    1    1    5   17   18    1    0    0    0    0    0
    2    5    7   17   18    2    0    0    0    0    0
    3    1    3   17   18    3    0    0    0    0    0
    4    3    7   17   18    4    0    0    0    0    0
    5    3    5   17   18    5    0    0    0    0    0
    6    2    6   18   19    1    0    0    0    0    0
    7    6    8   18   19    2    0    0    0    0    0
    8    2    4   18   19    3    0    0    0    0    0
    9    4    8   18   19    4    0    0    0    0    0
   10    4    6   18   19    5    0    0    0    0    0


itotal number of nonlinear elements   =   16


 element type of l/nl indicator.....

   element ind   element ind   element ind   element ind   element ind
   number  type  number  type  number  type  number  type  number  type

      1     2       2     2       3     2       4     2       5     2
      6     2       7    -2       8    -2       9    -2      10     6
     11     6      12     6      13     6      14     6      15     6
     16     6      17     6      18     6      19     6


 system setup information...

 total number of equations   =   42

 band width                  =   15


 element load multiplier for static analysis.....

 structure       element load multiplier
 load case       a         b         c         d

     1          1.000      .000      .000      .000
lprint of static displacements.....
```

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0        1         2         3         4         5         6         7         8         9         10        11
```

```
0         1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
```

node no.	node, type	x	y	z	xx	yy	zz
1	fixe	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	fixe	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3		-5.929E-07	0.000E+00	-4.908E-02	0.000E+00	-1.364E-07	0.000E+00
4		4.296E-07	0.000E+00	-4.903E-02	0.000E+00	-8.799E-08	0.000E+00
5		-6.344E-07	0.000E+00	-1.068E-01	0.000E+00	-4.798E-08	0.000E+00
6		4.597E-07	0.000E+00	-1.066E-01	0.000E+00	-3.094E-08	0.000E+00
7		-2.459E-06	0.000E+00	-2.429E-01	0.000E+00	-2.342E-07	0.000E+00
8		1.781E-06	0.000E+00	-2.427E-01	0.000E+00	-1.511E-07	0.000E+00
9		-1.320E-05	0.000E+00	-2.446E-01	0.000E+00	-3.577E-07	0.000E+00
10		-5.210E-06	0.000E+00	-2.444E-01	0.000E+00	-2.407E-07	0.000E+00
11		-1.565E-04	0.000E+00	-2.555E-01	0.000E+00	-7.990E-07	0.000E+00
12		-1.447E-04	0.000E+00	-2.552E-01	0.000E+00	-1.055E-06	0.000E+00
13		-1.856E-04	0.000E+00	-2.572E-01	0.000E+00	-8.150E-07	0.000E+00
14		-1.856E-04	0.000E+00	-2.569E-01	0.000E+00	-1.223E-06	0.000E+00
15		-1.856E-04	0.000E+00	-2.573E-01	0.000E+00	-8.827E-07	0.000E+00
16		-1.856E-04	0.000E+00	-2.568E-01	0.000E+00	-1.155E-06	0.000E+00
17	fixe	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
18	fixe	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
19	fixe	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

1 static stress output.....

0 ....straight beam forces and moments

0beam no.	load no.	axial r1	shear r2	shear r3	torsion m1	bending m2	bending m3
1	1	2.359E+02	2.145E-03	0.000E+00	0.000E+00	0.000E+00	6.886E-01
		-2.359E+02	-2.145E-03	0.000E+00	0.000E+00	0.000E+00	-6.114E-01
2	1	2.359E+02	2.145E-03	0.000E+00	0.000E+00	0.000E+00	6.114E-01
		-2.359E+02	-2.145E-03	0.000E+00	0.000E+00	0.000E+00	-1.224E-01
3	1	2.359E+02	2.144E-03	0.000E+00	0.000E+00	0.000E+00	1.224E-01
		-2.359E+02	-2.144E-03	0.000E+00	0.000E+00	0.000E+00	-4.518E-02
4	1	2.356E+02	-1.554E-03	0.000E+00	0.000E+00	0.000E+00	4.441E-01
		-2.356E+02	1.554E-03	0.000E+00	0.000E+00	0.000E+00	-5.000E-01
5	1	2.356E+02	-1.554E-03	0.000E+00	0.000E+00	0.000E+00	5.000E-01
		-2.356E+02	1.554E-03	0.000E+00	0.000E+00	0.000E+00	-8.543E-01
6	1	2.356E+02	-1.554E-03	0.000E+00	0.000E+00	0.000E+00	8.543E-01
		-2.356E+02	1.554E-03	0.000E+00	0.000E+00	0.000E+00	-9.103E-01
7	1	1.770E-03	1.439E+02	0.000E+00	0.000E+00	0.000E+00	4.219E+03
		-1.770E-03	1.440E+02	0.000E+00	0.000E+00	0.000E+00	-4.233E+03
8	1	0.000E+00	-1.053E-01	0.000E+00	0.000E+00	0.000E+00	-2.999E+01
		0.000E+00	9.211E+01	0.000E+00	0.000E+00	0.000E+00	-4.214E+03
9	1	0.000E+00	9.239E+01	0.000E+00	0.000E+00	0.000E+00	4.245E+03
		0.000E+00	-3.872E-01	0.000E+00	0.000E+00	0.000E+00	8.852E+00

1 static stress output.....

.....ssi element forces and moments

0beam no.	load no.	axial r1	shear r2	shear r3	torsion m1	bending m2	bending m3
1	1	1.487E+02	1.078E-03	0.000E+00	0.000E+00	0.000E+00	2.433E-01
		-1.487E+02	-1.078E-03	0.000E+00	0.000E+00	0.000E+00	-2.433E-01
2	1	1.487E+02	1.078E-03	0.000E+00	0.000E+00	0.000E+00	2.433E-01
		-1.487E+02	-1.078E-03	0.000E+00	0.000E+00	0.000E+00	-2.433E-01
3	1	8.726E+01	1.066E-03	0.000E+00	0.000E+00	0.000E+00	4.452E-01
		-8.726E+01	-1.066E-03	0.000E+00	0.000E+00	0.000E+00	-4.452E-01
4	1	8.726E+01	1.066E-03	0.000E+00	0.000E+00	0.000E+00	4.452E-01
		-8.726E+01	-1.066E-03	0.000E+00	0.000E+00	0.000E+00	-4.452E-01
5	1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	1	1.485E+02	-7.813E-04	0.000E+00	0.000E+00	0.000E+00	1.569E-01
		-1.485E+02	7.813E-04	0.000E+00	0.000E+00	0.000E+00	-1.569E-01
7	1	1.485E+02	-7.813E-04	0.000E+00	0.000E+00	0.000E+00	1.569E-01
		-1.485E+02	7.813E-04	0.000E+00	0.000E+00	0.000E+00	-1.569E-01
8	1	8.716E+01	-7.726E-04	0.000E+00	0.000E+00	0.000E+00	2.872E-01
		-8.716E+01	7.726E-04	0.000E+00	0.000E+00	0.000E+00	-2.872E-01
9	1	8.716E+01	-7.726E-04	0.000E+00	0.000E+00	0.000E+00	2.872E-01
		-8.716E+01	7.726E-04	0.000E+00	0.000E+00	0.000E+00	-2.872E-01
10	1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

1dynamic load input control data.....

time increment dt (sec) = .020

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0         1         2         3         4         5         6         7         8         9         10        11
```

```
0        1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
```

total number of time steps = 800

output interval = 2

number of time functions = 1

step-by-step dynamic analysis control data.....

integration indicator = 0

damping factor alpha = 5.869E-01

damping factor beta = 4.260E-03

lsubdivision of time increment control data .....

number of subdivision = 5

relative tolerance of subdivision = .5000000E-01

lequilibrium iteration control data .....

maximum number of iteration = 10

type of iteration = 1

relative tolerance to use iteration = .1000000E-01

relative tolerance for convergence = .5000000E-02

lground motion input key.....

	direction x	y	z
function number...	1	0	0
scale factor.....	1.434	.000	.000

ltime history no. 1..... 940 peri Val y Eq El ntro 00E c: E = 0 79g

number of data point = 2689

scaling factor = 135.0000

time increment of data (sec)= .020000

zero correction = .0000

1	.000	-.551	-4.252	-3.976	-3.465	-3.740	-4.724	-5.590
2	-5.039	-4.331	-3.347	-3.347	-5.158	-6.929	-7.638	-6.378
3	-5.669	-4.252	-3.228	-1.653	-2.598	-5.158	-7.480	-7.717
4	-2.598	1.181	5.551	-1.929	-5.039	-5.669	-7.992	-10.236
5	-12.795	-12.047	-6.772	-7.756	-6.417	-6.457	-2.638	.984
6	5.906	9.291	9.921	13.228	18.228	19.370	16.496	14.134
7	10.669	9.252	13.347	16.221	20.866	25.158	28.819	25.669
8	23.583	15.748	15.748	2.480	-20.276	-30.984	-23.740	-19.055
9	-9.843	-2.323	5.276	12.126	19.646	27.953	39.173	47.992
10	60.197	57.047	45.472	36.811	35.118	36.457	33.032	35.472
11	39.095	47.598	12.913	-58.071	-81.339	-78.307	-80.079	-71.496
12	-67.913	-68.976	-69.016	-71.063	-64.173	-53.032	-42.795	-30.787
13	-16.890	-.669	14.173	30.906	45.827	62.913	77.165	94.961
14	107.441	119.528	125.984	134.527	111.063	91.496	-47.165	-93.425
15	-64.567	-73.425	-43.110	-29.646	-6.811	4.449	20.984	35.236
16	46.693	69.173	22.677	-103.583	-60.906	-68.071	-39.843	-22.795
17	9.331	-26.378	-77.953	-64.606	-66.339	-58.307	-48.465	-39.409
18	-29.567	-20.591	-10.669	-1.732	7.402	-3.740	-17.047	-32.992
19	-37.441	-28.189	-23.583	-13.150	-4.252	7.284	16.535	26.496
20	-3.819	-14.646	-1.575	.433	13.543	22.244	34.764	44.488
21	53.661	8.622	9.488	26.890	27.126	51.890	53.268	80.315
22	-36.654	-51.496	-27.244	-21.496	2.835	26.575	-42.008	-58.583
23	-42.165	-45.748	-30.000	-22.008	-8.465	-4.961	-26.535	-12.756
24	-13.268	-4.291	.669	11.772	19.213	23.937	8.740	-1.260
25	-9.646	3.032	8.307	22.362	32.520	47.480	58.189	68.386
26	16.575	1.142	10.197	11.535	-2.165	-5.787	5.630	8.110
27	19.646	25.394	37.677	44.409	56.969	64.134	76.575	73.071
28	78.110	69.646	49.213	-47.520	-21.339	-15.118	-12.244	-44.016
29	-65.394	-97.008	-79.724	-72.244	-51.850	-37.795	-12.795	6.063
30	32.126	51.929	71.575	-2.284	-6.654	11.221	17.598	38.701
31	56.063	72.953	96.693	66.339	-54.331	-39.331	-42.874	-35.709
32	-18.465	-49.213	-83.110	-63.661	-66.614	-51.417	-43.740	-30.433
33	-20.079	-21.417	-47.244	-47.598	-45.591	-45.079	-28.228	-21.496
34	2.520	-31.654	-64.331	-33.819	-37.835	-15.591	-5.787	12.559
35	25.512	34.488	18.583	7.795	-1.063	11.496	17.520	30.906
36	40.669	53.228	63.228	73.268	50.433	25.197	8.032	12.362
37	14.685	19.528	9.252	-3.307	-6.614	-4.449	-9.016	-9.764
38	-6.181	-2.716	5.787	14.921	22.795	10.039	-1.614	-16.850
39	-5.236	3.740	9.055	-5.079	-1.969	3.150	6.268	14.961
40	20.079	6.181	-1.260	-4.370	.197	2.992	1.378	-3.740
41	-1.417	-.630	1.496	3.347	-2.205	-11.969	-16.575	-9.606
42	-9.291	-6.969	-5.079	-.709	7.992	-4.252	-3.583	-1.339

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0        1         2         3         4         5         6         7         8         9         10        11
```

43	-4.173	-4.370	-3.898	-.079	2.874	9.252	13.976	27.756
44	30.669	7.244	-10.354	-4.882	-1.653	6.260	1.890	-8.622
45	-18.386	-16.850	-8.504	-1.693	6.260	12.598	16.496	4.843
46	-6.299	-8.032	-3.228	-8.110	-5.394	-2.165	2.087	5.276
47	10.472	9.134	3.110	-.315	7.874	17.126	19.370	7.520
48	3.622	-.866	-.827	2.047	3.661	10.039	14.488	20.669
49	21.299	16.732	15.669	22.008	29.764	14.370	16.181	3.858
50	-8.032	-9.803	-15.945	-16.260	-18.543	-17.047	-18.032	-2.244
51	7.008	-8.189	-19.370	-20.866	-14.252	-15.945	-12.126	-12.441
52	-10.433	-10.433	-10.591	-13.583	-12.165	-8.543	-3.071	3.425
53	11.063	12.205	14.095	13.425	14.095	11.299	12.008	4.410
54	8.425	5.354	15.118	-33.898	-53.110	-52.835	-53.307	-46.969
55	-41.024	-32.638	-25.630	-17.480	-10.158	-2.362	-3.583	-7.165
56	-5.787	3.347	6.417	1.969	10.394	22.913	34.134	47.244
57	66.732	43.740	-43.307	-14.409	-17.520	-9.291	-37.795	-25.827
58	-23.504	-26.378	-21.732	-1.063	14.882	42.205	65.709	37.283
59	16.063	26.260	5.197	-3.740	-20.472	-32.559	-45.354	-45.276
60	-31.614	-14.528	1.142	21.457	46.378	63.386	-10.630	1.339
61	-2.205	.787	5.748	21.142	31.417	-8.071	-23.228	-6.654
62	-6.890	-1.102	2.913	15.039	22.323	29.646	31.535	23.307
63	11.969	.905	2.520	-15.984	-17.756	-3.110	6.614	22.323
64	3.661	-2.165	1.732	-4.843	-11.102	-17.205	-13.858	-10.039
65	-4.370	8.071	20.433	33.622	45.039	28.858	9.331	-14.488
66	-10.669	-8.543	-34.370	-38.307	-23.189	-13.228	3.032	10.197
67	20.000	14.213	3.189	-2.205	-8.228	-12.480	-9.370	-14.803
68	-21.654	-28.425	-31.614	-20.591	-13.386	-.433	2.559	-1.457
69	-.197	-6.614	-16.142	-3.150	3.110	14.724	24.213	26.181
70	10.000	-2.244	-18.661	-14.016	-9.567	-1.890	4.961	14.921
71	9.488	-8.937	-16.850	-26.732	-26.024	-23.228	-20.197	-16.063
72	-12.165	-10.472	-21.299	-24.724	-35.748	-43.583	-34.685	-30.315
73	-22.913	-18.622	-13.110	-7.835	.787	8.307	17.008	24.134
74	30.197	36.732	41.969	44.488	46.732	49.095	52.520	62.756
75	70.748	80.197	48.661	17.402	-5.512	-26.221	-21.850	-27.283
76	-38.740	-49.055	-46.417	-41.339	-36.221	-29.252	-31.850	-33.465
77	-33.858	-33.976	-34.370	-34.173	-34.843	-21.142	2.047	8.465
78	9.646	22.835	12.362	9.291	19.095	23.189	20.669	13.976
79	7.756	7.835	19.370	13.504	11.339	17.008	9.410	3.465
80	3.032	-5.827	-3.032	-.748	2.953	1.732	-5.709	-12.441
81	-9.488	-1.102	7.165	16.772	17.284	20.158	18.347	18.858
82	7.598	8.740	10.787	15.472	19.843	22.717	23.150	32.362
83	31.378	37.362	13.583	1.772	-4.843	-13.661	-16.772	-16.378
84	-10.827	-10.630	2.913	16.850	-9.095	-15.236	-3.268	5.472
85	17.520	1.063	-27.441	-31.339	-9.882	-5.315	3.110	-4.527
86	-9.882	-13.110	-10.591	-11.850	-7.874	-2.638	-1.496	4.134
87	11.654	13.543	37.677	35.354	7.047	-14.252	-39.134	-31.772
88	-29.291	-21.221	-12.992	-5.039	1.221	5.827	20.000	-.866
89	-19.252	-14.095	-27.205	-20.315	-14.606	3.465	24.882	33.110
90	50.236	54.646	46.969	29.567	8.858	-3.465	-8.937	2.913
91	7.126	21.417	15.709	1.772	-3.228	-7.284	-.787	.236
92	-4.606	-8.268	-11.929	-20.158	-28.622	-22.795	-10.472	-7.008
93	1.575	3.858	5.394	8.701	17.205	3.583	-21.575	-21.850
94	-9.567	-3.189	9.843	16.142	7.165	-1.063	-9.567	-.590
95	9.724	18.976	30.827	24.488	13.032	-.551	-7.677	-9.724
96	-8.347	-4.331	1.969	9.488	-1.339	-8.504	-18.543	-14.291
97	-7.677	-.709	6.693	-3.150	.197	9.055	14.724	23.661
98	20.315	17.008	13.543	19.882	25.709	26.890	6.772	-6.693
99	-20.748	-26.142	-15.236	-8.740	-1.299	4.685	-5.039	-13.819
100	-20.236	-13.189	-8.583	-.473	5.590	2.756	-2.480	-4.724
101	-12.677	-13.622	-3.583	2.874	12.165	18.583	23.740	22.677
102	12.992	-2.874	-30.591	-23.937	-17.244	-8.228	1.221	13.780
103	11.535	4.764	13.307	12.480	10.000	8.110	7.795	6.850
104	.827	-5.669	-13.504	-13.347	-5.709	-1.102	6.693	-3.780
105	-10.039	-10.984	-15.276	-9.528	-8.465	-7.165	-6.850	-1.496
106	-1.063	-7.284	-4.843	3.425	13.504	27.362	35.827	33.583
107	29.921	20.197	7.323	.590	-7.480	-5.945	-2.874	.827
108	5.079	8.465	.945	-4.882	-12.953	-20.433	-27.874	-22.795
109	-18.189	-12.087	-5.709	-.354	-7.087	-12.520	-18.307	-15.394
110	-13.583	-12.441	-17.126	-19.331	-18.701	-16.535	-14.213	-10.906
111	-10.158	-5.472	-2.677	19.961	28.425	34.567	30.787	30.118
112	17.284	3.150	.512	-4.961	-.590	1.181	4.095	4.095
113	7.598	8.071	2.913	-2.205	-2.835	2.756	4.173	5.787
114	-.354	-6.260	-7.362	-.276	6.102	4.134	-4.527	-11.890
115	-12.165	-3.740	-2.284	.158	.787	1.969	2.244	3.819
116	5.276	6.969	8.583	10.276	11.890	13.622	15.197	18.661
117	15.472	9.370	4.527	-3.110	-4.882	2.126	1.063	-9.843
118	-22.284	-24.803	-23.268	-16.260	-2.677	10.709	10.906	-.827
119	-2.362	-4.331	-8.701	-16.378	-20.433	-8.740	1.181	3.110
120	5.472	6.732	9.961	12.717	15.394	6.457	-5.354	-12.717
121	-11.457	-11.299	-11.969	-13.347	-9.646	-2.992	4.921	14.803
122	15.827	9.646	6.142	-1.575	-6.024	-11.378	-12.441	-4.370
123	3.701	13.189	22.677	16.693	5.630	-.276	-5.315	-10.630
124	-13.425	-14.055	-15.591	-15.827	-19.213	-18.898	-15.984	-16.024
125	-13.819	-7.362	-2.244	1.732	-.748	-2.835	-6.654	-4.527
126	4.961	14.095	25.748	28.189	30.000	29.095	24.724	19.055
127	10.394	-1.732	-11.339	-15.118	-19.370	-16.850	-16.378	-10.866
128	-2.047	9.331	16.772	23.780	17.795	11.181	4.961	-2.126
129	-10.827	-16.654	-6.890	.039	10.000	18.937	25.236	21.811
130	16.260	7.244	-1.890	-11.929	-20.906	-27.874	-36.535	-33.976
131	-24.843	-14.803	3.425	12.165	23.189	24.173	15.158	13.819
132	12.244	9.685	.748	-7.795	-6.221	-.590	3.898	11.260
133	16.063	22.165	20.906	12.362	6.496	-.945	-7.441	-10.866
134	-14.606	-17.717	-21.024	-19.016	-14.921	-11.654	-7.717	-7.244
135	-6.260	-4.685	-2.087	.079	2.323	-.905	-4.410	-8.071
136	-12.677	-15.276	-13.425	-11.299	-12.913	-16.024	-19.173	-22.165
137	-25.354	-21.850	-17.559	-.315	9.961	16.181	25.354	22.795
138	18.661	15.118	15.158	13.386	14.055	.315	-10.000	-18.110
139	-18.543	-8.740	-2.559	6.457	13.976	19.843	14.606	11.024
140	6.221	1.614	-1.063	.827	1.732	3.898	5.315	3.701

141	2.284	.866	-1.221	-1.221	.158	-.984	-4.882	-9.252
142	-15.984	-20.866	-27.598	-12.717	-2.047	3.701	12.913	18.819
143	20.039	14.095	13.465	12.047	11.221	10.354	6.614	-.197
144	-8.347	-14.370	-12.205	-11.693	-11.024	-9.331	-10.472	-12.126
145	-14.409	-14.055	-12.126	-7.598	.748	7.717	6.299	5.079
146	5.512	4.331	4.252	3.622	3.504	.748	-5.158	-9.724
147	-17.165	-17.008	-11.811	-7.559	-1.890	3.819	6.614	5.827
148	6.811	3.071	-2.284	-8.465	-9.213	2.362	10.315	10.591
149	3.307	-1.614	-8.937	-2.992	1.221	7.165	12.205	18.858
150	18.071	6.535	-2.284	-15.591	-17.480	-9.488	-3.976	8.543
151	10.276	4.764	.315	-6.614	-15.039	-22.284	-30.748	-24.370
152	-10.079	1.732	17.953	30.827	43.425	37.520	19.252	4.803
153	-15.236	-33.307	-48.268	-34.016	-24.252	-8.976	5.906	18.780
154	12.717	9.764	3.740	8.937	13.307	19.882	23.386	20.433
155	21.732	23.425	24.291	23.346	18.347	6.221	-3.032	-9.055
156	-11.929	-12.953	-14.331	-19.291	-25.984	-28.465	-30.866	-33.307
157	-22.284	-8.228	5.039	15.000	19.213	14.291	9.843	6.221
158	14.843	23.386	24.803	14.567	8.543	1.575	.905	-2.441
159	-11.260	-14.961	-17.992	-19.882	-30.591	-24.724	-7.441	2.441
160	20.039	29.291	29.488	22.126	17.913	20.669	25.000	28.780
161	33.504	36.496	38.386	36.575	32.047	10.394	-11.378	-35.472
162	-53.701	-33.819	-18.425	3.189	23.386	32.402	21.890	11.850
163	-.433	-14.961	-13.661	-.787	7.087	24.921	39.882	44.173
164	43.583	37.008	31.693	23.937	20.000	8.110	-7.913	-22.520
165	-40.197	-52.441	-48.228	-47.520	-39.606	-30.000	-21.575	-19.252
166	-15.945	-11.457	-6.929	-5.551	-3.858	-1.969	.748	3.150
167	1.378	-1.142	-2.402	-1.339	-.512	2.992	8.071	12.874
168	17.717	22.717	22.126	18.268	11.811	4.213	-.158	-1.299
169	-2.716	-3.976	-7.913	-7.402	.984	5.276	9.567	10.472
170	10.433	6.102	-.748	-3.740	-8.504	-6.575	-4.724	-2.520
171	-5.079	-6.417	-7.598	-9.528	-9.291	-6.890	-4.882	-7.284
172	-10.433	-12.717	-13.228	-17.874	-16.929	-13.150	-8.386	-2.716
173	1.181	.118	-3.661	-3.504	-5.906	-6.457	-9.370	-12.717
174	-16.575	-17.992	-15.630	-13.740	-10.158	-6.772	-.787	6.142
175	11.181	14.252	13.937	10.591	3.976	-1.772	-4.921	-9.646
176	-9.016	-4.961	-2.677	.709	3.661	7.874	11.260	14.370
177	12.244	7.126	.945	-6.142	-12.559	-8.622	-4.646	.590
178	6.024	11.732	9.567	5.354	4.016	.945	-.394	-.905
179	-1.417	-1.890	-3.504	-6.102	-5.827	-2.992	.000	-.787
180	-5.827	-8.858	-14.724	-14.370	-9.882	-6.457	-.551	6.024
181	11.890	15.472	15.984	15.158	12.953	7.205	4.921	2.756
182	-.039	-2.677	-5.118	-5.039	-4.527	-4.016	-3.307	-5.551
183	-8.071	-10.591	-13.780	-14.134	-11.693	-8.937	.709	3.898
184	7.992	10.079	7.835	6.299	4.213	6.142	7.795	9.528
185	5.551	2.165	-2.598	-3.819	-1.024	.630	3.937	3.701
186	1.535	.000	-2.598	-3.898	-4.291	-4.527	-5.158	-6.614
187	-7.835	-4.095	-.394	2.165	5.079	7.874	7.835	6.654
188	5.630	4.291	5.039	5.984	5.394	4.606	3.819	2.362
189	-1.102	-1.969	-3.307	-7.008	-12.638	-16.535	-20.394	-18.583
190	-15.512	-11.417	-4.331	1.969	5.197	6.181	6.969	7.677
191	10.039	13.032	12.913	9.921	6.811	1.772	-3.347	-7.480
192	-9.016	-11.969	-10.906	-8.937	-6.850	-4.764	-4.961	-5.079
193	-3.150	-1.024	1.535	2.559	2.165	1.969	2.520	4.961
194	7.047	9.567	12.087	11.732	9.882	8.504	6.417	7.559
195	9.213	11.102	11.850	7.717	4.173	-1.535	-6.417	-12.677
196	-13.189	-8.622	-5.827	-.394	.433	-2.087	-3.976	-4.961
197	-5.630	-5.079	-4.095	-2.795	-.709	1.299	3.347	6.221
198	9.410	12.559	13.425	12.520	8.386	2.874	.354	-.590
199	-1.850	-2.953	-4.764	-6.142	-4.567	-2.205	-.236	-.118
200	-.118	.551	1.811	2.835	3.386	3.858	4.882	5.787
201	6.772	7.874	10.079	12.480	11.299	9.095	4.134	-.039
202	-.433	-1.417	-2.087	-3.268	-2.047	-.276	1.457	3.780
203	6.102	8.071	5.630	2.874	.827	-.866	-2.756	-3.937
204	-2.953	-2.126	-1.142	-.590	.000	-.039	-.236	-.433
205	-.394	-.118	.039	.630	2.087	3.386	4.961	6.063
206	5.158	4.016	2.205	.236	-1.575	-3.858	-3.780	-1.811
207	-.276	1.221	1.772	2.677	2.047	1.772	.709	-.079
208	-1.142	-1.102	-.669	-.236	-.197	-.669	-.866	-1.417
209	-1.260	-.276	.551	1.614	2.559	2.480	2.047	.236
210	-1.772	-2.992	-2.520	-2.559	-4.213	-6.339	-6.850	-4.606
211	-2.756	-1.417	-.984	-.079	.158	1.417	3.228	4.527
212	2.756	1.496	-.394	-.984	-1.339	-1.614	-1.772	-2.559
213	-4.724	-4.606	-4.252	-3.858	-3.189	-2.992	-4.331	-5.433
214	-6.535	-5.669	-5.118	-4.370	-4.252	-3.858	-3.858	-2.480
215	-.079	2.126	4.331	5.984	7.756	6.693	5.512	4.055
216	2.520	.394	-2.638	-4.134	-4.803	-5.433	-6.535	-8.465
217	-10.591	-10.787	-8.543	-7.008	-4.567	-2.402	.000	2.126
218	3.898	5.669	7.362	9.134	10.315	10.039	8.937	6.732
219	5.000	2.126	-1.850	-5.866	-8.268	-10.000	-9.921	-9.646
220	-8.898	-7.047	-5.354	-3.228	-.551	1.732	3.504	3.819
221	3.937	3.937	4.095	5.354	4.764	3.937	2.835	.748
222	-1.102	-3.268	-5.158	-7.480	-7.638	-5.472	-3.937	-1.732
223	-1.732	-1.575	-1.772	-1.929	-1.535	-.827	-.866	-.630
224	-.630	-.473	-.473	1.102	2.677	4.527	3.780	2.205
225	.669	-1.221	-3.071	-3.622	-3.622	-3.740	-3.622	-3.386
226	-2.047	-.866	.551	1.496	1.339	1.339	1.142	1.575
227	2.126	2.638	3.347	3.425	3.032	2.756	2.402	2.953
228	3.425	4.016	4.370	3.543	2.953	2.087	2.441	3.110
229	3.819	4.646	5.315	4.134	3.032	1.732	.473	-.827
230	-1.653	-2.677	-3.425	-4.724	-6.260	-7.795	-9.173	-10.158
231	-10.630	-10.945	-11.299	-10.945	-10.630	-10.158	-9.882	-8.622
232	-6.811	-5.079	-4.291	-4.134	-3.740	-3.583	-2.835	-2.323
233	-1.575	-.905	.709	1.378	1.653	1.890	1.693	1.693
234	1.496	1.417	1.260	1.850	2.480	3.347	4.331	5.276
235	6.299	7.126	6.811	6.614	6.260	5.787	4.252	2.677
236	1.260	.354	.748	1.102	1.575	2.126	2.716	3.740
237	4.606	5.630	5.630	4.921	4.803	4.882	4.961	5.118
238	5.236	4.173	3.110	1.811	.787	.197	-.433	-.984

239	-.433	.709	1.693	2.992	4.055	5.236	3.976	2.441
240	.709	-1.063	-3.150	-3.504	-2.126	-1.181	.236	.473
241	.866	1.063	1.260	1.890	2.716	3.504	4.410	5.236
242	5.512	5.394	5.512	5.315	5.472	4.016	1.181	-1.260
243	-2.480	-3.347	-4.410	-6.181	-7.756	-7.402	-7.165	-6.693
244	-6.142	-5.590	-5.079	-4.921	-4.724	-4.567	-4.488	-4.173
245	-2.520	-.827	.079	-.158	-.158	-.551	-.748	-.315
246	.433	1.063	1.969	2.087	1.653	1.181	.433	-.197
247	-.945	-.787	-.276	.158	.748	1.299	1.890	2.244
248	2.559	2.913	3.189	3.583	5.000	6.654	5.669	4.134
249	2.756	1.378	.079	-1.260	-2.520	-3.740	-3.583	-3.268
250	-2.874	-2.008	-1.181	-.158	1.299	2.047	1.732	1.575
251	1.181	.787	.394	.039	-.394	-.551	.079	.630
252	1.181	.905	.630	.630	1.024	1.260	1.772	1.811
253	.827	-.118	-1.181	-2.362	-3.425	-4.567	-4.213	-3.701
254	-3.071	-2.677	-2.480	-2.244	-1.969	-1.614	-1.299	-.945
255	-.551	-.197	.158	.512	.827	.039	-.709	-1.575
256	-2.520	-3.425	-4.331	-5.079	-5.945	-6.496	-6.850	-7.244
257	-7.638	-7.953	-8.386	-7.795	-6.811	-5.315	-2.559	-.551
258	.787	2.165	3.228	3.504	4.016	3.661	3.150	2.402
259	1.299	.118	-.945	-2.244	-1.772	-.512	.512	1.299
260	1.890	2.126	2.284	2.441	2.559	2.716	2.835	2.953
261	3.032	2.874	2.716	2.520	2.284	2.126	1.890	2.402
262	3.110	3.780	4.488	4.961	5.472	5.158	4.843	4.488
263	4.055	3.425	2.835	2.205	1.575	.945	.276	.158
264	.315	.354	.905	1.653	2.047	2.402	2.835	3.110
265	3.504	3.740	3.740	3.661	3.504	.984	.000	-.197
266	-.787	-.945	-1.299	-1.890	-2.520	-3.150	-3.819	-4.488
267	-5.039	-4.173	-3.504	-2.598	-1.693	-.748	-.433	-.354
268	-.197	-.158	.197	.551	.945	1.378	1.693	1.732
269	1.535	.512	-.315	-1.417	-1.850	-2.165	-2.441	-2.677
270	-2.874	-3.150	-2.953	-2.520	-1.102	.197	1.811	2.559
271	2.362	2.362	2.126	1.929	1.732	1.535	1.142	.000
272	-1.024	-2.047	-1.653	-1.457	-.984	-.590	-.079	.079
273	.000	-.039	-.158	-.276	-.236	-.039	.118	.276
274	-.039	-.276	-.590	-.945	-1.142	-1.102	-1.102	-.984
275	-.945	-.827	-1.063	-1.732	-2.284	-2.992	-3.307	-3.228
276	-3.268	-2.953	-1.969	-1.102	-.079	.709	.709	.827
277	.827	.827	1.221	1.693	1.929	1.929	1.929	1.890
278	1.850	2.047	2.638	3.110	3.740	3.819	3.780	3.780
279	3.661	3.583	3.504	3.425	3.307	3.228	3.150	3.032
280	2.441	1.850	1.378	1.417	1.339	1.378	1.417	1.260
281	.748	.590	.551	.473	.473	.433	.000	-.394
282	-.787	-.984	-1.142	-1.299	-1.457	-1.890	-2.480	-3.032
283	-3.622	-4.213	-4.803	-5.433	-5.630	-4.724	-4.055	-3.071
284	-2.638	-2.480	-2.284	-2.205	-2.087	-1.969	-1.890	-1.772
285	-1.653	-1.535	-1.221	-1.024	-.433	.394	1.221	1.811
286	1.890	2.126	2.165	2.480	3.307	3.976	3.307	2.795
287	2.087	1.299	1.102	1.142	1.102	1.063	.473	-.039
288	-.394	-.433	-.630	-.590	-1.221	-2.677	-3.898	-4.016
289	-4.134	-4.173	-3.898	-3.504	-3.110	-2.913	-2.835	-2.677
290	-2.638	-2.480	-1.575	-.512	.512	1.693	2.795	3.898
291	3.386	2.480	1.614	.512	-.551	-1.378	-1.457	-1.732
292	-1.811	-1.929	-2.008	-2.126	-2.205	-2.284	-1.811	-1.142
293	-.512	.276	.669	.748	.984	.984	1.378	1.969
294	2.520	3.150	3.701	3.819	4.016	4.134	4.252	4.331
295	4.095	3.898	3.661	3.386	3.110	2.835	2.480	2.165
296	1.811	1.496	1.221	1.063	.827	.669	.473	.276
297	.118	.315	.512	.748	.866	.354	-.118	-.669
298	-1.221	-1.850	-2.087	-1.890	-1.693	-1.496	-.984	-.354
299	.276	.669	.866	1.378	2.402	3.268	4.410	4.213
300	3.425	2.795	1.850	1.063	.158	-.630	-.945	-1.299
301	-1.811	-2.716	-3.307	-3.465	-3.661	-3.740	-3.819	-3.898
302	-3.976	-4.016	-3.858	-3.740	-3.543	-3.425	-3.504	-3.583
303	-3.661	-3.780	-3.819	-3.465	-3.189	-2.795	-2.677	-2.677
304	-2.638	-2.638	-2.598	-2.598	-2.520	-2.205	-1.969	-1.693
305	-1.339	-.905	-.512	-.079	.394	.669	.354	.118
306	-.197	-.551	-.276	.236	.630	.512	.473	.315
307	.197	.000	.079	.354	.551	.827	.866	.394
308	.000	-.473	-.945	-.945	-.748	-.630	-.709	-.866
309	-1.063	-1.181	-1.024	-.866	-.866	-1.260	-1.614	-2.008
310	-1.811	-1.693	-1.496	-1.260	-1.024	-.787	-.748	-.709
311	-.590	.512	1.614	2.638	2.756	2.992	3.071	3.150
312	3.189	3.307	3.071	2.402	1.890	1.221	1.142	1.181
313	1.260	1.378	1.457	.945	.276	-.315	-1.102	-1.378
314	-.866	-.512	.039	.118	.039	-.039	-.197	-.315
315	-.433	-.590	-.473	-.315	-.158	.039	.197	.315
316	.315	.354	.394	.866	1.299	1.811	2.323	2.835
317	3.110	2.441	1.969	1.260	.630	-.158	.000	1.181
318	2.047	3.425	3.228	1.221	-.079	-2.441	-1.102	2.284
319	5.118	8.701	7.284	3.701	3.583	3.032	3.543	.630
320	-3.307	-7.874	-5.827	-.276	4.213	3.898	1.890	.118
321	-2.716	-4.213	-.590	2.716	5.433	2.638	.787	1.378
322	3.543	3.386	2.047	.945	.630	.512	-.433	-1.339
323	-2.638	-2.126	-.787	.551	1.890	3.819	2.284	-1.890
324	-4.685	-3.740	-2.362	-.945	1.260	1.496	.551	-.039
325	-.276	.236	.394	.945	.512	.158	-.315	-1.063
326	-2.165	-3.307	-3.661	-2.402	-1.417	-.079	1.299	1.457
327	-.551	-1.772	-4.055	-3.032	-.905	1.221	1.614	1.024
328	.512	.590	2.402	2.874	2.913	2.992	2.874	2.795
329	2.244	1.496	.827	-.079	-1.299	-2.520	-2.677	-2.008
330	-2.126	-2.126	-2.244	-1.299	.000	1.299	2.756	3.780
331	3.347	3.150	2.677	2.953	3.032	3.347	2.402	1.457
332	.276	-.039	.158	.197	-.394	-1.142	-1.811	-2.716
333	-2.559	-1.732	-1.102	-.276	-.905	-1.299	-2.008	-2.362
334	-2.205	-2.126	-1.969	-2.598	-3.583	-4.488	-5.512	-5.433
335	-5.512	-4.764	-3.780	-2.913	-1.811	-1.339	-1.653	-1.772
336	-2.165	-2.480	-2.835	-3.150	-2.874	-2.047	-1.457	-1.024

```
0        1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
```

```
     337          -.551
 last =       3383
1displacement  components  for which
 output time history is required....

 node     displacement components

    7        1   5   0   0   0   0
   13        1   5   0   0   0   0

 output type.... 1
 plot spacing... 0
1element stress components for which
 output time history is required....

  element       desired stress components
 type  no.

   2   3        7  8 12  0  0  0  0  0  0  0  0  0

 output type.... 1
 plot spacing... 0
1time history for selected acceleration components.....  1                                   file no.  1
```

	node numbers and acceleration components			
time	7- 1	7- 5	13- 1	13- 5
.040	2.815E-02	1.826E-03	7.762E-01	3.937E-05
.080	-5.811E+00	1.072E-02	-9.033E-01	1.470E-03
.120	-4.764E+00	7.421E-03	-1.234E+00	2.759E-03
.160	-6.529E+00	9.966E-03	-1.998E+00	2.102E-03
.200	-7.132E+00	1.234E-03	-6.256E+00	1.194E-03
.240	-4.907E+00	-4.679E-03	-6.924E+00	-4.722E-04
.280	-7.383E+00	2.467E-03	-6.462E+00	-9.571E-04
.320	-1.102E+01	-5.105E-03	-1.289E+01	-5.370E-05
.360	-8.470E+00	-1.492E-02	-1.462E+01	-1.284E-04
.400	-5.194E+00	-2.358E-02	-1.534E+01	-3.870E-03
.440	-4.085E+00	-8.789E-03	-8.295E+00	-5.405E-03
.480	-1.079E+01	-1.532E-04	-1.083E+01	-1.582E-03
.520	-4.304E+00	-2.403E-02	-1.470E+01	-1.205E-04
.560	7.491E+00	-3.654E-03	4.273E+00	-5.089E-03
.600	-7.034E+00	1.182E-02	-2.510E+00	-2.905E-03
.640	-1.086E+01	2.829E-02	1.611E+00	5.113E-03
.680	-1.753E+01	3.183E-02	-2.686E+00	9.842E-03
.720	-9.300E+00	1.736E-02	-1.371E+00	6.605E-03
.760	-8.951E+00	9.535E-03	-4.823E+00	8.590E-04
.800	-4.119E+00	-1.814E-02	-1.197E+01	-2.044E-03
.840	7.442E+00	-4.325E-02	-1.182E+01	-6.262E-03
.880	1.299E+01	-4.860E-02	-9.173E+00	-1.094E-02
.920	2.466E+01	-5.390E-02	-3.329E-01	-1.231E-02
.960	2.289E+01	-1.843E-02	1.318E+01	-9.671E-03
1.000	1.540E+01	1.192E-02	2.000E+01	-4.583E-04
1.040	1.922E+01	4.508E-03	2.170E+01	5.155E-03
1.080	2.982E+01	-7.586E-03	2.732E+01	2.357E-03
1.120	4.157E+01	1.808E-02	4.778E+01	-3.046E-03
1.160	3.506E+01	6.185E-02	6.018E+01	3.920E-03
1.200	2.490E+01	1.130E-01	7.173E+01	1.379E-02
1.240	-2.438E+01	1.902E-01	6.006E+01	3.209E-02
1.280	-3.057E+01	1.171E-01	2.328E+01	4.105E-02
1.320	-1.297E+01	2.116E-02	-2.391E+00	1.982E-02
1.360	6.618E+00	-5.708E-02	-2.059E+01	-1.150E-02
1.400	2.523E+01	-1.343E-01	-3.733E+01	-3.024E-02
1.440	5.123E+01	-2.055E-01	-4.273E+01	-3.913E-02
1.480	8.069E+01	-2.037E-01	-1.586E+01	-4.876E-02
1.520	6.193E+01	-9.763E-02	1.175E+01	-4.095E-02
1.560	4.861E+01	-5.145E-02	2.201E+01	-1.459E-02
1.600	4.703E+01	2.344E-03	4.698E+01	3.919E-03
1.640	5.640E+01	2.027E-02	6.457E+01	5.699E-03
1.680	2.597E+01	3.948E-01	1.933E+02	2.301E-02
1.720	-1.056E+02	4.121E-01	8.363E+01	8.550E-02
1.760	-1.058E+02	3.144E-01	4.173E+01	1.095E-01
1.800	-9.100E+01	2.215E-01	9.852E+00	6.545E-02
1.840	-9.527E+01	1.064E-01	-4.867E+01	1.504E-02
1.880	-9.263E+01	-8.678E-02	-1.300E+02	-5.293E-03
1.920	-8.486E+01	-1.036E+00	-1.725E+02	-4.865E-02
1.960	-3.424E+01	-4.107E-01	-1.856E+02	-1.338E-01
2.000	1.174E+01	-4.206E-01	-1.801E+02	-1.133E-01
2.040	5.722E+01	-3.297E-01	-1.562E+02	-3.860E-02
2.080	9.502E+01	-7.197E-01	-1.075E+02	-1.826E-02
2.120	1.393E+02	-6.446E-01	-3.614E+01	-9.842E-02
2.160	1.698E+02	-5.003E-01	5.693E+01	-1.098E-01
2.200	1.667E+02	-1.581E-01	1.877E+02	-8.764E-04
2.240	-6.083E+01	-1.235E-01	2.496E+02	2.778E-01
2.280	-9.500E+01	-5.190E-01	1.923E+02	2.123E-01
2.320	-5.691E+01	3.362E-01	1.367E+02	-3.097E-02
2.360	-9.789E+00	1.475E-01	1.134E+02	-7.141E-02
2.400	3.209E+01	1.655E-01	8.940E+01	1.243E-03
2.440	6.474E+01	-5.337E-02	3.497E+01	5.214E-02
2.480	3.811E+01	4.764E-01	2.192E+02	2.853E-02
2.520	-8.332E+01	2.153E-01	-1.871E+00	3.801E-02
2.560	-5.931E+01	-4.716E-02	-9.157E+01	3.190E-02
2.600	7.741E+00	-9.938E-02	-6.014E+01	-3.758E-02
2.640	-1.264E+02	-3.515E-01	-1.574E+02	-9.513E-02
2.680	-1.010E+02	-2.099E-01	-1.624E+02	-8.736E-02
2.720	-6.911E+01	1.258E-01	-1.666E+02	-2.509E-02
2.760	-5.428E+01	-9.383E-01	-1.606E+02	8.510E-03
2.800	-2.488E+01	-1.137E+00	-1.411E+02	-2.210E-02
2.840	-1.110E+00	-1.227E+00	-9.309E+01	-3.878E-02
2.880	-3.356E+01	-1.064E+00	-5.558E+01	-4.190E-02

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12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
0        1         2         3         4         5         6         7         8         9         10        11
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0 1 2 3 4 5 6 7 8 9 10 11					
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234					
2.920	-6.078E+01	-1.025E+00	-6.035E+01	-7.541E-03	
2.960	-4.040E+01	-1.007E+00	-2.953E+01	8.799E-03	
3.000	-1.247E+01	-9.949E-01	1.689E+00	1.324E-03	
3.040	1.759E+01	-9.856E-01	3.505E+01	-2.211E-03	
3.080	-7.677E+00	-8.161E-01	8.575E+01	1.650E-02	
3.120	-4.518E+00	-8.430E-01	8.107E+01	4.508E-02	
3.160	1.591E+01	-8.874E-01	7.873E+01	3.772E-02	
3.200	4.468E+01	-9.652E-01	7.343E+01	9.255E-03	
3.240	7.313E+01	-8.474E-01	1.466E+02	-4.579E-03	
3.280	9.371E+00	-9.545E-01	4.565E+01	1.790E-02	
3.320	3.200E+01	-1.061E+00	2.136E+01	1.675E-02	
3.360	6.678E+01	-1.169E+00	6.322E+00	-1.299E-02	
3.400	-5.379E+01	-7.847E-01	5.298E+01	-1.647E-03	
3.440	-4.313E+01	-9.495E-01	-2.244E+00	4.578E-02	
3.480	-4.860E+00	-1.149E+00	-5.273E+01	2.317E-02	
3.520	-6.477E+01	-9.171E-01	-1.769E+01	-1.265E-02	
3.560	-6.677E+01	-1.025E+00	-6.481E+01	-6.374E-03	
3.600	-5.236E+01	-1.151E+00	-1.024E+02	2.423E-04	
3.640	-2.359E+01	-1.198E+00	-1.027E+02	-4.031E-02	
3.680	-4.913E+01	-1.207E+00	-1.270E+02	-4.621E-02	
3.720	-3.039E+01	-1.205E+00	-1.109E+02	-4.599E-02	
3.760	-1.082E+01	-1.207E+00	-9.364E+01	-4.892E-02	
3.800	1.631E+01	-1.183E+00	-5.392E+01	-3.720E-02	
3.840	4.827E+00	-1.017E+00	5.455E+00	-2.749E-02	
3.880	-1.936E+01	-9.727E-01	7.440E+00	9.275E-03	
3.920	6.653E+00	-9.626E-01	3.854E+01	2.288E-02	
3.960	4.111E+01	-9.809E-01	6.566E+01	2.046E-02	
4.000	8.044E+01	-9.327E-01	1.004E+02	2.750E-03	
4.040	2.461E+01	-7.874E-01	1.499E+02	6.569E-02	
4.080	1.981E+01	1.964E-01	1.172E+02	7.895E-02	
4.120	1.217E+00	2.080E-01	1.100E+02	3.065E-02	
4.160	1.329E+01	2.070E-01	8.201E+01	1.040E-02	
4.200	3.068E+01	8.962E-02	4.853E+01	1.370E-02	
4.240	5.335E+01	-2.856E-02	1.778E+01	6.549E-03	
4.280	7.840E+01	-1.266E-01	-2.523E+00	-2.362E-02	
4.320	1.051E+02	-1.582E-01	5.045E+00	-5.856E-02	
4.360	1.076E+02	-1.340E-01	1.823E+01	-5.349E-02	
4.400	7.342E+01	2.734E-01	1.571E+02	-1.617E-02	
4.440	-2.737E+01	1.350E-01	1.231E+01	3.873E-02	
4.480	-1.333E+01	2.286E-01	6.476E+01	4.777E-02	
4.520	-8.594E+01	3.551E-01	4.873E+01	4.706E-02	
4.560	-1.087E+02	2.004E-01	-3.716E+01	5.146E-02	
4.600	-7.319E+01	2.375E-02	-8.056E+01	3.473E-02	
4.640	-2.187E+01	-1.643E-01	-1.168E+02	-3.122E-02	
4.680	3.827E+01	-3.214E-01	-1.291E+02	-6.467E-02	
4.720	9.706E+01	-9.432E-02	1.593E+01	-8.495E-02	
4.760	-1.302E+01	-1.341E-01	-9.694E+01	-3.263E-02	
4.800	2.109E+01	-1.436E-01	-6.815E+01	-1.074E-02	
4.840	7.576E+01	-1.516E-01	-2.051E+01	-3.324E-02	
4.880	1.365E+02	9.729E-03	1.038E+02	-4.726E-02	
4.920	-6.848E+01	3.837E-01	7.845E+01	2.410E-02	
4.960	-5.006E+01	2.780E-01	1.096E+02	1.166E-01	
5.000	-1.785E+01	2.548E-01	1.632E+02	1.263E-01	
5.040	-1.090E+02	3.068E-01	6.333E+01	5.890E-02	
5.080	-8.740E+01	1.822E-01	2.724E+01	4.635E-02	
5.120	-5.953E+01	-1.323E-02	-2.904E+01	4.182E-02	
5.160	-2.986E+01	-1.522E-01	-6.491E+01	4.671E-03	
5.200	-6.954E+01	-1.790E-01	-1.183E+02	-2.952E-02	
5.240	-7.782E+01	-7.004E-01	-1.557E+02	-6.952E-02	
5.280	-5.532E+01	-1.683E+00	-1.754E+02	-9.855E-02	
5.320	5.098E+00	1.757E+00	-1.027E+02	-7.140E-02	
5.360	-8.860E+01	1.765E+00	-1.864E+02	1.022E-02	
5.400	-5.117E+01	1.763E+00	-1.579E+02	3.347E-02	
5.440	-9.891E+00	1.616E+00	-1.298E+02	-1.936E-02	
5.480	3.524E+01	1.659E+00	-7.465E+01	-8.314E-02	
5.520	2.932E+01	1.847E+00	-1.221E-01	-7.074E-02	
5.560	3.774E+00	1.913E+00	1.455E+01	5.586E-03	
5.600	3.126E+01	1.946E+00	5.792E+01	2.682E-02	
5.640	6.848E+01	1.962E+00	9.969E+01	5.349E-03	
5.680	1.001E+02	1.852E+00	1.254E+02	5.411E-02	
5.720	7.824E+01	1.641E+00	1.860E+02	7.948E-02	
5.760	1.121E+01	3.525E-01	1.321E+02	3.511E-02	
5.800	1.834E+01	2.956E-01	1.232E+02	7.267E-03	
5.840	1.049E+01	3.160E-01	1.254E+02	-1.247E-02	
5.880	-1.007E+01	2.972E-01	7.569E+01	4.629E-02	
5.920	-1.542E+01	2.354E-01	4.304E+01	5.316E-02	
5.960	-1.410E+01	1.208E-01	-7.919E+00	2.380E-02	
6.000	-4.337E-02	-1.120E-02	-5.539E+01	-2.636E-02	
6.040	2.238E+01	-5.339E-02	-5.424E+01	-4.472E-02	
6.080	-1.184E+01	-1.724E-02	-7.030E+01	-3.244E-02	
6.120	-1.886E+01	-1.054E-01	-1.130E+02	-1.548E-02	
6.160	1.943E+00	-5.411E-02	-7.400E+01	-2.417E-02	
6.200	-1.307E+01	-5.015E-02	-8.901E+01	-5.096E-02	
6.240	2.177E+00	-2.402E-02	-6.467E+01	-5.242E-02	
6.280	2.079E+01	8.130E-02	-9.782E-01	-2.738E-02	
6.320	-6.783E+00	1.816E-01	1.793E+01	-1.646E-02	
6.360	-3.495E+00	2.126E-01	3.983E+01	2.182E-02	
6.400	-5.020E-02	2.931E-01	7.786E+01	2.817E-02	
6.440	-3.137E+00	3.065E-01	8.378E+01	3.873E-02	
6.480	1.078E+00	3.022E-01	8.489E+01	2.486E-02	
6.520	-3.875E+00	3.130E-01	9.075E+01	3.661E-02	
6.560	-2.512E+01	2.657E-01	5.086E+01	4.222E-02	
6.600	-1.637E+01	1.993E-01	2.966E+01	2.540E-02	
6.640	-1.219E+01	1.260E-01	-1.997E+00	-5.384E-03	
6.680	4.774E+00	7.437E-02	-6.957E+00	1.809E-03	
6.720	-1.309E+01	2.138E-02	-5.171E+01	-2.873E-02	
6.760	-1.484E+01	-9.095E-03	-6.759E+01	-3.046E-02	
6.800	-1.526E+01	-4.139E-02	-8.178E+01	-2.885E-02	
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234					
0 1 2 3 4 5 6 7 8 9 10 11					

6.840	-6.188E+00	-6.510E-02	-8.419E+01	-4.395E-02
6.880	8.957E+00	-9.486E-02	-8.410E+01	-4.331E-02
6.920	3.473E+01	3.019E-02	-7.514E+00	-5.191E-02
6.960	-2.097E+01	1.112E-01	-2.146E+01	-1.708E-02
7.000	-7.993E+00	1.262E-01	1.451E+00	1.829E-02
7.040	-8.563E-01	2.316E-01	5.168E+01	5.669E-03
7.080	-2.798E+01	2.798E-01	4.990E+01	2.482E-02
7.120	-1.451E+01	2.408E-01	5.095E+01	4.844E-02
7.160	5.741E+00	2.076E-01	5.230E+01	2.065E-02
7.200	2.046E+01	2.207E-01	7.192E+01	1.327E-02
7.240	-1.159E+01	2.354E-01	4.737E+01	2.976E-02
7.280	-8.125E+00	1.963E-01	3.372E+01	3.053E-02
7.320	-1.261E+01	1.267E-01	6.858E-01	2.415E-02
7.360	-3.500E+00	6.882E-02	-1.864E+01	1.277E-03
7.400	7.262E+00	3.522E-02	-2.791E+01	-3.495E-02
7.440	-3.307E+00	3.716E-02	-3.513E+01	-1.934E-02
7.480	2.198E+00	-2.177E-02	-5.781E+01	-3.921E-02
7.520	1.894E+01	1.768E-02	-2.404E+01	-2.295E-02
7.560	-2.188E+00	6.965E-02	-2.303E+01	-2.191E-02
7.600	-8.093E+00	7.851E-02	-2.171E+01	2.761E-03
7.640	-1.416E+00	8.611E-02	-1.196E+01	1.158E-03
7.680	1.424E+01	9.380E-02	5.447E+00	-7.035E-03
7.720	2.509E+01	1.499E-01	3.912E+01	-1.172E-02
7.760	1.766E+01	1.555E-01	3.652E+01	-5.048E-03
7.800	3.869E+01	2.150E-01	8.221E+01	3.688E-03
7.840	2.072E+01	2.614E-01	8.681E+01	2.188E-02
7.880	-1.286E+01	2.886E-01	6.930E+01	5.160E-02
7.920	-2.404E+01	2.861E-01	5.583E+01	4.687E-02
7.960	-2.873E+01	2.442E-01	3.102E+01	3.162E-02
8.000	-3.014E+01	1.405E-01	-1.442E+01	2.272E-02
8.040	4.087E+00	1.167E-01	3.578E+00	-5.657E-03
8.080	-3.384E+01	9.296E-02	-4.144E+01	3.735E-03
8.120	-2.808E+01	3.769E-02	-6.175E+01	-9.165E-03
8.160	-2.620E+01	3.569E-03	-7.792E+01	-2.108E-02
8.200	-2.427E+01	-1.453E-02	-8.533E+01	-3.106E-02
8.240	-2.429E+01	-6.891E-03	-8.053E+01	-2.895E-02
8.280	-2.642E+01	-1.168E-02	-8.234E+01	-1.426E-02
8.320	-1.329E+01	4.211E-03	-6.587E+01	-2.732E-02
8.360	7.414E+00	3.252E-02	-3.313E+01	-2.055E-02
8.400	1.322E+01	9.132E-02	-3.444E-01	-1.048E-02
8.440	1.505E+01	1.676E-01	3.429E+01	-9.135E-03
8.480	1.409E+01	2.398E-01	6.830E+01	7.193E-03
8.520	1.004E+01	2.759E-01	8.330E+01	3.977E-02
8.560	2.228E+01	4.271E-01	1.569E+02	4.357E-02
8.600	-7.298E+01	4.602E-01	8.008E+01	6.006E-02
8.640	-7.492E+01	3.689E-01	4.270E+01	8.153E-02
8.680	-6.047E+01	2.488E-01	9.583E-01	4.970E-02
8.720	-4.165E+01	1.229E-01	-4.035E+01	1.792E-03
8.760	-2.273E+01	-1.395E-03	-7.886E+01	-3.000E-02
8.800	-1.510E+01	-5.089E-02	-9.533E+01	-4.596E-02
8.840	-2.081E+01	-7.532E-02	-1.264E+02	-5.123E-02
8.880	-1.541E+00	2.687E-02	-1.050E+02	-7.035E-02
8.920	4.701E+00	1.627E-03	-1.178E+02	-3.532E-02
8.960	3.726E+01	3.998E-03	-8.798E+01	-3.408E-02
9.000	8.583E+01	1.382E-01	1.151E+01	-6.149E-02
9.040	-6.367E+01	3.913E-01	-1.753E+01	-2.594E-02
9.080	-2.561E+01	4.407E-01	4.856E+01	5.659E-02
9.120	-5.196E+01	5.391E-01	6.630E+01	6.489E-02
9.160	-3.093E+01	5.699E-01	9.798E+01	5.265E-02
9.200	-2.990E+01	4.708E-01	5.634E+01	3.548E-02
9.240	1.864E+01	3.017E-01	3.288E+01	2.632E-02
9.280	8.975E+01	3.141E-01	9.974E+01	-1.622E-02
9.320	1.951E+01	2.884E-01	2.701E+01	-7.854E-03
9.360	4.643E+00	3.474E-01	3.880E+01	3.192E-02
9.400	-3.119E+01	3.862E-01	2.108E+01	4.237E-02
9.440	-6.697E+01	3.655E-01	-2.505E+01	2.608E-02
9.480	-5.071E+01	1.990E-01	-8.021E+01	1.605E-02
9.520	-7.742E+00	5.688E-02	-1.059E+02	-2.890E-02
9.560	5.351E+01	-6.772E-02	-1.042E+02	-6.385E-02
9.600	-2.360E+01	1.343E-01	-8.958E+01	-4.434E-02
9.640	-1.079E+01	1.735E-01	-6.002E+01	-1.484E-02
9.680	3.203E-01	1.548E-01	-5.551E+01	4.813E-04
9.720	3.974E+01	3.286E-01	5.371E+01	-1.538E-02
9.760	-3.570E+01	3.654E-01	-5.568E-01	-1.376E-02
9.800	-1.188E+01	3.843E-01	3.601E+01	2.715E-02
9.840	1.838E+00	3.646E-01	4.350E+01	4.476E-02
9.880	2.929E+01	3.528E-01	6.035E+01	3.862E-03
9.920	4.304E+01	3.814E-01	8.675E+01	-1.709E-04
9.960	1.683E+01	4.639E-01	9.621E+01	3.426E-02
10.000	3.944E+00	4.867E-01	9.310E+01	2.488E-02
10.040	-2.627E+01	3.978E-01	2.903E+01	4.269E-02
10.080	5.590E+00	2.727E-01	2.809E+00	1.269E-02
10.120	1.481E+00	3.083E-01	9.776E+00	-1.340E-02
10.160	-2.274E+00	2.667E-01	-1.196E+01	-1.586E-02
10.200	-2.096E+01	2.578E-01	-3.279E+01	-1.839E-03
10.240	-2.638E+01	1.920E-01	-6.450E+01	7.689E-03
10.280	-1.437E+01	1.312E-01	-8.524E+01	-4.041E-02
10.320	1.923E+01	5.433E-02	-8.447E+01	-4.662E-02
10.360	5.485E+01	1.168E-01	-2.497E+01	-5.350E-02
10.400	8.017E+00	2.947E-01	8.477E+00	-3.049E-02
10.440	-1.918E+01	3.160E-01	-5.312E+00	3.384E-03
10.480	-5.020E+01	4.376E-01	2.124E+01	4.149E-02
10.520	-3.498E+01	3.782E-01	1.210E+01	4.583E-02
10.560	1.230E+00	3.273E-01	2.326E+01	2.041E-02
10.600	2.541E+01	3.348E-01	4.723E+01	-1.190E-02
10.640	2.603E+00	3.826E-01	4.692E+01	5.932E-03
10.680	-1.331E+01	3.998E-01	4.115E+01	2.171E-02
10.720	-1.542E+01	3.825E-01	3.245E+01	3.354E-02

10.760	-3.272E+01	3.915E-01	1.785E+01	1.367E-02
10.800	-4.818E+01	3.179E-01	-2.899E+01	6.376E-03
10.840	-2.482E+01	2.068E-01	-5.254E+01	1.929E-02
10.880	-3.276E+00	1.883E-01	-4.331E+01	-6.660E-03
10.920	-7.419E+00	1.907E-01	-5.131E+01	-4.063E-02
10.960	-3.046E+01	1.613E-01	-8.105E+01	-1.263E-02
11.000	-4.317E+00	1.104E-01	-7.663E+01	-1.325E-02
11.040	2.565E+01	1.227E-01	-4.584E+01	-4.070E-02
11.080	8.313E+00	2.620E-01	-3.588E+00	-3.987E-02
11.120	-3.027E+01	3.350E-01	-6.461E+00	-1.426E-02
11.160	-1.726E+01	3.237E-01	6.596E+00	2.425E-02
11.200	3.247E+00	3.054E-01	1.901E+01	2.667E-02
11.240	1.181E+01	4.213E-01	7.334E+01	-2.710E-03
11.280	-2.401E+01	4.708E-01	6.460E+01	1.597E-02
11.320	-3.762E+01	4.352E-01	3.939E+01	5.379E-02
11.360	-3.059E+01	3.832E-01	2.135E+01	2.934E-02
11.400	-2.045E+01	3.257E-01	5.043E+00	4.261E-03
11.440	-3.382E+01	3.209E-01	-1.082E+01	2.345E-03
11.480	-5.472E+01	3.209E-01	-3.020E+01	1.844E-02
11.520	-5.526E+01	2.258E-01	-7.410E+01	-9.025E-04
11.560	-4.046E+01	1.457E-01	-9.693E+01	-2.633E-02
11.600	-2.780E+01	1.041E-01	-1.063E+02	-4.411E-02
11.640	-9.069E+00	5.868E-02	-1.076E+02	-6.550E-02
11.680	1.344E+01	5.274E-02	-9.098E+01	-6.527E-02
11.720	3.285E+01	6.703E-02	-6.293E+01	-6.225E-02
11.760	5.097E+01	1.306E-01	-1.561E+01	-3.562E-02
11.800	6.007E+01	2.187E-01	3.371E+01	-1.887E-02
11.840	7.013E+01	2.734E-01	7.256E+01	1.029E-02
11.880	1.019E+02	6.774E-01	1.242E+02	5.141E-03
11.920	7.776E+01	4.934E-01	2.070E+02	9.925E-02
11.960	-2.675E+00	3.508E-01	1.949E+02	1.439E-01
12.000	-2.885E+01	2.158E+00	1.567E+02	6.724E-02
12.040	-5.121E+01	2.423E+00	1.247E+02	7.181E-03
12.080	-6.112E+01	2.279E+00	5.532E+01	3.690E-02
12.120	-5.091E+01	2.107E+00	-6.933E+00	5.866E-02
12.160	-4.786E+01	2.004E+00	-5.366E+01	2.989E-02
12.200	-5.353E+01	1.889E+00	-1.136E+02	-1.800E-02
12.240	-6.846E+01	1.475E+00	-1.441E+02	-9.540E-02
12.280	-5.753E+01	1.600E+00	-1.746E+02	-1.280E-01
12.320	-4.079E+00	1.433E+00	-1.610E+02	-3.738E-02
12.360	-3.710E+00	-8.881E-03	-1.516E+02	6.592E-03
12.400	4.160E-01	4.128E-02	-1.057E+02	-2.074E-02
12.440	9.500E+00	9.325E-02	-7.573E+01	-3.269E-02
12.480	1.479E+01	2.281E-01	-1.269E+01	-4.260E-02
12.520	-4.643E-01	3.439E-01	2.717E+01	-7.434E-03
12.560	1.791E+01	4.156E-01	8.115E+01	3.998E-02
12.600	8.531E+00	4.928E-01	1.057E+02	5.307E-02
12.640	1.159E+01	7.624E-01	1.394E+02	8.941E-02
12.680	-4.495E-01	7.116E-01	1.396E+02	9.700E-02
12.720	-1.161E+01	6.192E-01	1.050E+02	5.878E-02
12.760	-2.431E+00	6.478E-01	9.255E+01	8.023E-03
12.800	-1.482E+01	6.145E-01	6.959E+01	3.348E-02
12.840	-2.307E+01	4.888E-01	8.027E+00	3.310E-02
12.880	-2.634E+00	3.570E-01	-3.004E+01	1.677E-02
12.920	9.920E+00	2.980E-01	-5.097E+01	-4.484E-02
12.960	1.025E+01	2.562E-01	-6.984E+01	-6.189E-02
13.000	-5.059E+00	2.731E-01	-7.802E+01	-3.711E-02
13.040	-1.044E+00	2.600E-01	-8.033E+01	-3.235E-02
13.080	1.208E+01	2.679E-01	-6.432E+01	-3.707E-02
13.120	1.766E+01	2.997E-01	-4.772E+01	-6.096E-02
13.160	3.053E+01	3.497E-01	-1.001E+01	-2.300E-02
13.200	9.133E+00	5.305E-01	5.057E+01	1.124E-02
13.240	-1.430E+01	6.435E-01	7.656E+01	1.768E-02
13.280	-2.987E+01	6.751E-01	7.978E+01	3.687E-02
13.320	-2.147E+01	6.549E-01	8.139E+01	4.773E-02
13.360	-3.458E+00	5.554E-01	5.579E+01	2.052E-02
13.400	-1.944E+01	6.318E-01	7.385E+01	2.029E-02
13.440	-1.371E+01	5.037E-01	2.641E+01	3.399E-02
13.480	1.439E+01	4.799E-01	3.907E+01	1.013E-02
13.520	-4.870E+01	5.157E-01	-6.780E+00	3.745E-03
13.560	-2.678E+01	3.729E-01	-4.745E+01	-5.119E-04
13.600	-9.868E+00	3.349E-01	-5.139E+01	-1.989E-02
13.640	-2.847E+01	3.296E-01	-7.125E+01	-2.343E-02
13.680	-3.000E+01	3.083E-01	-8.256E+01	-3.123E-02
13.720	-2.662E+01	2.821E-01	-8.994E+01	-3.626E-02
13.760	-1.756E+01	2.872E-01	-7.837E+01	-2.986E-02
13.800	1.595E+00	3.098E-01	-5.072E+01	-3.663E-02
13.840	3.865E+01	3.060E-01	-1.457E+01	-2.955E-02
13.880	-9.837E-02	5.346E-01	4.650E+01	-1.819E-02
13.920	-6.287E+01	6.203E-01	3.003E+01	3.609E-02
13.960	-4.877E+01	6.117E-01	4.184E+01	4.673E-02
14.000	-2.632E+01	5.646E-01	4.509E+01	5.386E-02
14.040	-6.648E+00	5.448E-01	4.913E+01	6.468E-04
14.080	1.982E+01	5.590E-01	7.840E+01	-1.274E-03
14.120	-3.567E+01	5.500E-01	2.592E+01	2.020E-02
14.160	-4.768E+01	5.201E-01	6.333E-01	2.024E-02
14.200	-3.254E+01	3.928E-01	-3.942E+01	1.765E-02
14.240	2.066E+01	2.745E-01	-4.320E+01	-2.570E-02
14.280	5.490E+01	2.100E-01	-4.222E+01	-5.868E-02
14.320	5.171E+01	2.987E-01	-4.705E+00	-3.556E-02
14.360	3.477E-01	4.243E-01	7.108E-01	-1.261E-02
14.400	-2.437E+01	4.248E-01	-2.125E+01	5.522E-04
14.440	-2.019E+00	3.912E-01	-1.033E+01	1.861E-02
14.480	1.207E+01	4.993E-01	4.518E+01	-9.852E-03
14.520	-1.347E+01	5.435E-01	4.220E+01	1.090E-02
14.560	-1.025E+01	5.140E-01	3.893E+01	4.842E-02
14.600	-1.511E+01	5.511E-01	4.652E+01	2.366E-02
14.640	-2.497E+01	5.810E-01	4.799E+01	1.625E-02

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0        1         2         3         4         5         6         7         8         9         10        11
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14.680	-4.910E+01	5.441E-01	9.246E+00	6.205E-03
14.720	-2.544E+01	4.538E-01	-6.301E+00	1.129E-02
14.760	-1.010E+01	3.793E-01	-2.209E+01	1.595E-02
14.800	-5.595E+00	3.496E-01	-3.664E+01	-3.007E-02
14.840	1.080E+01	3.465E-01	-2.006E+01	-1.403E-02
14.880	-4.294E+01	4.105E-01	-4.320E+01	2.499E-03
14.920	-2.725E+01	3.424E-01	-5.458E+01	1.895E-02
14.960	-5.243E-01	3.084E-01	-4.802E+01	-2.247E-02
15.000	-2.782E+00	3.887E-01	-1.646E+01	-3.080E-02
15.040	-2.551E+01	4.145E-01	-2.753E+01	-3.586E-02
15.080	1.113E+00	3.735E-01	-1.218E+01	2.174E-02
15.120	3.158E+01	4.071E-01	2.929E+01	3.704E-03
15.160	9.057E+00	5.302E-01	5.763E+01	-1.480E-02
15.200	-1.897E+01	5.791E-01	5.366E+01	1.494E-02
15.240	-2.005E+01	5.597E-01	4.847E+01	3.892E-02
15.280	-6.435E+00	5.070E-01	3.989E+01	3.977E-02
15.320	-1.035E+01	5.540E-01	5.335E+01	1.586E-02
15.360	-3.509E+01	5.346E-01	2.146E+01	1.590E-02
15.400	-2.164E+01	4.529E-01	-2.226E+00	1.155E-02
15.440	-2.334E+00	4.306E-01	2.237E+00	-1.261E-02
15.480	-1.297E+01	3.490E-01	-4.112E+01	-1.246E-02
15.520	6.027E+00	2.836E-01	-5.161E+01	-1.939E-02
15.560	1.403E+01	3.163E-01	-3.386E+01	-3.457E-02
15.600	4.717E+00	3.195E-01	-4.182E+01	-4.212E-02
15.640	2.214E+01	3.234E-01	-2.123E+01	-2.986E-02
15.680	-1.895E+00	4.686E-01	1.788E+01	-1.649E-02
15.720	-3.890E+01	5.506E-01	2.022E+01	1.281E-02
15.760	-3.146E+01	5.087E-01	1.143E+01	1.688E-02
15.800	-1.226E+01	4.743E-01	1.669E+01	2.100E-02
15.840	-1.632E+01	5.462E-01	3.981E+01	-4.673E-03
15.880	-3.808E+01	5.119E-01	1.160E+01	4.645E-02
15.920	-2.282E+01	4.605E-01	1.375E+00	2.525E-02
15.960	-3.456E+00	4.421E-01	7.811E+00	-4.802E-03
16.000	-1.489E+01	4.453E-01	-2.383E+00	-1.043E-02

maximum absolute values

maximum	1.698E+02	2.423E+00	2.496E+02	2.778E-01
time	2.160E+00	1.204E+01	2.240E+00	2.240E+00

1time history for selected displacement components..... 1 file no. 2

node numbers and displacement components

time	7- 1	7- 5	13- 1	13- 5
.040	1.476E-06	1.409E-07	5.329E-05	1.152E-09
.080	1.269E-04	7.943E-06	3.368E-03	2.593E-07
.120	6.523E-04	3.193E-05	1.441E-02	2.830E-06
.160	1.530E-03	8.913E-05	3.197E-02	9.533E-06
.200	2.762E-03	1.195E-04	5.603E-02	1.965E-05
.240	4.141E-03	1.720E-04	8.160E-02	3.162E-05
.280	5.422E-03	2.199E-04	1.049E-01	4.283E-05
.320	6.715E-03	2.697E-04	1.288E-01	5.231E-05
.360	7.936E-03	3.135E-04	1.503E-01	6.167E-05
.400	8.698E-03	3.360E-04	1.622E-01	7.003E-05
.440	8.706E-03	3.285E-04	1.596E-01	7.265E-05
.480	8.223E-03	3.073E-04	1.494E-01	6.768E-05
.520	7.537E-03	2.764E-04	1.348E-01	5.992E-05
.560	6.016E-03	2.075E-04	1.030E-01	5.103E-05
.600	3.841E-03	1.236E-04	6.247E-02	3.518E-05
.640	2.002E-03	5.968E-05	3.029E-02	1.532E-05
.680	1.150E-03	3.976E-05	1.870E-02	2.919E-06
.720	1.483E-03	6.289E-05	2.886E-02	4.903E-06
.760	2.522E-03	1.094E-04	5.110E-02	1.701E-05
.800	3.911E-03	1.634E-04	7.755E-02	3.079E-05
.840	4.790E-03	1.862E-04	9.022E-02	4.092E-05
.880	4.188E-03	1.453E-04	7.283E-02	4.091E-05
.920	1.624E-03	2.453E-05	1.723E-02	2.406E-05
.960	-3.077E-03	-1.743E-04	-7.694E-02	-1.214E-05
1.000	-8.909E-03	-4.025E-04	-1.874E-01	-6.300E-05
1.040	-1.471E-02	-6.217E-04	-2.942E-01	-1.151E-04
1.080	-2.035E-02	-8.353E-04	-3.975E-01	-1.596E-04
1.120	-2.606E-02	-1.053E-03	-5.023E-01	-2.007E-04
1.160	-3.140E-02	-1.246E-03	-5.969E-01	-2.438E-04
1.200	-3.496E-02	-1.356E-03	-6.541E-01	-2.813E-04
1.240	-3.461E-02	-1.285E-03	-6.278E-01	-2.940E-04
1.280	-2.757E-02	-9.472E-04	-4.731E-01	-2.546E-04
1.320	-1.532E-02	-4.395E-04	-2.306E-01	-1.523E-04
1.360	-1.339E-03	9.809E-05	3.175E-02	-1.933E-05
1.400	1.098E-02	5.360E-04	2.493E-01	9.751E-05
1.440	1.839E-02	7.502E-04	3.615E-01	1.686E-04
1.480	1.788E-02	6.359E-04	3.175E-01	1.776E-04
1.520	8.808E-03	2.100E-04	1.197E-01	1.117E-04
1.560	-5.777E-03	-3.919E-04	-1.685E-01	-1.674E-05
1.600	-2.319E-02	-1.076E-03	-4.993E-01	-1.696E-04
1.640	-4.129E-02	-1.766E-03	-8.333E-01	-3.186E-04
1.680	-5.771E-02	-2.342E-03	-1.119E+00	-4.555E-04
1.720	-6.309E-02	-2.384E-03	-1.162E+00	-5.456E-04
1.760	-5.164E-02	-1.778E-03	-8.909E-01	-5.003E-04
1.800	-2.607E-02	-6.708E-04	-3.673E-01	-2.883E-04
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1.880	5.018E-02	2.357E-03	1.092E+00	3.682E-04
1.920	8.707E-02	3.715E-03	1.805E+00	6.997E-04
1.960	1.006E-01	4.285E-03	2.342E+00	9.470E-04
2.000	1.005E-01	4.301E-03	2.620E+00	9.945E-04
2.040	9.161E-02	3.877E-03	2.582E+00	8.688E-04
2.080	7.288E-02	3.022E-03	2.197E+00	6.820E-04
2.120	3.671E-02	1.448E-03	1.462E+00	4.524E-04
2.160	-1.657E-02	-7.316E-04	4.278E-01	7.847E-05
2.200	-7.939E-02	-3.184E-03	-7.789E-01	-4.557E-04
2.240	-1.182E-01	-4.848E-03	-1.869E+00	-9.474E-04

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2.480	-4.967E-02	-2.294E-03	-1.591E+00	-2.542E-04	
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2.720	9.166E-02	3.624E-03	1.610E+00	8.907E-04	
2.760	9.335E-02	3.787E-03	1.806E+00	8.331E-04	
2.800	8.860E-02	3.630E-03	1.817E+00	7.793E-04	
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3.200	-6.807E-02	-2.225E-03	-1.010E+00	-4.969E-04	
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3.720	6.477E-02	2.790E-03	1.426E+00	6.065E-04	
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3.960	-5.478E-02	-1.945E-03	-8.503E-01	-3.759E-04	
4.000	-7.469E-02	-2.681E-03	-1.208E+00	-5.212E-04	
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4.960	-8.314E-02	-3.222E-03	-1.604E+00	-6.185E-04	
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5.760	-1.072E-01	-4.111E-03	-1.738E+00	-7.774E-04	
5.800	-1.023E-01	-3.998E-03	-1.767E+00	-6.918E-04	
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5.920	-5.348E-02	-1.998E-03	-8.566E-01	-3.316E-04	
5.960	-2.514E-02	-8.831E-04	-3.197E-01	-9.791E-05	
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6.520	-6.612E-02	-2.723E-03	-1.181E+00	-4.091E-04
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10.120	-1.864E-02	-7.203E-04	-1.948E-01	-2.689E-05
10.160	-2.496E-03	-1.070E-04	1.030E-01	1.099E-04
10.200	1.280E-02	4.613E-04	3.787E-01	2.265E-04
10.240	2.647E-02	9.556E-04	6.199E-01	3.287E-04
10.280	3.656E-02	1.291E-03	7.888E-01	4.240E-04
10.320	4.033E-02	1.353E-03	8.299E-01	4.745E-04
10.360	3.495E-02	1.044E-03	6.933E-01	4.505E-04
10.400	2.135E-02	4.626E-04	4.172E-01	3.419E-04
10.440	5.196E-03	-1.625E-04	1.124E-01	1.856E-04
10.480	-9.846E-03	-7.082E-04	-1.580E-01	3.805E-05
10.520	-2.035E-02	-1.057E-03	-3.330E-01	-5.887E-05
10.560	-2.697E-02	-1.275E-03	-4.401E-01	-9.984E-05
10.600	-3.170E-02	-1.436E-03	-5.173E-01	-1.147E-04
10.640	-3.462E-02	-1.519E-03	-5.610E-01	-1.410E-04
10.680	-3.397E-02	-1.454E-03	-5.363E-01	-1.606E-04
10.720	-2.912E-02	-1.228E-03	-4.325E-01	-1.348E-04
10.760	-2.040E-02	-8.507E-04	-2.540E-01	-5.718E-05
10.800	-7.595E-03	-3.210E-04	-1.424E-03	4.886E-05
10.840	7.459E-03	2.574E-04	2.784E-01	1.682E-04
10.880	2.077E-02	7.304E-04	5.125E-01	2.877E-04
10.920	3.004E-02	1.039E-03	6.681E-01	3.806E-04
10.960	3.513E-02	1.189E-03	7.452E-01	4.200E-04
11.000	3.571E-02	1.152E-03	7.328E-01	4.205E-04
11.040	2.978E-02	8.499E-04	5.962E-01	3.869E-04
11.080	1.724E-02	3.181E-04	3.453E-01	3.010E-04
11.120	2.301E-03	-2.550E-04	6.615E-02	1.665E-04
11.160	-1.139E-02	-7.621E-04	-1.836E-01	2.931E-05
11.200	-2.351E-02	-1.208E-03	-4.006E-01	-6.704E-05
11.240	-3.413E-02	-1.587E-03	-5.852E-01	-1.377E-04
11.280	-4.059E-02	-1.770E-03	-6.818E-01	-2.001E-04
11.320	-4.003E-02	-1.674E-03	-6.464E-01	-2.272E-04
11.360	-3.289E-02	-1.340E-03	-4.908E-01	-1.718E-04
11.400	-2.111E-02	-8.482E-04	-2.554E-01	-6.232E-05
11.440	-6.531E-03	-2.663E-04	2.422E-02	6.160E-05
11.480	1.021E-02	3.917E-04	3.398E-01	1.897E-04
11.520	2.838E-02	1.087E-03	6.761E-01	3.330E-04
11.560	4.506E-02	1.691E-03	9.727E-01	4.766E-04
11.600	5.698E-02	2.082E-03	1.171E+00	5.912E-04
11.640	6.175E-02	2.178E-03	1.228E+00	6.454E-04
11.680	5.751E-02	1.912E-03	1.111E+00	6.199E-04
11.720	4.323E-02	1.263E-03	8.087E-01	5.180E-04
11.760	1.969E-02	2.740E-04	3.399E-01	3.335E-04
11.800	-1.096E-02	-9.545E-04	-2.489E-01	8.563E-05
11.840	-4.530E-02	-2.287E-03	-8.928E-01	-2.015E-04
11.880	-8.039E-02	-3.620E-03	-1.539E+00	-4.886E-04
11.920	-1.082E-01	-4.654E-03	-2.123E+00	-7.448E-04
11.960	-1.178E-01	-4.974E-03	-2.495E+00	-8.740E-04
12.000	-1.123E-01	-4.718E-03	-2.568E+00	-8.129E-04
12.040	-9.805E-02	-4.121E-03	-2.347E+00	-6.431E-04
12.080	-7.384E-02	-3.060E-03	-1.850E+00	-4.529E-04
12.120	-3.792E-02	-1.600E-03	-1.157E+00	-2.113E-04
12.160	3.409E-03	2.494E-06	-3.830E-01	1.262E-04
12.200	4.469E-02	1.559E-03	3.764E-01	4.981E-04
12.240	7.688E-02	2.747E-03	1.036E+00	8.032E-04
12.280	8.930E-02	3.440E-03	1.543E+00	9.378E-04
12.320	9.336E-02	3.765E-03	1.845E+00	8.929E-04
12.360	8.978E-02	3.644E-03	1.892E+00	7.825E-04
12.400	7.805E-02	3.156E-03	1.688E+00	6.687E-04
12.440	5.795E-02	2.290E-03	1.283E+00	5.352E-04
12.480	2.889E-02	1.108E-03	7.211E-01	3.328E-04
12.520	-4.648E-03	-1.919E-04	9.236E-02	5.157E-05
12.560	-3.786E-02	-1.443E-03	-5.186E-01	-2.509E-04
12.600	-6.755E-02	-2.519E-03	-1.047E+00	-5.066E-04
12.640	-8.795E-02	-3.220E-03	-1.432E+00	-6.857E-04
12.680	-9.456E-02	-3.461E-03	-1.625E+00	-7.488E-04
12.720	-9.106E-02	-3.320E-03	-1.613E+00	-6.906E-04
12.760	-8.101E-02	-2.889E-03	-1.419E+00	-5.752E-04
12.800	-6.416E-02	-2.165E-03	-1.079E+00	-4.502E-04
12.840	-4.038E-02	-1.204E-03	-6.214E-01	-2.854E-04
12.880	-1.378E-02	-1.859E-04	-1.277E-01	-6.345E-05
12.920	1.053E-02	7.005E-04	3.094E-01	1.662E-04
12.960	2.921E-02	1.343E-03	6.300E-01	3.395E-04
13.000	4.065E-02	1.696E-03	8.089E-01	4.285E-04
13.040	4.448E-02	1.754E-03	8.450E-01	4.518E-04
13.080	4.000E-02	1.493E-03	7.286E-01	4.244E-04
13.120	2.739E-02	9.322E-04	4.669E-01	3.383E-04
13.160	7.935E-03	1.247E-04	8.281E-02	1.827E-04
13.200	-1.591E-02	-8.085E-04	-3.680E-01	-1.704E-05
13.240	-3.857E-02	-1.635E-03	-7.746E-01	-2.201E-04
13.280	-5.532E-02	-2.196E-03	-1.057E+00	-3.790E-04
13.320	-6.384E-02	-2.429E-03	-1.180E+00	-4.610E-04
13.360	-6.435E-02	-2.369E-03	-1.158E+00	-4.606E-04
13.400	-5.857E-02	-2.078E-03	-1.024E+00	-4.069E-04
13.440	-4.607E-02	-1.539E-03	-7.703E-01	-3.178E-04
13.480	-3.000E-02	-9.075E-04	-4.656E-01	-1.836E-04
13.520	-1.234E-02	-2.076E-04	-1.293E-01	-3.236E-05
13.560	7.536E-03	5.562E-04	2.396E-01	1.213E-04
13.600	2.552E-02	1.201E-03	5.572E-01	2.738E-04
13.640	3.889E-02	1.660E-03	7.859E-01	3.975E-04
13.680	4.725E-02	1.921E-03	9.187E-01	4.697E-04
13.720	4.989E-02	1.956E-03	9.423E-01	4.932E-04
13.760	4.603E-02	1.737E-03	8.445E-01	4.688E-04
13.800	3.552E-02	1.266E-03	6.244E-01	3.907E-04
13.840	1.837E-02	5.406E-04	2.820E-01	2.638E-04
13.880	-4.275E-03	-3.532E-04	-1.480E-01	8.518E-05
13.920	-2.533E-02	-1.106E-03	-5.220E-01	-1.178E-04
13.960	-3.956E-02	-1.573E-03	-7.593E-01	-2.673E-04
14.000	-4.671E-02	-1.773E-03	-8.632E-01	-3.253E-04

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12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
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0         1         2         3         4         5         6         7         8         9         10        11
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234
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14.040	-4.804E-02	-1.763E-03	-8.618E-01	-3.155E-04
14.080	-4.501E-02	-1.607E-03	-7.893E-01	-2.832E-04
14.120	-3.790E-02	-1.284E-03	-6.394E-01	-2.350E-04
14.160	-2.559E-02	-7.641E-04	-3.952E-01	-1.550E-04
14.200	-9.513E-03	-1.283E-04	-8.957E-02	-2.827E-05
14.240	5.822E-03	4.238E-04	1.849E-01	1.245E-04
14.280	1.515E-02	6.987E-04	3.301E-01	2.317E-04
14.320	1.559E-02	6.222E-04	3.041E-01	2.518E-04
14.360	9.315E-03	3.310E-04	1.660E-01	1.872E-04
14.400	8.402E-04	-6.184E-06	7.430E-04	8.948E-05
14.440	-8.385E-03	-3.700E-04	-1.747E-01	7.528E-06
14.480	-1.885E-02	-7.741E-04	-3.680E-01	-5.854E-05
14.520	-2.831E-02	-1.106E-03	-5.319E-01	-1.324E-04
14.560	-3.427E-02	-1.296E-03	-6.298E-01	-2.031E-04
14.600	-3.660E-02	-1.345E-03	-6.583E-01	-2.287E-04
14.640	-3.470E-02	-1.221E-03	-6.035E-01	-2.100E-04
14.680	-2.758E-02	-8.909E-04	-4.504E-01	-1.607E-04
14.720	-1.587E-02	-4.123E-04	-2.225E-01	-7.459E-05
14.760	-2.945E-03	7.975E-05	1.761E-02	4.344E-05
14.800	8.371E-03	4.875E-04	2.202E-01	1.594E-04
14.840	1.626E-02	7.438E-04	3.497E-01	2.301E-04
14.880	2.060E-02	8.803E-04	4.164E-01	2.495E-04
14.920	2.313E-02	9.500E-04	4.517E-01	2.573E-04
14.960	2.217E-02	8.680E-04	4.185E-01	2.646E-04
15.000	1.644E-02	6.060E-04	2.982E-01	2.399E-04
15.040	7.973E-03	2.664E-04	1.346E-01	1.655E-04
15.080	-1.664E-03	-1.210E-04	-5.293E-02	6.625E-05
15.120	-1.357E-02	-6.013E-04	-2.818E-01	-2.300E-05
15.160	-2.707E-02	-1.113E-03	-5.287E-01	-1.166E-04
15.200	-3.814E-02	-1.492E-03	-7.181E-01	-2.185E-04
15.240	-4.411E-02	-1.664E-03	-8.096E-01	-2.908E-04
15.280	-4.501E-02	-1.649E-03	-8.074E-01	-3.011E-04
15.320	-4.195E-02	-1.486E-03	-7.322E-01	-2.642E-04
15.360	-3.417E-02	-1.135E-03	-5.685E-01	-2.069E-04
15.400	-2.198E-02	-6.381E-04	-3.320E-01	-1.205E-04
15.440	-8.438E-03	-1.215E-04	-8.093E-02	-3.604E-06
15.480	4.259E-03	3.490E-04	1.499E-01	1.137E-04
15.520	1.414E-02	6.820E-04	3.170E-01	2.040E-04
15.560	1.873E-02	7.944E-04	3.788E-01	2.506E-04
15.600	1.771E-02	6.991E-04	3.388E-01	2.476E-04
15.640	1.149E-02	4.035E-04	2.015E-01	1.949E-04
15.680	7.165E-04	-4.103E-05	-1.145E-02	1.029E-04
15.720	-1.040E-02	-4.484E-04	-2.129E-01	-5.152E-06
15.760	-1.842E-02	-7.182E-04	-3.483E-01	-8.163E-05
15.800	-2.353E-02	-8.852E-04	-4.311E-01	-1.180E-04
15.840	-2.638E-02	-9.637E-04	-4.715E-01	-1.327E-04
15.880	-2.558E-02	-8.886E-04	-4.408E-01	-1.363E-04
15.920	-2.101E-02	-6.835E-04	-3.452E-01	-1.079E-04
15.960	-1.478E-02	-4.378E-04	-2.259E-01	-4.806E-05
16.000	-8.331E-03	-1.885E-04	-1.047E-01	1.238E-05

maximum absolute values

maximum	1.275E-01	5.380E-03	2.737E+00	1.043E-03
time	2.280E+00	2.280E+00	2.320E+00	2.280E+00

ltime histories for selected nonlinear stresses
and corresponding nonlinear deformations ..... 1 file no. 3

element type - element number - stress component

time	stress 2 - 3- 7	deformation 2 - 3- 7	stress 2 - 3- 8	deformation 2 - 3- 8	stress 2 - 3-12	deformation 2 - 3-12	stress	deformation
.040	-2.359E+02	0.000E+00	3.919E-04	0.000E+00	-5.139E-01	0.000E+00		
.080	-2.359E+02	0.000E+00	1.650E-01	0.000E+00	-2.996E+01	0.000E+00		
.120	-2.354E+02	0.000E+00	7.079E-01	0.000E+00	-1.249E+02	0.000E+00		
.160	-2.343E+02	0.000E+00	1.547E+00	0.000E+00	-2.701E+02	0.000E+00		
.200	-2.329E+02	0.000E+00	2.691E+00	0.000E+00	-4.671E+02	0.000E+00		
.240	-2.312E+02	0.000E+00	3.897E+00	0.000E+00	-6.737E+02	0.000E+00		
.280	-2.298E+02	0.000E+00	4.994E+00	0.000E+00	-8.614E+02	0.000E+00		
.320	-2.286E+02	0.000E+00	6.134E+00	0.000E+00	-1.058E+03	0.000E+00		
.360	-2.274E+02	0.000E+00	7.155E+00	0.000E+00	-1.233E+03	0.000E+00		
.400	-2.264E+02	0.000E+00	7.690E+00	0.000E+00	-1.322E+03	0.000E+00		
.440	-2.263E+02	0.000E+00	7.535E+00	0.000E+00	-1.292E+03	0.000E+00		
.480	-2.272E+02	0.000E+00	7.054E+00	0.000E+00	-1.210E+03	0.000E+00		
.520	-2.283E+02	0.000E+00	6.383E+00	0.000E+00	-1.095E+03	0.000E+00		
.560	-2.296E+02	0.000E+00	4.831E+00	0.000E+00	-8.242E+02	0.000E+00		
.600	-2.320E+02	0.000E+00	2.890E+00	0.000E+00	-4.899E+02	0.000E+00		
.640	-2.347E+02	0.000E+00	1.412E+00	0.000E+00	-2.404E+02	0.000E+00		
.680	-2.359E+02	0.000E+00	9.223E-01	0.000E+00	-1.622E+02	0.000E+00		
.720	-2.350E+02	0.000E+00	1.427E+00	0.000E+00	-2.512E+02	0.000E+00		
.760	-2.331E+02	0.000E+00	2.458E+00	0.000E+00	-4.277E+02	0.000E+00		
.800	-2.313E+02	0.000E+00	3.696E+00	0.000E+00	-6.388E+02	0.000E+00		
.840	-2.302E+02	0.000E+00	4.264E+00	0.000E+00	-7.321E+02	0.000E+00		
.880	-2.307E+02	0.000E+00	3.379E+00	0.000E+00	-5.735E+02	0.000E+00		
.920	-2.337E+02	0.000E+00	6.865E-01	0.000E+00	-1.040E+02	0.000E+00		
.960	-2.393E+02	0.000E+00	-3.820E+00	0.000E+00	6.747E+02	0.000E+00		
1.000	-2.465E+02	0.000E+00	-9.035E+00	0.000E+00	1.569E+03	0.000E+00		
1.040	-2.532E+02	0.000E+00	-1.405E+01	0.000E+00	2.427E+03	0.000E+00		
1.080	-2.588E+02	0.000E+00	-1.895E+01	0.000E+00	3.269E+03	0.000E+00		
1.120	-2.642E+02	0.000E+00	-2.396E+01	0.000E+00	4.131E+03	0.000E+00		
1.160	-2.699E+02	0.000E+00	-2.843E+01	0.000E+00	4.898E+03	0.000E+00		
1.200	-2.745E+02	0.000E+00	-3.105E+01	0.000E+00	5.336E+03	0.000E+00		
1.240	-2.748E+02	0.000E+00	-2.962E+01	0.000E+00	5.069E+03	0.000E+00		
1.280	-2.672E+02	0.000E+00	-2.205E+01	0.000E+00	3.744E+03	0.000E+00		
1.320	-2.512E+02	0.000E+00	-1.052E+01	0.000E+00	1.759E+03	0.000E+00		
1.360	-2.329E+02	0.000E+00	1.764E+00	0.000E+00	-3.395E+02	0.000E+00		
1.400	-2.185E+02	0.000E+00	1.190E+01	0.000E+00	-2.063E+03	0.000E+00		
1.440	-2.112E+02	0.000E+00	1.706E+01	0.000E+00	-2.927E+03	0.000E+00		
1.480	-2.129E+02	0.000E+00	1.476E+01	0.000E+00	-2.504E+03	0.000E+00		
1.520	-2.247E+02	0.000E+00	5.207E+00	0.000E+00	-8.435E+02	0.000E+00		

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1.560	-2.439E+02	0.000E+00	-8.429E+00	0.000E+00	1.501E+03	0.000E+00
1.600	-2.648E+02	0.000E+00	-2.403E+01	0.000E+00	4.178E+03	0.000E+00
1.640	-2.842E+02	0.000E+00	-3.983E+01	0.000E+00	6.890E+03	0.000E+00
1.680	-3.017E+02	0.000E+00	-5.334E+01	0.000E+00	9.194E+03	0.000E+00
1.720	-3.107E+02	0.000E+00	-5.483E+01	0.000E+00	9.386E+03	0.000E+00
1.760	-2.982E+02	0.000E+00	-4.134E+01	0.000E+00	7.010E+03	0.000E+00
1.800	-2.636E+02	0.000E+00	-1.639E+01	0.000E+00	2.702E+03	0.000E+00
1.840	-2.188E+02	0.000E+00	1.629E+01	0.000E+00	-2.913E+03	0.000E+00
1.880	-1.727E+02	0.000E+00	5.259E+01	0.000E+00	-9.144E+03	0.000E+00
1.920	-2.977E+02	5.598E-03	4.855E+01	0.000E+00	-1.251E+04	-5.042E-04
1.960	-2.983E+02	1.799E-02	2.390E+02	0.000E+00	-1.252E+04	-1.664E-03
2.000	-2.588E+02	2.903E-02	2.764E+02	0.000E+00	-1.209E+04	-2.679E-03
2.040	-1.815E+02	3.544E-02	2.959E+02	0.000E+00	-1.121E+04	-3.252E-03
2.080	-1.609E+02	3.576E-02	2.915E+02	0.000E+00	-8.385E+03	-3.280E-03
2.120	-2.005E+02	3.576E-02	2.559E+02	0.000E+00	-2.198E+03	-3.280E-03
2.160	-2.556E+02	3.576E-02	2.062E+02	0.000E+00	6.397E+03	-3.280E-03
2.200	-4.769E+02	3.878E-02	1.987E+02	0.000E+00	1.433E+04	-2.982E-03
2.240	-6.319E+02	5.400E-02	-9.959E+02	0.000E+00	1.573E+04	-1.247E-03
2.280	-5.778E+02	6.942E-02	-1.543E+03	0.000E+00	1.526E+04	5.482E-04
2.320	-4.763E+02	8.231E-02	-1.582E+03	0.000E+00	1.432E+04	1.959E-03
2.360	-3.506E+02	8.914E-02	-1.607E+03	0.000E+00	1.307E+04	2.654E-03
2.400	-2.928E+02	8.961E-02	-1.609E+03	0.000E+00	1.096E+04	2.699E-03
2.440	-2.799E+02	8.961E-02	-1.591E+03	0.000E+00	7.776E+03	2.699E-03
2.480	-2.521E+02	8.961E-02	-1.573E+03	0.000E+00	4.612E+03	2.699E-03
2.520	-2.207E+02	8.961E-02	-1.545E+03	0.000E+00	-8.319E+01	2.699E-03
2.560	-1.826E+02	8.961E-02	-1.513E+03	0.000E+00	-5.687E+03	2.699E-03
2.600	-1.408E+02	8.961E-02	-1.484E+03	0.000E+00	-1.068E+04	2.699E-03
2.640	-2.687E+02	9.677E-02	-1.455E+03	0.000E+00	-1.220E+04	2.062E-03
2.680	-2.811E+02	1.081E-01	-1.179E+03	0.000E+00	-1.233E+04	1.024E-03
2.720	-2.747E+02	1.195E-01	-1.026E+03	0.000E+00	-1.224E+04	-2.897E-05
2.760	-2.573E+02	1.298E-01	-9.944E+02	0.000E+00	-1.207E+04	-9.619E-04
2.800	-1.990E+02	1.368E-01	-9.786E+02	0.000E+00	-1.142E+04	-1.590E-03
2.840	-1.365E+02	1.382E-01	-9.679E+02	0.000E+00	-1.009E+04	-1.716E-03
2.880	-1.574E+02	1.382E-01	-9.847E+02	0.000E+00	-7.173E+03	-1.716E-03
2.920	-1.846E+02	1.382E-01	-1.004E+03	0.000E+00	-3.852E+03	-1.716E-03
2.960	-2.100E+02	1.382E-01	-1.024E+03	0.000E+00	-5.154E+02	-1.716E-03
3.000	-2.320E+02	1.382E-01	-1.043E+03	0.000E+00	2.774E+03	-1.716E-03
3.040	-2.531E+02	1.382E-01	-1.061E+03	0.000E+00	5.972E+03	-1.716E-03
3.080	-2.745E+02	1.382E-01	-1.078E+03	0.000E+00	8.772E+03	-1.716E-03
3.120	-2.900E+02	1.382E-01	-1.088E+03	0.000E+00	1.047E+04	-1.716E-03
3.160	-2.952E+02	1.382E-01	-1.092E+03	0.000E+00	1.117E+04	-1.716E-03
3.200	-2.922E+02	1.382E-01	-1.092E+03	0.000E+00	1.124E+04	-1.716E-03
3.240	-2.882E+02	1.382E-01	-1.091E+03	0.000E+00	1.098E+04	-1.716E-03
3.280	-2.837E+02	1.382E-01	-1.085E+03	0.000E+00	1.000E+04	-1.716E-03
3.320	-2.745E+02	1.382E-01	-1.077E+03	0.000E+00	8.532E+03	-1.716E-03
3.360	-2.623E+02	1.382E-01	-1.069E+03	0.000E+00	7.275E+03	-1.716E-03
3.400	-2.536E+02	1.382E-01	-1.063E+03	0.000E+00	6.132E+03	-1.716E-03
3.440	-2.440E+02	1.382E-01	-1.049E+03	0.000E+00	3.798E+03	-1.716E-03
3.480	-2.241E+02	1.382E-01	-1.034E+03	0.000E+00	1.167E+03	-1.716E-03
3.520	-2.024E+02	1.382E-01	-1.020E+03	0.000E+00	-1.172E+03	-1.716E-03
3.560	-1.845E+02	1.382E-01	-1.004E+03	0.000E+00	-3.915E+03	-1.716E-03
3.600	-1.672E+02	1.382E-01	-9.891E+02	0.000E+00	-6.532E+03	-1.716E-03
3.640	-1.516E+02	1.382E-01	-9.787E+02	0.000E+00	-8.295E+03	-1.716E-03
3.680	-1.449E+02	1.382E-01	-9.748E+02	0.000E+00	-8.924E+03	-1.716E-03
3.720	-1.481E+02	1.382E-01	-9.772E+02	0.000E+00	-8.503E+03	-1.716E-03
3.760	-1.597E+02	1.382E-01	-9.863E+02	0.000E+00	-6.915E+03	-1.716E-03
3.800	-1.792E+02	1.382E-01	-1.003E+03	0.000E+00	-4.096E+03	-1.716E-03
3.840	-2.060E+02	1.382E-01	-1.024E+03	0.000E+00	-3.716E+02	-1.716E-03
3.880	-2.362E+02	1.382E-01	-1.046E+03	0.000E+00	3.415E+03	-1.716E-03
3.920	-2.626E+02	1.382E-01	-1.067E+03	0.000E+00	6.888E+03	-1.716E-03
3.960	-2.841E+02	1.382E-01	-1.085E+03	0.000E+00	1.006E+04	-1.716E-03
4.000	-3.232E+02	1.385E-01	-1.096E+03	0.000E+00	1.278E+04	-1.691E-03
4.040	-4.052E+02	1.432E-01	-1.084E+03	0.000E+00	1.363E+04	-1.236E-03
4.080	-3.925E+02	1.486E-01	-1.088E+03	0.000E+00	1.350E+04	-6.877E-04
4.120	-3.281E+02	1.518E-01	-1.098E+03	0.000E+00	1.284E+04	-3.823E-04
4.160	-2.891E+02	1.519E-01	-1.095E+03	0.000E+00	1.115E+04	-3.699E-04
4.200	-2.730E+02	1.519E-01	-1.079E+03	0.000E+00	8.362E+03	-3.699E-04
4.240	-2.513E+02	1.519E-01	-1.061E+03	0.000E+00	5.397E+03	-3.699E-04
4.280	-2.298E+02	1.519E-01	-1.047E+03	0.000E+00	2.994E+03	-3.699E-04
4.320	-2.169E+02	1.519E-01	-1.040E+03	0.000E+00	1.723E+03	-3.699E-04
4.360	-2.177E+02	1.519E-01	-1.040E+03	0.000E+00	1.801E+03	-3.699E-04
4.400	-2.287E+02	1.519E-01	-1.046E+03	0.000E+00	2.896E+03	-3.699E-04
4.440	-2.400E+02	1.519E-01	-1.050E+03	0.000E+00	3.462E+03	-3.699E-04
4.480	-2.412E+02	1.519E-01	-1.050E+03	0.000E+00	3.459E+03	-3.699E-04
4.520	-2.335E+02	1.519E-01	-1.044E+03	0.000E+00	2.467E+03	-3.699E-04
4.560	-2.169E+02	1.519E-01	-1.029E+03	0.000E+00	-1.161E+02	-3.699E-04
4.600	-1.915E+02	1.519E-01	-1.009E+03	0.000E+00	-3.585E+03	-3.699E-04
4.640	-1.625E+02	1.519E-01	-9.903E+02	0.000E+00	-6.806E+03	-3.699E-04
4.680	-1.433E+02	1.519E-01	-9.791E+02	0.000E+00	-8.676E+03	-3.699E-04
4.720	-1.427E+02	1.519E-01	-9.805E+02	0.000E+00	-8.378E+03	-3.699E-04
4.760	-1.597E+02	1.519E-01	-9.903E+02	0.000E+00	-6.702E+03	-3.699E-04
4.800	-1.824E+02	1.519E-01	-1.006E+03	0.000E+00	-3.981E+03	-3.699E-04
4.840	-2.080E+02	1.519E-01	-1.029E+03	0.000E+00	3.257E+01	-3.699E-04
4.880	-2.419E+02	1.519E-01	-1.060E+03	0.000E+00	5.385E+03	-3.699E-04
4.920	-2.851E+02	1.519E-01	-1.091E+03	0.000E+00	1.056E+04	-3.699E-04
4.960	-3.521E+02	1.527E-01	-1.097E+03	0.000E+00	1.309E+04	-2.985E-04
5.000	-3.657E+02	1.558E-01	-1.096E+03	0.000E+00	1.323E+04	1.072E-05
5.040	-3.002E+02	1.568E-01	-1.100E+03	0.000E+00	1.194E+04	1.046E-04
5.080	-2.716E+02	1.568E-01	-1.077E+03	0.000E+00	7.992E+03	1.046E-04
5.120	-2.345E+02	1.568E-01	-1.045E+03	0.000E+00	2.442E+03	1.046E-04
5.160	-1.892E+02	1.568E-01	-1.011E+03	0.000E+00	-3.485E+03	1.046E-04
5.200	-1.451E+02	1.568E-01	-9.782E+02	0.000E+00	-9.036E+03	1.046E-04
5.240	-2.541E+02	1.615E-01	-9.927E+02	0.000E+00	-1.204E+04	-3.074E-04
5.280	-2.825E+02	1.735E-01	-8.697E+02	0.000E+00	-1.235E+04	-1.408E-03
5.320	-2.516E+02	1.846E-01	-8.292E+02	0.000E+00	-1.201E+04	-2.423E-03
5.360	-2.101E+02	1.924E-01	-8.165E+02	0.000E+00	-1.154E+04	-3.120E-03
5.400	-1.562E+02	1.959E-01	-8.029E+02	0.000E+00	-1.092E+04	-3.425E-03
5.440	-1.436E+02	1.960E-01	-8.072E+02	0.000E+00	-9.165E+03	-3.434E-03

0	1	2	3	4	5	6	7	8	9	10	11
5.480	-1.626E+02	1.960E-01	-8.274E+02	0.000E+00	-5.640E+03	-3.434E-03					
5.520	-1.968E+02	1.960E-01	-8.549E+02	0.000E+00	-9.059E+02	-3.434E-03					
5.560	-2.381E+02	1.960E-01	-8.840E+02	0.000E+00	4.082E+03	-3.434E-03					
5.600	-2.746E+02	1.960E-01	-9.119E+02	0.000E+00	8.856E+03	-3.434E-03					
5.640	-3.362E+02	1.964E-01	-9.272E+02	0.000E+00	1.292E+04	-3.293E-03					
5.680	-4.717E+02	2.038E-01	-9.041E+02	0.000E+00	1.428E+04	-2.651E-03					
5.720	-5.066E+02	2.153E-01	-9.245E+02	0.000E+00	1.461E+04	-1.427E-03					
5.760	-4.733E+02	2.264E-01	-9.399E+02	0.000E+00	1.430E+04	-2.413E-04					
5.800	-3.976E+02	2.345E-01	-9.573E+02	0.000E+00	1.355E+04	5.911E-04					
5.840	-3.022E+02	2.375E-01	-9.751E+02	0.000E+00	1.256E+04	8.757E-04					
5.880	-2.813E+02	2.375E-01	-9.626E+02	0.000E+00	1.000E+04	8.757E-04					
5.920	-2.584E+02	2.375E-01	-9.407E+02	0.000E+00	6.206E+03	8.757E-04					
5.960	-2.239E+02	2.375E-01	-9.152E+02	0.000E+00	1.830E+03	8.757E-04					
6.000	-1.884E+02	2.375E-01	-8.902E+02	0.000E+00	-2.459E+03	8.757E-04					
6.040	-1.606E+02	2.375E-01	-8.697E+02	0.000E+00	-5.941E+03	8.757E-04					
6.080	-1.449E+02	2.375E-01	-8.555E+02	0.000E+00	-8.259E+03	8.757E-04					
6.120	-1.378E+02	2.375E-01	-8.471E+02	0.000E+00	-9.788E+03	8.757E-04					
6.160	-1.352E+02	2.375E-01	-8.467E+02	0.000E+00	-9.829E+03	8.757E-04					
6.200	-1.414E+02	2.375E-01	-8.536E+02	0.000E+00	-8.619E+03	8.757E-04					
6.240	-1.587E+02	2.375E-01	-8.667E+02	0.000E+00	-6.355E+03	8.757E-04					
6.280	-1.832E+02	2.375E-01	-8.853E+02	0.000E+00	-3.159E+03	8.757E-04					
6.320	-2.099E+02	2.375E-01	-9.062E+02	0.000E+00	4.337E+02	8.757E-04					
6.360	-2.359E+02	2.375E-01	-9.258E+02	0.000E+00	3.785E+03	8.757E-04					
6.400	-2.571E+02	2.375E-01	-9.422E+02	0.000E+00	6.591E+03	8.757E-04					
6.440	-2.705E+02	2.375E-01	-9.534E+02	0.000E+00	8.490E+03	8.757E-04					
6.480	-2.762E+02	2.375E-01	-9.582E+02	0.000E+00	9.303E+03	8.757E-04					
6.520	-2.753E+02	2.375E-01	-9.566E+02	0.000E+00	8.998E+03	8.757E-04					
6.560	-2.653E+02	2.375E-01	-9.479E+02	0.000E+00	7.488E+03	8.757E-04					
6.600	-2.465E+02	2.375E-01	-9.336E+02	0.000E+00	5.020E+03	8.757E-04					
6.640	-2.236E+02	2.375E-01	-9.162E+02	0.000E+00	2.017E+03	8.757E-04					
6.680	-2.005E+02	2.375E-01	-8.984E+02	0.000E+00	-1.032E+03	8.757E-04					
6.720	-1.795E+02	2.375E-01	-8.824E+02	0.000E+00	-3.770E+03	8.757E-04					
6.760	-1.641E+02	2.375E-01	-8.697E+02	0.000E+00	-5.926E+03	8.757E-04					
6.800	-1.545E+02	2.375E-01	-8.617E+02	0.000E+00	-7.285E+03	8.757E-04					
6.840	-1.506E+02	2.375E-01	-8.595E+02	0.000E+00	-7.844E+03	8.757E-04					
6.880	-1.556E+02	2.375E-01	-8.640E+02	0.000E+00	-6.847E+03	8.757E-04					
6.920	-1.692E+02	2.375E-01	-8.759E+02	0.000E+00	-4.784E+03	8.757E-04					
6.960	-1.899E+02	2.375E-01	-8.916E+02	0.000E+00	-2.085E+03	8.757E-04					
7.000	-2.132E+02	2.375E-01	-9.076E+02	0.000E+00	6.573E+02	8.757E-04					
7.040	-2.326E+02	2.375E-01	-9.231E+02	0.000E+00	3.298E+03	8.757E-04					
7.080	-2.479E+02	2.375E-01	-9.348E+02	0.000E+00	5.296E+03	8.757E-04					
7.120	-2.557E+02	2.375E-01	-9.410E+02	0.000E+00	6.343E+03	8.757E-04					
7.160	-2.567E+02	2.375E-01	-9.427E+02	0.000E+00	6.625E+03	8.757E-04					
7.200	-2.536E+02	2.375E-01	-9.411E+02	0.000E+00	6.356E+03	8.757E-04					
7.240	-2.482E+02	2.375E-01	-9.359E+02	0.000E+00	5.439E+03	8.757E-04					
7.280	-2.374E+02	2.375E-01	-9.266E+02	0.000E+00	3.839E+03	8.757E-04					
7.320	-2.219E+02	2.375E-01	-9.149E+02	0.000E+00	1.820E+03	8.757E-04					
7.360	-2.051E+02	2.375E-01	-9.026E+02	0.000E+00	-2.866E+02	8.757E-04					
7.400	-1.911E+02	2.375E-01	-8.920E+02	0.000E+00	-2.094E+03	8.757E-04					
7.440	-1.823E+02	2.375E-01	-8.844E+02	0.000E+00	-3.393E+03	8.757E-04					
7.480	-1.762E+02	2.375E-01	-8.802E+02	0.000E+00	-4.110E+03	8.757E-04					
7.520	-1.760E+02	2.375E-01	-8.809E+02	0.000E+00	-3.969E+03	8.757E-04					
7.560	-1.830E+02	2.375E-01	-8.856E+02	0.000E+00	-3.153E+03	8.757E-04					
7.600	-1.935E+02	2.375E-01	-8.924E+02	0.000E+00	-1.975E+03	8.757E-04					
7.640	-2.035E+02	2.375E-01	-9.009E+02	0.000E+00	-5.225E+02	8.757E-04					
7.680	-2.149E+02	2.375E-01	-9.106E+02	0.000E+00	1.158E+03	8.757E-04					
7.720	-2.272E+02	2.375E-01	-9.213E+02	0.000E+00	3.002E+03	8.757E-04					
7.760	-2.404E+02	2.375E-01	-9.315E+02	0.000E+00	4.735E+03	8.757E-04					
7.800	-2.517E+02	2.375E-01	-9.404E+02	0.000E+00	6.264E+03	8.757E-04					
7.840	-2.611E+02	2.375E-01	-9.467E+02	0.000E+00	7.331E+03	8.757E-04					
7.880	-2.645E+02	2.375E-01	-9.481E+02	0.000E+00	7.544E+03	8.757E-04					
7.920	-2.594E+02	2.375E-01	-9.433E+02	0.000E+00	6.695E+03	8.757E-04					
7.960	-2.459E+02	2.375E-01	-9.326E+02	0.000E+00	4.847E+03	8.757E-04					
8.000	-2.257E+02	2.375E-01	-9.176E+02	0.000E+00	2.274E+03	8.757E-04					
8.040	-2.040E+02	2.375E-01	-9.017E+02	0.000E+00	-4.607E+02	8.757E-04					
8.080	-1.849E+02	2.375E-01	-8.862E+02	0.000E+00	-3.113E+03	8.757E-04					
8.120	-1.685E+02	2.375E-01	-8.720E+02	0.000E+00	-5.553E+03	8.757E-04					
8.160	-1.541E+02	2.375E-01	-8.612E+02	0.000E+00	-7.397E+03	8.757E-04					
8.200	-1.449E+02	2.375E-01	-8.551E+02	0.000E+00	-8.422E+03	8.757E-04					
8.240	-1.436E+02	2.375E-01	-8.543E+02	0.000E+00	-8.536E+03	8.757E-04					
8.280	-1.496E+02	2.375E-01	-8.584E+02	0.000E+00	-7.817E+03	8.757E-04					
8.320	-1.612E+02	2.375E-01	-8.673E+02	0.000E+00	-6.286E+03	8.757E-04					
8.360	-1.777E+02	2.375E-01	-8.808E+02	0.000E+00	-3.953E+03	8.757E-04					
8.400	-1.981E+02	2.375E-01	-8.980E+02	0.000E+00	-9.893E+02	8.757E-04					
8.440	-2.220E+02	2.375E-01	-9.166E+02	0.000E+00	2.218E+03	8.757E-04					
8.480	-2.458E+02	2.375E-01	-9.343E+02	0.000E+00	5.236E+03	8.757E-04					
8.520	-2.644E+02	2.375E-01	-9.484E+02	0.000E+00	7.644E+03	8.757E-04					
8.560	-2.760E+02	2.375E-01	-9.575E+02	0.000E+00	9.193E+03	8.757E-04					
8.600	-2.782E+02	2.375E-01	-9.572E+02	0.000E+00	9.095E+03	8.757E-04					
8.640	-2.660E+02	2.375E-01	-9.452E+02	0.000E+00	6.987E+03	8.757E-04					
8.680	-2.381E+02	2.375E-01	-9.244E+02	0.000E+00	3.408E+03	8.757E-04					
8.720	-2.032E+02	2.375E-01	-8.993E+02	0.000E+00	-8.939E+02	8.757E-04					
8.760	-1.698E+02	2.375E-01	-8.746E+02	0.000E+00	-5.133E+03	8.757E-04					
8.800	-1.436E+02	2.375E-01	-8.543E+02	0.000E+00	-8.599E+03	8.757E-04					
8.840	-1.429E+02	2.377E-01	-8.452E+02	0.000E+00	-1.076E+04	8.567E-04					
8.880	-1.610E+02	2.403E-01	-8.482E+02	0.000E+00	-1.097E+04	6.387E-04					
8.920	-1.295E+02	2.413E-01	-8.423E+02	0.000E+00	-1.037E+04	5.498E-04					
8.960	-1.481E+02	2.413E-01	-8.560E+02	0.000E+00	-7.984E+03	5.498E-04					
9.000	-1.759E+02	2.413E-01	-8.803E+02	0.000E+00	-3.761E+03	5.498E-04					
9.040	-2.127E+02	2.413E-01	-9.089E+02	0.000E+00	1.143E+03	5.498E-04					
9.080	-2.489E+02	2.413E-01	-9.330E+02	0.000E+00	5.245E+03	5.498E-04					
9.120	-2.738E+02	2.413E-01	-9.507E+02	0.000E+00	8.246E+03	5.498E-04					
9.160	-2.828E+02	2.413E-01	-9.594E+02	0.000E+00	9.713E+03	5.498E-04					
9.200	-2.806E+02	2.413E-01	-9.587E+02	0.000E+00	9.584E+03	5.498E-04					
9.240	-2.701E+02	2.413E-01	-9.517E+02	0.000E+00	8.358E+03	5.498E-04					
9.280	-2.562E+02	2.413E-01	-9.437E+02	0.000E+00	7.003E+03	5.498E-04					
9.320	-2.461E+02	2.413E-01	-9.355E+02	0.000E+00	5.594E+03	5.498E-04					
9.360	-2.372E+02	2.413E-01	-9.257E+02	0.000E+00	3.899E+03	5.498E-04					

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9.400	-2.247E+02	2.413E-01	-9.134E+02	0.000E+00	1.762E+03	5.498E-04					
9.440	-2.044E+02	2.413E-01	-8.974E+02	0.000E+00	-9.916E+02	5.498E-04					
9.480	-1.808E+02	2.413E-01	-8.791E+02	0.000E+00	-4.133E+03	5.498E-04					
9.520	-1.594E+02	2.413E-01	-8.635E+02	0.000E+00	-6.786E+03	5.498E-04					
9.560	-1.458E+02	2.413E-01	-8.564E+02	0.000E+00	-7.966E+03	5.498E-04					
9.600	-1.485E+02	2.413E-01	-8.592E+02	0.000E+00	-7.451E+03	5.498E-04					
9.640	-1.622E+02	2.413E-01	-8.670E+02	0.000E+00	-6.110E+03	5.498E-04					
9.680	-1.795E+02	2.413E-01	-8.793E+02	0.000E+00	-3.996E+03	5.498E-04					
9.720	-1.990E+02	2.413E-01	-8.962E+02	0.000E+00	-1.072E+03	5.498E-04					
9.760	-2.207E+02	2.413E-01	-9.132E+02	0.000E+00	1.836E+03	5.498E-04					
9.800	-2.407E+02	2.413E-01	-9.271E+02	0.000E+00	4.197E+03	5.498E-04					
9.840	-2.535E+02	2.413E-01	-9.376E+02	0.000E+00	5.999E+03	5.498E-04					
9.880	-2.609E+02	2.413E-01	-9.455E+02	0.000E+00	7.347E+03	5.498E-04					
9.920	-2.665E+02	2.413E-01	-9.510E+02	0.000E+00	8.289E+03	5.498E-04					
9.960	-2.704E+02	2.413E-01	-9.529E+02	0.000E+00	8.602E+03	5.498E-04					
10.000	-2.682E+02	2.413E-01	-9.494E+02	0.000E+00	7.970E+03	5.498E-04					
10.040	-2.574E+02	2.413E-01	-9.396E+02	0.000E+00	6.272E+03	5.498E-04					
10.080	-2.391E+02	2.413E-01	-9.260E+02	0.000E+00	3.938E+03	5.498E-04					
10.120	-2.182E+02	2.413E-01	-9.121E+02	0.000E+00	1.553E+03	5.498E-04					
10.160	-2.003E+02	2.413E-01	-8.980E+02	0.000E+00	-8.576E+02	5.498E-04					
10.200	-1.869E+02	2.413E-01	-8.849E+02	0.000E+00	-3.109E+03	5.498E-04					
10.240	-1.738E+02	2.413E-01	-8.734E+02	0.000E+00	-5.078E+03	5.498E-04					
10.280	-1.609E+02	2.413E-01	-8.656E+02	0.000E+00	-6.405E+03	5.498E-04					
10.320	-1.570E+02	2.413E-01	-8.639E+02	0.000E+00	-6.667E+03	5.498E-04					
10.360	-1.636E+02	2.413E-01	-8.707E+02	0.000E+00	-5.472E+03	5.498E-04					
10.400	-1.808E+02	2.413E-01	-8.839E+02	0.000E+00	-3.192E+03	5.498E-04					
10.440	-2.028E+02	2.413E-01	-8.981E+02	0.000E+00	-7.582E+02	5.498E-04					
10.480	-2.220E+02	2.413E-01	-9.107E+02	0.000E+00	1.381E+03	5.498E-04					
10.520	-2.328E+02	2.413E-01	-9.188E+02	0.000E+00	2.758E+03	5.498E-04					
10.560	-2.356E+02	2.413E-01	-9.240E+02	0.000E+00	3.638E+03	5.498E-04					
10.600	-2.369E+02	2.413E-01	-9.278E+02	0.000E+00	4.305E+03	5.498E-04					
10.640	-2.411E+02	2.413E-01	-9.298E+02	0.000E+00	4.644E+03	5.498E-04					
10.680	-2.428E+02	2.413E-01	-9.284E+02	0.000E+00	4.376E+03	5.498E-04					
10.720	-2.373E+02	2.413E-01	-9.233E+02	0.000E+00	3.487E+03	5.498E-04					
10.760	-2.244E+02	2.413E-01	-9.148E+02	0.000E+00	2.031E+03	5.498E-04					
10.800	-2.095E+02	2.413E-01	-9.028E+02	0.000E+00	-3.700E+01	5.498E-04					
10.840	-1.936E+02	2.413E-01	-8.895E+02	0.000E+00	-2.323E+03	5.498E-04					
10.880	-1.778E+02	2.413E-01	-8.786E+02	0.000E+00	-4.191E+03	5.498E-04					
10.920	-1.672E+02	2.413E-01	-8.714E+02	0.000E+00	-5.401E+03	5.498E-04					
10.960	-1.648E+02	2.413E-01	-8.678E+02	0.000E+00	-6.014E+03	5.498E-04					
11.000	-1.660E+02	2.413E-01	-8.684E+02	0.000E+00	-5.898E+03	5.498E-04					
11.040	-1.720E+02	2.413E-01	-8.751E+02	0.000E+00	-4.726E+03	5.498E-04					
11.080	-1.856E+02	2.413E-01	-8.872E+02	0.000E+00	-2.628E+03	5.498E-04					
11.120	-2.050E+02	2.413E-01	-9.003E+02	0.000E+00	-3.801E+02	5.498E-04					
11.160	-2.229E+02	2.413E-01	-9.119E+02	0.000E+00	1.592E+03	5.498E-04					
11.200	-2.336E+02	2.413E-01	-9.222E+02	0.000E+00	3.354E+03	5.498E-04					
11.240	-2.415E+02	2.413E-01	-9.311E+02	0.000E+00	4.876E+03	5.498E-04					
11.280	-2.503E+02	2.413E-01	-9.355E+02	0.000E+00	5.617E+03	5.498E-04					
11.320	-2.518E+02	2.413E-01	-9.335E+02	0.000E+00	5.234E+03	5.498E-04					
11.360	-2.406E+02	2.413E-01	-9.260E+02	0.000E+00	3.936E+03	5.498E-04					
11.400	-2.241E+02	2.413E-01	-9.149E+02	0.000E+00	2.030E+03	5.498E-04					
11.440	-2.077E+02	2.413E-01	-9.016E+02	0.000E+00	-2.438E+02	5.498E-04					
11.480	-1.903E+02	2.413E-01	-8.866E+02	0.000E+00	-2.834E+03	5.498E-04					
11.520	-1.708E+02	2.413E-01	-8.706E+02	0.000E+00	-5.580E+03	5.498E-04					
11.560	-1.525E+02	2.413E-01	-8.567E+02	0.000E+00	-7.964E+03	5.498E-04					
11.600	-1.389E+02	2.413E-01	-8.475E+02	0.000E+00	-9.515E+03	5.498E-04					
11.640	-1.341E+02	2.413E-01	-8.450E+02	0.000E+00	-9.913E+03	5.498E-04					
11.680	-1.413E+02	2.413E-01	-8.508E+02	0.000E+00	-8.900E+03	5.498E-04					
11.720	-1.576E+02	2.413E-01	-8.653E+02	0.000E+00	-6.369E+03	5.498E-04					
11.760	-1.851E+02	2.413E-01	-8.877E+02	0.000E+00	-2.504E+03	5.498E-04					
11.800	-2.207E+02	2.413E-01	-9.157E+02	0.000E+00	2.314E+03	5.498E-04					
11.840	-2.600E+02	2.413E-01	-9.462E+02	0.000E+00	7.545E+03	5.498E-04					
11.880	-3.116E+02	2.414E-01	-9.724E+02	0.000E+00	1.266E+04	5.636E-04					
11.920	-4.897E+02	2.492E-01	-9.423E+02	0.000E+00	1.445E+04	1.353E-03					
11.960	-5.020E+02	2.608E-01	-9.423E+02	0.000E+00	1.457E+04	2.595E-03					
12.000	-4.133E+02	2.697E-01	-9.589E+02	0.000E+00	1.371E+04	3.525E-03					
12.040	-2.865E+02	2.725E-01	-9.776E+02	0.000E+00	1.221E+04	3.798E-03					
12.080	-2.664E+02	2.725E-01	-9.546E+02	0.000E+00	8.111E+03	3.798E-03					
12.120	-2.343E+02	2.725E-01	-9.212E+02	0.000E+00	2.331E+03	3.798E-03					
12.160	-1.825E+02	2.725E-01	-8.845E+02	0.000E+00	-3.970E+03	3.798E-03					
12.200	-1.323E+02	2.725E-01	-8.488E+02	0.000E+00	-1.007E+04	3.798E-03					
12.240	-2.777E+02	2.803E-01	-6.809E+02	0.000E+00	-1.230E+04	3.106E-03					
12.280	-2.800E+02	2.928E-01	-1.409E+02	0.000E+00	-1.232E+04	1.955E-03					
12.320	-2.590E+02	3.047E-01	7.191E+01	0.000E+00	-1.209E+04	8.641E-04					
12.360	-2.066E+02	3.134E-01	9.157E+01	0.000E+00	-1.150E+04	8.286E-05					
12.400	-1.272E+02	3.157E-01	1.082E+02	0.000E+00	-1.017E+04	-1.176E-04					
12.440	-1.486E+02	3.157E-01	8.886E+01	0.000E+00	-6.783E+03	-1.176E-04					
12.480	-1.786E+02	3.157E-01	6.187E+01	0.000E+00	-2.115E+03	-1.176E-04					
12.520	-2.170E+02	3.157E-01	3.210E+01	0.000E+00	2.992E+03	-1.176E-04					
12.560	-2.573E+02	3.157E-01	3.456E+00	0.000E+00	7.889E+03	-1.176E-04					
12.600	-2.888E+02	3.157E-01	-2.139E+01	0.000E+00	1.214E+04	-1.176E-04					
12.640	-4.034E+02	3.199E-01	-6.179E+00	0.000E+00	1.361E+04	2.881E-04					
12.680	-4.100E+02	3.268E-01	-6.951E+00	0.000E+00	1.368E+04	9.857E-04					
12.720	-3.467E+02	3.318E-01	-1.818E+01	0.000E+00	1.303E+04	1.479E-03					
12.760	-2.783E+02	3.328E-01	-2.465E+01	0.000E+00	1.174E+04	1.568E-03					
12.800	-2.648E+02	3.328E-01	-8.373E+00	0.000E+00	8.914E+03	1.568E-03					
12.840	-2.409E+02	3.328E-01	1.361E+01	0.000E+00	5.113E+03	1.568E-03					
12.880	-2.077E+02	3.328E-01	3.698E+01	0.000E+00	1.105E+03	1.568E-03					
12.920	-1.779E+02	3.328E-01	5.737E+01	0.000E+00	-2.369E+03	1.568E-03					
12.960	-1.583E+02	3.328E-01	7.229E+01	0.000E+00	-4.904E+03	1.568E-03					
13.000	-1.505E+02	3.328E-01	8.070E+01	0.000E+00	-6.332E+03	1.568E-03					
13.040	-1.496E+02	3.328E-01	8.237E+01	0.000E+00	-6.604E+03	1.568E-03					
13.080	-1.550E+02	3.328E-01	7.666E+01	0.000E+00	-5.601E+03	1.568E-03					
13.120	-1.696E+02	3.328E-01	6.402E+01	0.000E+00	-3.405E+03	1.568E-03					
13.160	-1.928E+02	3.328E-01	4.572E+01	0.000E+00	-2.481E+02	1.568E-03					
13.200	-2.208E+02	3.328E-01	2.436E+01	0.000E+00	3.420E+03	1.568E-03					
13.240	-2.472E+02	3.328E-01	5.283E+00	0.000E+00	6.675E+03	1.568E-03					
13.280	-2.657E+02	3.328E-01	-7.790E+00	0.000E+00	8.891E+03	1.568E-03					

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13.320	-2.729E+02	3.328E-01	-1.343E+01	0.000E+00	9.832E+03	1.568E-03
13.360	-2.701E+02	3.328E-01	-1.231E+01	0.000E+00	9.626E+03	1.568E-03
13.400	-2.616E+02	3.328E-01	-5.936E+00	0.000E+00	8.519E+03	1.568E-03
13.440	-2.476E+02	3.328E-01	6.277E+00	0.000E+00	6.402E+03	1.568E-03
13.480	-2.279E+02	3.328E-01	2.072E+01	0.000E+00	3.922E+03	1.568E-03
13.520	-2.076E+02	3.328E-01	3.660E+01	0.000E+00	1.194E+03	1.568E-03
13.560	-1.869E+02	3.328E-01	5.417E+01	0.000E+00	-1.828E+03	1.568E-03
13.600	-1.678E+02	3.328E-01	6.913E+01	0.000E+00	-4.382E+03	1.568E-03
13.640	-1.532E+02	3.328E-01	7.976E+01	0.000E+00	-6.189E+03	1.568E-03
13.680	-1.450E+02	3.328E-01	8.595E+01	0.000E+00	-7.236E+03	1.568E-03
13.720	-1.437E+02	3.328E-01	8.697E+01	0.000E+00	-7.397E+03	1.568E-03
13.760	-1.493E+02	3.328E-01	8.220E+01	0.000E+00	-6.557E+03	1.568E-03
13.800	-1.623E+02	3.328E-01	7.162E+01	0.000E+00	-4.722E+03	1.568E-03
13.840	-1.808E+02	3.328E-01	5.523E+01	0.000E+00	-1.884E+03	1.568E-03
13.880	-2.061E+02	3.328E-01	3.473E+01	0.000E+00	1.642E+03	1.568E-03
13.920	-2.339E+02	3.328E-01	1.732E+01	0.000E+00	4.601E+03	1.568E-03
13.960	-2.506E+02	3.328E-01	6.462E+00	0.000E+00	6.430E+03	1.568E-03
14.000	-2.542E+02	3.328E-01	1.642E+00	0.000E+00	7.244E+03	1.568E-03
14.040	-2.512E+02	3.328E-01	1.617E+00	0.000E+00	7.247E+03	1.568E-03
14.080	-2.463E+02	3.328E-01	5.045E+00	0.000E+00	6.654E+03	1.568E-03
14.120	-2.389E+02	3.328E-01	1.228E+01	0.000E+00	5.396E+03	1.568E-03
14.160	-2.262E+02	3.328E-01	2.408E+01	0.000E+00	3.348E+03	1.568E-03
14.200	-2.077E+02	3.328E-01	3.864E+01	0.000E+00	8.422E+02	1.568E-03
14.240	-1.868E+02	3.328E-01	5.139E+01	0.000E+00	-1.322E+03	1.568E-03
14.280	-1.754E+02	3.328E-01	5.792E+01	0.000E+00	-2.408E+03	1.568E-03
14.320	-1.767E+02	3.328E-01	5.642E+01	0.000E+00	-2.122E+03	1.568E-03
14.360	-1.883E+02	3.328E-01	4.990E+01	0.000E+00	-1.002E+03	1.568E-03
14.400	-2.021E+02	3.328E-01	4.229E+01	0.000E+00	2.912E+02	1.568E-03
14.440	-2.115E+02	3.328E-01	3.403E+01	0.000E+00	1.708E+03	1.568E-03
14.480	-2.201E+02	3.328E-01	2.470E+01	0.000E+00	3.322E+03	1.568E-03
14.520	-2.306E+02	3.328E-01	1.693E+01	0.000E+00	4.650E+03	1.568E-03
14.560	-2.394E+02	3.328E-01	1.253E+01	0.000E+00	5.385E+03	1.568E-03
14.600	-2.401E+02	3.328E-01	1.128E+01	0.000E+00	5.587E+03	1.568E-03
14.640	-2.366E+02	3.328E-01	1.390E+01	0.000E+00	5.127E+03	1.568E-03
14.680	-2.288E+02	3.328E-01	2.130E+01	0.000E+00	3.840E+03	1.568E-03
14.720	-2.152E+02	3.328E-01	3.223E+01	0.000E+00	1.953E+03	1.568E-03
14.760	-1.990E+02	3.328E-01	4.350E+01	0.000E+00	2.501E+01	1.568E-03
14.800	-1.838E+02	3.328E-01	5.287E+01	0.000E+00	-1.565E+03	1.568E-03
14.840	-1.768E+02	3.328E-01	5.890E+01	0.000E+00	-2.586E+03	1.568E-03
14.880	-1.761E+02	3.328E-01	6.214E+01	0.000E+00	-3.146E+03	1.568E-03
14.920	-1.753E+02	3.328E-01	6.390E+01	0.000E+00	-3.449E+03	1.568E-03
14.960	-1.745E+02	3.328E-01	6.216E+01	0.000E+00	-3.131E+03	1.568E-03
15.000	-1.798E+02	3.328E-01	5.620E+01	0.000E+00	-2.088E+03	1.568E-03
15.040	-1.915E+02	3.328E-01	4.847E+01	0.000E+00	-7.607E+02	1.568E-03
15.080	-2.052E+02	3.328E-01	3.976E+01	0.000E+00	7.289E+02	1.568E-03
15.120	-2.170E+02	3.328E-01	2.882E+01	0.000E+00	2.616E+03	1.568E-03
15.160	-2.292E+02	3.328E-01	1.697E+01	0.000E+00	4.657E+03	1.568E-03
15.200	-2.427E+02	3.328E-01	8.141E+00	0.000E+00	6.157E+03	1.568E-03
15.240	-2.509E+02	3.328E-01	4.076E+00	0.000E+00	6.829E+03	1.568E-03
15.280	-2.497E+02	3.328E-01	4.277E+00	0.000E+00	6.784E+03	1.568E-03
15.320	-2.427E+02	3.328E-01	7.787E+00	0.000E+00	6.178E+03	1.568E-03
15.360	-2.342E+02	3.328E-01	1.566E+01	0.000E+00	4.812E+03	1.568E-03
15.400	-2.217E+02	3.328E-01	2.702E+01	0.000E+00	2.848E+03	1.568E-03
15.440	-2.048E+02	3.328E-01	3.887E+01	0.000E+00	8.181E+02	1.568E-03
15.480	-1.898E+02	3.328E-01	4.967E+01	0.000E+00	-1.025E+03	1.568E-03
15.520	-1.800E+02	3.328E-01	5.746E+01	0.000E+00	-2.348E+03	1.568E-03
15.560	-1.755E+02	3.328E-01	6.024E+01	0.000E+00	-2.805E+03	1.568E-03
15.600	-1.773E+02	3.328E-01	5.822E+01	0.000E+00	-2.445E+03	1.568E-03
15.640	-1.866E+02	3.328E-01	5.167E+01	0.000E+00	-1.308E+03	1.568E-03
15.680	-2.011E+02	3.328E-01	4.155E+01	0.000E+00	4.321E+02	1.568E-03
15.720	-2.154E+02	3.328E-01	3.216E+01	0.000E+00	2.030E+03	1.568E-03
15.760	-2.232E+02	3.328E-01	2.589E+01	0.000E+00	3.093E+03	1.568E-03
15.800	-2.261E+02	3.328E-01	2.196E+01	0.000E+00	3.764E+03	1.568E-03
15.840	-2.277E+02	3.328E-01	2.001E+01	0.000E+00	4.098E+03	1.568E-03
15.880	-2.285E+02	3.328E-01	2.160E+01	0.000E+00	3.810E+03	1.568E-03
15.920	-2.224E+02	3.328E-01	2.625E+01	0.000E+00	3.000E+03	1.568E-03
15.960	-2.129E+02	3.328E-01	3.185E+01	0.000E+00	2.043E+03	1.568E-03
16.000	-2.056E+02	3.328E-01	3.751E+01	0.000E+00	1.073E+03	1.568E-03
maximum absolute values						
maximum	6.319E+02	3.328E-01	1.609E+03	0.000E+00	1.573E+04	3.798E-03
time	2.240E+00	1.276E+01	2.400E+00	0.000E+00	2.240E+00	1.204E+01

Appendix C

Discrete Foundation Element Subroutines Added to NEABS Coding

```
0         1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678901234567890
c     ***** DF1 subroutine ****************************************** jm
c                                                                      jm
      subroutine df1                                                   jm
c                                                                      jm
c     implicit double precision(a-h,o-z), integer(i-n)                 jm
      common/biga/ a(99000)                                            jm
      common/epar/ npar(14),numnp,neltyp,numel,nelcount,numnel,        jm
     +             neq,mband,mtot,nnn(7)                               jm
c                                                                  ** jm
c     **  Subroutine DF1 by W. Cofer & J. McGuire, 12/10/92          ** jm
c                                                                      jm
c     **  This subroutine allocates space in the global "a" matrix   ** jm
c     **  for temporary storage of discrete foundation (DF) element  ** jm
c     **  data prior to its permanent storage on tape.               ** jm
c                                                                      jm
c     **  Variable list:                                             ** jm
c     **    'mtype'   = 6 (for element type 6--DF element            ** jm
c     **    'numssi'  = number of DF elements                        ** jm
c     **    'npset'   = number of element property sets              ** jm
c     **    'n1'      = location in 'a' of beginning of nodal fixity ** jm
c     **                codes (n1=1 set in SETUP)                    ** jm
c     **    'n2'      = location in 'a' of beginning of nodal x-coord** jm
c     **    'n3'      = location in 'a' of beginning of nodal y-coord** jm
c     **    'n4'      = location in 'a' of beginning of nodal z-coord** jm
c     **    'n5'      = location in 'a' of beginning of element      ** jm
c     **                linear/nonlinear indicators                  ** jm
c     **    'n6'      = location in 'a' of beginning of element      ** jm
c     **                stiffness data                               ** jm
c     **    'n7'      = location in 'a' of beginning of element      ** jm
c     **                damping data                                 ** jm
c     **    'n8'      = location in 'a' of beginning of element      ** jm
c     **                mass data                                    ** jm
c     **    'n9'      = location in 'a' just after end of element    ** jm
c     **                mass data, (end of DF data storage in 'a')   ** jm
c                                                                      jm
c     write(*,7777) 1                                                  jm
c                                                                      jm
      numdof =  6                                                      jm
      nkpar  =  9                                                      jm
      ncpar  =  1                                                      jm
      nmpar  =  2                                                      jm
      nelpar = 10                                                      jm
      nlsv1  = 11                                                      jm
      nlsv2  = 17                                                      jm
c                                                                      jm
      mtype  = npar(1)                                                 jm
      numssi = npar(2)                                                 jm
      npset  = npar(3)                                                 jm
      if ((mtype.ne.6).or.(numssi.lt.1).or.(npset.lt.1)) then          jm
12345678901234567890123456789012345678901234567890123456789012345678901234567890
0         1         2         3         4         5         6         7
```

```
0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
        write (31,4010)                                                 jm
        stop                                                            jm
      end if                                                            jm
      if (numssi+nelcount.gt.numel) then                                jm
        write (31,4020)                                                 jm
        stop                                                            jm
      end if                                                            jm
c                                                                       jm
      n1    = nnn(1)                                                    jm
      n2    = nnn(2)                                                    jm
      n3    = nnn(3)                                                    jm
      n4    = nnn(4)                                                    jm
      n5    = nnn(5)                                                    jm
      n6    = nnn(6)                                                    jm
      n7    = n6  + npset *numdof*nkpar                                 jm
      n8    = n7  + npset *numdof*ncpar                                 jm
      n9    = n8  + npset *numdof*nmpar                                 jm
      n10   = n9  + numssi*nelpar                                       jm
      n11   = n10 + numdof*nlsv1                                        jm
      n12   = n11 + numdof*nlsv2                                        jm
      last = n12                                                        jm
c                                                                       jm
      if (last.ge.mtot) then                                            jm
        iover = last - mot                                              jm
c       write(*,7778) 3                                                 jm
        call error (1,iover,7hbeam   )                                  jm
c       write(*,7777) 4                                                 jm
      end if                                                            jm
c                                                                       jm
c     write(*,7778) 4                                                   jm
      call df2       (numnp,    numel,    nelcount, mband,             jm
     +                mtype,    numssi,   npset,    nlsv1,    nlsv2,   jm
     +                numdof,   nkpar,    ncpar,    nmpar,    nelpar,  jm
     +                a(n1),    a(n2),    a(n3),    a(n4),    a(n5),   jm
     +                a(n6),    a(n7),    a(n8),    a(n9),             jm
     +                a(n10),   a(n11)                              )   jm
c     write(*,7777) 5                                                   jm
c                                                                       jm
c     write(*,7778) 5                                                   jm
      return                                                            jm
c                                                                       jm
 4010 format (1x,'ERROR:   1')                                          jm
 4020 format (1x,'ERROR:   2')                                          jm
 7777 format (1x,'DF1 enter ',i2)                                       jm
 7778 format (1x,'DF1 exit  ',i2)                                       jm
 7779 format (1x,'DF1 stop  ',i2)                                       jm
c                                                                       jm
      end                                                               jm
c                                                                       jm
c                                                                       jm
c                                                                       jm
c     *****  DF2 subroutine  ***************************************** jm
c                                                                       jm
      subroutine df2 ( numnp,    numel,    nelcount, mband,           jm
     +                 mtype,    numssi,   npset,    nlsv1,    nlsv2, jm
     +                 numdof,   nkpar,    ncpar,    nmpar,    nelpar,jm
     +                 id,       x,        y,        z,        ind,   jm
     +                 qssi,     cssi,     wssi,     iessi,           jm
     +                 rnlm1,    rnlm2                           )    jm
c                                                                       jm
c     implicit    double precision(a-h,o-z), integer(i-n)               jm
      dimension   id(numnp,numdof),x(numnp),y(numnp),z(numnp),ind(numel)jm
     +           ,qssi(npset,numdof,nkpar), cssi(npset,numdof,ncpar),   jm
     +            wssi(npset,numdof,nmpar), iessi(numssi,nelpar),       jm
     +            rnlm1(numdof,nlsv1),      rnlm2(numdof,nlsv2),        jm
     +            told(3,3), emul(3,4)                                  jm
      common/emtx/lm(24),nd,ns,asa(24,24),rf(24,4),xm(24),sa(12,24),    jm
     +            sf(12,4),enpar(24),s(12,12),f(48),                    jm
     +            lms(12),ec(12),t(3,3),q(45),                          jm
     +            aca(24,24),ca(12,24),c(12,12)                         jm
      common/misc/nfn,ngm,nt,not,dt,alfa,beta,intg,igm(3),fgm(3),       jm
     +            kk1,kk2,nrflg                                         jm
12345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7
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0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
                                                                      jm
c                                                                     jm
c     **  Subroutine DF2 by W. Cofer & J. McGuire, 12/10/92         ** jm
c                                                                     jm
c                                                                     jm
c     **  This subroutine reads DF element data from the input file, ** jm
c     **  manages the creation of DF element stiffness, damping, and ** jm
c     **  mass matrices (performed in subroutine DF3), and writes    ** jm
c     **  element data to tape for permanent storage.                ** jm
c                                                                     jm
c                                                                     jm
c     write (*,7777) 1                                              jm
c                                                                   ** jm
c     **  INITIALIZE VARIABLES                                       jm
c                                                                     jm
      rewind (13)                                                     jm
      rewind (14)                                                     jm
      rewind (15)                                                     jm
      rewind (16)                                                     jm
      iflag1    =  0                                                  jm
      iflag2    =  0                                                  jm
      iflag3    =  0                                                  jm
      igen      =  0                                                  jm
      nind      =  1                                                  jm
      nd        = 12                                                  jm
      ns        = 12                                                  jm
      ndeclare  =  3                                                  jm
      ldeclare = numssi                                               jm
      do 310 i = 1,24                                                 jm
        lm(i) = 0                                                     jm
  310 continue                                                        jm
c     do 320 i = 1,1352                                               jm
c       stif(i) = 0.0                                                 jm
  320 continue                                                        jm
      do 370 i = 1,(npset+1)                                          jm
        do 360 j = 1,numdof                                           jm
          do 330 k = 1,nkpar                                          jm
            qssi(i,j,k) = 0.0                                         jm
  330       continue                                                  jm
            do 340 k = 1,ncpar                                        jm
              cssi(i,j,k) = 0.0                                       jm
  340       continue                                                  jm
            do 350 k = 1,nmpar                                        jm
              wssi(i,j,k) = 0.0                                       jm
  350       continue                                                  jm
  360     continue                                                    jm
  370 continue                                                        jm
      do 390 i = 1,(numssi+1)                                         jm
        do 380 j = 1,nelpar                                           jm
          iessi(i,j) = 0                                              jm
  380   continue                                                      jm
  390 continue                                                        jm
c                                                                   ** jm
c     **  PRINT DF ELEMENT CONTROL DATA                              jm
c                                                                     jm
      write (31,2010) numssi, npset                                   jm
c                                                                     jm
c     **  READ & PRINT DF ELEMENT PROPERTIES: STIFFNESS PARAMETERS   ** jm
c                                                                     jm
c                                                                     jm
      do 410 i1=1,npset*numdof                                        jm
        iflag1 = 0                                                    jm
        read (21,1010) np,idof                                        jm
        if ((np.lt.1).or.(np.gt.npset)) then                          jm
          if ((i1.eq.1).or.((idof.lt.1).or.(idof.gt.numdof))) then    jm
c           ERROR: DF element property set number or degree-of-       jm
c                  freedom number outside of applicable range.        jm
            write (31,4010)                                           jm
            stop                                                      jm
          end if                                                      jm
          if (np.eq.0) then                                           jm
            np = npp                                                  jm
          end if                                                      jm
        end if                                                        jm
        do 400 k=1,nkpar                                              jm
          if ((qssi(np,idof,k).ne.0.0).and.(iflag1.eq.0)) then        jm
12345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7
```

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0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
```

```
            iflag1 = 1                                                  jm
c           WARNING: the stiffness properties of this degree-of-        jm
c                    freedom for this element property set number       jm
c                    have already been specified; will now overwrite.   jm
            write (31,3010) np,idof                                     jm
          end if                                                        jm
  400   continue                                                        jm
        backspace (21)                                                  jm
        read (21,1010) np,idof,(qssi(np,idof,k),k=1,nkpar)              jm
        npp = np                                                        jm
  410 continue                                                          jm
      write (31,2020)                                                   jm
      do 430 i=1,npset                                                  jm
        do 420 j=1;numdof                                               jm
          write (31,2030) i,j,(qssi(i,j,k),k=1,nkpar)                   jm
  420   continue                                                        jm
  430 continue                                                          jm
c                                                                       jm
c     **  READ & PRINT DF ELEMENT PROPERTIES: DAMPING PARAMETERS     ** jm
c                                                                       jm
      do 450 i1=1,npset*numdof                                          jm
        iflag1 = 0                                                      jm
        read (21,1020) np,idof                                          jm
        if ((np.lt.1).or.(np.gt.npset)) then                            jm
          if ((i1.eq.1).or.((idof.lt.1).or.(idof.gt.numdof))) then      jm
c           ERROR: DF element property set number or degree-of-         jm
c                  freedom number outside of applicable range.          jm
            write (31,4020)                                             jm
            stop                                                        jm
          end if                                                        jm
          if (np.eq.0) then                                             jm
            np = npp                                                    jm
          end if                                                        jm
        end if                                                          jm
        do 440 k=1,ncpar                                                jm
          if ((cssi(np,idof,k).ne.0.0).and.(iflag1.eq.0)) then          jm
            iflag1 = 1                                                  jm
c           WARNING: the damping properties of this degree-of-          jm
c                    freedom for this element property set number       jm
c                    have already been specified; will now overwrite.   jm
            write (31,3020) np,idof                                     jm
          end if                                                        jm
  440   continue                                                        jm
        backspace (21)                                                  jm
        read (21,1020) np,idof,(cssi(np,idof,k),k=1,ncpar)              jm
        npp = np                                                        jm
  450 continue                                                          jm
      write (31,2040)                                                   jm
      do 470 i=1,npset                                                  jm
        do 460 j=1,numdof                                               jm
          write (31,2050) i,j,(cssi(i,j,k),k=1,ncpar)                   jm
  460   continue                                                        jm
  470 continue                                                          jm
c                                                                       jm
c     **  READ & PRINT DF ELEMENT PROPERTIES: MASS PARAMETERS        ** jm
c                                                                       jm
      do 490 i1=1,npset*numdof                                          jm
        iflag1 = 0                                                      jm
        read (21,1030) np,idof                                          jm
        if ((np.lt.1).or.(np.gt.npset)) then                            jm
          if ((i1.eq.1).or.((idof.lt.1).or.(idof.gt.numdof))) then      jm
c           ERROR: DF element property set number or degree-of-         jm
c                  freedom number outside of applicable range.          jm
            write (31,4030)                                             jm
            stop                                                        jm
          end if                                                        jm
          if (np.eq.0) then                                             jm
            np = npp                                                    jm
          end if                                                        jm
        end if                                                          jm
        do 480 k=1,nmpar                                                jm
          if ((wssi(np,idof,k).ne.0.0).and.(iflag1.eq.0)) then          jm
```

```
12345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7
```

```
0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
            iflag1 = 1                                                      jm
c           WARNING: the mass properties of this element property set       jm
c                    number have already been specified; will overwrite.    jm
            write (31,3030) np, idof                                        jm
          end if                                                            jm
  480   continue                                                            jm
        backspace (21)                                                      jm
        read (21,1030) np,idof,(wssi(np,idof,k),k=1,nmpar)                  jm
  490 continue                                                              jm
      write (31,2060)                                                       jm
      do 500 i=1,npset                                                      jm
        do 505 j = 1, numdof                                                jm
          write (31,2070) i,j,(wssi(i,j,k),k=1,nmpar)                       jm
  505   continue                                                            jm
  500 continue                                                              jm
c                                                                           jm
c     **  READ & PRINT ELEMENT LOAD FACTORS                               ** jm
c                                                                           jm
      read (21,1035) ((emul(i,j),j=1,4),i=1,3)                              jm
      write(31,2075) ((emul(i,j),j=1,4),i=1,3)                              jm
c                                                                           jm
c     **  READ DF ELEMENT DATA                                            ** jm
c                                                                           jm
      do 530 i1=1,numssi                                                    jm
        read (21,1040) ne                                                   jm
        if ((ne.lt.1).or.(ne.gt.numssi)) then                               jm
          if (ne.eq.-999) then                                              jm
            go to 540                                                       jm
          else                                                              jm
c           ERROR: element number outside of range.                         jm
            write (31,4040)                                                 jm
            stop                                                            jm
          end if                                                            jm
        end if                                                              jm
        if (iessi(ne,1).ne.0) then                                          jm
c         WARNING: the element data for this DF element have                jm
c                  already been specified; will now overwrite.              jm
          write (31,3040) ne                                                jm
        end if                                                              jm
        backspace (21)                                                      jm
        read (21,1040) ne,(iessi(ne,j),j=1,nelpar)                          jm
        if ((iessi(ne,5).lt.1).or.(iessi(ne,5).gt.npset)) then              jm
c         ERROR: element property set number outside of range.              jm
          write (31,4050)                                                   jm
          stop                                                              jm
        end if                                                              jm
        isupt = iessi(ne,8)                                                 jm
        if ((isupt.ne.0).and.(isupt.ne.1).and.(isupt.ne.-1)) then           jm
          iessi(ne,8) = 0                                                   jm
c         WARNING: uspecified change of support indicator                   jm
c                  to 0 (neither end supported condition).                  jm
          write (31,3050) ne                                                jm
        end if                                                              jm
        do 520 i2 = 1,4                                                     jm
          if ((iessi(ne,i2).lt.1).or.(iessi(ne,i2).gt.numnp)) then          jm
c           ERROR: node number outside of range.                            jm
            write (31,4060)                                                 jm
            stop                                                            jm
          end if                                                            jm
          do 510 i3=1,4                                                     jm
            if ((i2.ne.i3).and.(iessi(ne,i2).eq.iessi(ne,i3))) then         jm
              ick = i2*i3                                                   jm
              if ((ick.ne.6).and.(ick.ne.8).and.(ick.ne.12)) then           jm
c               ERROR: i- and j-node nos. not different, or i-, k-,         jm
c                      & l-node nos. not different.                         jm
                write (31,4070)                                             jm
                stop                                                        jm
              end if                                                        jm
            end if                                                          jm
  510     continue                                                          jm
  520   continue                                                            jm
  530 continue                                                              jm
```

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
0        1         2         3         4         5         6         7
```

```
0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
  540 continue                                                          jm
c                                                                       jm
c     **  AUTOMATIC MESH GENERATION ALGORITHM                        ** jm
c                                                                       jm
      do 550 i1=numssi,1,-1                                             jm
        if (iessi(i1,1).eq.0) ldeclare = i1 - 1                         jm
  550 continue                                                          jm
      if (ldeclare.eq.0) then                                           jm
c       ERROR: first DF element data not explicitly specified.          jm
        write (31,4080)                                                 jm
        stop                                                            jm
      end if                                                            jm
      if ((numssi.ge.2).and.(ldeclare.lt.numssi)) then                  jm
        do 560 i1=1,(numssi-1)                                          jm
          if ((iessi(i1,1).ne.0).and.(iessi(i1+1,1).ne.0)) then         jm
            if (iessi(i1,nelpar).ne.0) then                             jm
              iessi(i1,nelpar) = 0                                      jm
c             WARNING: unspecified mesh generation de-invokation.       jm
              write (31,3060) i1,i1+1                                   jm
            end if                                                      jm
          end if                                                        jm
  560   continue                                                        jm
        do 640 i1=ldeclare,(numssi-1)                                   jm
          if ((iessi(i1,1).eq.0).and.(iflag2.eq.0)) then                jm
            iflag2 = 1                                                  jm
            igen   = 0                                                  jm
            if (iessi(ldeclare,nelpar).eq.0) then                       jm
              iessi(ldeclare,nelpar) = 1                                jm
c             WARNING: unspecified mesh generation invokation.          jm
              write (31,3070) ldeclare,i1                               jm
            end if                                                      jm
            incr = iessi(ldeclare,nelpar)                               jm
            if (numssi.ge.3) then                                       jm
              do 570 i2=(i1+1),numssi                                   jm
                if (iessi(i2,1).ne.0) then                              jm
                  go to 580                                             jm
                end if                                                  jm
  570           continue                                                jm
                i2 = numssi + 1                                         jm
  580           continue                                                jm
                ndeclare = i2                                           jm
            end if                                                      jm
            do 630 i2=i1,(ndeclare-1)                                   jm
              igen = igen + 1                                           jm
              do 590 i3=1,2                                             jm
                iessi(i2,i3) = iessi(ldeclare,i3) + igen*incr           jm
                if ((iessi(i2,i3).lt.1).or.(iessi(i2,i3).gt.numnp)) thenjm
c                 ERROR: generated node number outside of range.        jm
                  write (31,4090)                                       jm
                  stop                                                  jm
                end if                                                  jm
  590           continue                                                jm
                do 600 i3=3,(nelpar-1)                                  jm
                  iessi(i2,i3) = iessi(ldeclare,i3)                     jm
  600           continue                                                jm
                do 620 i3=1,4                                           jm
                  do 610 i4=1,4                                         jm
                    if((i3.ne.i4).and.(iessi(i2,i3).eq.iessi(i2,i4))) thenjm
                      ick = i3*i4                                       jm
                      if ((ick.ne.6).and.(ick.ne.8).and.(ick.ne.12)) then jm
c                       ERROR: i- and j-node nos. not different, or i-, jm
c                              k-, & l-node nos. not different          jm
                        write (31,4100)                                 jm
                        stop                                            jm
                      end if                                            jm
                    end if                                              jm
  610             continue                                              jm
  620           continue                                                jm
  630         continue                                                  jm
            else                                                        jm
              iflag2   =  0                                             jm
              ldeclare = i1                                             jm
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0        1         2         3         4         5         6         7
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          end if                                                        jm
  640   continue                                                      jm
      end if                                                        jm
c                                                                   jm
c     **  PRINT DF ELEMENT DATA                                   ** jm
c                                                                   jm
      write (31,2080)                                               jm
      do 650 i=1,numssi                                             jm
          write (31,2090) i,  (iessi(i,j),  j=1,nelpar)             jm
  650 continue                                                      jm
      write (31,2100)                                               jm
c                                                                   jm
c                                                                   jm
c     ********    LOOP THROUGH DF ELEMENTS TO GENERATE ELEMENT   ****** jm
c     ********  STIFFNESS, MASS, DAMPING, AND LOADING MATRICIES. ****** jm
c                                                                   jm
c     **  FORM GLOBAL TO LOCAL COORDINATE TRANSFORMATION          ** jm
c                                                                   jm
      do 730 i1=1,numssi                                            jm
        iflag3 = 0                                                  jm
        ni    = iessi(i1,1)                                         jm
        nj    = iessi(i1,2)                                         jm
        nk    = iessi(i1,3)                                         jm
        nl    = iessi(i1,4)                                         jm
        np    = iessi(i1,5)                                         jm
        ireli = iessi(i1,6)                                         jm
        irelj = iessi(i1,7)                                         jm
        isupt = iessi(i1,8)                                         jm
        ird   = iessi(i1,9)                                         jm
        dx    = x(nj) - x(ni)                                       jm
        dy    = y(nj) - y(ni)                                       jm
        dz    = z(nj) - z(ni)                                       jm
        dl    = sqrt(dx*dx + dy*dy + dz*dz)                         jm
        a1    = x(nk) - x(ni)                                       jm
        a2    = y(nk) - y(ni)                                       jm
        a3    = z(nk) - z(ni)                                       jm
        b1    = x(nl) - x(ni)                                       jm
        b2    = y(nl) - y(ni)                                       jm
        b3    = z(nl) - z(ni)                                       jm
        ab    = a1*b1 + a2*b2 + a3*b3                               jm
        aa    = a1*a1 + a2*a2 + a3*a3                               jm
        bb    = b1*b1 + b2*b2 + b3*b3                               jm
        c1    = aa*b1 - ab*a1                                       jm
        c2    = aa*b2 - ab*a2                                       jm
        c3    = aa*b3 - ab*a3                                       jm
        cc    = c1*c1 + c2*c2 +c3*c3                                jm
        if ((aa.le.0.0).or.(bb.le.0.0).or.(cc.le.0.0)) then         jm
          write (31,4110)                                           jm
          stop                                                      jm
        end if                                                      jm
        da = sqrt(aa)                                               jm
        dc = sqrt(cc)                                               jm
        t(1,1) = a1/da                                              jm
        t(1,2) = a2/da                                              jm
        t(1,3) = a3/da                                              jm
        t(2,1) = c1/dc                                              jm
        t(2,2) = c2/dc                                              jm
        t(2,3) = c3/dc                                              jm
        t(3,1) = t(1,2)*t(2,3) - t(1,3)*t(2,2)                      jm
        t(3,2) = t(1,3)*t(2,1) - t(1,1)*t(2,3)                      jm
        t(3,3) = t(1,1)*t(2,2) - t(1,2)*t(2,1)                      jm
c                                                                   jm
c       **  CHECK IF NEW ELEMENT STIFFNESS IS NEEDED              ** jm
c                                                                   jm
        if (i1.ne.1) then                                           jm
          if (abs(dlnew-dlold).lt.dlnew/100.0) then                 jm
            if (np.eq.npold) then                                   jm
              if (ireli.eq.ireliold) then                           jm
                if (irelj.eq.ireljold) then                         jm
                  if (isupt.eq.isuptold) then                       jm
                    do 670 i2 =1,3                                  jm
                      do 660 i3=1,3                                 jm
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0        1         2         3         4         5         6         7
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0         1         2         3         4         5         6         7
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                        check1 = abs(told(i2,i3) - t(i2,i3))                jm
                        check2 = abs(t(i2,i3)/100.0)                        jm
                        if (check1.lt.check2) then                          jm
                          iflag3 = 1                                        jm
                        end if                                              jm
  660                 continue                                              jm
  670               continue                                                jm
                  end if                                                    jm
                end if                                                      jm
              end if                                                        jm
            end if                                                          jm
          end if                                                            jm
        end if                                                              jm
        dlold    = dl                                                       jm
        npold    = np                                                       jm
        ireliold = ireli                                                    jm
        ireljold = irelj                                                    jm
        isuptold = isupt                                                    jm
        do 690 i2 = 1,3                                                     jm
          do 680 i3 = 1,3                                                   jm
            told(i2,i3) = t(i2,i3)                                          jm
  680     continue                                                          jm
  690   continue                                                            jm
        iflag3 = 0                                                          jm
c                                                                           jm
c       **  GENERATE NEW STIFFNESS MATRIX                                 ** jm
c                                                                           jm
        if (iflag3.ne.1) then                                               jm
c         write(*,7778) 13                                                  jm
          call df3 (il,     np,   alfa,   beta,                             jm
     +              numssi, npset, numdof, nkpar, ncpar, nmpar, nelpar,     jm
     +              emul,   t,             qssi,  cssi,  wssi,  iessi,     jm
     +              s,      sa,    asa,    c,     ca,    aca,              jm
     +              xm,     sf,    rf,     nlsv1, rnlm1, nlsv2, rnlm2  )   jm
c         write(*,7777) 14                                                  jm
        end if                                                              jm
c                                                                           jm
c       **  FORM ELEMENT LOCATION MATRIX                                  ** jm
c                                                                           jm
        do 700 i2=1,6                                                       jm
          lm(i2)   = id(ni,i2)                                              jm
          lm(i2+6) = id(nj,i2)                                              jm
  700   continue                                                            jm
c                                                                           jm
c       **  TRANSFORM TO MASTER DEGREES OF FREEDOM                        ** jm
c                                                                           jm
c       write(*,7778) 14                                                    jm
        call slave (x, y, z, id, numnp, ni, nj)                             jm
c       write(*,7777) 15                                                    jm
c                                                                           jm
c       **  WRITE ELEMENT DATA ON TAPE (LINEAR PORTION)                   ** jm
c                                                                           jm
c       write(*,7778) 15                                                    jm
        call writet (mband, ndif)                                           jm
c       write(*,7777) 16                                                    jm
c                                                                           jm
c       **  WRITE ELEMENT DATA ON TAPE (NON-LINEAR PORTION)               ** jm
c                                                                           jm
        if (nind.gt.0) then                                                 jm
          nlmult =  1                                                       jm
          write (3)  mtype, nd,  ns, lm, asa, sa, s                         jm
          write (3)  lms, ec, t                                             jm
          write (3)  numdof, nlsv1, nlsv2                                   jm
          write (13) rnlm1                                                  jm
          write (14) rnlm2                                                  jm
          write (15) rnlm2                                                  jm
          write (16) rnlm2                                                  jm
        else                                                                jm
          nlmult = -1                                                       jm
c         ERROR: element failed test for nonlinearity                       jm
c                (DF element assumed to always be nonlinear).               jm
          write (31,4120)                                                   jm
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          stop                                                          jm
        end if                                                          jm
        nn = nelcount + il                                              jm
        ind(nn) = nlmult*mtype                                          jm
c                                                                       jm
  730 continue                                                          jm
      rewind (13)                                                       jm
      rewind (14)                                                       jm
      rewind (15)                                                       jm
      rewind (16)                                                       jm
c                                                                       jm
c     write(*,7778) 17                                                  jm
      return                                                            jm
c                                                                       jm
 1010 format (2i5, 5f10.0, 4f5.0)                                       jm
 1020 format (2i5,        1f10.0)                                       jm
 1030 format (2i5,        2f10.0)                                       jm
 1035 format (4f10.0              )                                     jm
 1040 format (6i5, 2i10, 3i5     )                                      jm
 2010 format ( ///,'......DF elements (Type 6)',//                      jm
     +             'number of DF elements:          ', 2x, i5, /,      jm
     +             'number of element property sets:', 2x, i5,     )  jm
 2020 format (//,1x,'STIFFNESS PARAMETER DATA',//,                      jm
     +              'np dof  rkei      fyi       rkpi      rkg1      ', jm
     +              'rkg2      sd    rik   rhop  riz'                  )jm
 2030 format (i2,i3,5(e10.3),4(1x,f5.3))                                jm
 2040 format (//,1x,'DAMPING PARAMETER DATA',//,                        jm
     +              'np dof  c'                    )                   jm
 2050 format (i2,i3,1(e11.4))                                           jm
 2060 format (//,1x,'MASS PARAMETER DATA',//                            jm
     +              'np dof  mi         mj'      )                     jm
 2070 format (i2,i3,2(e11.4))                                           jm
 2075 format (//,1x,'ELEMENT LOAD FACTORS',//,                          jm
     +           1x,'  Load Case:',9x,'a',14x,'b',14x,'c',14x,'d',/,    jm
     +           1x,'  Global X-dir: ',4e15.6,/,                       jm
     +           1x,'  Global Y-dir: ',4e15.6,/,                       jm
     +           1x,'  Global Z-dir: ',4e15.6                    )     jm
 2080 format (//,1x,'ELEMENT DATA',/)                                   jm
 2090 format (6(i5),2(i6),3(i5))                                        jm
 2100 format ( /// )                                                    jm
 3010 format (1x,'WARNING: The stiffness properties for property set ', jm
     +           'number ',i5,', degree-of-freedom ',i5,', have',/,     jm
     +         1x,'          been specified more than once, ',         jm
     +           'and will be overwritten.')                            jm
 3020 format (1x,'WARNING: The damping properties for property set ',   jm
     +           'number ',i5,', degree-of-freedom ',i5,', have',/,     jm
     +         1x,'          been specified more than once, ',         jm
     +           'and will be overwritten.')                            jm
 3030 format (1x,'WARNING: The mass properties for property set ',      jm
     +           'number ',i5,', degree-of-freedom ',i5,', have',/,     jm
     +         1x,'          been specified more than once, ',         jm
     +           'and will be overwritten.')                            jm
 3040 format (1x,'WARNING: The element data for DF element ',i5,' have' jm
     +     ,/,1x,'          been specified more than once, ',          jm
     +           'and will be overwritten.')                            jm
 3050 format (1x,'WARNING: Wrong support indicator specified ',         jm
     +         'on DF element ',i5,'; changed to 0.')                   jm
 3060 format (1x,'WARNING: Unspecified mesh generation de-invokation ', jm
     +         'on DF element ',i5,';',/,                               jm
     +         1x,'          DF element ',i5,' data already declared.') jm
 3070 format (1x,'WARNING: Unspecified mesh generation invoked ',       jm
     +         'on DF element ',i5,';',/,                               jm
     +         1x,'          DF element ',i5,' data undeclared.')       jm
 4010 format (1x,'ERROR:  1')                                           jm
 4020 format (1x,'ERROR:  2')                                           jm
 4030 format (1x,'ERROR:  3')                                           jm
 4040 format (1x,'ERROR:  4')                                           jm
 4050 format (1x,'ERROR:  5')                                           jm
 4060 format (1x,'ERROR:  6')                                           jm
 4070 format (1x,'ERROR:  7')                                           jm
 4080 format (1x,'ERROR:  8')                                           jm
 4090 format (1x,'ERROR:  9')                                           jm
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 4100 format (1x,'ERROR: 10')                                          jm
 4110 format (1x,'ERROR: 11')                                          jm
 4120 format (1x,'ERROR: 12')                                          jm
 7777 format (1x,'DF2 enter ',i2)                                      jm
 7778 format (1x,'DF2 exit  ',i2)                                      jm
 7779 format (1x,'DF2 stop  ',i2)                                      jm
c                                                                      jm
      end                                                              jm
c                                                                      jm
c                                                                      jm
c                                                                      jm
c     *****  DF3 subroutine  ***************************************** jm
c                                                                      jm
      subroutine df3( il,     np,    alfa,   beta,                     jm
     +               numssi, npset, numdof, nkpar, ncpar, nmpar, nelparjm
     +              ,emul,   t,             qssi,  cssi,  wssi,  iessi,jm
     +               s,      sa,    asa,    c,     ca,    aca,        jm
     +               xm,     sf,    rf,     nlsv1, rnlm1, nlsv2, rnlm2)jm
c                                                                      jm
c     implicit double precision(a-h,o-z), integer(i-n)                 jm
      dimension    qssi(npset,numdof,nkpar),  cssi(npset,numdof,ncpar), jm
     +             wssi(npset,numdof,nmpar), iessi(numssi,nelpar),     jm
     +             s(12,12), sa(12,24), asa(24,24), emul(3,4), t(3,3), jm
     +             c(12,12), ca(12,24), aca(24,24),                    jm
     +             xm(24),   xml(12),     sf(12,4), rf(24,4),          jm
     +             rs(12),    rc(12),    qs(12),    qc(12),           jm
     +             gl(3,4),  kkk(6,2),                                 jm
     +             rnlm1(numdof,nlsv1),  rnlm2(numdof,nlsv2)           jm
c     level 2,e,g,ro,coprop,sft                                        jm
c                                                                      jm
c     **  Subroutine DF3 by W. Cofer & J. McGuire, 12/10/92          ** jm
c                                                                      jm
c     **  This subroutine receives input data for a single DF        ** jm
c     **  element and forms element stiffness, damping, and mass     ** jm
c     **  matrices in local and global coordinates, determines       ** jm
c     **  fixed end forces, and initializes the "rnlm1" and           ** jm
c     **  "rnlm2" arrays.                                            ** jm
c                                                                      jm
c     write(*,7777) 1                                                  jm
c                                                                      jm
c     **  initialize variables.                                      ** jm
c                                                                      jm
      pi = 4.0*atan(1.0)                                               jm
      do  7 i=1,3                                                      jm
        do 5 j=1,4                                                     jm
          gl(i,j) = 0.0                                                jm
    5   continue                                                       jm
    7 continue                                                         jm
      do 40 i=1,12                                                     jm
        xml(i) = 0.0                                                   jm
        rs(i)  = 0.0                                                   jm
        rc(i)  = 0.0                                                   jm
        qs(i)  = 0.0                                                   jm
        qc(i)  = 0.0                                                   jm
        do 10 j=1,4                                                    jm
          sf(i,j) = 0.0                                                jm
   10   continue                                                       jm
        do 20 j=1,12                                                   jm
          s(i,j) = 0.0                                                 jm
          c(i,j) = 0.0                                                 jm
   20   continue                                                       jm
        do 30 j=1,24                                                   jm
          sa(i,j) = 0.0                                                jm
          ca(i,j) = 0.0                                                jm
   30   continue                                                       jm
   40 continue                                                         jm
      do 70 i=1,24                                                     jm
        xm(i) = 0.0                                                    jm
        do 50 j=1,4                                                    jm
          rf(i,j) = 0.0                                                jm
   50   continue                                                       jm
        do 60 j=1,24                                                   jm
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0        1         2         3         4         5         6         7
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          asa(i,j) = 0.0                                                jm
          aca(i,j) = 0.0                                                jm
   60   continue                                                        jm
   70 continue                                                         jm
c                                                                      jm
c     **  form element stiffness, damping, and mass                 ** jm
c     **  matricies in local coordinates                            ** jm
c                                                                      jm
      do 80 ij = 1, 6                                                  jm
        qk0           =  qssi(np,ij,1)                                 jm
        s(ij,  ij  ) =  qk0                                            jm
        s(ij+6,ij  ) = -qk0                                            jm
        s(ij,  ij+6) = -qk0                                            jm
        s(ij+6,ij+6) =  qk0                                            jm
        qc0           =  cssi(np,ij,1)                                 jm
        c(ij,  ij  ) =  qc0                                            jm
        c(ij+6,ij  ) = -qc0                                            jm
        c(ij,  ij+6) = -qc0                                            jm
        c(ij+6,ij+6) =  qc0                                            jm
   80 continue                                                         jm
      do 85 i = 1, 3                                                   jm
        xml(i  ) = wssi(np,i,1)                                        jm
        xml(i+6) = wssi(np,i,2)                                        jm
   85 continue                                                         jm
c                                                                      jm
c     **  Modify damping matrix for Proportional Damping Option     ** jm
c                                                                      jm
      ird = iessi(np,9)                                                jm
      if (ird.eq.1) then                                               jm
        do 100 i = 1, 12                                               jm
          c(i,i) = c(i,i) + alfa*xml(i)                                jm
          do 90 j = 1, 12                                              jm
            c(i,j) = c(i,j) + beta*s(i,j)                              jm
   90     continue                                                     jm
  100   continue                                                       jm
      end if                                                           jm
c                                                                      jm
c     **  determine gravitational acceleration components           ** jm
c     **  in local directions for load cases A-D.                   ** jm
c                                                                      jm
      do 135 j=1,4                                                     jm
        do 130 i=1,3                                                   jm
          sum = 0.0                                                    jm
          do 125 k=1,3                                                 jm
            sum = sum + t(i,k)*emul(k,j)                               jm
  125     continue                                                     jm
          gl(i,j) = sum                                                jm
  130   continue                                                       jm
  135 continue                                                         jm
c                                                                      jm
c     **  determine fixed end forces in local coordinates.          ** jm
c                                                                      jm
      virtual = 0.0                                                    jm
      do 140 j=1,4                                                     jm
        do 138 i = 1, 3                                                jm
          glc = gl(i,j)                                                jm
          sf(i,  j) = -virtual*xml(i  )*glc                            jm
          sf(i+6,j) = -virtual*xml(i+6)*glc                            jm
  138   continue                                                       jm
  140 continue                                                         jm
c                                                                      jm
c     **  modify stiffness, damping, and fixed end forces for       ** jm
c     **  zero end conditions                                       ** jm
c                                                                      jm
      inelki = iessi(il,6)                                             jm
      inelkj = iessi(il,7)                                             jm
      isupt  = iessi(il,8)                                             jm
      if ((inelki.ne.0).or.(inelkj.ne.0)) then                         jm
        do 160 j = 1, 2                                                jm
          if (j.eq.1) then                                             jm
            cd = real(inelki)                                          jm
          else                                                         jm
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0        1         2         3         4         5         6         7
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0        1         2         3         4         5         6         7
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            cd = real(inelkj)                                          jm
          end if                                                       jm
          cd = cd/1000000.0                                            jm
          do 142 i = 1, 6                                              jm
            qq  = anint(10.0**i)                                       jm
            ic1 =  nint(qq*cd)                                         jm
            ic2 =  nint(nint(ic1/10.0)*10.0)                           jm
            icq = ic1 - ic2                                            jm
            if ((icq.eq.0).or.(icq.eq.1)) then                         jm
              kkk(i,j) = icq                                           jm
            else                                                       jm
              stop                                                     jm
            end if                                                     jm
  142     continue                                                     jm
          do 154 n = 1, 6                                              jm
            i = 6*(j-1) + n                                            jm
            if (kkk(n,j).eq.1) then                                    jm
              sii = s(i,i)                                             jm
              cii = c(i,i)                                             jm
              do 144 k = 1, 12                                         jm
                rs(k) = s(i,k)                                         jm
                rc(k) = c(i,k)                                         jm
  144         continue                                                 jm
              do 148 k = 1, 12                                         jm
                qs(k) = s(k,i)/sii                                     jm
                qc(k) = c(k,i)/cii                                     jm
                do 146 m = 1, 12                                       jm
                  s(k,m) = s(k,m) - qs(k)*rs(m)                        jm
                  c(k,m) = c(k,m) - qc(k)*rc(m)                        jm
  146           continue                                               jm
  148         continue                                                 jm
              do 152 k = 1, 4                                          jm
                sfi   = sf(i,k)                                        jm
                do 150 m = 1, 12                                       jm
                  sf(m,k) = sf(m,k) - qs(m)*sfi                        jm
  150           continue                                               jm
  152         continue                                                 jm
            end if                                                     jm
  154     continue                                                     jm
  160   continue                                                       jm
      end if                                                           jm
c                                                                      jm
c     **  perform local to global transformation                   ** jm
c                                                                      jm
      do 180 la = 1, 10, 3                                             jm
        lb = la + 2                                                    jm
        do 178 ma = 1, 10, 3                                           jm
          mb = ma - 1                                                  jm
          do 176 i = la, lb                                            jm
            do 174 jm = 1, 3                                           jm
              j = jm + mb                                              jm
              xs = 0.0                                                 jm
              xc = 0.0                                                 jm
              do 170 k = 1, 3                                          jm
                xs = xs + s(i,k+mb)*t(k,jm)                            jm
                xc = xc + c(i,k+mb)*t(k,jm)                            jm
  170         continue                                                 jm
              sa(i,j) = xs                                             jm
              ca(i,j) = xc                                             jm
  174       continue                                                   jm
  176     continue                                                     jm
  178   continue                                                       jm
  180 continue                                                         jm
c                                                                      jm
c     **  elem stiffness asa(12,12), damping aca(12,12), and       ** jm
c     **  fixed end forces rf(12) in global coordinates            ** jm
c                                                                      jm
      do 200 la = 1, 10, 3                                             jm
        lb = la - 1                                                    jm
        do 198 ma = 1, 10, 3                                           jm
          mb = ma + 2                                                  jm
          do 196 il = 1, 3                                             jm
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```
            i = il + lb                                                  jm
            do 194 j = ma, mb                                            jm
              xs = 0.0                                                   jm
              xc = 0.0                                                   jm
              do 190 k = 1, 3                                            jm
                xs = xs + t(k,il)*sa(k+lb,j)                             jm
                xc = xc + t(k,il)*ca(k+lb,j)                             jm
  190         continue                                                   jm
              asa(i,j) = xs                                              jm
              aca(i,j) = xc                                              jm
  194       continue                                                     jm
  196     continue                                                       jm
  198   continue                                                         jm
  200 continue                                                         jm
c                                                                      jm
      do 220 la = 1, 10, 3                                             jm
        lb = la - 1                                                    jm
        do 218 il = 1, 3                                               jm
          i=il + lb                                                    jm
          do 216 n = 1, 4                                              jm
            xf = 0.0                                                   jm
            xw = 0.0                                                   jm
            do 210 k = 1, 3                                            jm
              xf = xf - t(k,il)*sf(k+lb,n)                             jm
              xw = xw + t(k,il)*xml(k+lb)                              jm
  210       continue                                                   jm
            rf(i,n) = xf                                               jm
            xm(i)   = xw                                               jm
  216     continue                                                     jm
  218   continue                                                       jm
  220 continue                                                         jm
c                                                                      jm
c     *** Determine 'rnlm1' and 'rnlm2' matricies  ***                 jm
c                                                                      jm
      do 250 n = 1, numdof                                             jm
c                                                                      jm
        rkei = qssi(np,n,1)                                            jm
        fyi  = qssi(np,n,2)                                            jm
        rkp  = qssi(np,n,3)                                            jm
        rkg1 = qssi(np,n,4)                                            jm
        rkg2 = qssi(np,n,5)                                            jm
        sd   = qssi(np,n,6)                                            jm
        rik  = qssi(np,n,7)                                            jm
        rhoe = 0.0                                                     jm
        rhop = qssi(np,n,8)                                            jm
        riz  = qssi(np,n,9)                                            jm
c                                                                      jm
        if (rkei.ne.0.0) then                                          jm
          ruyi = fyi/rkei                                              jm
        else                                                           jm
          if (fyi.eq.0.0) then                                         jm
            ruyi = 0.0                                                 jm
          else                                                         jm
            ruyi = 1.0e+12                                             jm
          end if                                                       jm
        end if                                                         jm
        elflag  = 1.0                                                  jm
        xorigin = 0.0                                                  jm
        yorigin = 0.0                                                  jm
        rke     = rkei                                                 jm
        fy      = fyi                                                  jm
        ruy     = ruyi                                                 jm
        rub     = 0.0                                                  jm
        drub    = 0.0                                                  jm
        rktb    = rke                                                  jm
        pb      = 0.0                                                  jm
        grt     = 0.0                                                  jm
        glt     = 0.0                                                  jm
        gap     = 0.0                                                  jm
        rubmax  = 0.0                                                  jm
        pbmax   = 0.0                                                  jm
        right   = 0.0                                                  jm
```

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        first   = 1.0                                                   jm
c                                                                       jm
        rnlm1(n, 1) = rkei                                              jm
        rnlm1(n, 2) = fyi                                               jm
        rnlm1(n, 3) = ruyi                                              jm
        rnlm1(n, 4) = rkp                                               jm
        rnlm1(n, 5) = rkg1                                              jm
        rnlm1(n, 6) = rkg2                                              jm
        rnlm1(n, 7) = sd                                                jm
        rnlm1(n, 8) = rik                                               jm
        rnlm1(n, 9) = rhoe                                              jm
        rnlm1(n,10) = rhop                                              jm
        rnlm1(n,11) = riz                                               jm
c                                                                       jm
        rnlm2(n, 1) = elflag                                            jm
        rnlm2(n, 2) = xorigin                                           jm
        rnlm2(n, 3) = yorigin                                           jm
        rnlm2(n, 4) = rke                                               jm
        rnlm2(n, 5) = fy                                                jm
        rnlm2(n, 6) = ruy                                               jm
        rnlm2(n, 7) = rub                                               jm
        rnlm2(n, 8) = drub                                              jm
        rnlm2(n, 9) = rktb                                              jm
        rnlm2(n,10) = pb                                                jm
        rnlm2(n,11) = grt                                               jm
        rnlm2(n,12) = glt                                               jm
        rnlm2(n,13) = gap                                               jm
        rnlm2(n,14) = rubmax                                            jm
        rnlm2(n,15) = pbmax                                             jm
        rnlm2(n,16) = right                                             jm
        rnlm2(n,17) = first                                             jm
c                                                                       jm
  250 continue                                                          jm
c                                                                       jm
c     write(*,7778) 1                                                   jm
      return                                                            jm
c                                                                       jm
 7777 format (1x,'DF3 enter ',i2)                                       jm
 7778 format (1x,'DF3 exit  ',i2)                                       jm
 7779 format (1x,'DF3 stop  ',i2)                                       jm
c                                                                       jm
      end                                                               jm
c                                                                       jm
c                                                                       jm
c                                                                       jm
c     *****  DF4 subroutine  ***************************************** jm
                                                                        jm
      subroutine df4 ( nel,icond,nind,last,mtot,asa,sa,s,lms,ec,t,      jm
     +                 assa,ssa,df,f,up,ex,dex,efi,ndof,nlsv1,nlsv2 )   jm
                                                                        jm
      implicit double precision (a-h, o-z), integer (i-n)               jm
      dimension    asa(24,24),sa(12,24),s(12,12),lms(12),ec(12),t(3,3), jm
     +             assa(24,24),ssa(12,24),df(24),f(12),up(12),          jm
     +             ex(24),dex(24),efi(12)                               jm
      common/biga/ a(99000)                                             jm
c                                                                       jm
c     **  Subroutine DF4 by W. Cofer & J. McGuire, 12/10/92             jm
c                                                                       jm
c     **  This subroutine allocates space in the global "a" matrix   ** jm
c     **  for temporary storage of DF element data for use by        ** jm
c     **  subroutines DF5 and DF6.                                   ** jm
c                                                                       jm
c     write (*,7777) 1                                                  jm
c                                                                       jm
      nn1 = last                                                        jm
      nn2 = nn1 + ndof*nlsv1                                            jm
      nn3 = nn2 + ndof*nlsv2                                            jm
      nn4 = nn3 + ndof*nlsv2                                            jm
      final = nn4                                                       jm
      if (final.gt.mtot) then                                           jm
        write (*,7778) 1                                                jm
        call error (1, last-mtot, 7hstepc   )                           jm
```

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       write (*,7777) 2                                                  jm
      end if                                                             jm
c                                                                        jm
      call df5(        nel, icond, nind, asa, sa, s, lms, ec, t,         jm
     +                 assa, ssa, df, f, up, ex, dex, efi,               jm
     +                 ndof, nlsv1, nlsv2, a(nn1), a(nn2), a(nn3) )      jm
c                                                                        jm
c     write (*,7778) 2                                                   jm
      return                                                             jm
c                                                                        jm
 7777 format (1x,'DF4 enter ',i2)                                        jm
 7778 format (1x,'DF4 exit  ',i2)                                        jm
 7779 format (1x,'DF4 stop  ',i2)                                        jm
                                                                         jm
      end                                                                jm
                                                                         jm
                                                                         jm
c     ***** DF5 subroutine *****************************************     jm
c                                                                        jm
      subroutine df5 ( nel, icond, nind, asa, sa, s, lms, ec, t,         jm
     +                 assa, ssa, df, f, up, ex, dex, efi,               jm
     +                 ndof, nlsv1, nlsv2, rnlm1, rnlm2, rnlm3    )      jm
c                                                                        jm
c     implicit double precision(a-h,o-z), integer(i-n)                   jm
      dimension   asa(24,24),sa(12,24),s(12,12),lms(12),ec(12),t(3,3),   jm
     +            assa(24,24),ssa(12,24),df(24),f(12),up(12),            jm
     +            ex(24),dex(24),efi(12),                                jm
     +            rnlm1(ndof,nlsv1),rnlm2(ndof,nlsv2),rnlm3(ndof,nlsv2)  jm
      dimension   ss(12,12),u(12),du(12),p(12),dp(12),x(12),dx(12)       jm
c                                                                        jm
c     ***  Subroutine DF5 by W. Cofer & J. McGuire, 12/10/92             jm
c                                                                        jm
c     ***  This subroutine receives and processes data for the DF    *** jm
c     ***  elements for the current time step, manages the           *** jm
c     ***  calculation of the tangential stiffness matrix and        *** jm
c     ***  element force vectors for each DF element (performed      *** jm
c     ***  in subroutine DF6).                                           jm
c                                                                        jm
c     write (*,7777) 1                                                   jm
c                                                                        jm
c     ***  Initialize variables; setting "nind" not equal to zero    *** jm
c     ***  indicates that element is responding nonlinearly.         *** jm
c                                                                        jm
      nind = 1                                                           jm
      do 120 i = 1, 12                                                   jm
        x(i)     = ex(i)                                                 jm
        dx(i)    = dex(i)                                                jm
        u(i)     = 0.0                                                   jm
        du(i)    = 0.0                                                   jm
        up(i)    = 0.0                                                   jm
        p(i)     = 0.0                                                   jm
        dp(i)    = 0.0                                                   jm
        f(i)     = 0.0                                                   jm
        efi(i)   = 0.0                                                   jm
        df(i)    = 0.0                                                   jm
        do 110 j = 1, 12                                                 jm
          ss  (i,   j   ) = 0.0                                          jm
          ssa (i,   j   ) = 0.0                                          jm
          ssa (i,   j+12) = 0.0                                          jm
          assa(i,   j   ) = 0.0                                          jm
          assa(i+12,j   ) = 0.0                                          jm
          assa(i,   j+12) = 0.0                                          jm
          assa(i+12,j+12) = 0.0                                          jm
  110   continue                                                         jm
  120 continue                                                           jm
c                                                                        jm
c     ***  Transform to master degrees-of-freedom  ***                   jm
c                                                                        jm
      kk = 1                                                             jm
      kd = 13                                                            jm
      do 140 nf = 1, 2                                                   jm
```

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        do 130 k = 1, 3                                                 jm
          i = 6*(nf-1) + k                                              jm
          if (lms(i).gt.0) then                                         jm
            d1    = ec(kk  )                                          jm
            d2    = ec(kk+1)                                          jm
            dx(i) = dx(i) + dex(kd)*d1 + dex(kd+1)*d2                   jm
            x(i)  =  x(i) - dex(i) + dx(i)                              jm
            kk    = kk + 2                                              jm
            kd    = kd + 2                                              jm
          end if                                                        jm
  130   continue                                                        jm
  140 continue                                                          jm
c                                                                       jm
c     ***  Convert elmnt displacement from global to local coords.  *** jm
c                                                                       jm
      do 170 n = 0, 9, 3                                                jm
        do 160 i = 1, 3                                                 jm
          sum1 = 0.0                                                    jm
          sum2 = 0.0                                                    jm
          do 150 j = 1, 3                                               jm
            sum1 = sum1 + t(i,j)* x(n+j)                                jm
            sum2 = sum2 + t(i,j)*dx(n+j)                                jm
  150     continue                                                      jm
          u(n+i)  = sum1                                                jm
          du(n+i) = sum2                                                jm
          up(n+i) = u(n+i)                                              jm
  160   continue                                                        jm
  170 continue                                                          jm
c                                                                       jm
c     ***  Determine following elmnt variables in local coords  ***    jm
c     ***       ss: tangential stiffness matrix                 ***    jm
c     ***    p, dp: "true" force & "nonlinear restoring" force  ***    jm
c                                                                       jm
      call df6 ( icond, ndof, nlsv1, nlsv2, rnlm1, rnlm2, rnlm3,        jm
     +           u, du, ss, p, dp                                    )  jm
c                                                                       jm
c     ***  Convert elemental tangential stiffnes matrix from  ***      jm
c     ***  local to global coords.                            ***      jm
c                                                                       jm
      do 220 la = 1, 10, 3                                              jm
        lb = la + 2                                                     jm
        do 210 ma = 1, 10, 3                                            jm
          mb = ma - 1                                                   jm
          do 200 i = la, lb                                             jm
            do 190 jm = 1, 3                                            jm
              j = jm + mb                                               jm
              sum = 0.0                                                 jm
              do 180 k = 1, 3                                           jm
                sum = sum + t(k,jm)*ss(i,k+mb)                          jm
  180         continue                                                  jm
              ssa(i,j) = sum                                            jm
  190       continue                                                    jm
  200     continue                                                      jm
  210   continue                                                        jm
  220 continue                                                          jm
c                                                                       jm
      do 270 la = 1, 10, 3                                              jm
        lb = la - 1                                                     jm
        do 260 ma = 1, 10, 3                                            jm
          mb = ma + 2                                                   jm
          do 250 il = 1, 3                                              jm
            i = il + lb                                                 jm
            do 240 j = ma, mb                                           jm
              sum = 0.0                                                 jm
              do 230 k = 1, 3                                           jm
                sum = sum + t(k,il)*ssa(k+lb,j)                         jm
  230         continue                                                  jm
              assa(i,j) = sum                                           jm
  240       continue                                                    jm
  250     continue                                                      jm
  260   continue                                                        jm
  270 continue                                                          jm
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0        1         2         3         4         5         6         7
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c                                                                      jm
c     ***  Transform to master degrees-of-freedom  ***                 jm
c                                                                      jm
      kk = 1                                                           jm
      kd = 13                                                          jm
      do 310 nf = 1, 2                                                 jm
        do 300 k = 1, 3                                                jm
          i = 6*(nf-1) + k                                             jm
          if (lms(i).gt.0) then                                        jm
            d1 = ec(kk  )                                              jm
            d2 = ec(kk+1)                                              jm
            do 280 ii = 1, 12                                          jm
              ssa(ii,kd  ) = ssa(ii,i)*d1                              jm
              ssa(ii,kd+1) = ssa(ii,i)*d2                              jm
  280       continue                                                   jm
            do 290 ii = 1, kd                                          jm
              assa(kd  ,ii  ) = assa(i, ii)*d1                         jm
              assa(kd+1,ii  ) = assa(i, ii)*d2                         jm
              assa(ii,  kd  ) = assa(ii,i )*d1                         jm
              assa(ii,  kd+1) = assa(ii,i )*d2                         jm
  290       continue                                                   jm
            assa(kd,  kd  ) = assa(i,i)*(d1**2)                        jm
            assa(kd+1,kd+1) = assa(i,i)*(d2**2)                        jm
            assa(kd,  kd+1) = assa(i,i)*(d1*d2)                        jm
            assa(kd+1,kd  ) = assa(kd,  kd+1)                          jm
            kk = kk + 2                                                jm
            kd = kd + 2                                                jm
          end if                                                       jm
  300   continue                                                       jm
  310 continue                                                         jm
c                                                                      jm
c     ***  Set elemental force vector, local coordinates.  ***         jm
c                                                                      jm
      do 320 n = 1, 12                                                 jm
        f(n) = p(n)                                                    jm
  320 continue                                                         jm
c                                                                      jm
c     ***  Convert true elemental "nonlinear restoring force"  ***     jm
c     ***  vector from local to global coordinates.            ***     jm
c                                                                      jm
      do 350 n = 0, 9, 3                                               jm
        do 340 i = 1, 3                                                jm
          sum = 0.0                                                    jm
          do 330 j = 1, 3                                              jm
            sum = sum + t(j,i)*dp(n+j )                                jm
  330     continue                                                     jm
          efi(n+i) = sum                                               jm
  340   continue                                                       jm
  350 continue                                                         jm
c                                                                      jm
c     write (*,7778) 1                                                 jm
      return                                                           jm
c                                                                      jm
 7777 format (1x,'DF5 enter ',i2)                                      jm
 7778 format (1x,'DF5 exit  ',i2)                                      jm
 7779 format (1x,'DF5 stop  ',i2)                                      jm
c                                                                      jm
      end                                                              jm
c                                                                      jm
c                                                                      jm
c                                                                      jm
c     *****  DF6 subroutine  ***************************************  jm
c                                                                      jm
      subroutine df6 ( icond, ndof, nlsv1, nlsv2, rnlm1, rnlm2, rnlm3, jm
     +                 u, du, ss, p, dp                              ) jm
c                                                                      jm
c     implicit double precision (a-h,o-z), integer (i-n)               jm
      dimension   u(12),du(12),ss(12,12),p(12),dp(12),                 jm
     +            rnlm1(ndof,nlsv1),rnlm2(ndof,nlsv2),rnlm3(ndof,nlsv2) jm
      dimension   tmp(6,3), tmp2(6,14)                                 jm
c                                                                      jm
c     ***  Subroutine DF6 by W. Cofer & J. McGuire, 12/10/92       *** jm
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0        1         2         3         4         5         6         7
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              end if                                                                jm
              if (jswitch.eq.-1) then                                               jm
                ielflag = -2                                                        jm
                xorigin = ru0                                                       jm
                yorigin = 0.0                                                       jm
              elseif (jswitch.eq.1) then                                            jm
                if (abs(eru).gt.ruy) then                                           jm
                  if (iz.eq.1) then                                                 jm
                    if (fy-abs(yorigin).ge.0.0) then                                jm
                      ielflag = -1                                                  jm
                      ixyalg  =  1                                                  jm
                    elseif ((iptrial.ne.iyorigin).or.                               jm
     +                     (yorigin.eq.0.0)          ) then                       jm
                      ielflag = -1                                                  jm
                      ixyalg  =  2                                                  jm
                    elseif ((iptrial.eq.iyorigin        ).and.                      jm
     +                     (abs(ptrial).ge.abs(yorigin))      ) then               jm
                      ielflag = -1                                                  jm
                      ixyalg  =  1                                                  jm
                    else                                                            jm
                      continue                                                      jm
                    end if                                                          jm
                  else                                                              jm
                    ielflag = -1                                                    jm
                    ixyalg  =  1                                                    jm
                  end if                                                            jm
                  if (ielflag.eq.-1) then                                           jm
                    if (ixyalg.eq.1) then                                           jm
                      if (eru.gt.0.0) then                                          jm
                        xorigin = xorigin + ruy                                     jm
                        yorigin = yorigin + fy                                      jm
                      else                                                          jm
                        xorigin = xorigin - ruy                                     jm
                        yorigin = yorigin - fy                                      jm
                      end if                                                        jm
                    elseif (ixyalg.eq.2) then                                       jm
                      if ((pb.eq.ptrial).or.(pb.eq.0.0)) then                       jm
                        ratio = 0.0                                                 jm
                      elseif (ptrial.eq.0.0) then                                   jm
                        ratio = 1.0                                                 jm
                      else                                                          jm
                        ratio = pb/(pb-ptrial)                                      jm
                      end if                                                        jm
                      ru0   = rub + ratio*dru                                       jm
                      xorigin = ru0                                                 jm
                      yorigin = 0.0                                                 jm
                    end if                                                          jm
                    delta = rhoe*(xorigin - rub) + rhop*(ru - xorigin)              jm
                  end if                                                            jm
                end if                                                              jm
                if (ptrial.ge.0.0) then                                             jm
                  gap = gap + delta                                                 jm
                  gr  = ru                                                          jm
                  gl  = gr - gap                                                    jm
                elseif (ptrial.lt.0.0) then                                         jm
                  gap = gap - delta                                                 jm
                  gl  = ru                                                          jm
                  gr  = gl + gap                                                    jm
                end if                                                              jm
              end if                                                                jm
c                                                                                   jm
c           ***  DF element currently plastic  ***                                  jm
c                                                                                   jm
              elseif (ielflag.eq.-1) then                                           jm
                delta   = rhop*dru                                                  jm
                jswitch = 1                                                         jm
                if (iptrial.ne.ipb) then                                            jm
                  if ((pb.eq.ptrial).or.(pb.eq.0.0)) then                           jm
                    ratio = 0.0                                                     jm
                  elseif (ptrial.eq.0.0) then                                       jm
                    ratio = 1.0                                                     jm
                  else                                                              jm
12345678901234567890123456789012345678901234567890123456789012345678
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0         1         2         3         4         5         6         7
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                ratio = pb/(pb -ptrial)                                  jm
              end if                                                     jm
              ru0   = rub + ratio*dru                                    jm
              if (ptrial.ge.0.0) then                                    jm
                glt = ru0                                                jm
                grt = glt + (gap - ratio*delta)                          jm
                if (ru.le.grt) then                                      jm
                  jswitch = -1                                           jm
                  gap     =  gap - ratio*delta                           jm
                  gl      =  glt                                         jm
                  gr      =  grt                                         jm
                end if                                                   jm
              elseif (ptrial.lt.0.0) then                                jm
                grt = ru0                                                jm
                glt = grt - (gap + ratio*delta)                          jm
                if (ru.ge.glt) then                                      jm
                  jswitch = -1                                           jm
                  gap     =  gap + ratio*delta                           jm
                  gr      =  grt                                         jm
                  gl      =  glt                                         jm
                end if                                                   jm
              end if                                                     jm
            end if                                                       jm
            if (jswitch.eq.-1) then                                      jm
              ielflag = -2                                               jm
              xorigin =  ru0                                             jm
              yorigin =  0.0                                             jm
            elseif (jswitch.eq.1) then                                   jm
              if (iswitch.eq.-1) then                                    jm
                ielflag =  1                                             jm
                if (rubmax.le.ruyi) then                                 jm
                  rke = rkei                                             jm
                elseif (rubmax.ne.0.0) then                              jm
                  rke = rkei*( (ruyi/rubmax)**sd )                       jm
                else                                                     jm
                  stop                                                   jm
                end if                                                   jm
                fy  = fyi + rik*(pbmax - fyi)                            jm
                if (rke.ne.0.0) then                                     jm
                  ruy = fy/rke                                           jm
                else                                                     jm
                  if (fy.eq.0.0) then                                    jm
                    ruy = 0.0                                            jm
                  else                                                   jm
                    ruy = 1.0e+12                                        jm
                  end if                                                 jm
                end if                                                   jm
                delta = rhoe*dru                                         jm
                if (dru.le.0.0) then                                     jm
                  xorigin = rub - ruy                                    jm
                  yorigin = pb  - fy                                     jm
                else                                                     jm
                  xorigin = rub + ruy                                    jm
                  yorigin = pb  + fy                                     jm
                end if                                                   jm
              end if                                                     jm
              if (ptrial.ge.0.0) then                                    jm
                gap = gap + delta                                        jm
                gr  = ru                                                 jm
                gl  = gr - gap                                           jm
              elseif (ptrial.lt.0.0) then                                jm
                gap = gap - delta                                        jm
                gl  = ru                                                 jm
                gr  = gl + gap                                           jm
              end if                                                     jm
            end if                                                       jm
c                                                                        jm
c         ***  DF element currently within gap at rkg1 stiffness  ***    jm
c                                                                        jm
            elseif( ielflag.eq.-2) then                                  jm
              if (iswitch.eq.-1) then                                    jm
                ielflag = 2                                              jm
12345678901234567890123456789012345678901234567890123456789012345678
0         1         2         3         4         5         6         7
```

```
0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
c                                                                      jm
c     ***  This subroutines receives current data for a single DF   *** jm
c     ***  DF element and determines the element tangential         *** jm
c     ***  stiffness matrix and element force vectors for current   *** jm
c     ***  time step.                                               *** jm
c                                                                      jm
      data nthru  / 0 /                                                jm
      save nthru                                                       jm
      nthru  =  nthru + 1                                              jm
c                                                                      jm
c     write (*,7777) 1                                                 jm
c                                                                      jm
      read (13) rnlm1                                                  jm
      if (icond.eq.2) then                                             jm
        read      (16) rnlm3                                           jm
        backspace (16)                                                 jm
        write     (14) rnlm3                                           jm
        backspace (14)                                                 jm
      end if                                                           jm
      read      (14) rnlm2                                           jm
      backspace (14)                                                 jm
      read      (15) rnlm3                                           jm
      if (icond.ne.3) then                                             jm
        backspace (15)                                                 jm
        write     (15) rnlm2                                           jm
        write     (16) rnlm3                                           jm
      end if                                                           jm
c                                                                      jm
      do 110 i = 1, ndof                                               jm
c                                                                      jm
        rkei    = rnlm1(i, 1)                                          jm
        fyi     = rnlm1(i, 2)                                          jm
        ruyi    = rnlm1(i, 3)                                          jm
        rkp     = rnlm1(i, 4)                                          jm
        rkg1    = rnlm1(i, 5)                                          jm
        rkg2    = rnlm1(i, 6)                                          jm
        sd      = rnlm1(i, 7)                                          jm
        rik     = rnlm1(i, 8)                                          jm
        rhoe    = rnlm1(i, 9)                                          jm
        rhop    = rnlm1(i,10)                                          jm
        riz     = rnlm1(i,11)                                          jm
c                                                                      jm
        elflag  = rnlm2(i, 1)                                          jm
        xorigin = rnlm2(i, 2)                                          jm
        yorigin = rnlm2(i, 3)                                          jm
        rke     = rnlm2(i, 4)                                          jm
        fy      = rnlm2(i, 5)                                          jm
        ruy     = rnlm2(i, 6)                                          jm
        rub     = rnlm2(i, 7)                                          jm
        drub    = rnlm2(i, 8)                                          jm
        rktb    = rnlm2(i, 9)                                          jm
        pb      = rnlm2(i,10)                                          jm
        gr      = rnlm2(i,11)                                          jm
        gl      = rnlm2(i,12)                                          jm
        gap     = rnlm2(i,13)                                          jm
        rubmax  = rnlm2(i,14)                                          jm
        pbmax   = rnlm2(i,15)                                          jm
        right   = rnlm2(i,16)                                          jm
        first   = rnlm2(i,17)                                          jm
c                                                                      jm
        ielflag = nint(         elflag )                               jm
        iz      = nint(riz             )                               jm
        ifirst  = nint(sign(1.0,first ))                               jm
c                                                                      jm
        ru   =  u(i) -  u(i+6)                                         jm
        dru  = ru - rub                                                jm
        if (icond.eq.3) then                                           jm
          trub = rnlm3(i,7)                                            jm
          tdru = ru - trub                                             jm
        else                                                           jm
          trub = rub                                                   jm
          tdru = dru                                                   jm
12345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7
```

```
0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
        end if                                                          jm
c                                                                       jm
        eru = ru - xorigin                                              jm
        ptrial = yorigin + rktb*eru                                     jm
c                                                                       jm
        if (icond.ne.3) then                                            jm
c                                                                       jm
c         ***  Determine if a change of state (elastic,      ***       jm
c         ***  plastic, or in-gap) has occurred; if so,      ***       jm
c         ***  update "ielflag", "xorigin", and "yorigin".   ***       jm
c                                                                       jm
c         ***     1. Update maximum displacement and force   ***       jm
c                                                                       jm
          if (abs(rub).gt.rubmax) then                                  jm
            rubmax = abs(rub)                                           jm
          end if                                                        jm
          if (abs(pb).gt.pbmax) then                                    jm
            pbmax = abs(pb)                                             jm
          end if                                                        jm
c                                                                       jm
c         ***     2. Check for reversal of direction; if          ***   jm
c         ***        continuing in present direction,             ***   jm
c         ***        "iswitch" = 1; if reverse, "iswitch" = -1.   ***   jm
c                                                                       jm
          iswitch = 1                                                   jm
          idru  = nint(sign(1.0,dru ))                                  jm
          idrub = nint(sign(1.0,drub))                                  jm
          if (idru.ne.idrub) then                                       jm
            iswitch = -1                                                jm
          end if                                                        jm
c                                                                       jm
c         ***     3. Determine if a change of state has occurred  ***   jm
c                                                                       jm
          ieru     = nint(sign(1.0,eru    ))                           jm
          iright   = nint(sign(1.0,right  ))                           jm
          ipb      = nint(sign(1.0,pb     ))                           jm
          iptrial  = nint(sign(1.0,ptrial ))                           jm
          iyorigin = nint(sign(1.0,yorigin))                           jm
c                                                                       jm
c         ***  DF element currently elastic  ***                       jm
c                                                                       jm
          if (ielflag.eq.1) then                                        jm
            delta   = rhoe*dru                                          jm
            jswitch = 1                                                 jm
            if ((iptrial.ne.ipb).and.(ifirst.lt.0)) then                jm
              if ((pb.eq.ptrial).or.(pb.eq.0.0)) then                   jm
                ratio = 0.0                                             jm
              elseif (ptrial.eq.0.0) then                               jm
                ratio = 0.0                                             jm
              else                                                      jm
                ratio = pb/(pb -ptrial)                                 jm
              end if                                                    jm
              ru0   = rub + ratio*dru                                   jm
              if (ptrial.ge.0.0) then                                   jm
                glt = ru0                                               jm
                grt = glt + (gap - ratio*delta)                         jm
                if (ru.le.grt) then                                     jm
                  jswitch = -1                                          jm
                  gap     =  gap - ratio*delta                          jm
                  gl      =  glt                                        jm
                  gr      =  grt                                        jm
                end if                                                  jm
              elseif (ptrial.lt.0.0) then                               jm
                grt = ru0                                               jm
                glt = grt - (gap + ratio*delta)                         jm
                if (ru.ge.glt)  then                                    jm
                  jswitch = -1                                          jm
                  gap     =  gap + ratio*delta                          jm
                  gr      =  grt                                        jm
                  gl      =  glt                                        jm
                end if                                                  jm
              end if                                                    jm
12345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7
```

```
0         1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
                xorigin = rub                                                   jm
                yorigin = pb                                                    jm
                if (drub.ge.0.0) then                                           jm
                  right =  1.0                                                  jm
                else                                                            jm
                  right = -1.0                                                  jm
                end if                                                          jm
              end if                                                            jm
              if ((ru.gt.gr).or.(ru.lt.gl)) then                                jm
                ielflag = 1                                                     jm
                if (ru.gt.gr) then                                              jm
                  rout  = gr                                                    jm
                  delta = rhoe*(ru - rout)                                      jm
                  gap   = gap + delta                                           jm
                  gr    = ru                                                    jm
                  gl    = gr - gap                                              jm
                elseif (ru.lt.gl) then                                          jm
                  rout  = gl                                                    jm
                  delta = rhoe*(ru - rout)                                      jm
                  gap   = gap - delta                                           jm
                  gl    = ru                                                    jm
                  gr    = gl + gap                                              jm
                end if                                                          jm
                yorigin = yorigin + rkg1*(rout - xorigin)                       jm
                xorigin = rout                                                  jm
              end if                                                            jm
c                                                                               jm
c         ***  DF element currently within gap at rkg2 stiffness  ***          jm
c                                                                               jm
            elseif( ielflag.eq.2) then                                          jm
              if ((iptrial.ne.ipb).or.(ieru.eq.iright)) then                    jm
                ielflag = -2                                                    jm
                if (iptrial.ne.ipb) then                                        jm
                  if ((pb.eq.ptrial).or.(pb.eq.0.0)) then                       jm
                    ratio = 0.0                                                 jm
                  elseif (ptrial.eq.0.0) then                                   jm
                    ratio = 1.0                                                 jm
                  else                                                          jm
                    ratio = pb/(pb - ptrial)                                    jm
                  end if                                                        jm
                  ru0   = rub + ratio*dru                                       jm
                  xorigin = ru0                                                 jm
                  yorigin = 0.0                                                 jm
                end if                                                          jm
              end if                                                            jm
              if ((ru.gt.gr).or.(ru.lt.gl)) then                                jm
                ielflag = 1                                                     jm
                if (ru.gt.gr) then                                              jm
                  rout  = gr                                                    jm
                  delta = rhoe*(ru - rout)                                      jm
                  gap   = gap + delta                                           jm
                  gr    = ru                                                    jm
                  gl    = gr - gap                                              jm
                elseif (ru.lt.gl) then                                          jm
                  rout  = gl                                                    jm
                  delta = rhoe*(ru - rout)                                      jm
                  gap   = gap - delta                                           jm
                  gl    = ru                                                    jm
                  gr    = gl + gap                                              jm
                end if                                                          jm
                yorigin = yorigin + rkg2*(rout - xorigin)                       jm
                xorigin = rout                                                  jm
              end if                                                            jm
            end if                                                              jm
c                                                                               jm
          elseif (icond.eq.3) then                                              jm
c                                                                               jm
            if ((ielflag.eq.1).or.(ielflag.eq.-1)) then                         jm
              if (ielflag.eq.1) then                                            jm
                delta = rhoe*dru                                                jm
              elseif (ielflag.eq.-1)  then                                      jm
                delta = rhop*dru                                                jm
12345678901234567890123456789012345678901234567890123456789012345678
0         1         2         3         4         5         6         7
```

```
0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
```

```
            end if                                                      jm
            if (ptrial.ge.0.0) then                                     jm
              gap = gap + delta                                         jm
              gr  = ru                                                  jm
              gl  = gr - gap                                            jm
            elseif (ptrial.lt.0.0) then                                 jm
              gap = gap - delta                                         jm
              gl  = ru                                                  jm
              gr  = gl + gap                                            jm
            end if                                                      jm
          end if                                                        jm
c                                                                       jm
        end if                                                          jm
c                                                                       jm
c       ***  Determine "pp", "rkt", and "dpp"  ***                      jm
c                                                                       jm
        eru = ru - xorigin                                              jm
        if     (ielflag.eq. 1) then                                     jm
          rkt =  rke                                                    jm
        elseif (ielflag.eq.-1) then                                     jm
          rkt = rkp                                                     jm
        elseif (ielflag.eq.-2) then                                     jm
          rkt = rkg1                                                    jm
        elseif (ielflag.eq. 2) then                                     jm
          rkt = rkg2                                                    jm
        end if                                                          jm
        pp  = yorigin + rkt*eru                                         jm
        dpp = pp - rkei*ru                                              jm
c                                                                       jm
c       ***  Store values  ***                                          jm
c                                                                       jm
        tmp(i,1) = rkt                                                  jm
        tmp(i,2) = pp                                                   jm
        tmp(i,3) = dpp                                                  jm
c                                                                       jm
        tmp2(i,1)  = rkt                                                jm
        tmp2(i,2)  = pp                                                 jm
        tmp2(i,3)  = dpp                                                jm
        tmp2(i,4)  = ru                                                 jm
        tmp2(i,5)  = dru                                                jm
        tmp2(i,6)  = rub                                                jm
        tmp2(i,7)  = drub                                               jm
        tmp2(i,8)  = pb                                                 jm
        tmp2(i,9)  = u(i)                                               jm
        tmp2(i,10) = u(i+6)                                             jm
        tmp2(i,11) = du(i)                                              jm
        tmp2(i,12) = du(i+6)                                            jm
        tmp2(i,13) = xorigin                                            jm
        tmp2(i,14) = yorigin                                            jm
c                                                                       jm
c       ***  Initialize current state variables as "previous"  ***     jm
c       ***  state varibles for next time step.                ***     jm
c                                                                       jm
        rub   =  ru                                                     jm
        drub  =  tdru                                                   jm
        rktb  =  rkt                                                    jm
        pb    =  pp                                                     jm
        first = -1.0                                                    jm
c                                                                       jm
        elflag      = real(ielflag)                                     jm
        rnlm2(i, 1) = elflag                                            jm
        rnlm2(i, 2) = xorigin                                           jm
        rnlm2(i, 3) = yorigin                                           jm
        rnlm2(i, 4) = rke                                               jm
        rnlm2(i, 5) = fy                                                jm
        rnlm2(i, 6) = ruy                                               jm
        rnlm2(i, 7) = rub                                               jm
        rnlm2(i, 8) = drub                                              jm
        rnlm2(i, 9) = rktb                                              jm
        rnlm2(i,10) = pb                                                jm
        rnlm2(i,11) = gr                                                jm
        rnlm2(i,12) = gl                                                jm
```

```
12345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7
```

```
0        1         2         3         4         5         6         7
12345678901234567890123456789012345678901234567890123456789012345678
        rnlm2(i,13) = gap                                                jm
        rnlm2(i,14) = rubmax                                             jm
        rnlm2(i,15) = pbmax                                              jm
        rnlm2(i,16) = right                                              jm
        rnlm2(i,17) = first                                              jm
c                                                                        jm
  110 continue                                                           jm
      do 112 i = 1, ndof                                                 jm
        xx1 = -tmp2(i,4)                                                 jm
        xx2 = -tmp2(i,5)                                                 jm
        xx3 = -tmp2(i,2)                                                 jm
        xx4 =  tmp2(i,1)                                                 jm
        xx5 = -tmp2(i,13)                                                jm
        xx6 = -tmp2(i,14)                                                jm
c       write (32,6000) nthru, i, xx1, xx2, xx3, xx4, xx5, xx6           jm
  112 continue                                                           jm
c     write (32,6010)                                                    jm
c                                                                        jm
      write (14) rnlm2                                                   jm
c                                                                        jm
c     ***  Elmnt. tangential stiffness matrix, local coords.  ***       jm
c                                                                        jm
      do 120 i = 1, 6                                                    jm
        rkt          =  tmp(i,1)                                         jm
        ss(i,  i  ) =  rkt                                               jm
        ss(i+6,i  ) = -rkt                                               jm
        ss(i,  i+6) = -rkt                                               jm
        ss(i+6,i+6) =  rkt                                               jm
  120 continue                                                           jm
c                                                                        jm
c     ***  Determine elmnt force vector in local coords. if element  ***jm
c     ***  had remained elastic (pe), the "true" elmnt force vector  ***jm
c     ***  (p), also in local coords, and the element "nonlinear     ***jm
c     ***  restoring force" vector (dp = p - pe).                    ***jm
c                                                                        jm
      do 130 i = 1, 6                                                    jm
        pp      =  tmp(i,2)                                              jm
        dpp     =  tmp(i,3)                                              jm
        p(i)    =  pp                                                    jm
        dp(i)   =  dpp                                                   jm
        p(i+6)  = -pp                                                    jm
        dp(i+6) = -dpp                                                   jm
  130 continue                                                           jm
c                                                                        jm
c     write (*,7778) 2                                                   jm
      return                                                             jm
c                                                                        jm
 6000 format ( i5,1x,i2,1x,                                              jm
     +         f9.6,1x,f9.6,1x,f12.6,1x,f8.2,1x,f9.6,1x,f12.6 )          jm
 6010 format ( ' ' )                                                     jm
c                                                                        jm
 7777 format (1x,'DF6 enter ',i2)                                        jm
 7778 format (1x,'DF6 exit  ',i2)                                        jm
 7779 format (1x,'DF6 stop  ',i2)                                        jm
c                                                                        jm
      end                                                                jm
12345678901234567890123456789012345678901234567890123456789012345678
0        1         2         3         4         5         6         7
```

Appendix D

Spread Footing Foundation Study

The 52 NEABS analyses performed in the parametric study of spread footing foundations are presented below in matrix form. Each run is identified by a name of the form "SF*nn–fff.see*," where *nn* is the run number, *fff* is the foundation model code, *s* is the soil stiffness code, and *ee* is the applied seismic record code. The values of the foundation model parameters are given in this appendix, in terms of the model configurations shown in Figure 3.3 of Chapter Three. References of the publications which describe the procedures used to determine these parameters accompany the values. The results of the NEABS analyses are also presented in this appendix; the presentation order of the results follows the numbering of the analyses given in the matrix below.

		El Centro Record		Olympia Record	
		Lower Intensity	Higher Intensity	Lower Intensity	Higher Intensity
Fixed		SF01-FX0._EL	SF02-FX0._EH	SF03-FX0._OL	SF04-FX0._OH
D01 Model (Springs only)	Soft	SF05-D01.FEL	SF06-D01.FEH	SF07-D01.FOL	SF08-D01.FOH
	Intermediate	SF09-D01.IEL	SF10-D01.IEH	SF11-D01.IOL	SF12-D01.IOH
	Stiff	SF13-D01.SEL	SF14-D01.SEH	SF15-D01.SOL	SF16-D01.SOH
D03 Model (Springs, Mass, & Dashpot)	Soft	SF17-D03.FEL	SF18-D03.FEH	SF19-D03.FOL	SF20-D03.FOH
	Intermediate	SF21-D03.IEL	SF22-D03.IEH	SF23-D03.IOL	SF24-D03.IOH
	Stiff	SF25-D03.SEL	SF26-D03.SEH	SF27-D03.SOL	SF28-D03.SOH
D05 Model (Meek & Veletsos)	Soft	SF29-D05.FEL	SF30-D05.FEH	SF31-D05.FOL	SF32-D05.FOH
	Intermediate	SF33-D05.IEL	SF34-D05.IEH	SF35-D05.IOL	SF36-D05.IOH
	Stiff	SF37-D05.SEL	SF38-D05.SEH	SF39-D05.SOL	SF40-D05.SOH
D11 Model (Jean et al.)	Soft	SF41-D11.FEL	SF42-D11.FEH	SF43-D11.FOL	SF44-D11.FOH
	Intermediate	SF45-D11.IEL	SF46-D11.IEH	SF47-D11.IOL	SF48-D11.IOH
	Stiff	SF49-D11.SEL	SF50-D11.SEH	SF51-D11.SOL	SF52-D11.SOH

Spread Footing Foundation Models: Parameter Values*

		Soft Soil				Intermediate Soil				Stiff Soil			
		D01	D03	D05	D11	D01	D03	D05	D11	D01	D03	D05	D11
Lateral Translation	k1	866.5	866.5	866.5	591.1	4718	4718	4718	3218	16271	16271	16271	11100
	k2				1700				9254				31919
	k3				571.6				3112				10733
	k4				1798				9791				33770
	c1		11.78	10.29	13.11		27.49	24.01	30.6		51.06	44.59	56.83
	c2			0.0	36.02			0.0	84.04			0.0	156.1
	c3				1.983				4.627				8.593
	c4				24.75				57.77				107.3
	c5				30.39				70.90				131.7
	m1		0.0452	0.0	0.0527		0.0452	0.0	0.0527		0.452	0.0	0.0527
	m2			0.0	0.2975			0.0	0.2975			0.0	0.2975
Vertical Translation	k1	983.1	983.1	983.1	1091	5353	5353	5353	5943	18461	18461	18461	20499
	k2				1393				7582				26149
	k3				450.2				2451				8453
	k4				1778				9680				33385
	c1		17.78	14.01	13.67		41.49	32.69	31.89		77.05	60.71	59.23
	c2			4.700	31.43			10.90	73.34			20.24	136.2
	c3				7.306				17.04				31.66
	c4				24.48				57.12				106.1
	c5				27.96				65.23				121.1
	m1		0.1202	0.0	0.3931		0.1202	0.0	0.3931		0.1202	0.0	0.3931
	m2			0.0345	0.2537			0.0345	0.2537			0.0345	0.2537
Rocking	k1	3.00E6	3.00E6	3.00E6	1.31E6	16.34E6	16.34E6	16.34E6	7.113E6	56.37E6	56.37E6	56.37E6	24.53E6
	k2				5.07E6				27.61E6				95.24E6
	k3				4.55E6				24.79E6				85.49E6
	k4				3.26E6				17.77E6				61.28E6
	c1		16553	0.0	-16789		38624	0.0	-39175		71732	0.0	-72754
	c2			21389	64412			49909	150.3E6			92688	279.1E3
	c3				39968				93259				173.2E6
	c4				3164				7383				13712
	c5				33788				78839				146.4E3
	m1		276.6	0.0	1228		276.6	0.0	1228		276.6	0.0	1228
	m2			255.9	392.4			255.9	392.4			255.9	392.4

* unit of force = kip; unit of length = inch; unit of rotation = radian; unit of time = second

D01 Model: John P. Wolf, *Soil–Structure Interaction Analysis in Time Domain*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1988.

D03 Model: Anestis S. Veletsos and B. Verbič, "Vibration of Viscoelastic Foundations," *International Journal of Earthquake Engineering and Structural Dynamics*, Vol. 2, No. 1, July–September, 1973, pp. 87–102.

D05 Model: John P. Wolf, *Soil–Structure Interaction Analysis in Time Domain*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1988.

D11 Model: Wen-Ye Jean, Tsung-Wu Lin, and Joseph Penzien, "System Parameters of Soil Foundations for Time Domain Dynamic Analysis," *Earthquake Engineering and Structural Dynamics*, Vol 19, 1990, pp. 541–553.

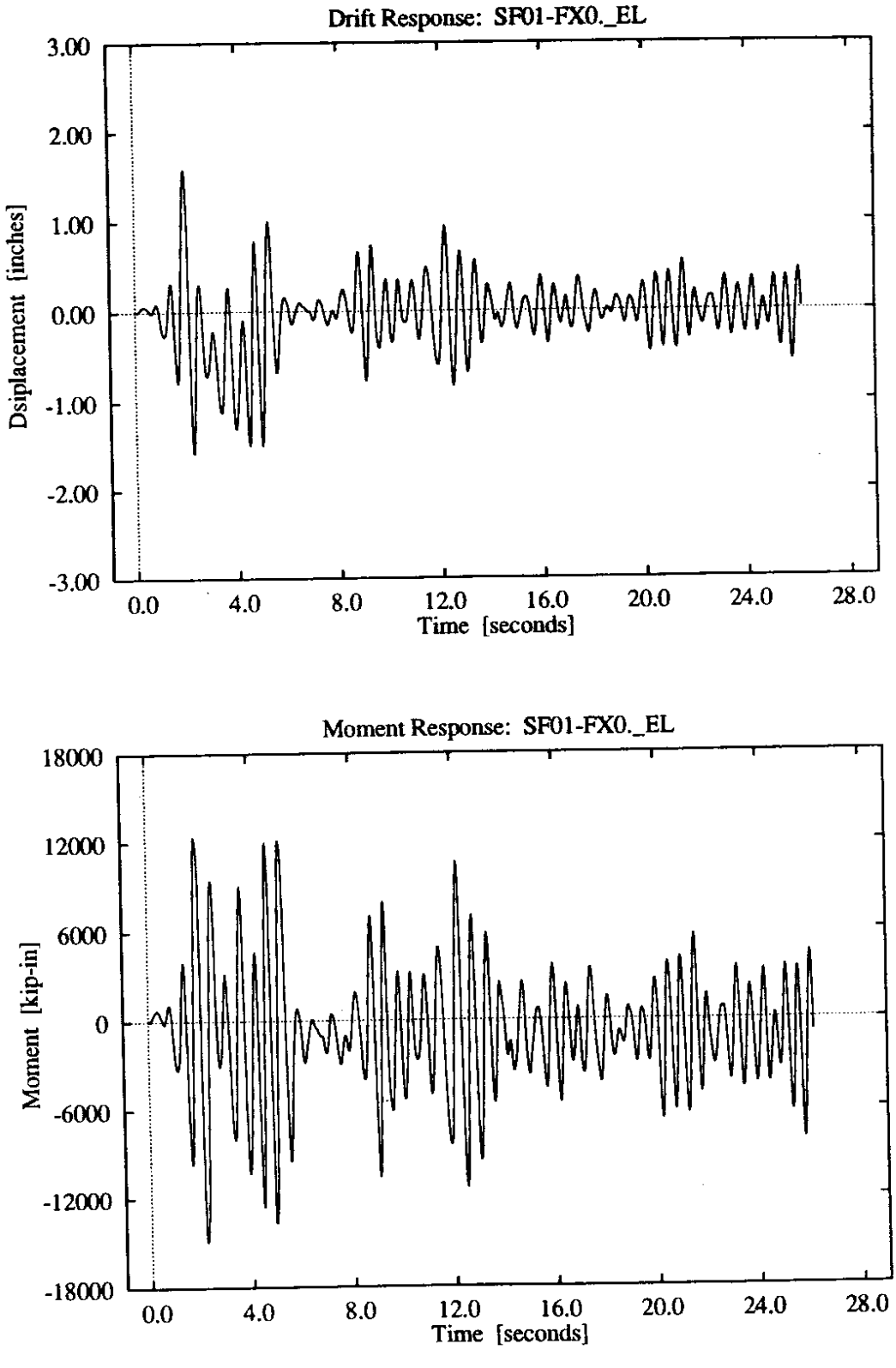
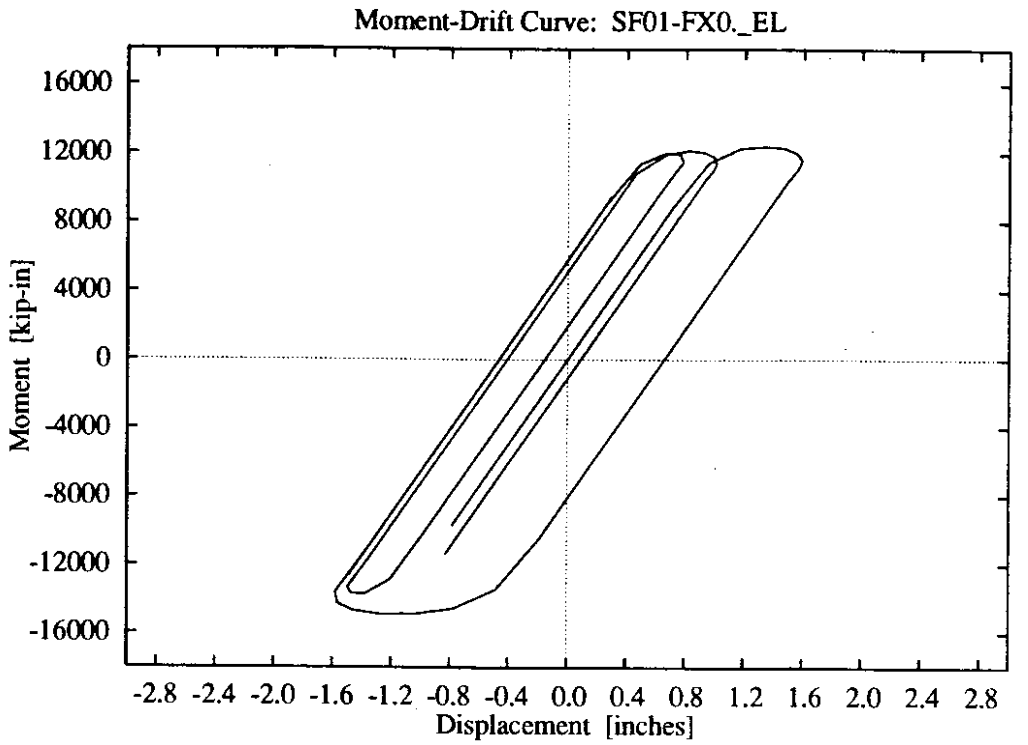


Figure D-1: Fixed-base foundation, lower intensity El Centro record.



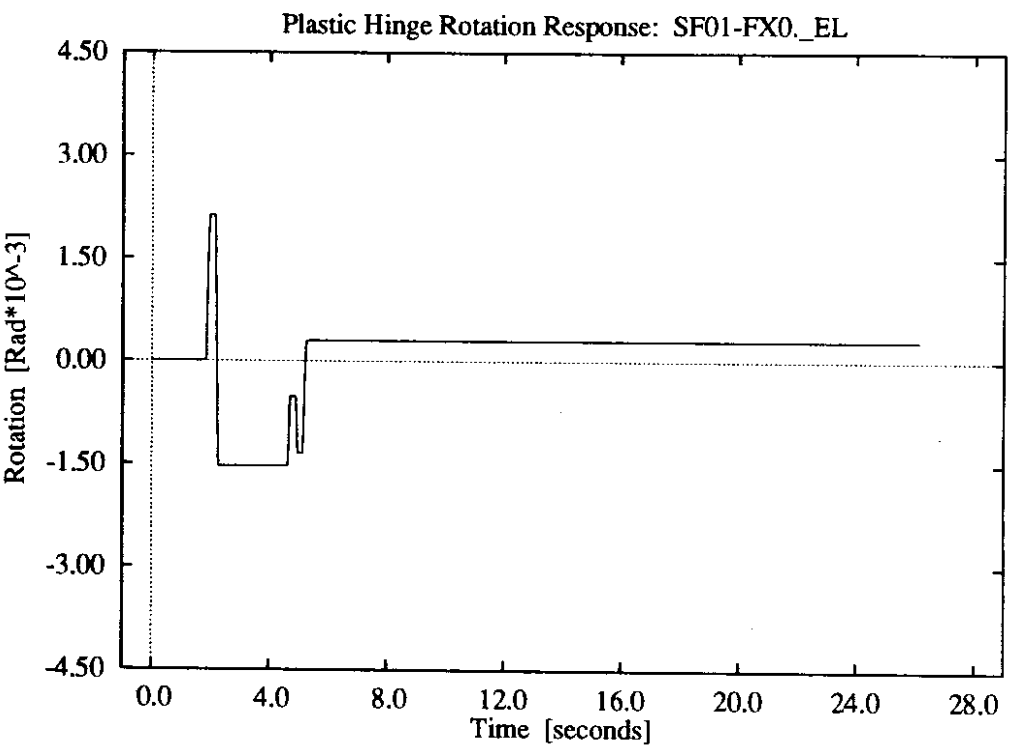
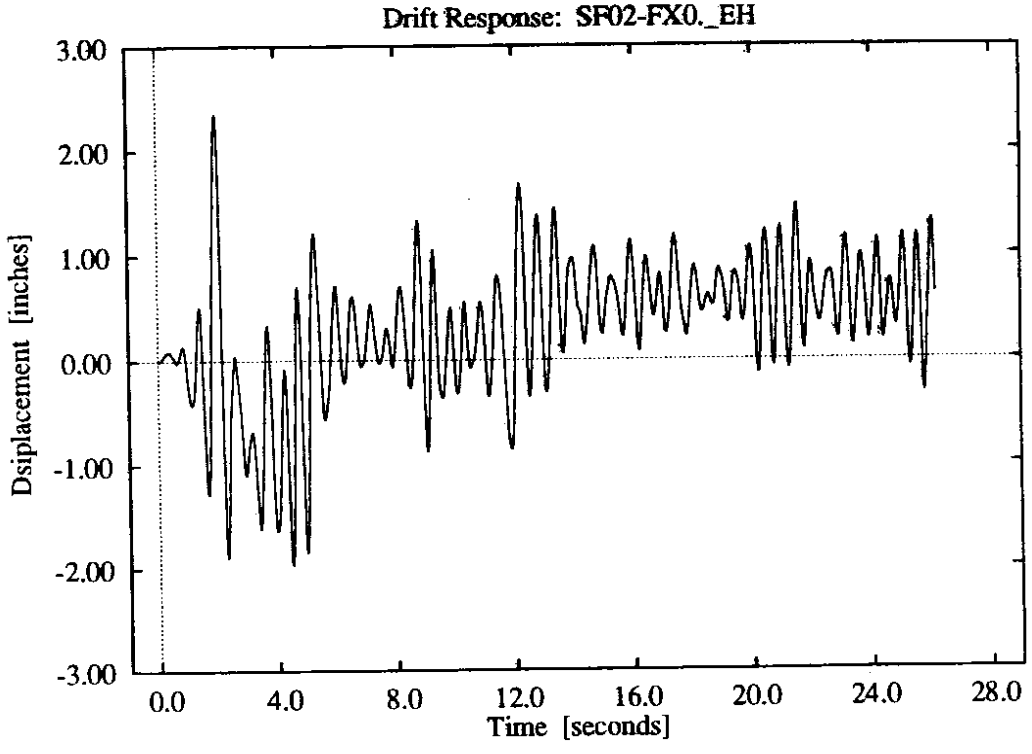


Figure D-2: Fixed-base foundation, lower intensity El Centro record.



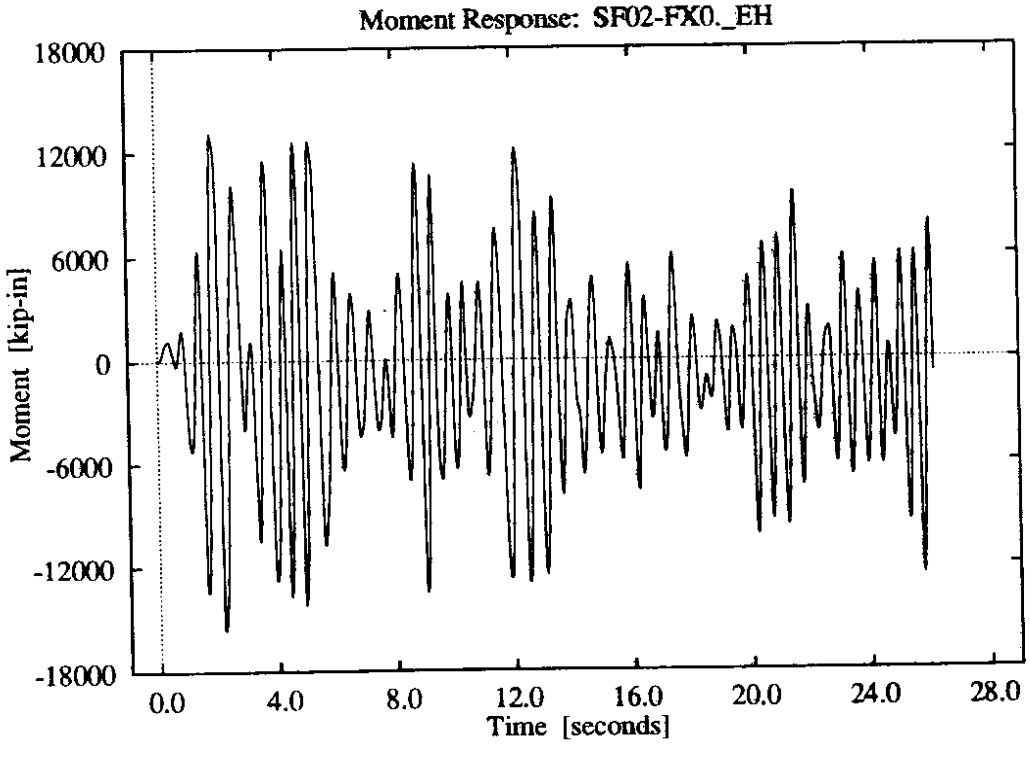
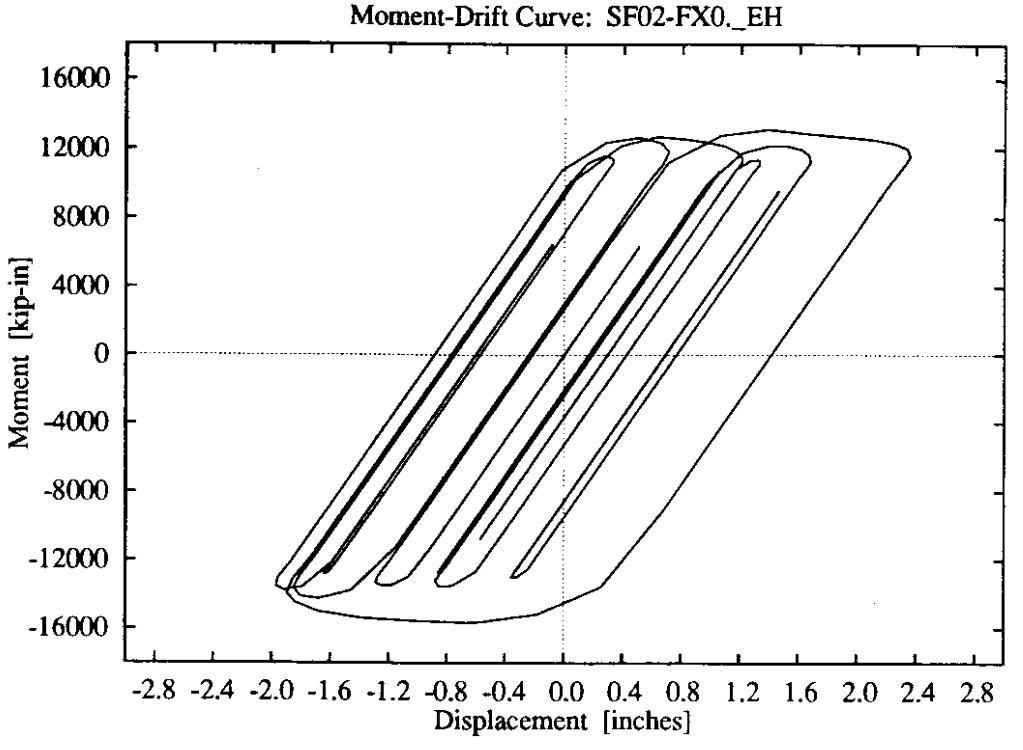


Figure D-3: Fixed-base foundation, higher intensity El Centro record.



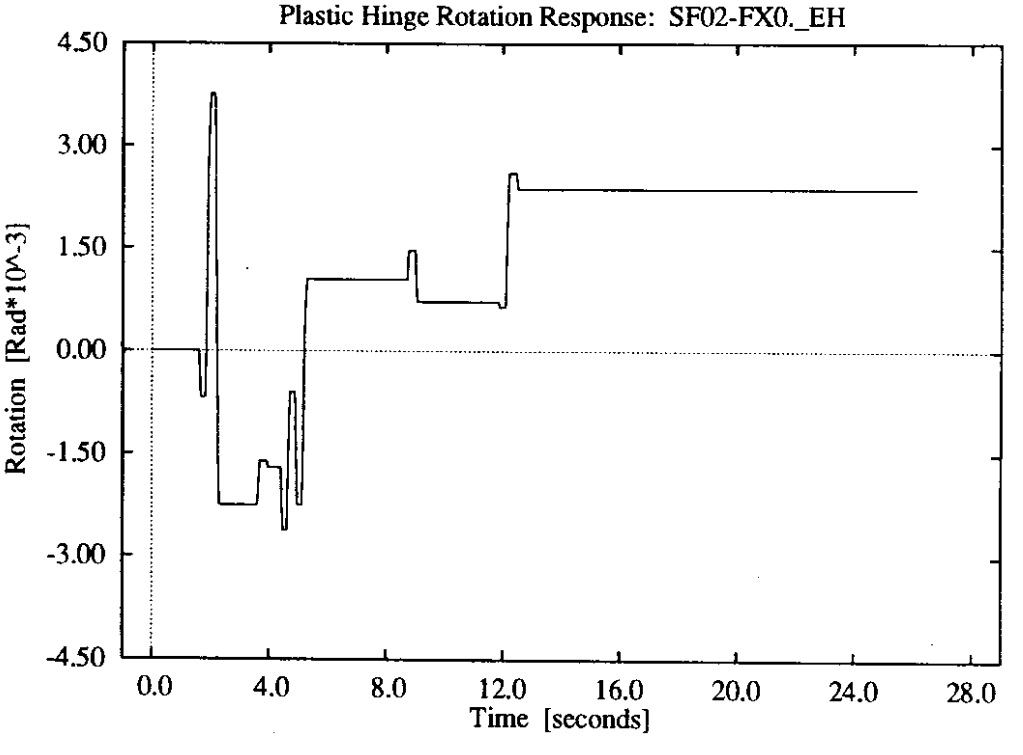
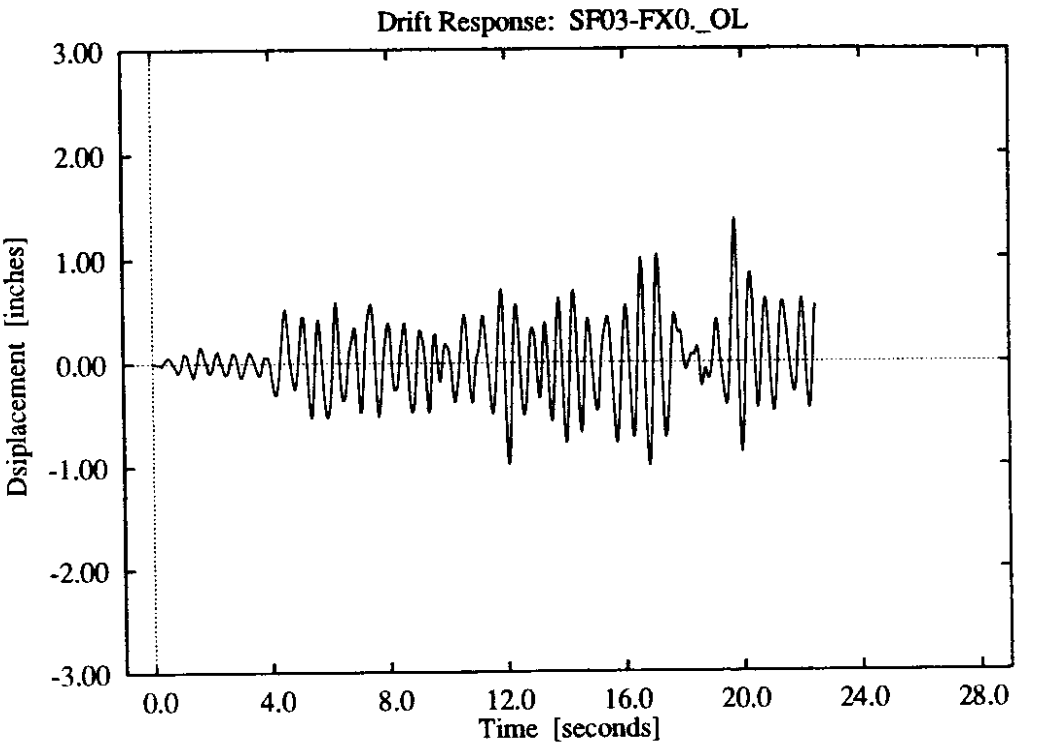


Figure D-4: Fixed-base foundation, higher intensity El Centro record.



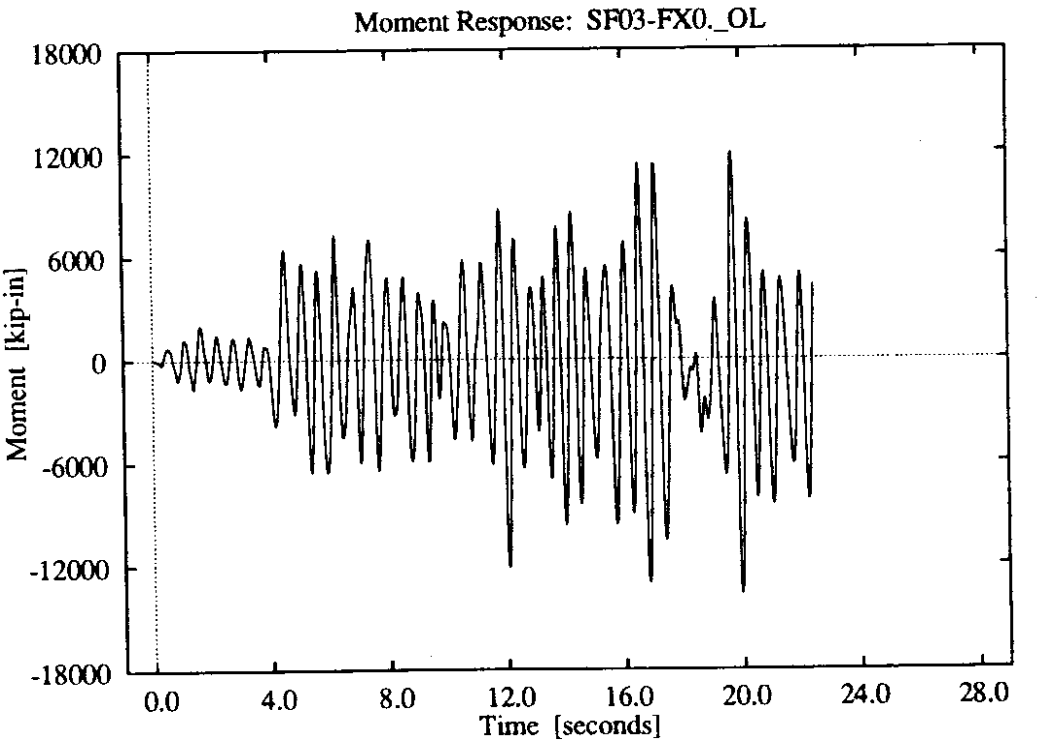
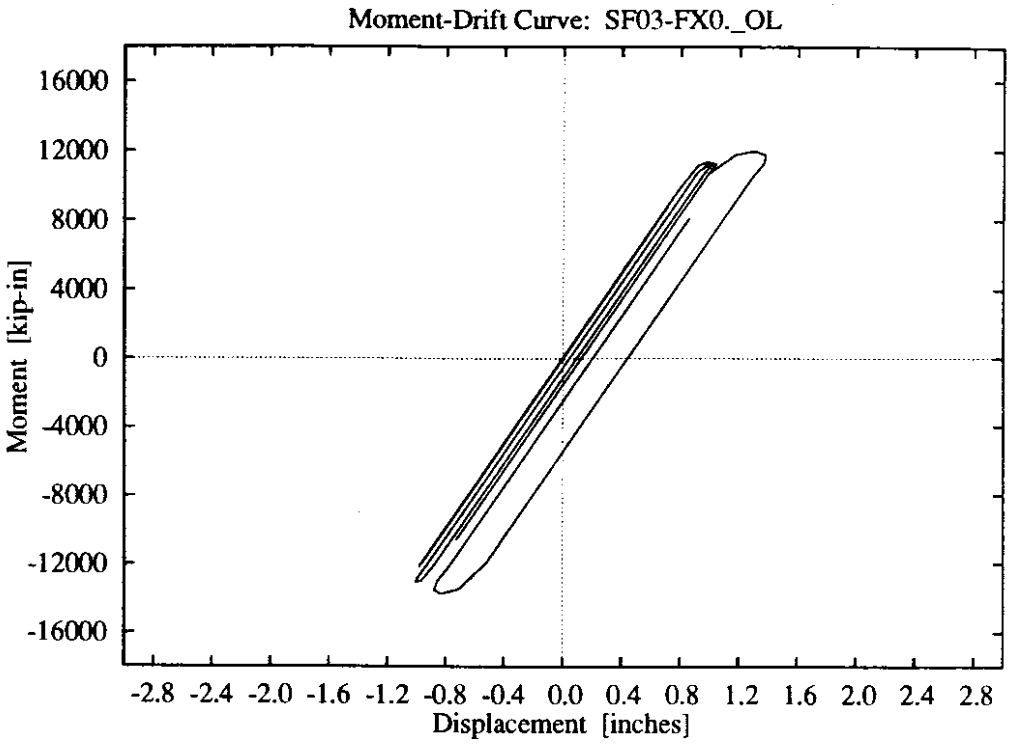


Figure D-5: Fixed-base foundation, lower intensity Olympia record.



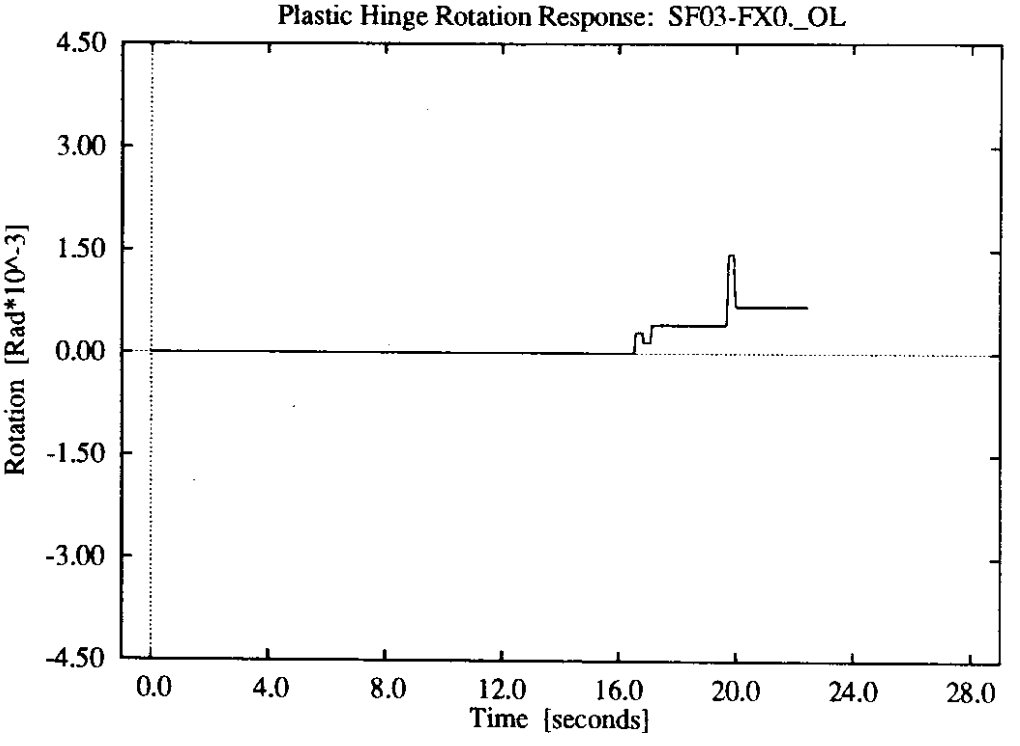
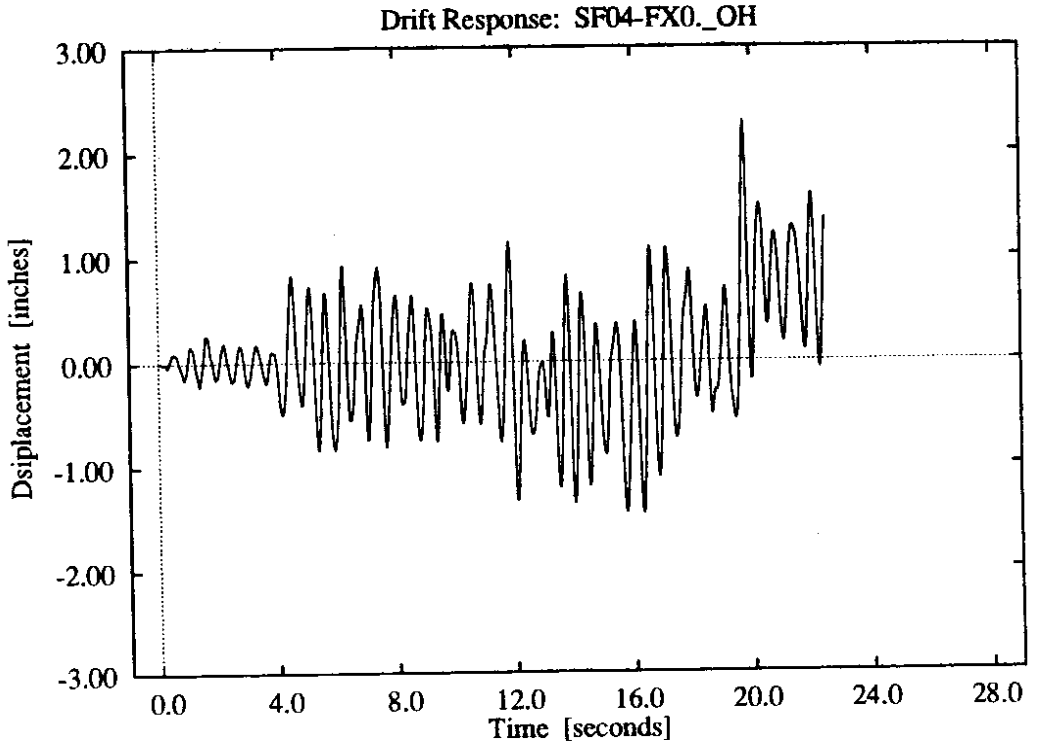


Figure D-6: Fixed-base foundation, lower intensity Olympia record.



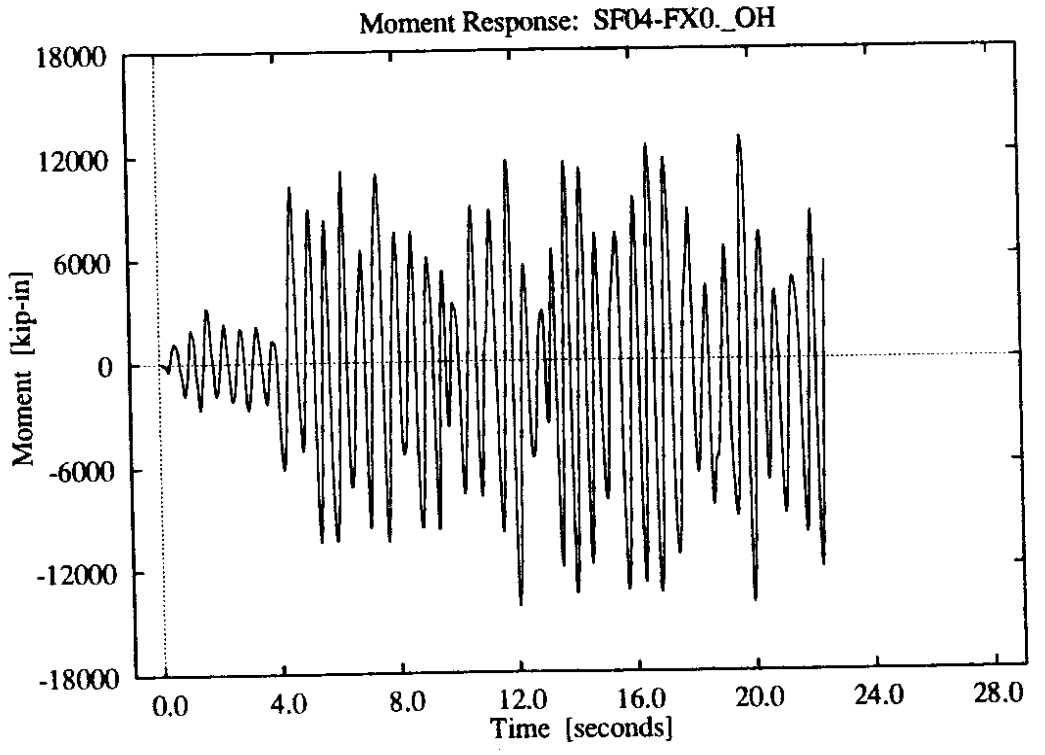
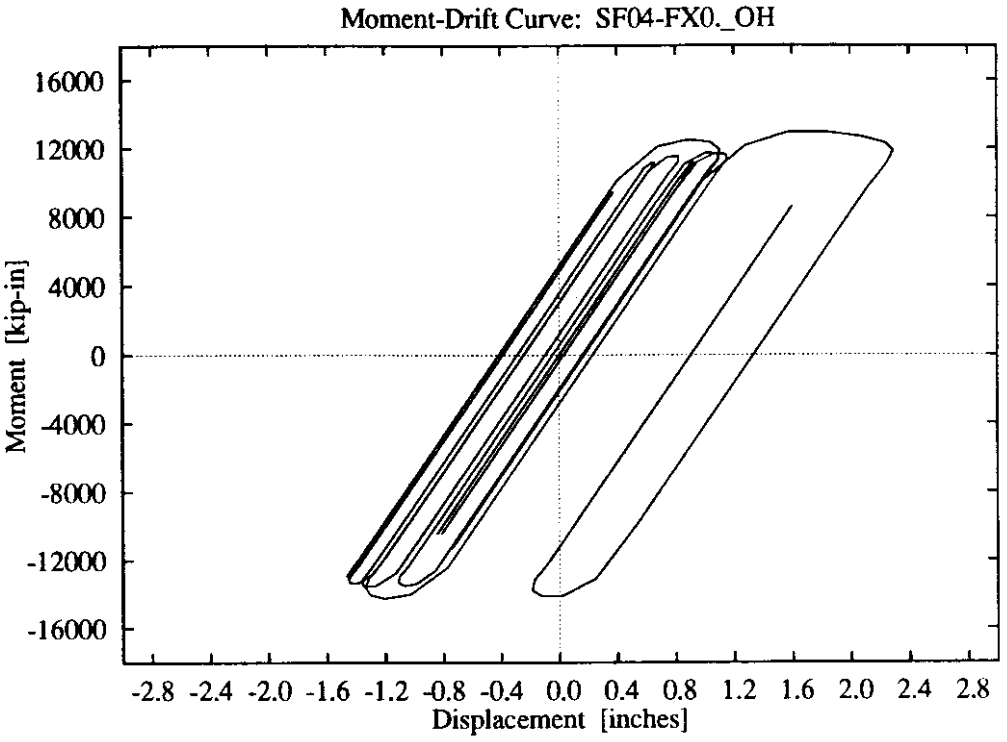


Figure D-7: Fixed-base foundation, higher intensity Olympia record.



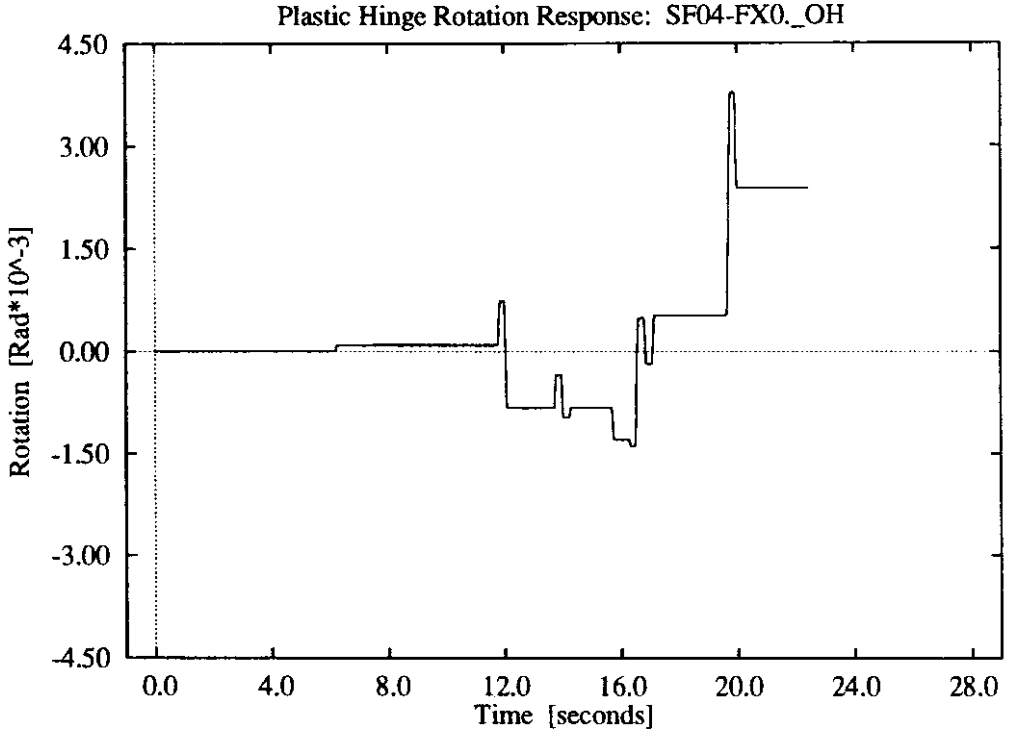
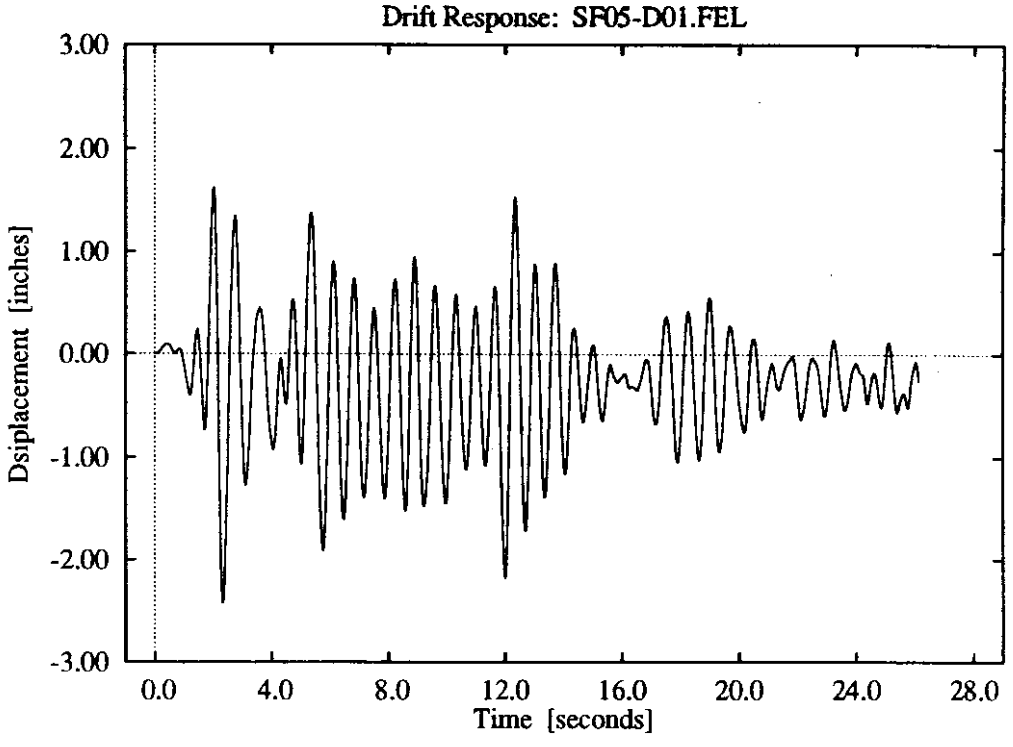


Figure D-8: Fixed-base foundation, higher intensity Olympia record.



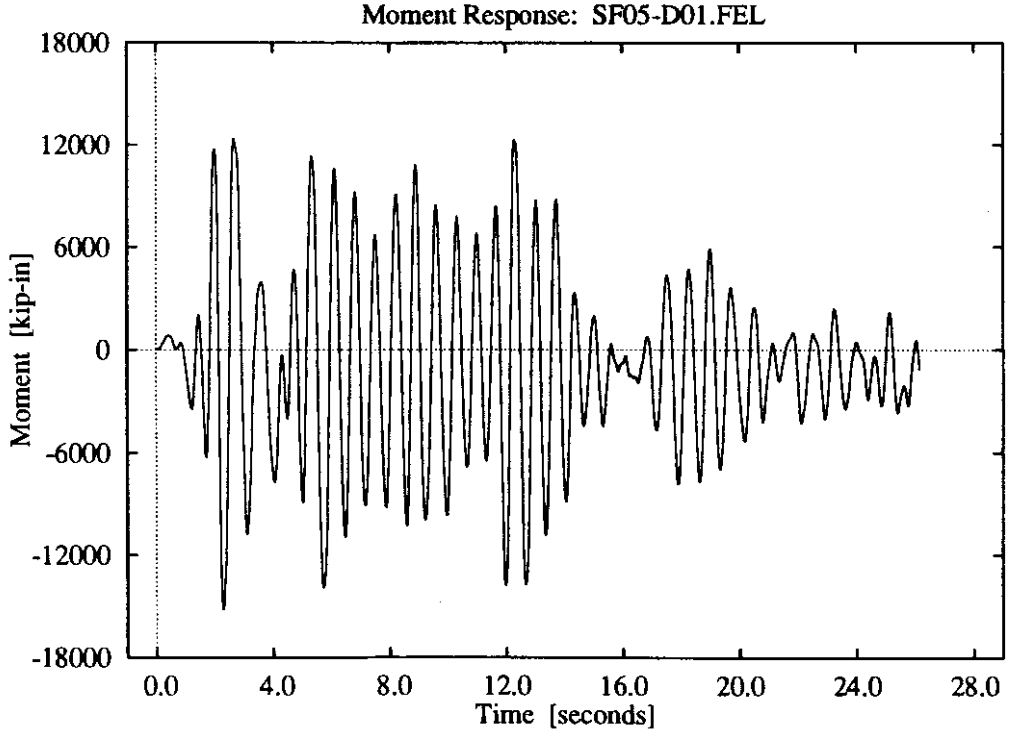
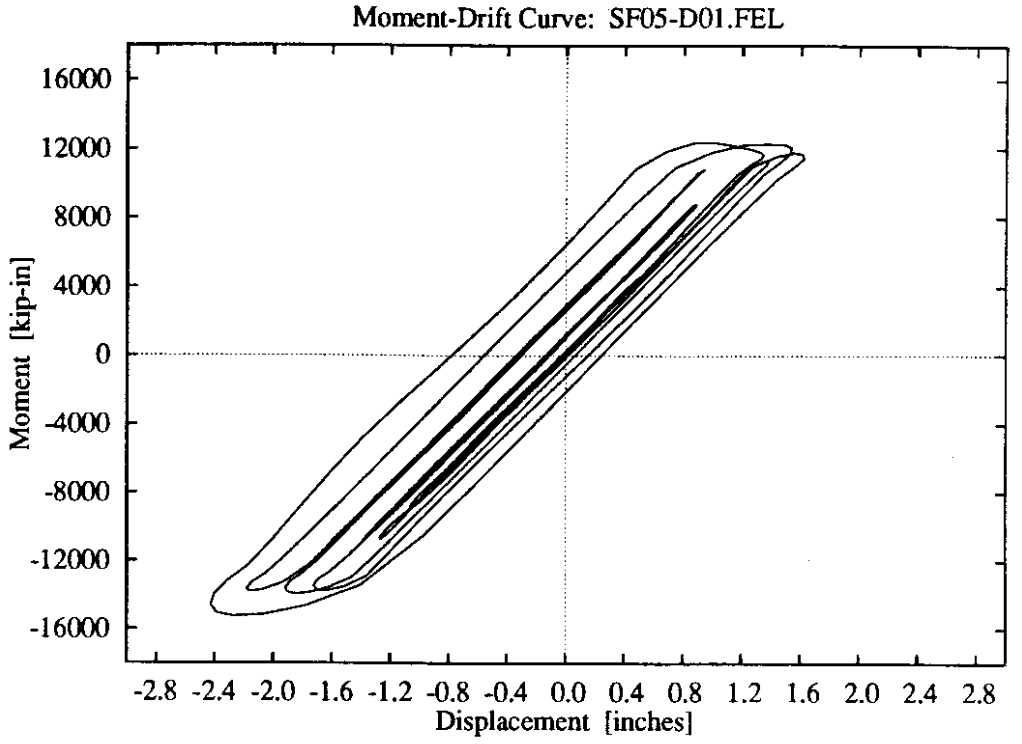


Figure D-9: 1 parameter foundation model, low soil stiffness, lower intensity El Centro record.



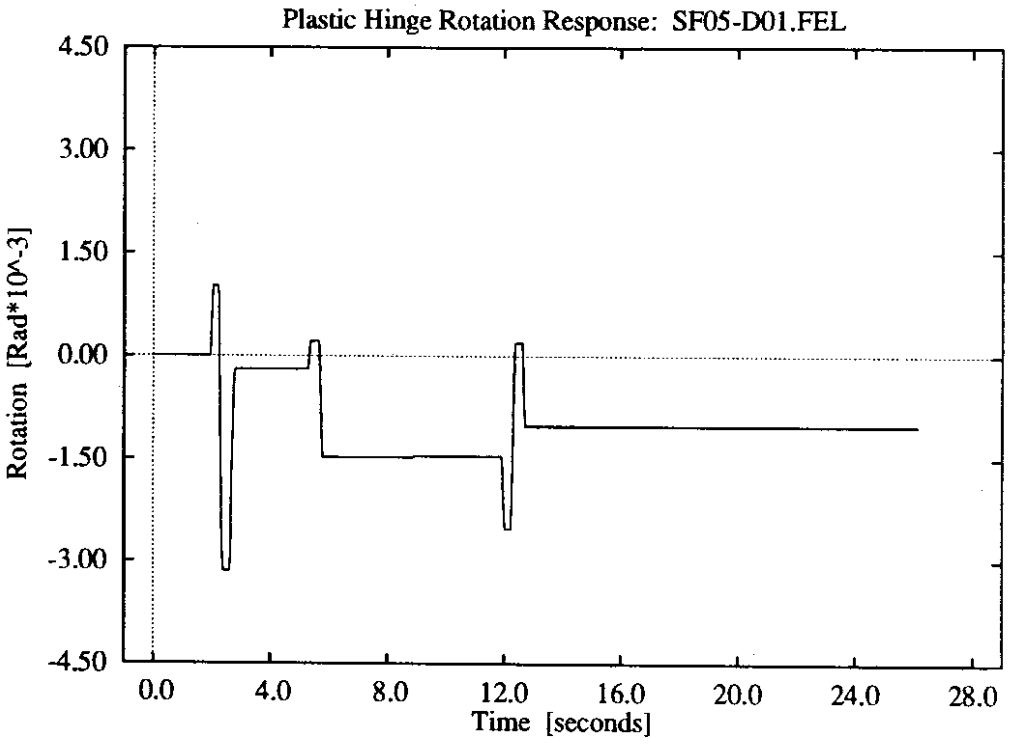
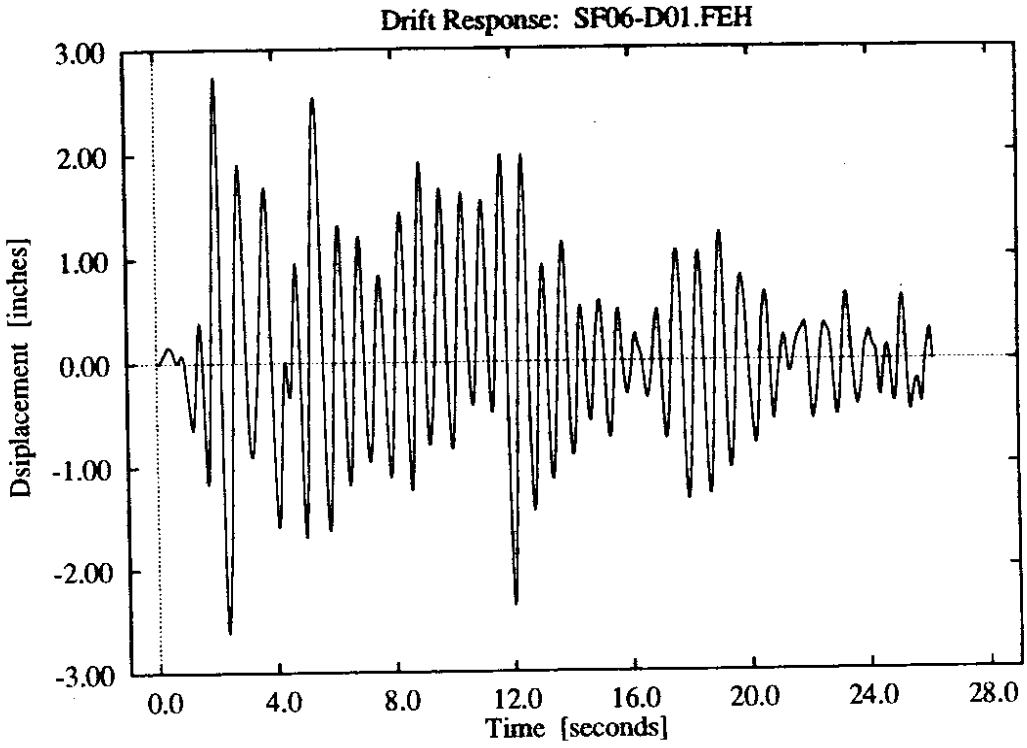


Figure D-10: 1 parameter foundation model, low soil stiffness, lower intensity El Centro record.



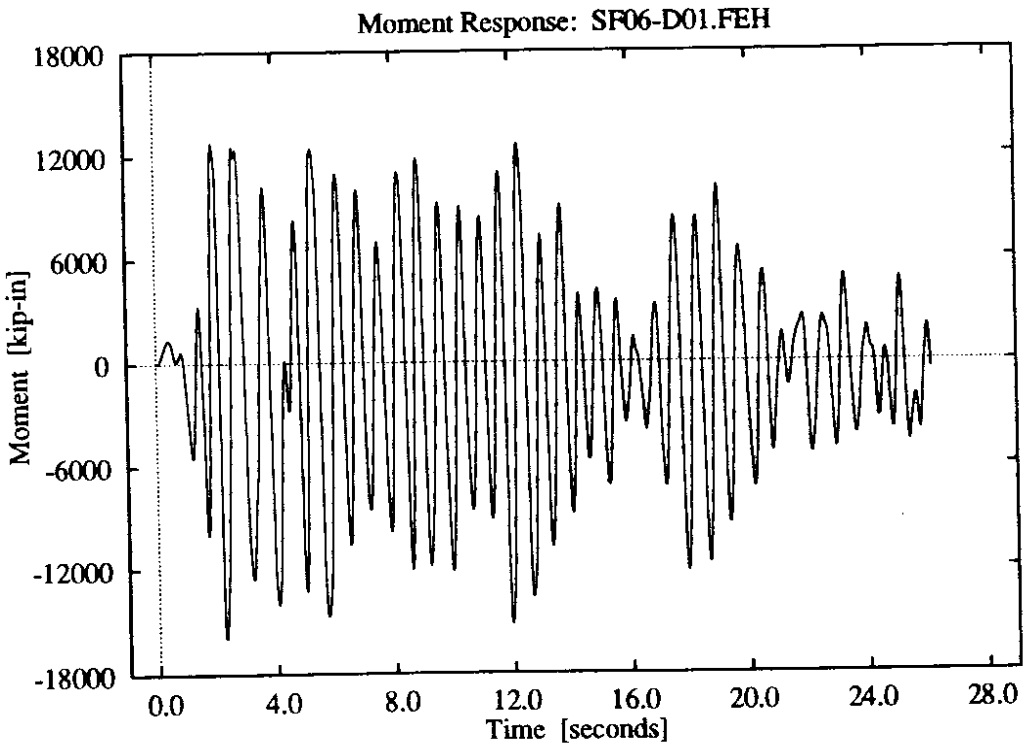
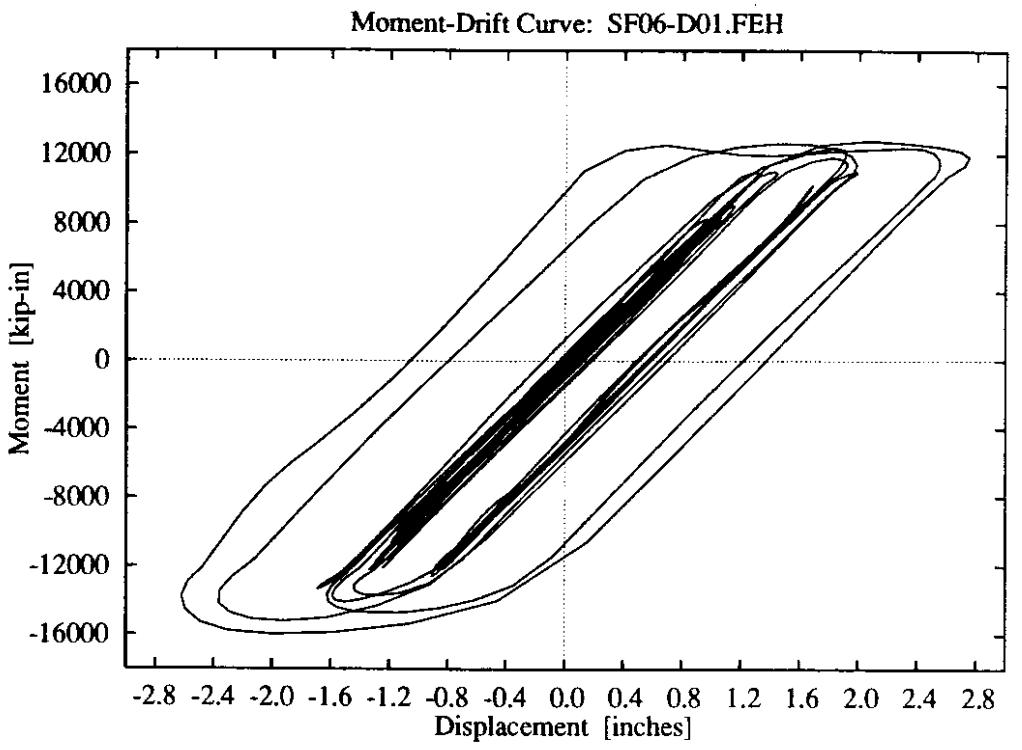


Figure D-11: 1 parameter foundation model, low soil stiffness, higher intensity El Centro record.



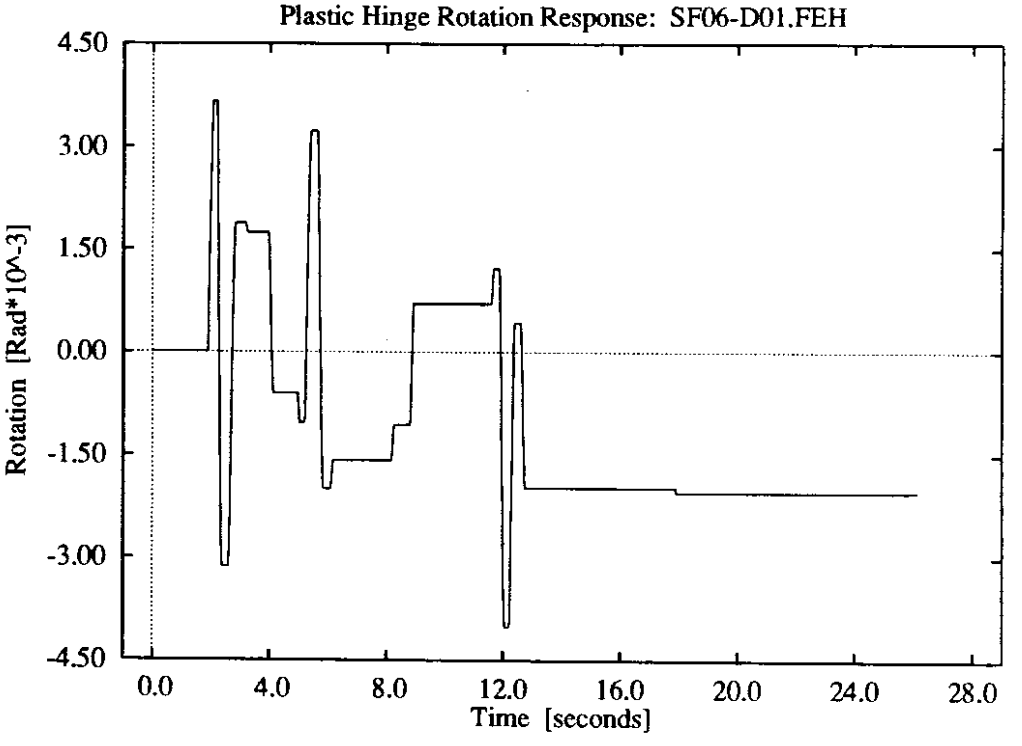
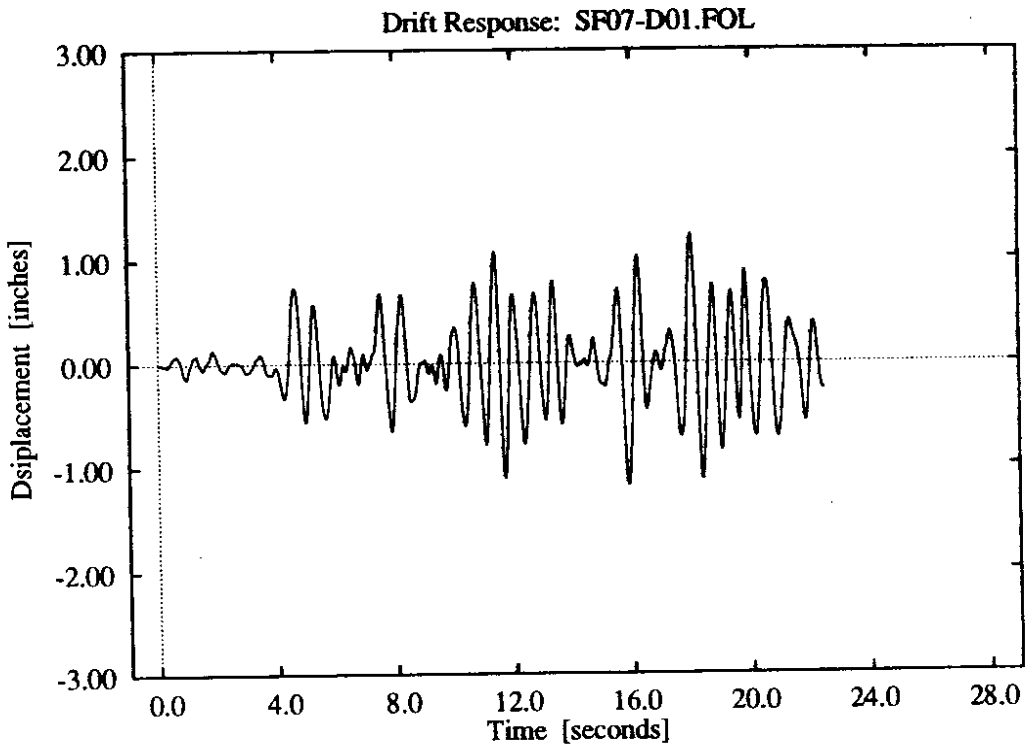


Figure D-12: 1 parameter foundation model, low soil stiffness, higher intensity El Centro record.



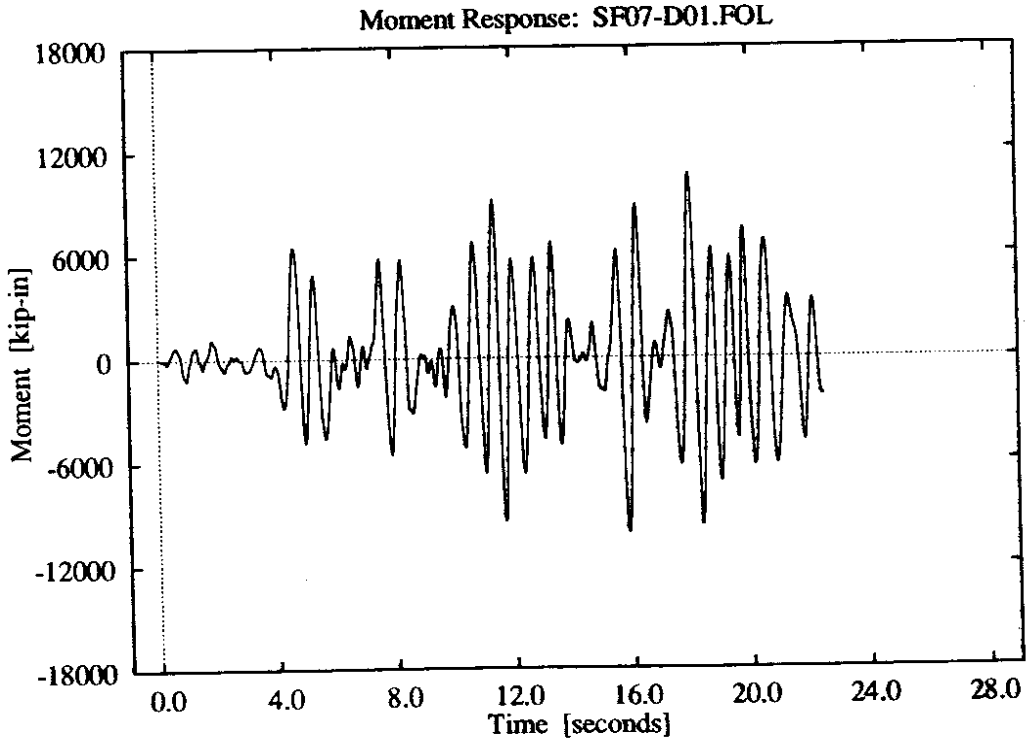
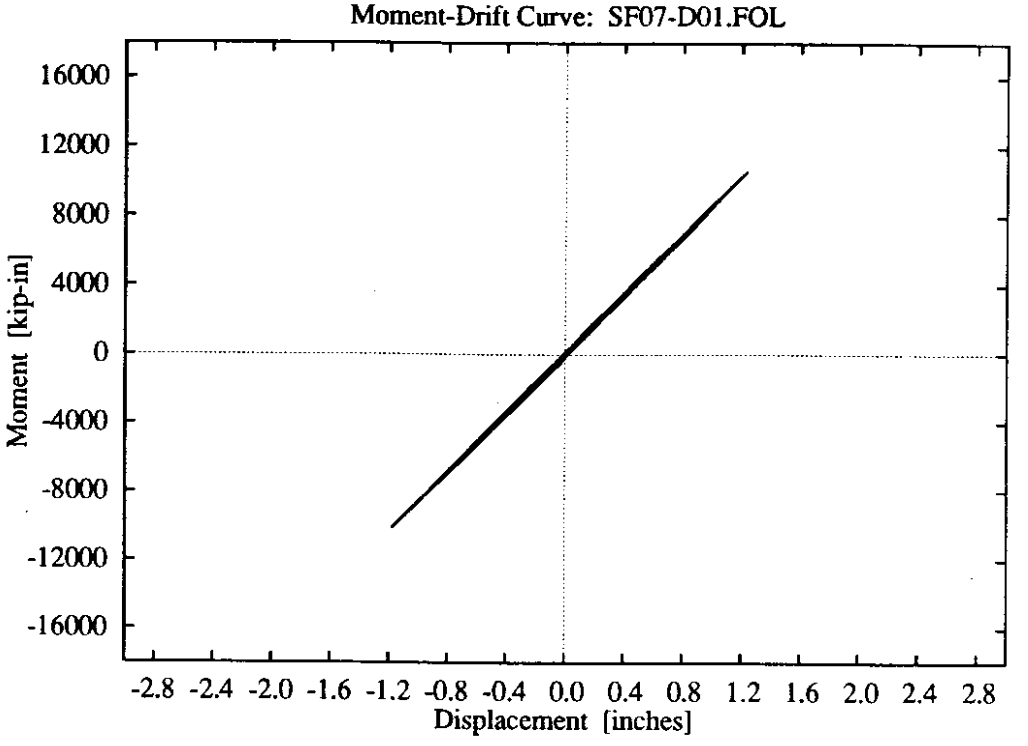


Figure D-13: 1 parameter foundation model, low soil stiffness, lower intensity Olympia record.



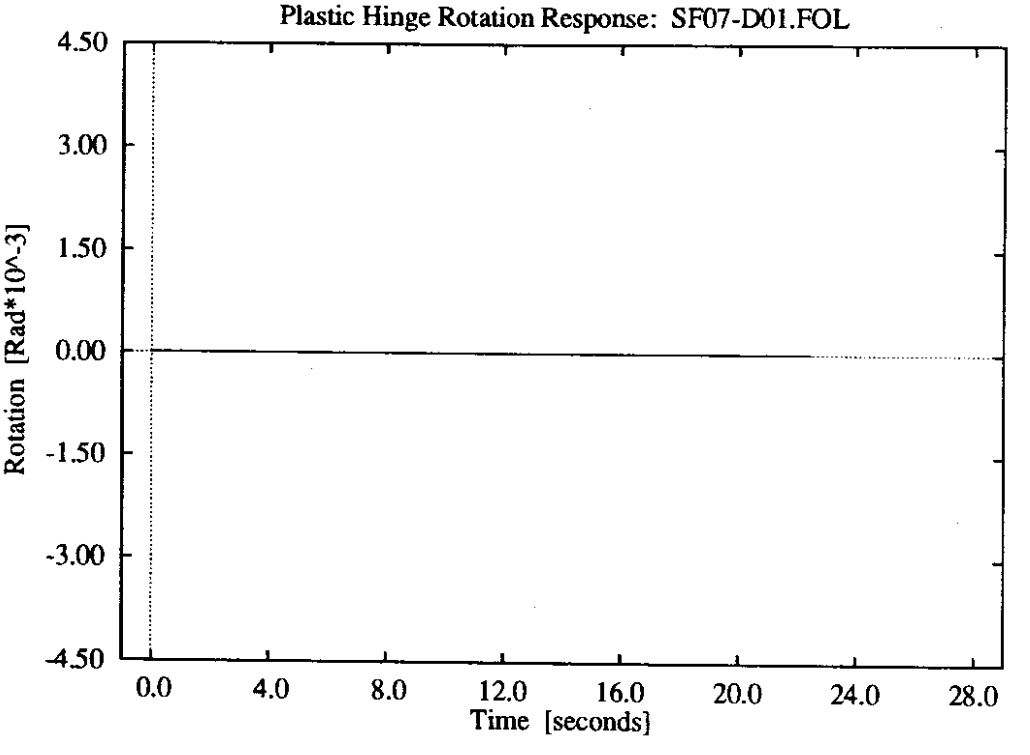


Figure D-14: 1 parameter foundation model, low soil stiffness, lower intensity Olympia record.

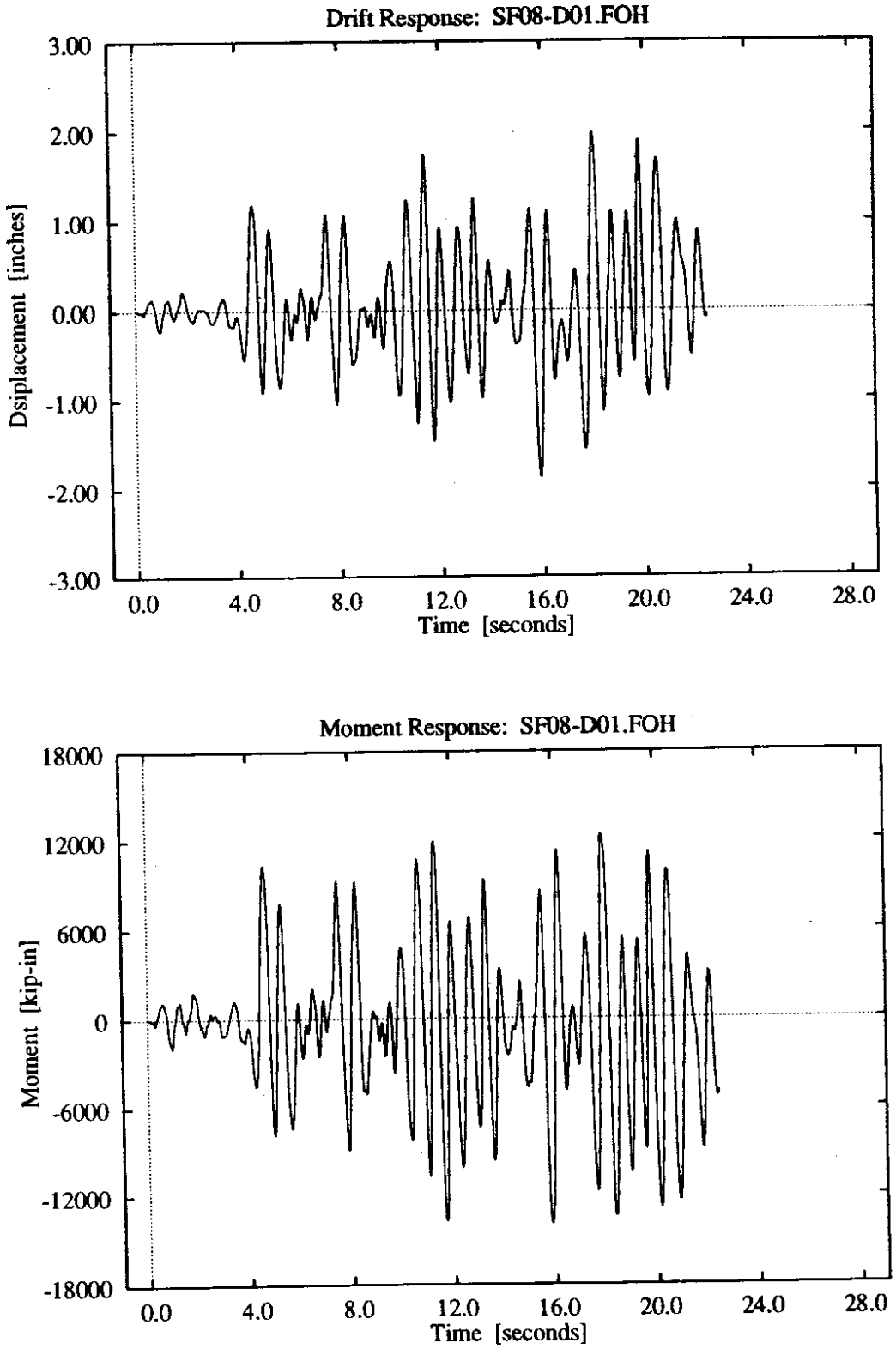
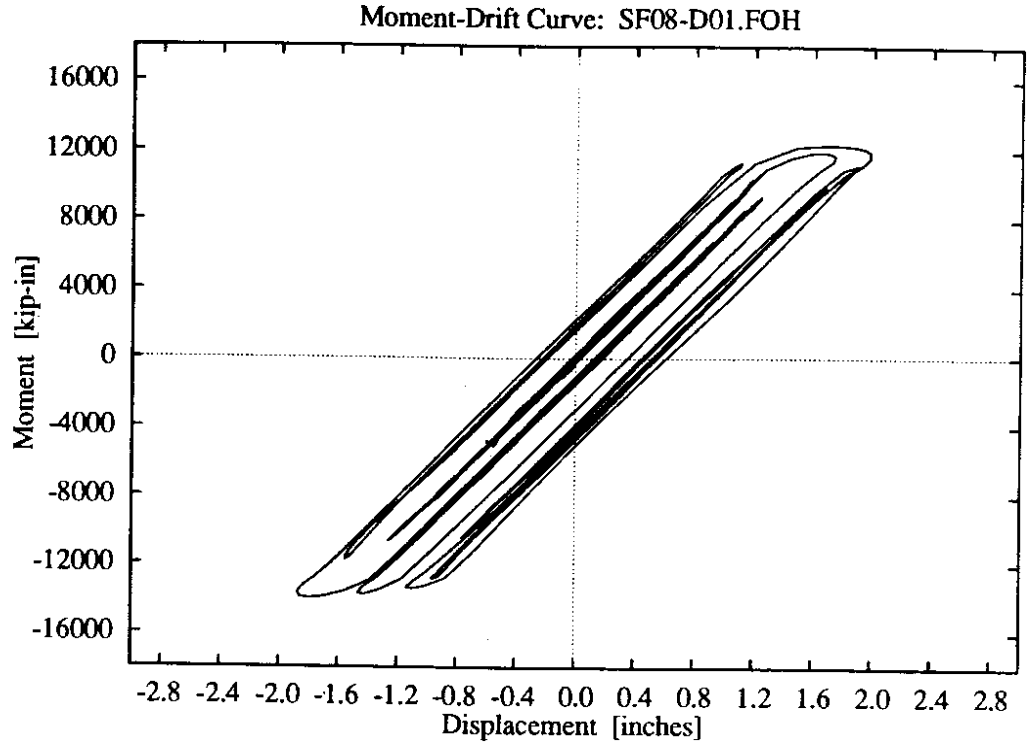


Figure D-15: 1 parameter foundation model, low soil stiffness, higher intensity Olympia record.



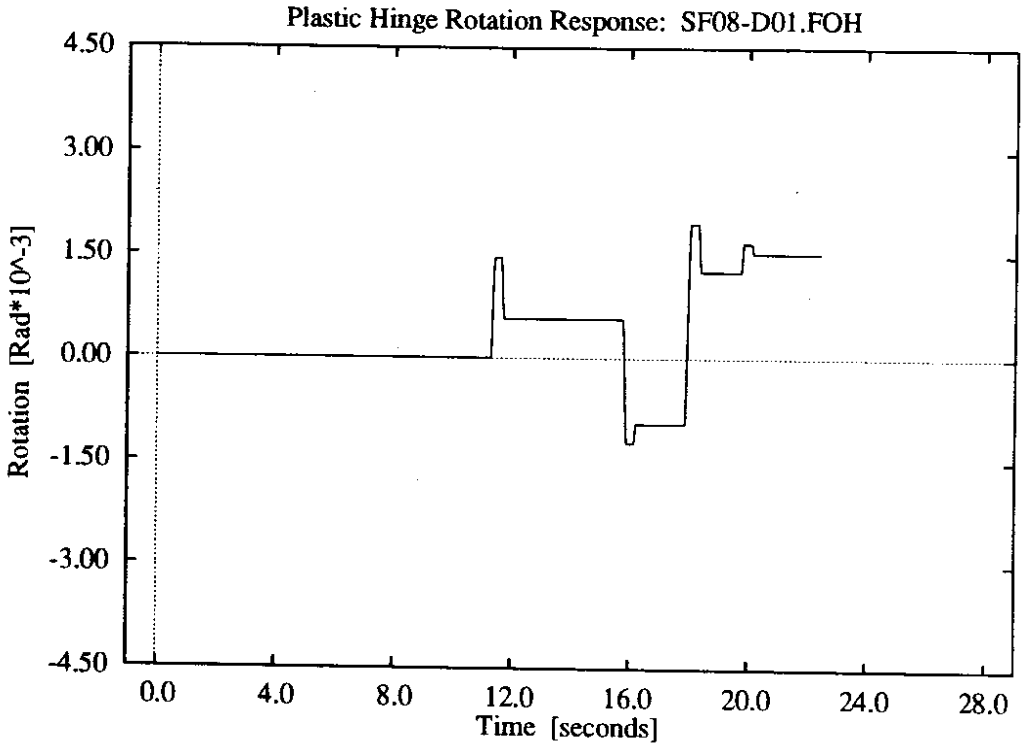


Figure D-16: 1 parameter foundation model, low soil stiffness, higher intensity Olympia record.

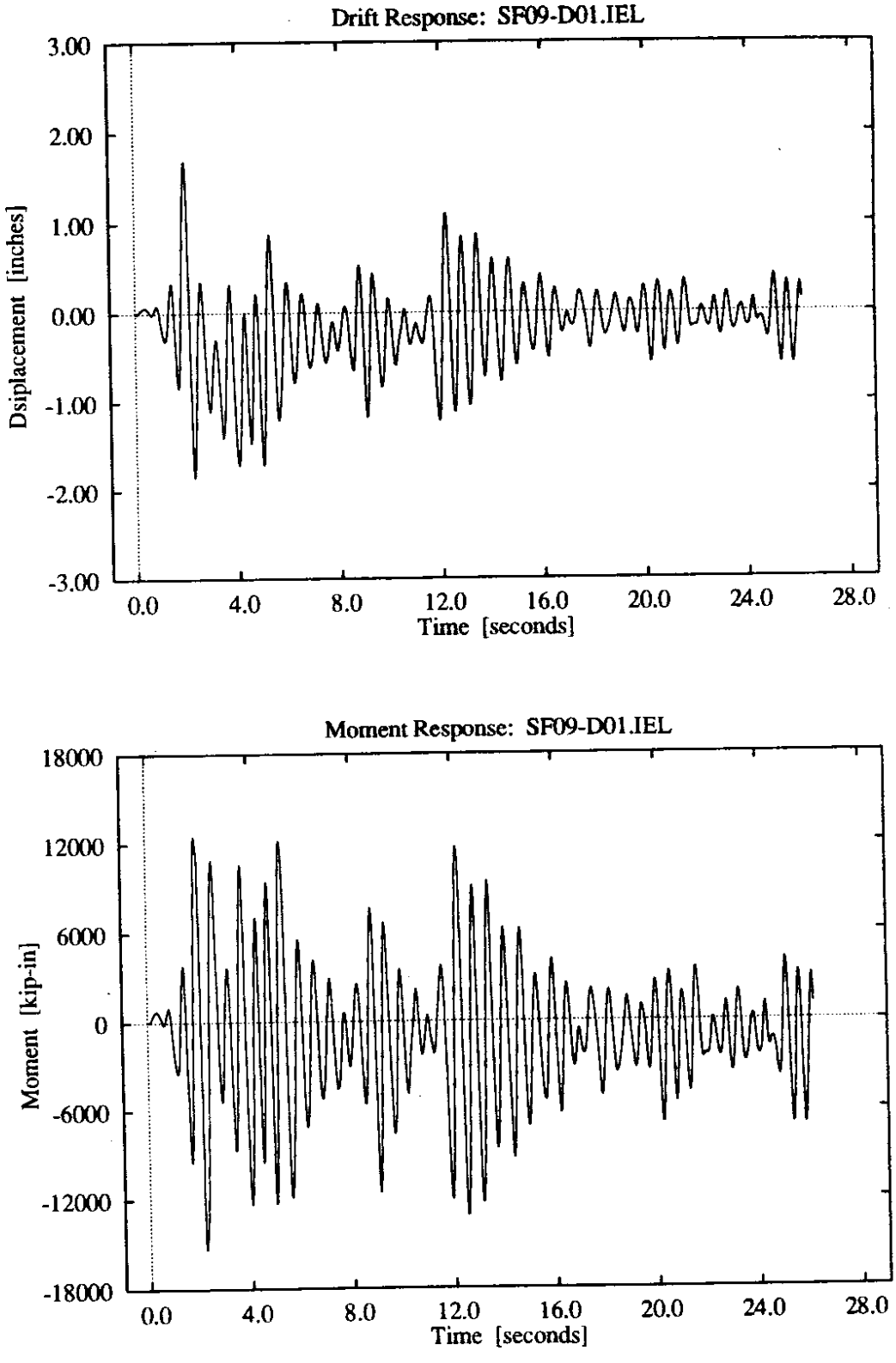
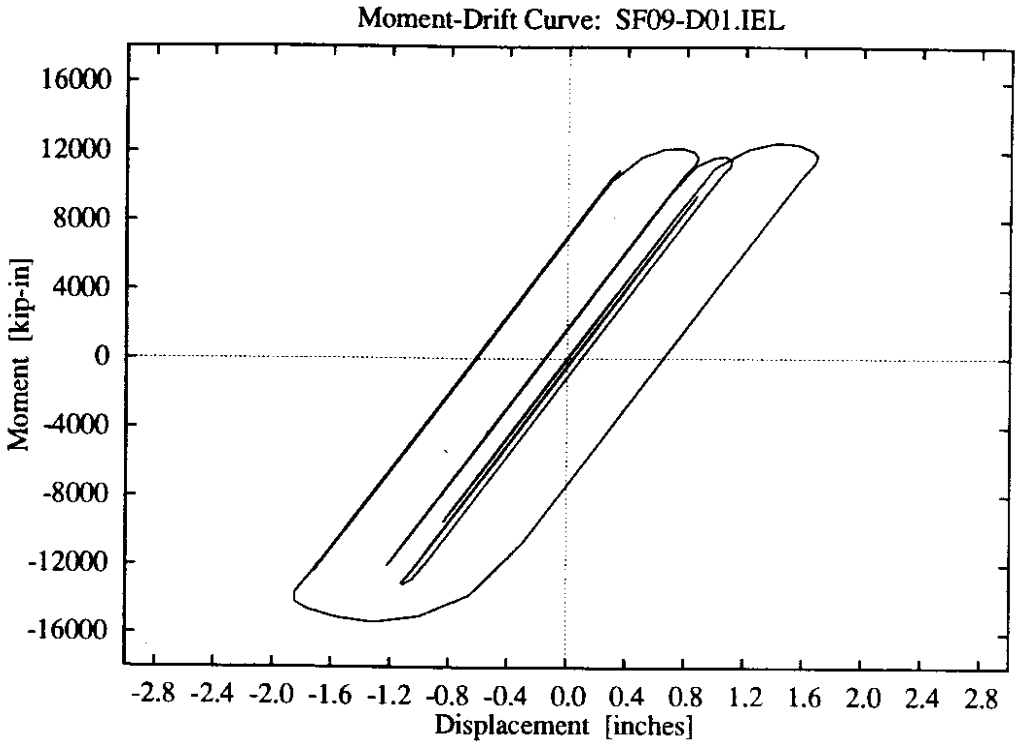


Figure D-17: 1 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.



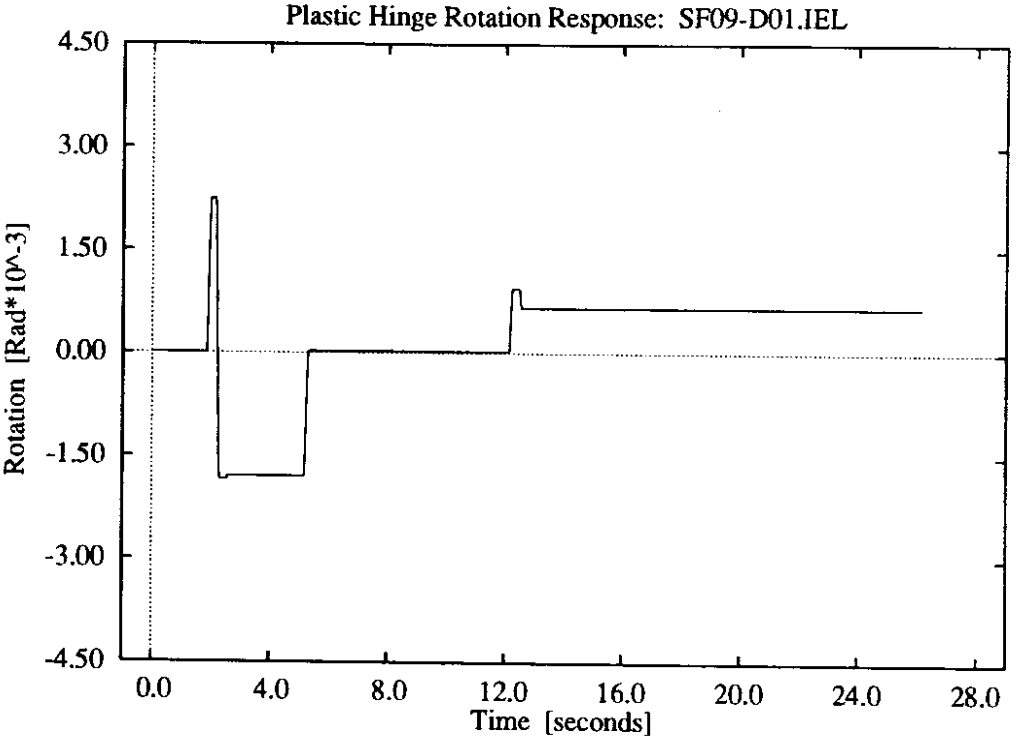


Figure D-18: 1 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.

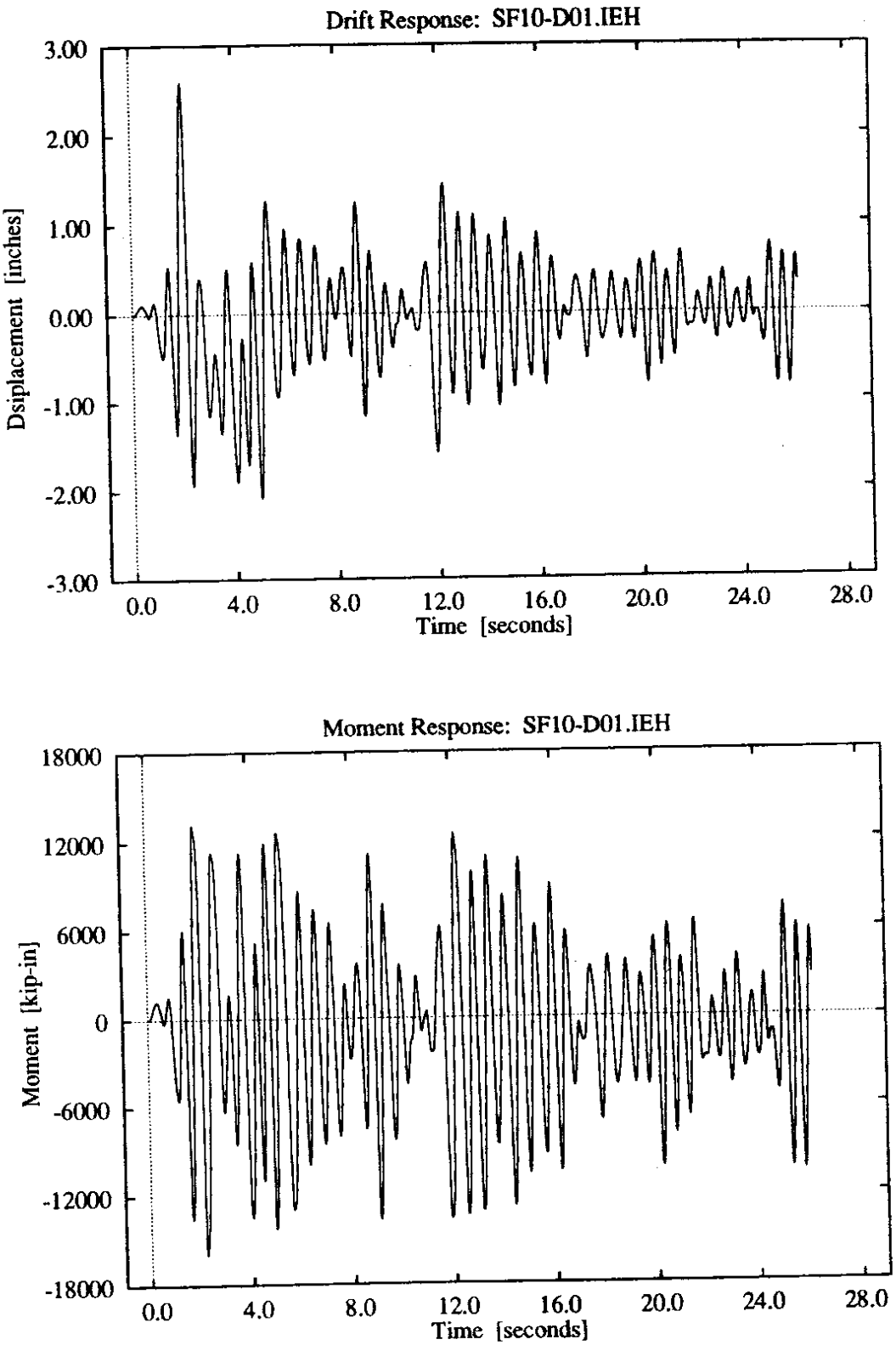


Figure D-19: 1 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.

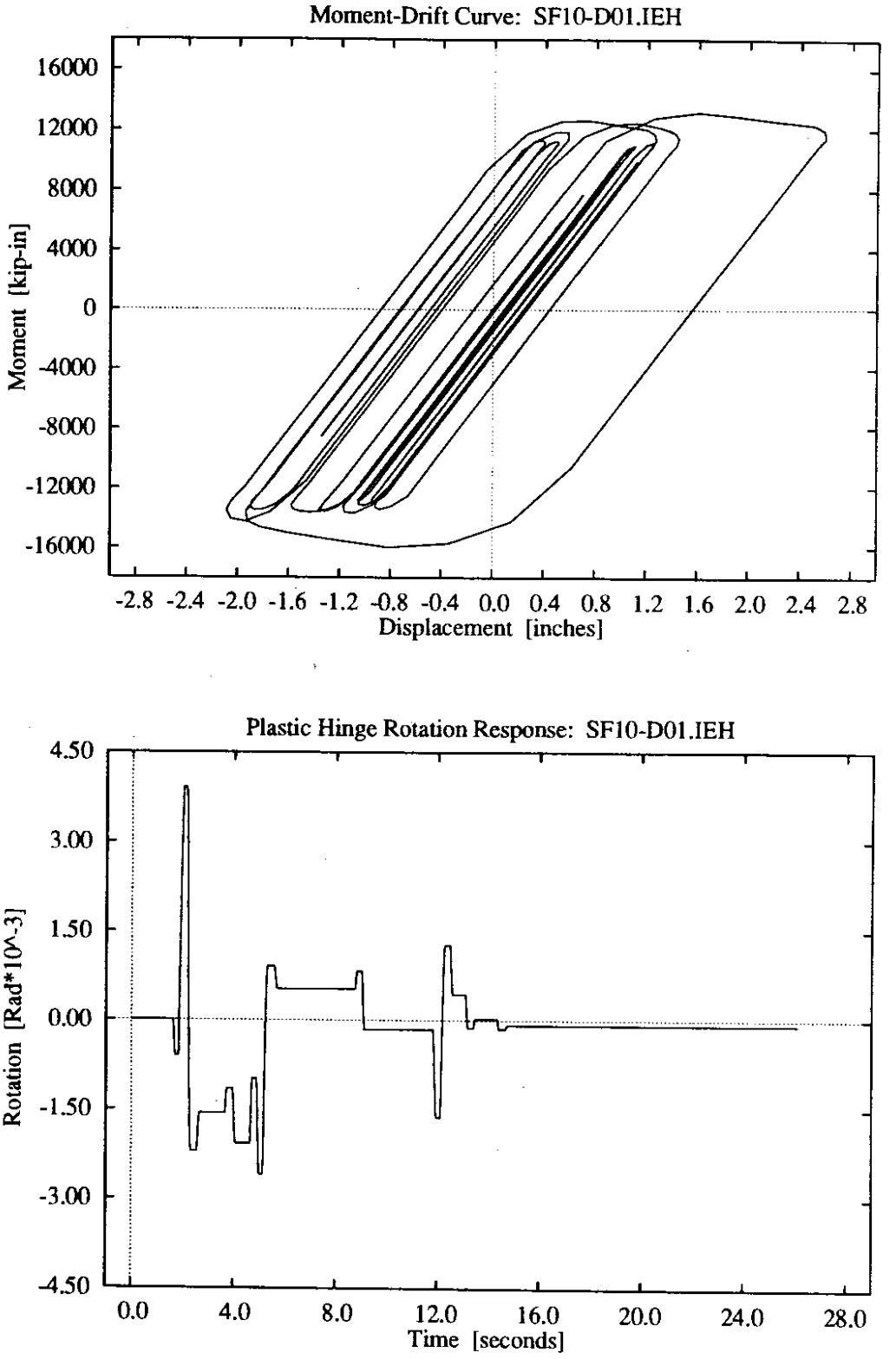


Figure D-20: 1 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.

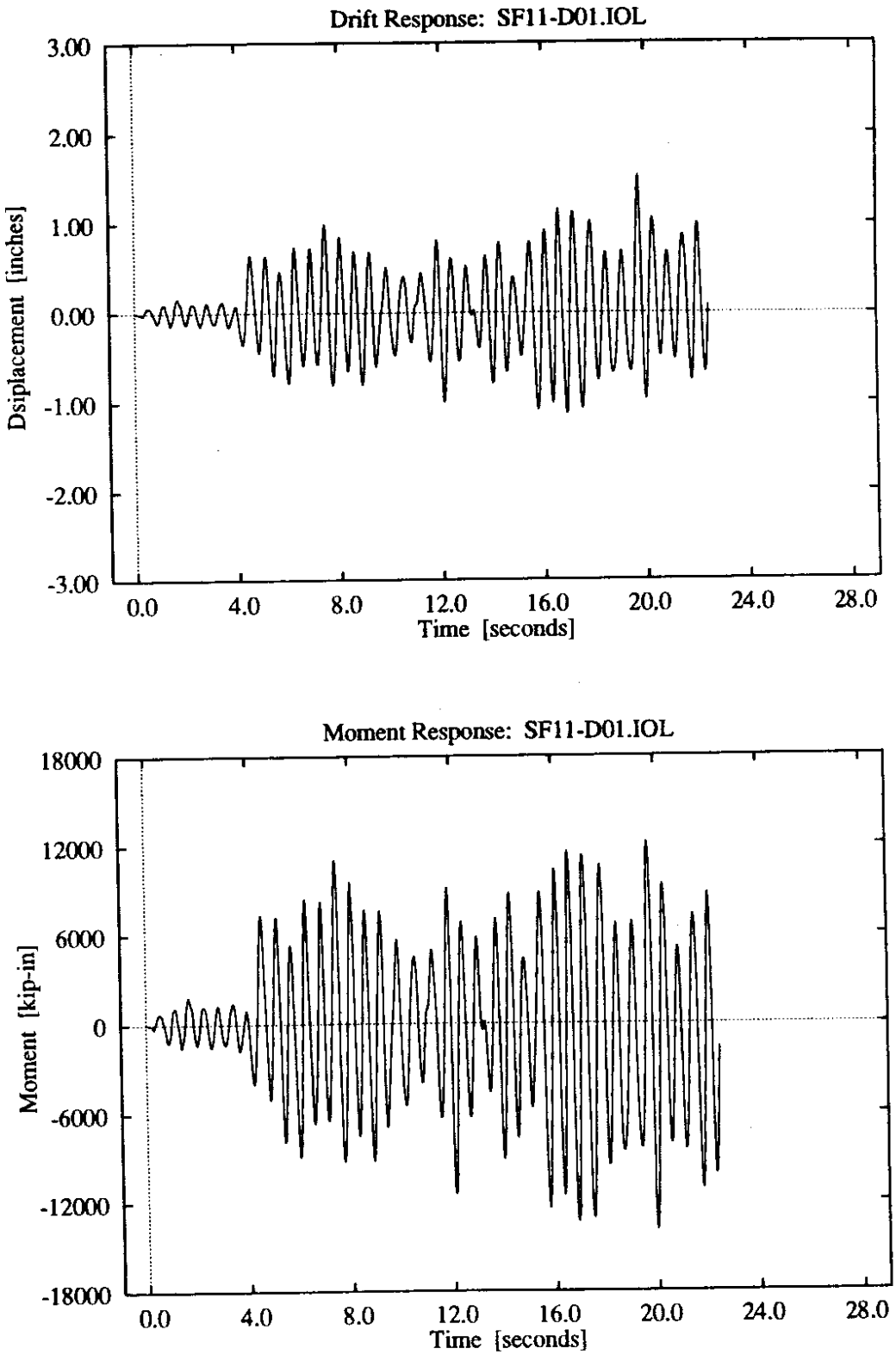
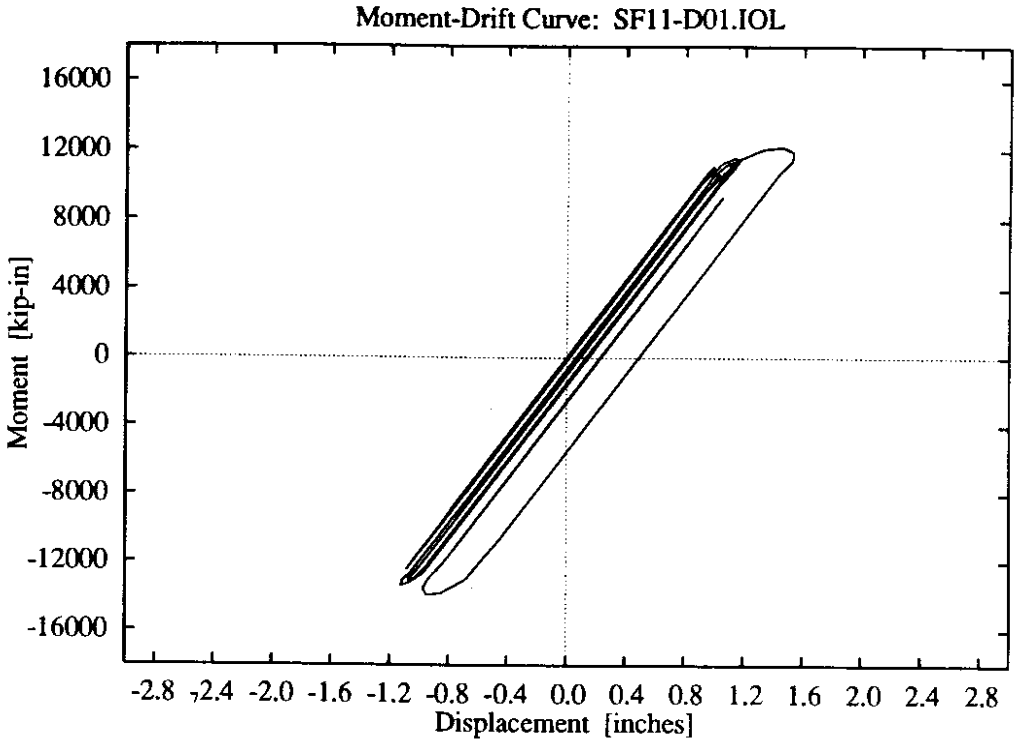


Figure D-21: 1 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.



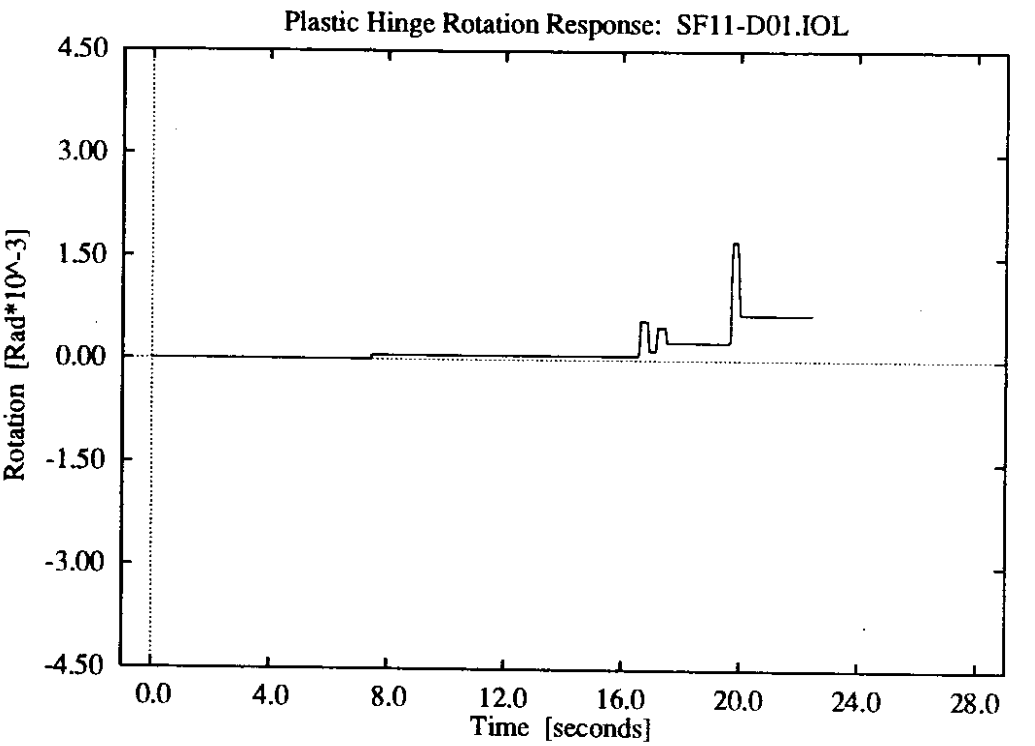


Figure D-22: 1 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.

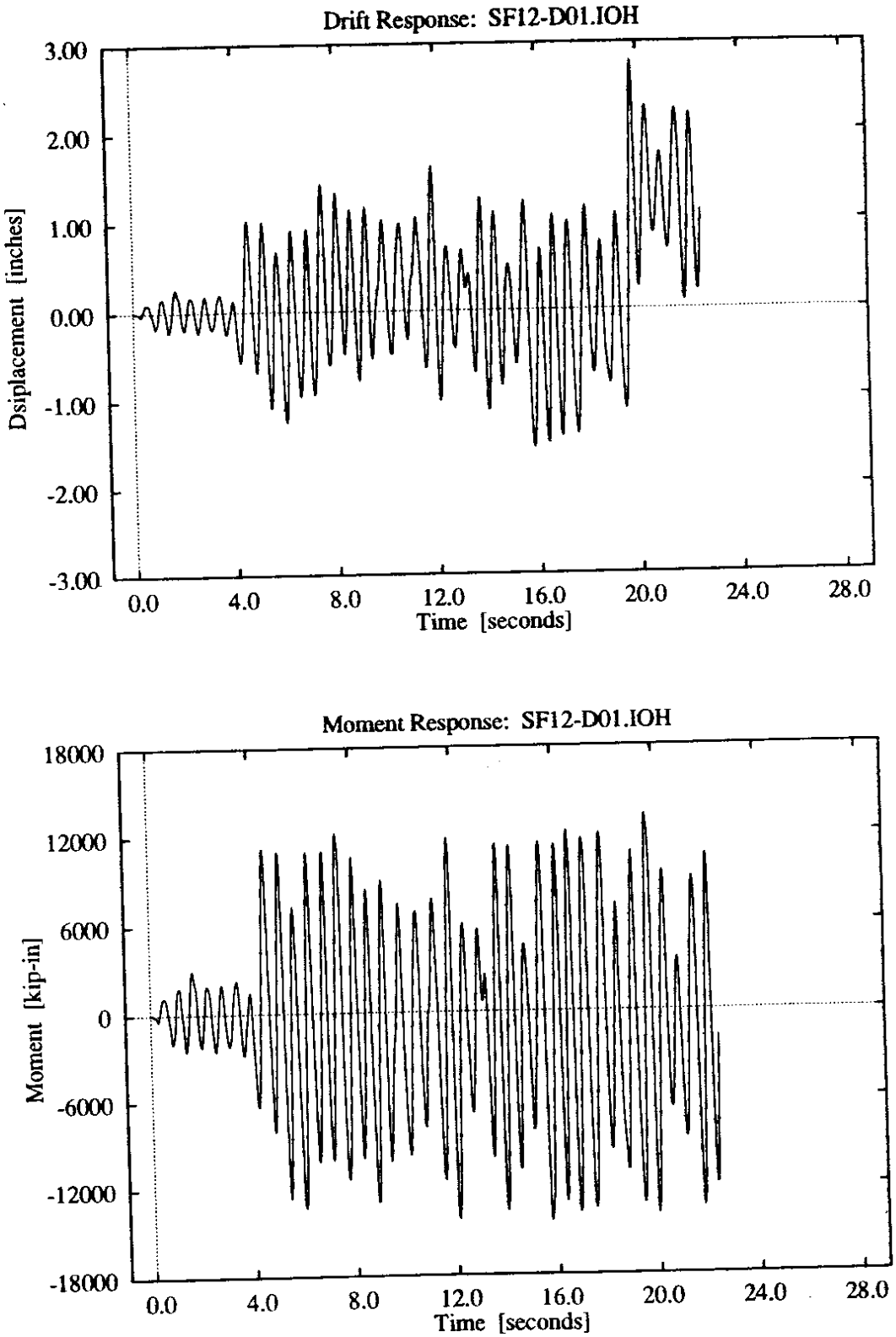


Figure D-23: 1 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.

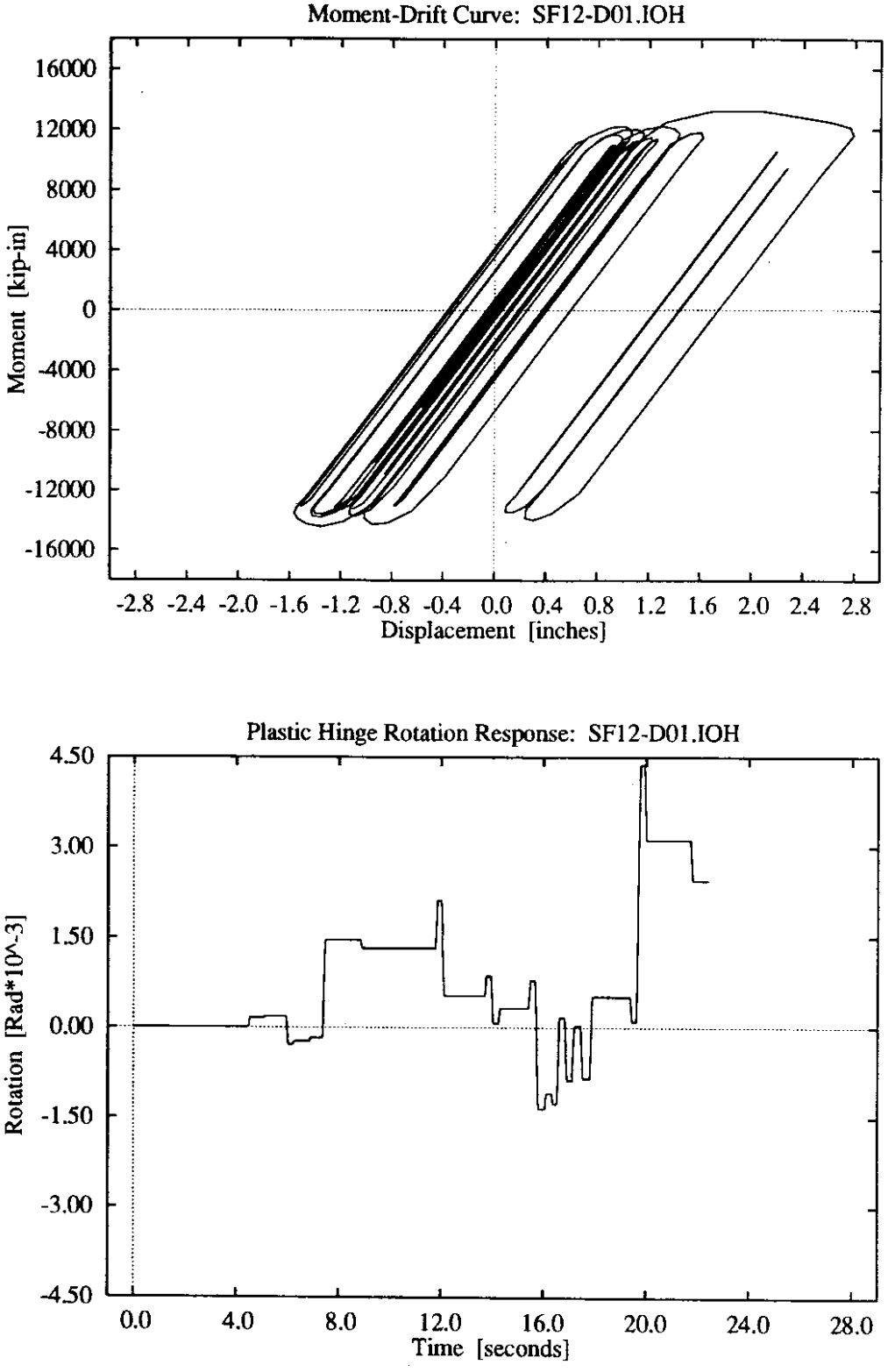
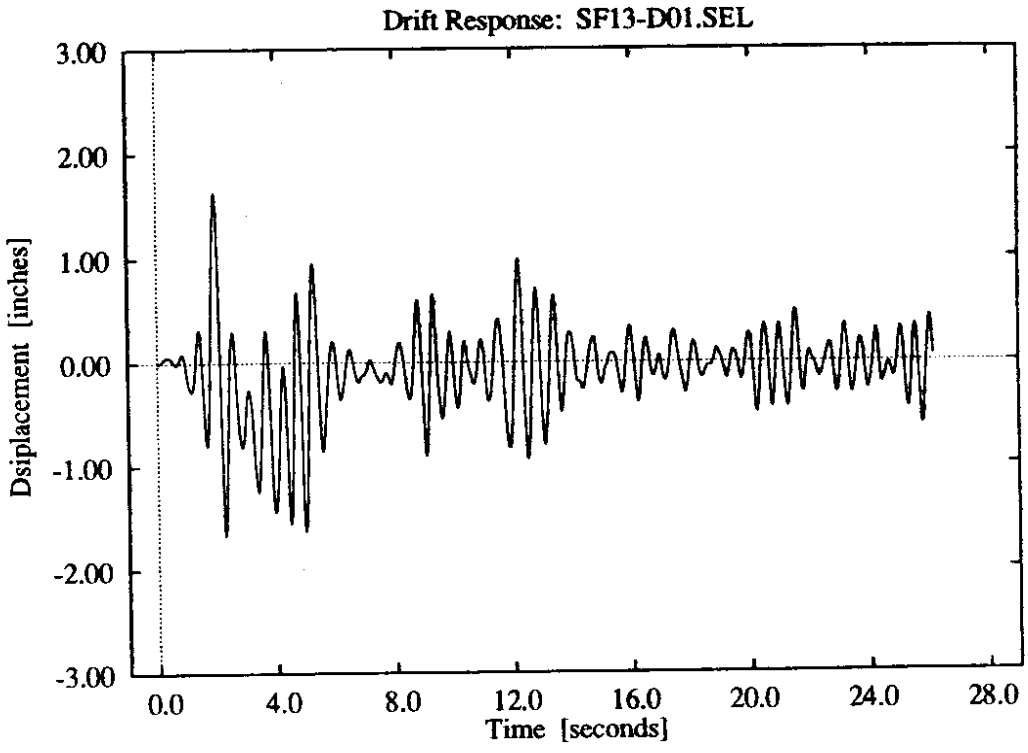


Figure D-24: 1 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.



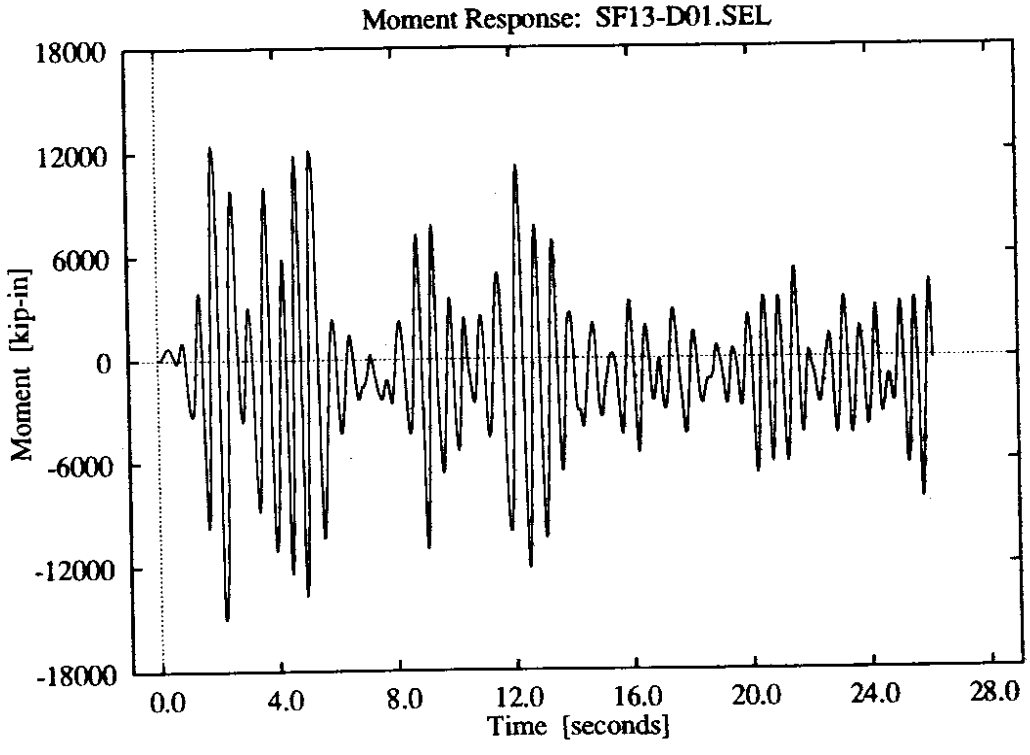
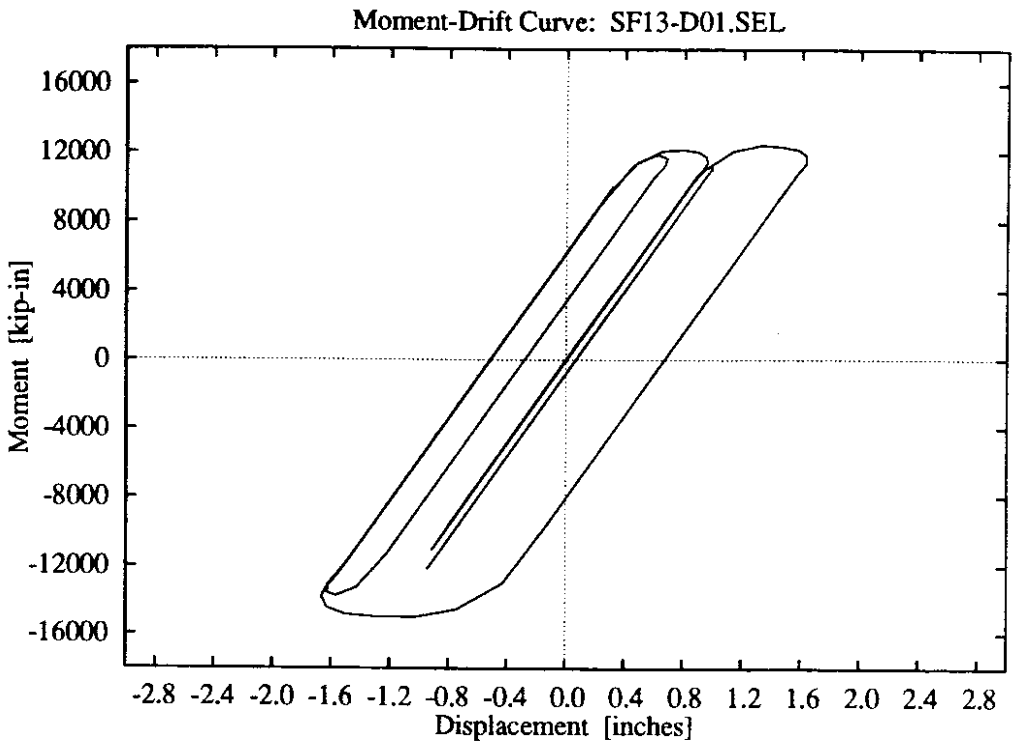


Figure D-25: 1 parameter foundation model, high soil stiffness, lower intensity El Centro record.



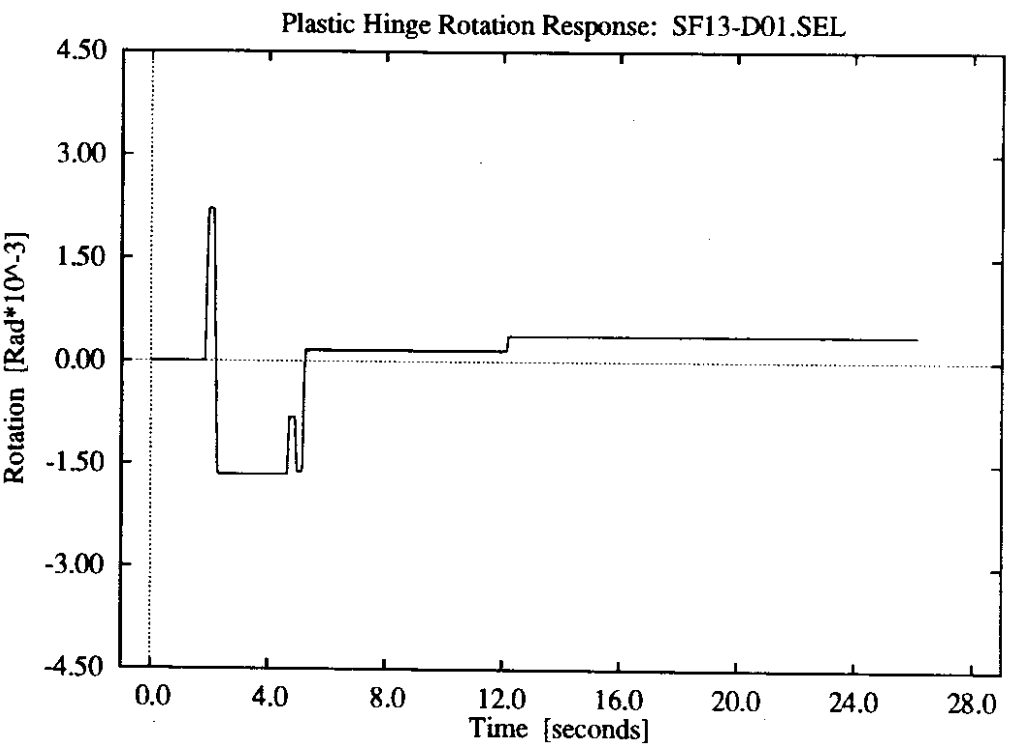


Figure D-26: 1 parameter foundation model, high soil stiffness, lower intensity El Centro record.

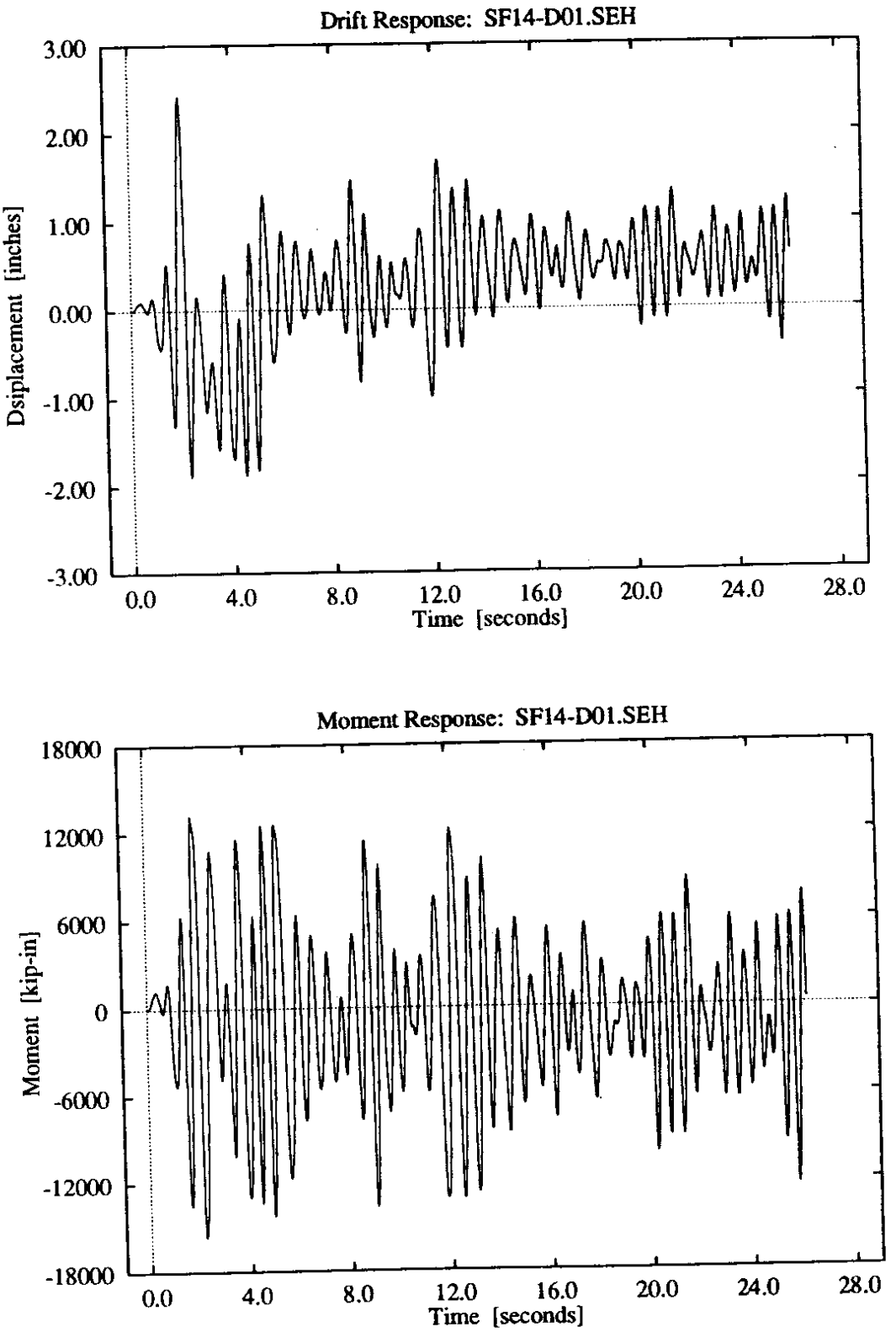
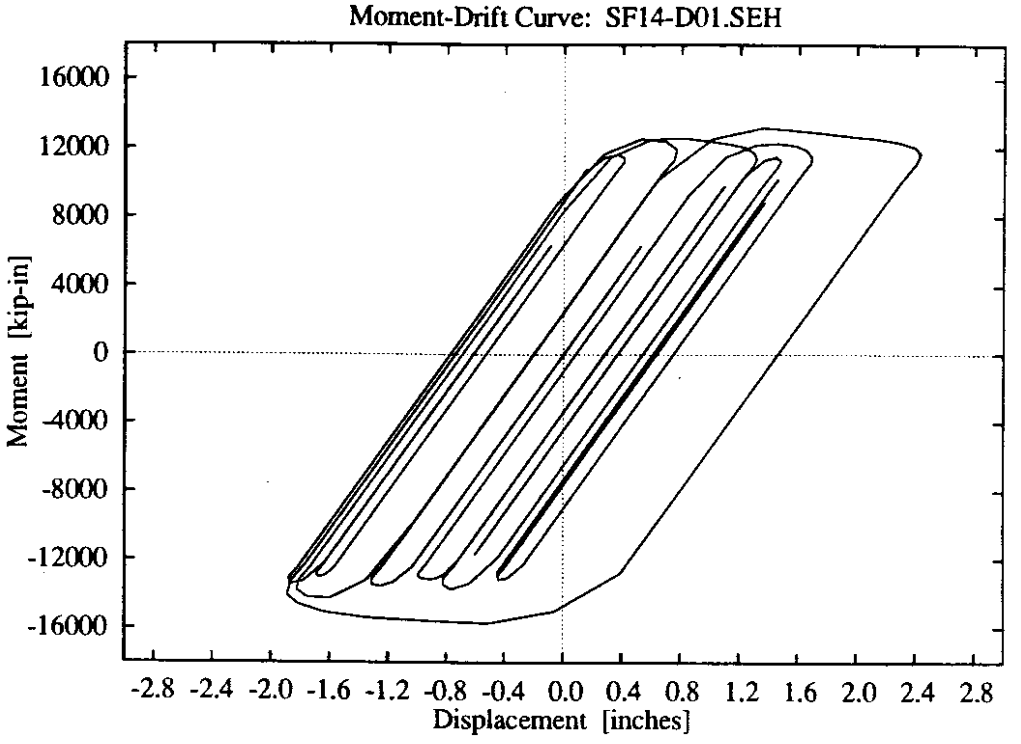


Figure D-27: 1 parameter foundation model, high soil stiffness, higher intensity El Centro record.



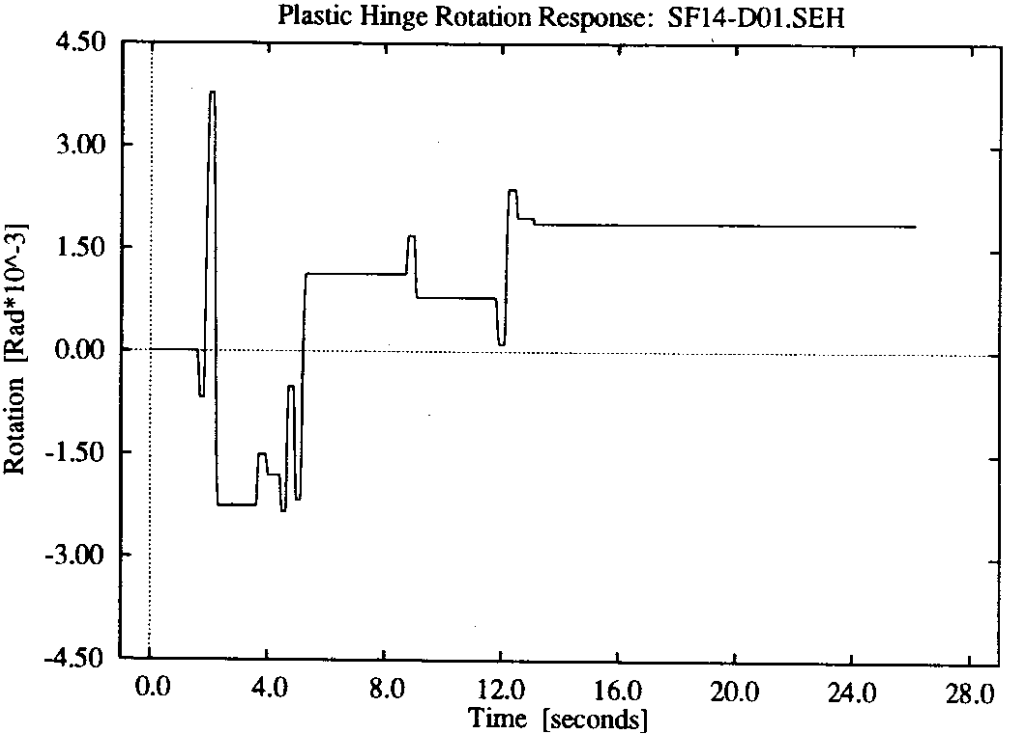


Figure D-28: 1 parameter foundation model, high soil stiffness, higher intensity El Centro record.

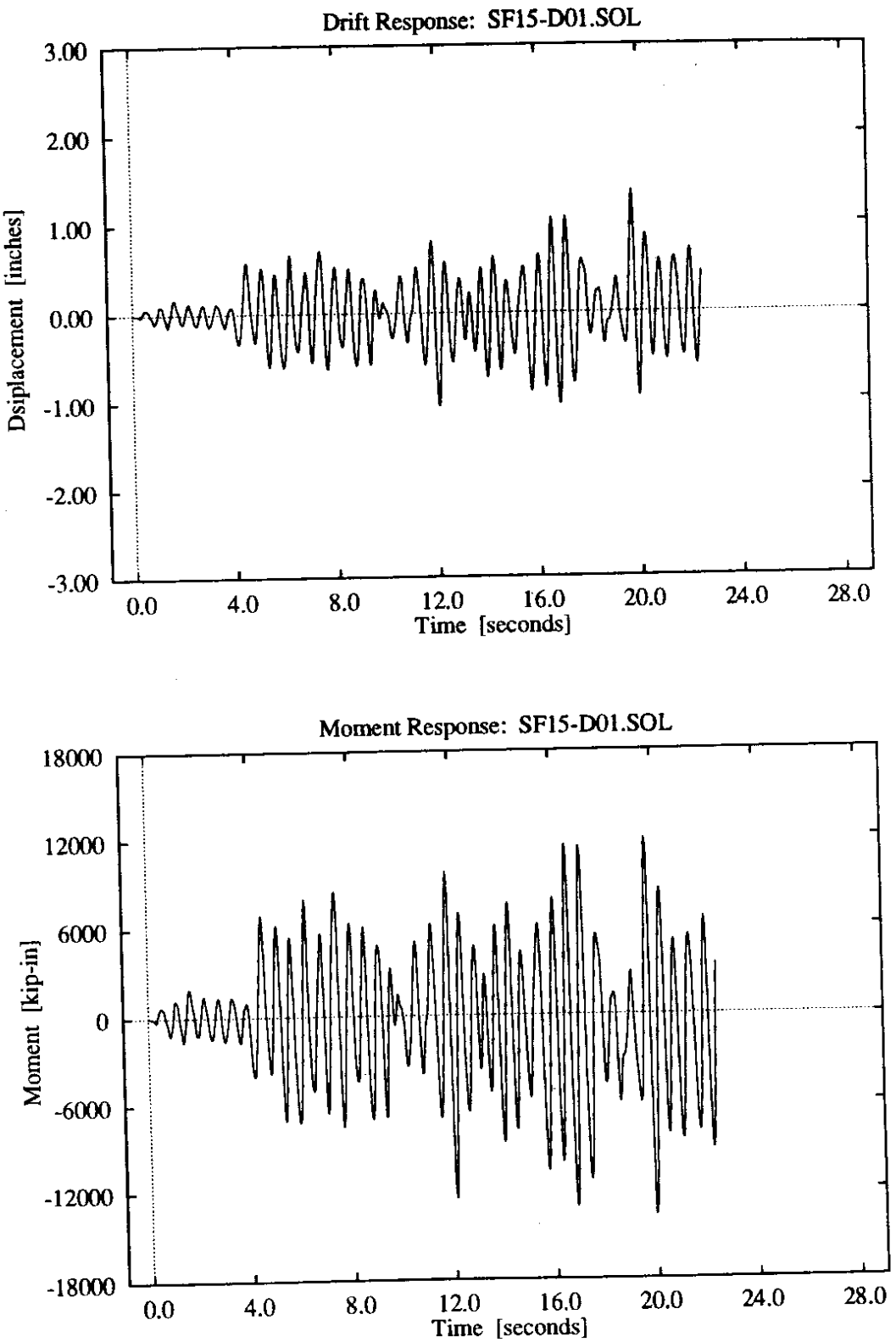
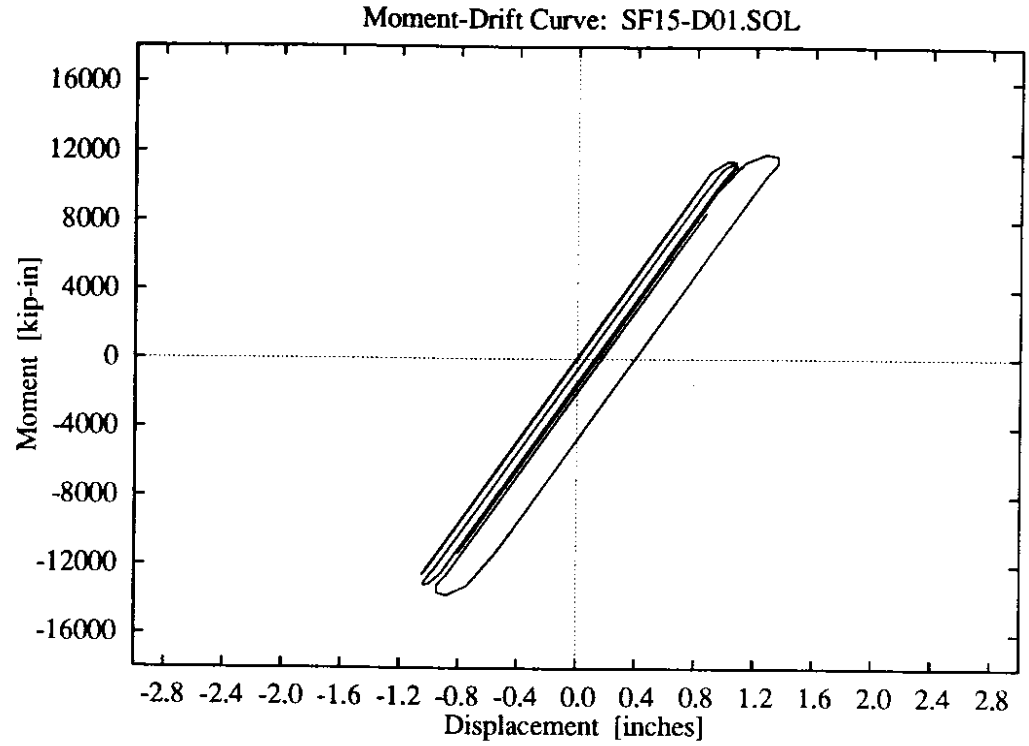


Figure D-29: 1 parameter foundation model, high soil stiffness, lower intensity Olympia record.



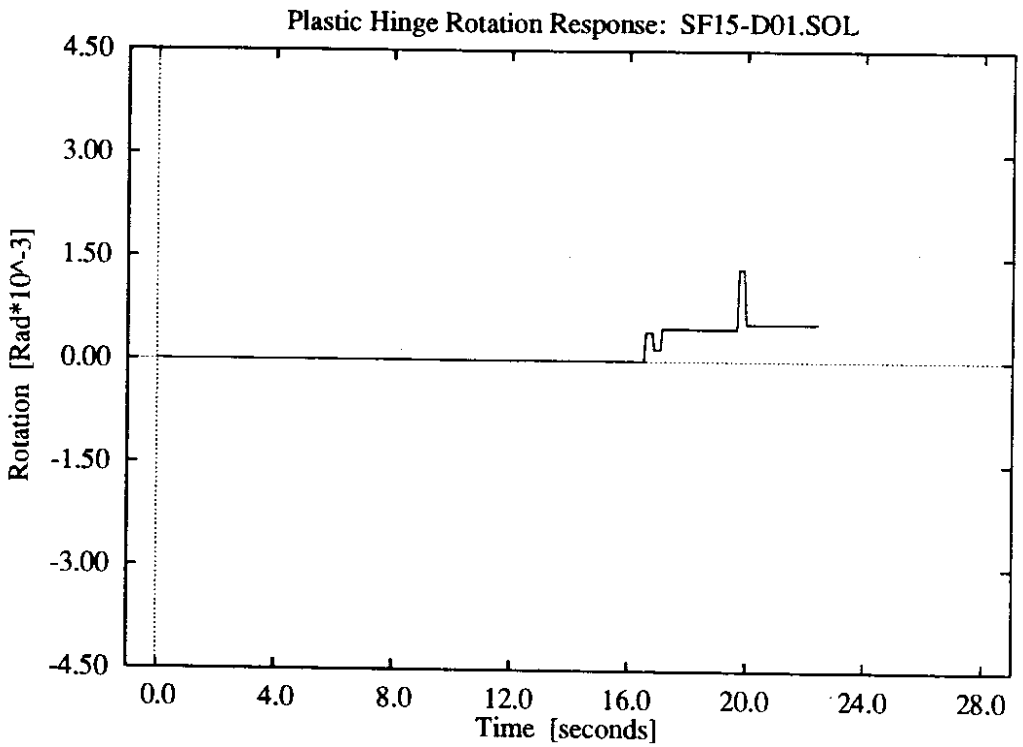


Figure D-30: 1 parameter foundation model, high soil stiffness, lower intensity Olympia record.

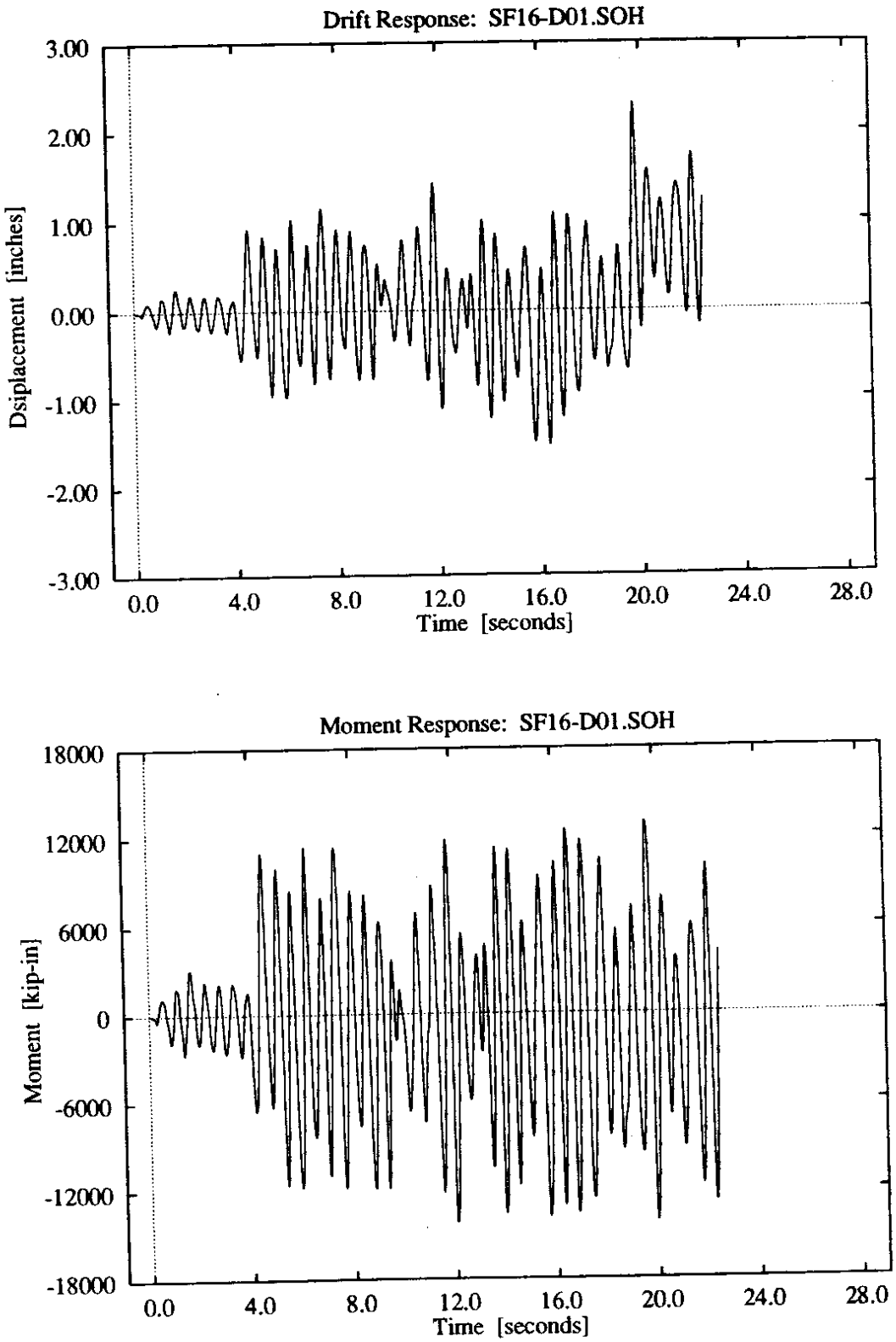


Figure D-31: 1 parameter foundation model, high soil stiffness, higher intensity Olympia record.

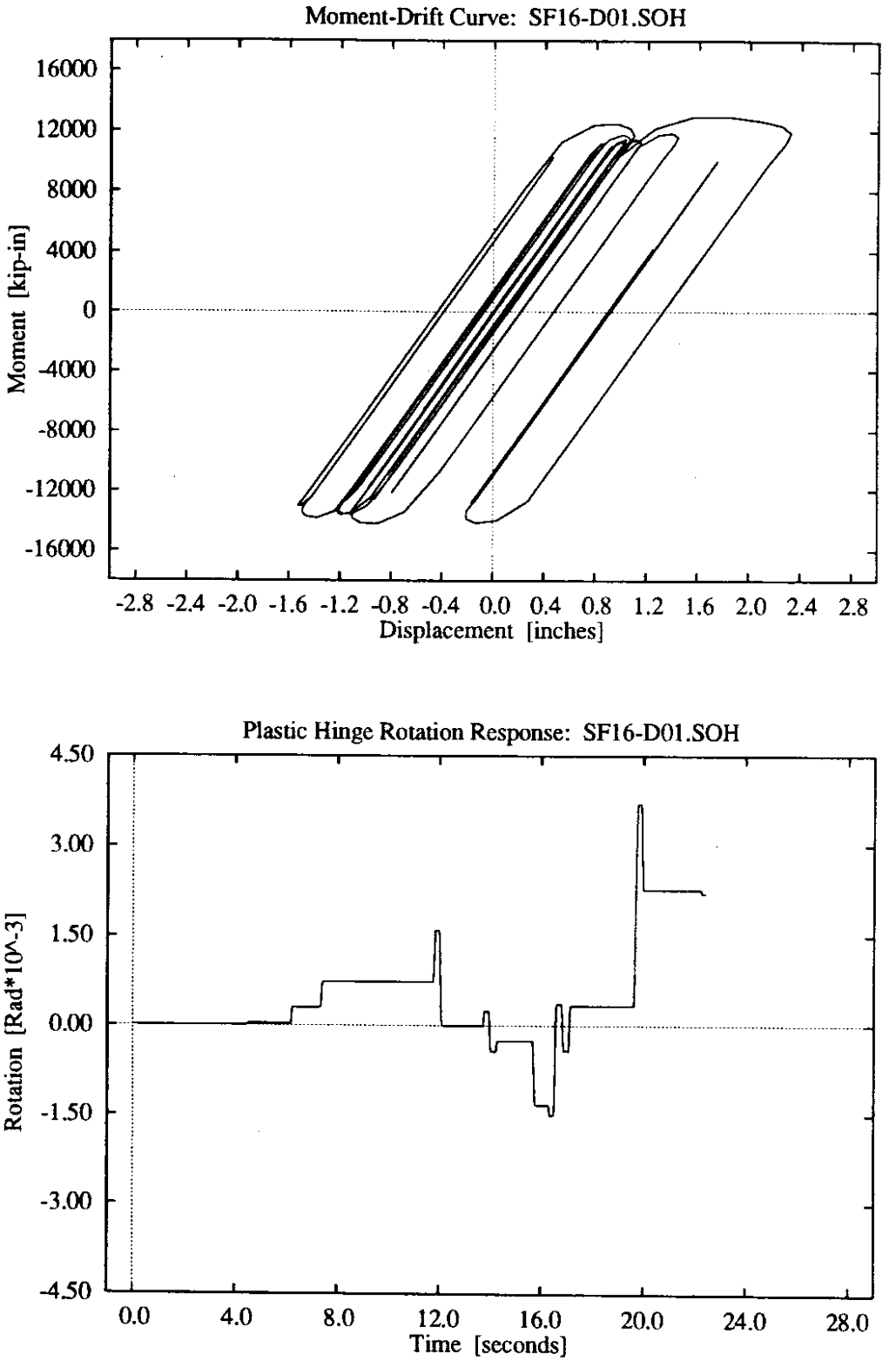


Figure D-32: 1 parameter foundation model, high soil stiffness, higher intensity Olympia record.

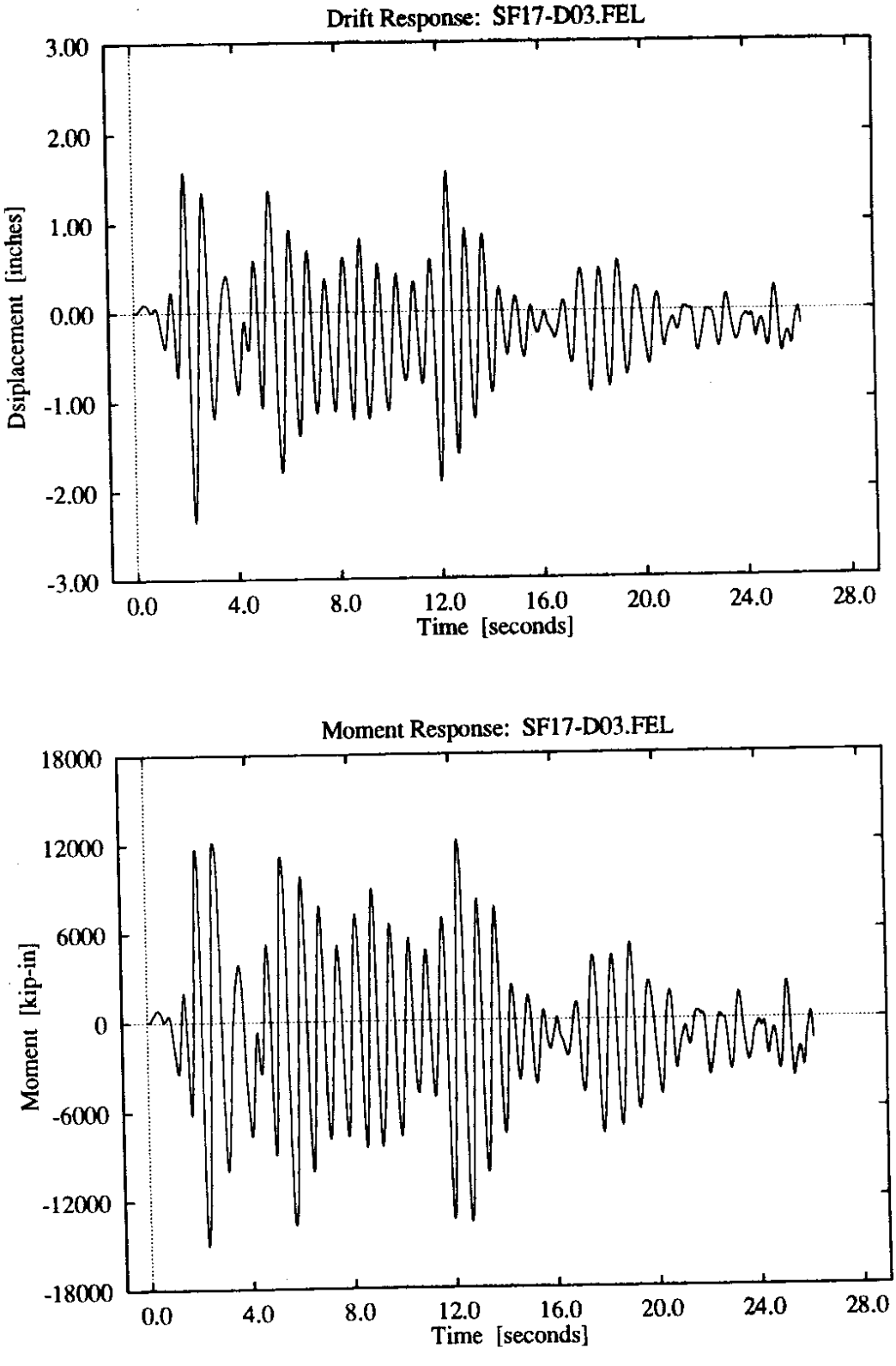
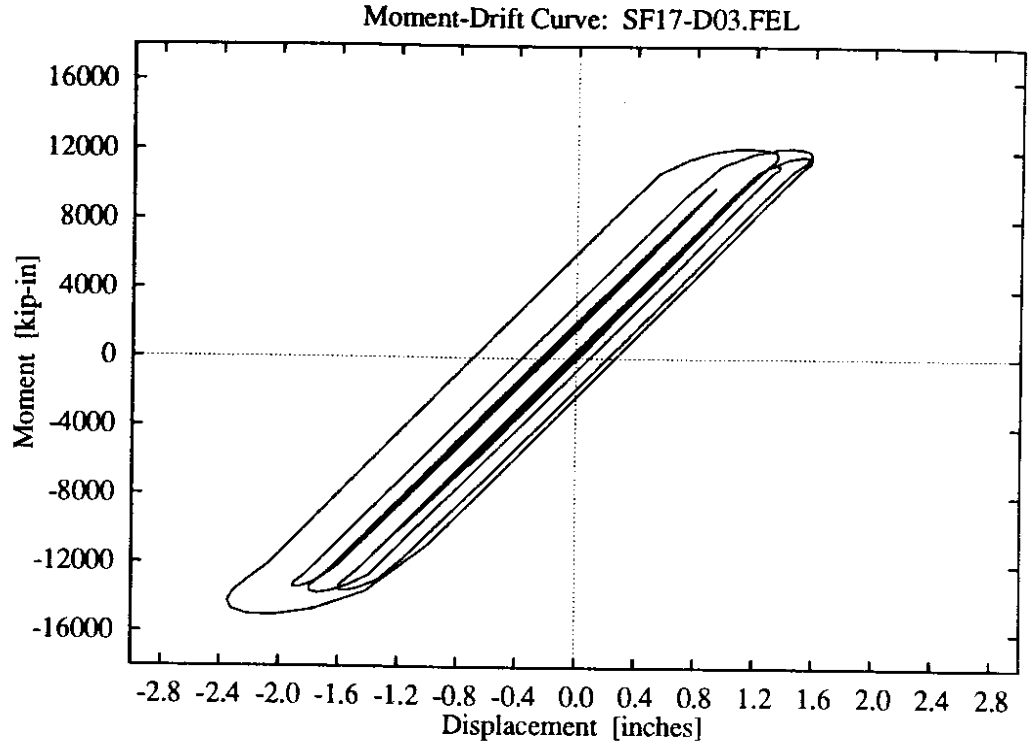


Figure D-33: 3 parameter foundation model, low soil stiffness, lower intensity El Centro record.



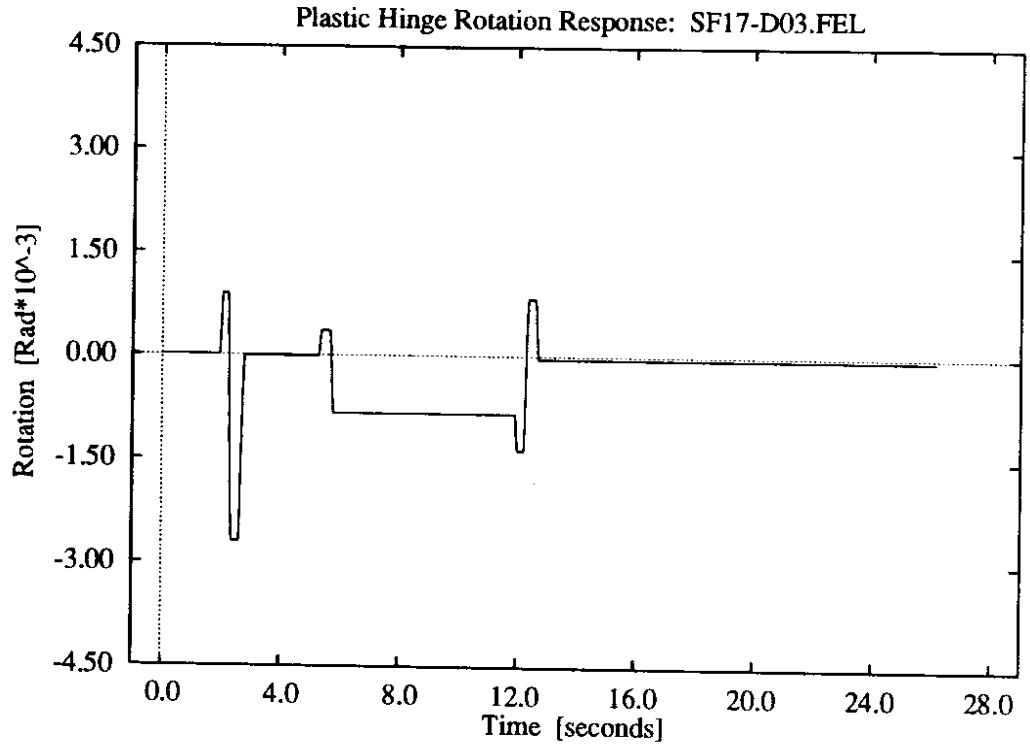


Figure D-34: 3 parameter foundation model, low soil stiffness, lower intensity El Centro record.

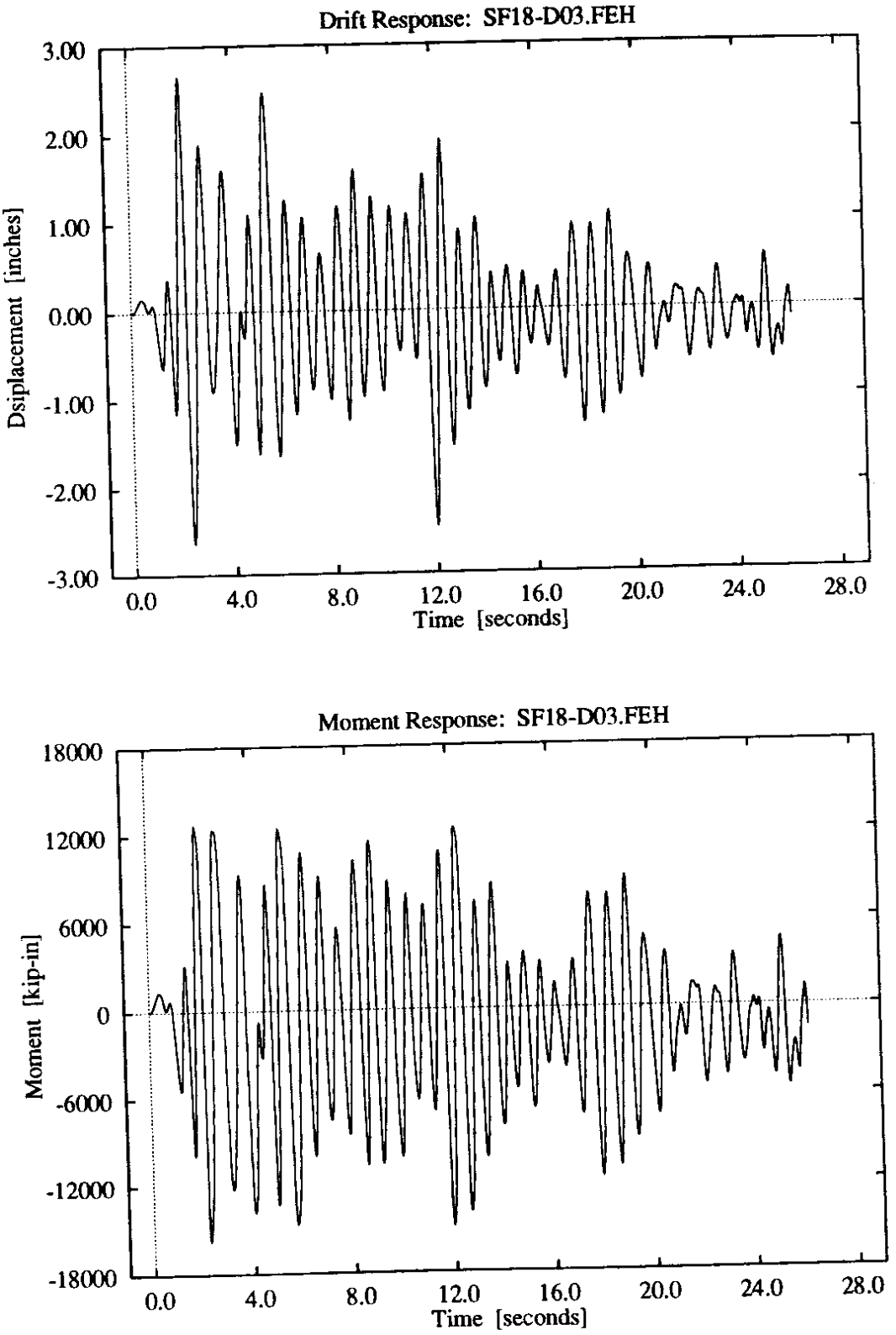
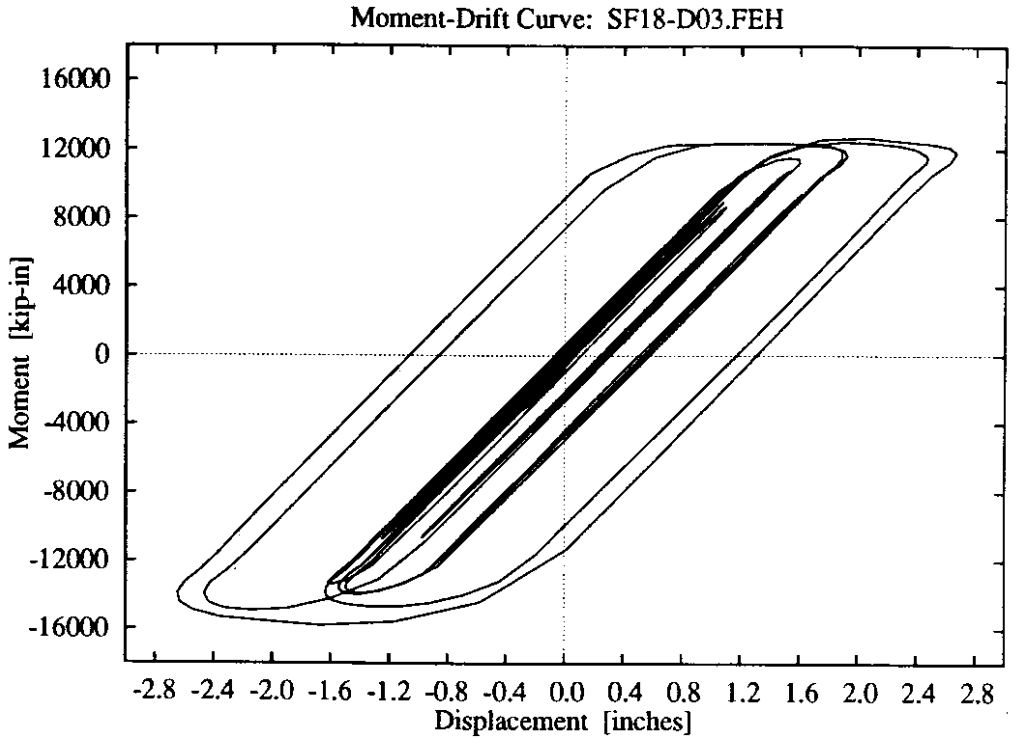


Figure D-35: 3 parameter foundation model, low soil stiffness, higher intensity El Centro record.



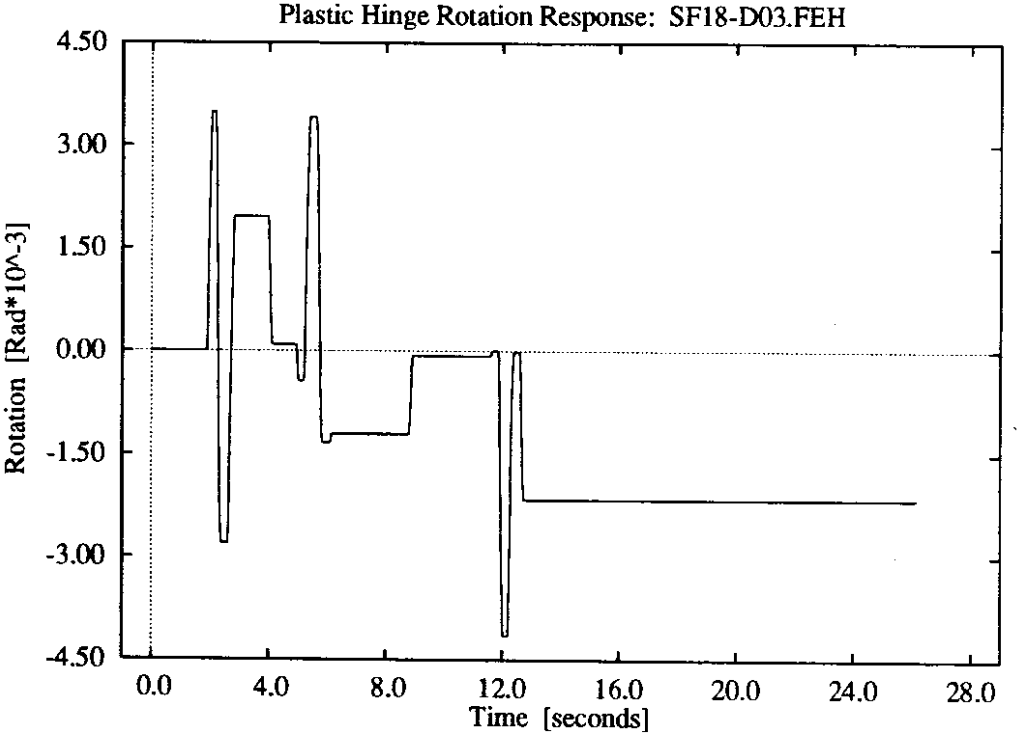
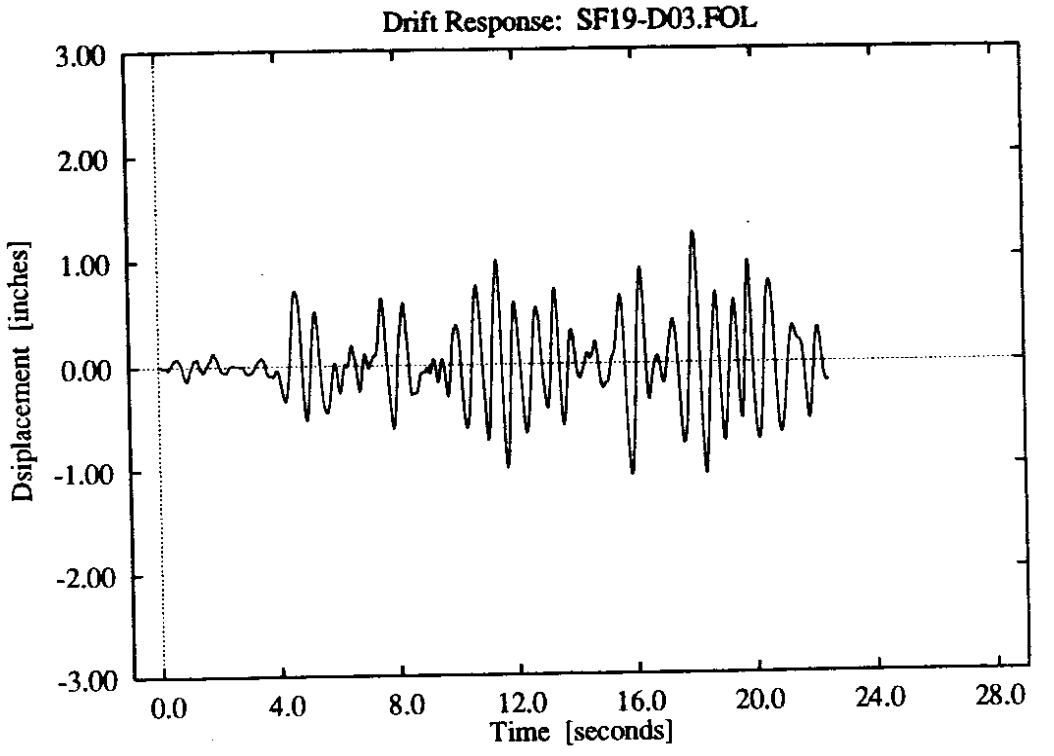


Figure D-36: 3 parameter foundation model, low soil stiffness, higher intensity El Centro record.



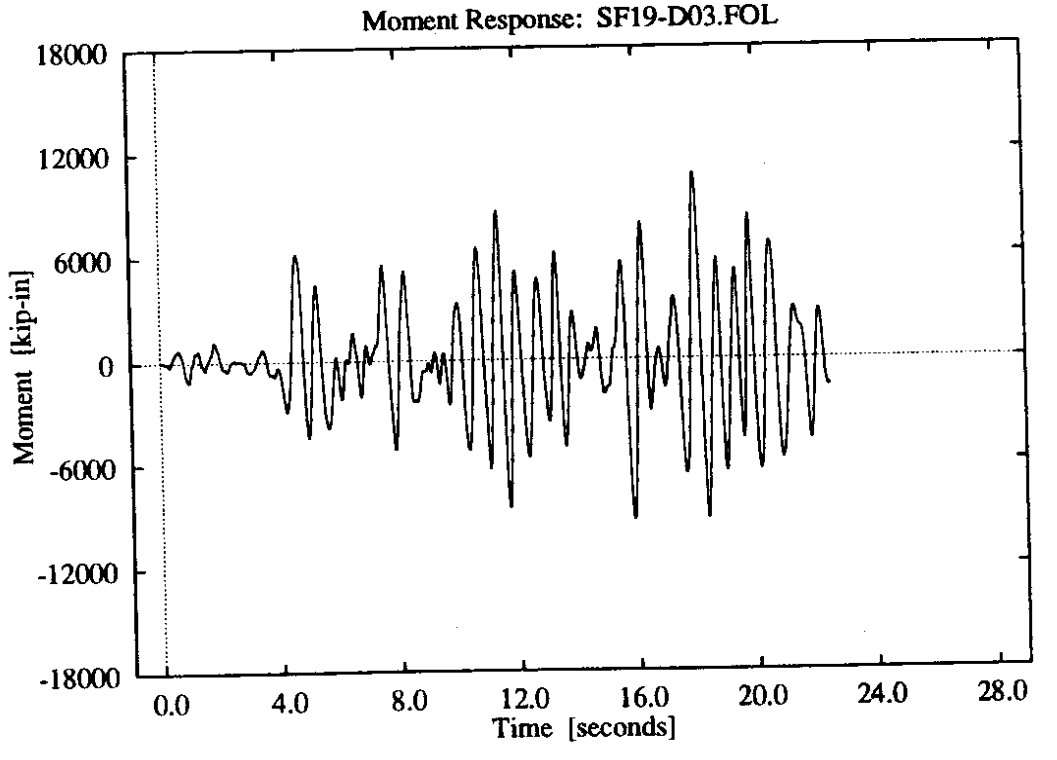
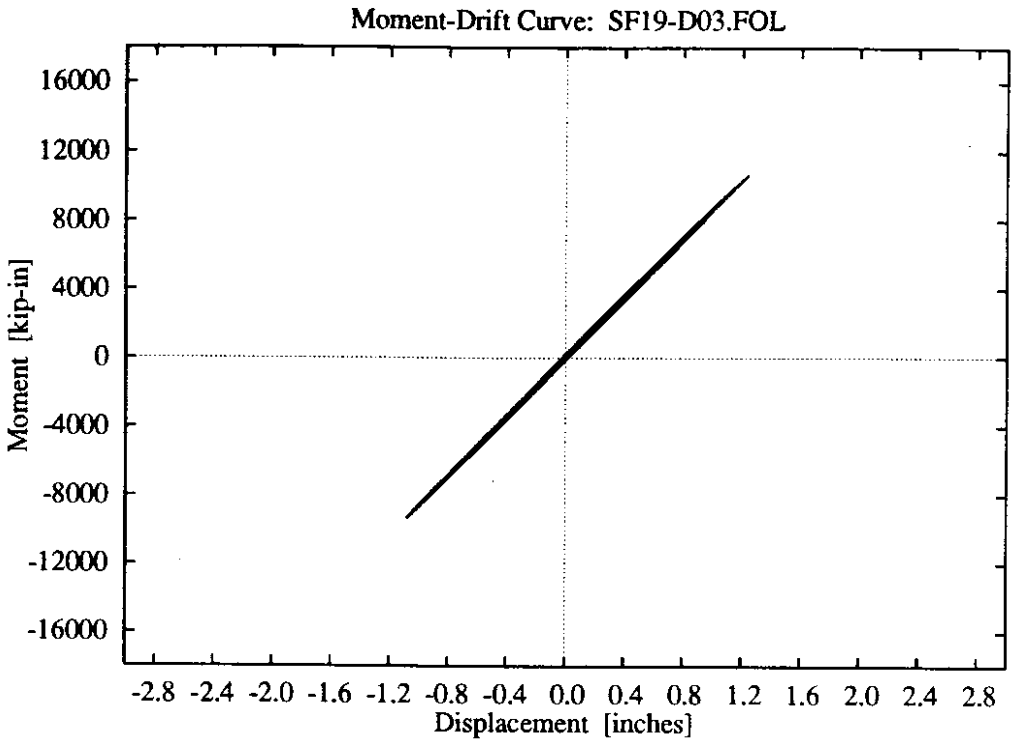


Figure D-37: 3 parameter foundation model, low soil stiffness, lower intensity Olympia record.



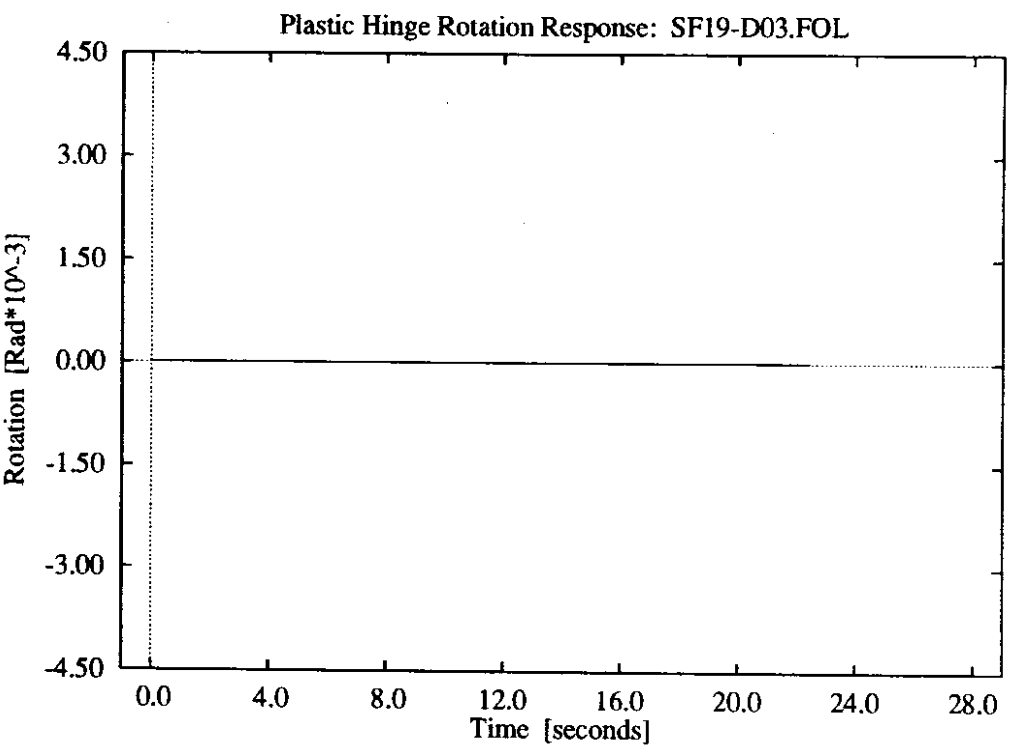
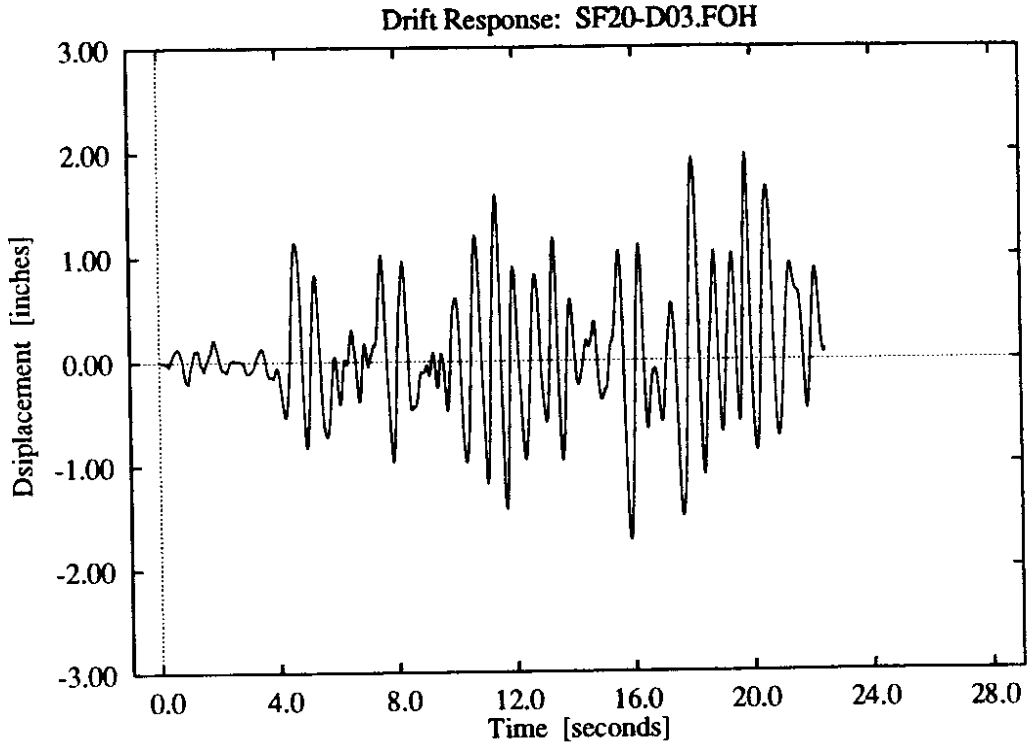


Figure D-38: 3 parameter foundation model, low soil stiffness, lower intensity Olympia record.



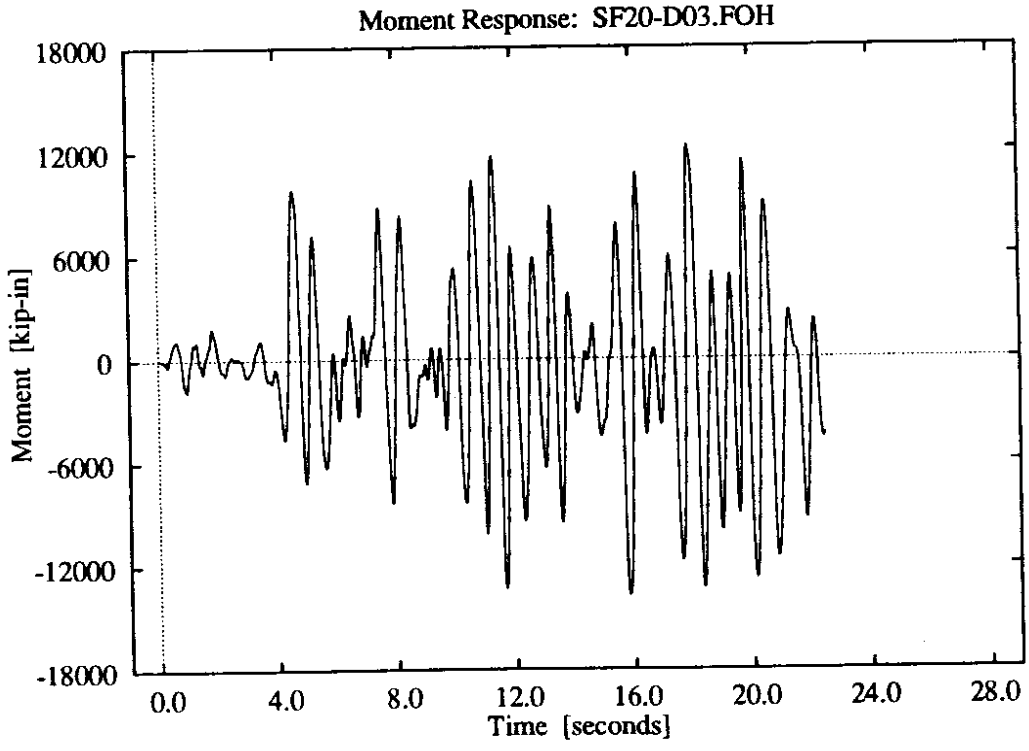
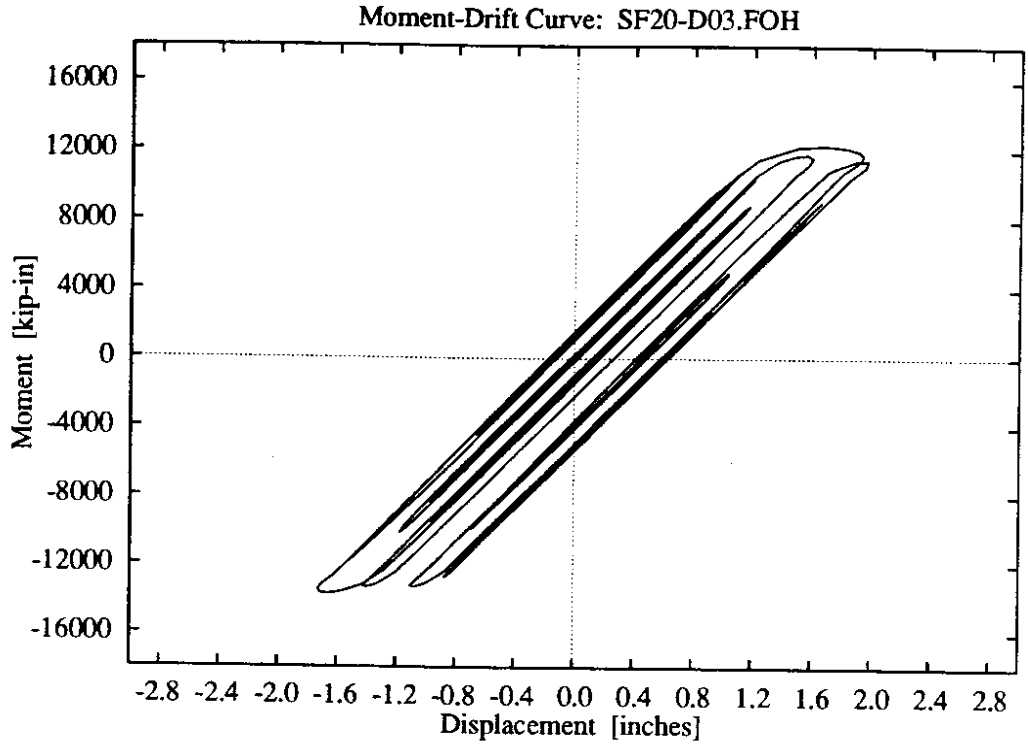


Figure D-39: 3 parameter foundation model, low soil stiffness, higher intensity Olympia record.



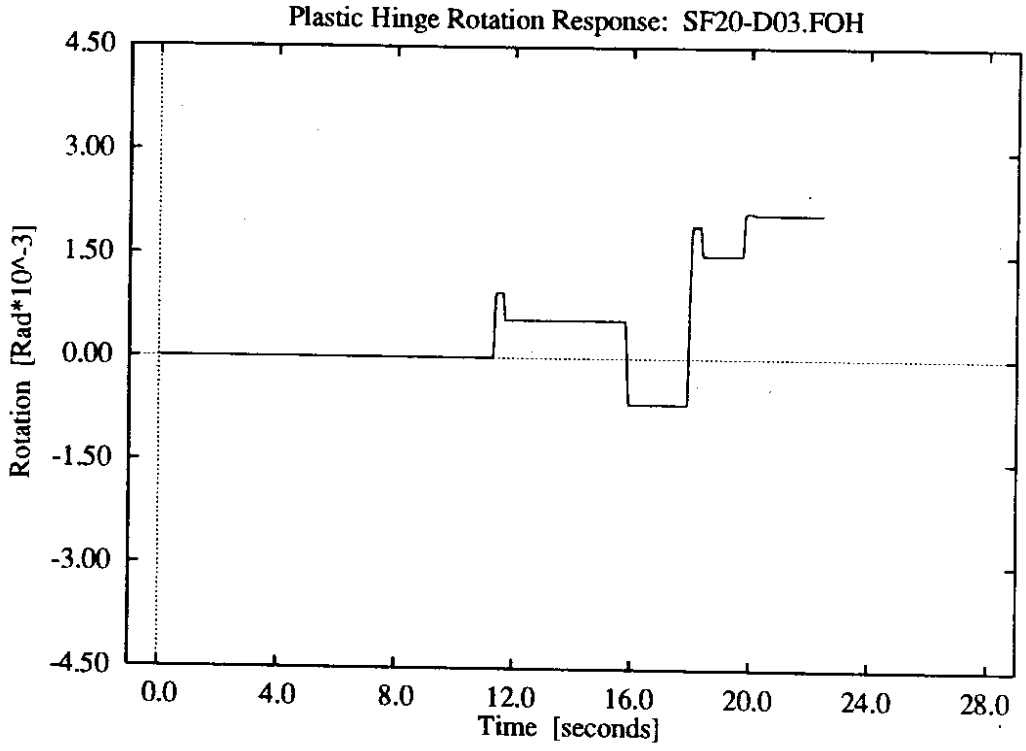


Figure D-40: 3 parameter foundation model, low soil stiffness, higher intensity Olympia record.

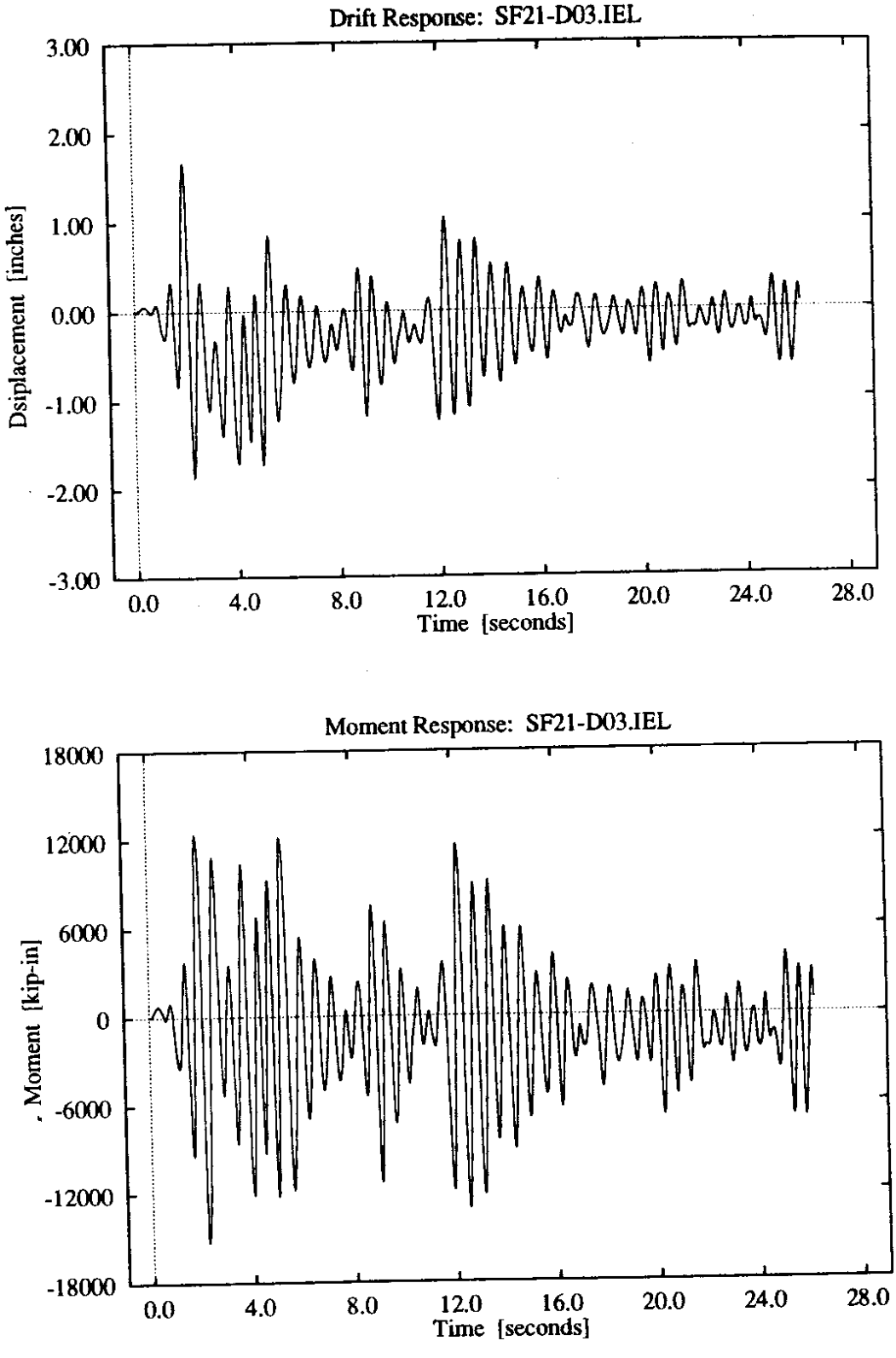
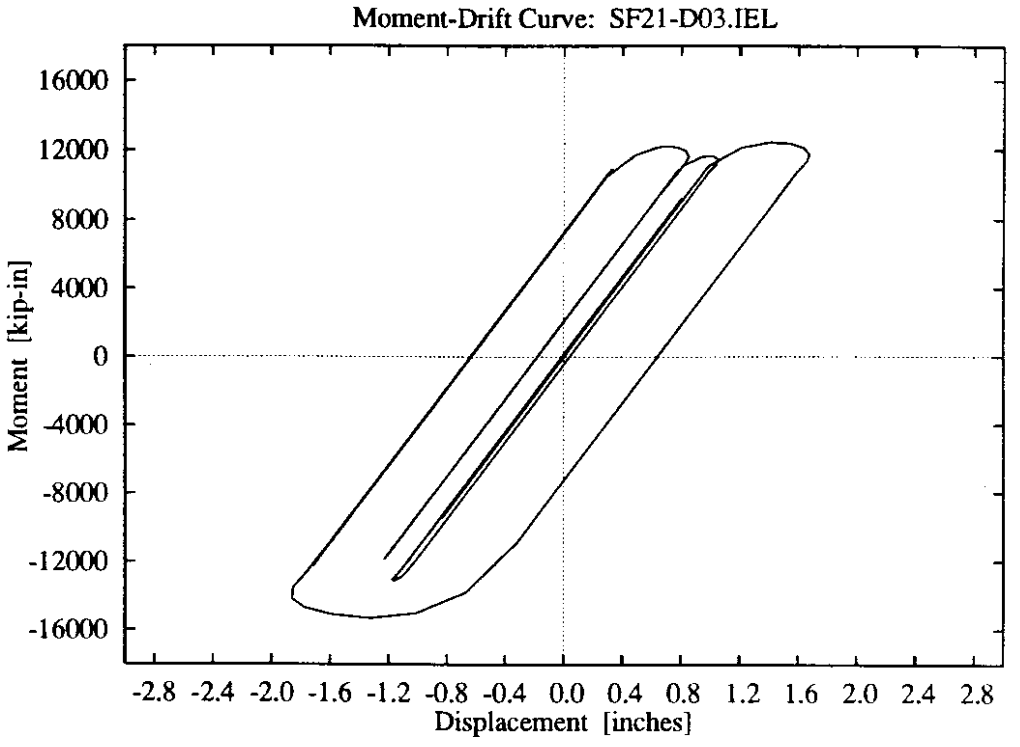


Figure D-41: 3 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.



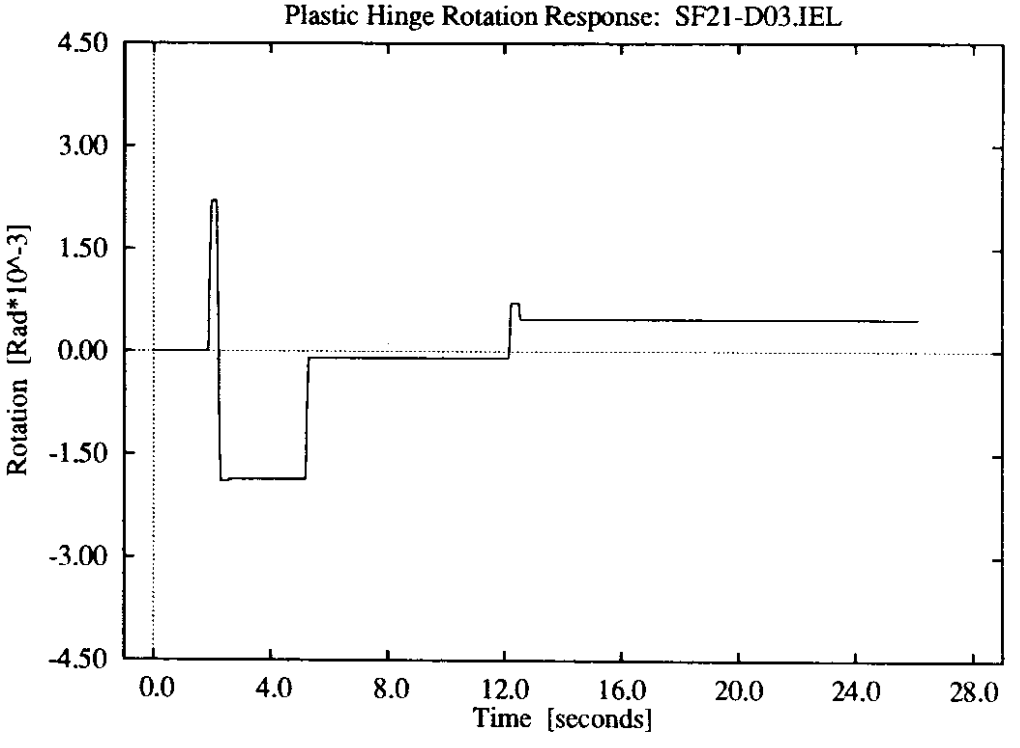
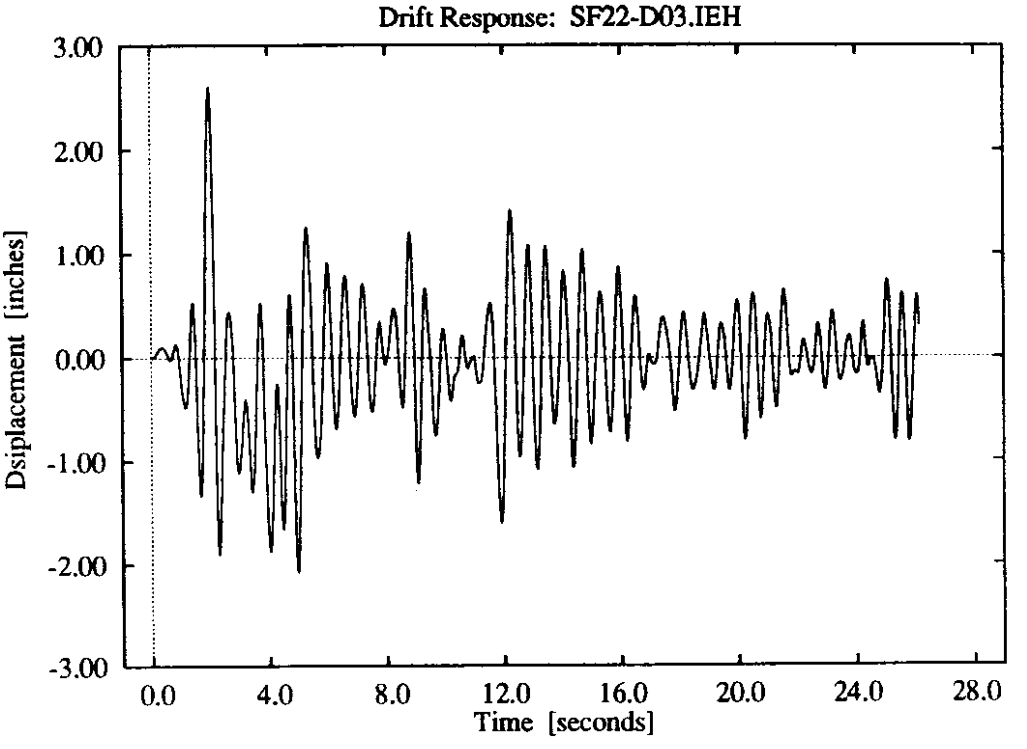


Figure D-42: 3 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.



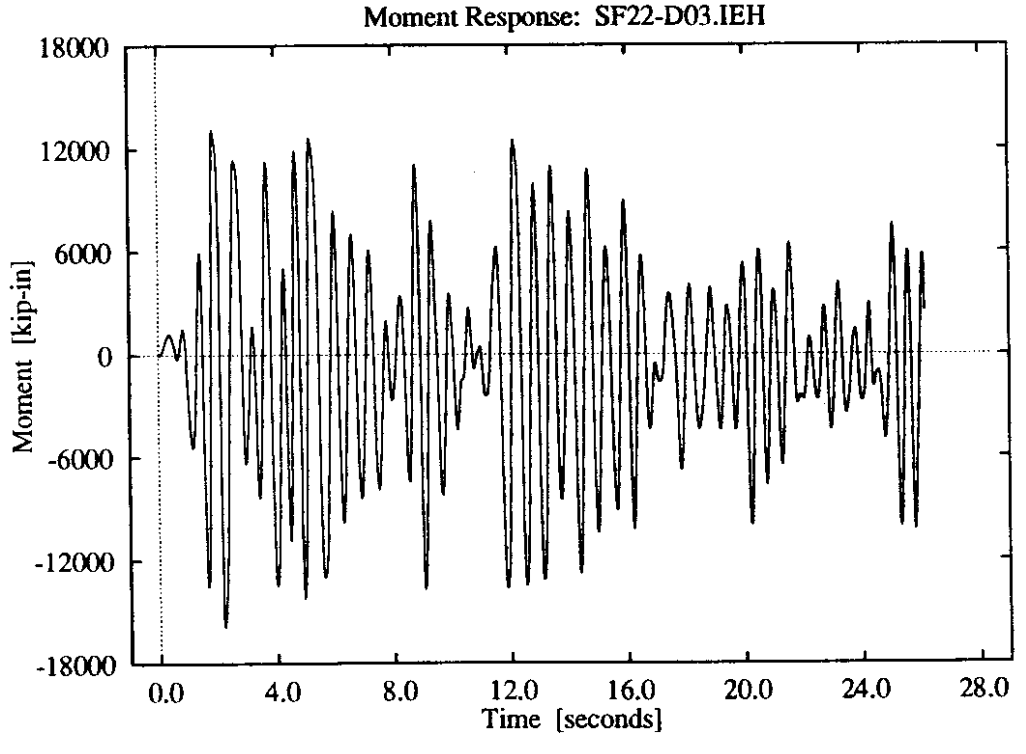
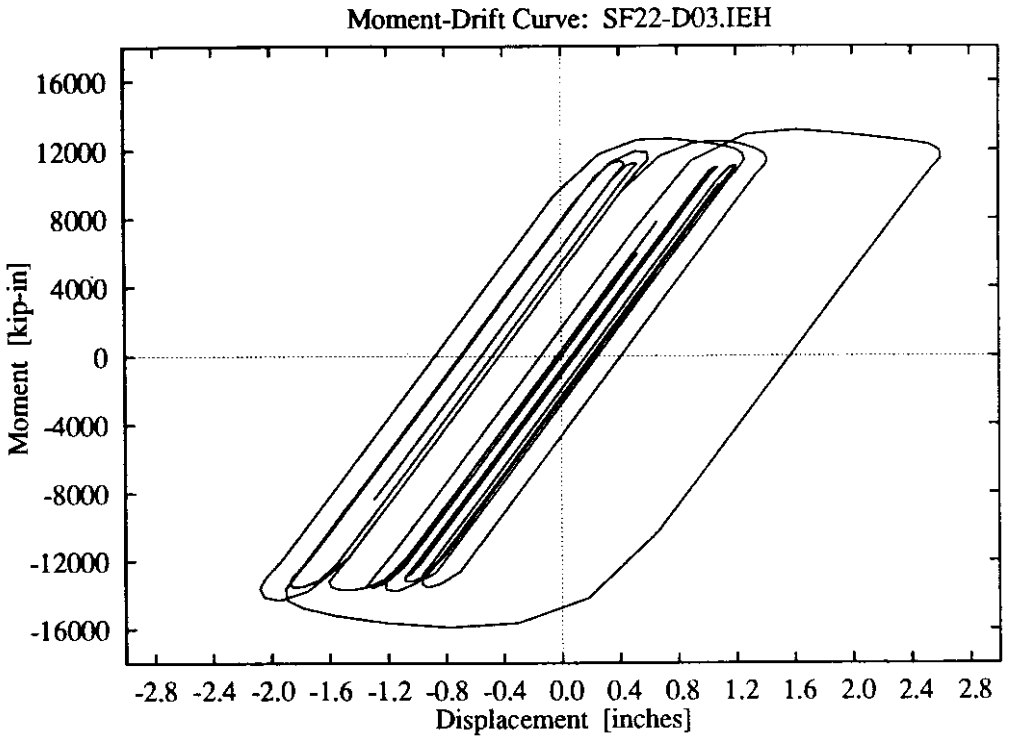


Figure D-43: 3 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.



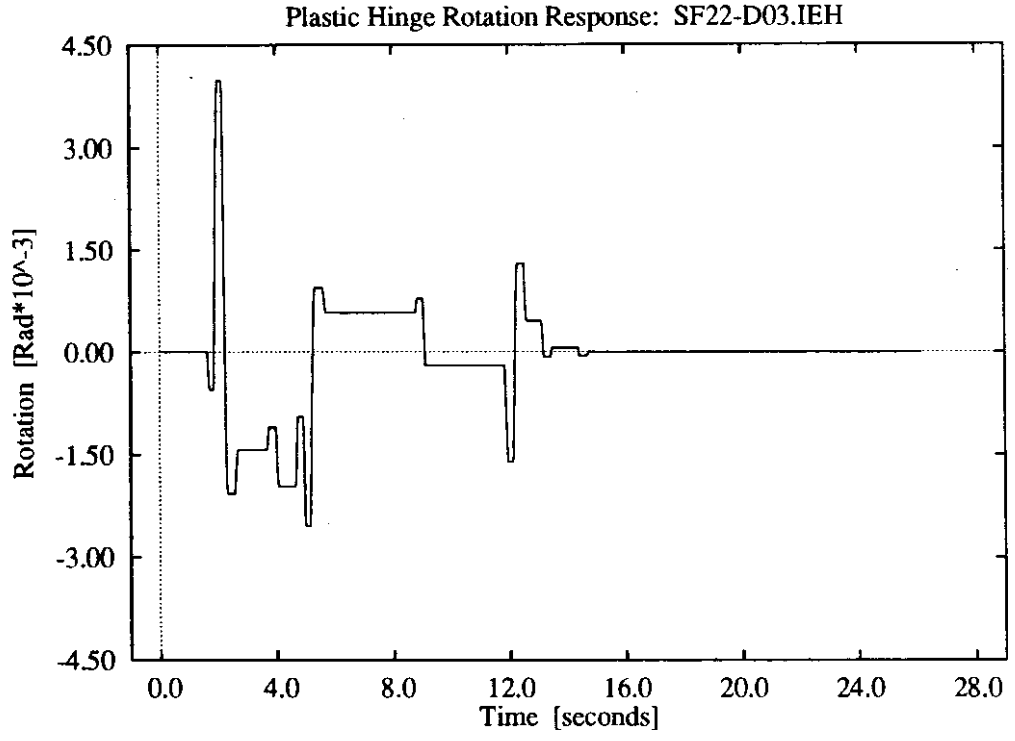
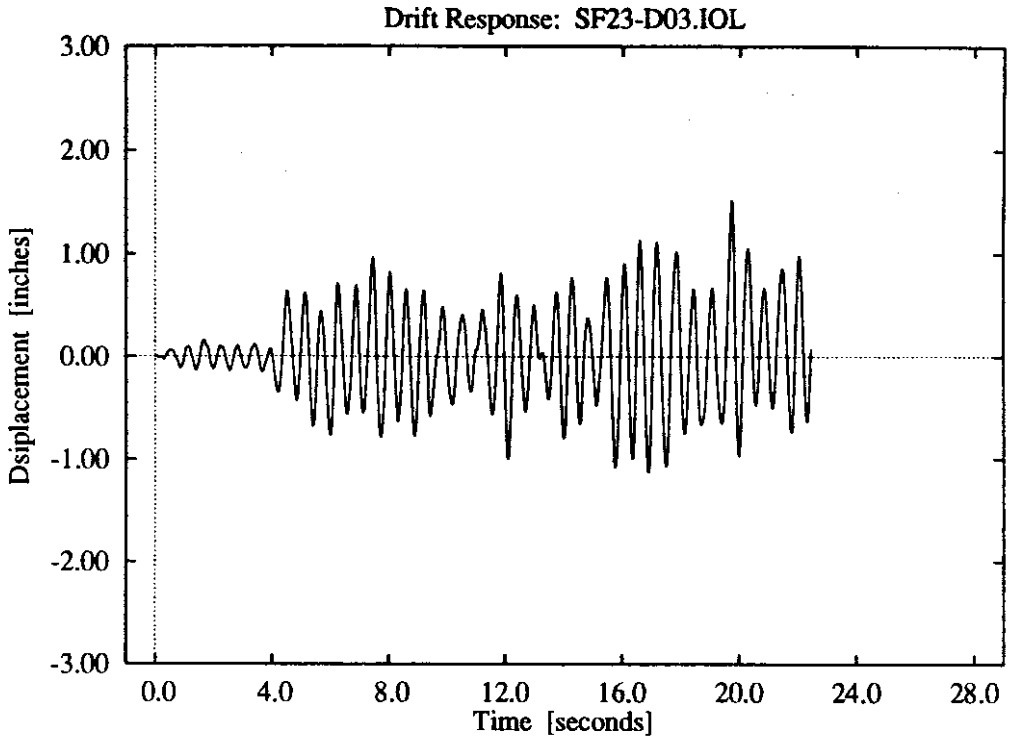


Figure D-44: 3 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.



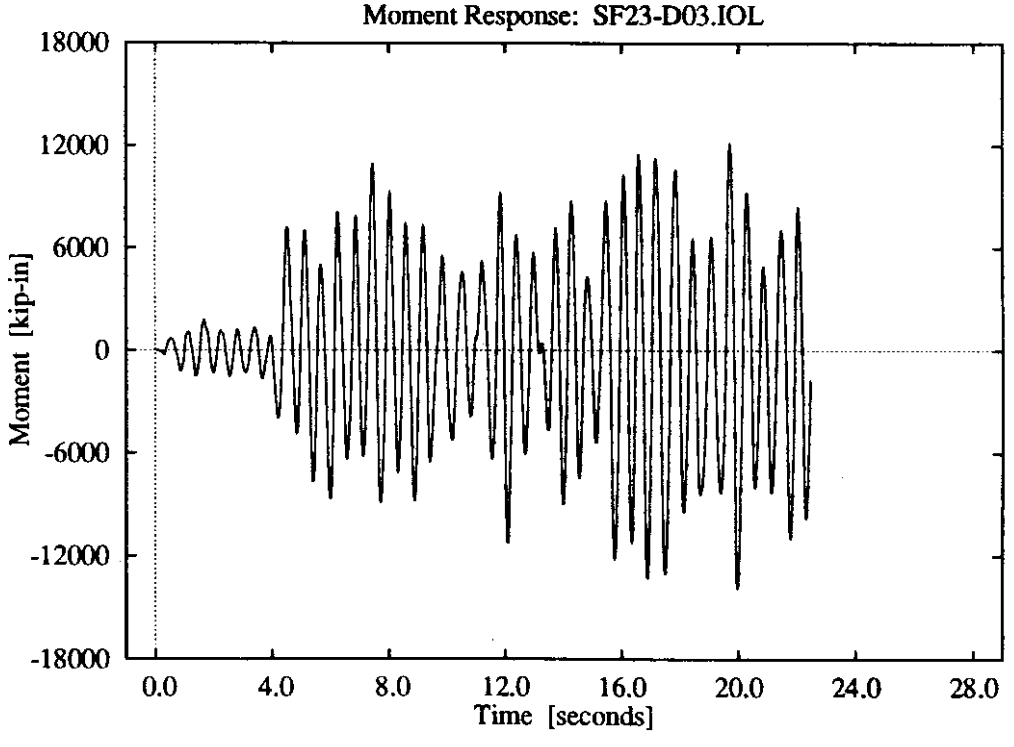
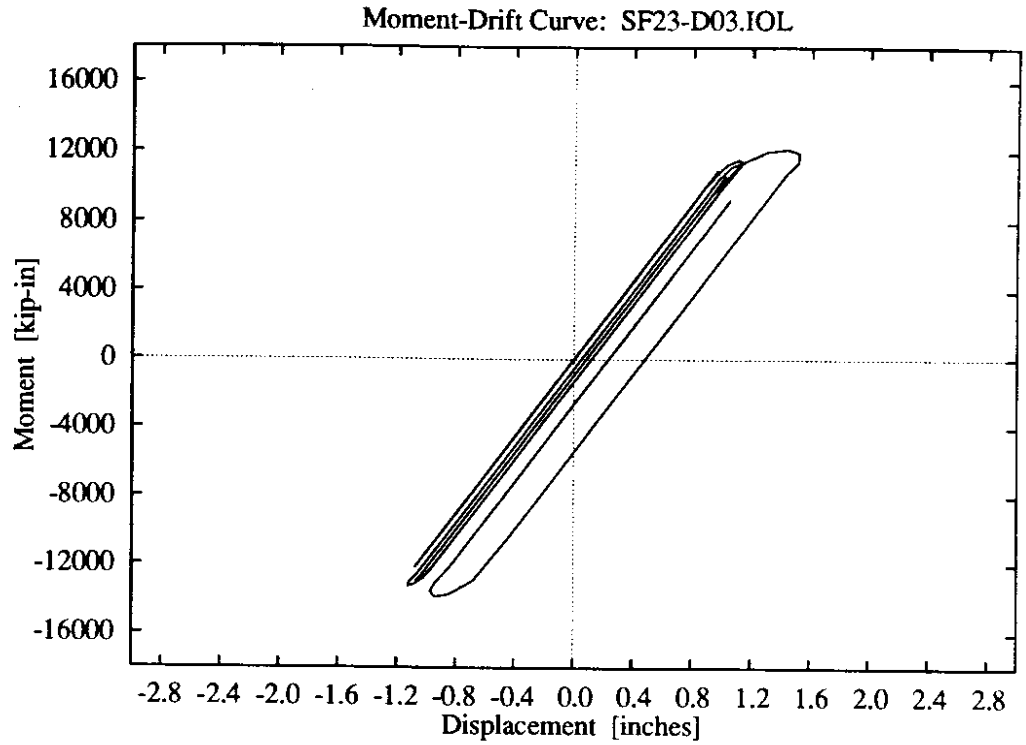


Figure D-45: 3 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.



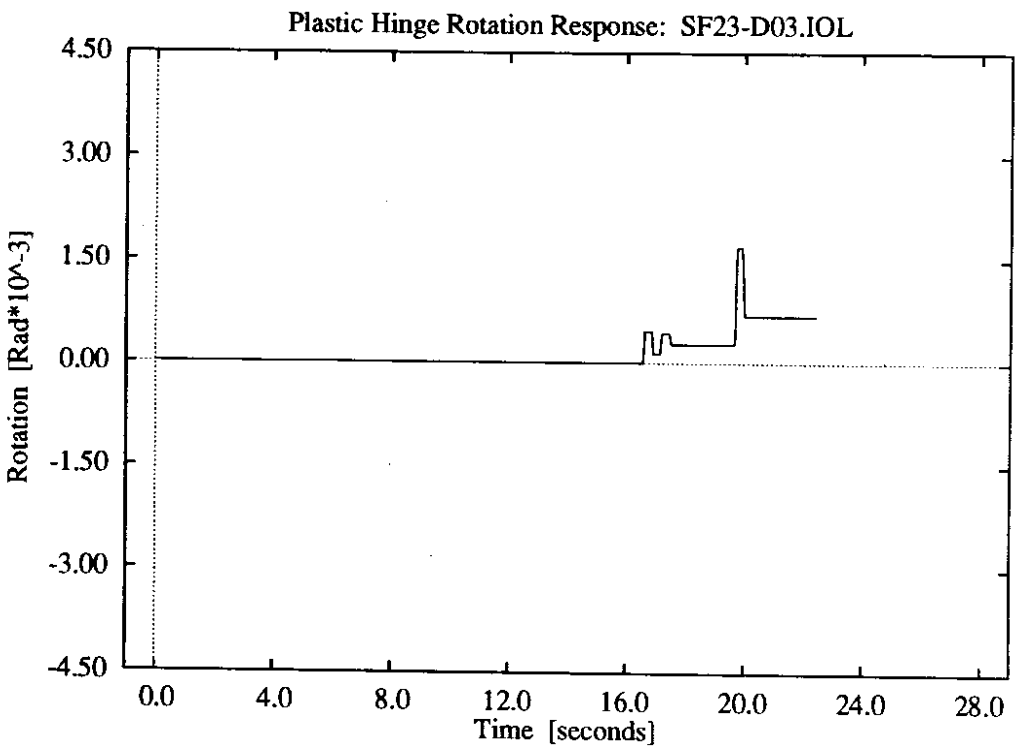
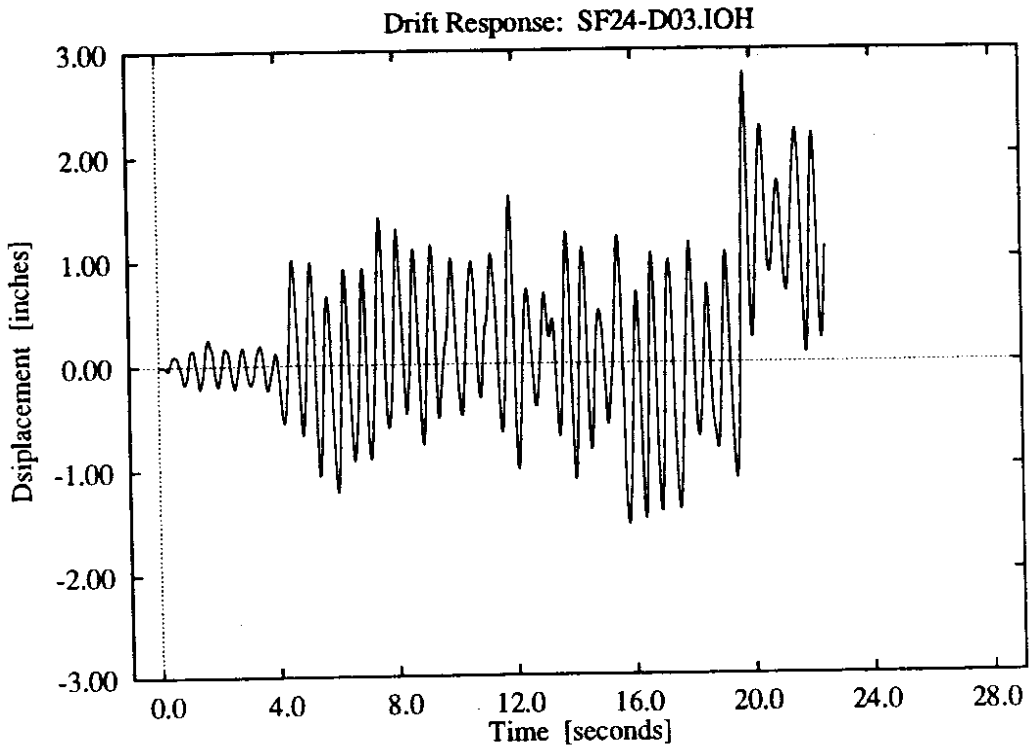


Figure D-46: 3 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.



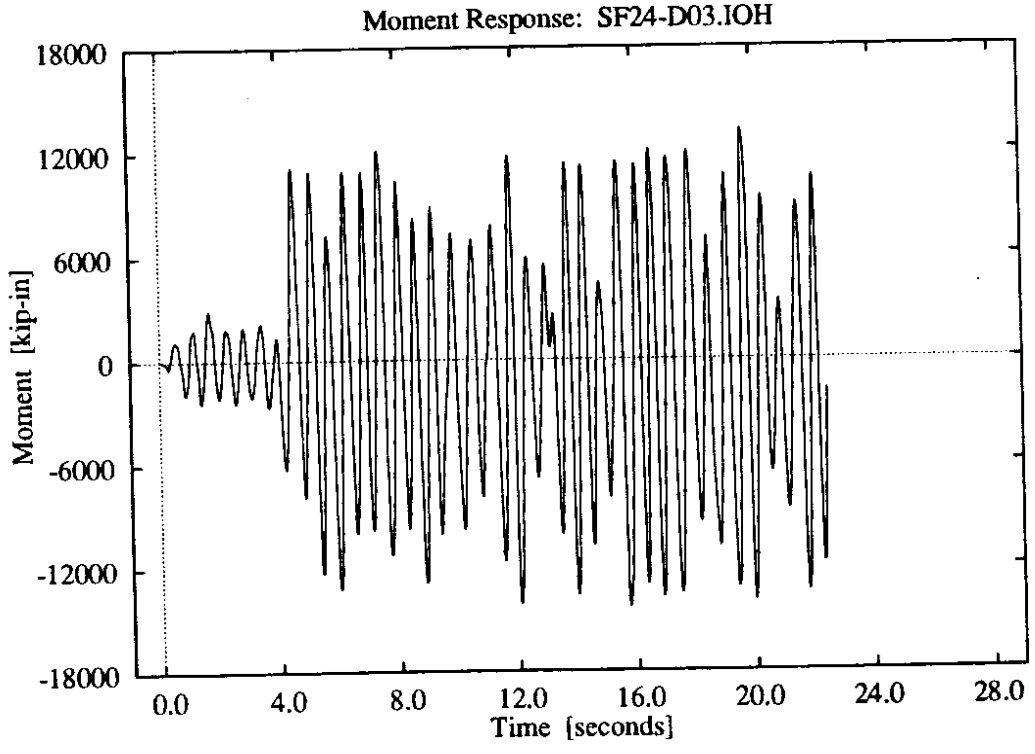
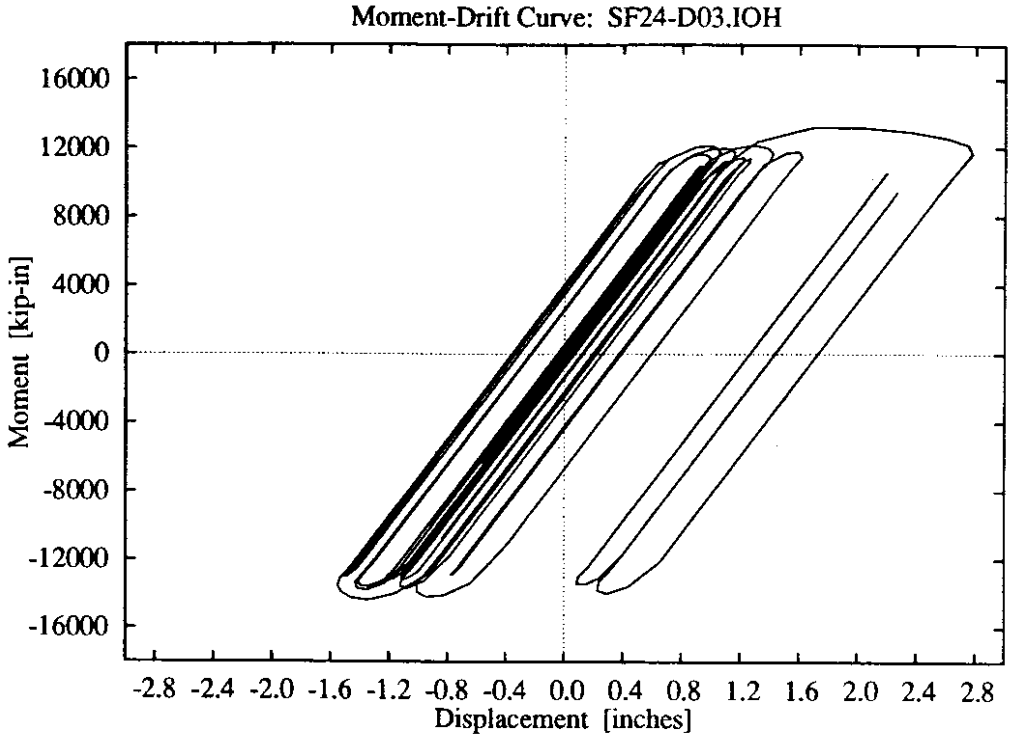


Figure D-47: 3 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.



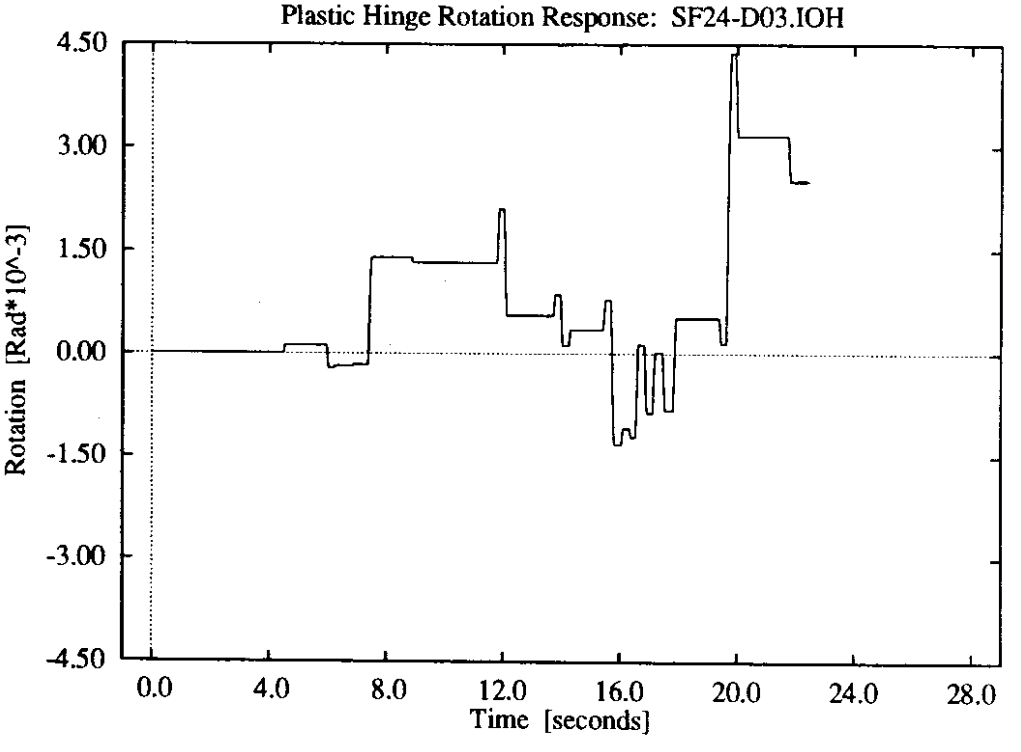
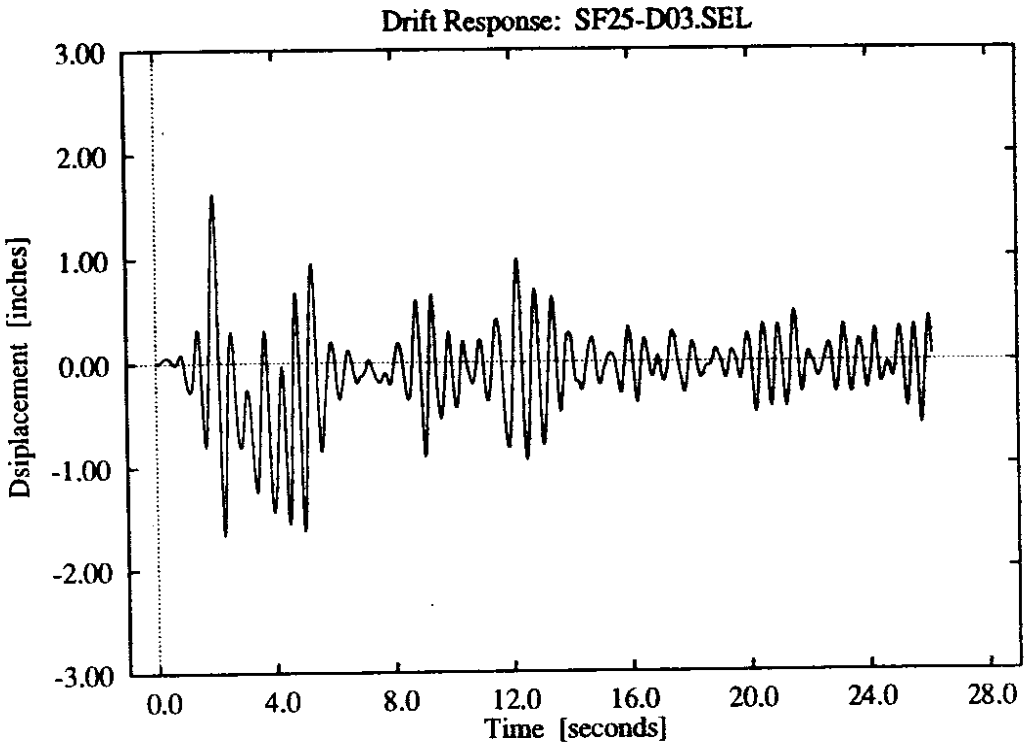


Figure D-48: 3 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.



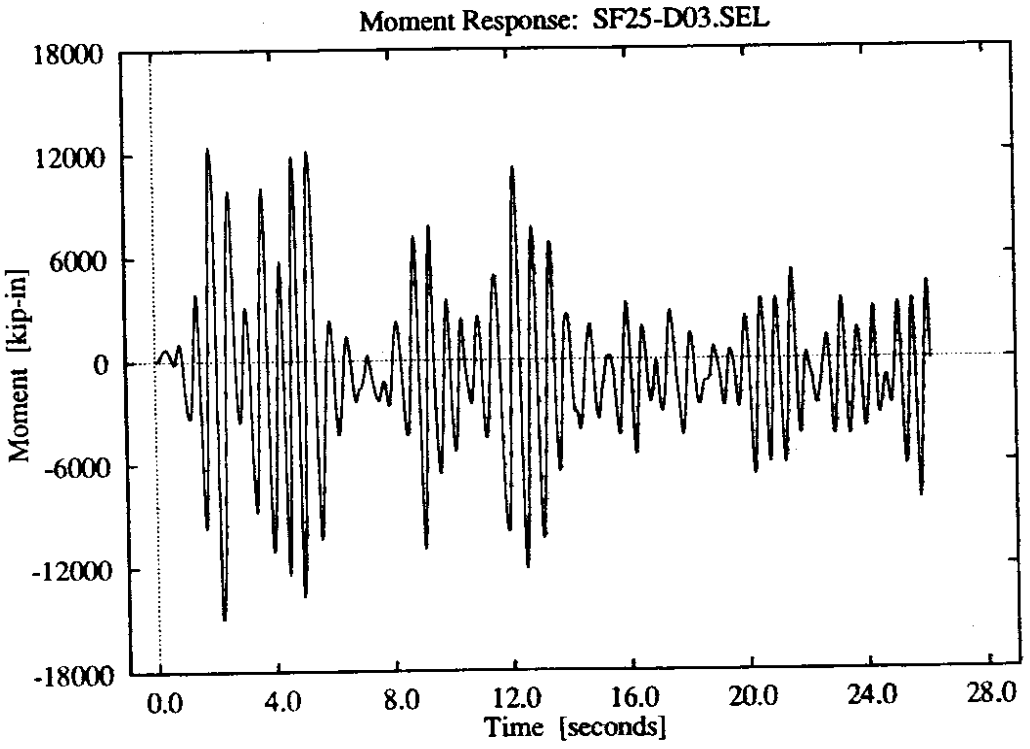
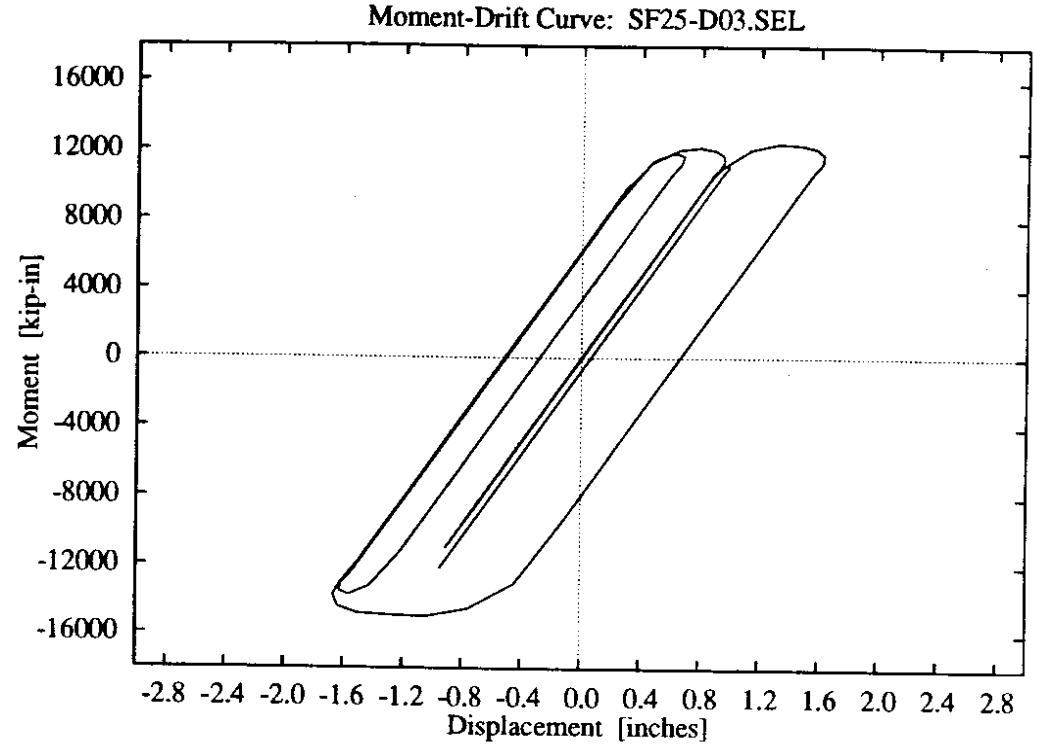


Figure D-49: 3 parameter foundation model, high soil stiffness, lower intensity El Centro record.



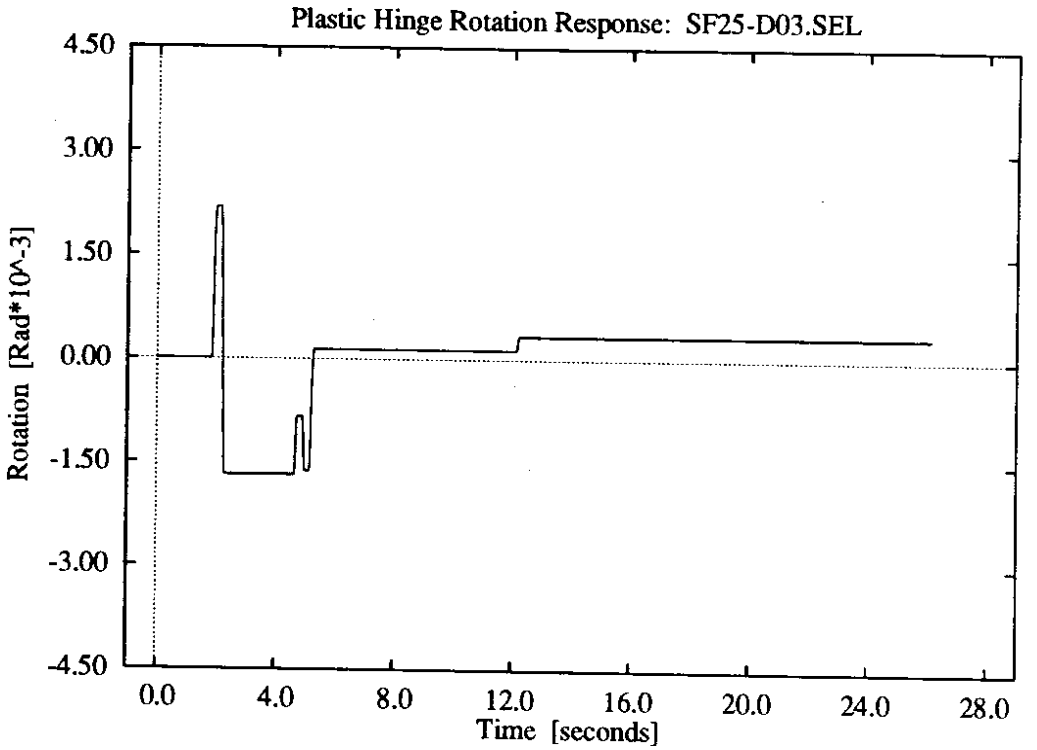


Figure D-50: 3 parameter foundation model, high soil stiffness, lower intensity El Centro record.

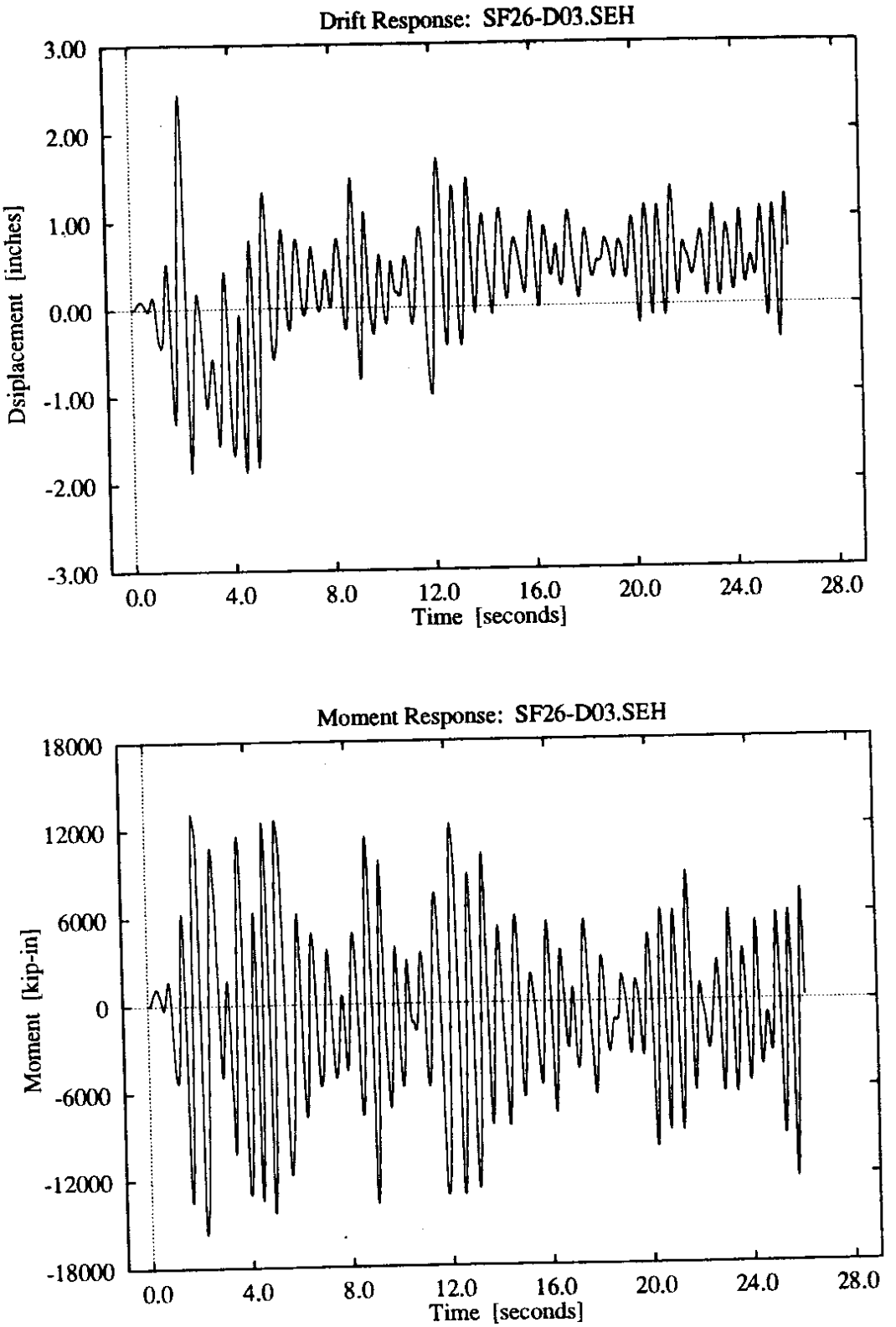
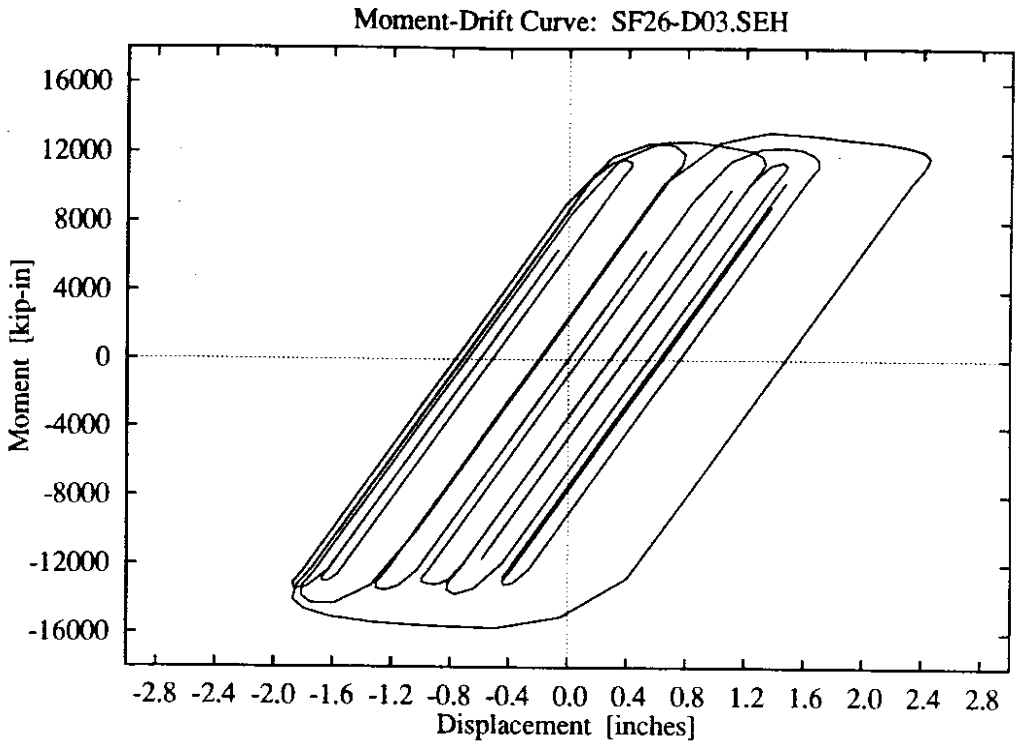


Figure D-51: 3 parameter foundation model, high soil stiffness, higher intensity El Centro record.



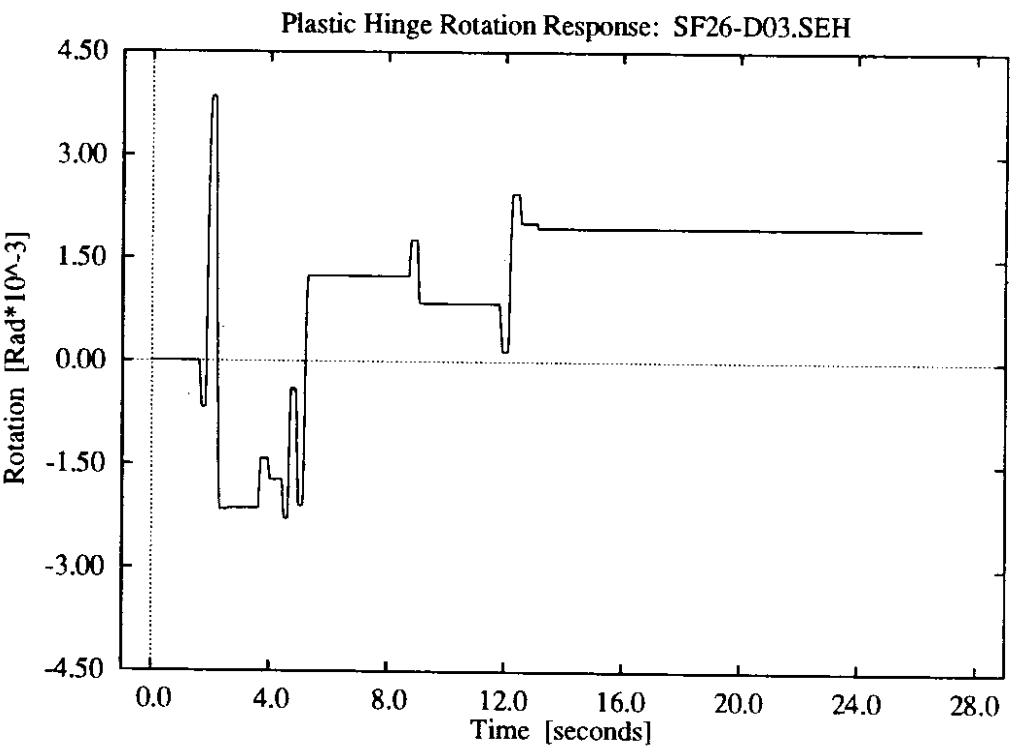
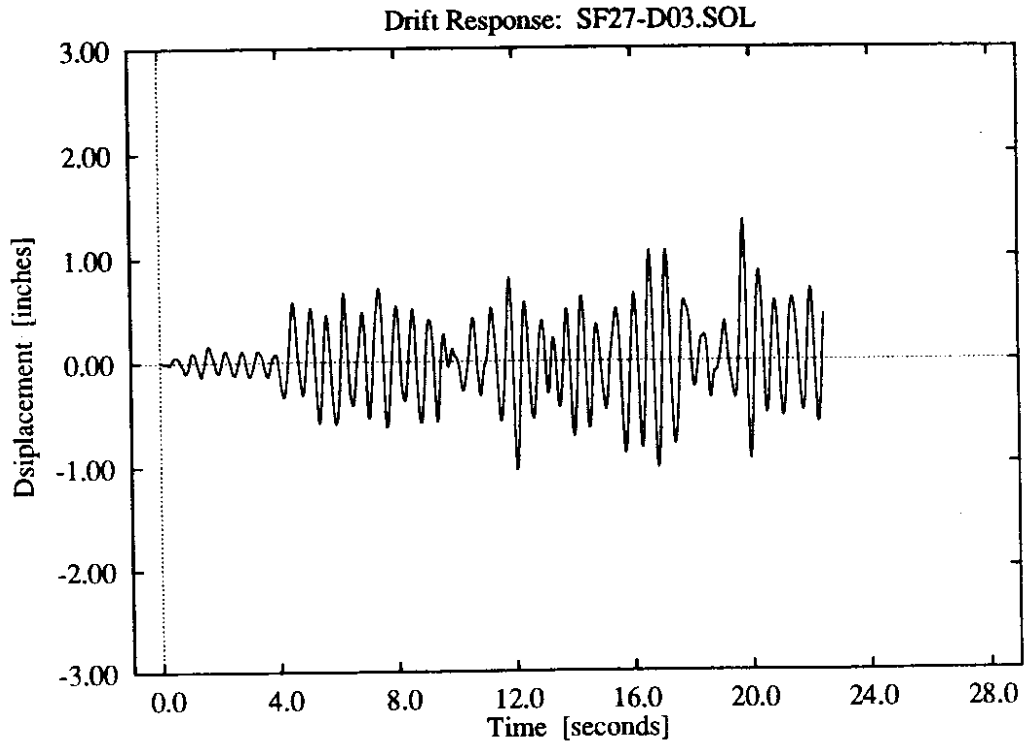


Figure D-52: 3 parameter foundation model, high soil stiffness, higher intensity El Centro record.



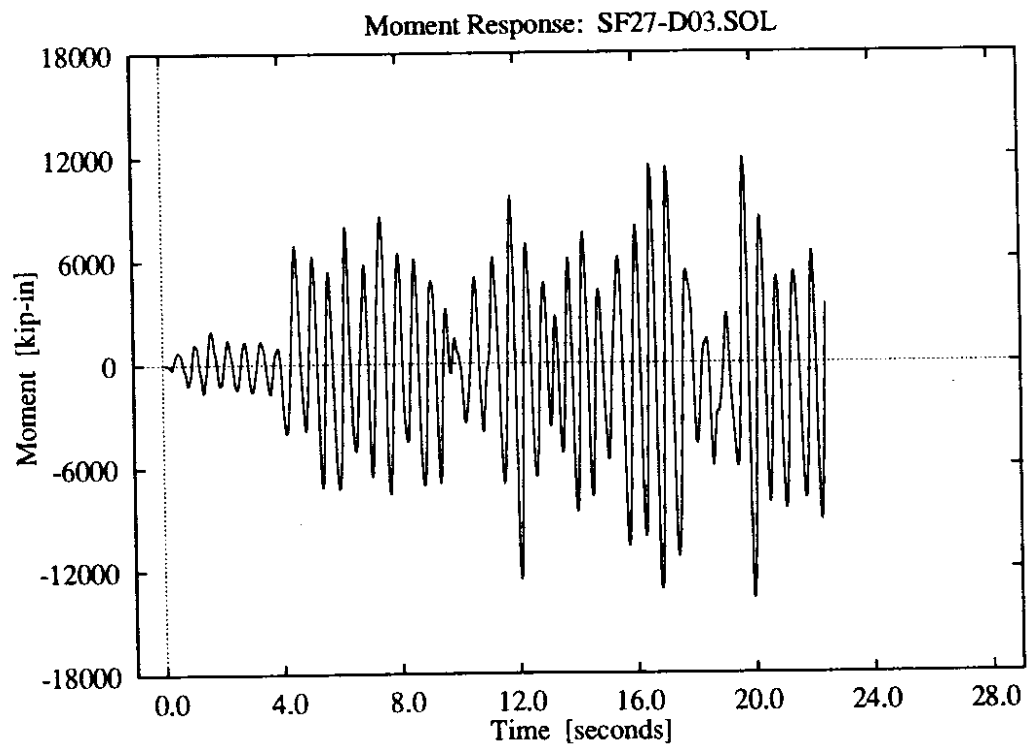
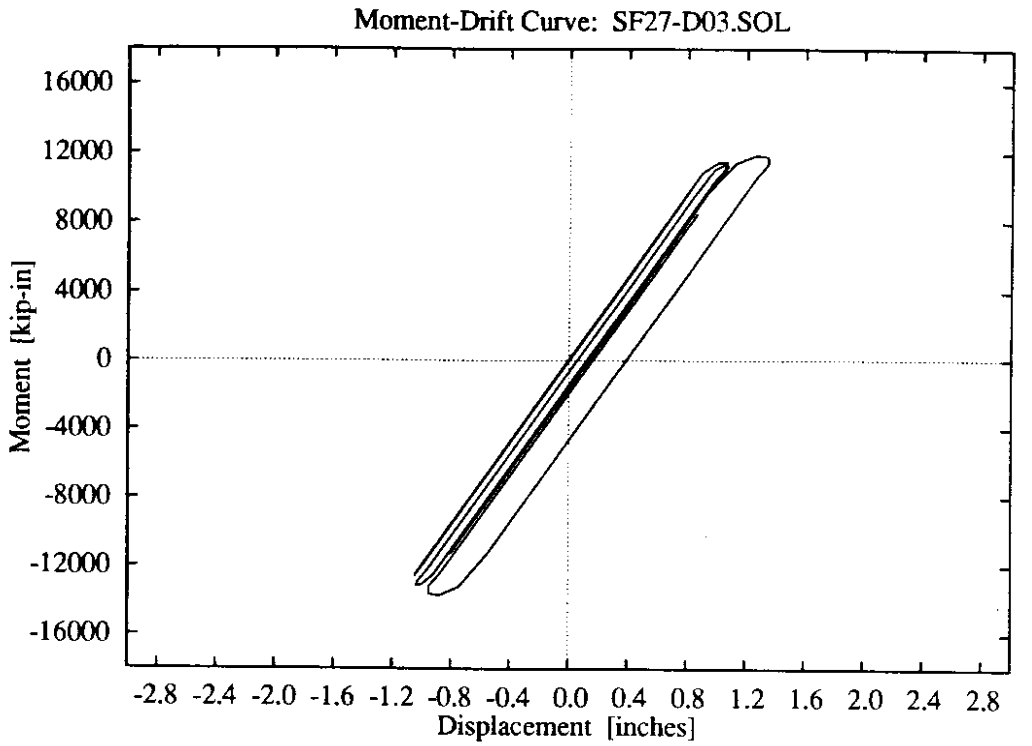


Figure D-53: 3 parameter foundation model, high soil stiffness, lower intensity Olympia record.



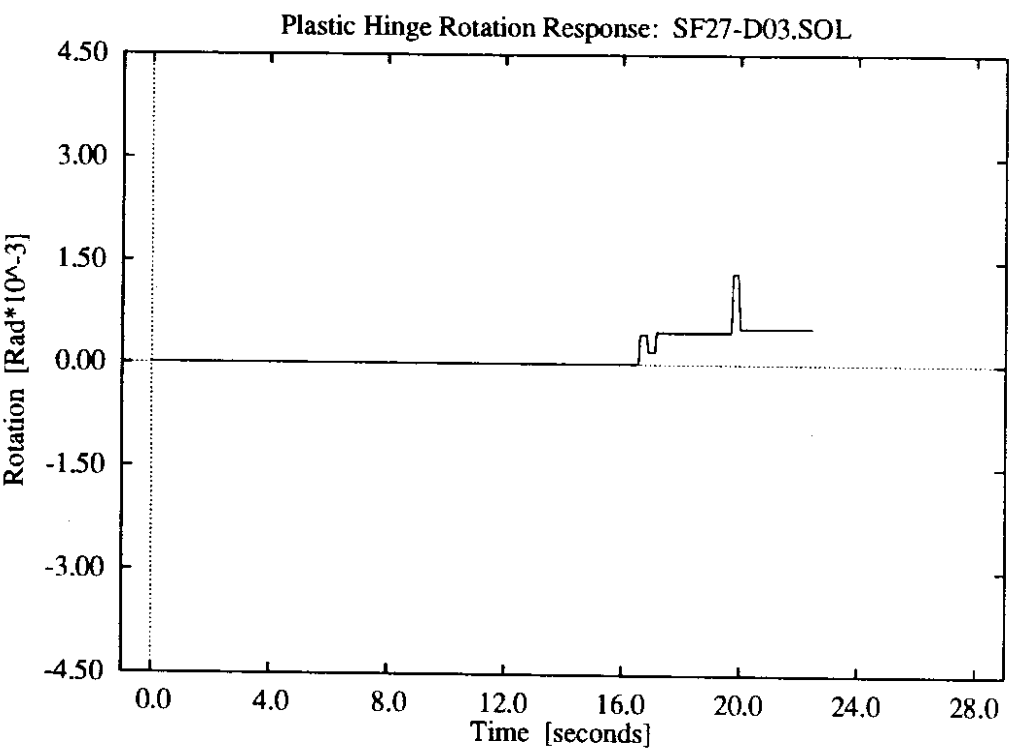


Figure D-54: 3 parameter foundation model, high soil stiffness, lower intensity Olympia record.

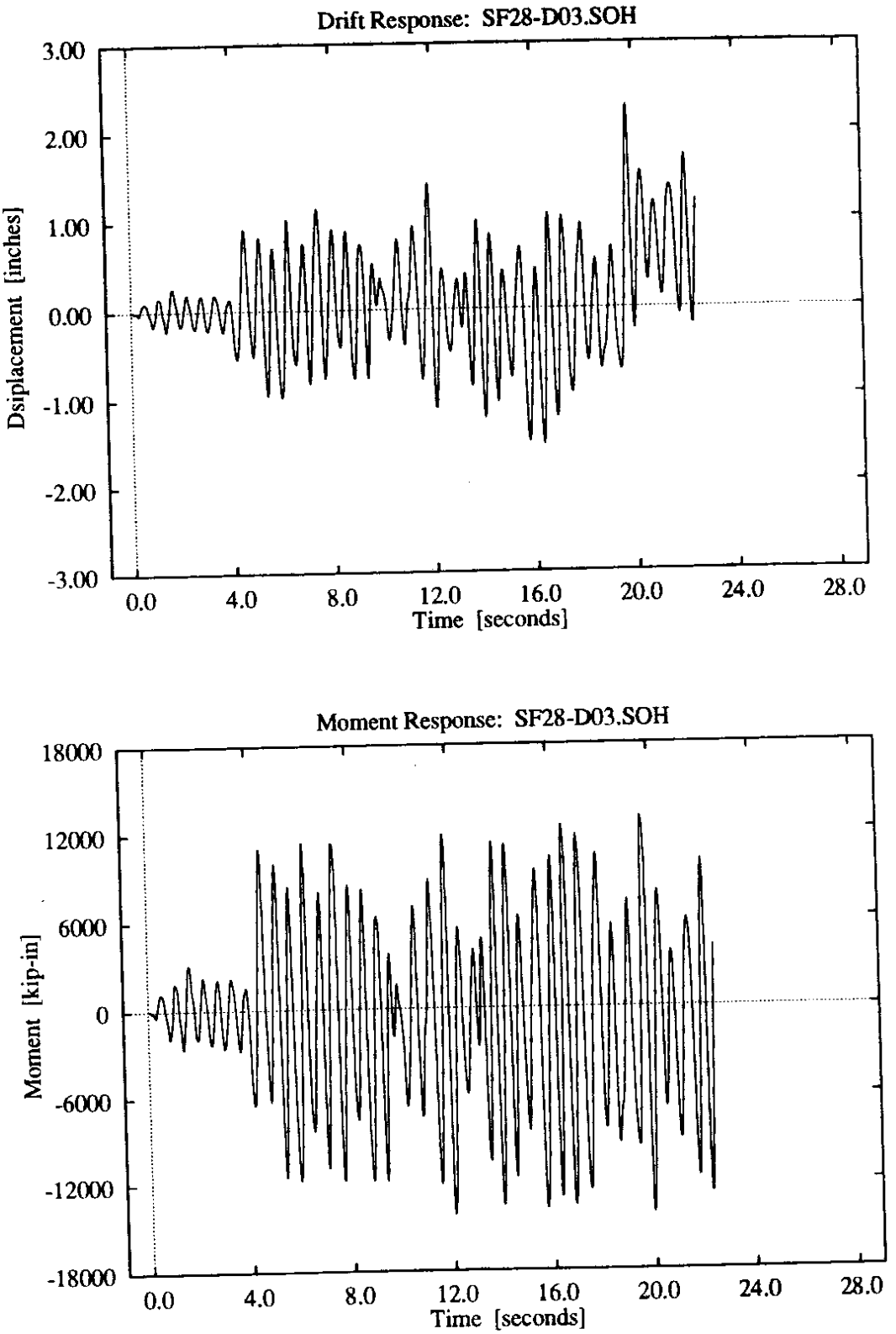
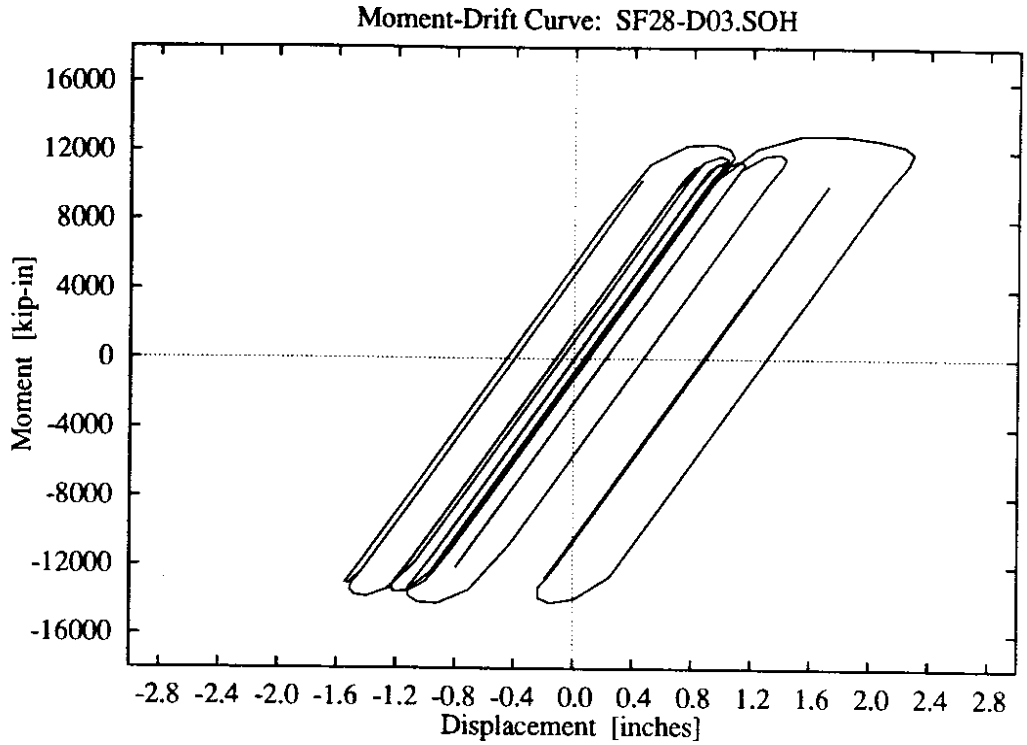


Figure D-55: 3 parameter model, high soil stiffness, higher intensity Olympia record.



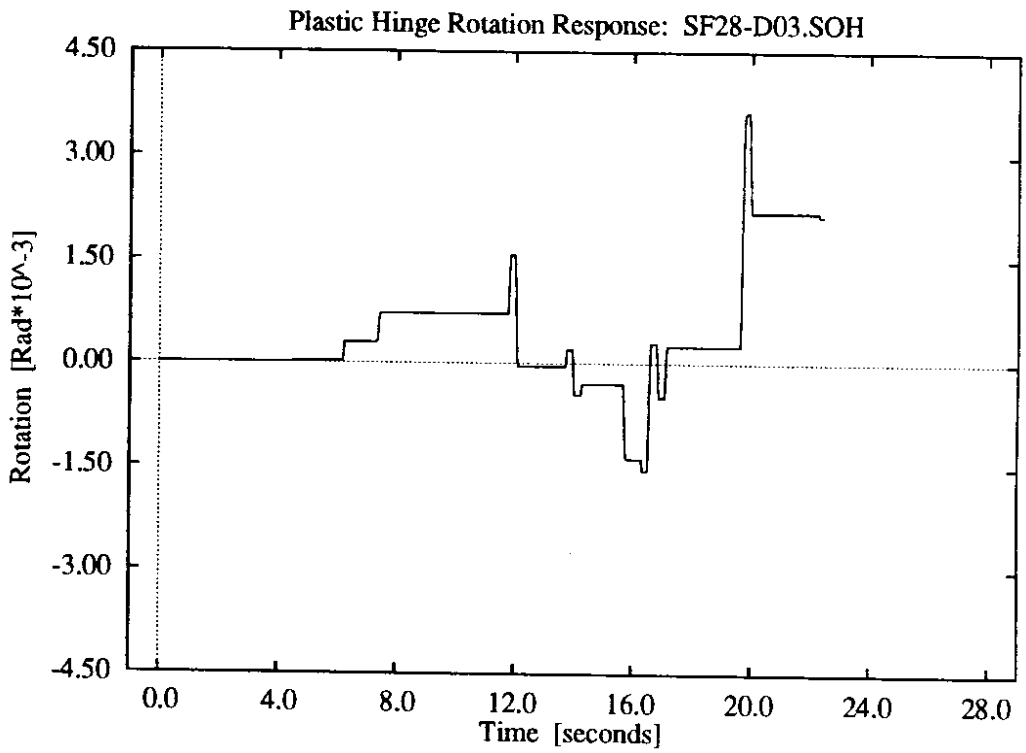
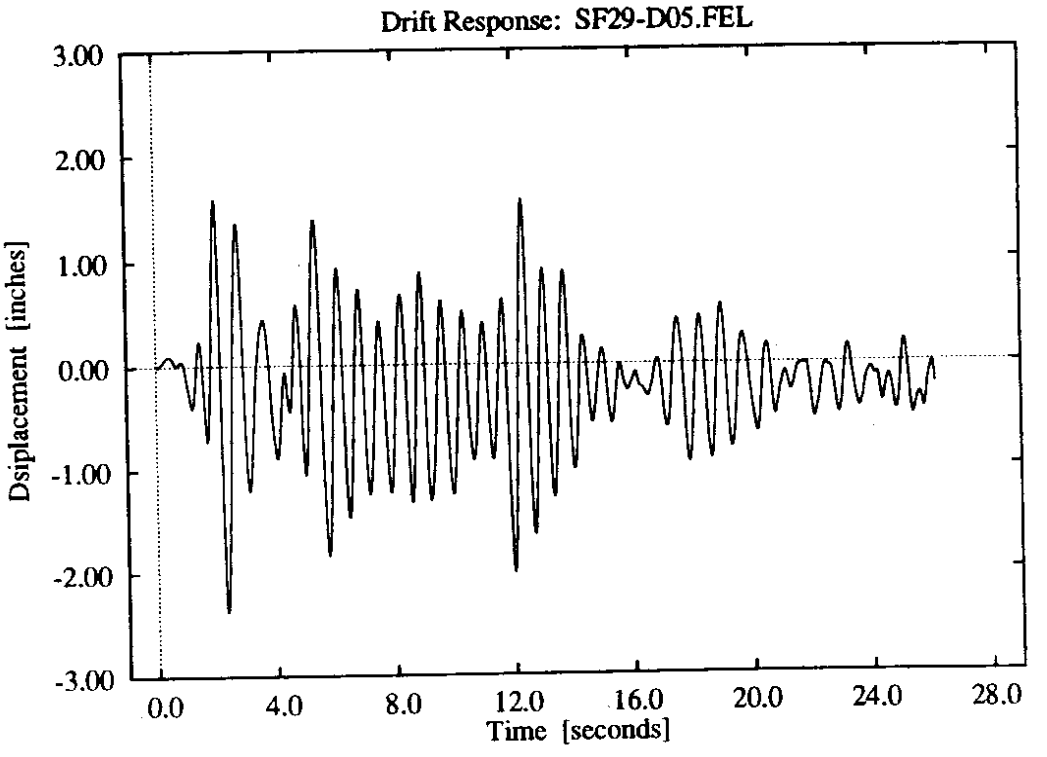


Figure D-56: 3 parameter model, high soil stiffness, higher intensity Olympia record.



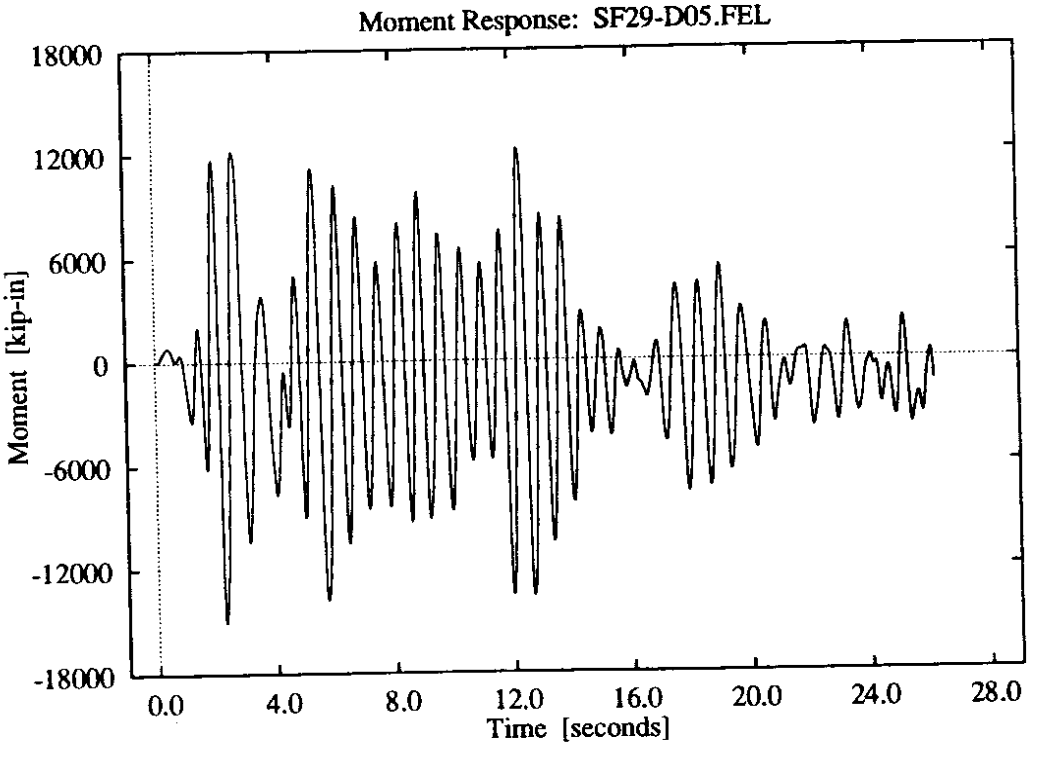
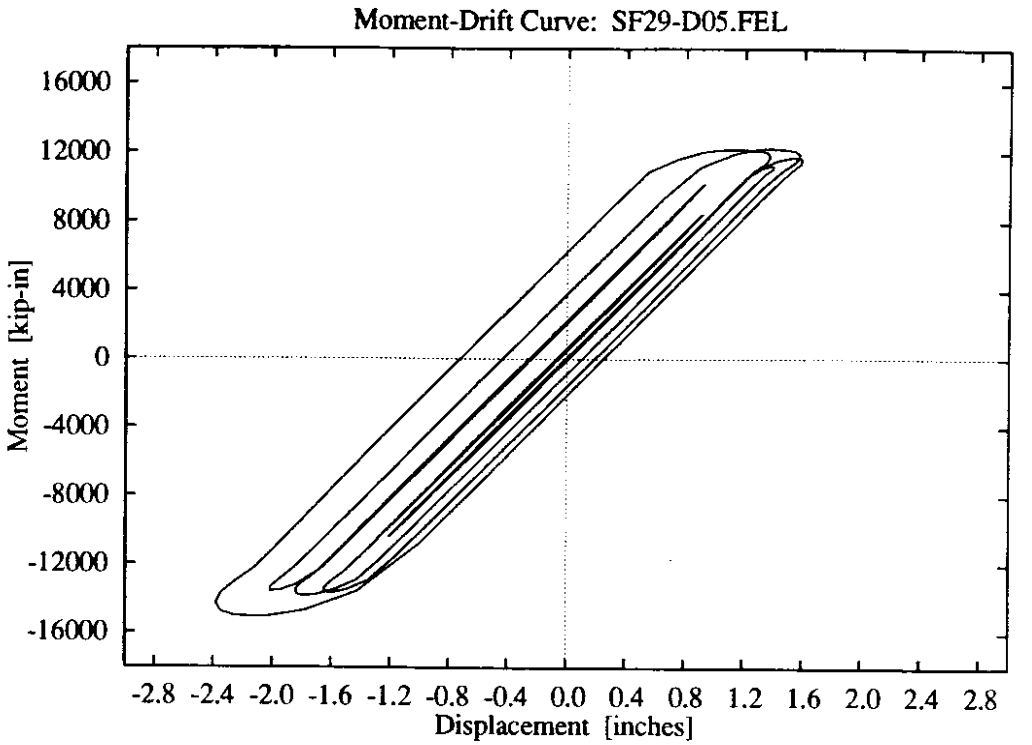


Figure D-57: 5 parameter foundation model, low soil stiffness, lower intensity El Centro.



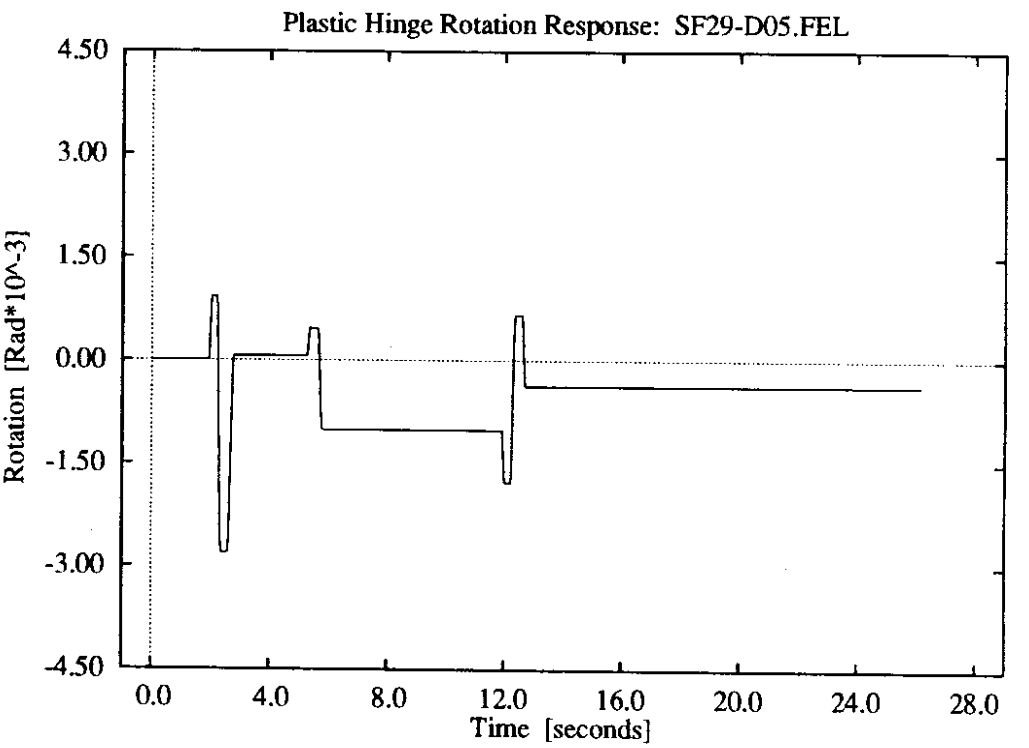


Figure D-58: 5 parameter foundation model, low soil stiffness, lower intensity El Centro.

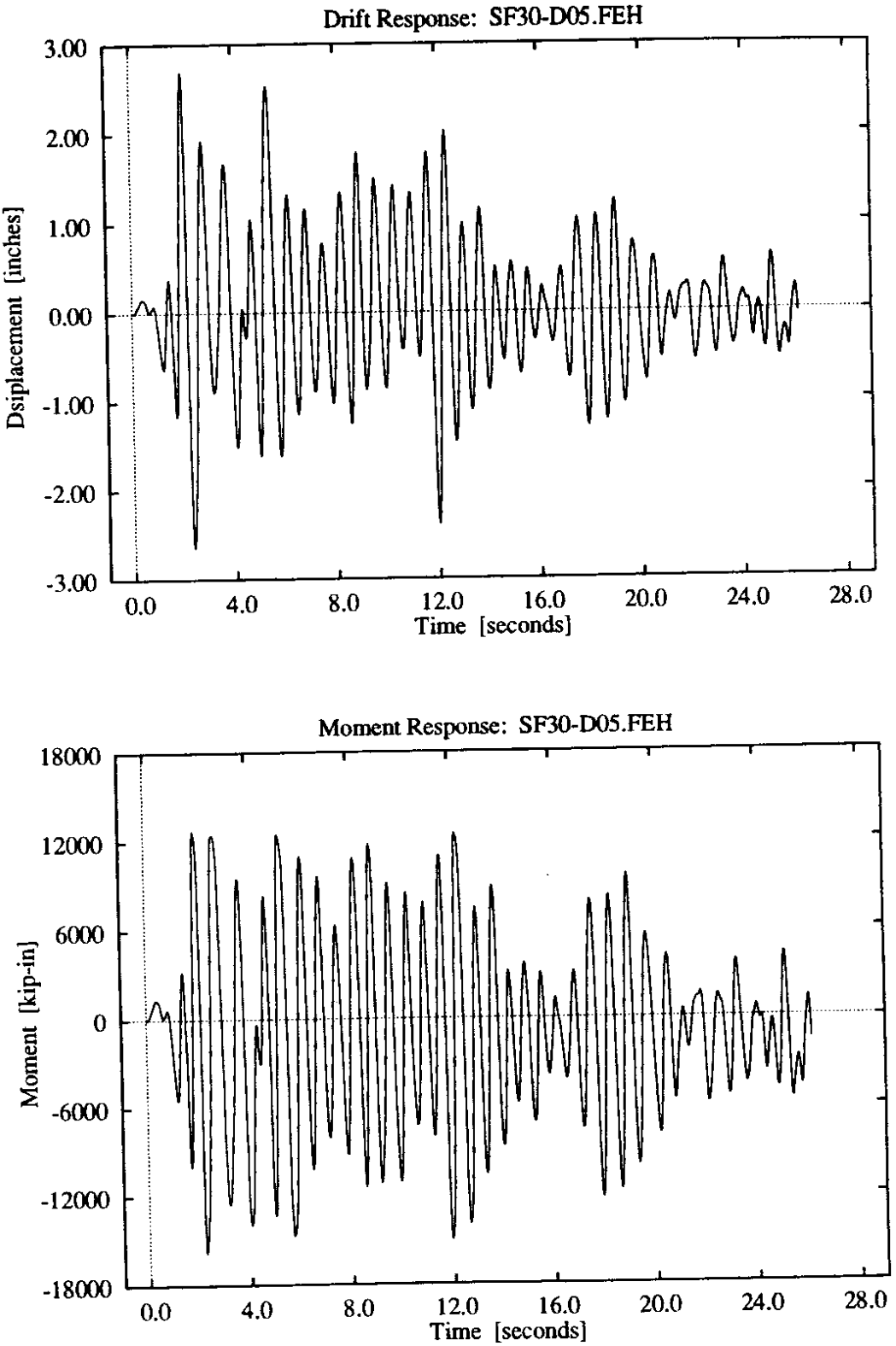
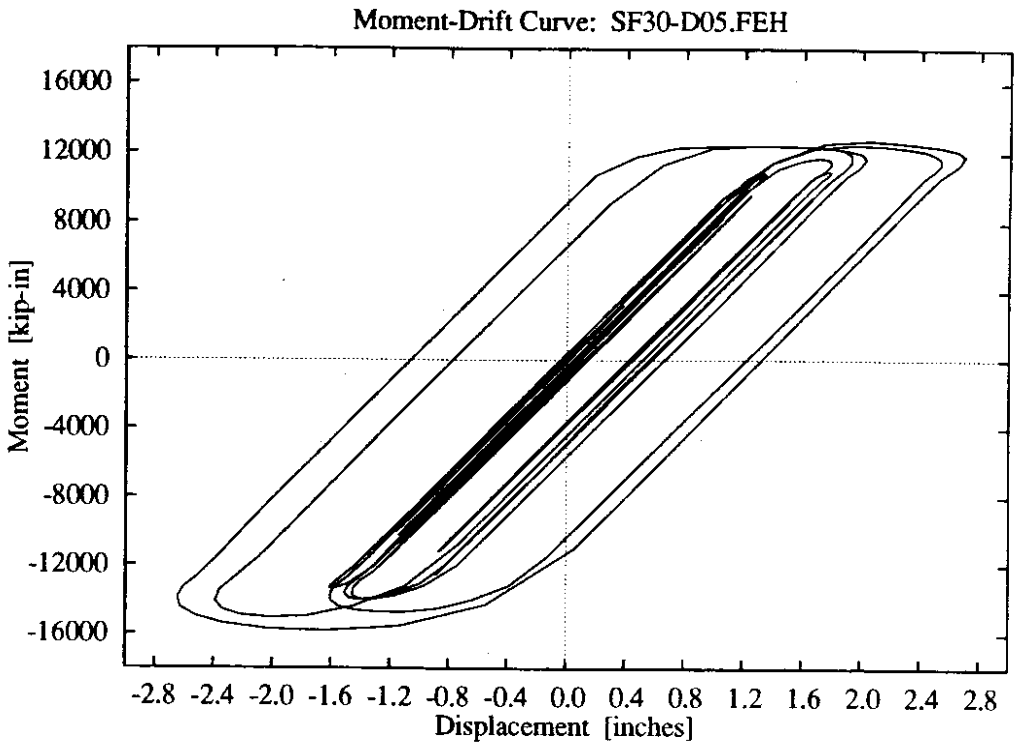


Figure D-59: 5 parameter foundation model, low soil stiffness, higher intensity El Centro.



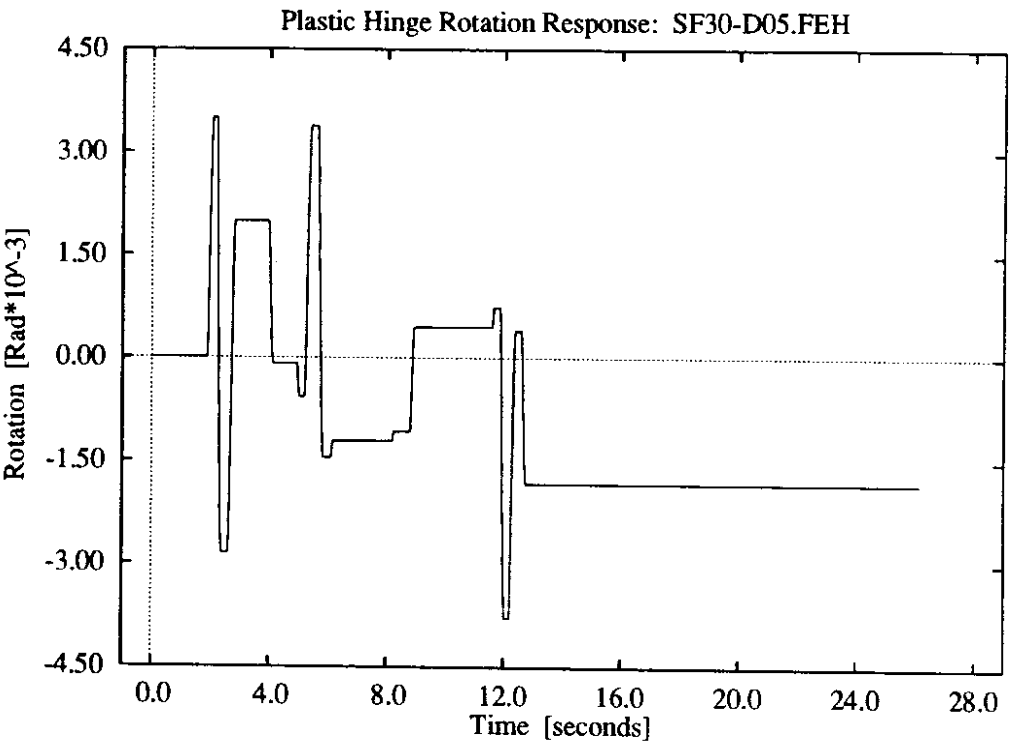


Figure D-60: 5 parameter foundation model, low soil stiffness, higher intensity El Centro.

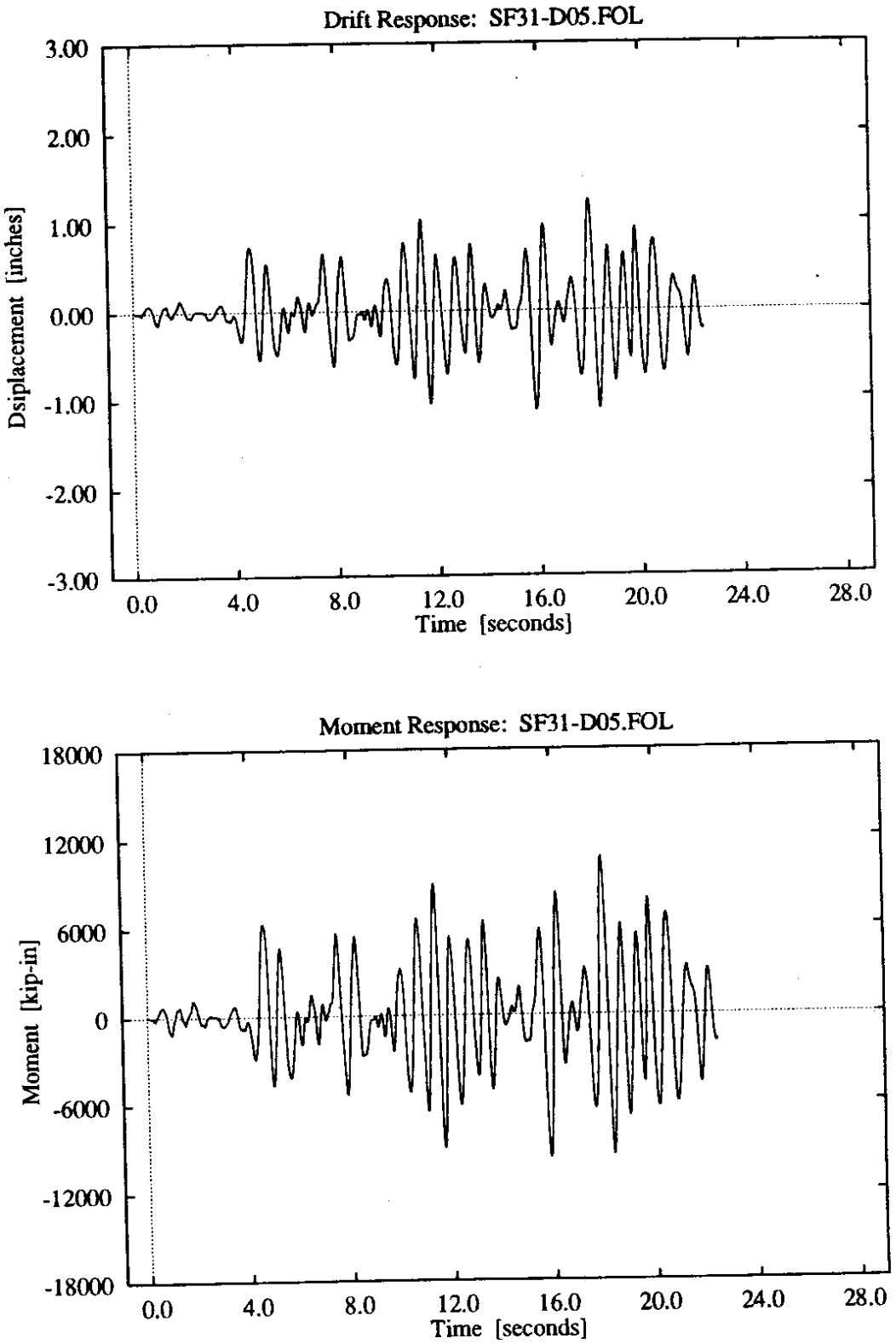
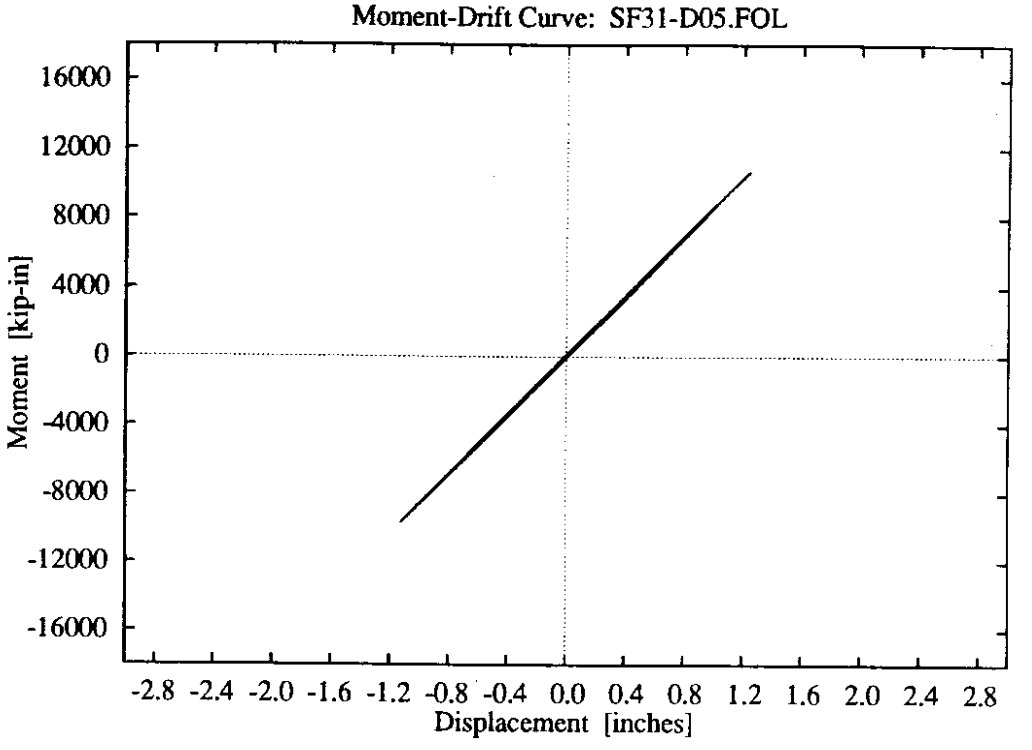


Figure D-61: 5 parameter foundation model, low soil stiffness, lower intensity Olympia record.



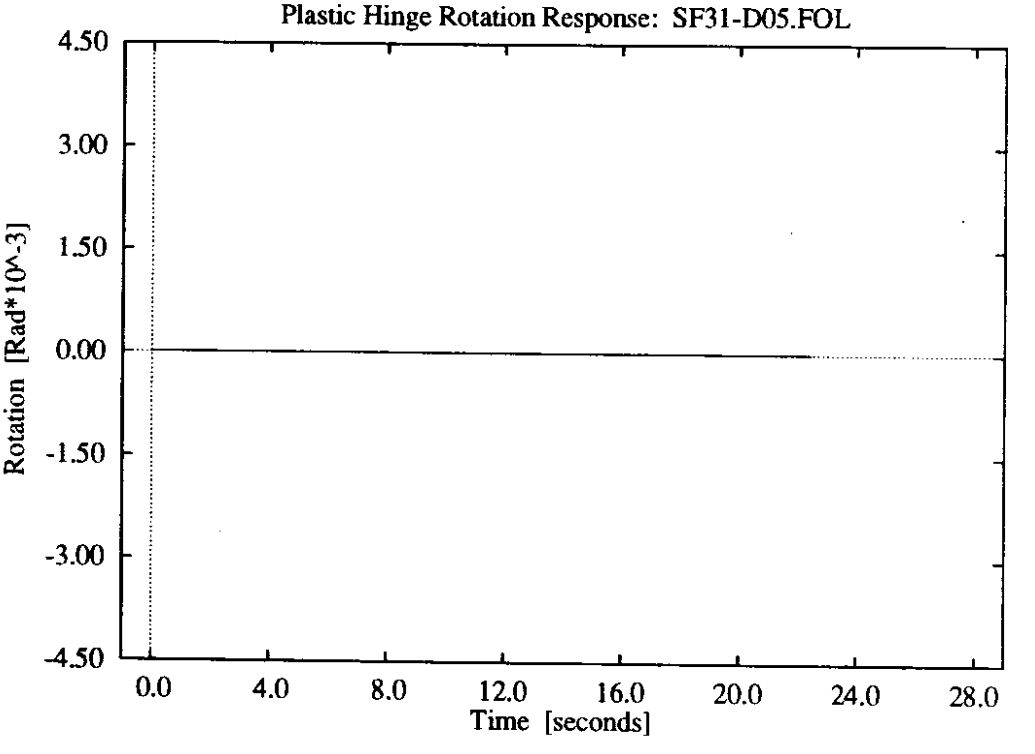


Figure D-62: 5 parameter foundation model, low soil stiffness, lower intensity Olympia record.

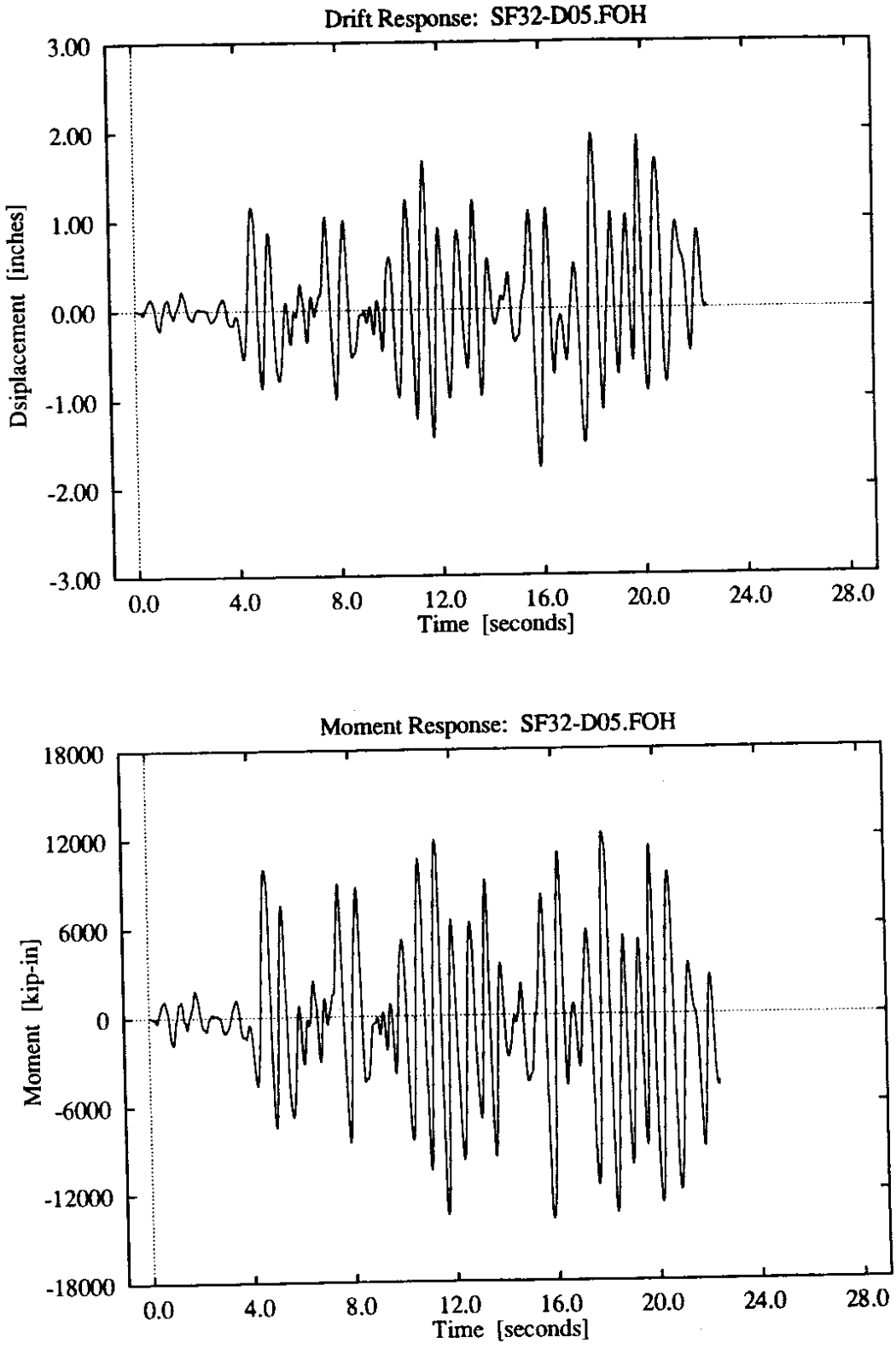
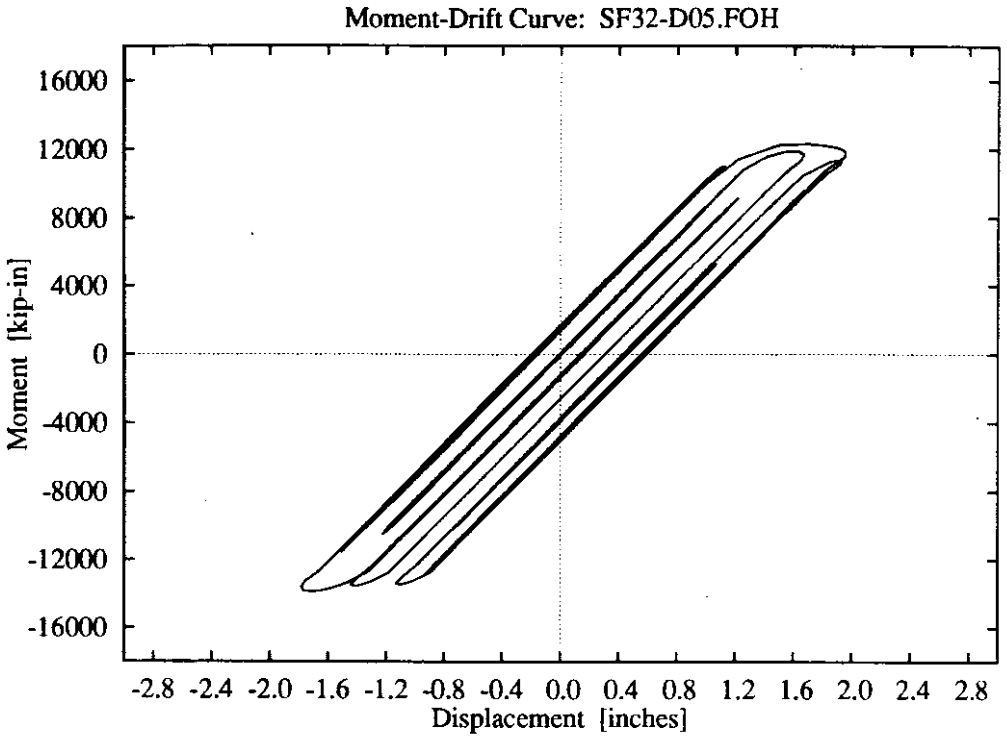


Figure D-63: 5 parameter foundation model, low soil stiffness, higher intensity Olympia record.



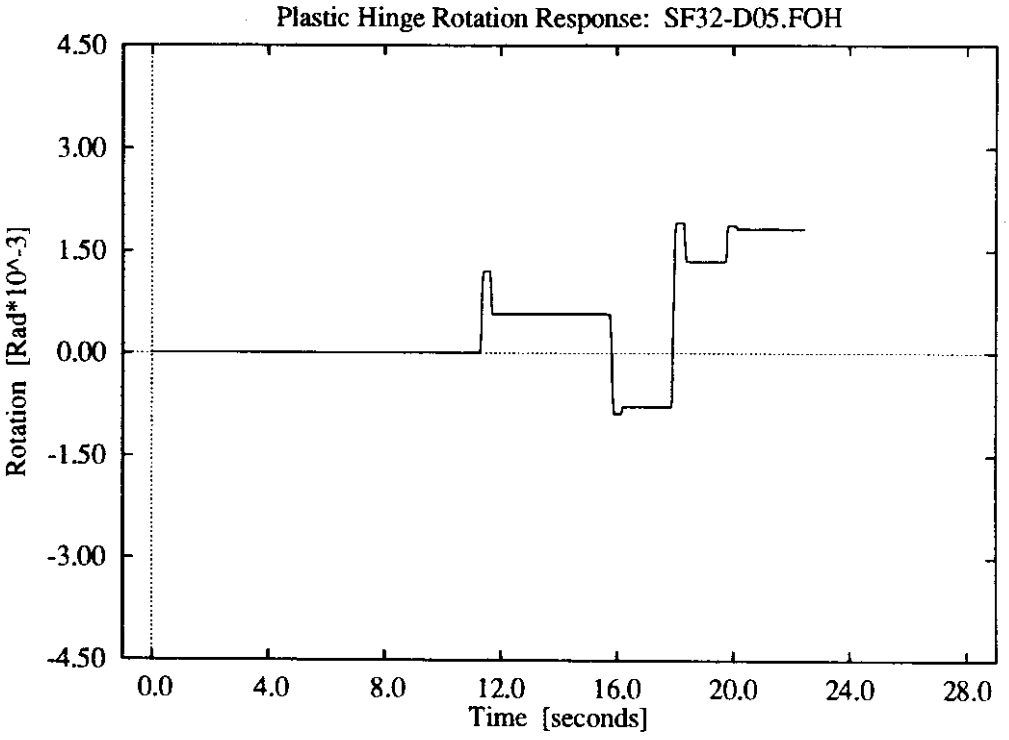


Figure D-64: 5 parameter foundation model, low soil stiffness, higher intensity Olympia record.

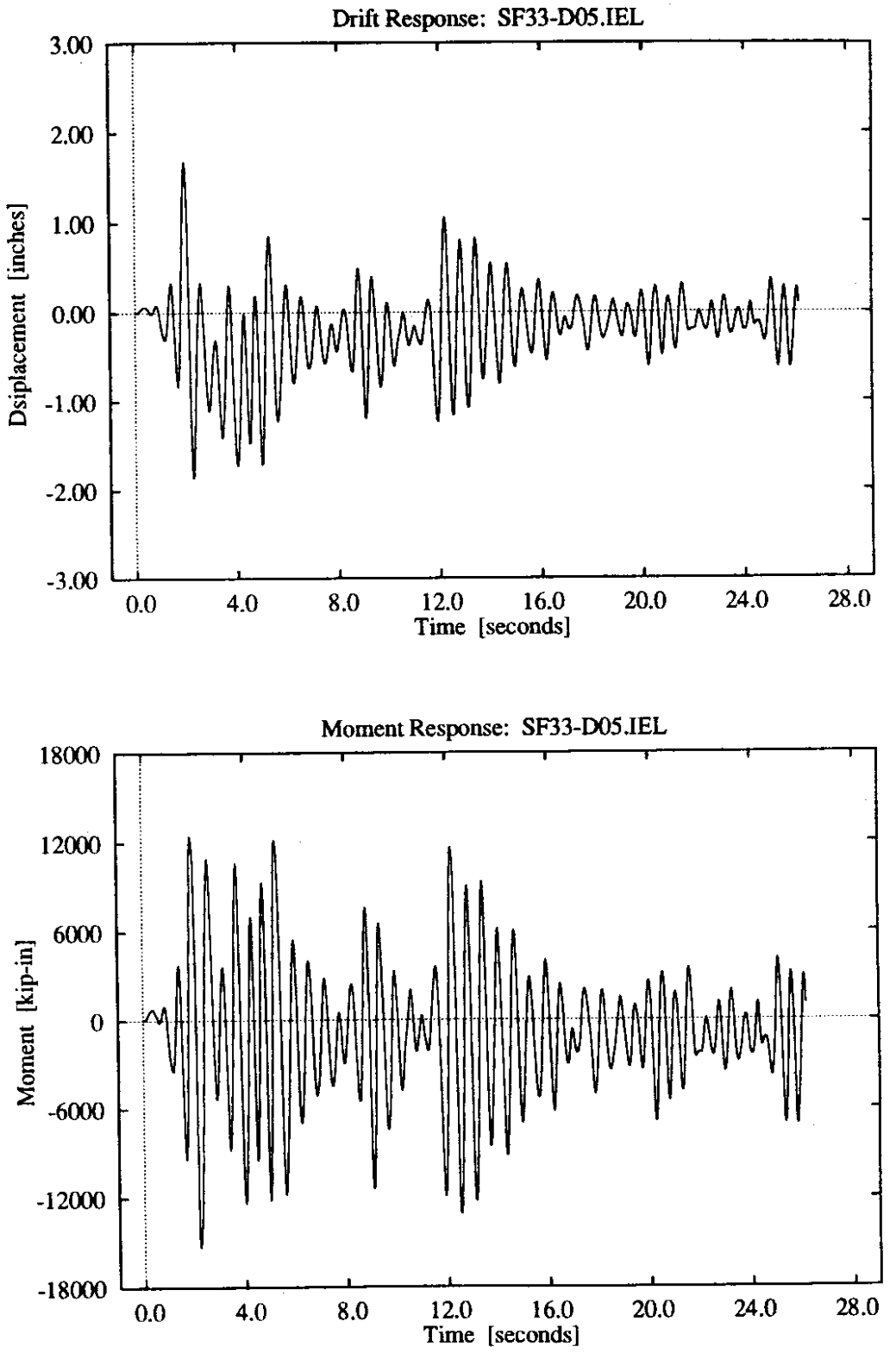
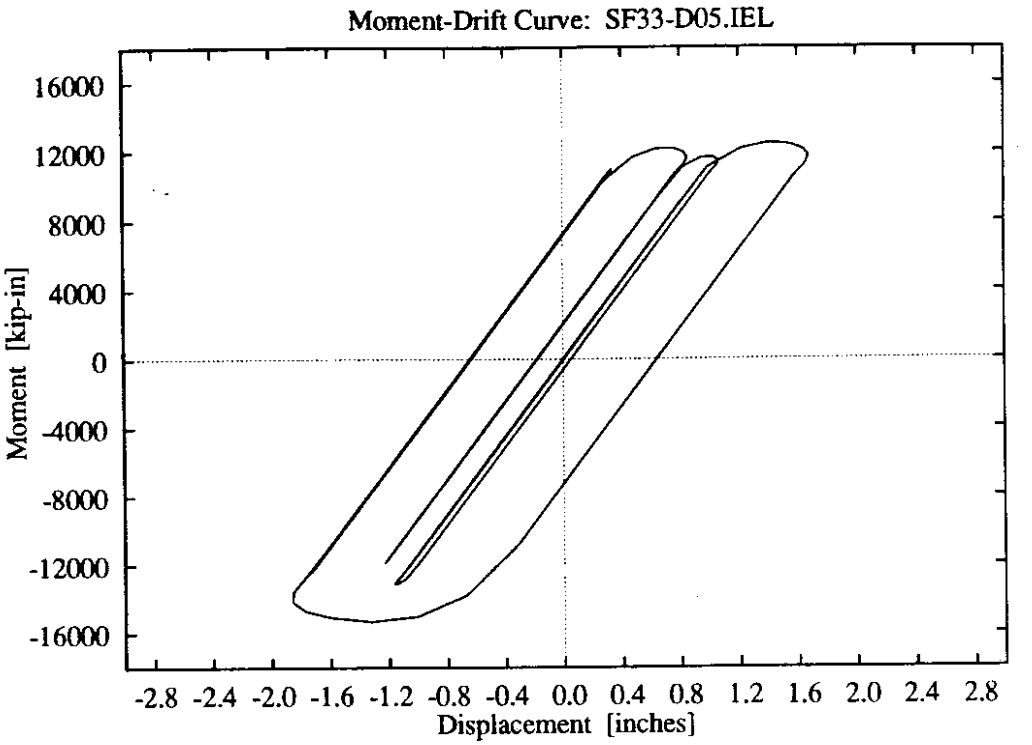


Figure D-65: 5 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.



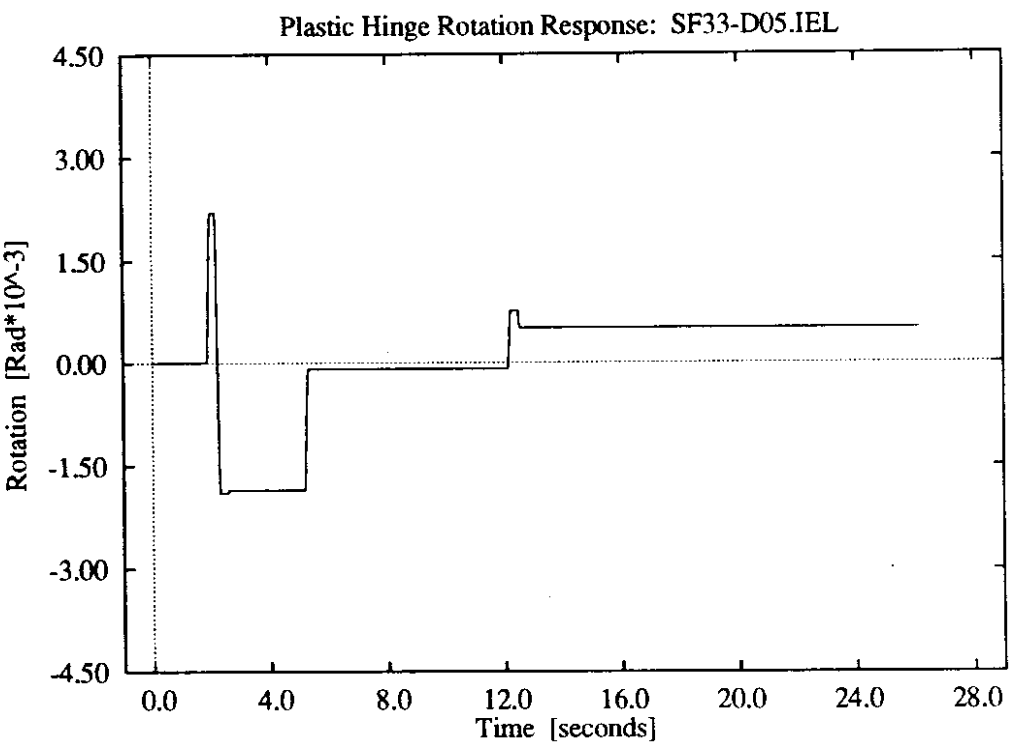
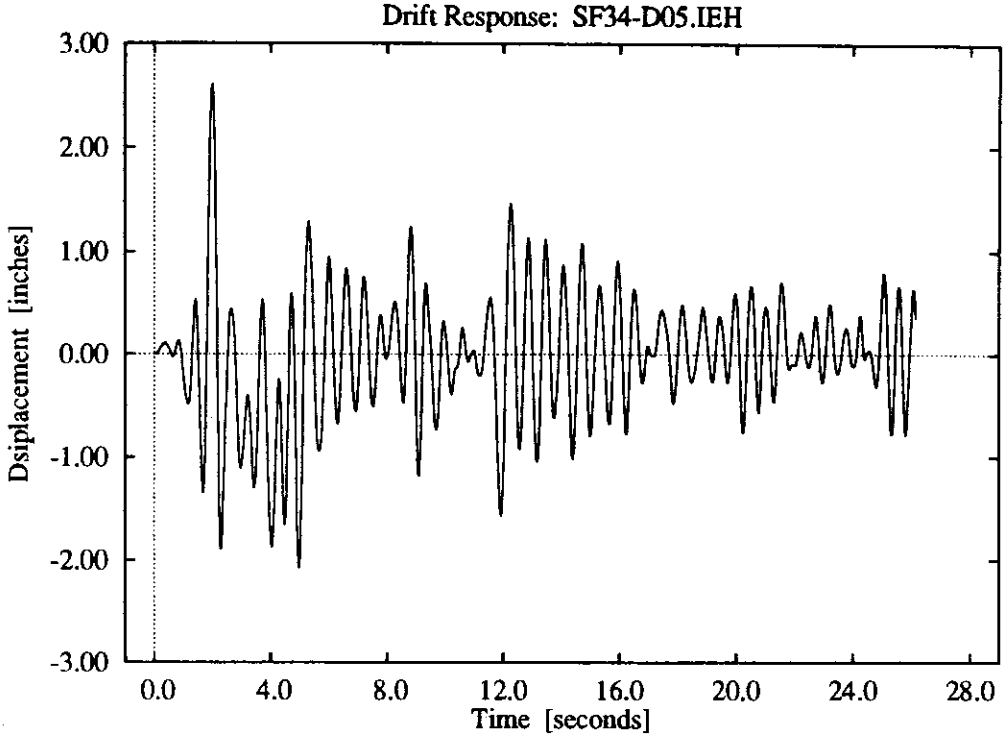


Figure D-66: 5 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.



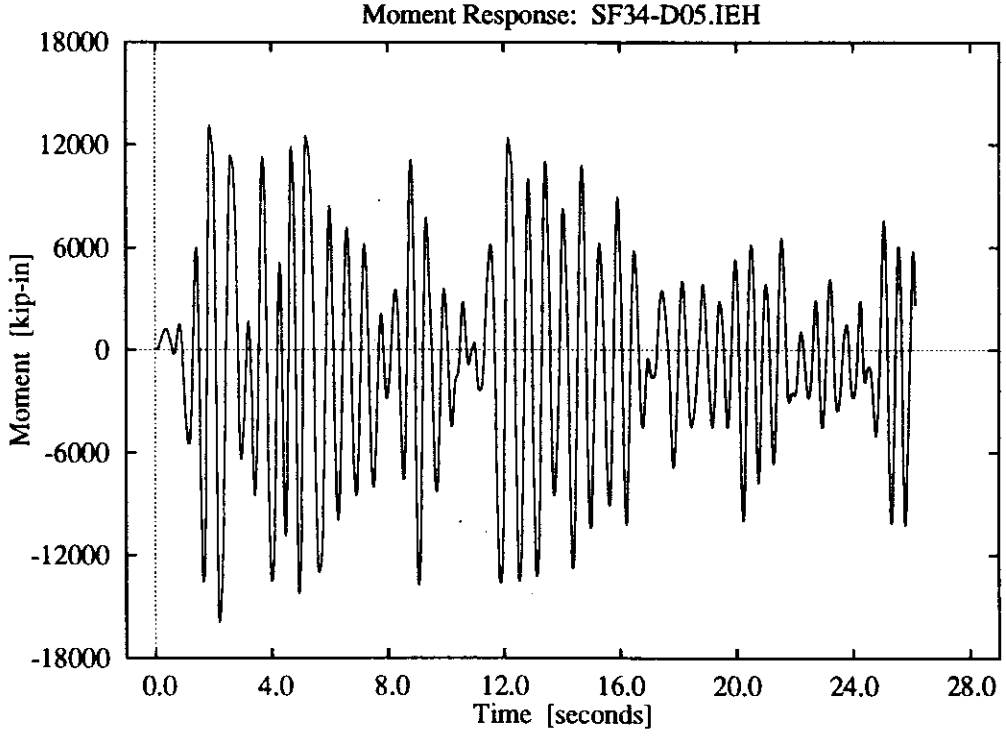


Figure D-67: 5 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.

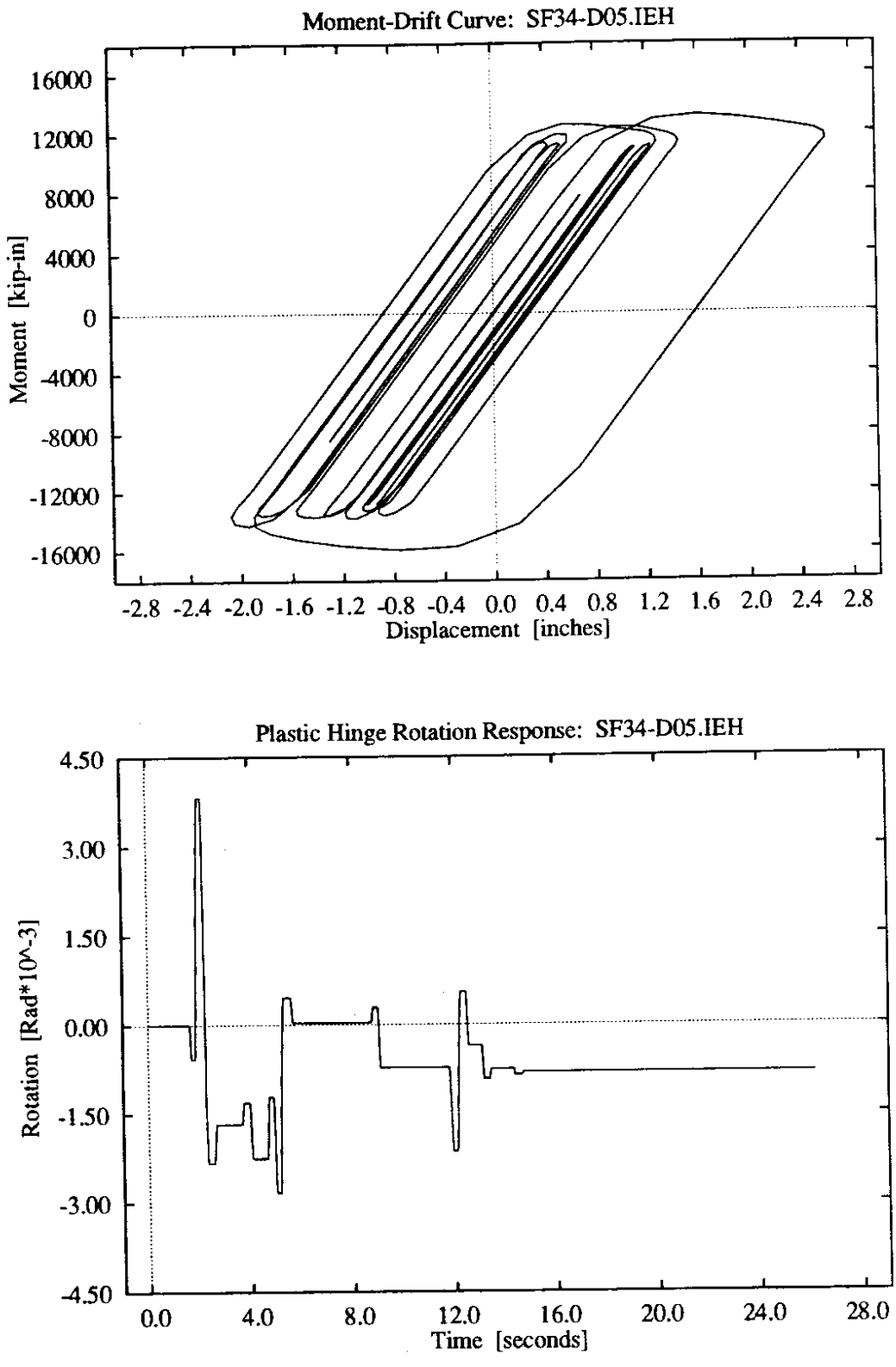


Figure D-68: 5 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.

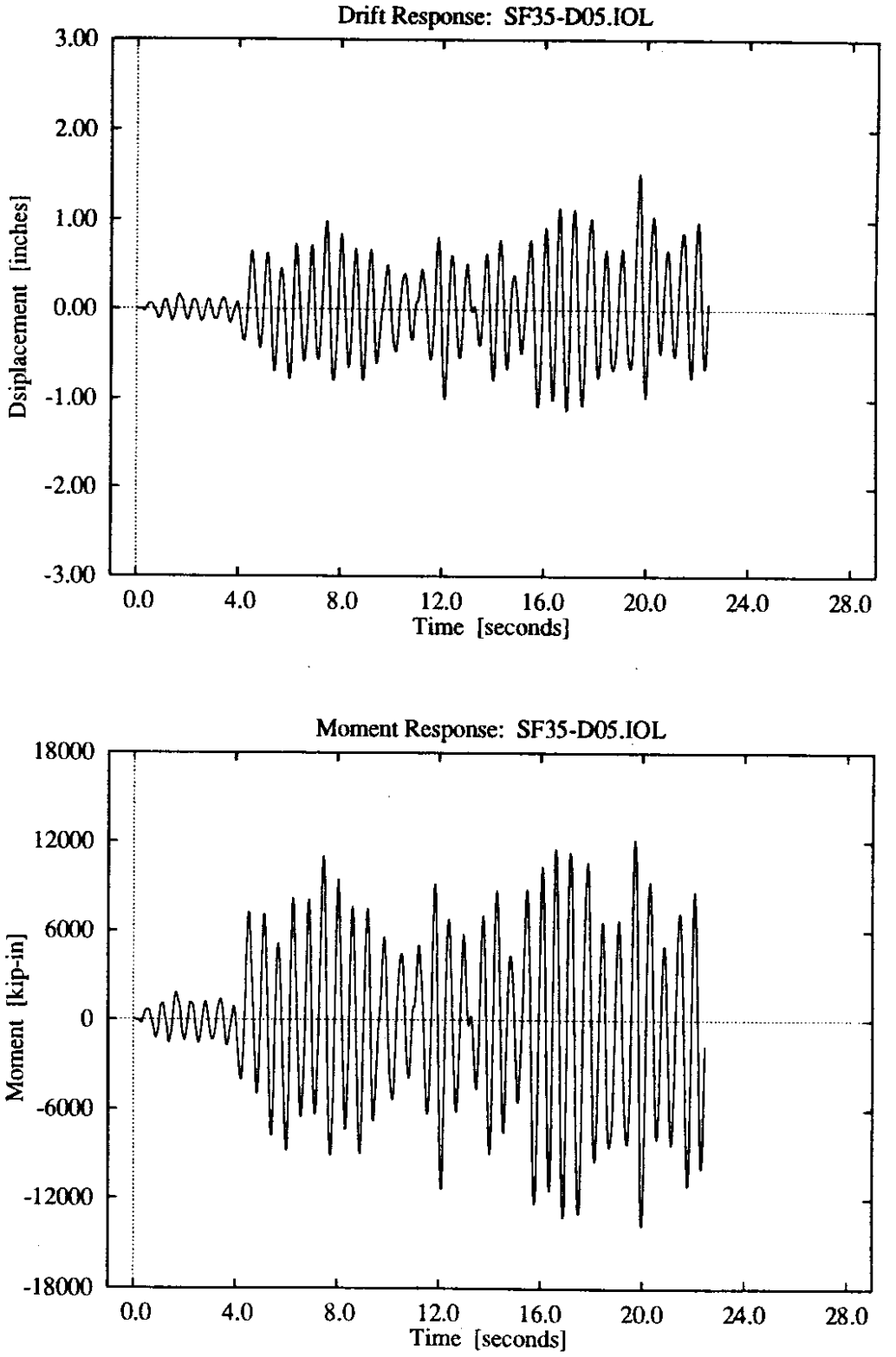


Figure D-69: 5 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.

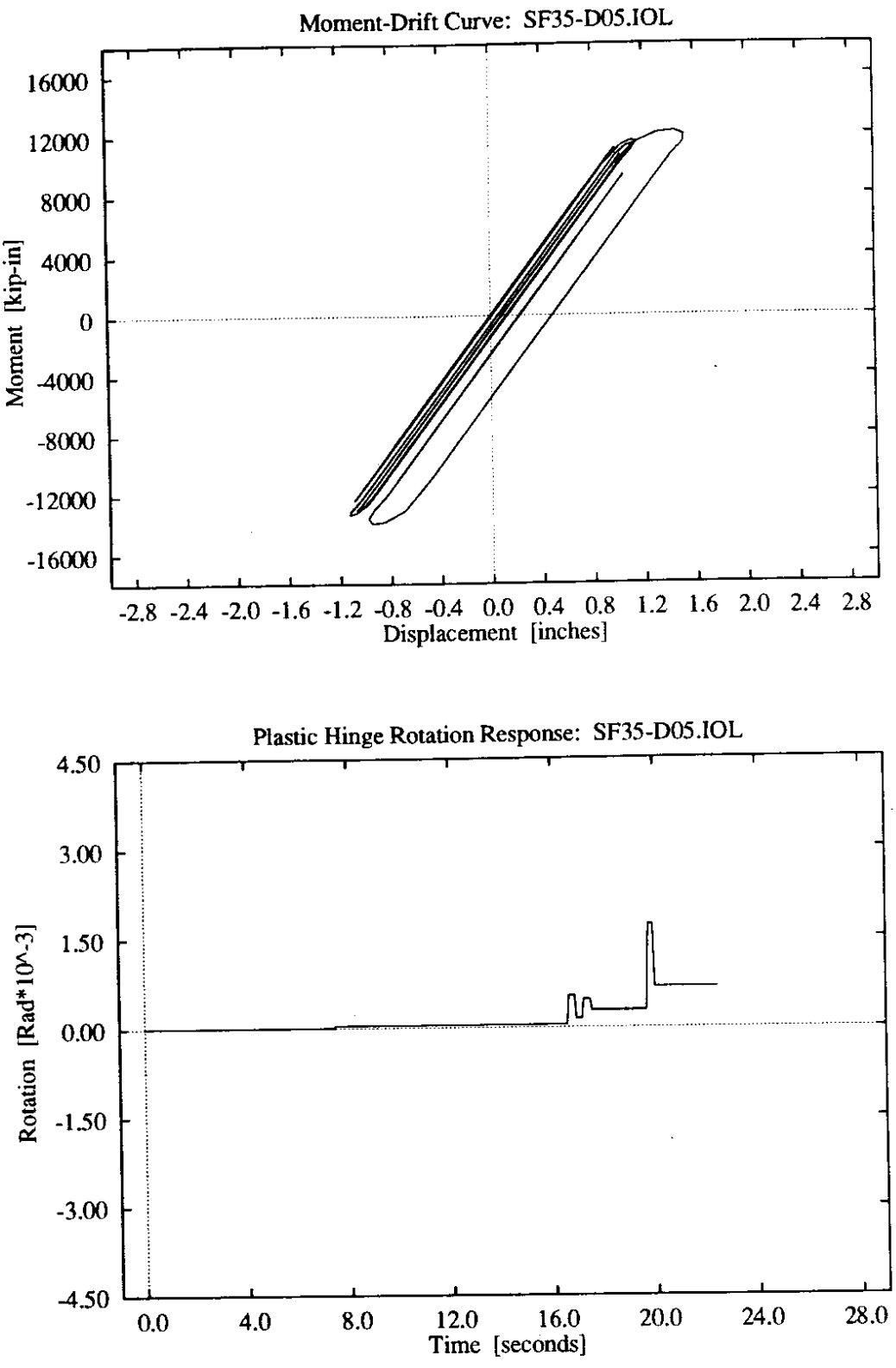


Figure D-70: 5 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.

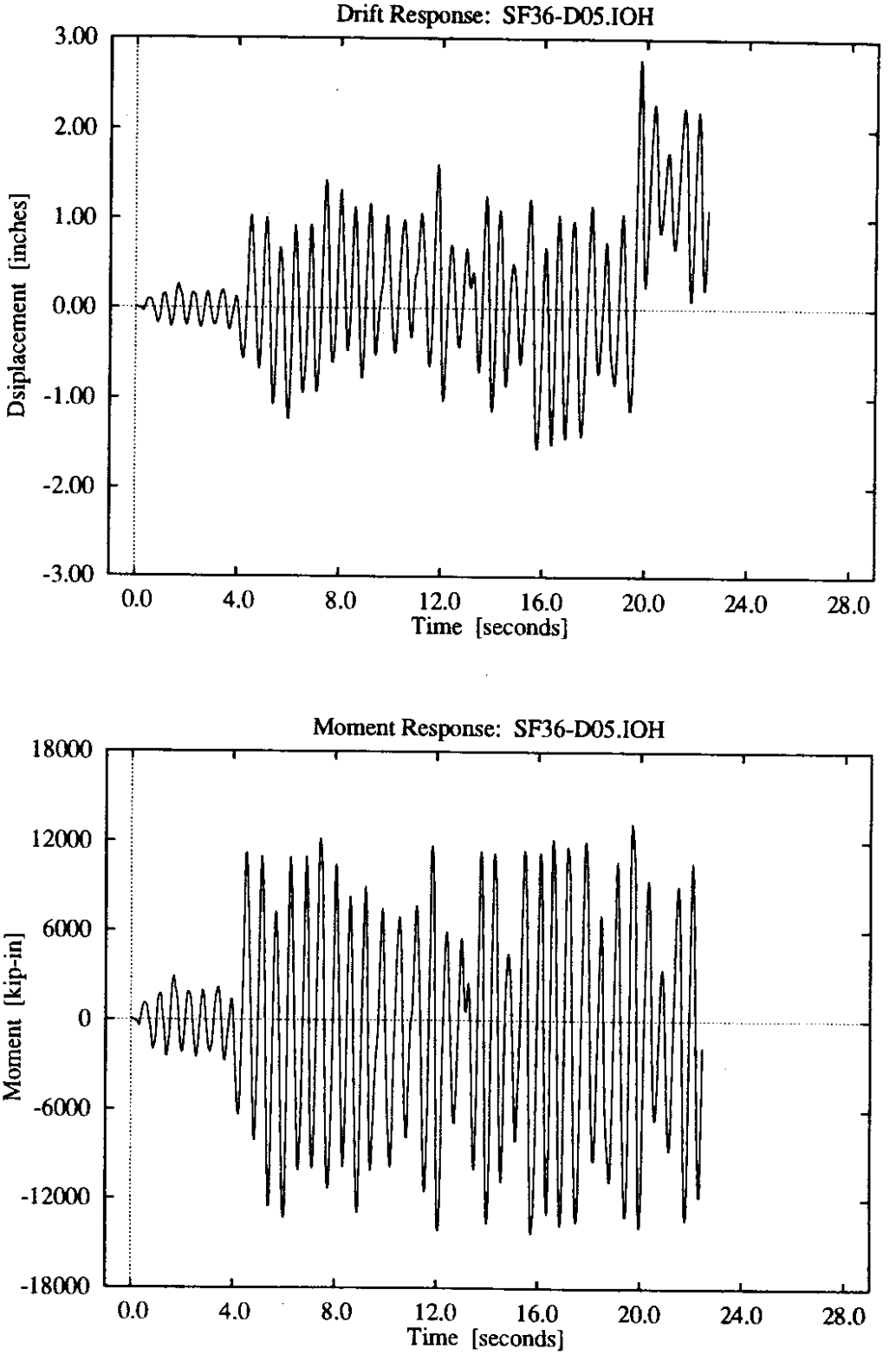
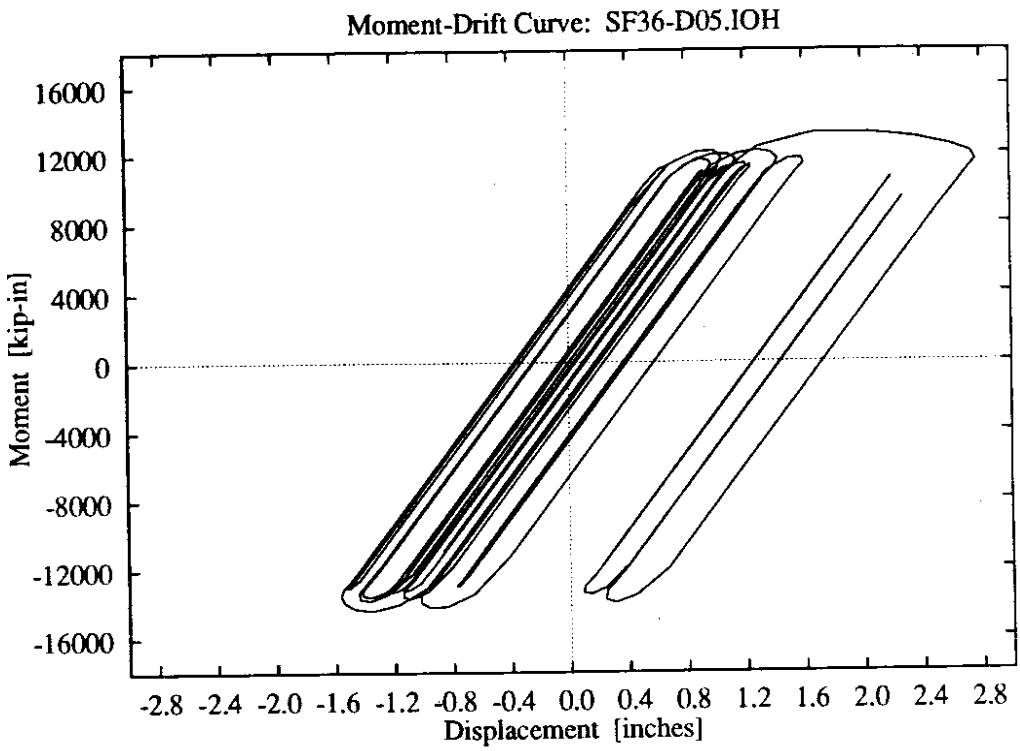


Figure D-71: 5 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.



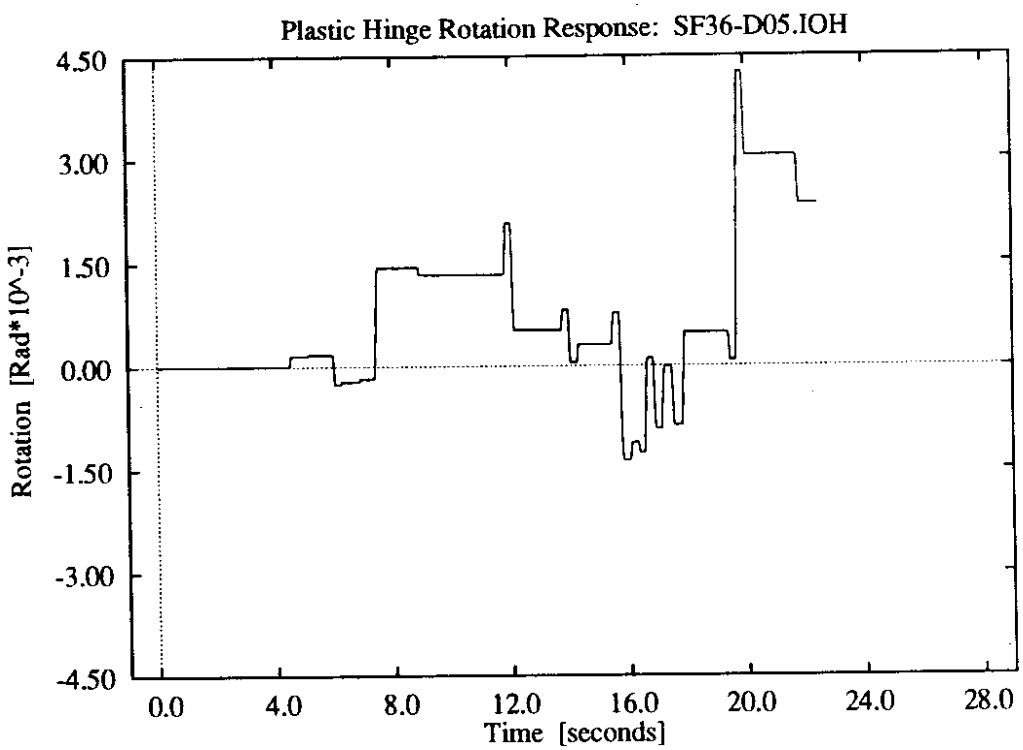


Figure D-72: 5 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.

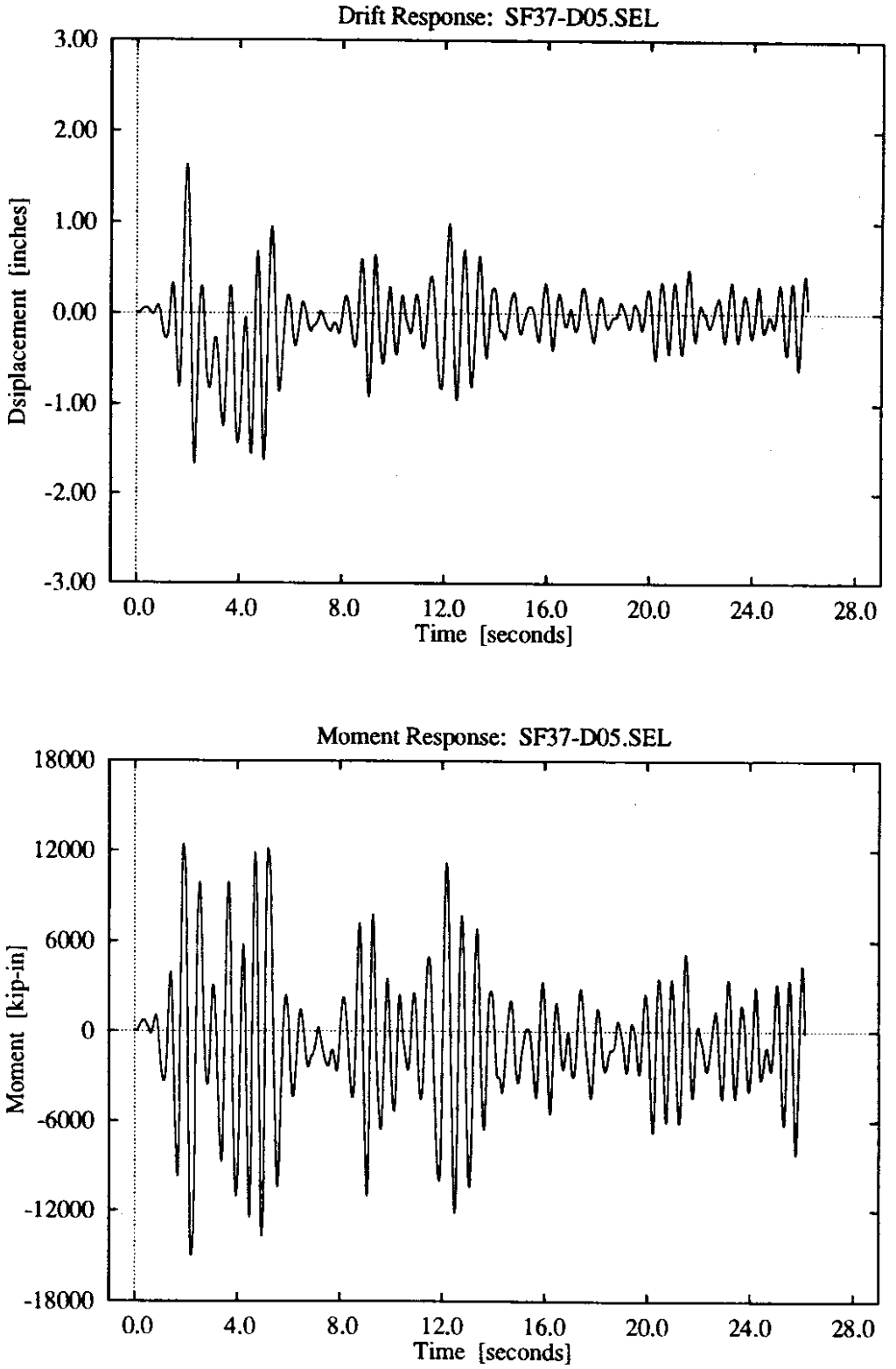
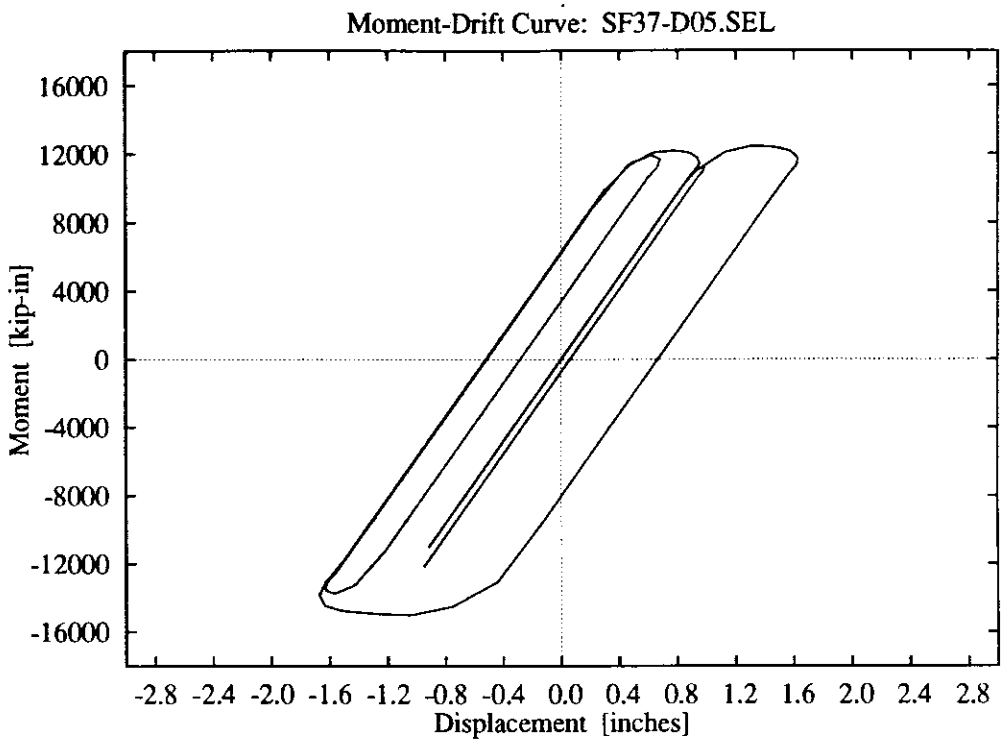


Figure D-73: 5 parameter foundation model, high soil stiffness, lower intensity El Centro record.



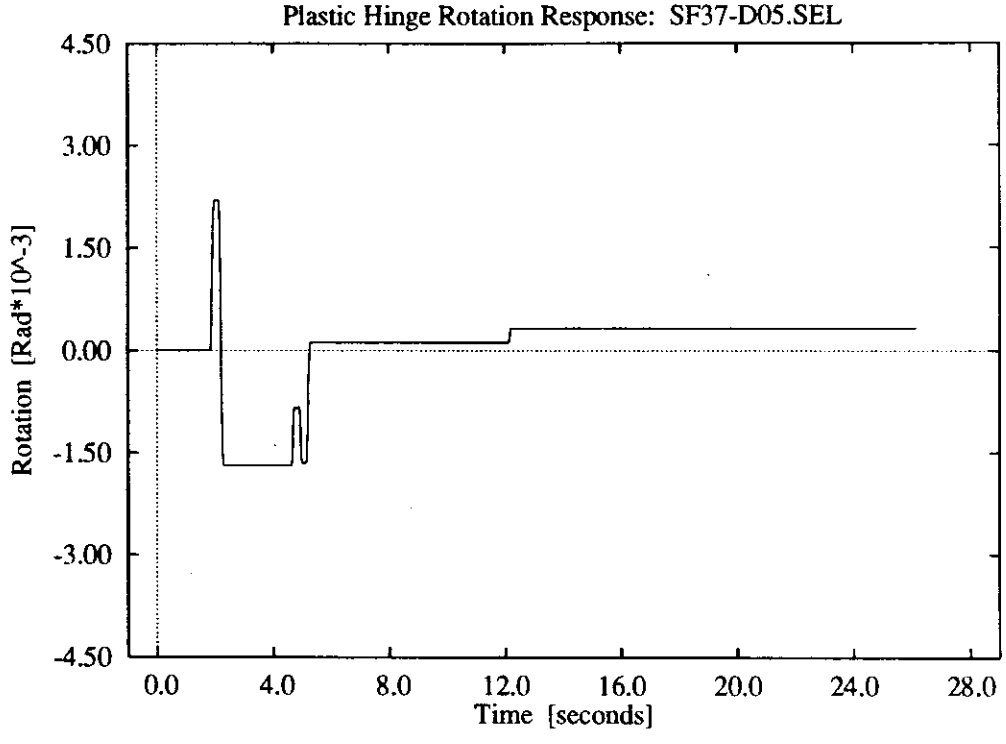
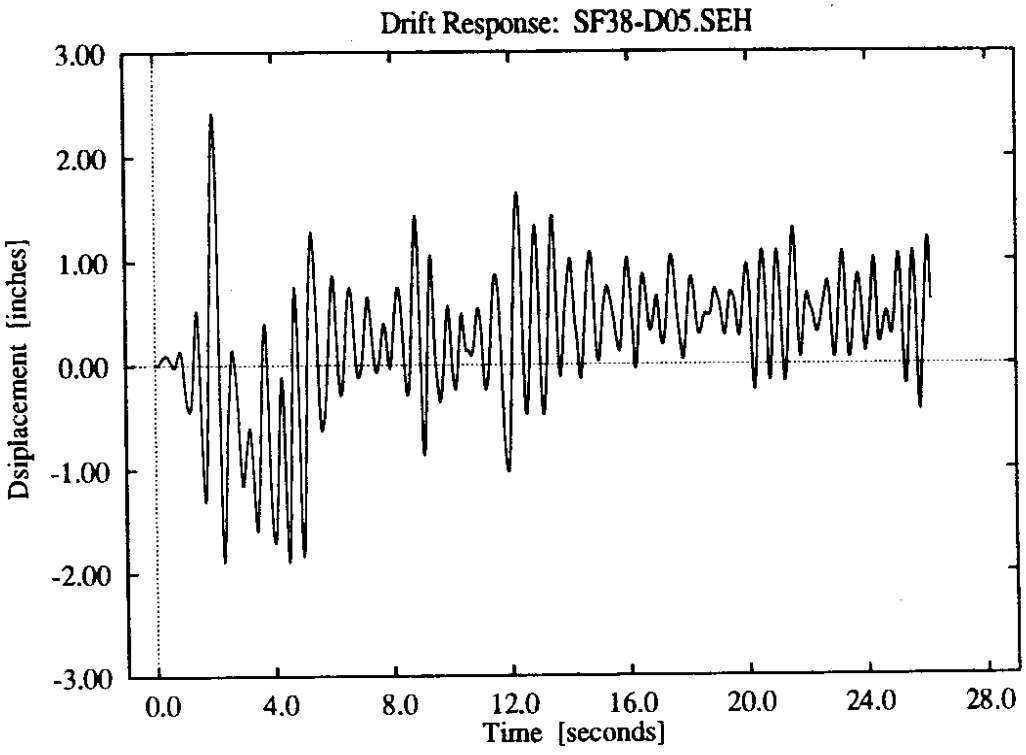


Figure D-74: 5 parameter foundation model, high soil stiffness, lower intensity El Centro record.



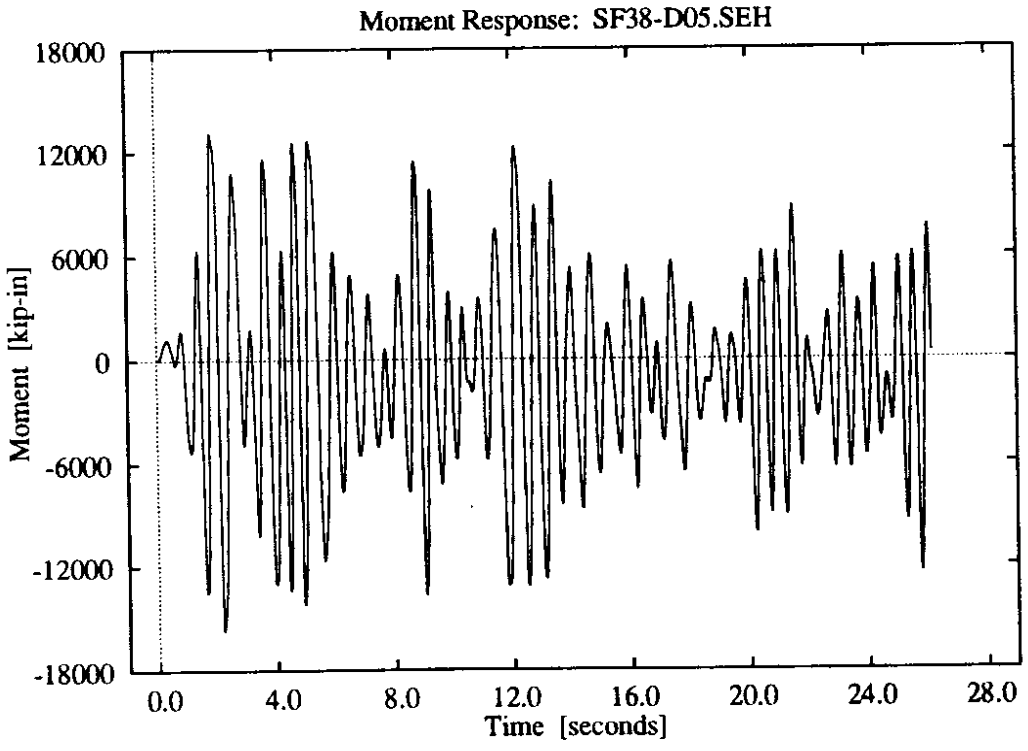


Figure D-75: 5 parameter foundation model, high soil stiffness, higher intensity El Centro record.

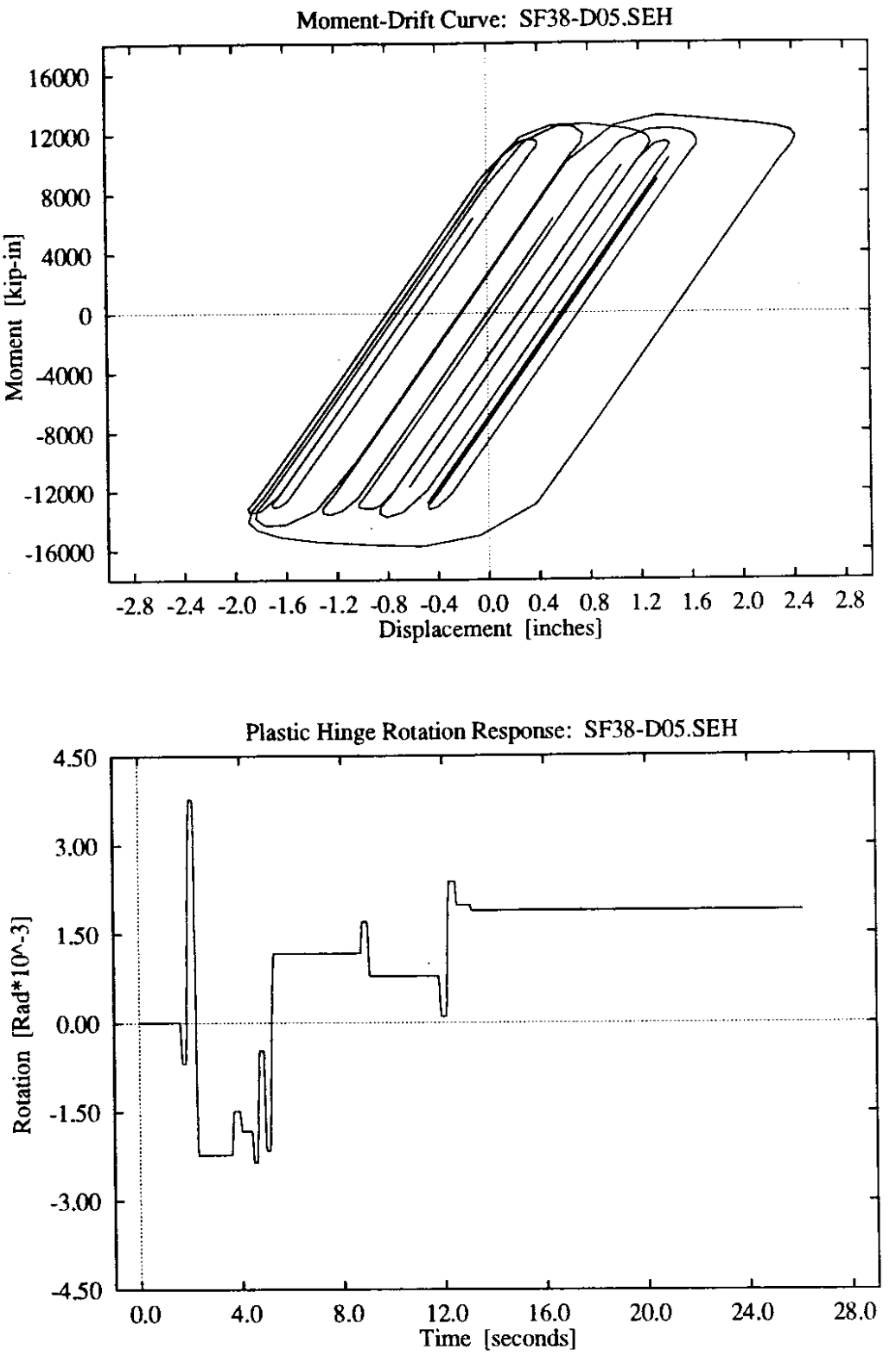
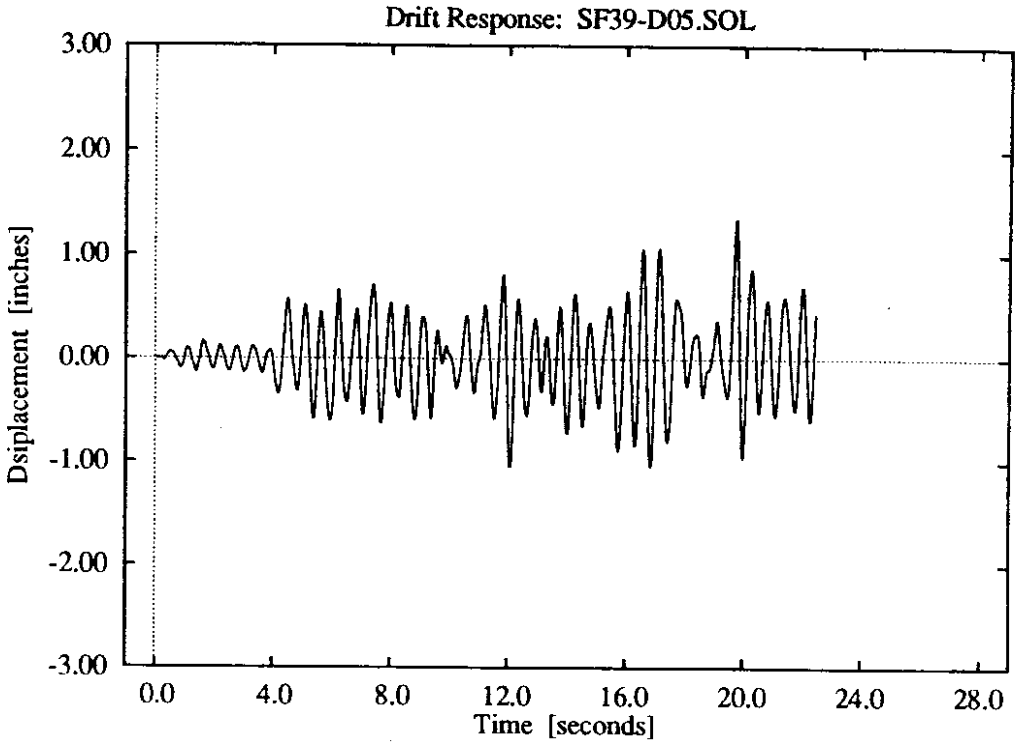


Figure D-76: 5 parameter foundation model, high soil stiffness, higher intensity El Centro record.



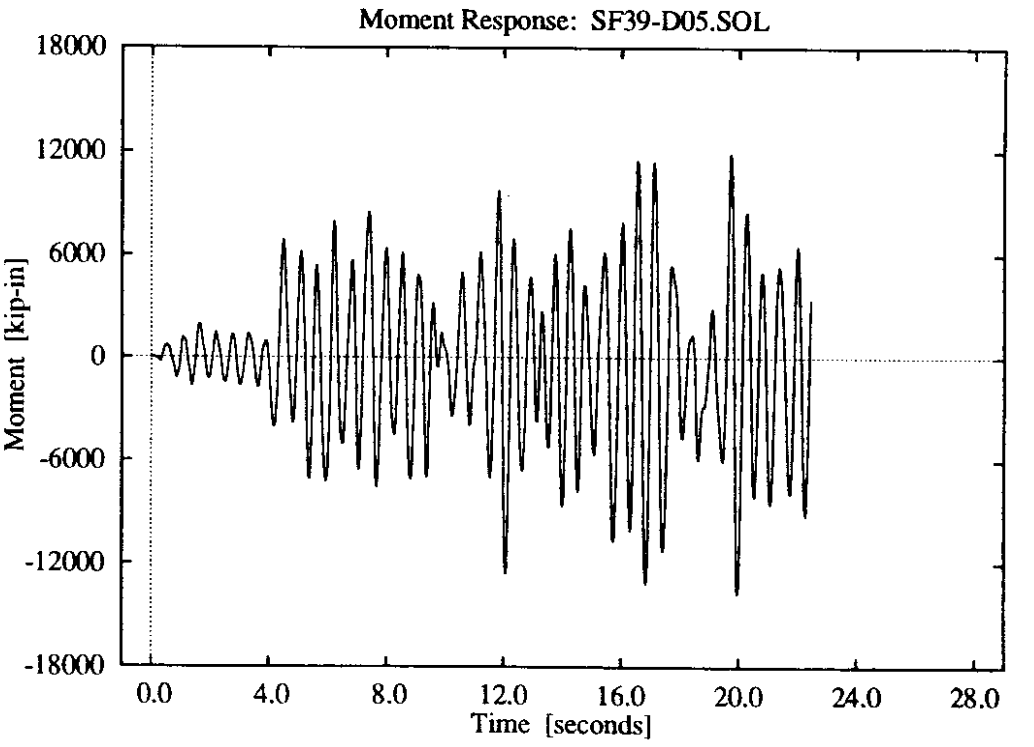
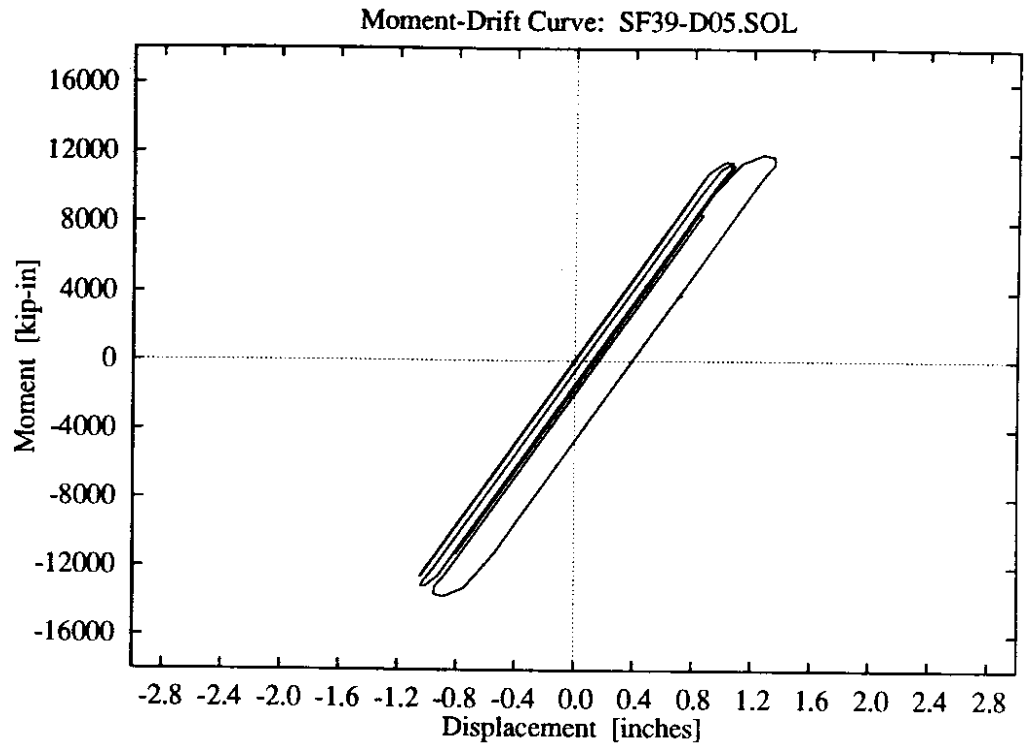


Figure D-77: 5 parameter foundation model, high soil stiffness, lower intensity Olympia record.



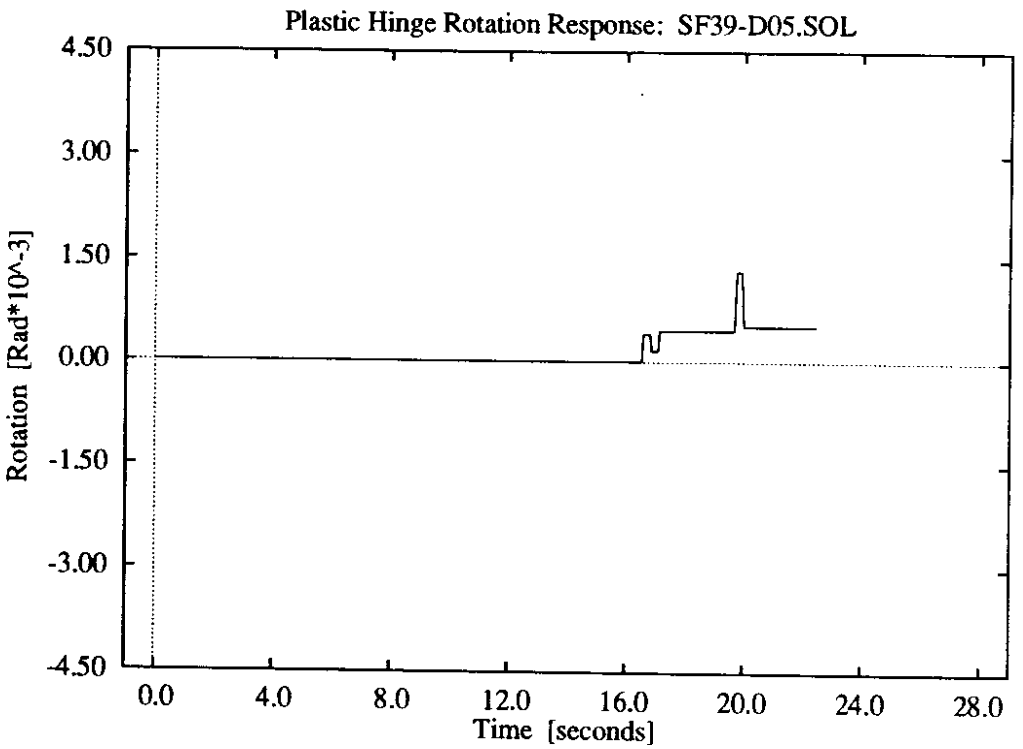


Figure D-78: 5 parameter foundation model, high soil stiffness, lower intensity Olympia record.

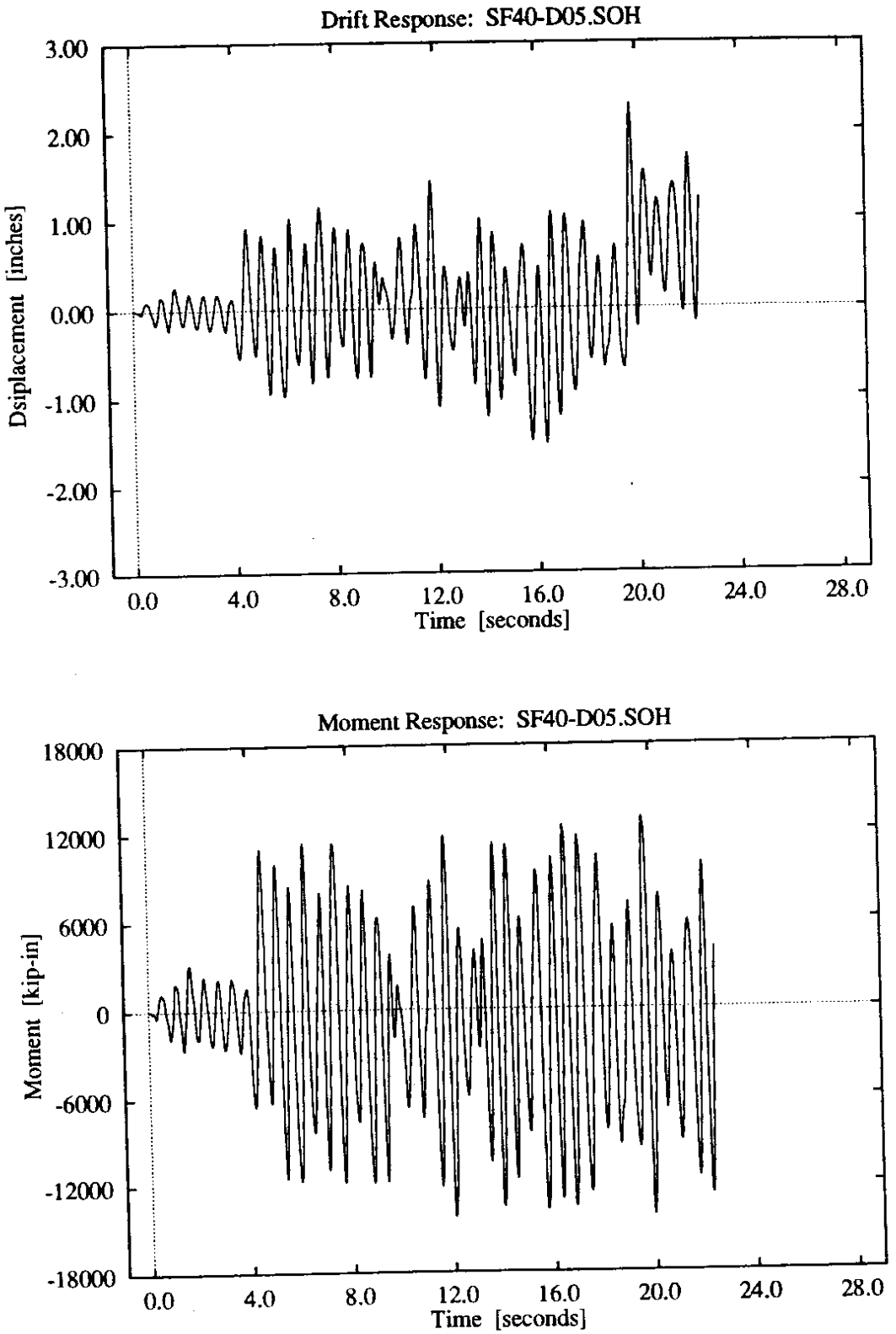
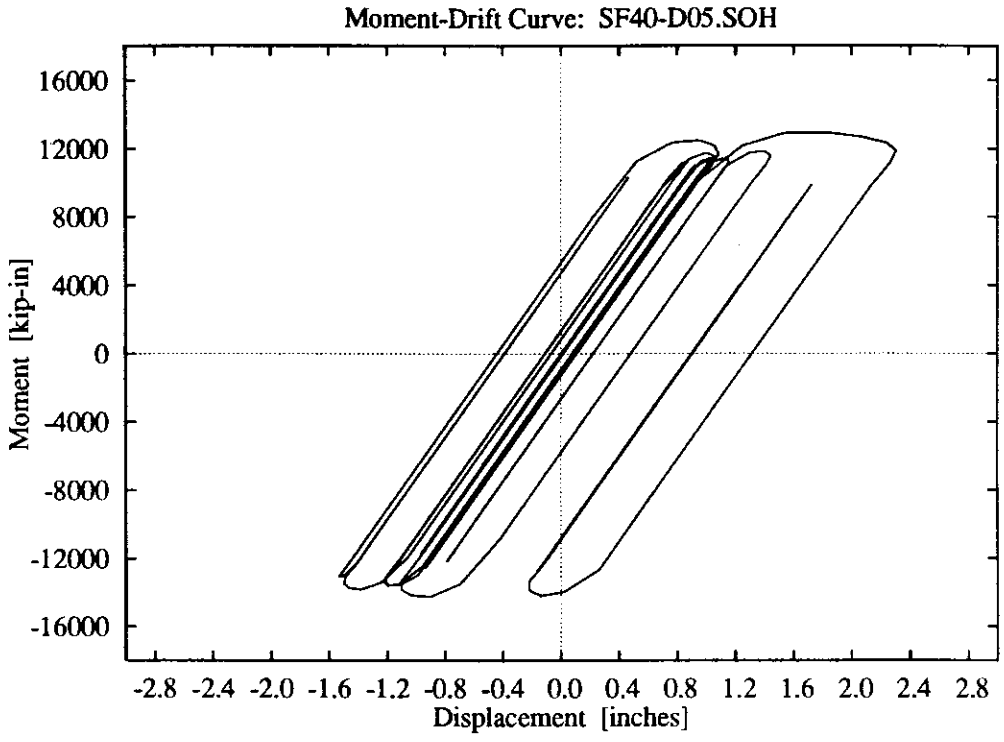


Figure D-79: 5 parameter foundation model, high soil stiffness, higher intensity Olympia record.



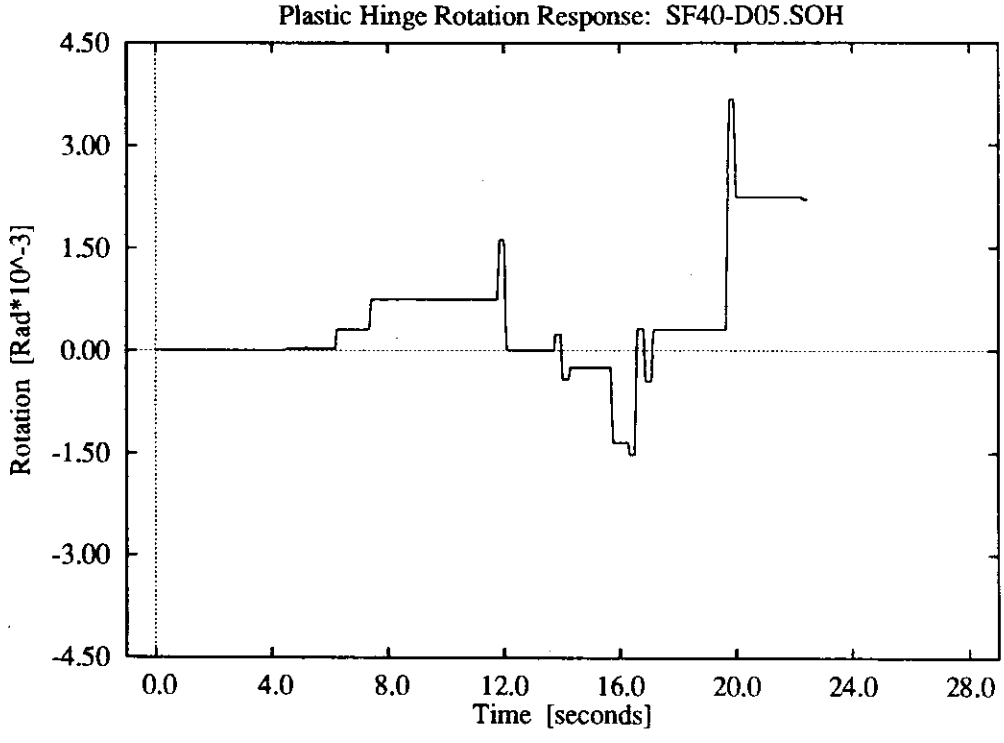
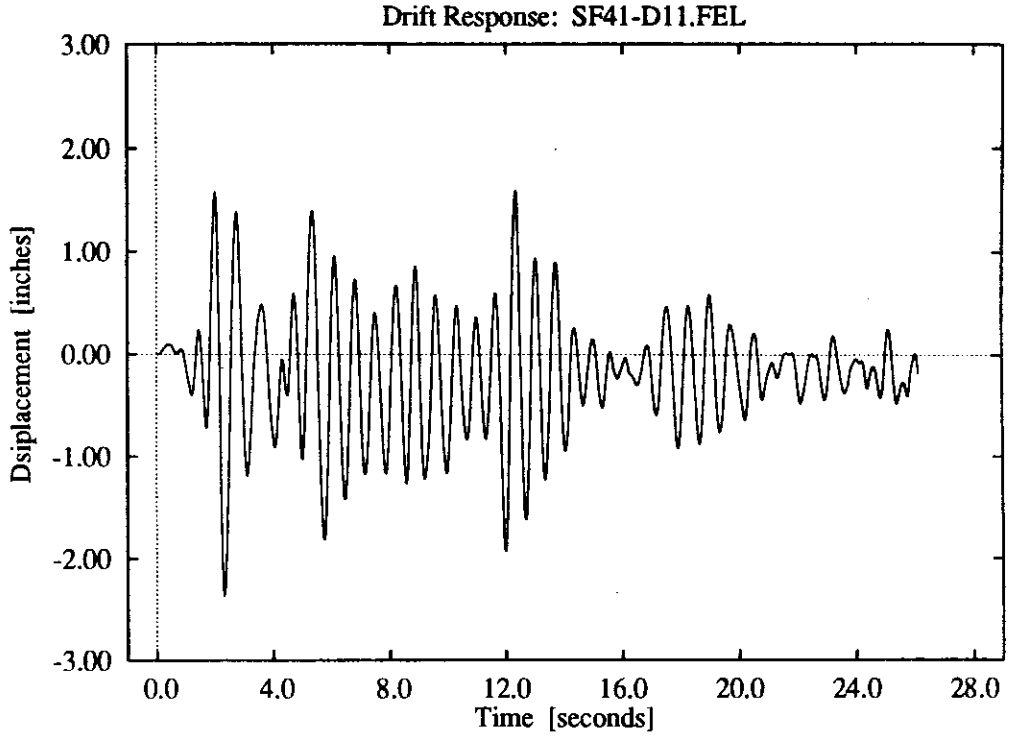


Figure D-80: 5 parameter foundation model, high soil stiffness, higher intensity Olympia record.



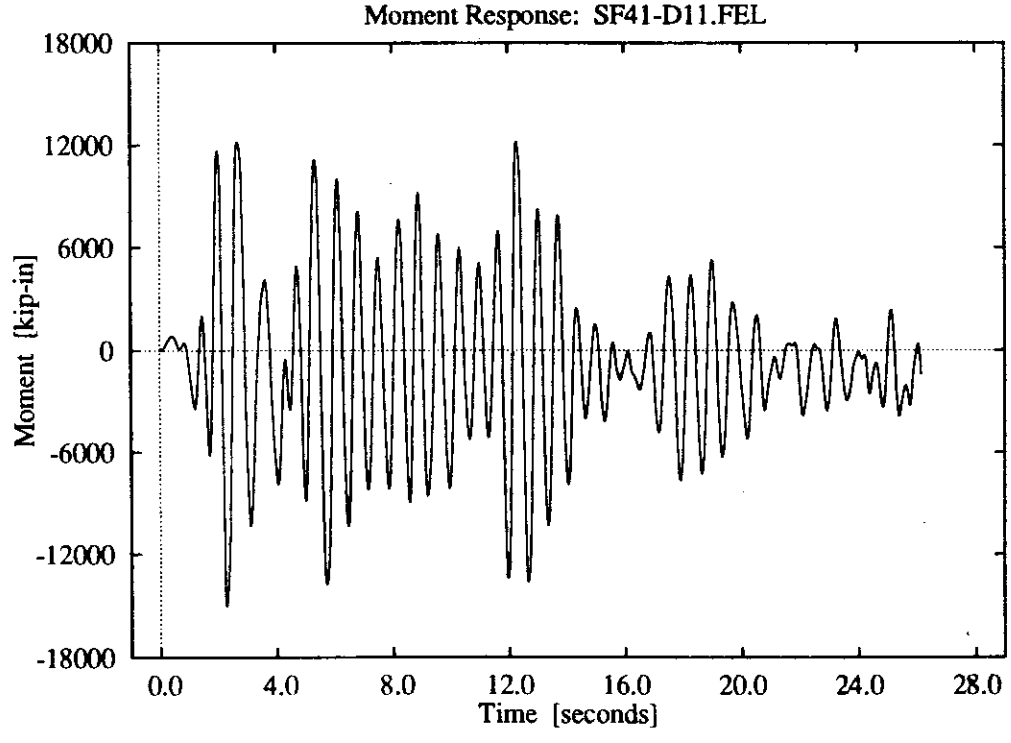
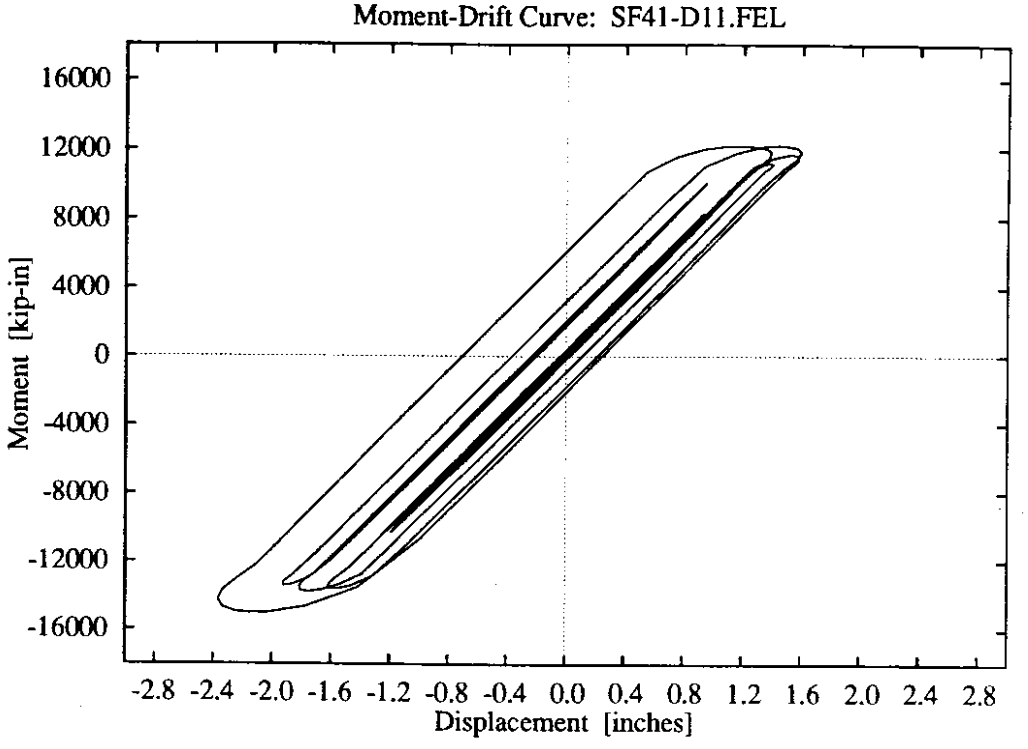


Figure D-81: 11 parameter foundation model, low soil stiffness, lower intensity El Centro record.



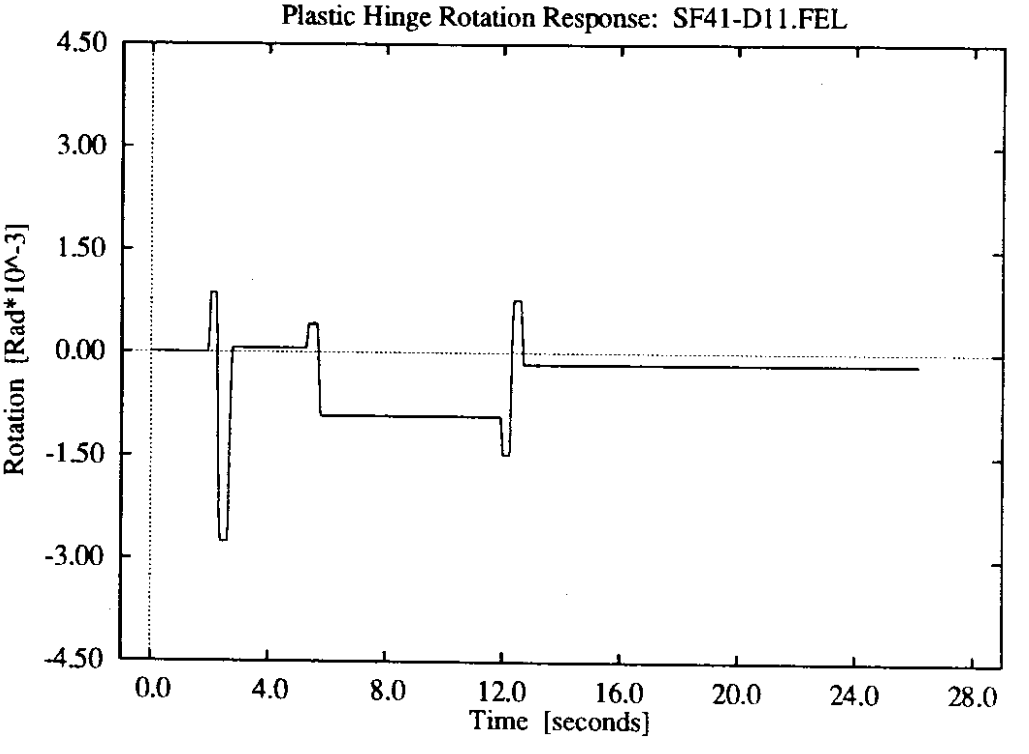
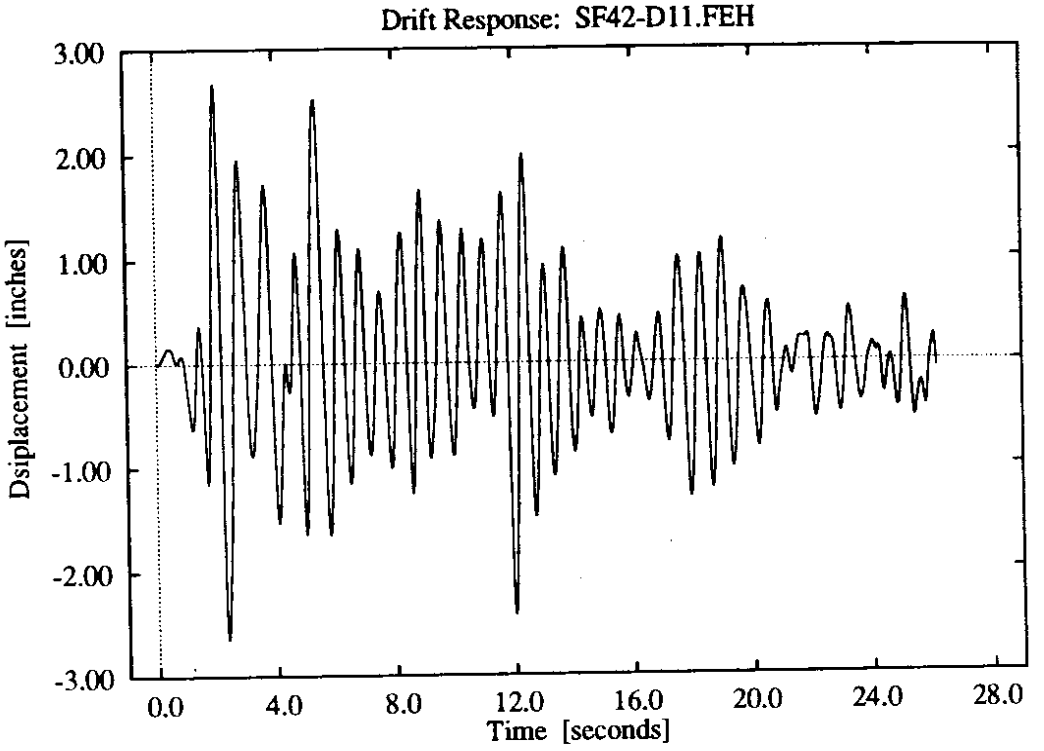


Figure D-82: 11 parameter foundation model, low soil stiffness, lower intensity El Centro record.



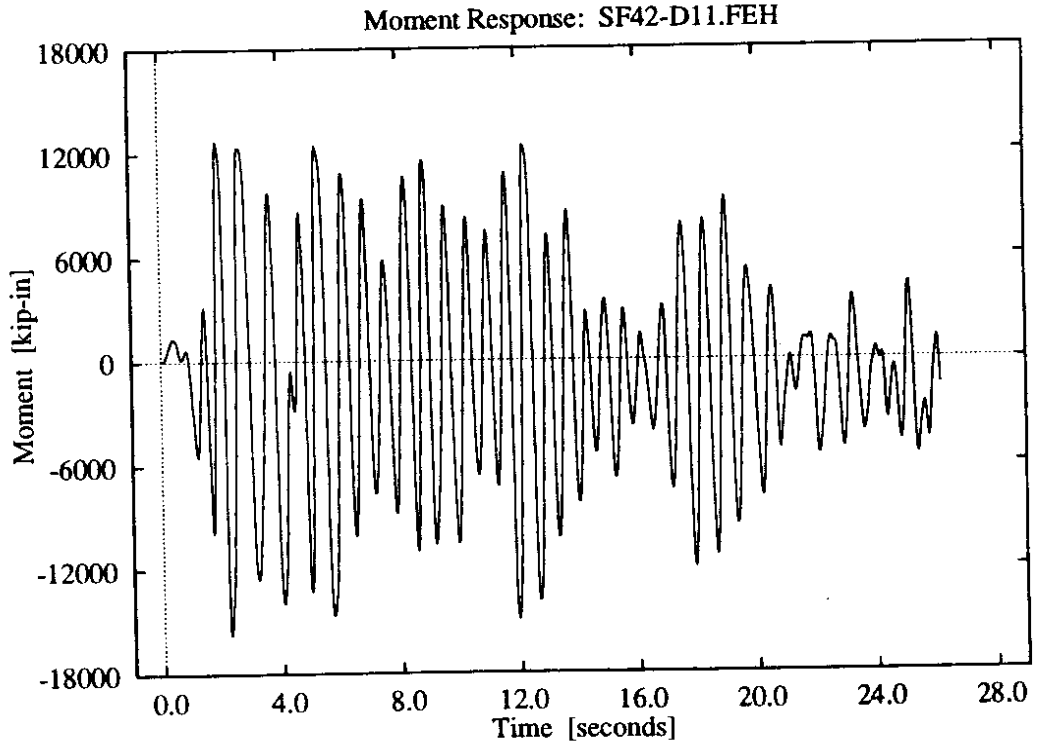
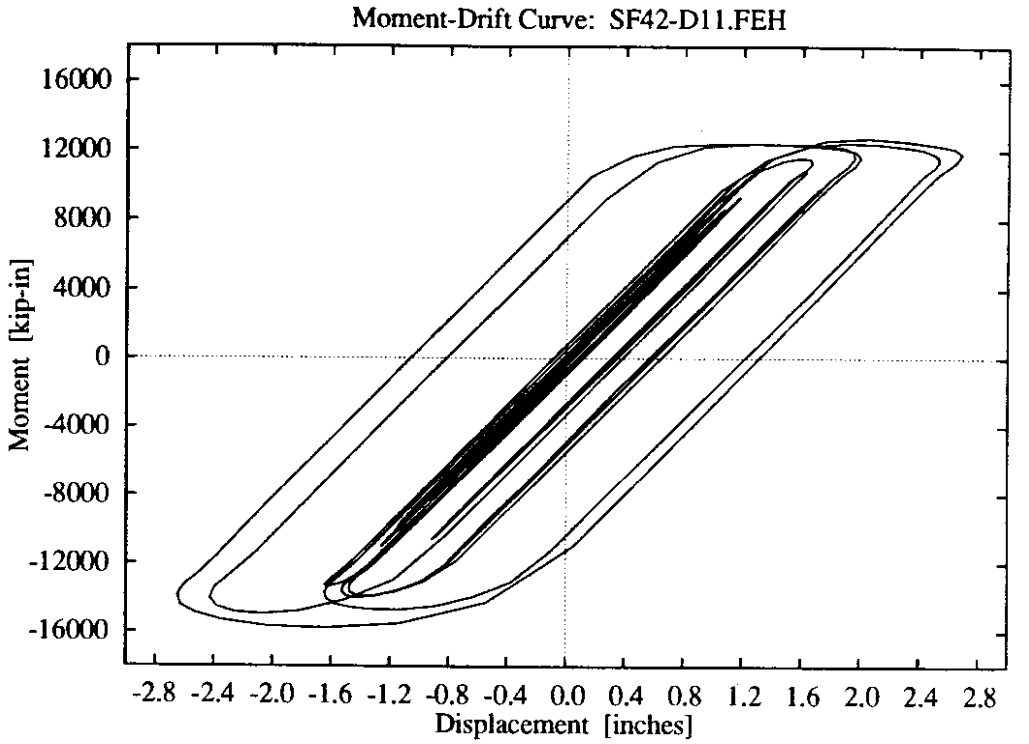


Figure D-83: 11 parameter foundation model, low soil stiffness, higher intensity El Centro record.



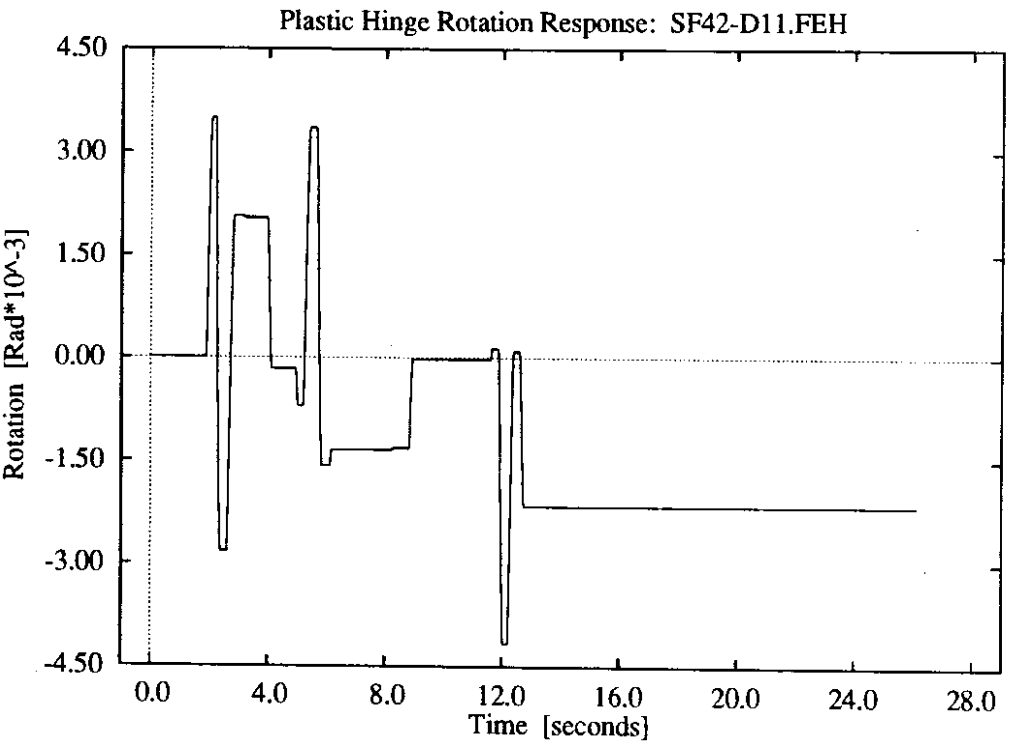
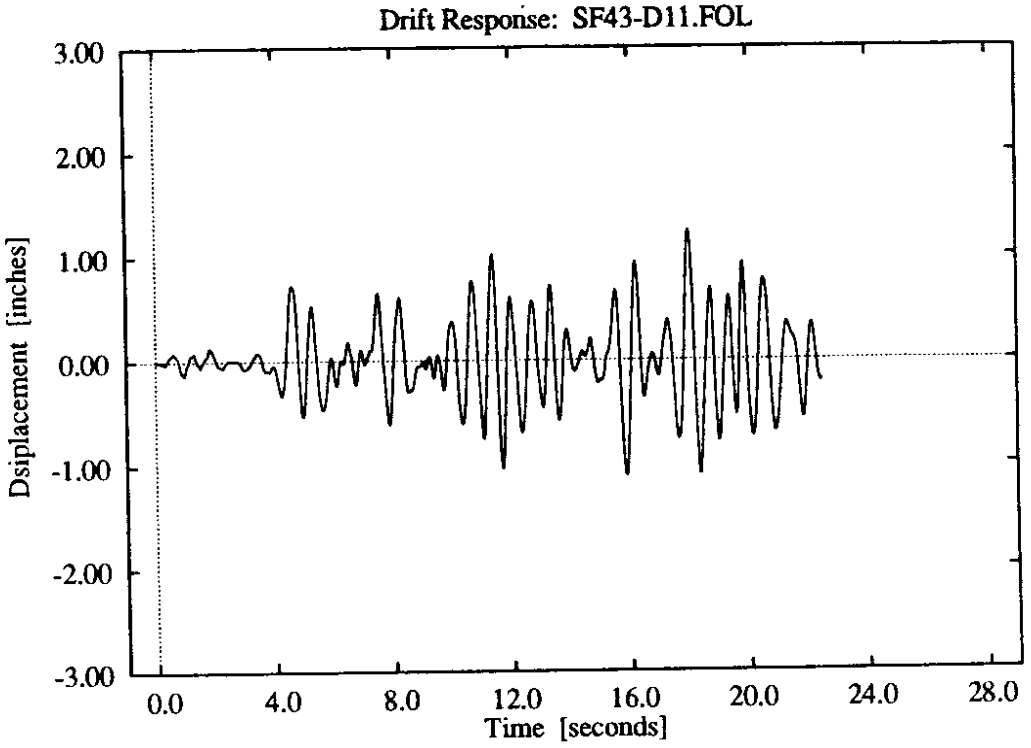


Figure D-84: 11 parameter foundation model, low soil stiffness, higher intensity El Centro record.



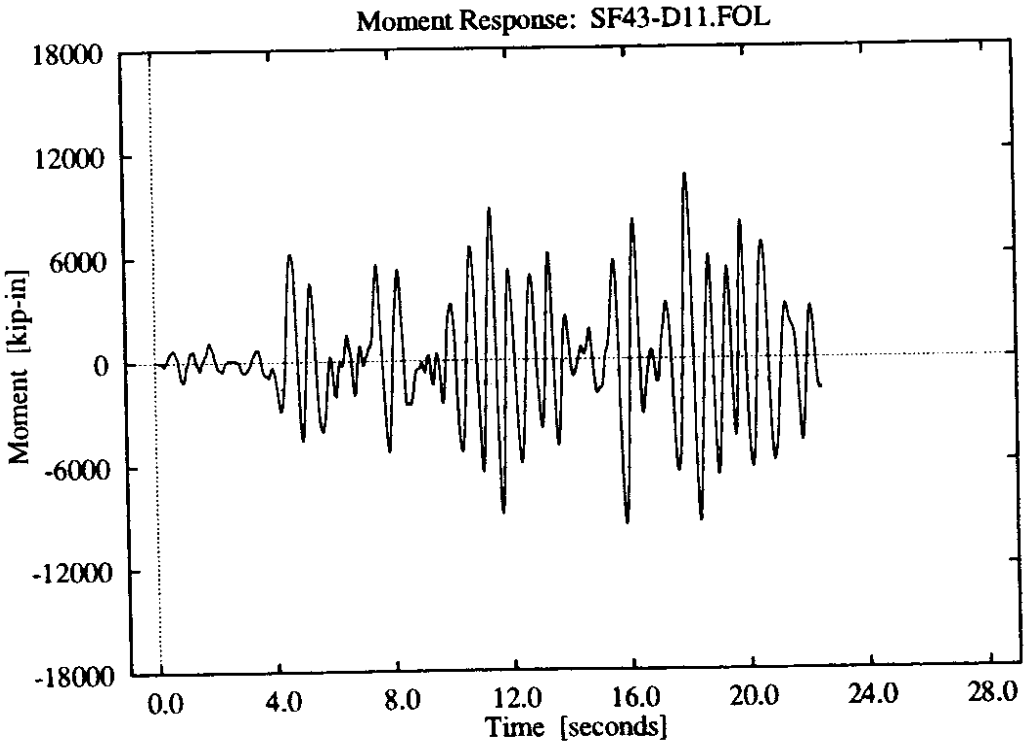
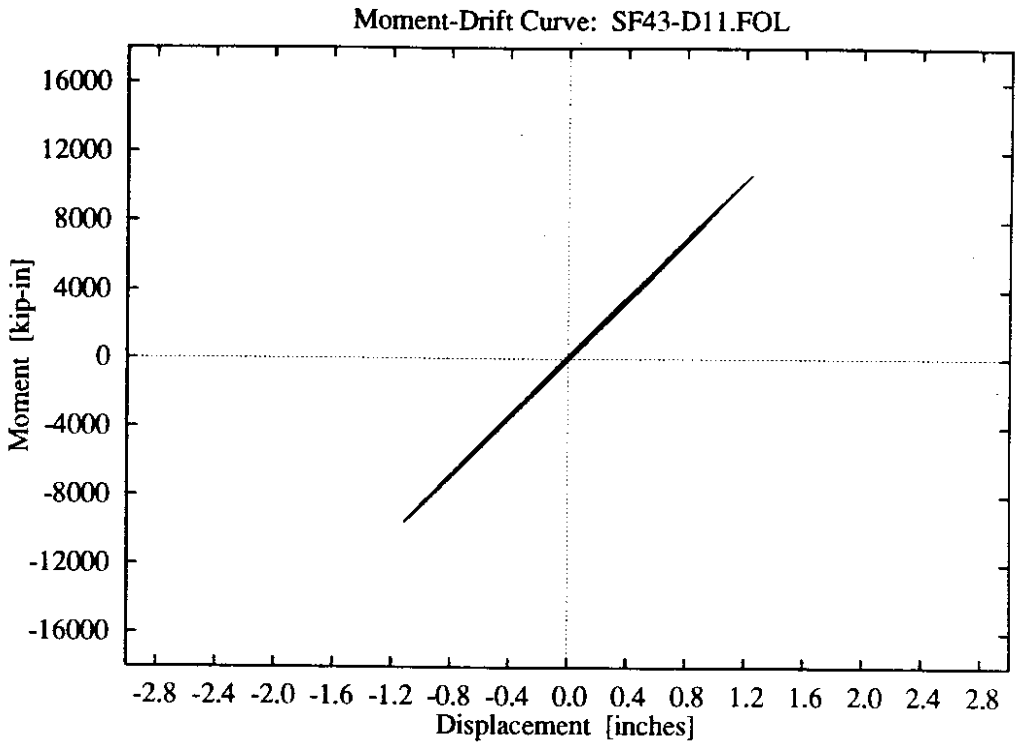


Figure D-85: 11 parameter foundation model, low soil stiffness, lower intensity Olympia record.



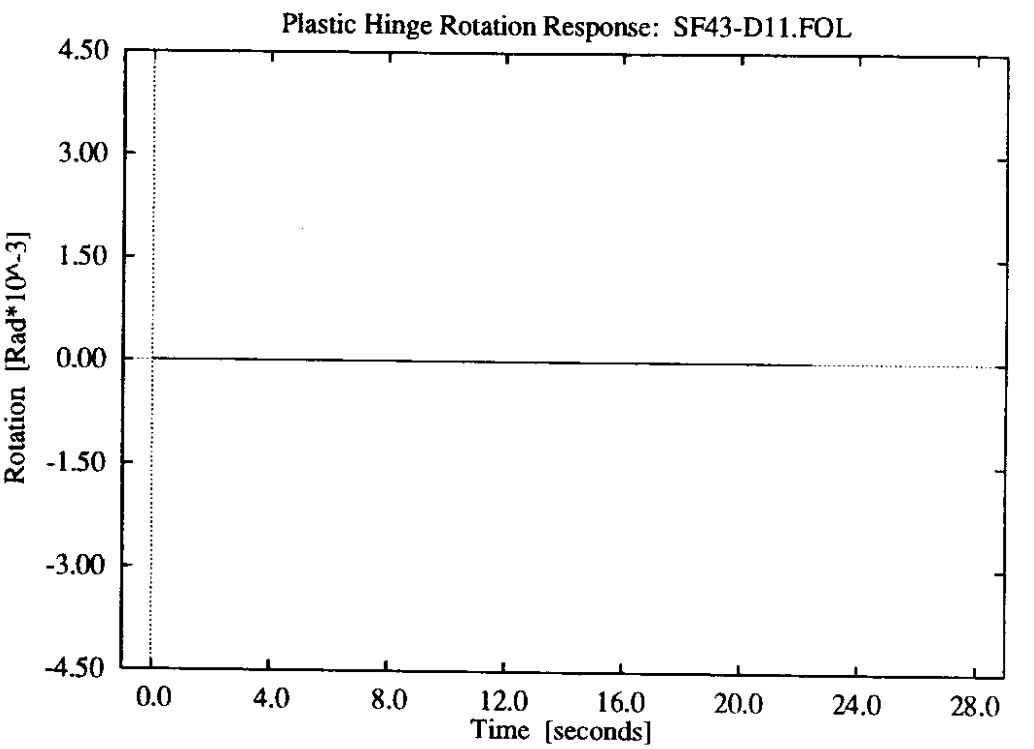
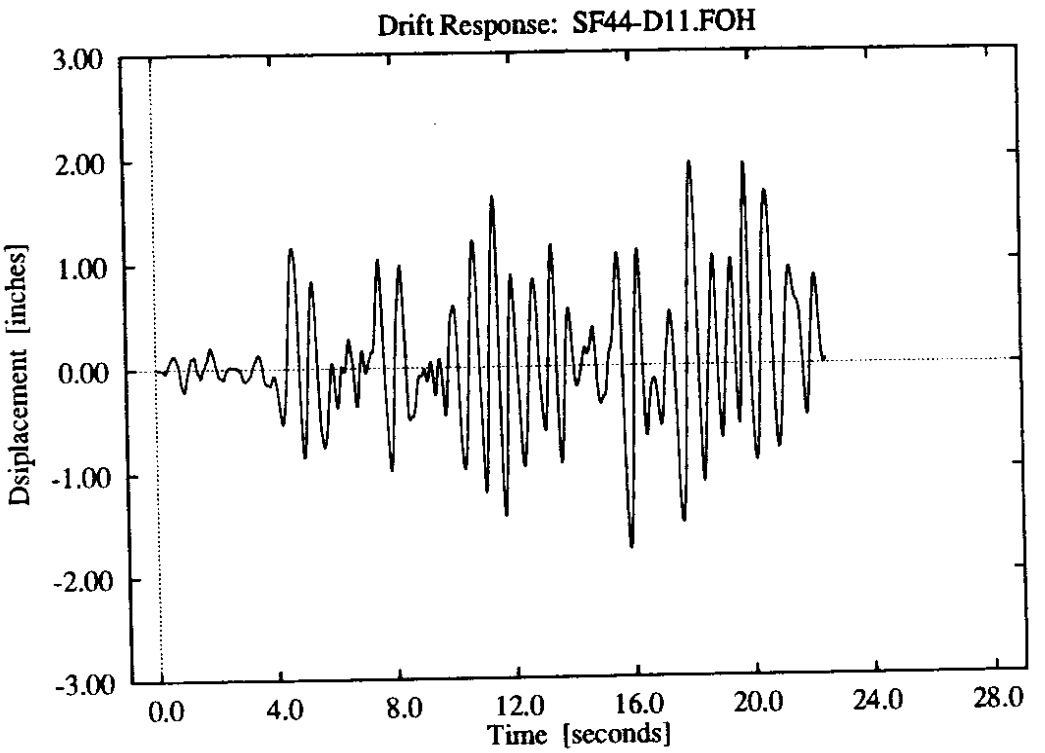


Figure D-86: 11 parameter foundation model, low soil stiffness, lower intensity Olympia record.



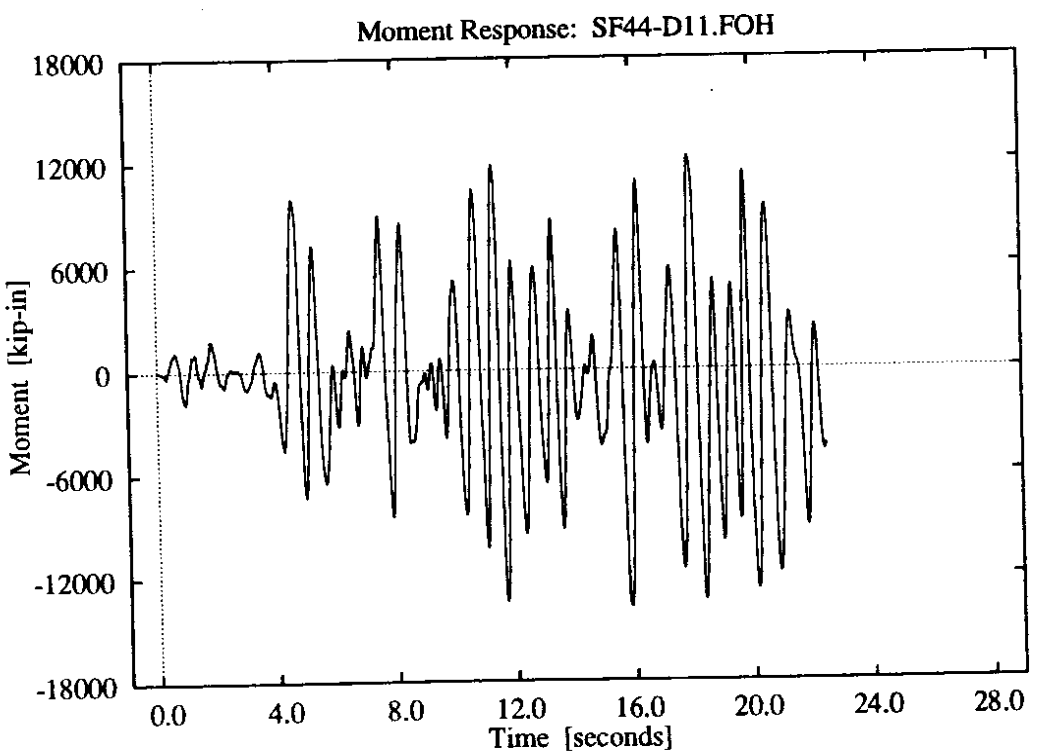
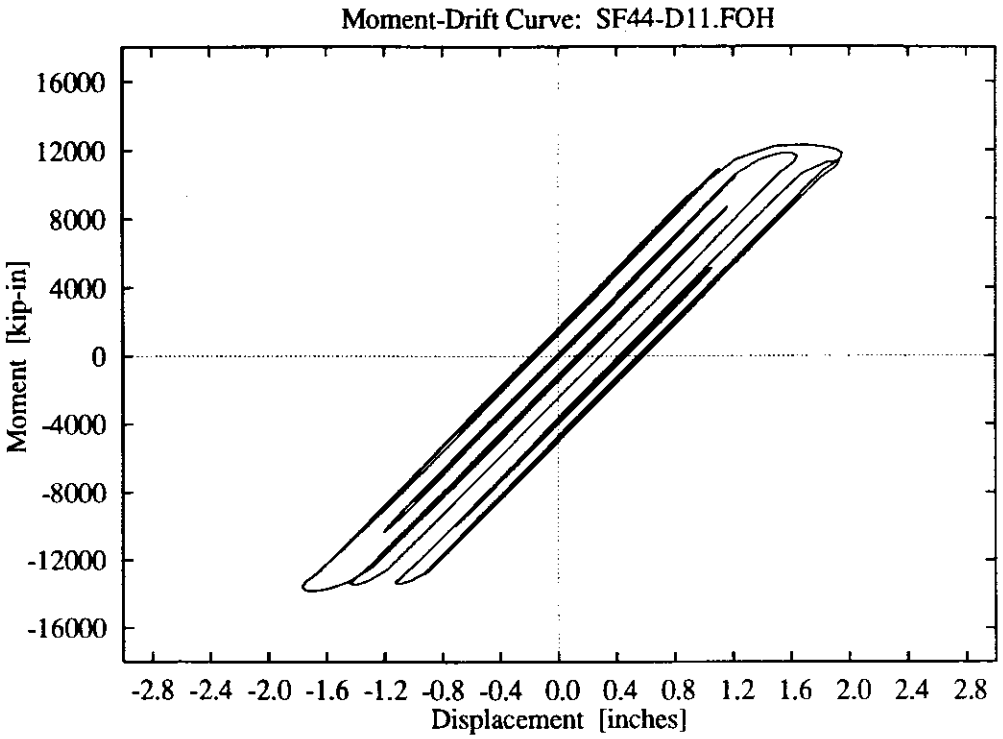


Figure D-87: 11 parameter foundation model, low soil stiffness, higher intensity Olympia record.



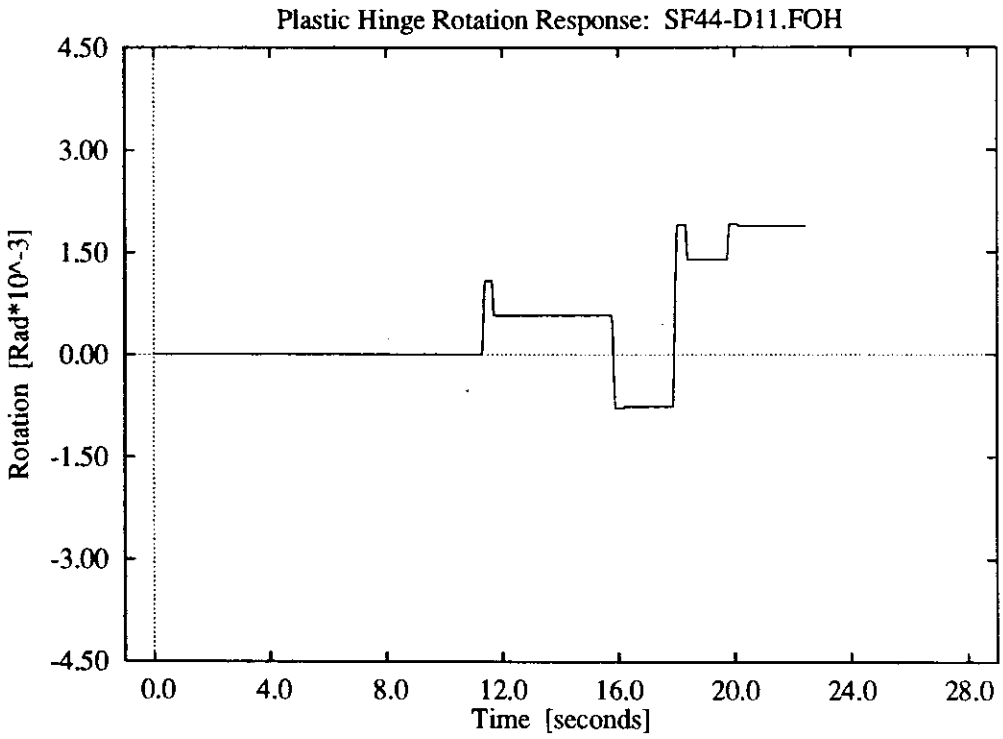
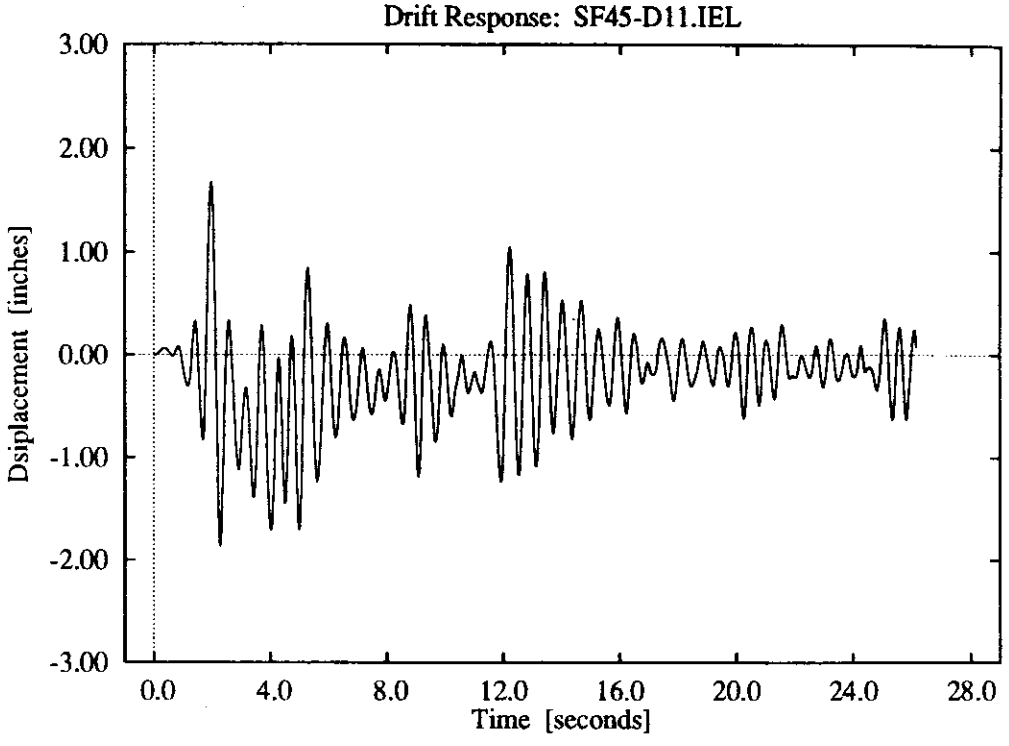


Figure D-88: 11 parameter foundation model, low soil stiffness, higher intensity Olympia record.



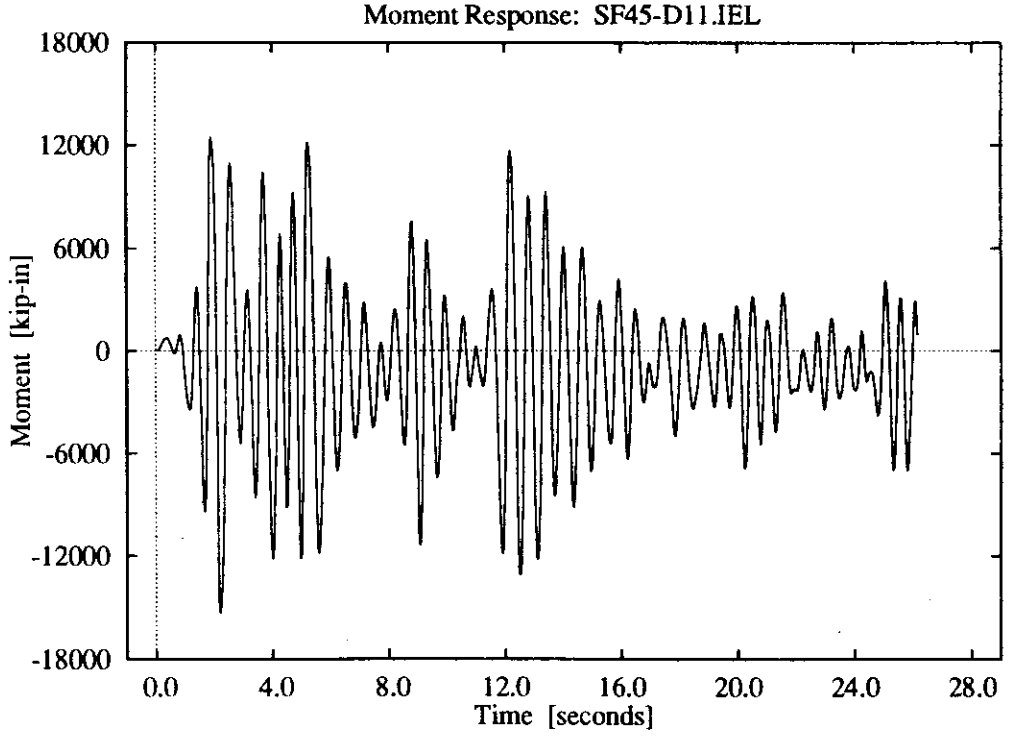
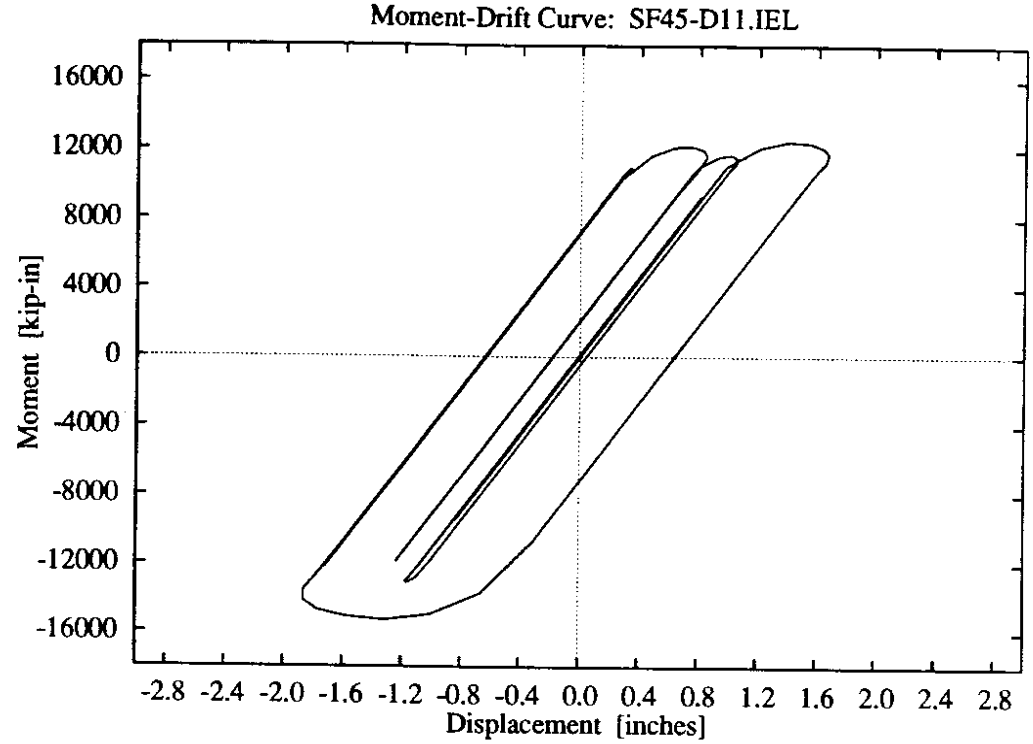


Figure D-89: 11 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.



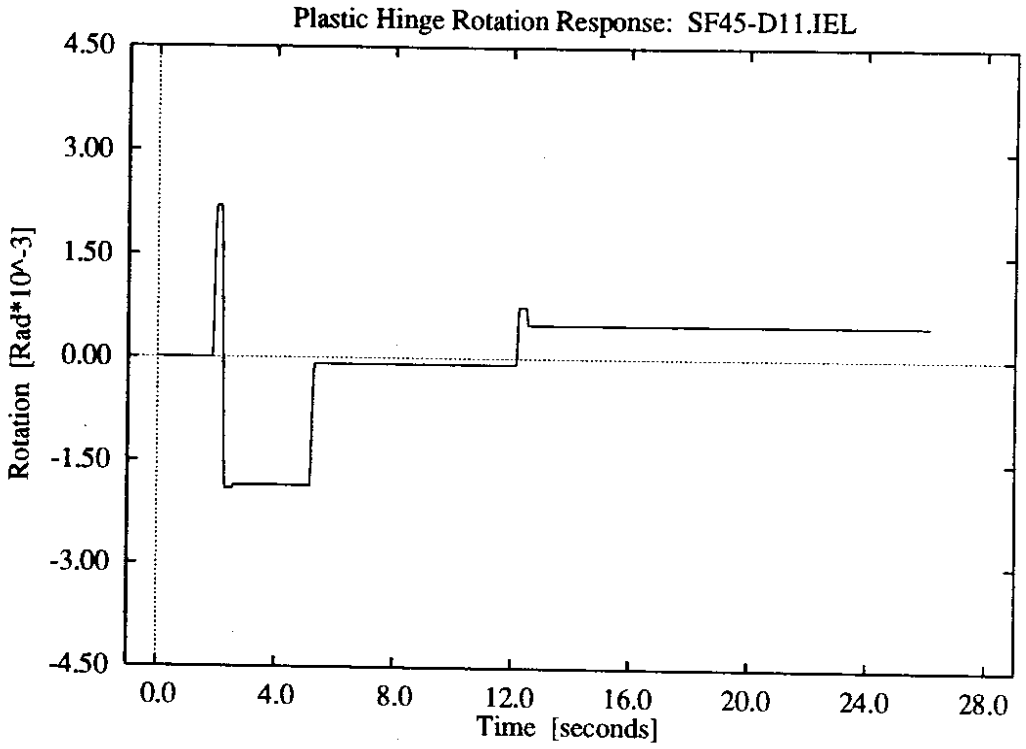


Figure D-90: 11 parameter foundation model, intermediate soil stiffness, lower intensity El Centro record.

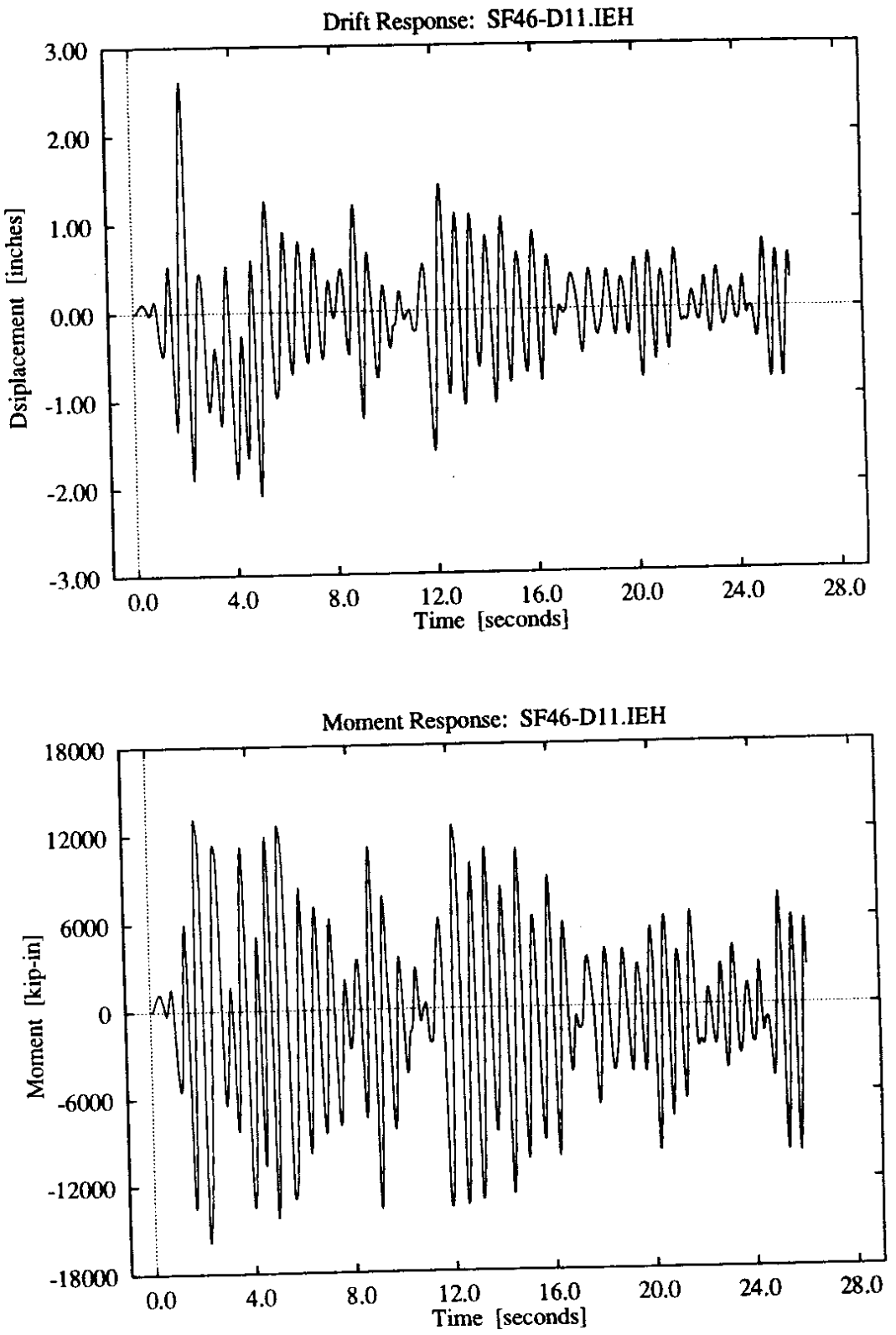
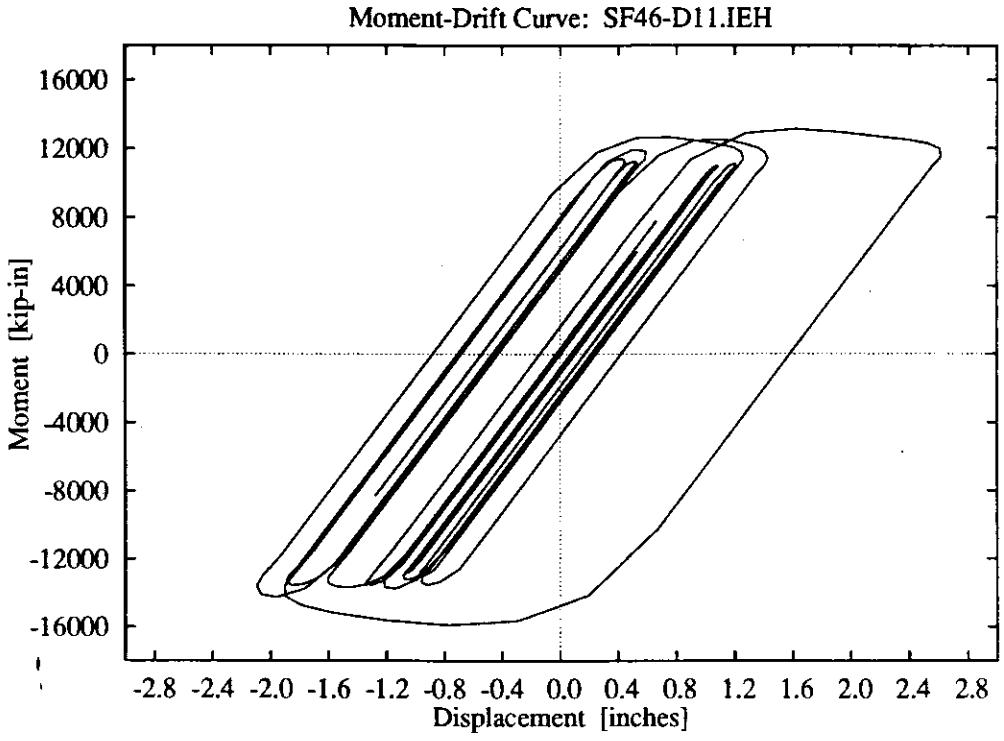


Figure D-91: 11 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.



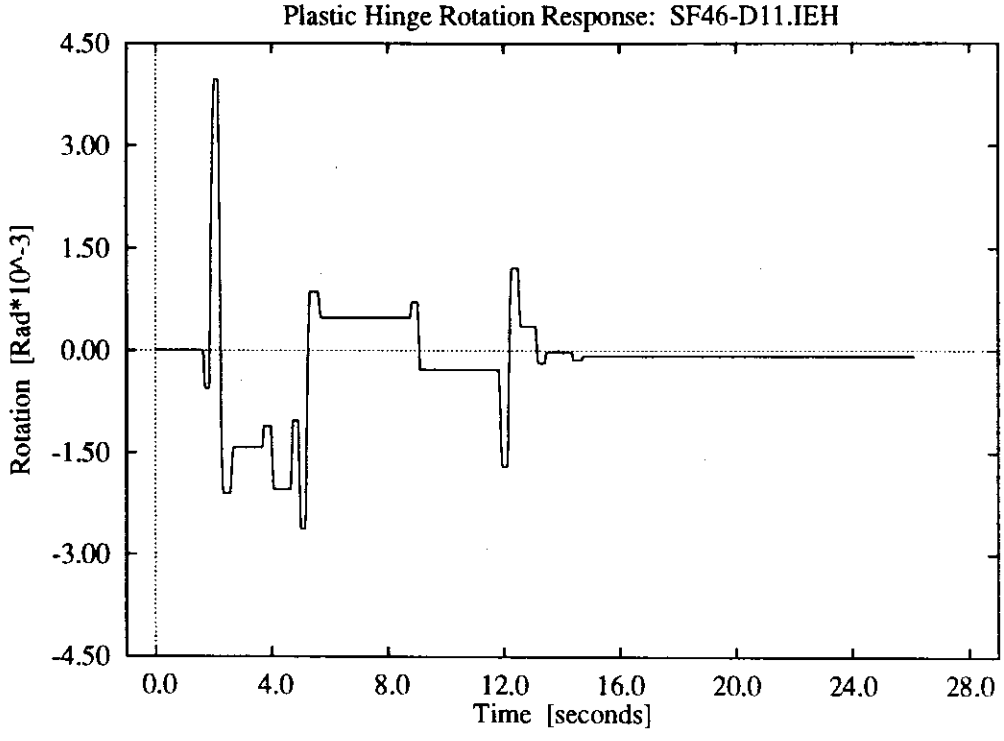
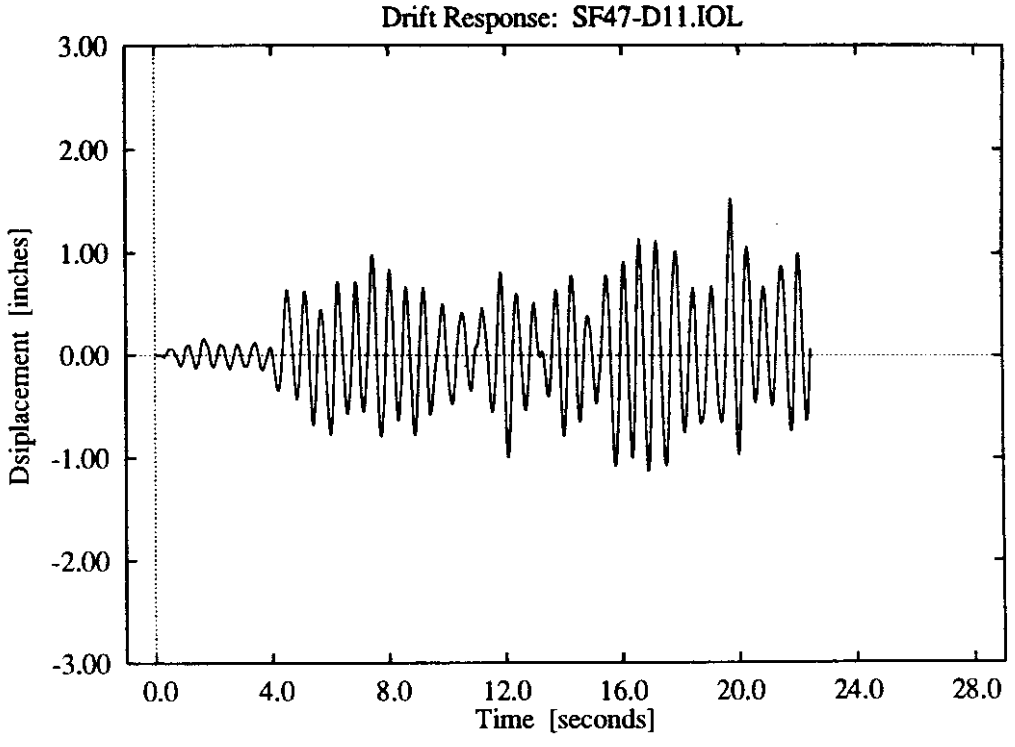


Figure D-92: 11 parameter foundation model, intermediate soil stiffness, higher intensity El Centro record.



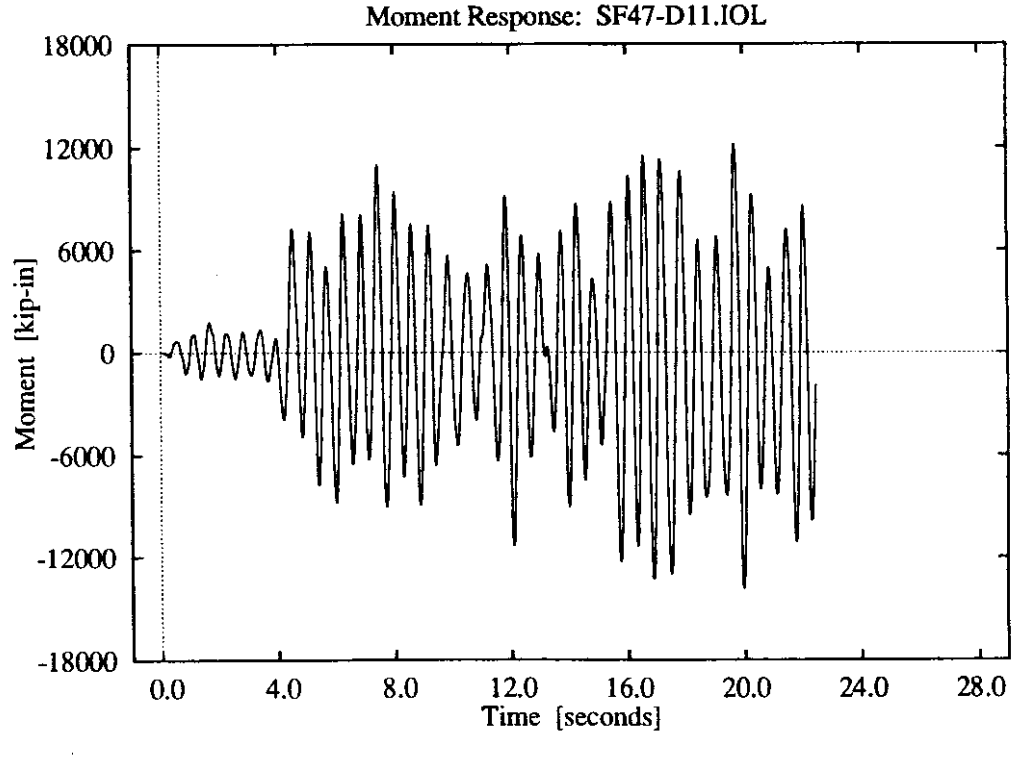
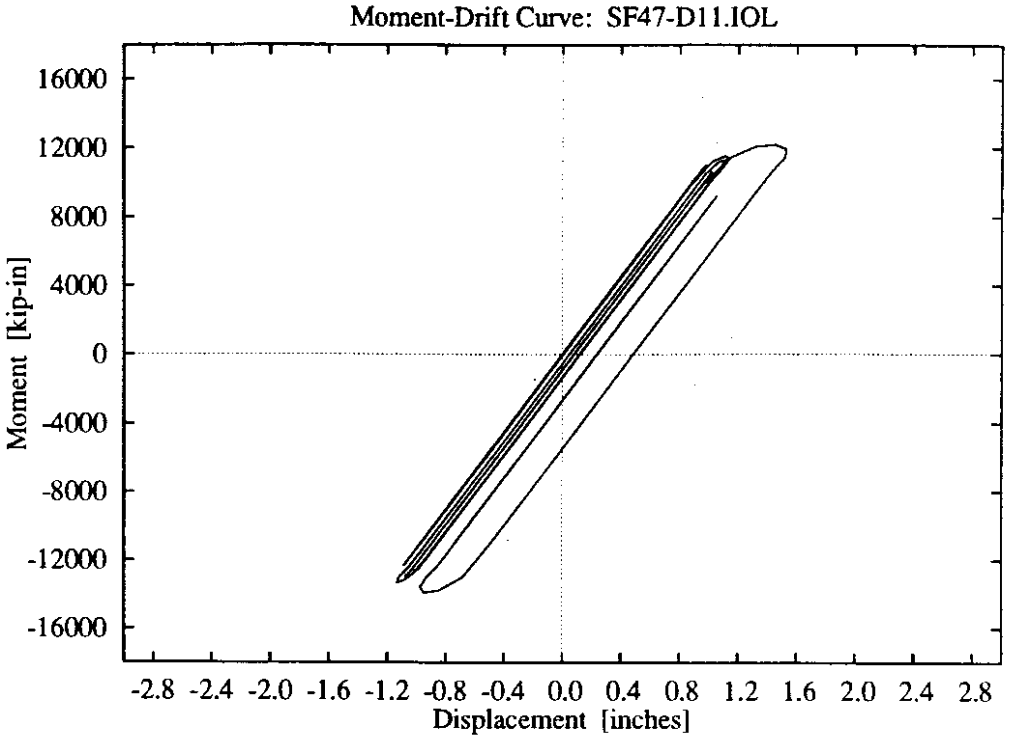


Figure D-93: 11 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.



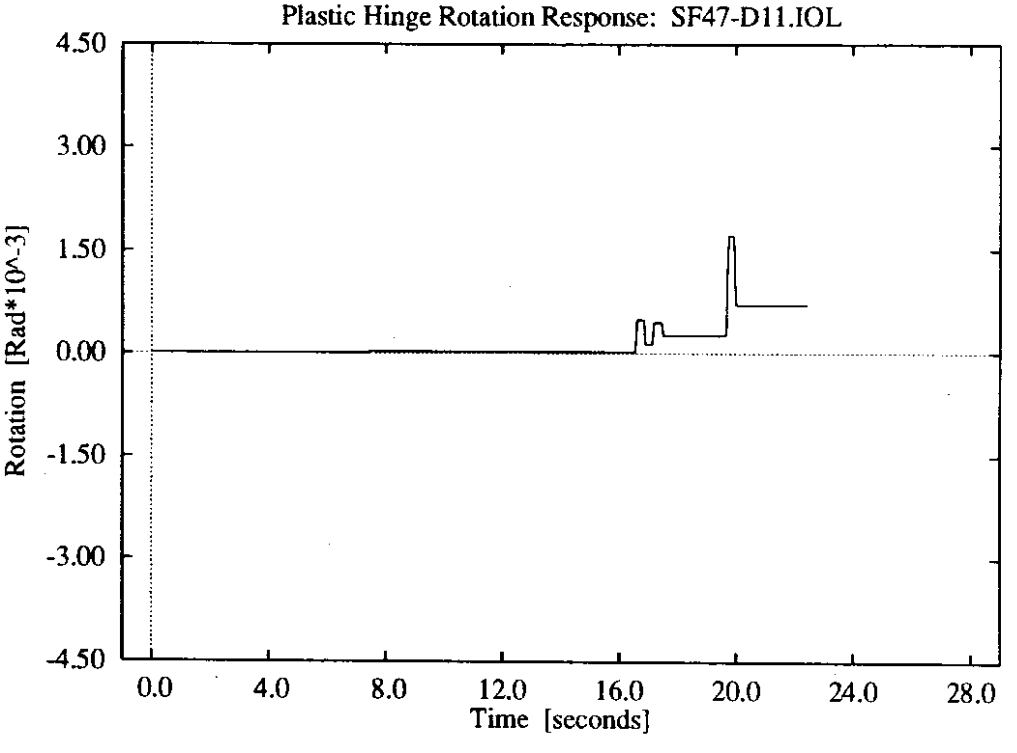
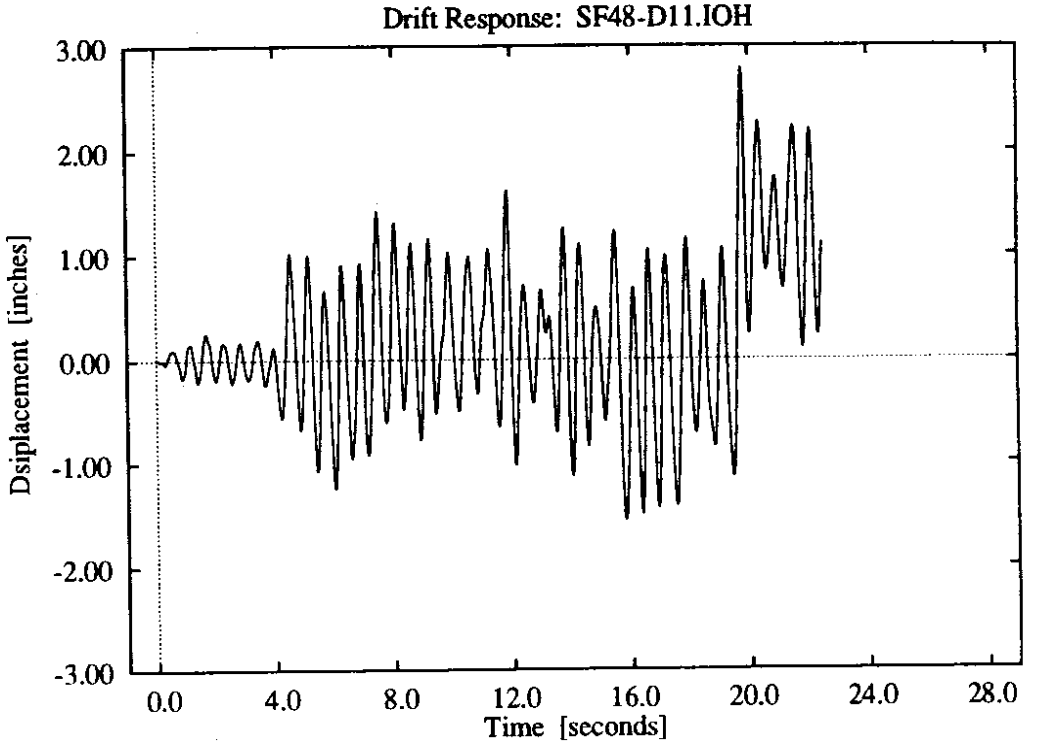


Figure D-94: 11 parameter foundation model, intermediate soil stiffness, lower intensity Olympia record.



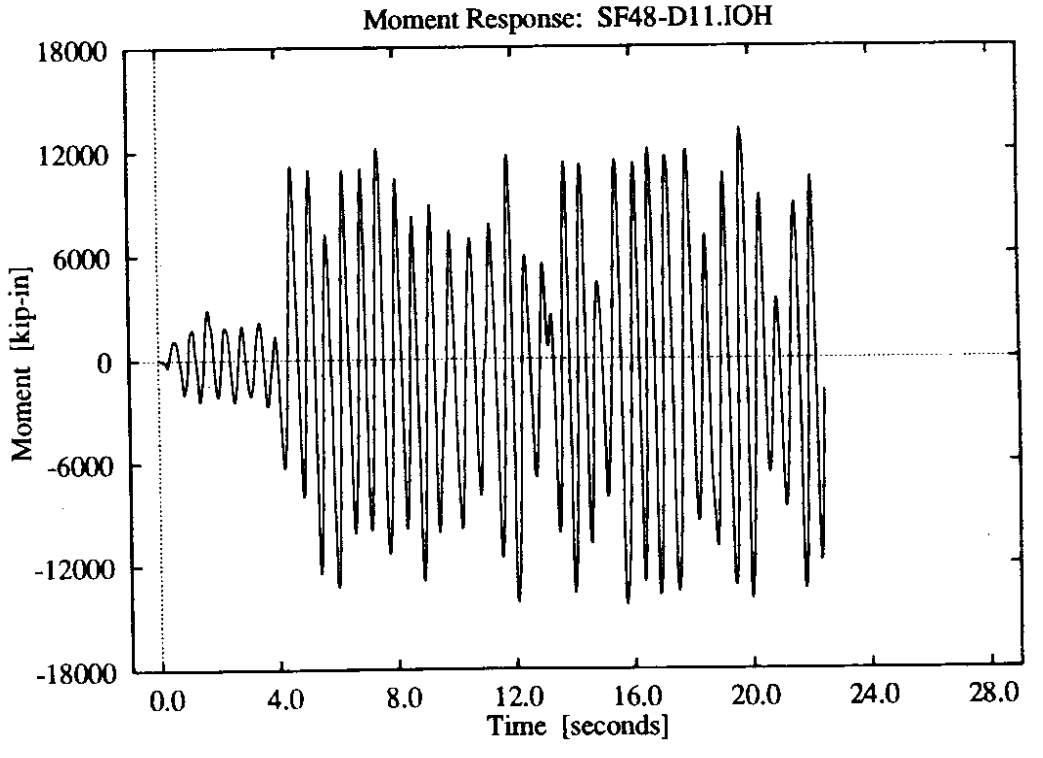
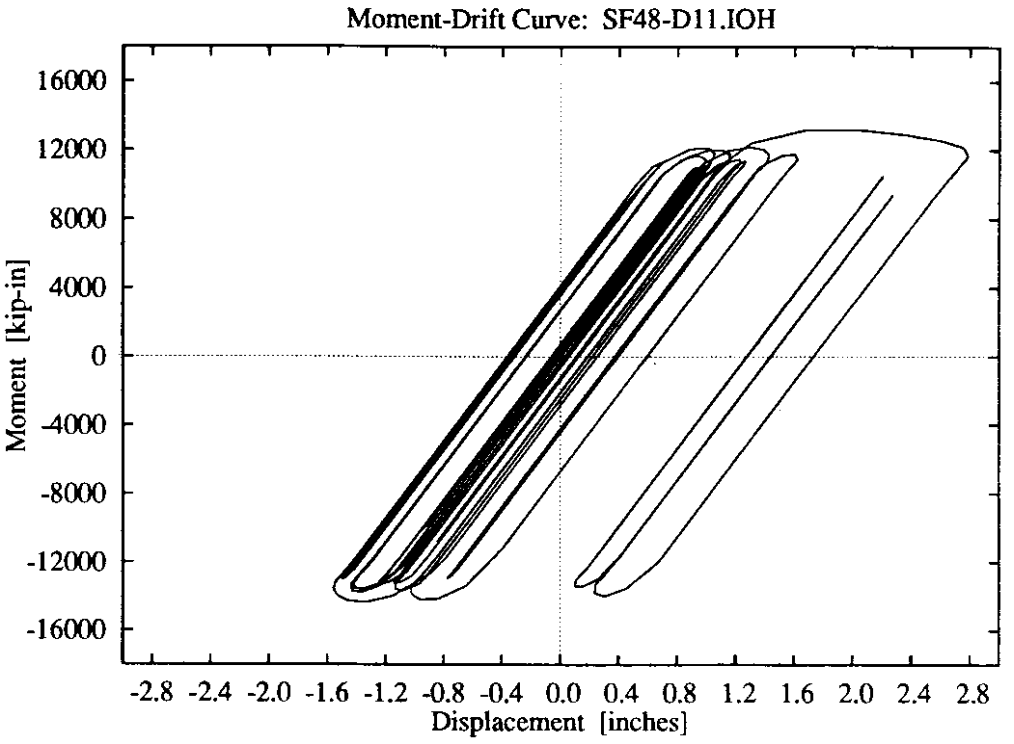


Figure D-95: 11 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.



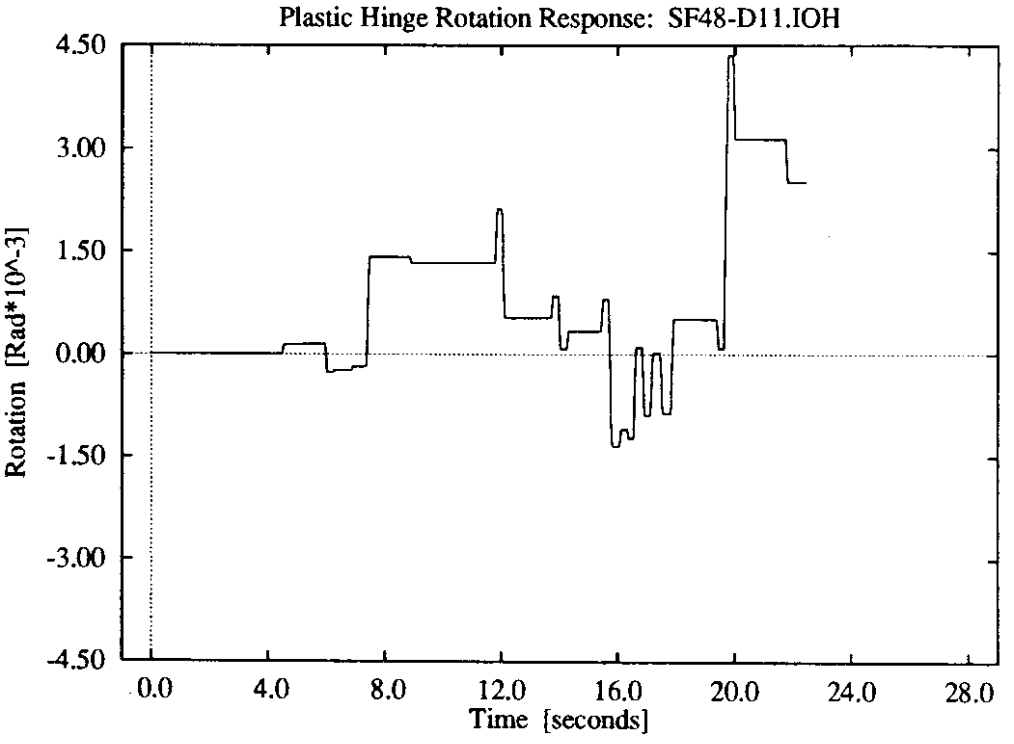
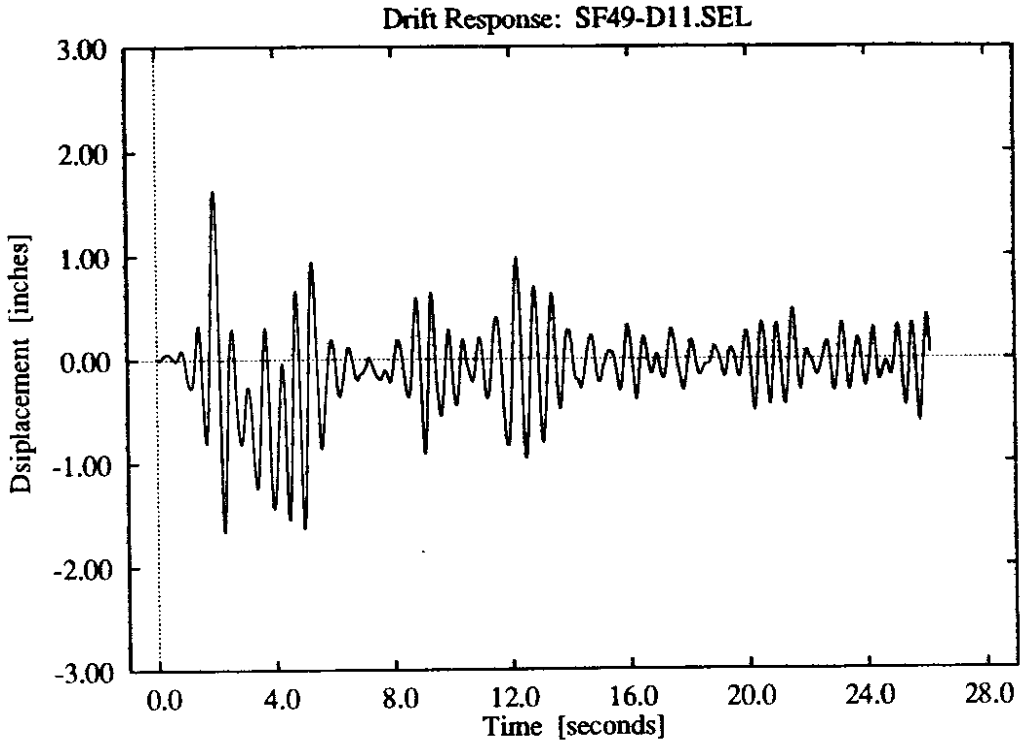


Figure D-96: 11 parameter foundation model, intermediate soil stiffness, higher intensity Olympia record.



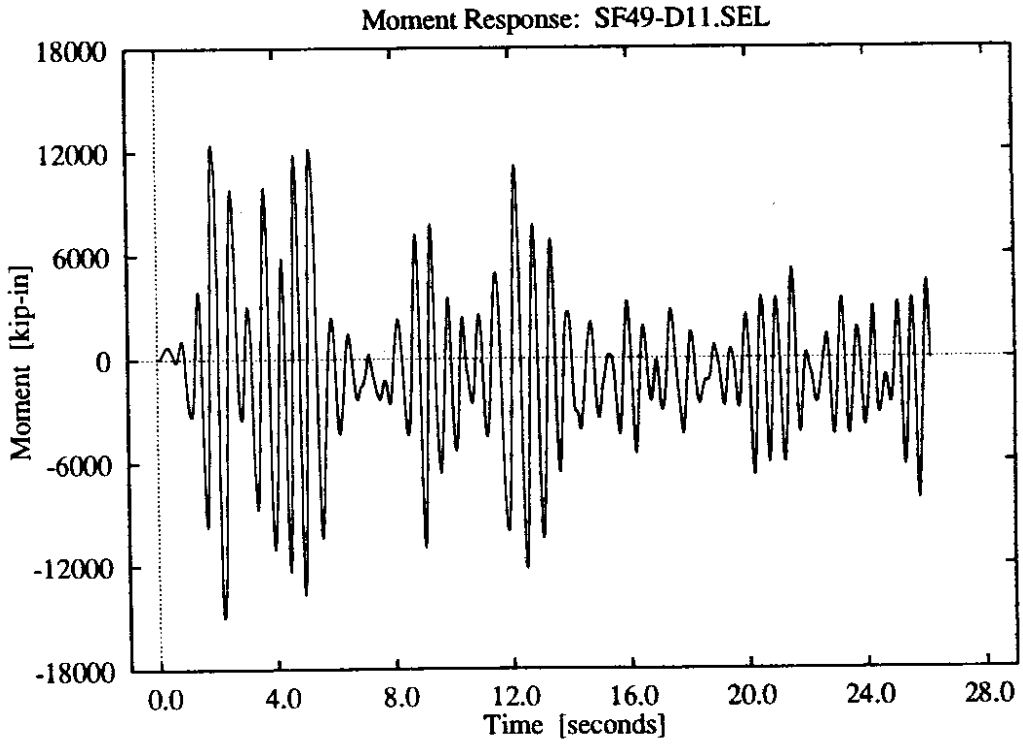
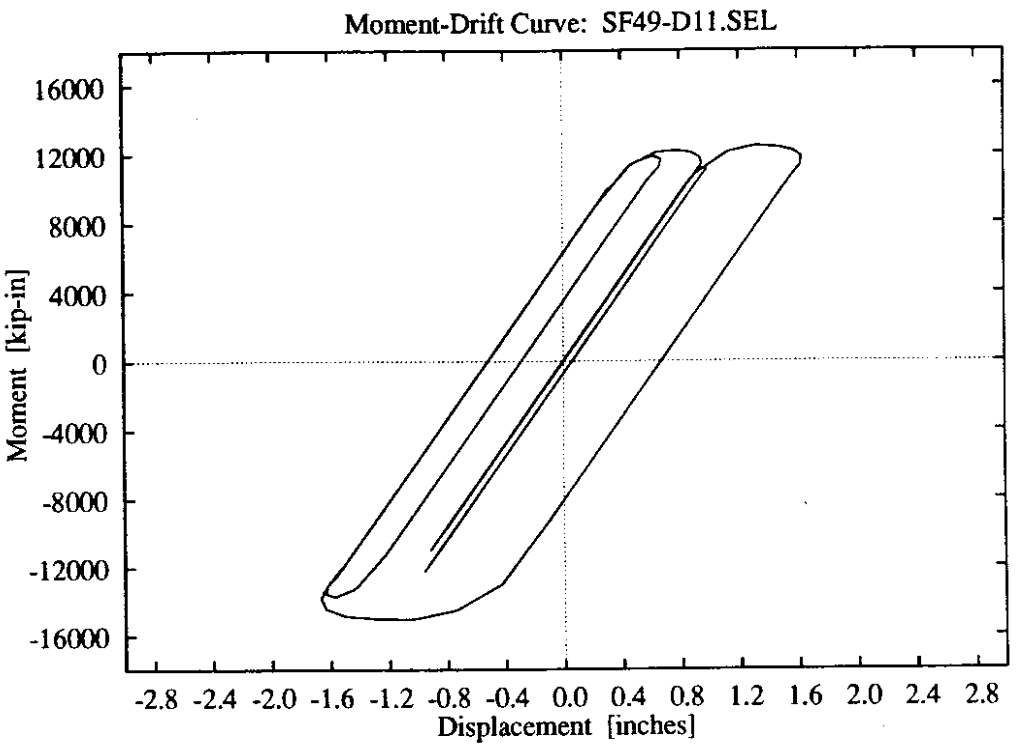


Figure D-97: 11 parameter foundation model, high soil stiffness, lower intensity El Centro record.



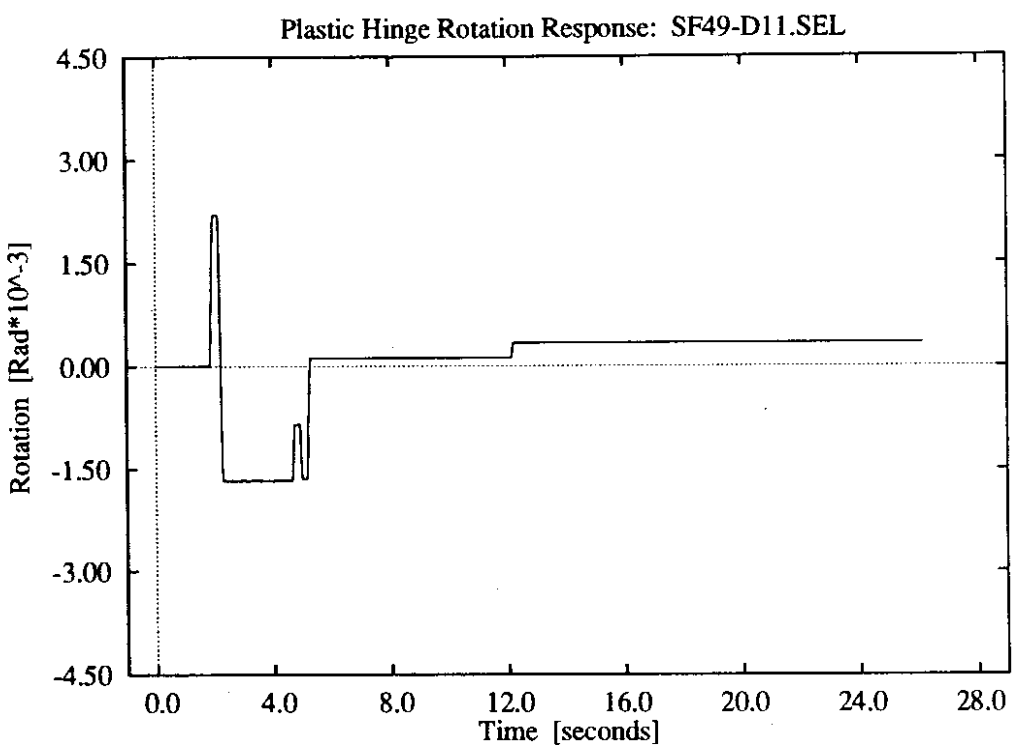
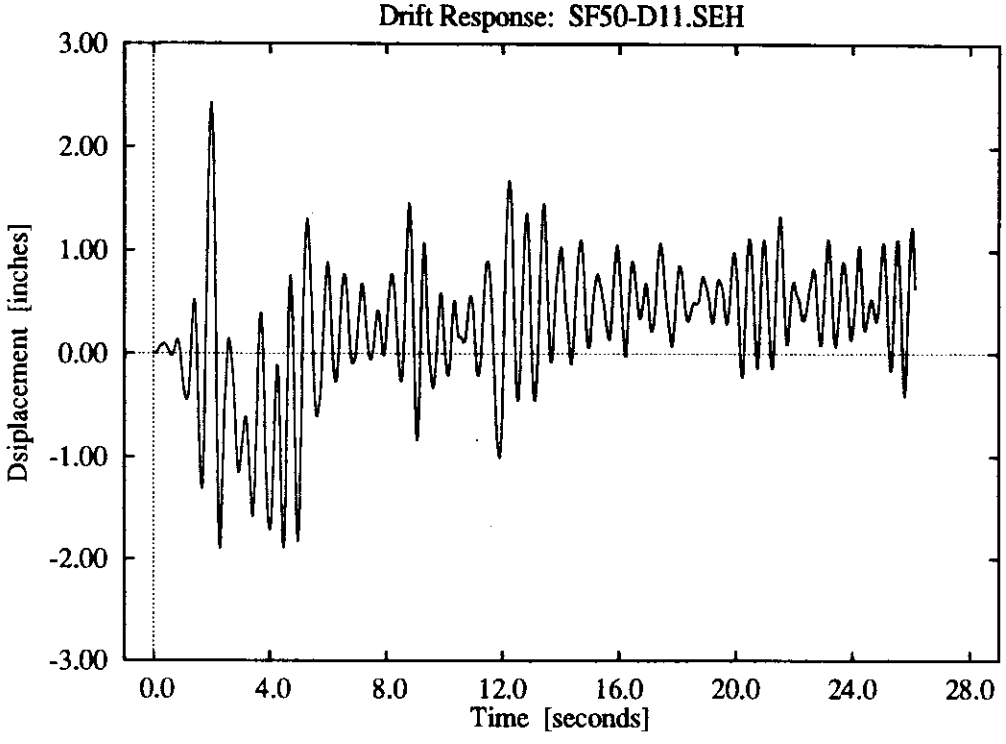


Figure D-98: 11 parameter foundation model, high soil stiffness, lower intensity El Centro record.



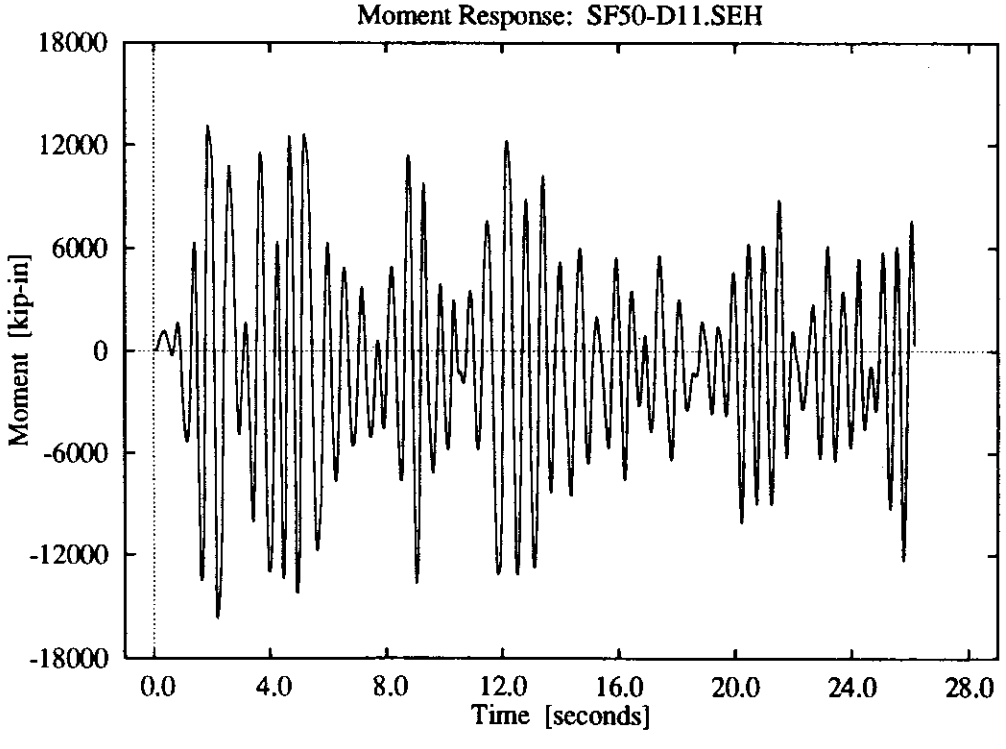
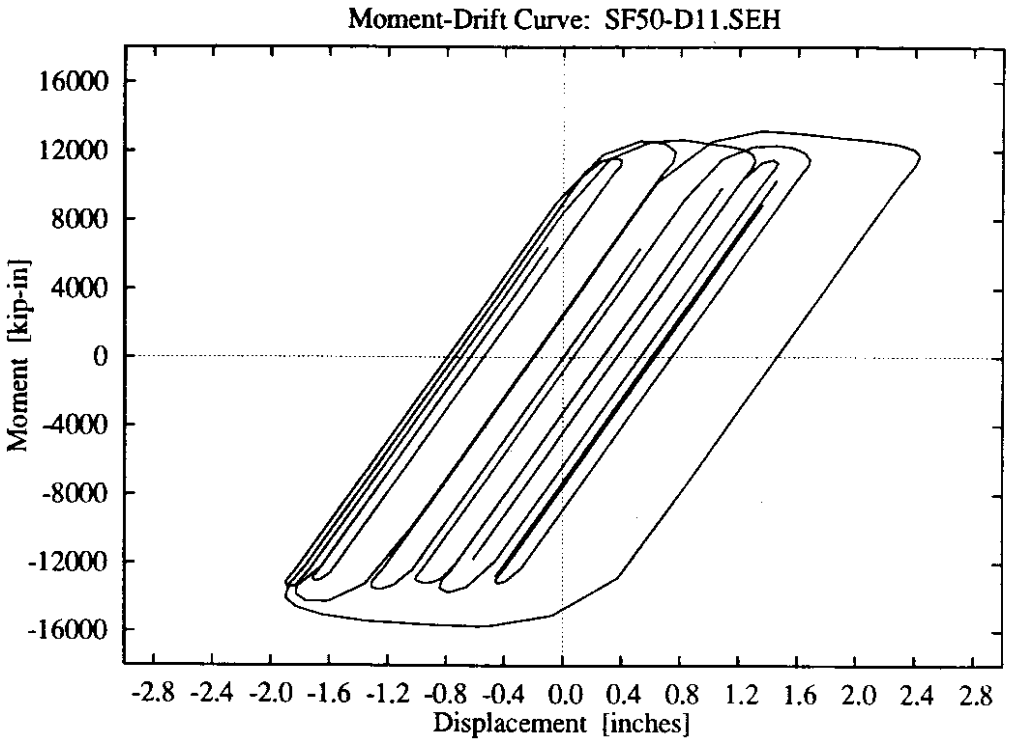


Figure D-99: 11 parameter foundation model, high soil stiffness, higher intensity El Centro record.



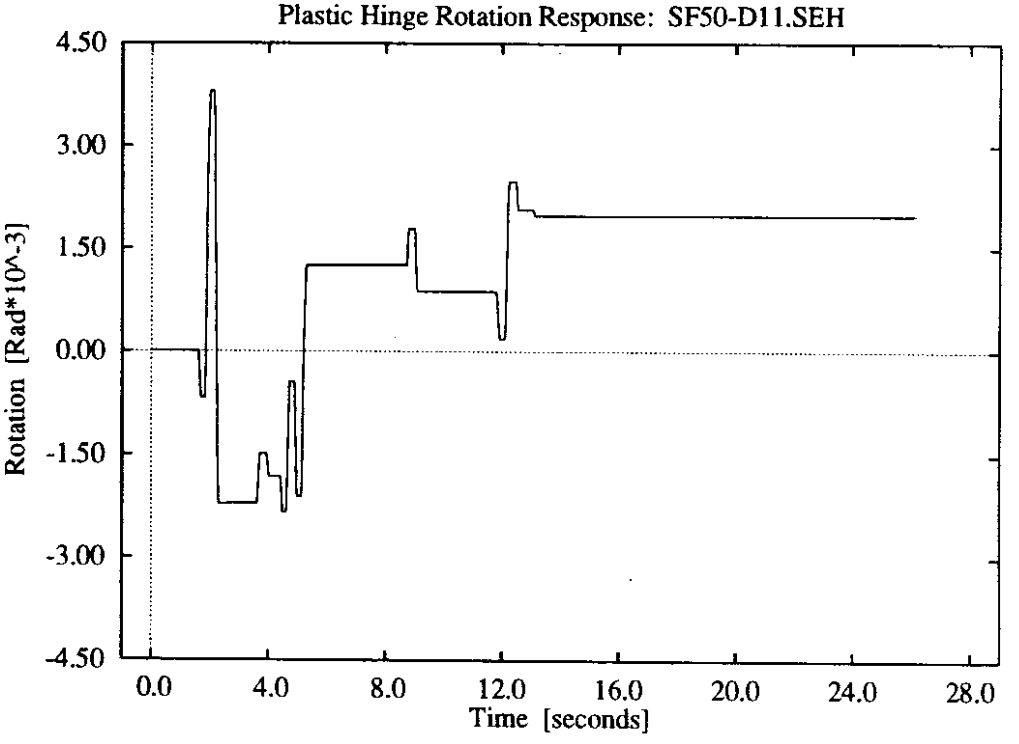
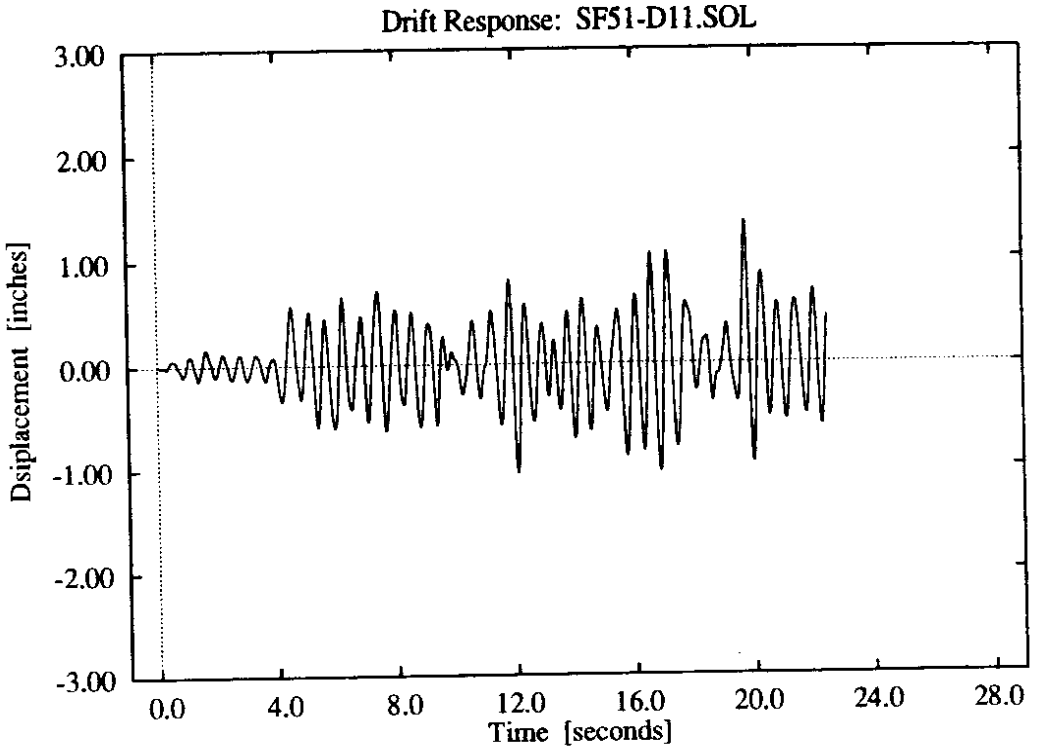


Figure D-100: 11 parameter foundation model, high soil stiffness, higher intensity El Centro record.



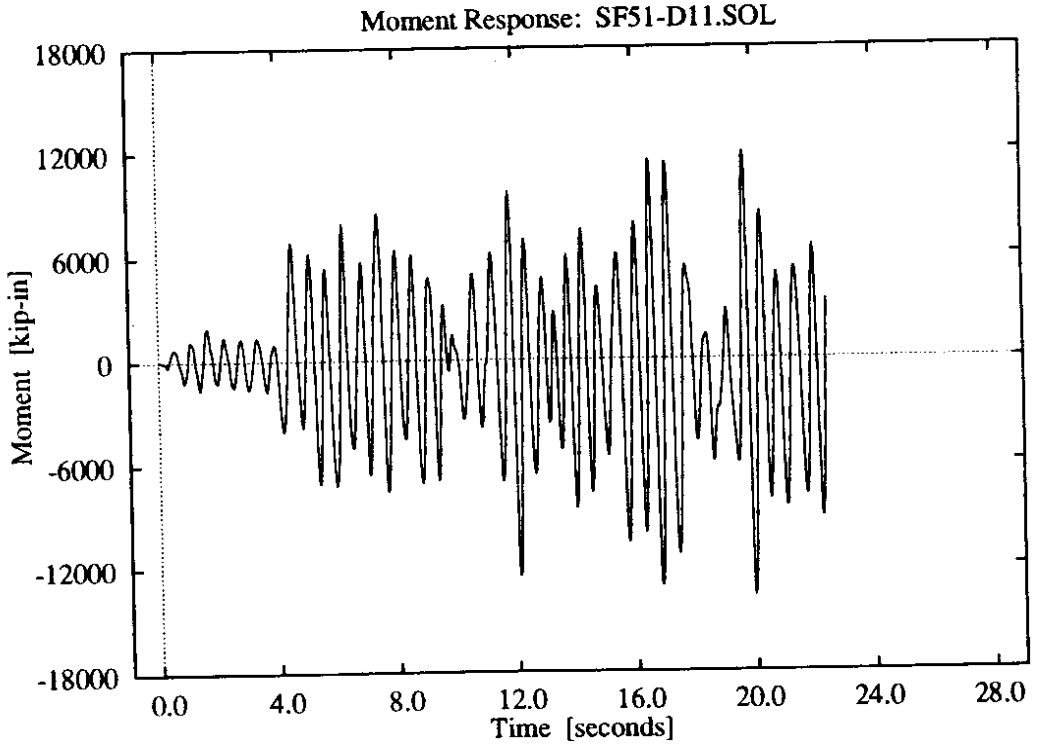


Figure D-101: 11 parameter foundation model, high soil stiffness, lower intensity Olympia record.

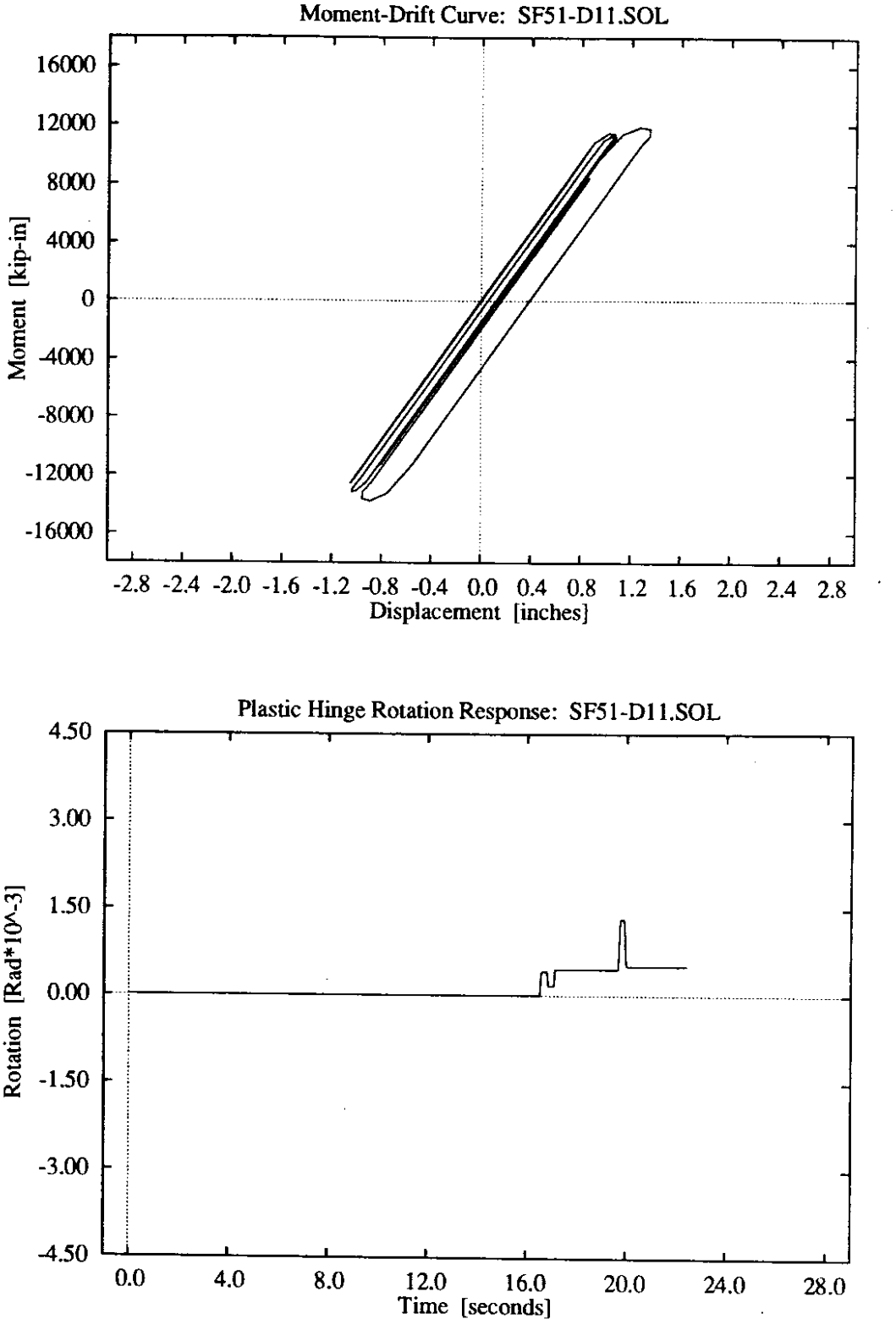


Figure D-102: 11 parameter foundation model, high soil stiffness, lower intensity Olympia record.

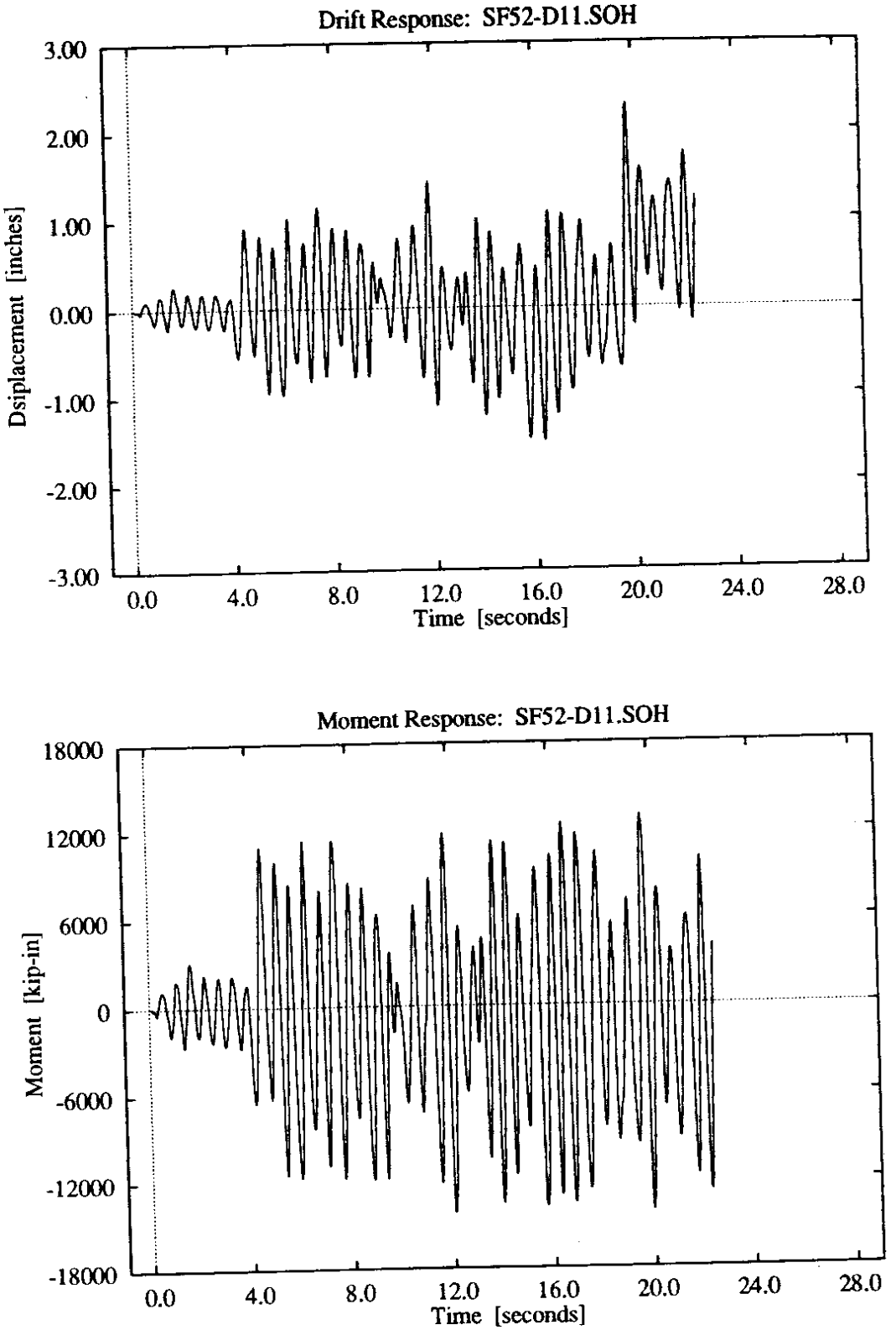
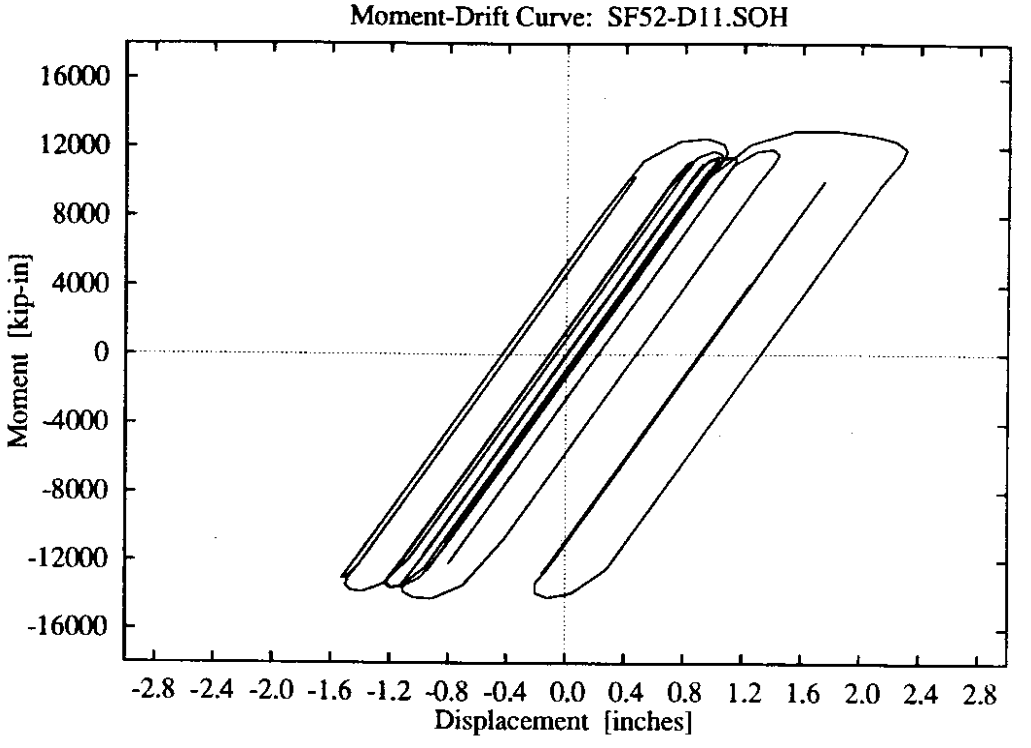


Figure D-103: 11 parameter foundation model, high soil stiffness, higher intensity Olympia record.



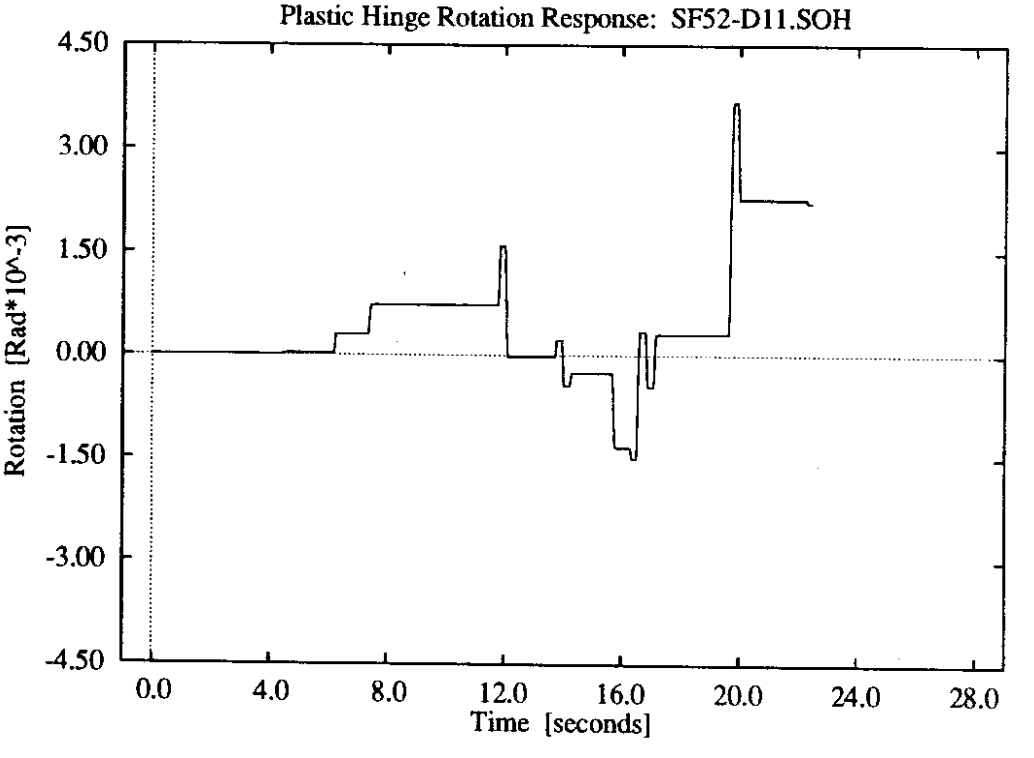


Figure D-104: 11 parameter foundation model, high soil stiffness, higher intensity Olympia record.

Appendix E

Pile Foundation Study

The 25 NEABS analyses performed in the parametric study of spread footing foundations are presented below in matrix form. Each run is identified by a name of the form "PF*nn–fff.eee*," where *nn* is the run number, *fff* is the foundation model code, and *eee* is the applied seismic record code. The values of the foundation model parameters are given in this appendix, in terms of the model configurations shown in Figure 3.18 of Chapter Three. References of the publications which describe the procedures used to determine these parameters accompany the values. The results of the NEABS analyses are also presented in this appendix; the presentation order of the results follows the numbering of the analyses given in the matrix below.

	Filtered Records				Unfiltered Records	
	El Centro		Lake Hughes		El Centro	
	Zone 3	Zone 4	Zone 1	Zone 2	Lower Inten.	Higher Inten.
Fixed	PF01-FX_.3EL	PF02-FX_.4EL	PF03-FX_.1LH	PF04-FX_.2LH	PF05-FX_.LEL	PF06-FX_.HEL
DF1	PF07-DF1.3EL	PF08-DF1.4EL	PF09-DF1.1LH	PF10-DF1.2LH	PF11-DF1.LEL	PF12-DF1.HEL
DF2	PF13-DF2.3EL	PF14-DF2.4EL	PF15-DF2.1LH	PF16-DF2.2LH	PF17-DF2.LEL	PF18-DF2.HEL
DF3						PF19-DF3.HEL
WPF	PF20-WPF.3EL	PF21-WPF.4EL	PF22-WPF.1LH	PF23-WPF.2LH	PF24-WPF.LEL	PF25-WPF.HEL

Pile Foundation Models: Parameter Values*

All Models:

Elastic Rotational Pile Head Spring:	k = 516,000
Lateral Pile Head Damper (when used):	c = 0.1625

Pile Head Models:

	DF1	DF2	DF3
Elastic Stiffness	8.2	11.6	9.0
Yield Force	-	26.8	-
Plastic Stiffness	-	2.1	-

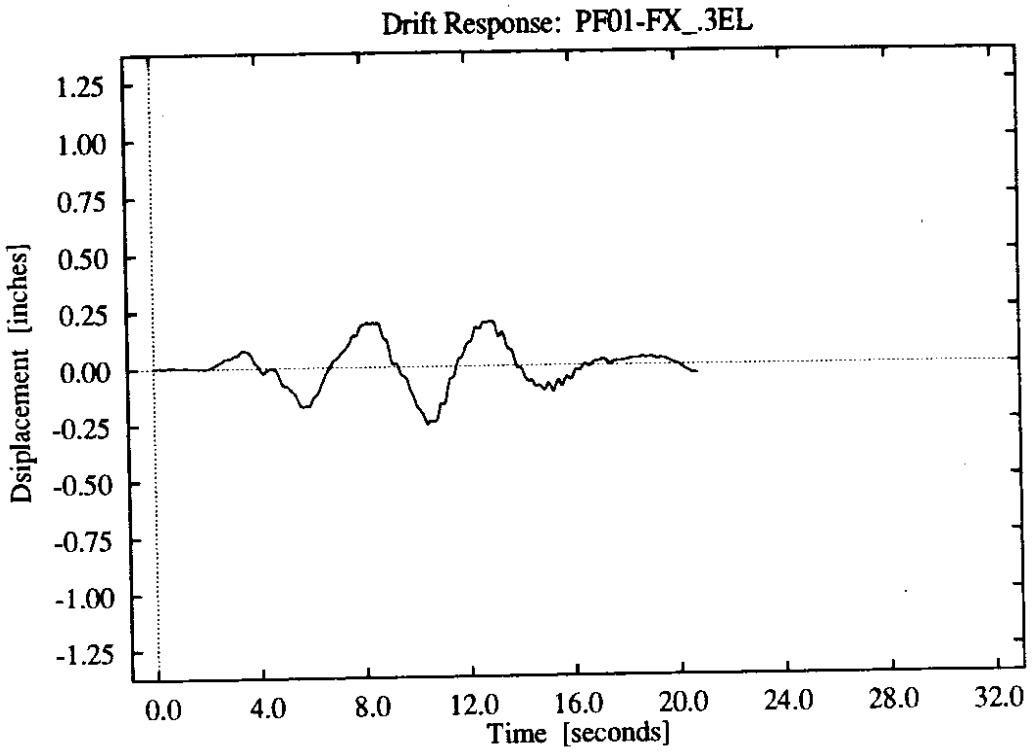
WPF Model:

depth	m	k1	c1	k2	c2	k3	c3
43	0.01060	68.28	43.90	69.50	9.756	107.3	3.634
105	0.01164	74.96	48.19	76.30	10.71	117.8	3.989
179	0.01306	84.08	54.06	85.59	12.01	132.1	4.475
266	0.01517	97.67	62.80	99.42	13.96	153.5	5.198
370	0.01884	121.3	77.98	123.5	17.33	190.6	6.455
515	0.02835	182.5	117.4	185.8	26.08	286.9	9.715

* unit of force = kip; unit of length = inch; unit of rotation = radians; unit of time = second

DF1 Model: David I. McLean and Ian B. S. Cannon, *Seismic Analysis of the I–90 Mercer Slough Wesbound Lanes*, WSDOT Technical Report, 1992.

WPG Model: Toyoaki Nogami and K. Konagai, "Time Domain Flexural Response of Dyanmically Loaded Single Piles," *Journal of Engineering Mechanics*, ASCE, Vol. 114, No. 9, September, 1988, pp. 1512–1525.



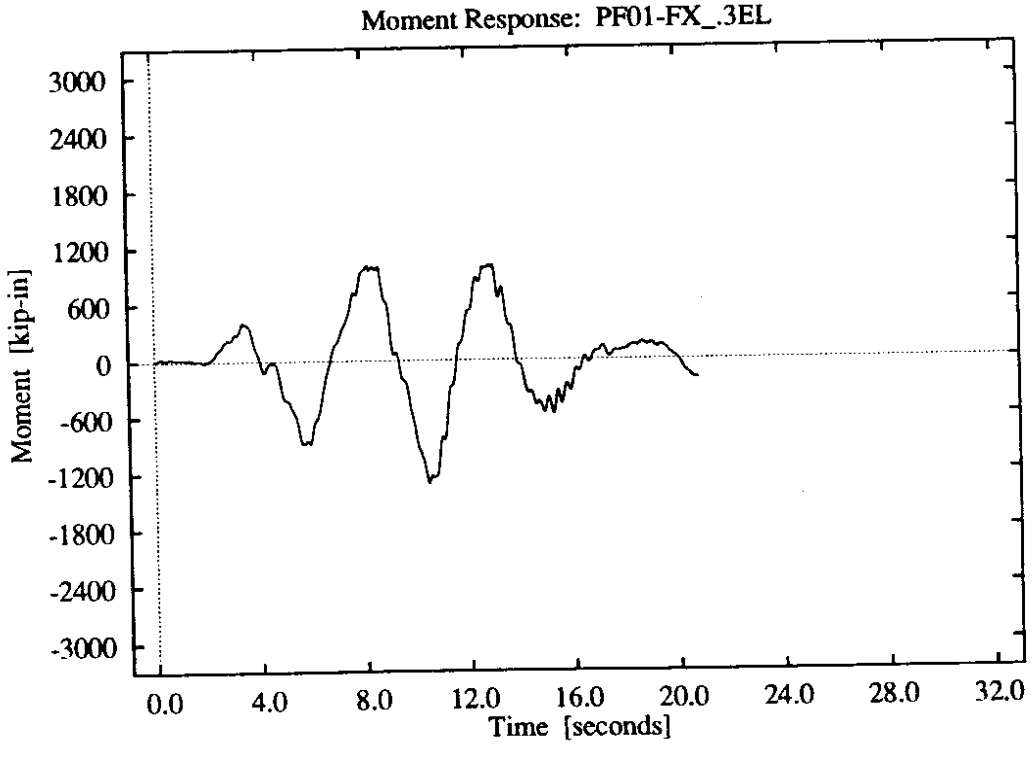


Figure E-1: Fixed-base foundation, El Centro Z3 record.

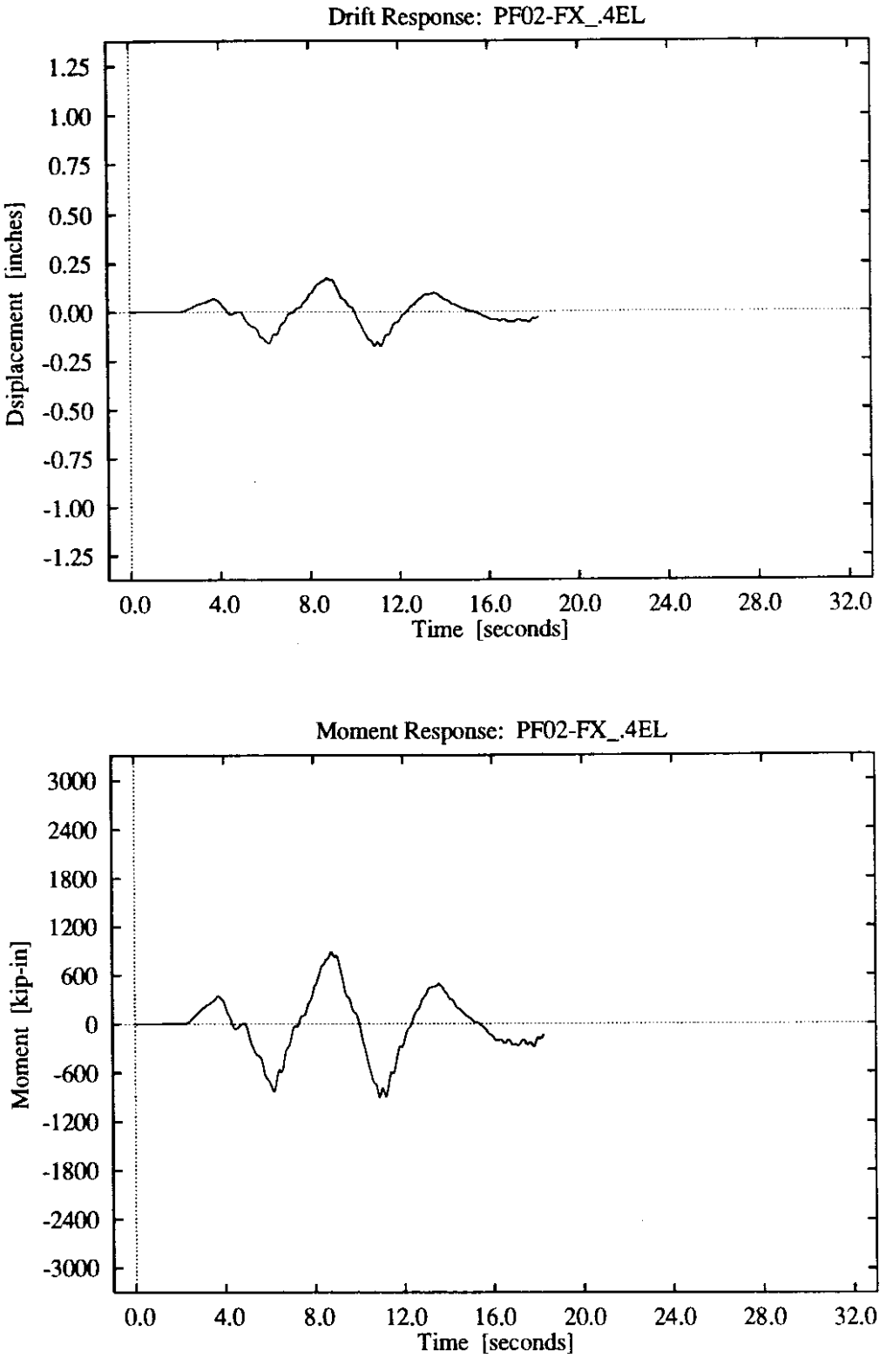


Figure E-2: Fixed-base foundation, El Centro Z4 record.

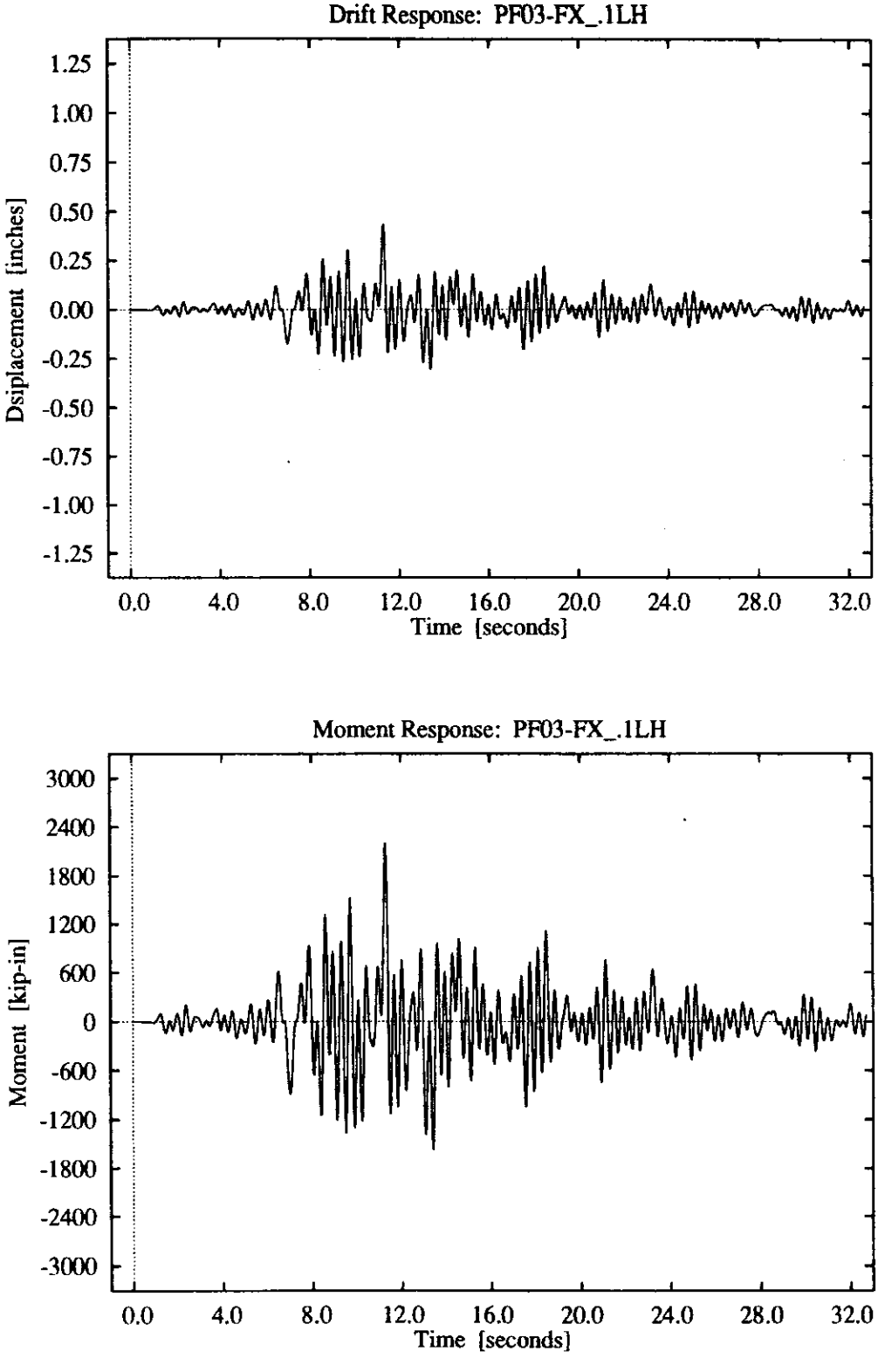


Figure E-3: Fixed-base foundation, Lake Hughes Z1 record.

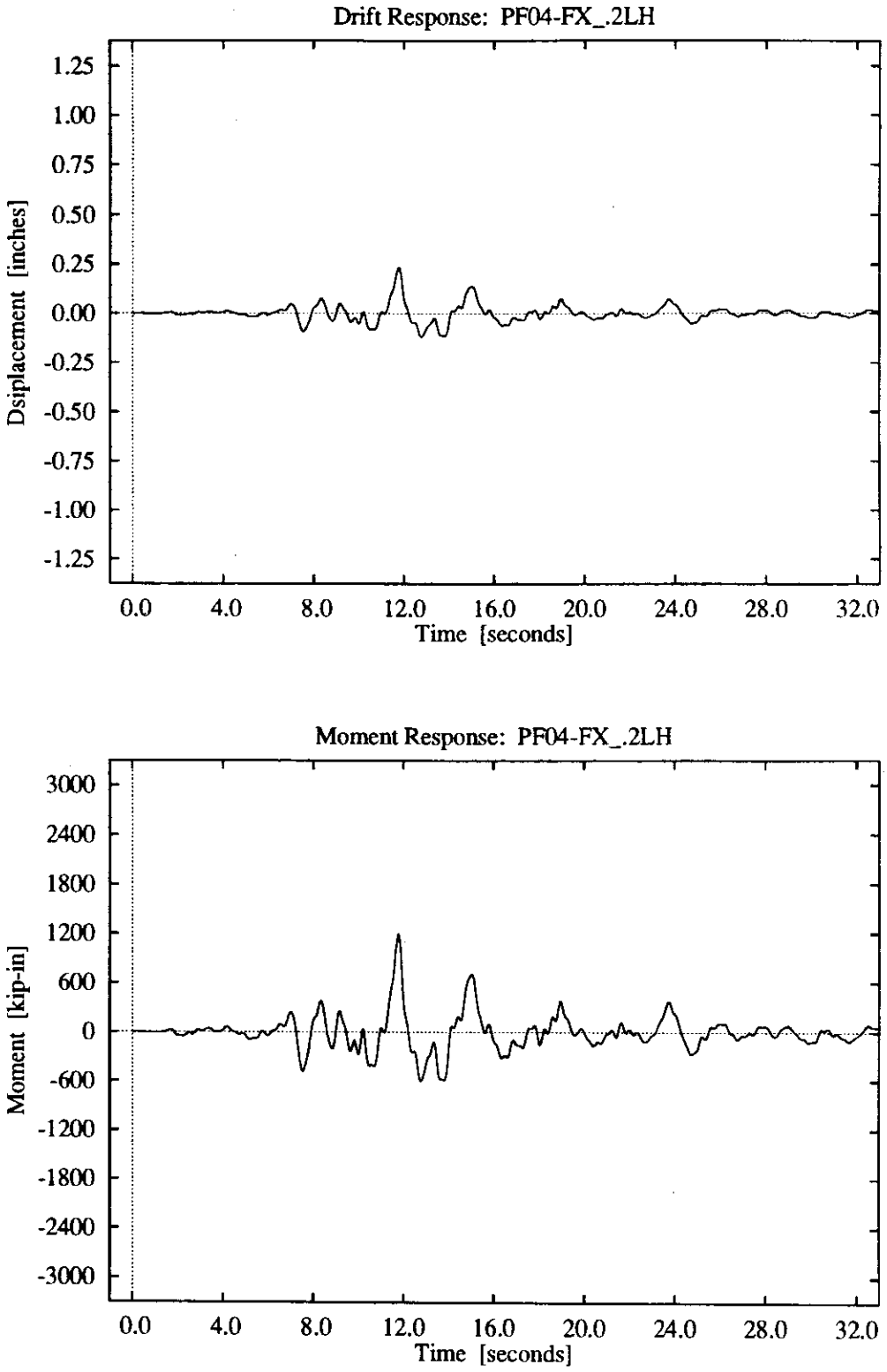


Figure E-4: Fixed-base foundation, Lake Hughes Z2 record.

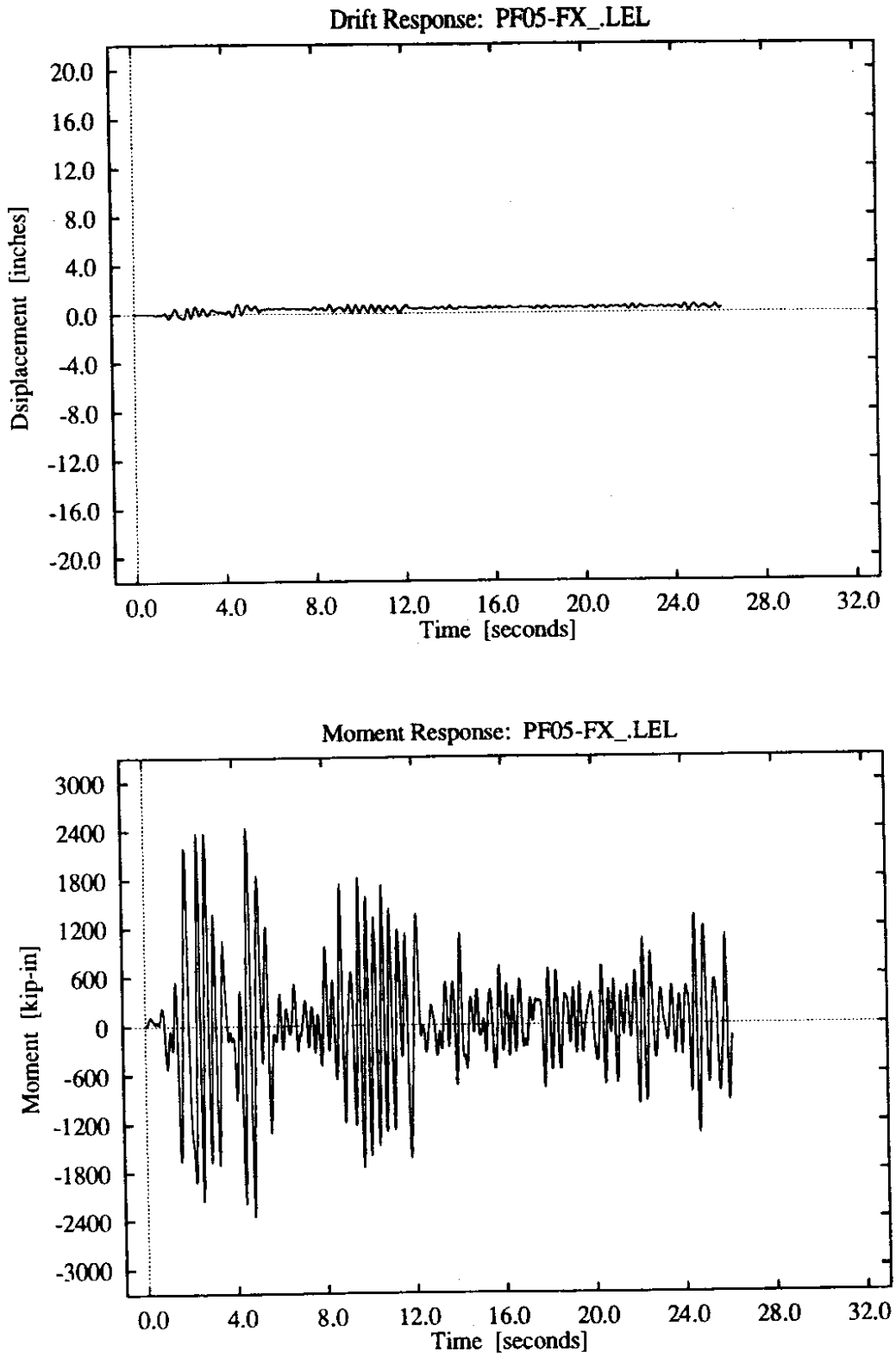
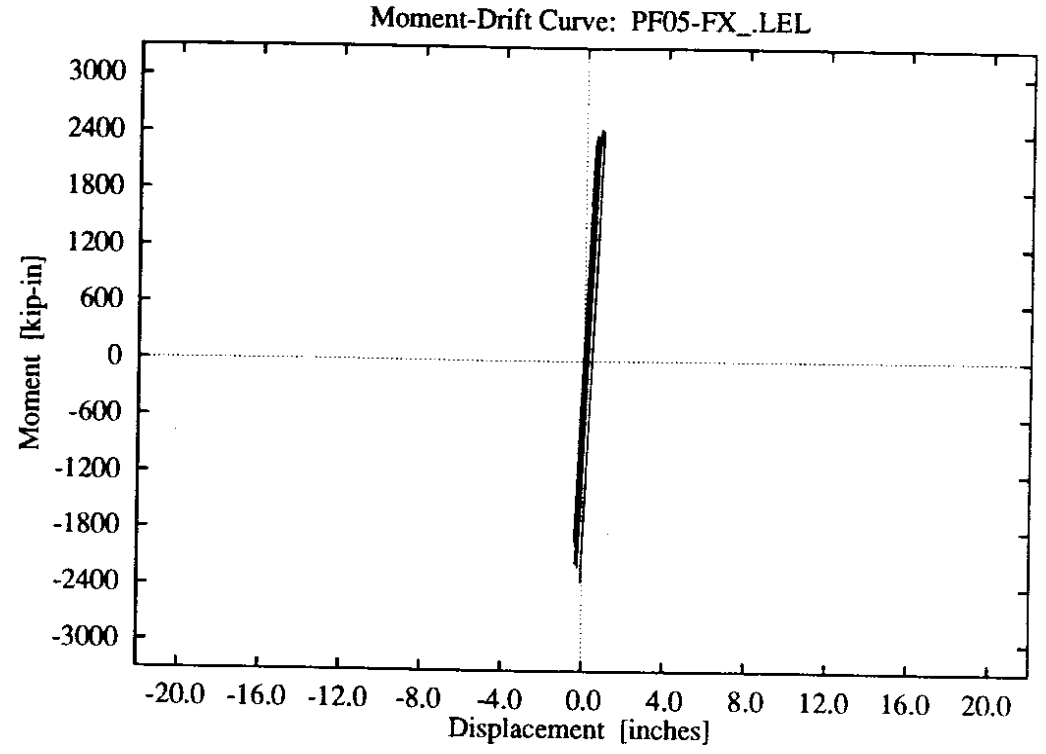


Figure E-5: Fixed-base foundation, lower intensity El Centro record.



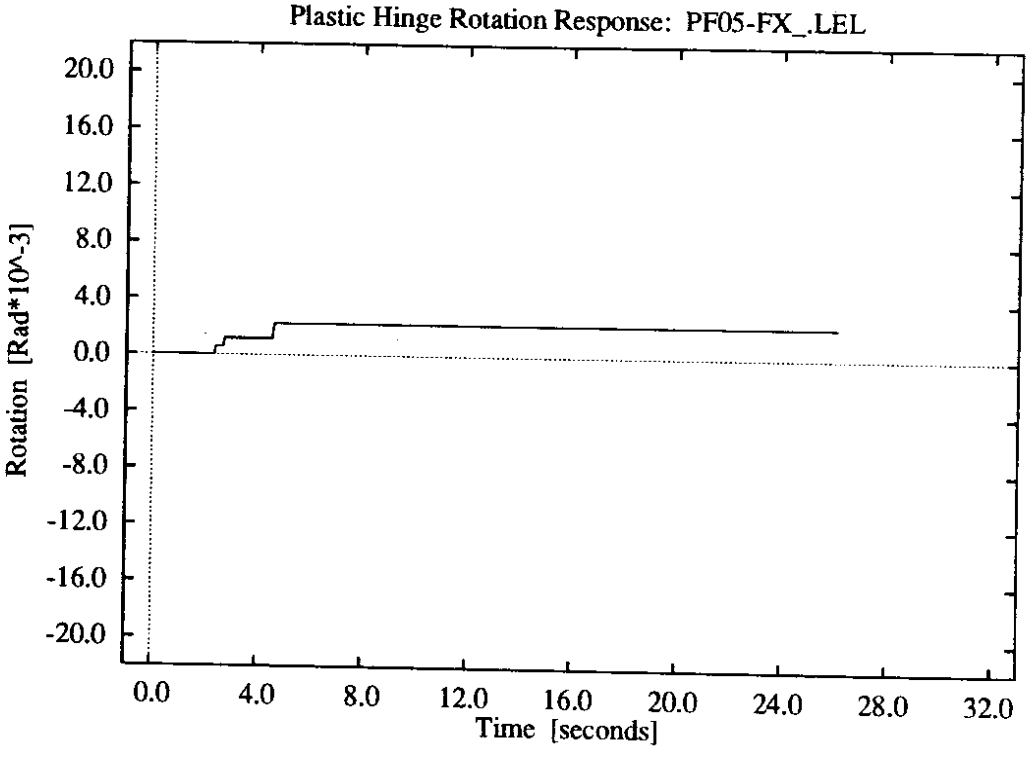


Figure E-6: Fixed-base foundation, lower intensity El Centro record.

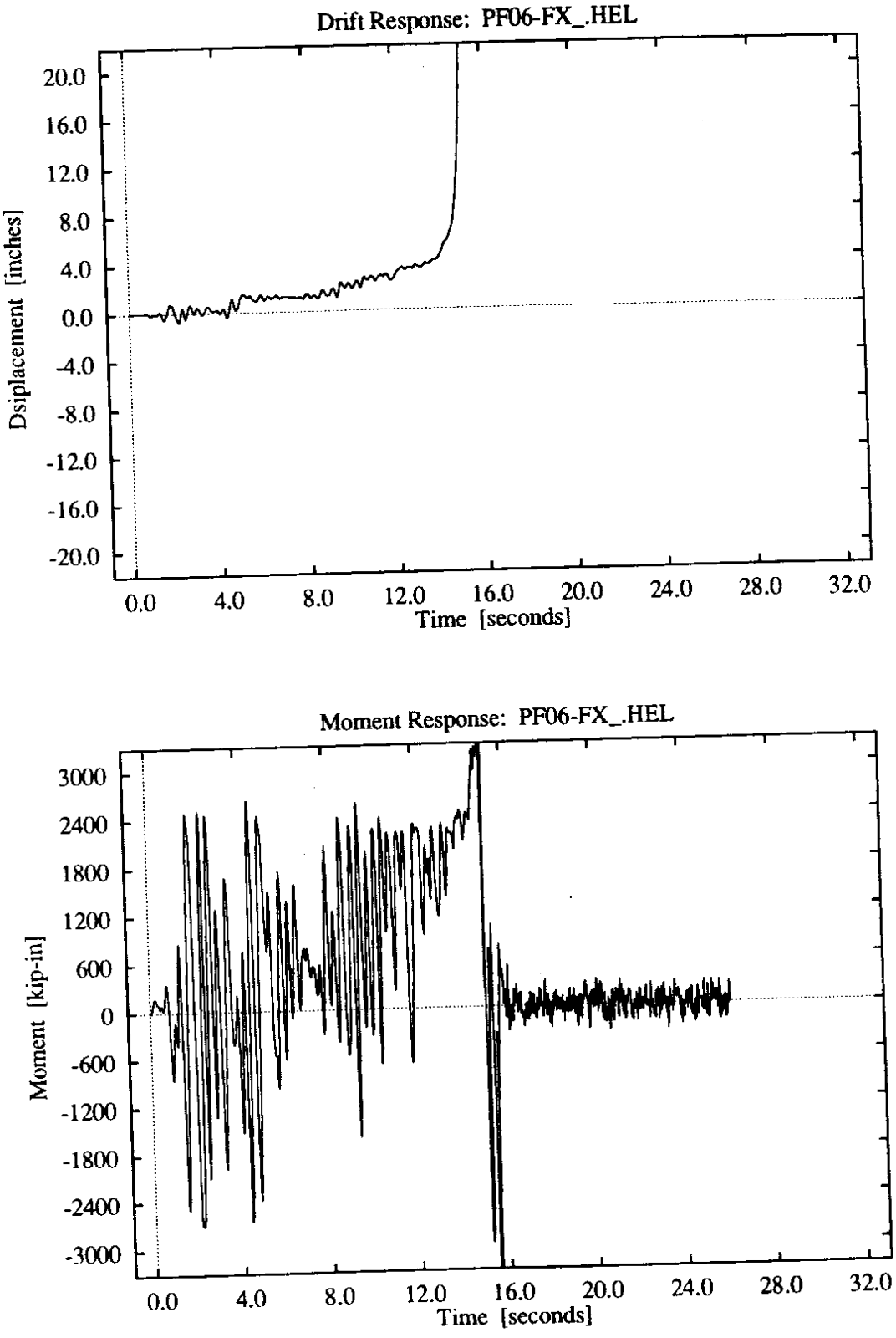


Figure E-7: Fixed-base foundation, higher intensity El Centro record.

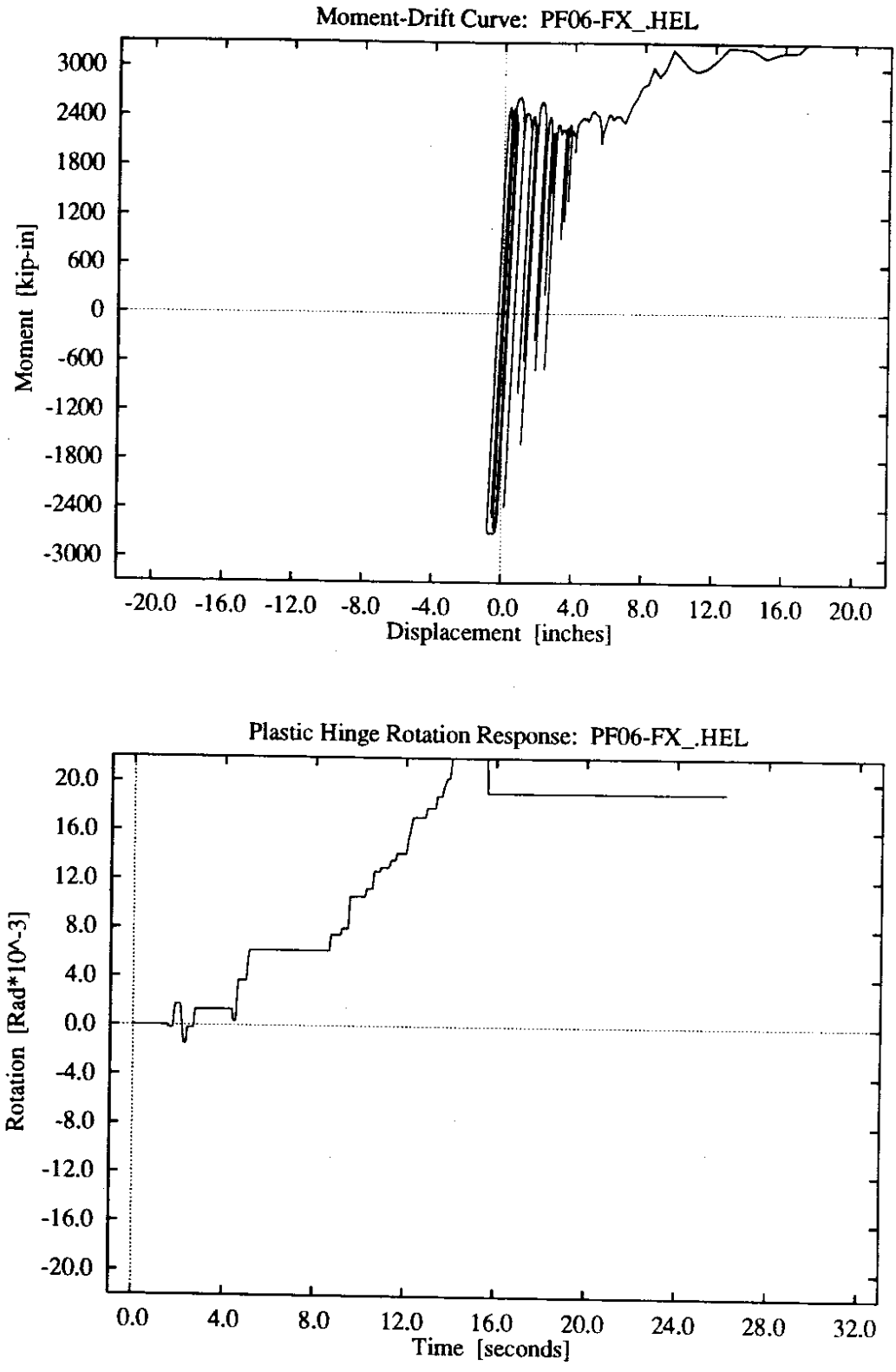


Figure E-8: Fixed-base foundation, higher intensity El Centro record.

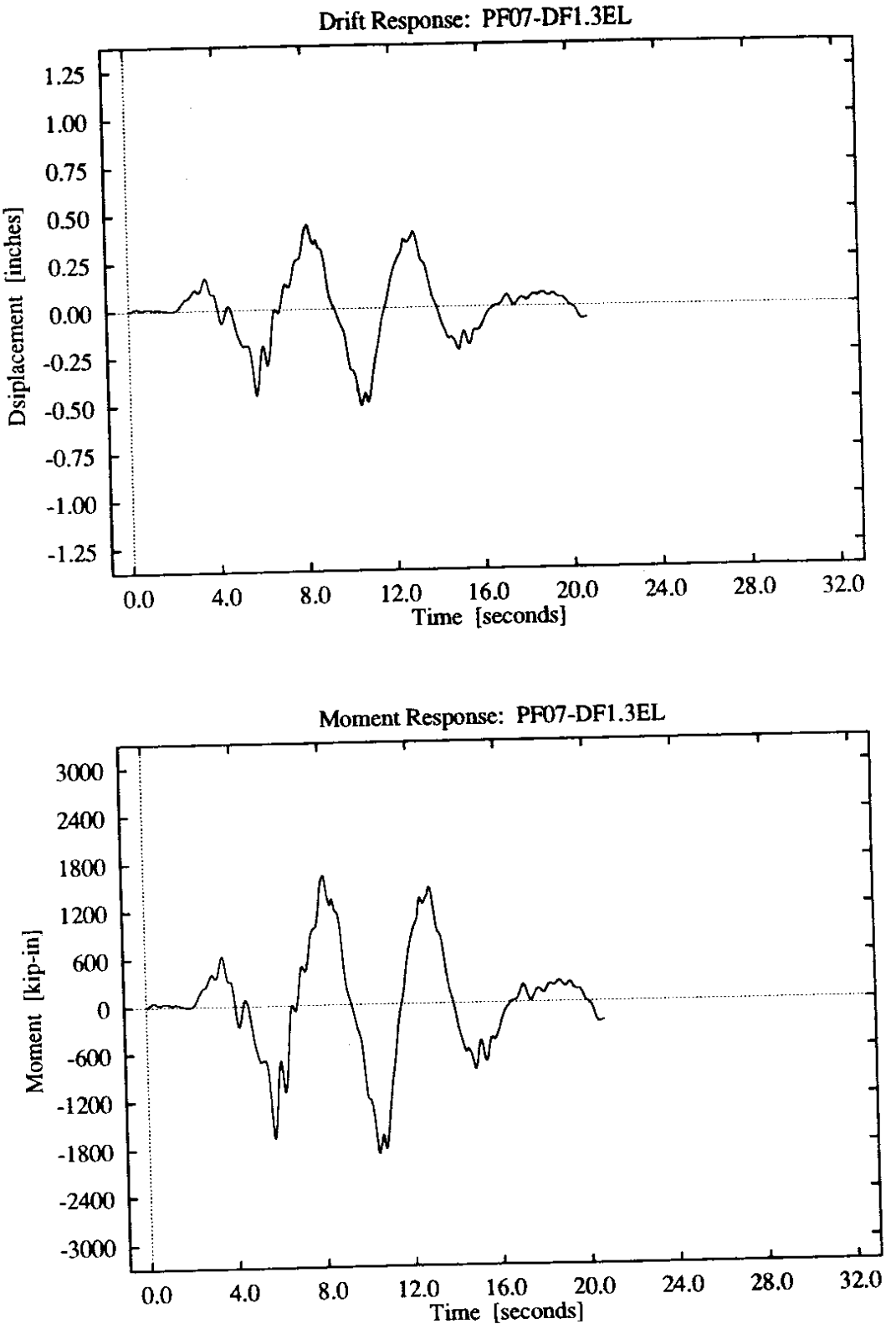


Figure E-9: DF1 foundation model, El Centro Z3 record.

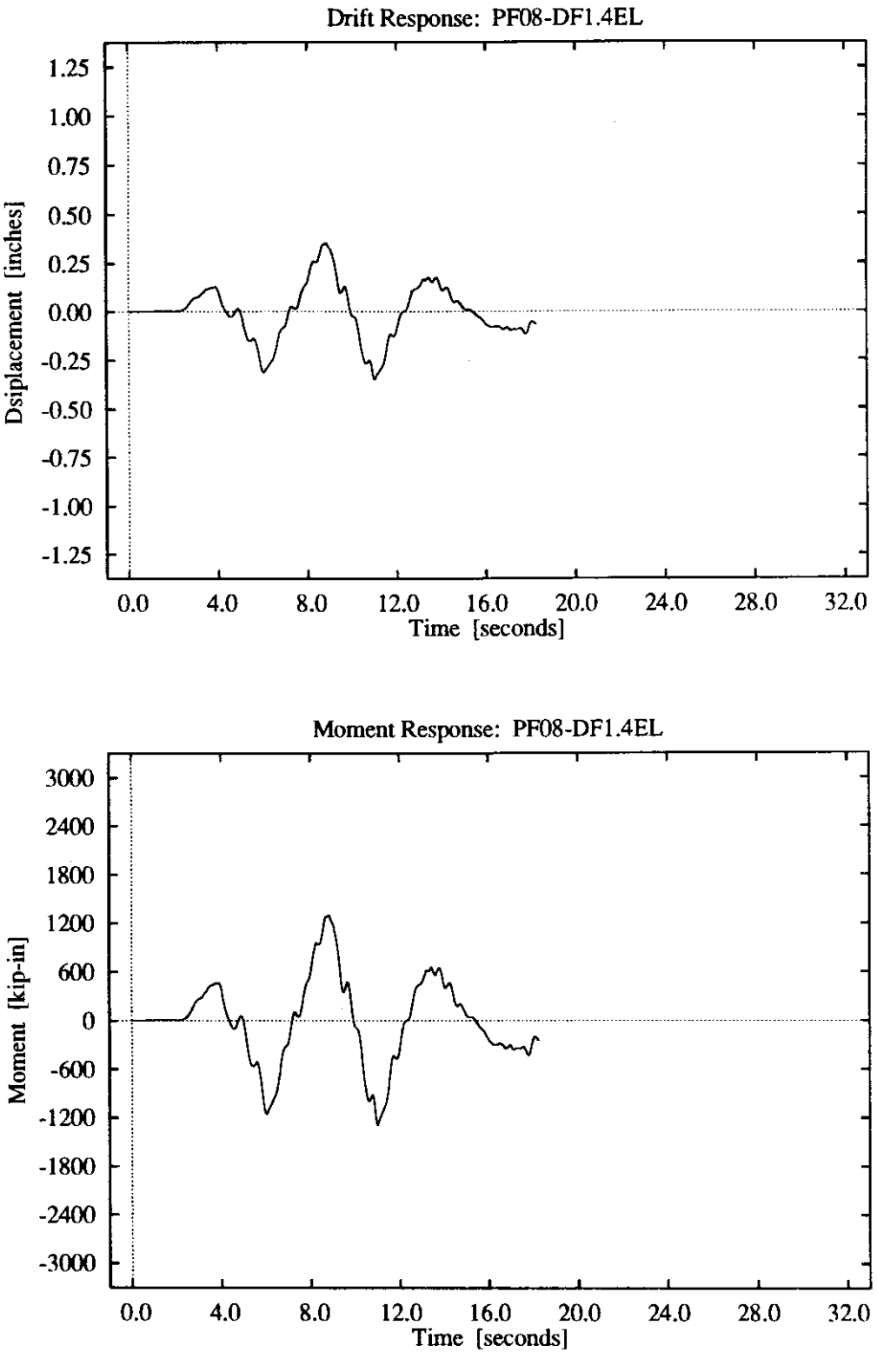


Figure E-10: DF1 foundation model, El Centro Z4 record.

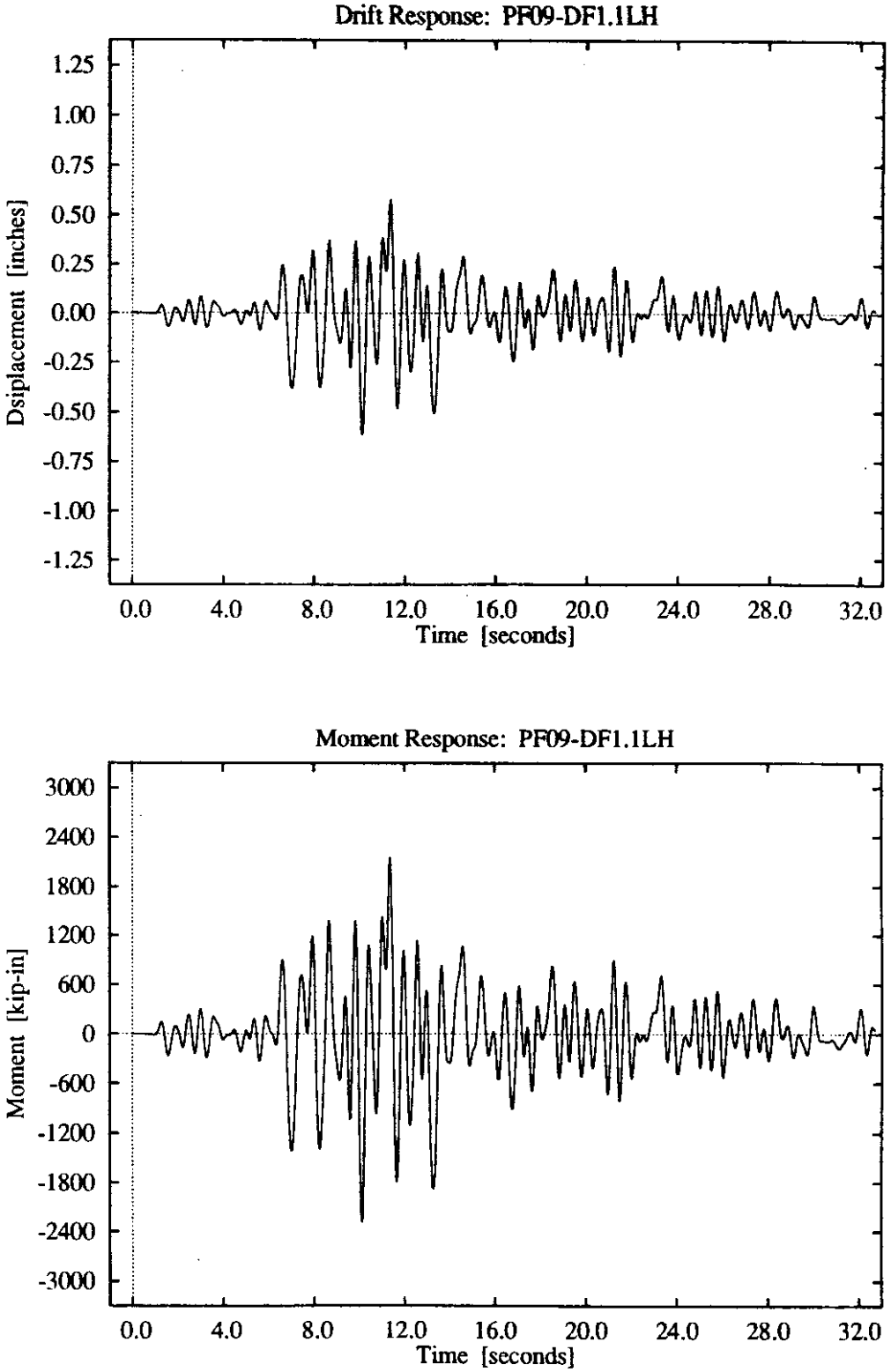


Figure E-11: DF1 foundation model, Lake Hughes Z1 record.

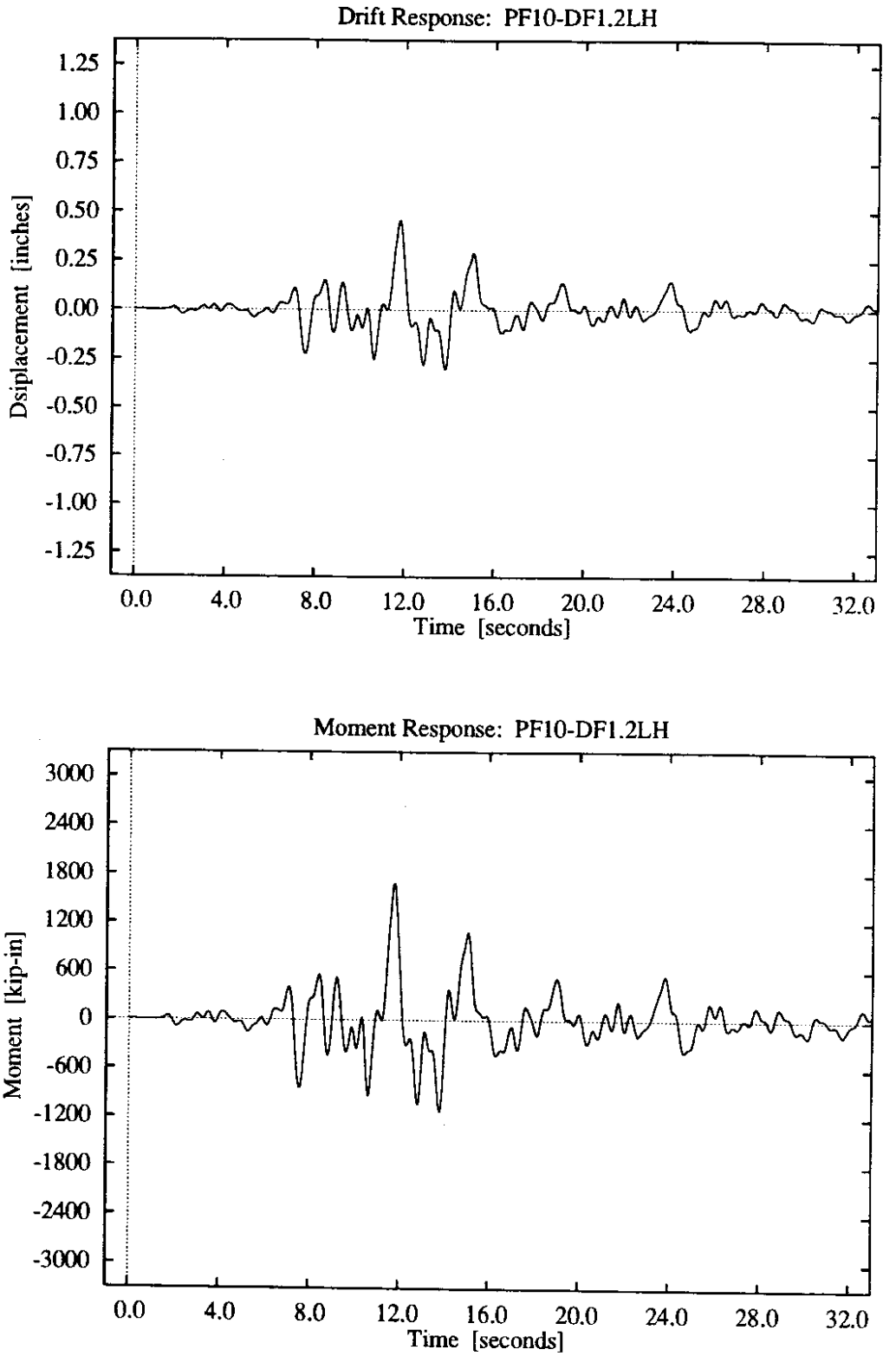


Figure E-12: DF1 foundation model, Lake Hughes Z2 record.

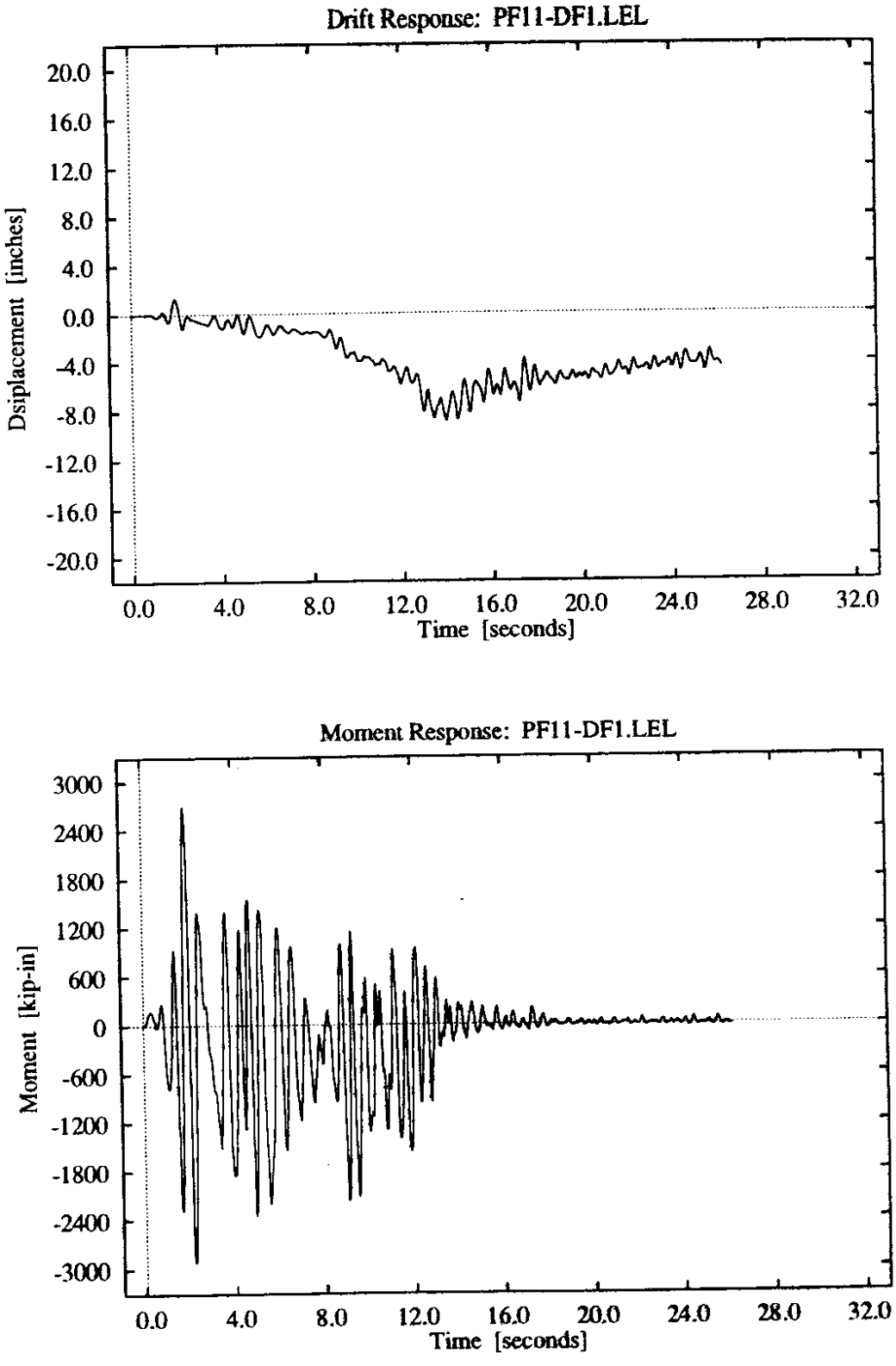


Figure E-13: DF1 foundation model, lower intensity El Centro record.

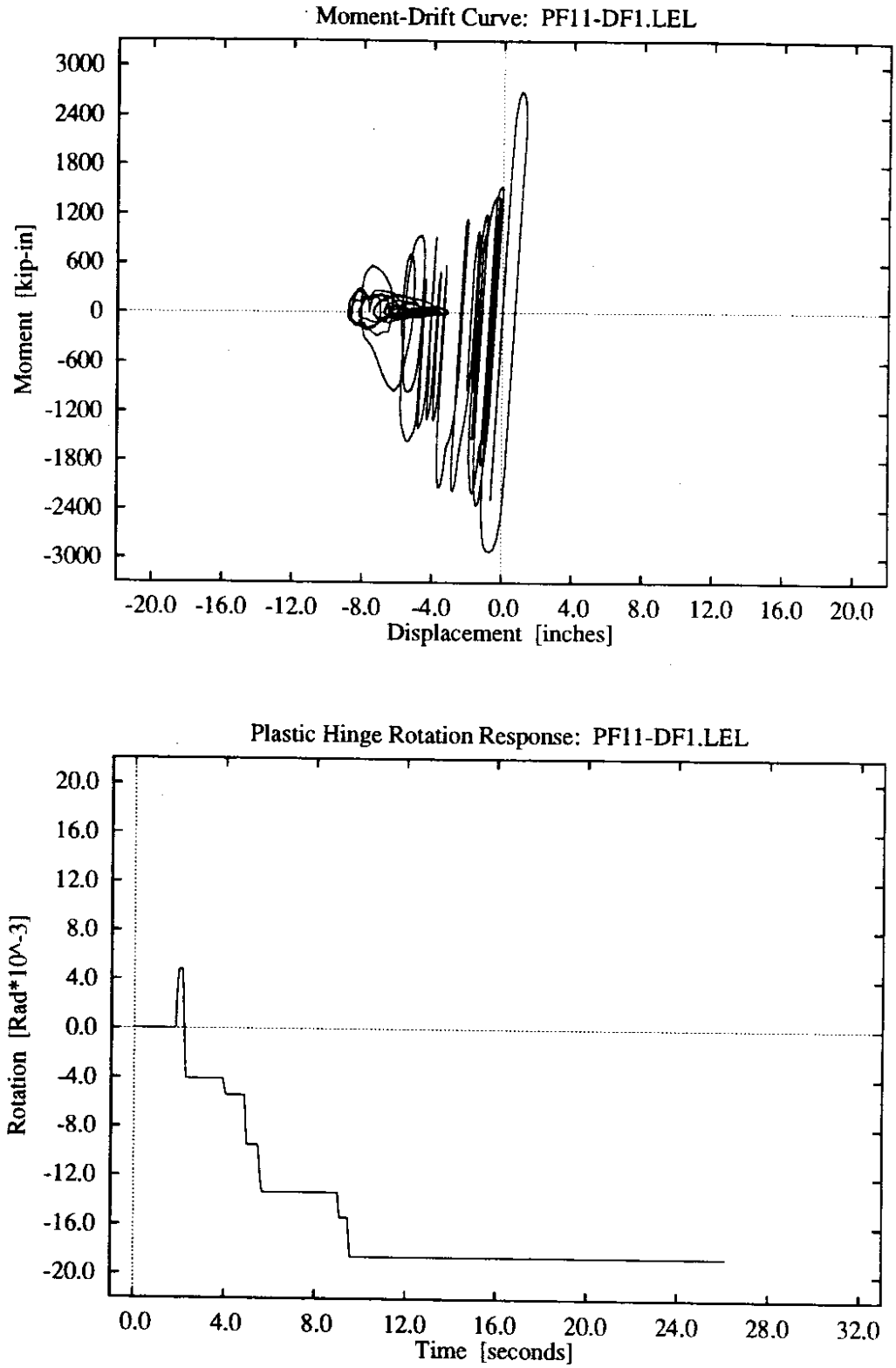


Figure E-14: DF1 foundation model, lower intensity El Centro record.

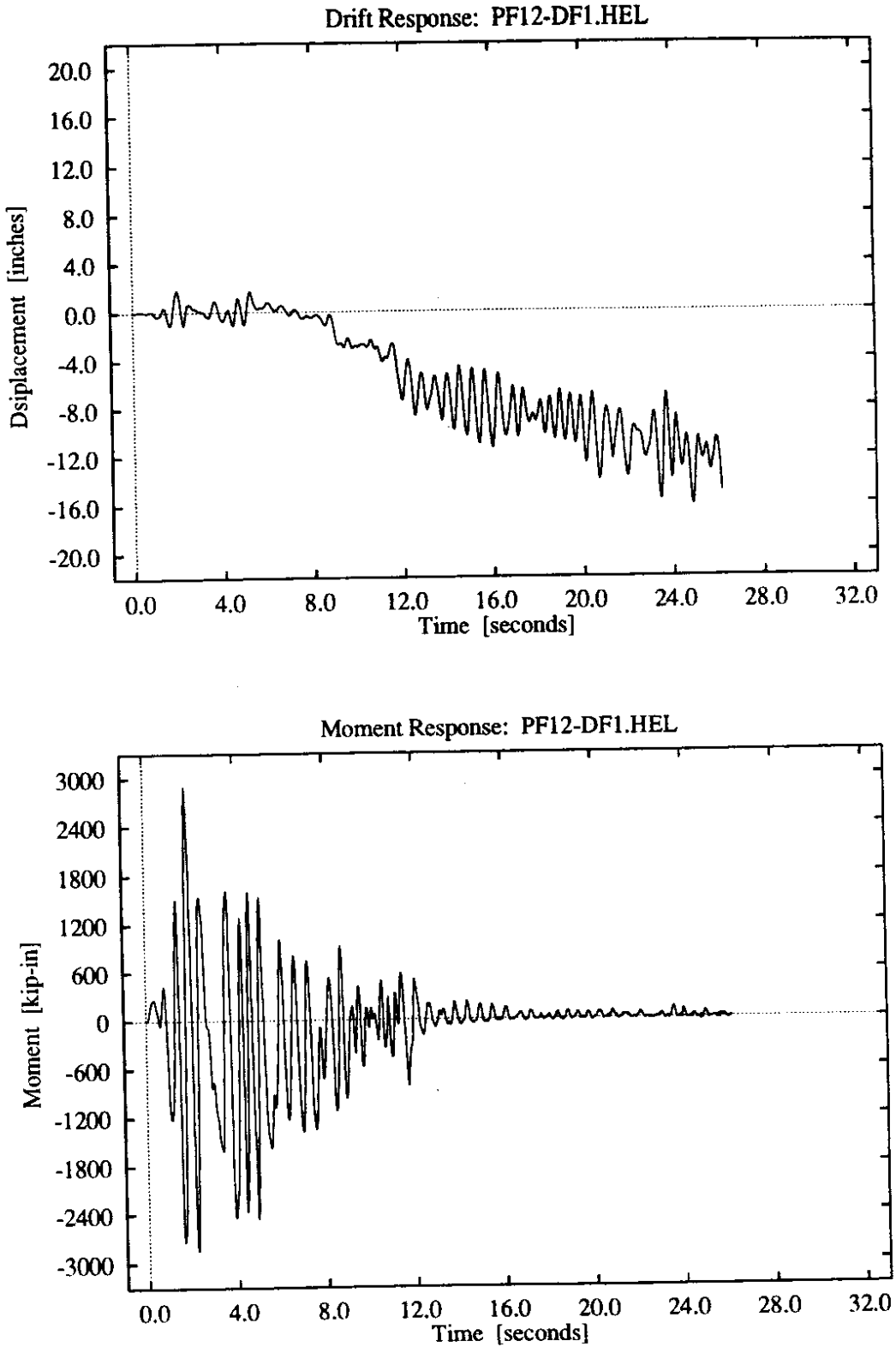
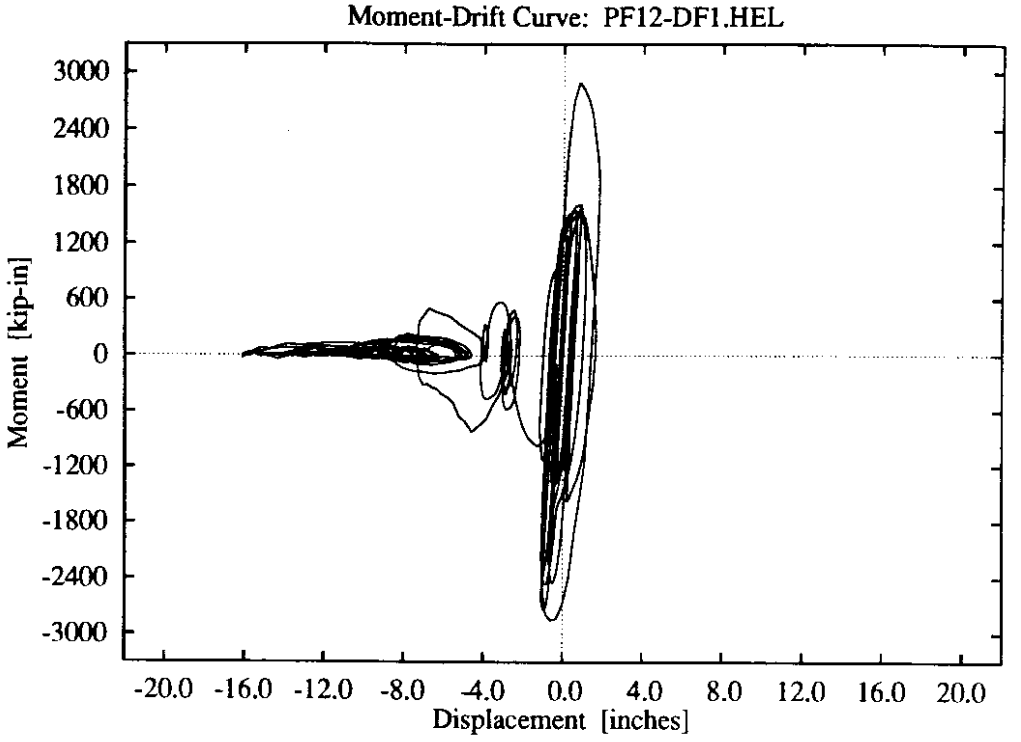


Figure E-15: DF1 foundation model, higher intensity El Centro record.



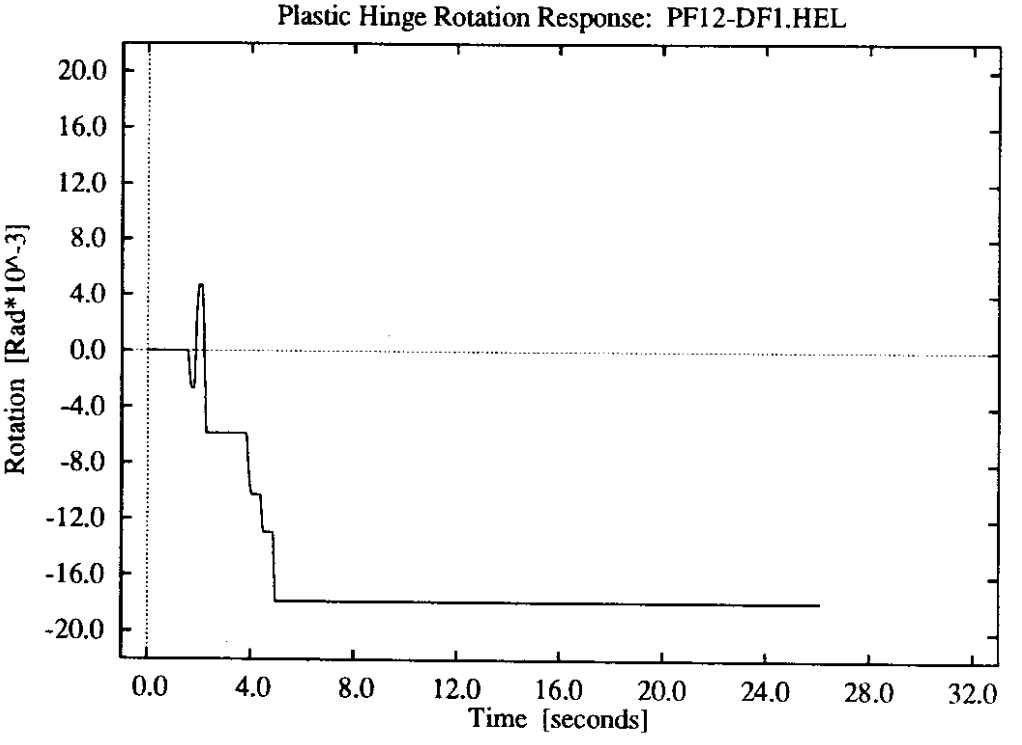


Figure E-16: DF1 foundation model, higher intensity El Centro record.

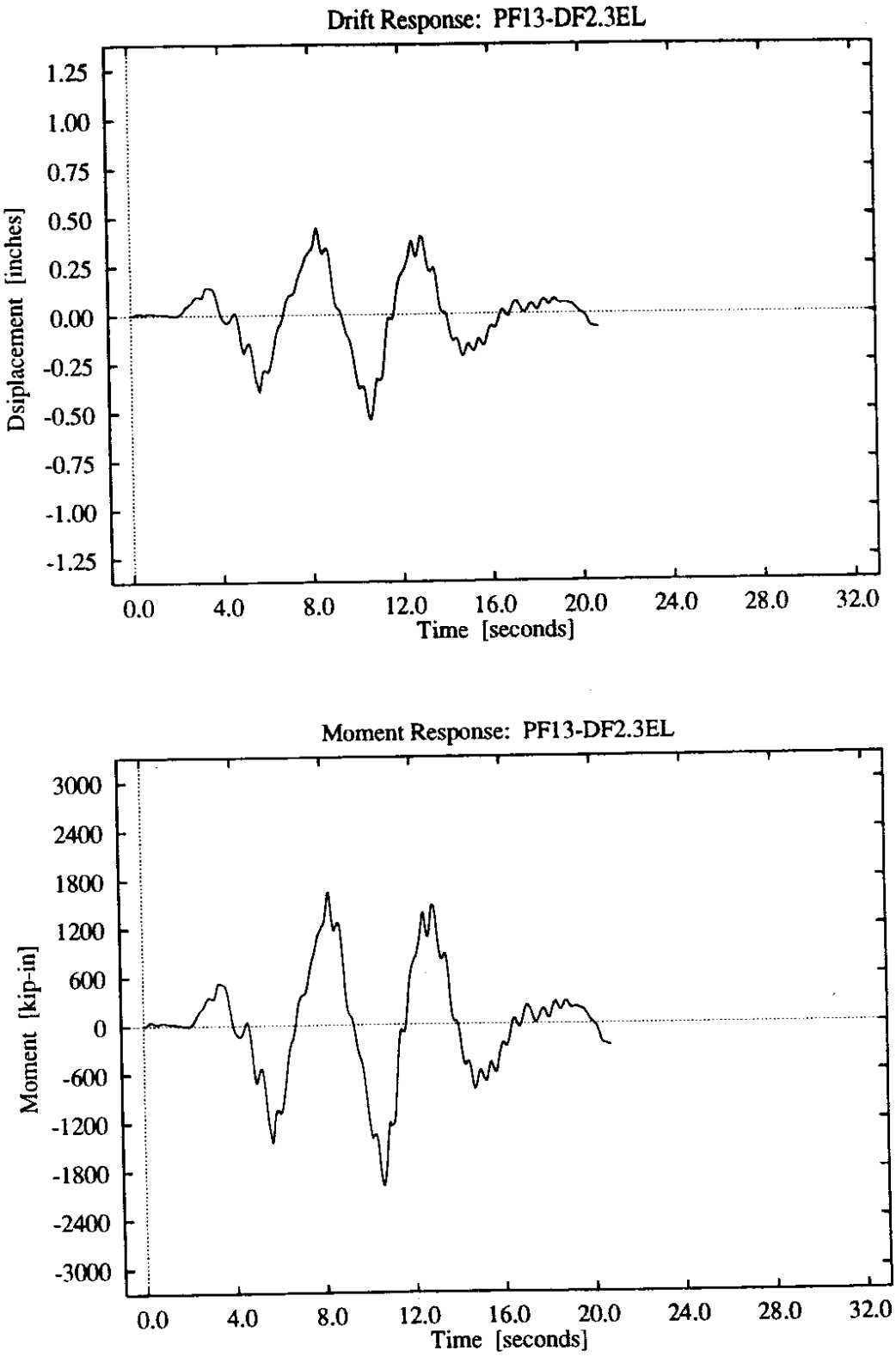


Figure E-17: DF2 foundation model, El Centro Z3 record.

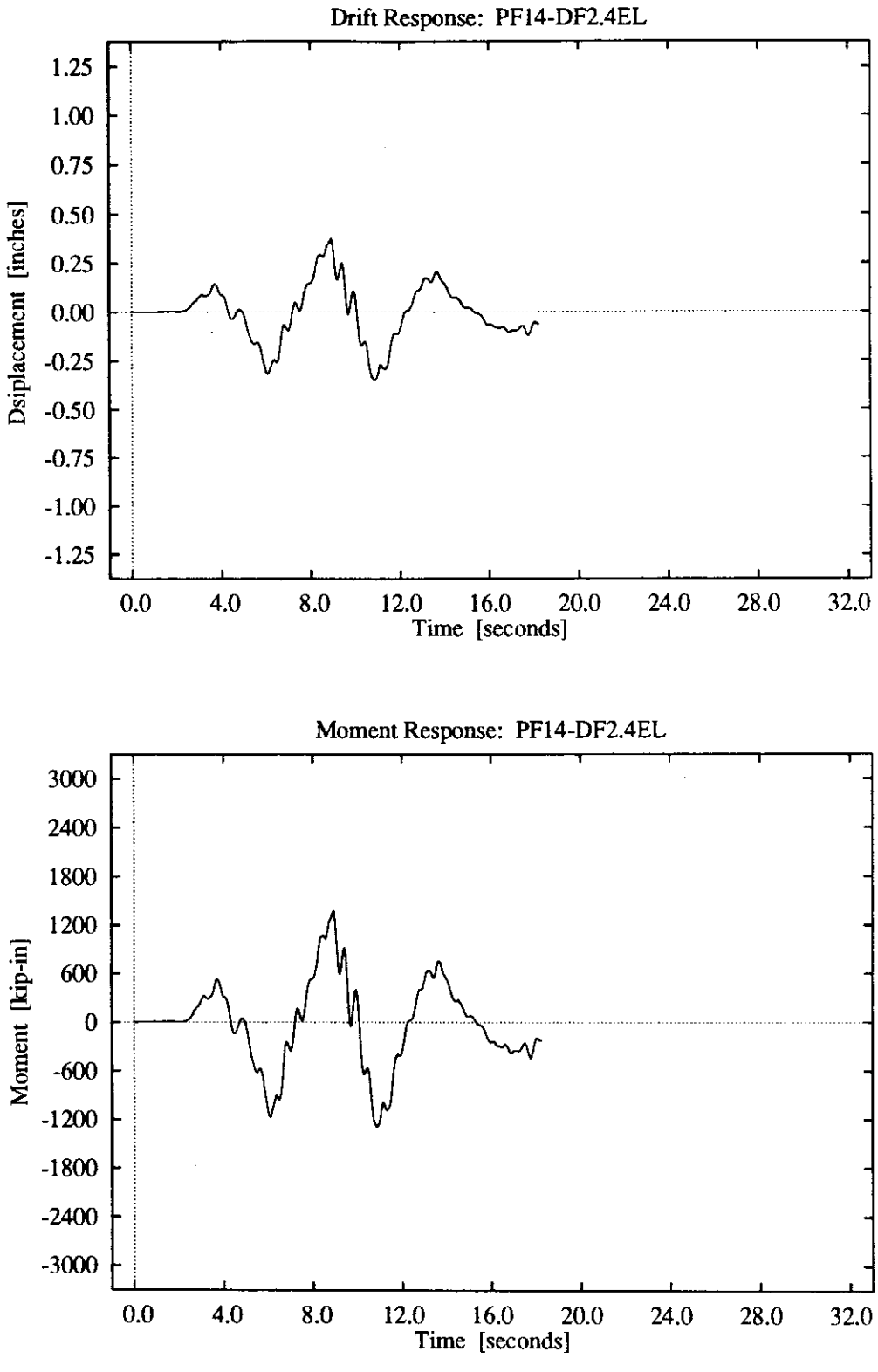


Figure E-18: DF2 foundation model, El Centro Z4 record.

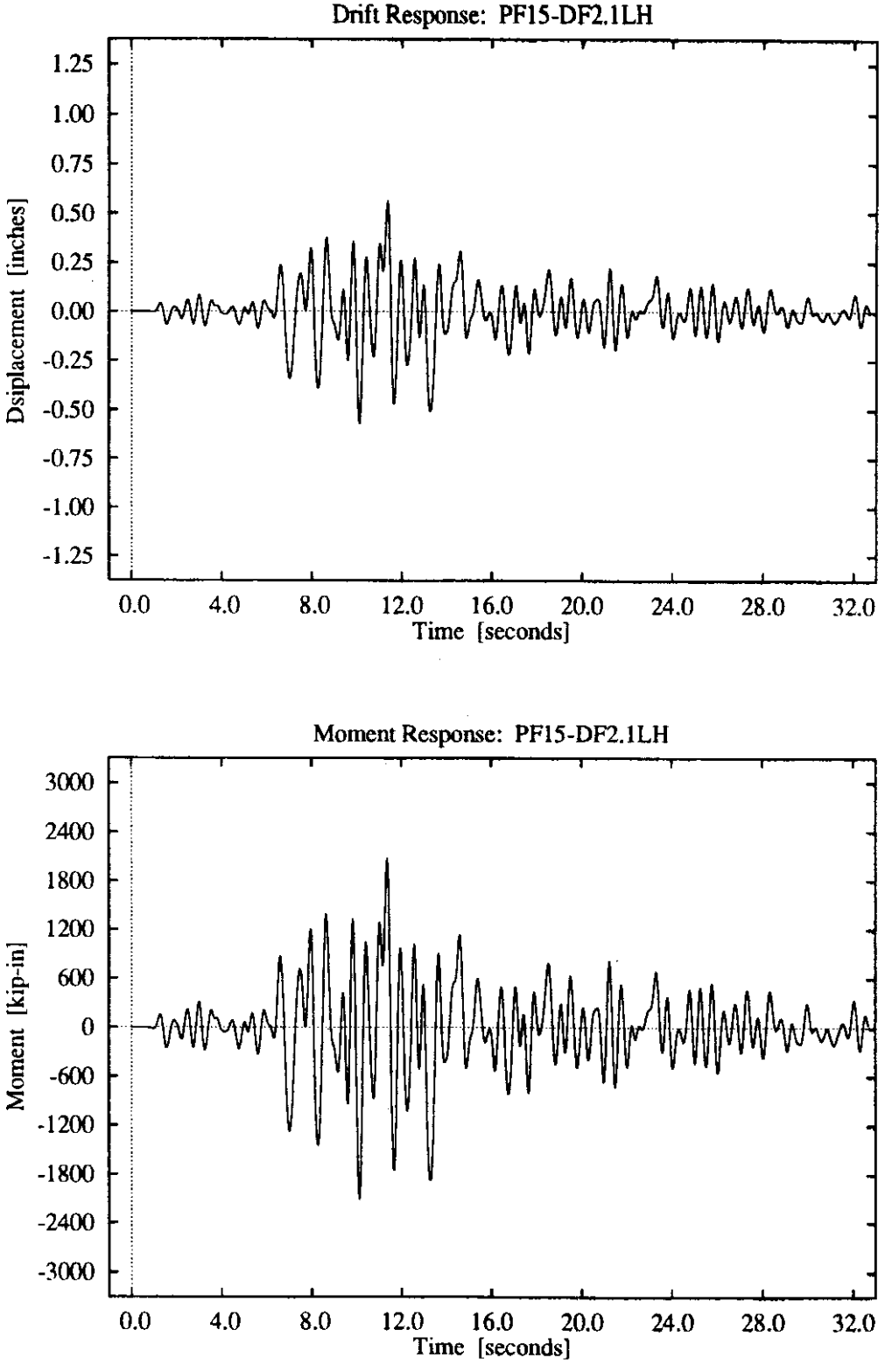
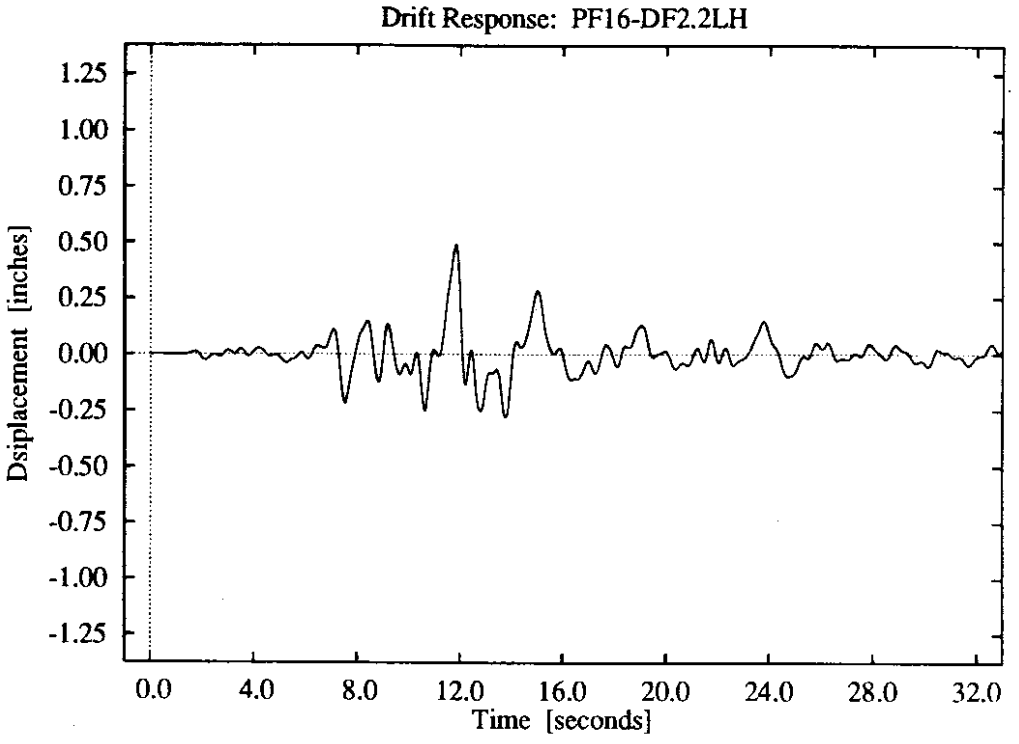


Figure E-19: DF2 foundation model, Lake Hughes Z1 record.



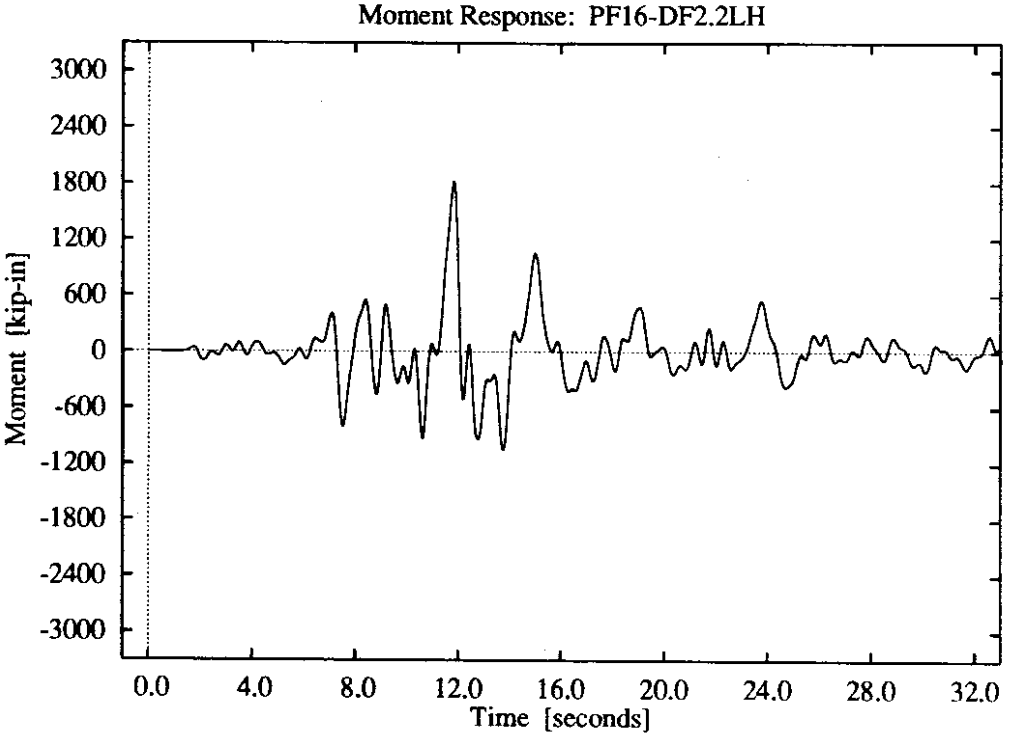


Figure E-20: DF2 foundation model, Lake Hughes Z2 record.

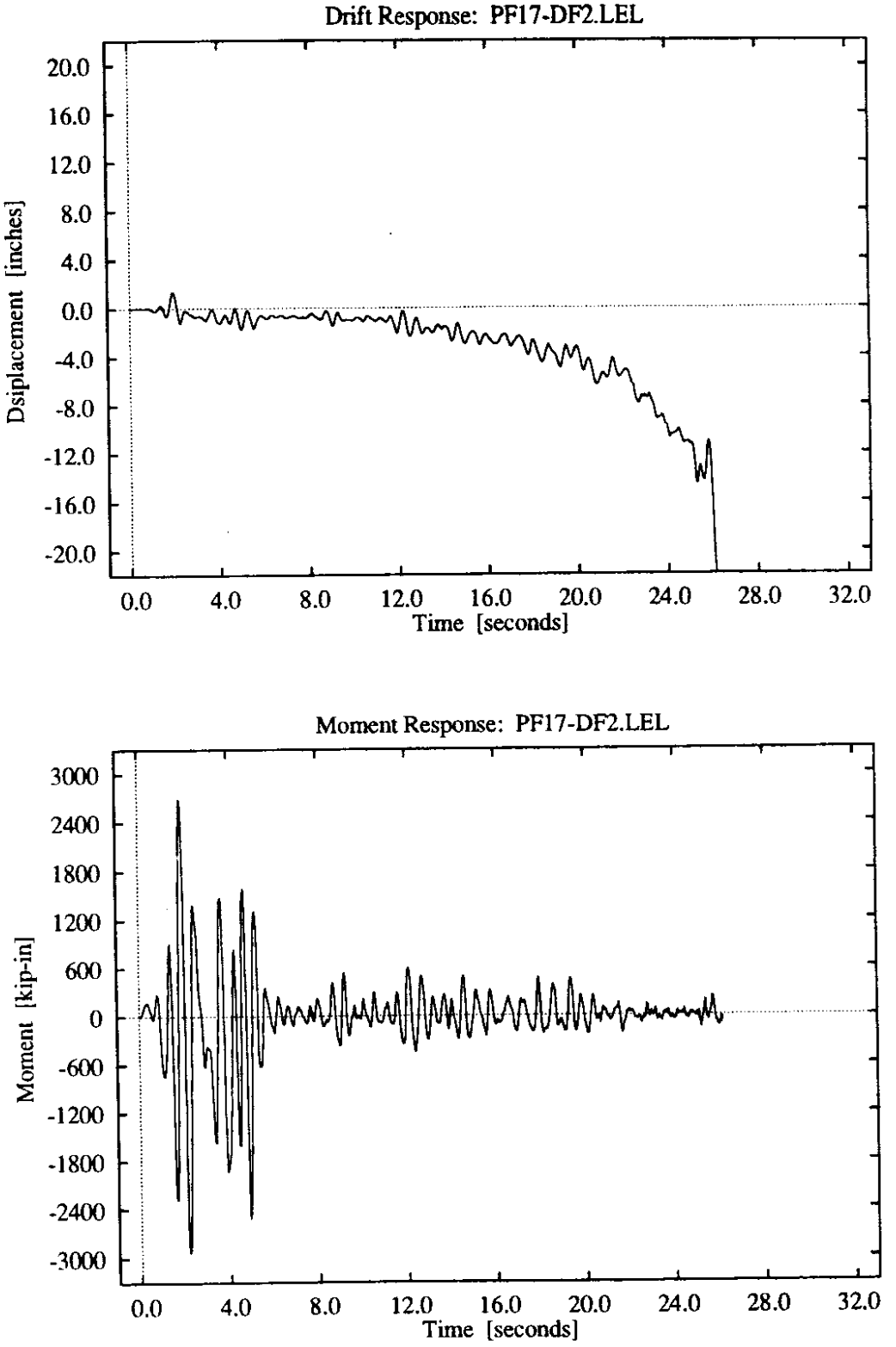


Figure E-21: DF2 foundation model, lower intensity El Centro record.

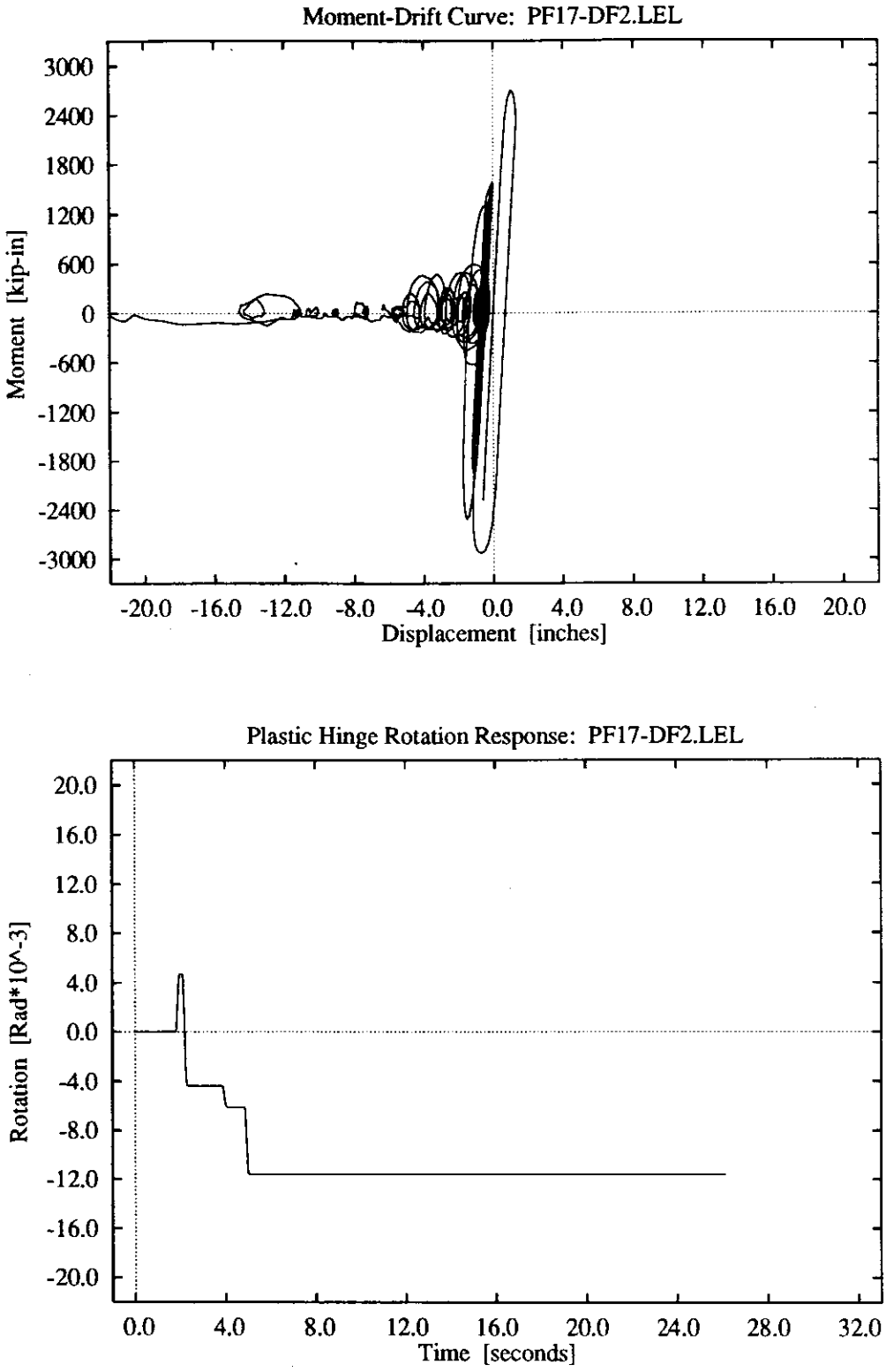


Figure E-22: DF2 foundation model, lower intensity El Centro record.

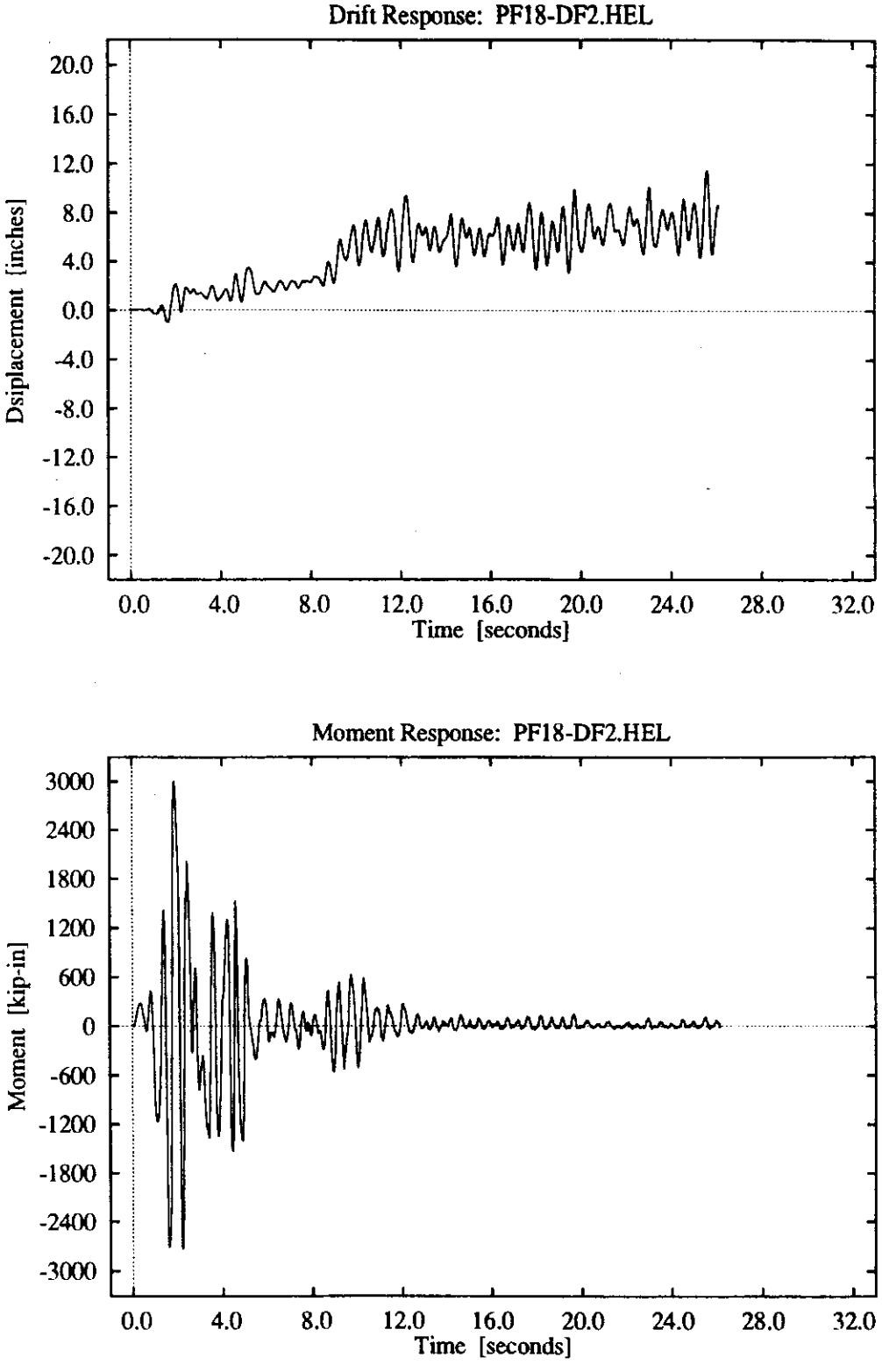


Figure E-23: DF2 foundation model, higher intensity El Centro record.

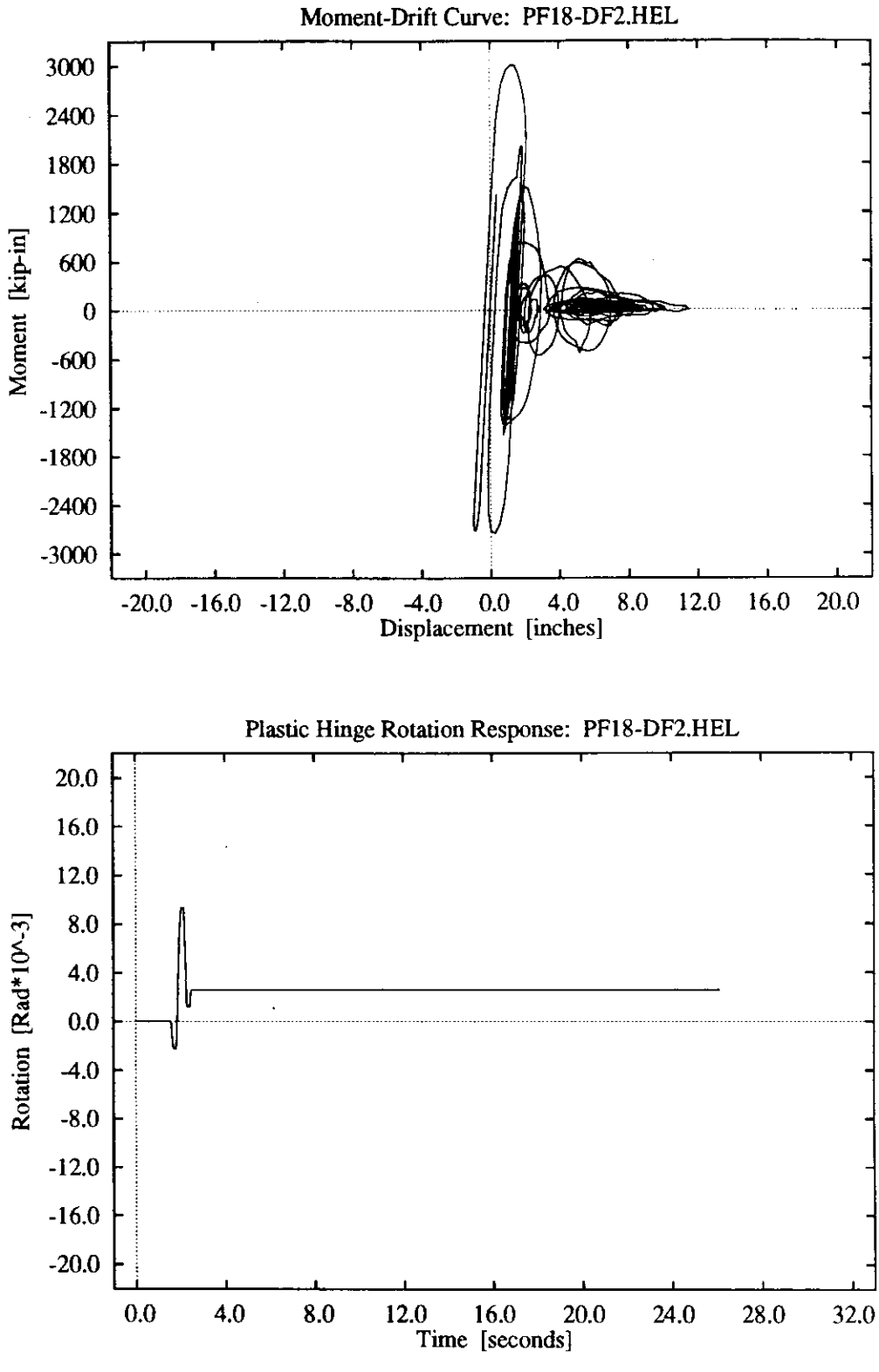


Figure E-24: DF2 foundation model, higher intensity El Centro record.

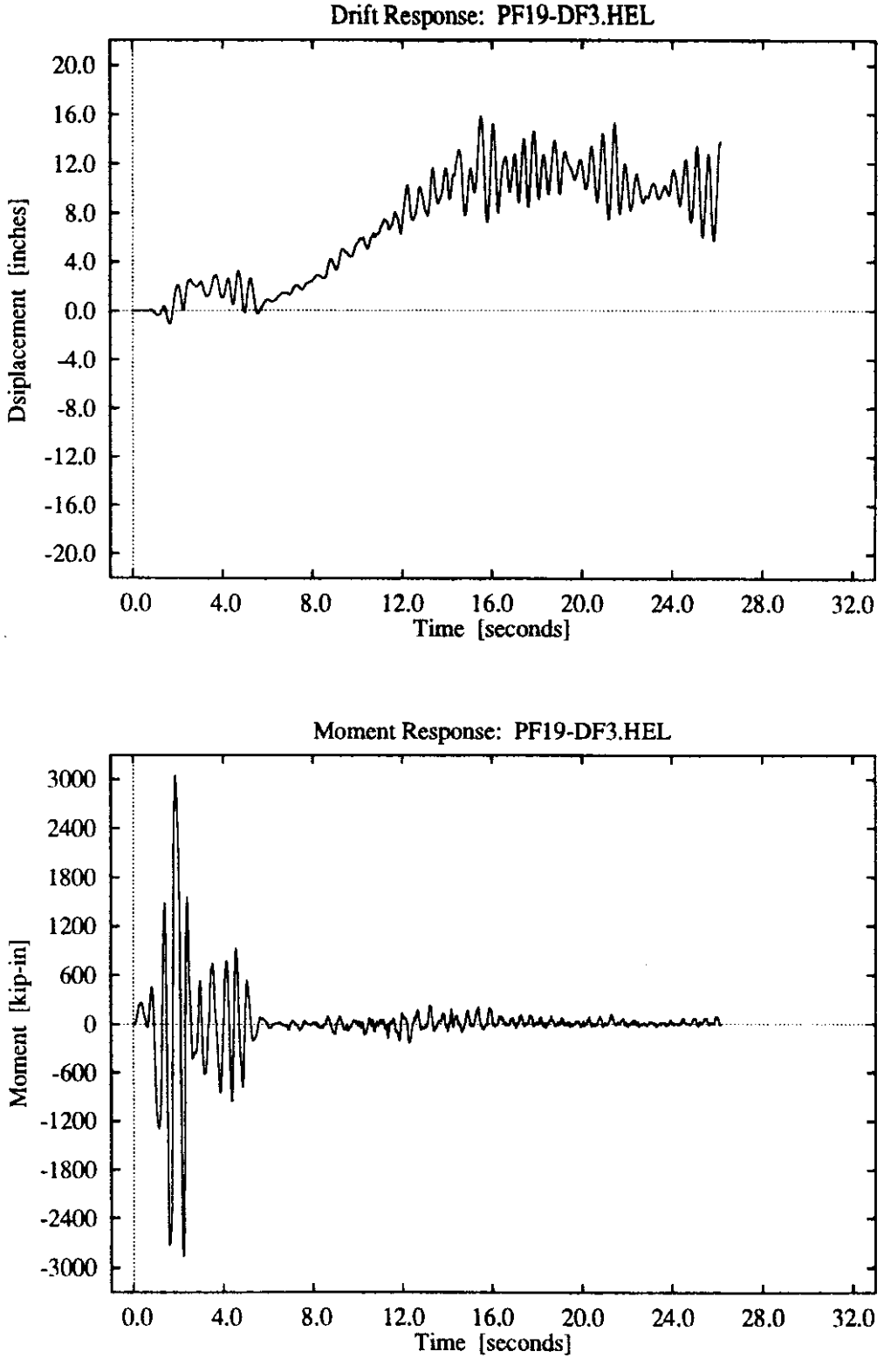


Figure E-25: DF3 foundation model, higher intensity El Centro record.

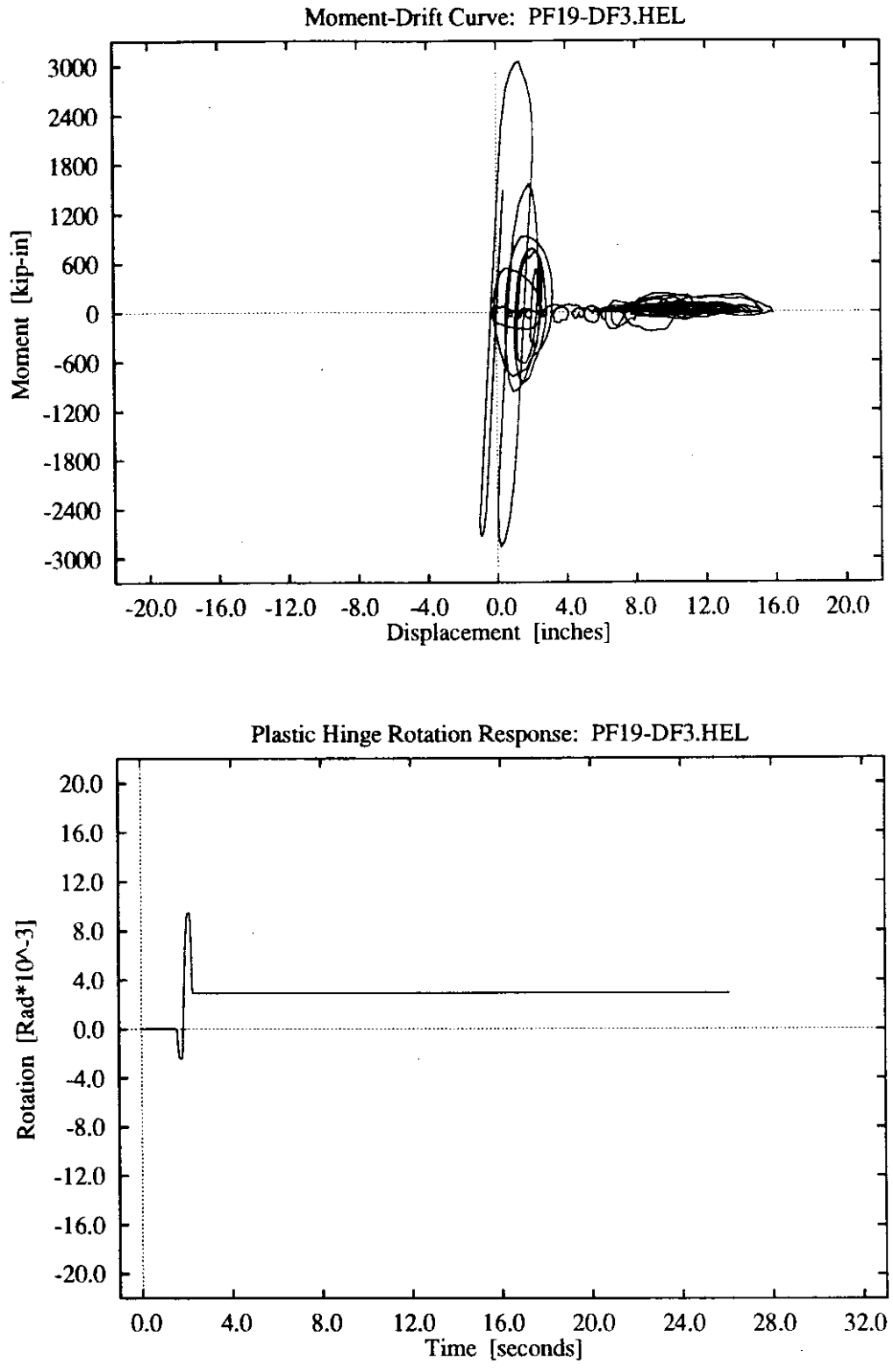


Figure E-26: DF3 foundation model, higher intensity El Centro record.

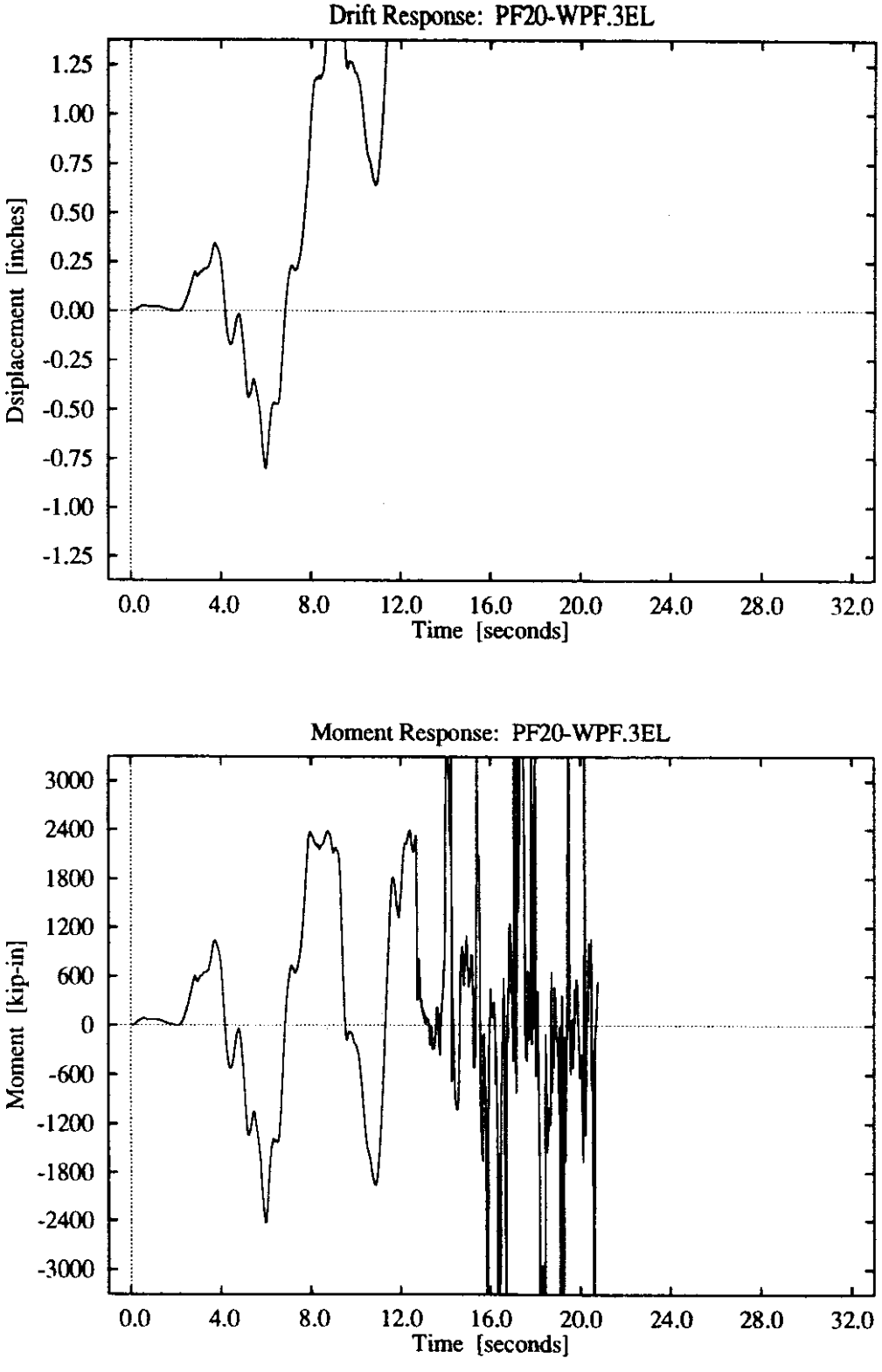
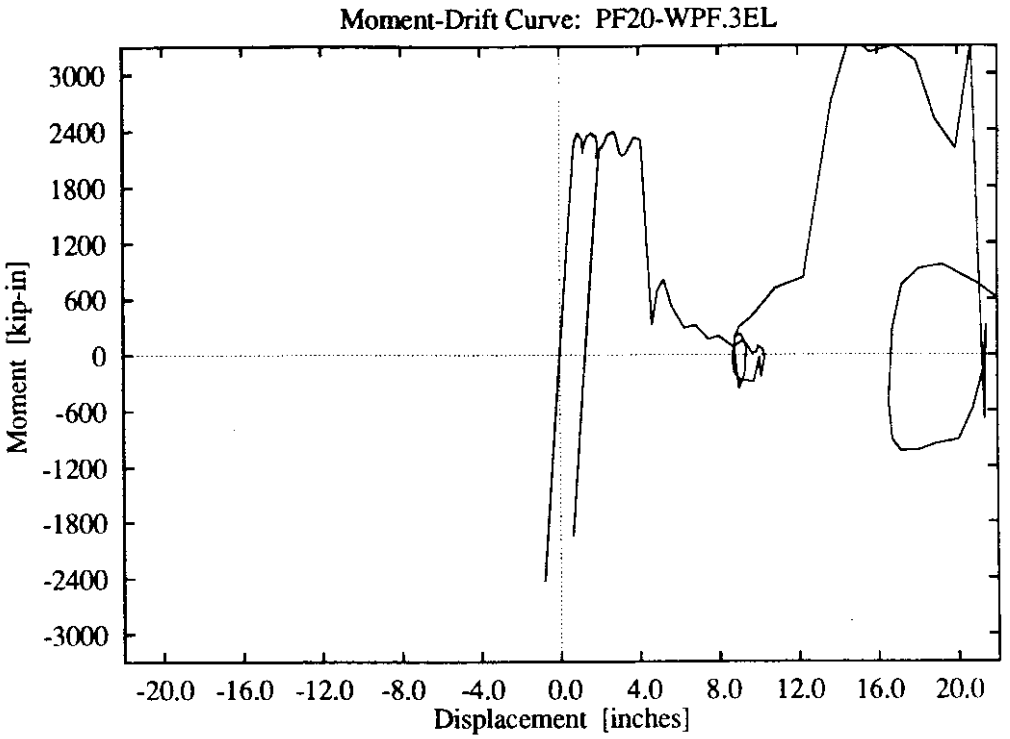


Figure E-27: WPF foundation model, El Centro Z3 record.



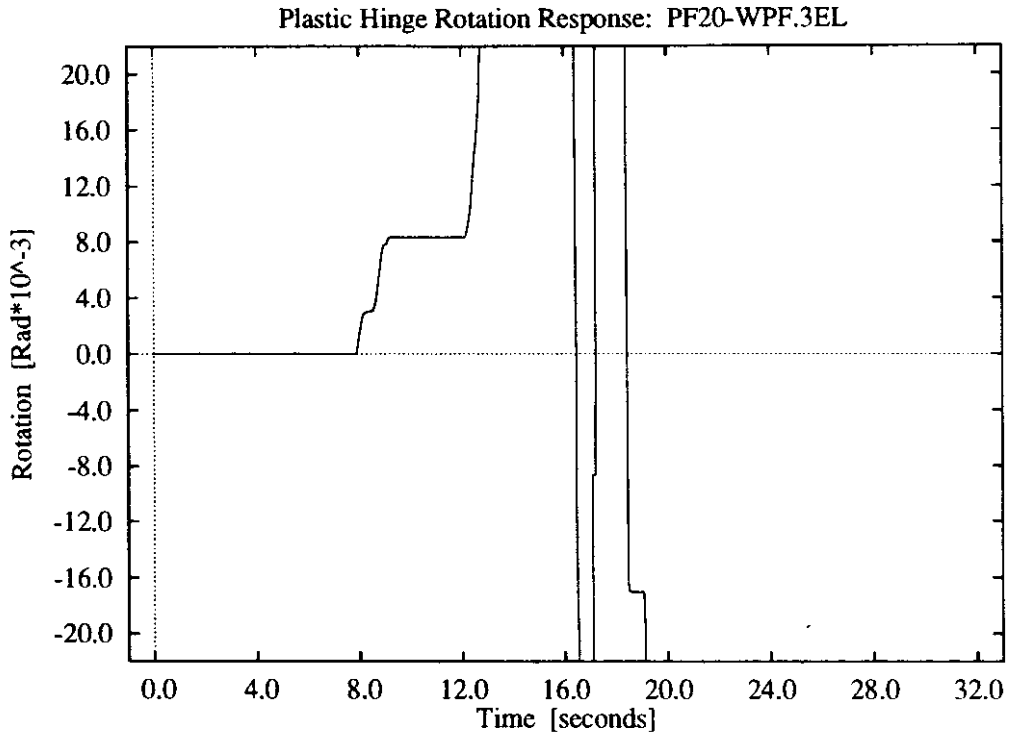


Figure E-28: WPF foundation model, El Centro Z3 record.

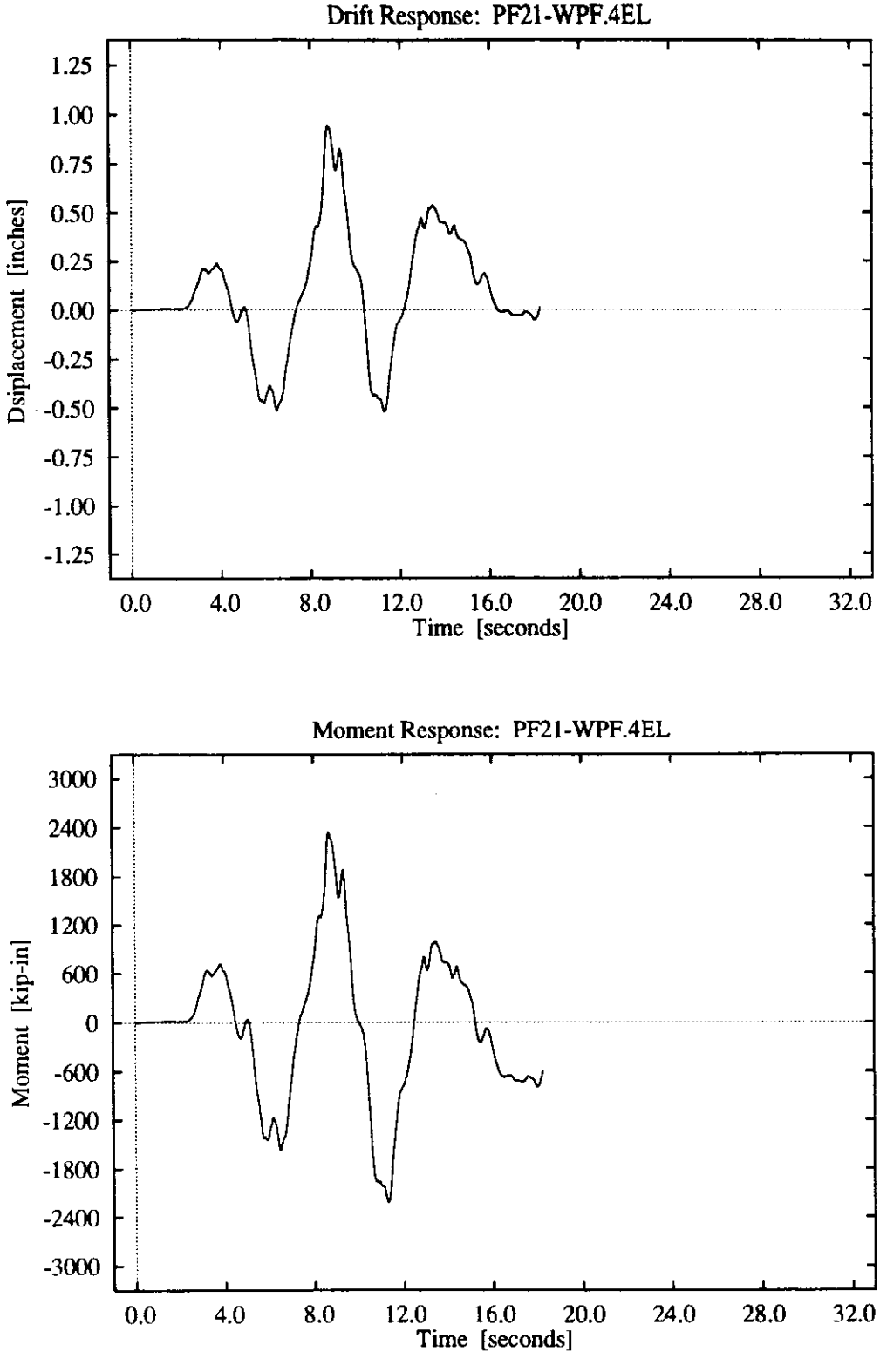


Figure E-29: WPF foundation model, El Centro Z4 record.

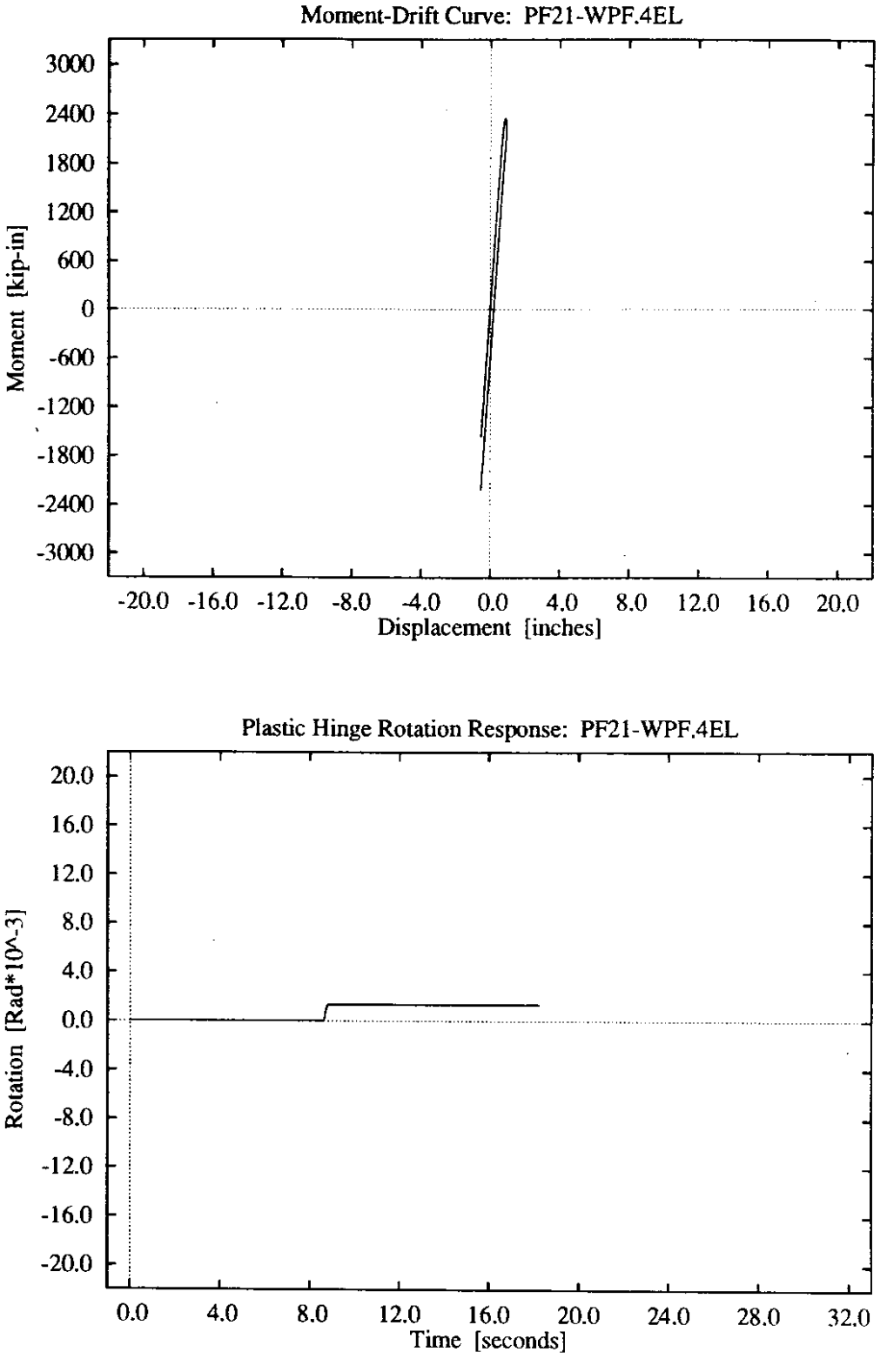


Figure E-30: WPF foundation model, El Centro Z4 record.

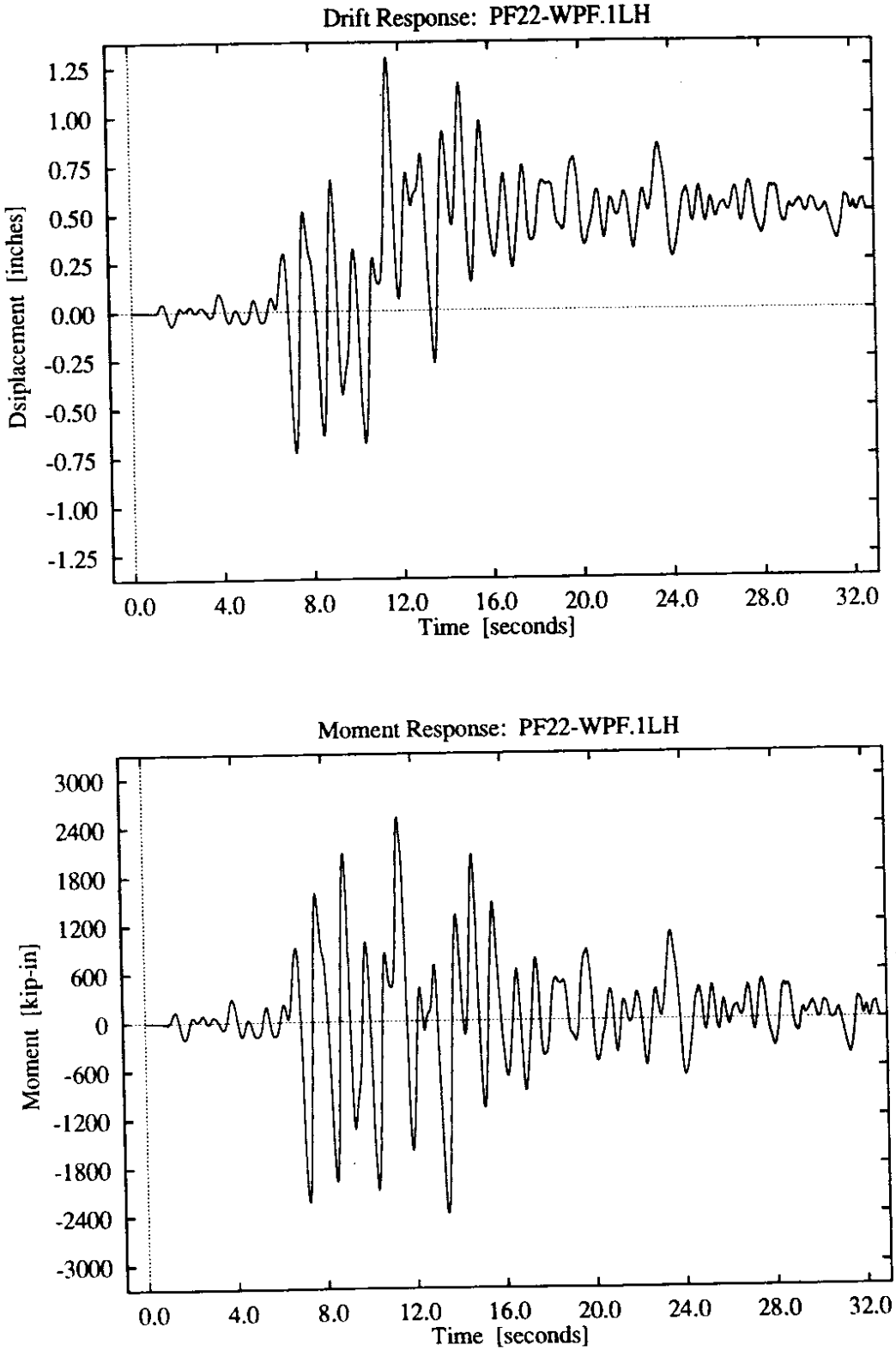
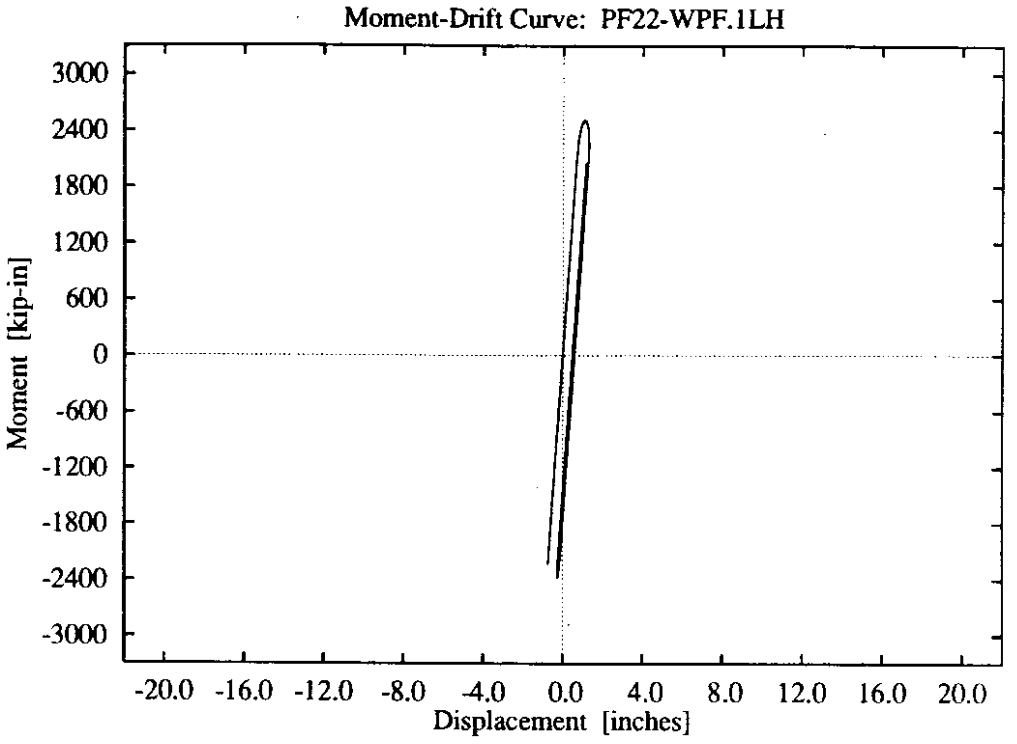


Figure E-31: WPF foundation model, Lake Hughes Z1 record.



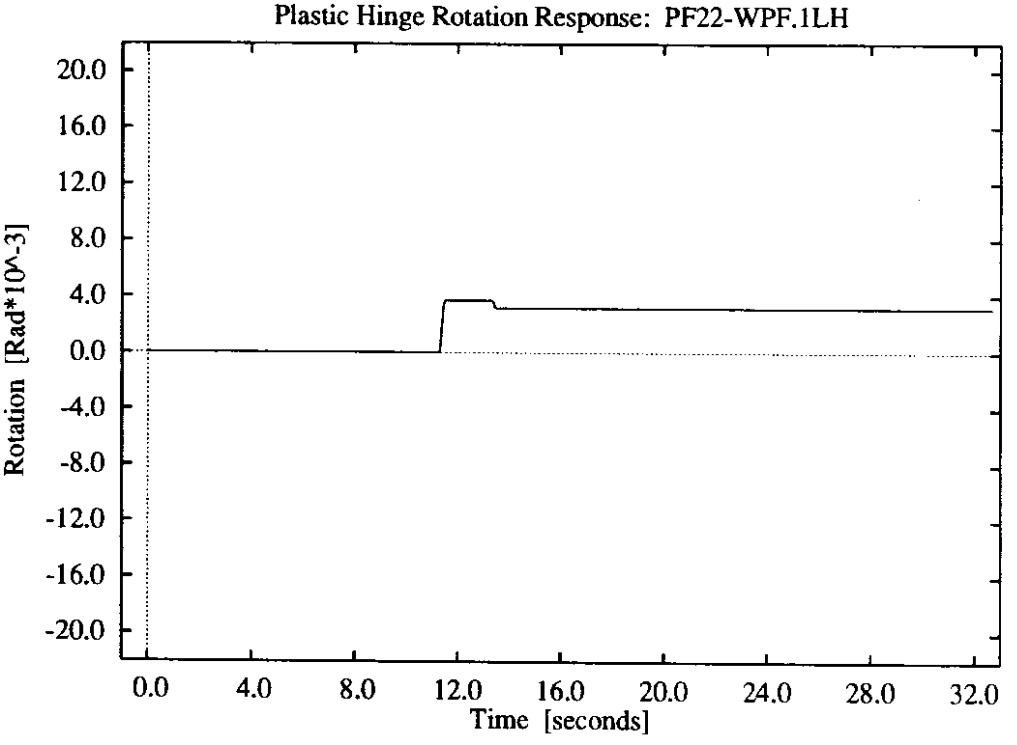


Figure E-32: WPF foundation model, Lake Hughes Z1 record.

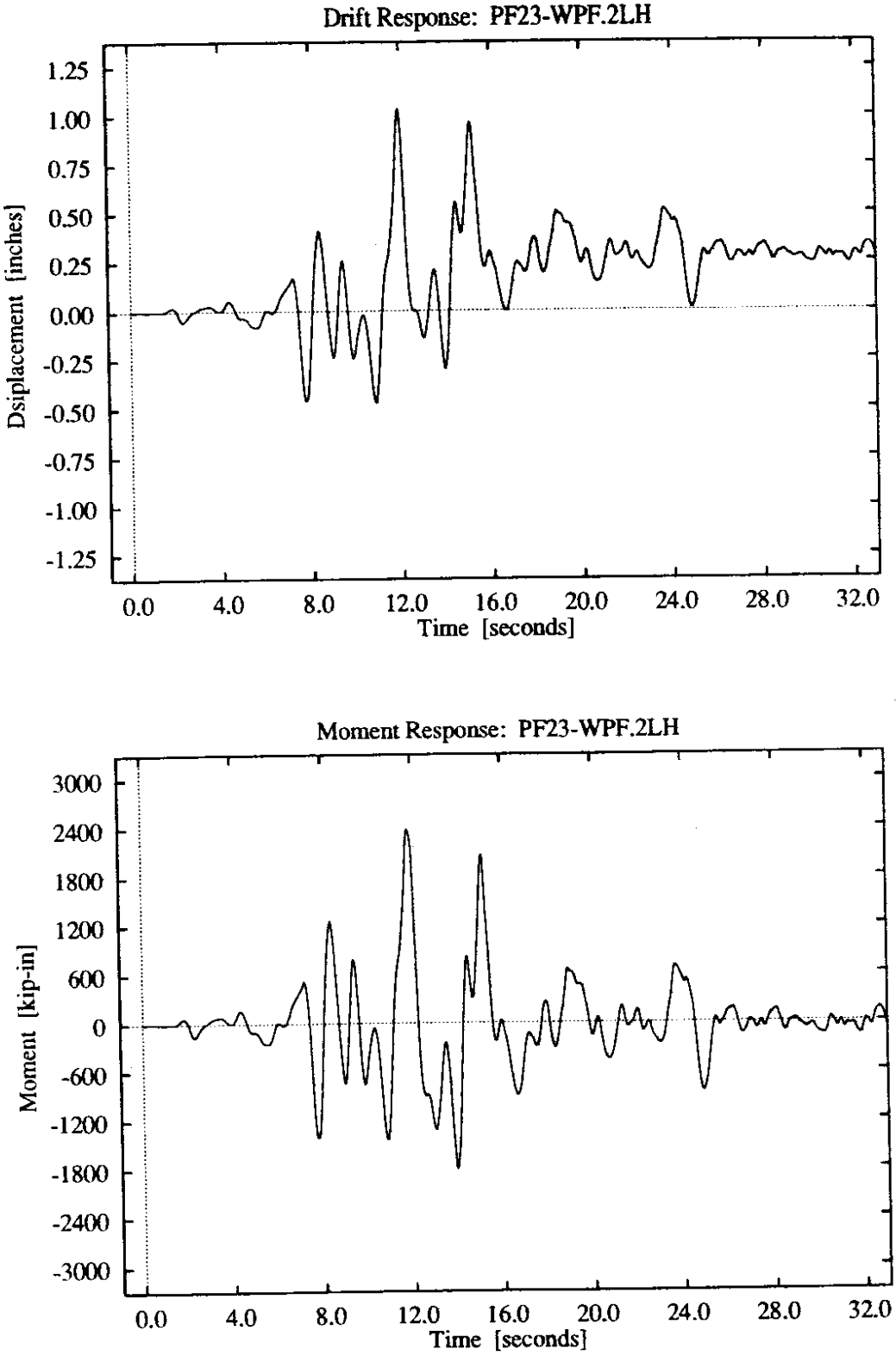


Figure E-33: WPF foundation model, Lake Hughes Z2 record.

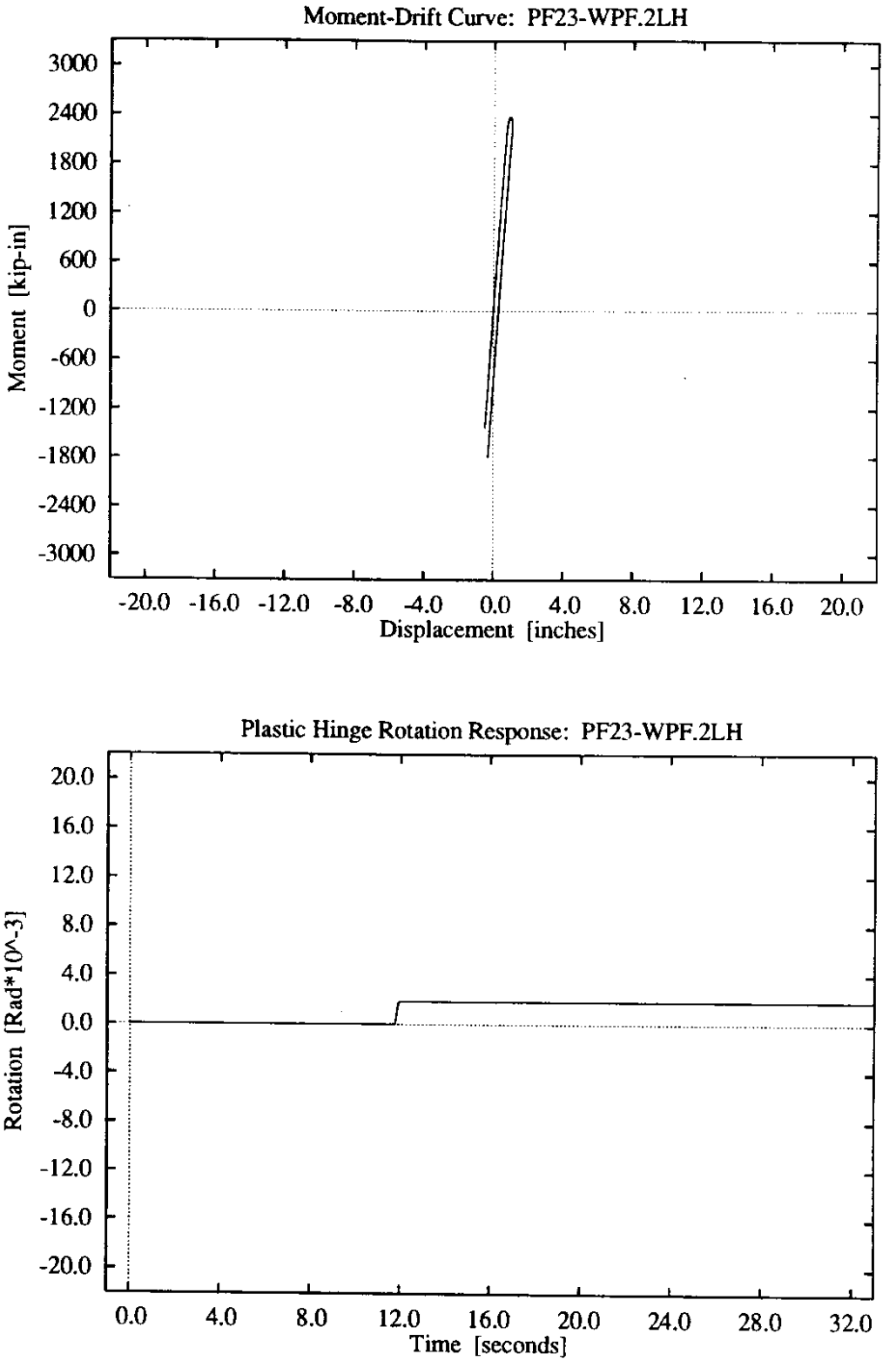


Figure E-34: WPF foundation model, Lake Hughes Z2 record.

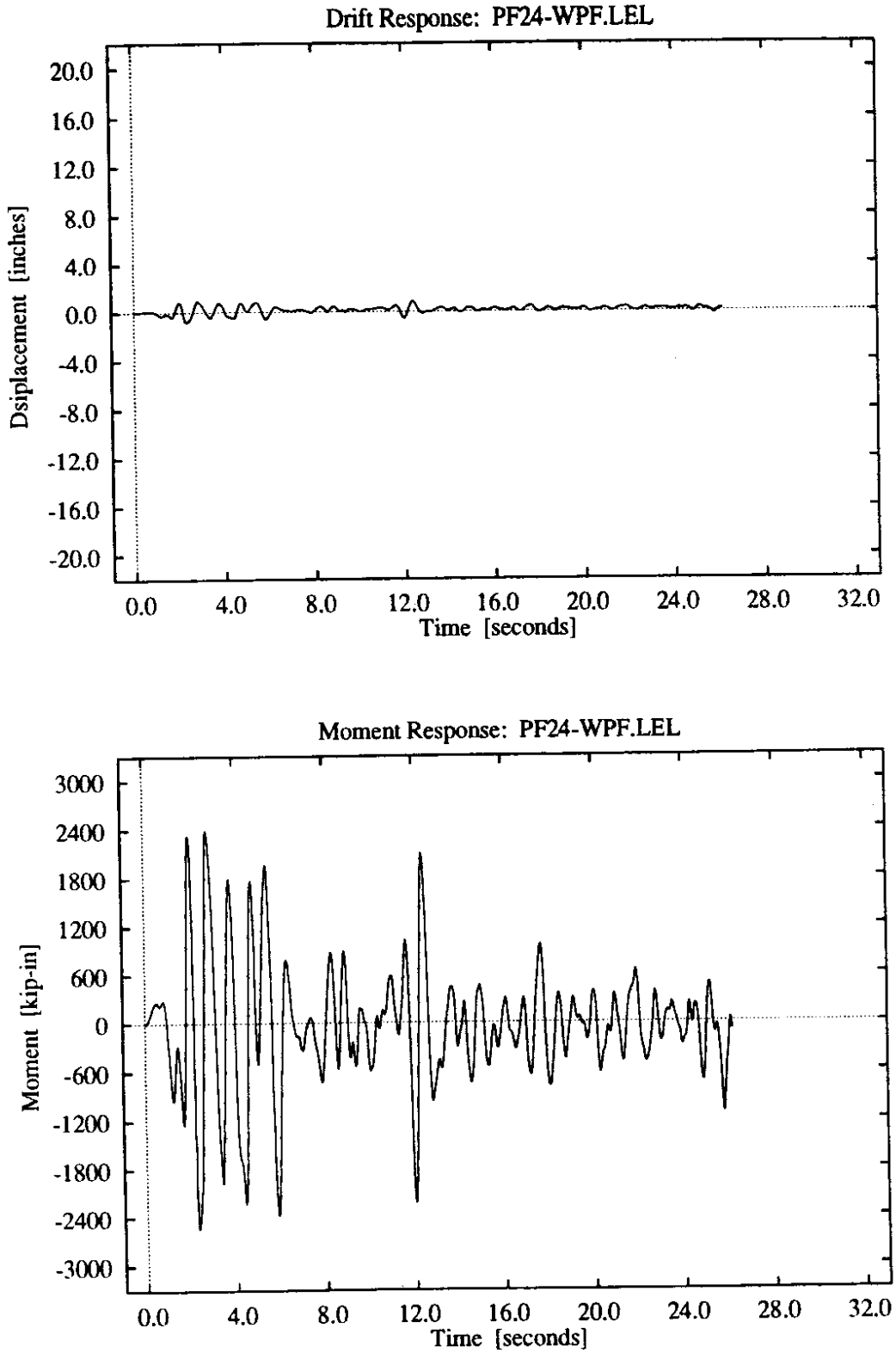
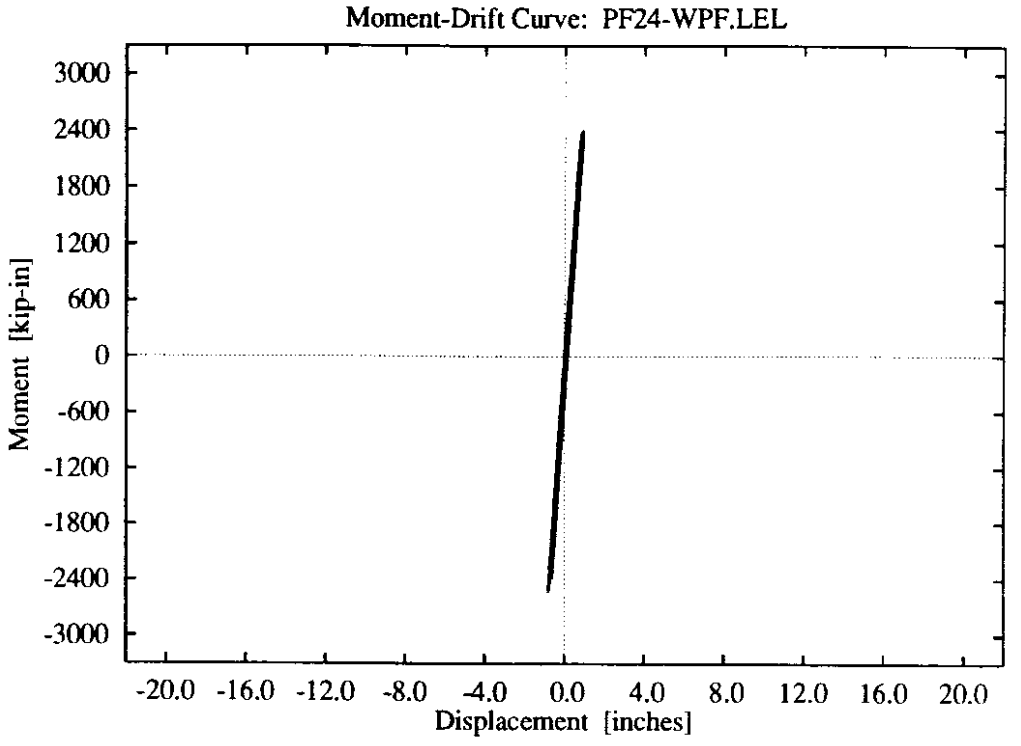


Figure E-35: WPF foundation model, lower intensity El Centro record.



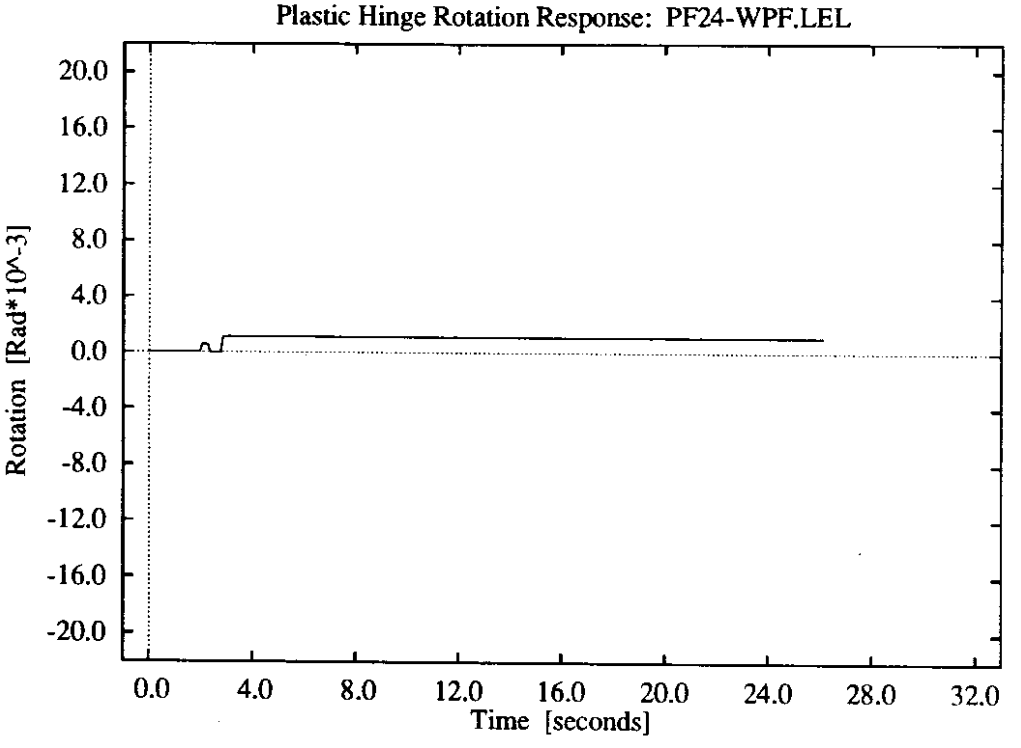


Figure E-36: WPF foundation model, lower intensity El Centro record.

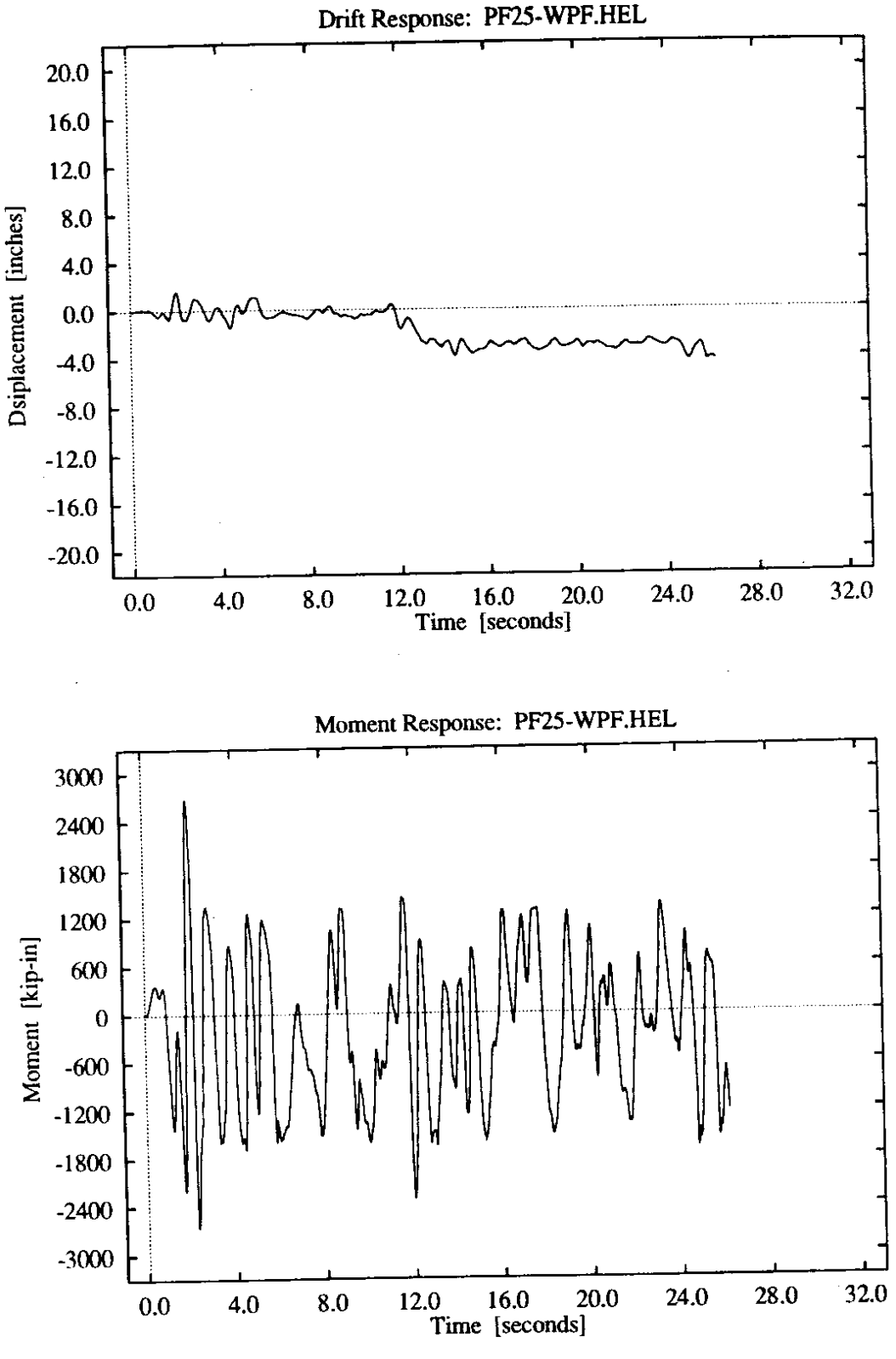


Figure E-37: WPF foundation model, higher intensity El Centro record.

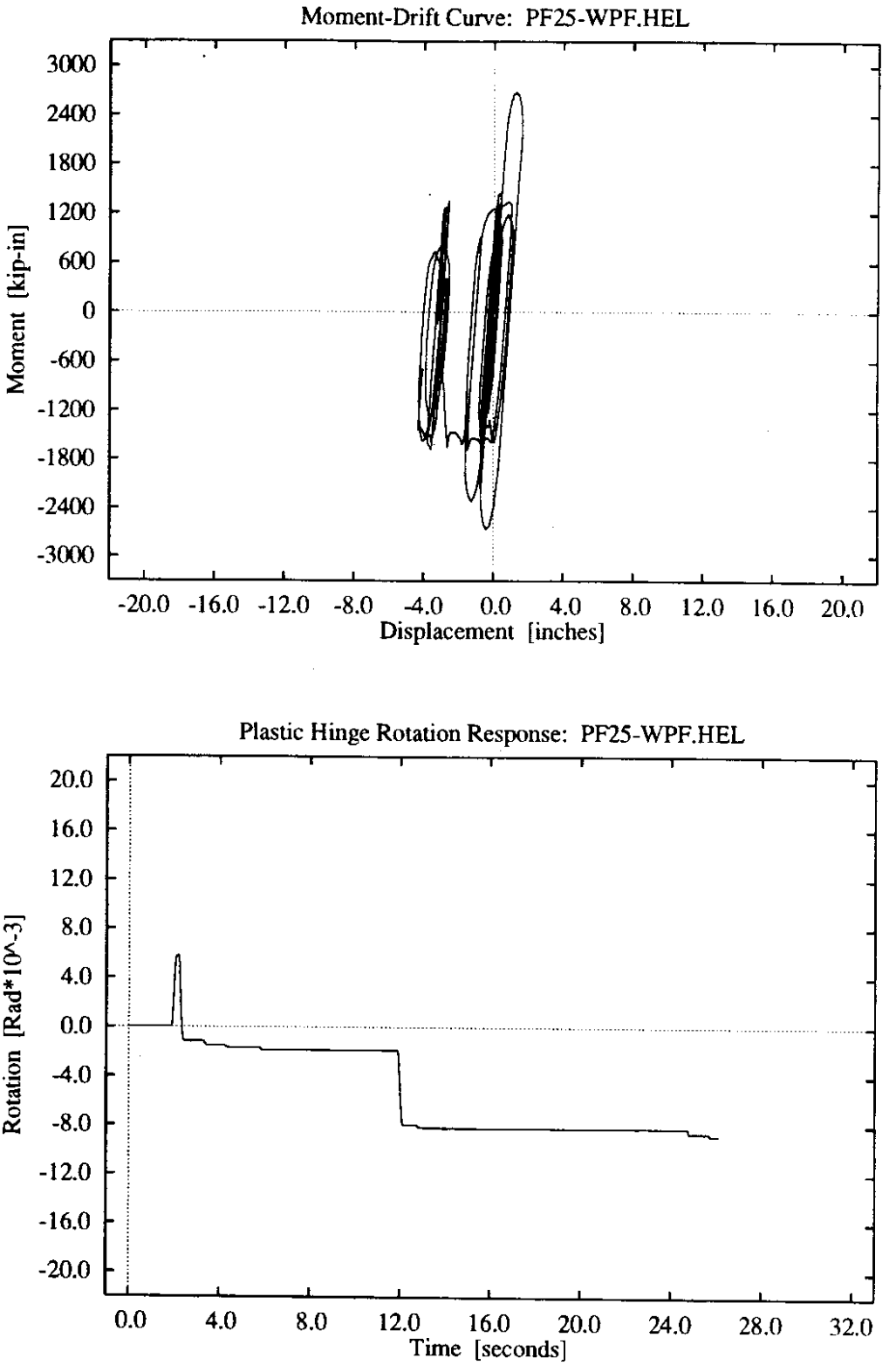


Figure E-38: WPF foundation model, higher intensity El Centro record.