Evaluation of Stump Strength for Temporary Forest Road Design

Séamus P.S. Parker
Senior Researcher, Forest Engineering Research Institute of Canada (FERIC), Western Division, 2601 East Mall, Vancouver, B.C. V6T 1Z4, Tel (604) 228-1555 Fax (604) 228-0999, Email: seamus-p@vcr.feric.ca

ABSTRACT - Historically, forest roads on the BC coast have sometimes been constructed using stumps and log cribs to retain the road fill on steep slopes. However, experience has shown that road fill failures may occur after several years often due to root strength deterioration. Currently, B.C.'s forest Practices Code permits the use of logs and stumps to retain the road fill if the technique is prescribed as a "measure to maintain slope stability" and the road will be permanently deactivated within five years of construction. Such measures must be prepared by a "qualified registered professional" (QRP). A strict interpretation of the code may lead QRPs to prepare a geotechnical design for the road fill retention structure.

At present more information is needed to develop design criteria for log and stump retaining structures, specifically load carrying capacity and failure characteristics of old-growth stumps present on coastal BC terrain. Therefore, the Forest Engineering Research Institute of Canada (FERIC) in cooperation with Weyerhaeuser Company's Ltd.'s B.C. Coastal Group and EBA Engineering Consultants Ltd., conducted tests in September 2000 in order to determine the strength of typical old-growth Douglas-fir stumps. This paper presents the results of the stump pulling trials.

Keywords: roadfill, stump rotation, lateral displacement, stump load, ultimate load, block purchase

INTRODUCTION

Prior to the introduction of the Forest Practices Code of B.C. (FPCBC) in 1995, forest roads were sometimes constructed using stumps and log cribs to retain the road fill on steep slopes. This technique is less expensive than excavating a full-bench cut and endhauling the waste material. However, experience has shown that road fill failures may occur after about 5 to 20 years often due to root strength deterioration suggesting that the assessment of stump strength is critical to the assessment of temporary roads.

Currently, the FPCBC Forest Road Regulation (FRR) permits the use of logs and stumps to retain the road fill if the technique is prescribed as a "measure to maintain slope stability" and the road will be permanently deactivated within five years of construction.1 Such measures must be prepared by a "qualified registered professional"(QRP).2 A strict interpretation of the FRR may lead QRPs to prepare a geotechnical design for the road fill retention structure. A problem with this approach is that more information is needed before design criteria can be

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1 See the Forest Practices Code Forest Road Regulation for a full explanation and exceptions to the rule.

2 "Qualified registered professional" is defined in the Forest Road Regulation.

developed for log and stump retaining structures. Specifically, knowledge about the load carrying capacity and failure characteristics of old-growth stumps is required. Some insight into stump strength is available in previous studies (Pyles et al. 1991, Smith, McMahon 1995, Peters, Biller 1986). However, these studies are not directly applicable because they were done for smaller, second-growth stumps located in gentle terrain.

Weyerhaeuser Company's Ltd.'s B.C. Coastal Group, in conjunction with EBA Engineering Consultants Ltd., began investigating geotechnical design criteria for temporary roads in steep terrain. The Forest Engineering Research Institute of Canada (FERIC) was asked to help determine the strength of typical old-growth Douglas-fir stumps used for log and stump retaining structures. Stump pull out tests were completed at Weyerhaeuser's Nanaimo River Operation in September 2000. The objective of the tests was to:

- Determine the strength and lateral displacement relationship for a range of stump diameters for old-growth Douglas-fir.

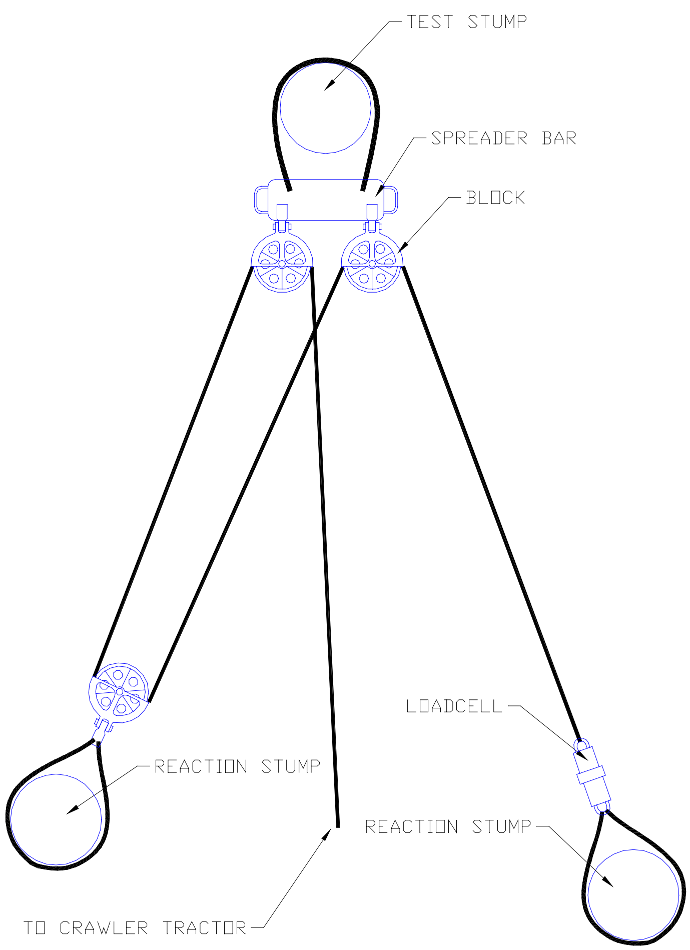

Figure 1. Rigging arrangement for stump pull tests.

METHODOLOGY

Site Description

The site was selected as being representative of east coast Vancouver Island conditions in slope, soil, terrain, and age of stumps (less than 5 years since harvesting). This site, located at the lower elevations of Weyerhaeuser's Nanaimo Lakes operation, had been harvested in 1998 (two years previously). Terrain in the area is concave in shape with slope gradients ranging from 30% to 45% over the area of the stump trials, and a western slope aspect. Stump elevations range from 580 m to 630 m. Many of the stumps are located on colluvial cones and aprons, and historic alluvial fans. The observed overburden consisted of well drained, gravely sand, some cobbles, and trace silt, and a natural soil moisture content ranging from 16-22%. The soil depth is greater than 2 m; with a rooting depth of aproximately 1 m.

Figure 2. Instrumented Stump.

Procedure

Nine old growth stumps (8 Douglas-fir and 1 Western Hemlock) were tested with a series of increasing loads until failure was achieved. A crawler tractor and block purchase system (Figure 1) was used so that sufficient force could be generated at the stump. The first seven pulls used the four part block purchase arrangement illustrated. The final two pulls used only a two part block purchase arrangement, with a single block at the test stump and a single reaction stump. Stumps were pulled downhill and parallel to the slope to simulate the loading in a stump-log retaining structure. In several instances, the load on the stump was backed off prior to stump failure in order to measure the effect of creep.

The load and displacement of the stump were monitored with a datalogger at 4Hz. The load was measured using a 445 kN (100,000 lb) loadcell installed in the block purchase system as illustrated. The stump load was calculated based on the angles of the lines in the block purchase system, assuming a block efficiency of 97%. The stump rotation was measured with an inclinometer (measuring both X and Y components), mounted on the stump (Figure 2, Figure 3). The lateral displacement of the stump was measured by two displacement transducers (string pots) mounted at separate referenced locations (e.g. stump or log) and connected by string to a pole mounted on the stump. Measurement of both the rotation angle of the stump and the lateral displacement at a known height allowed the sliding component of stump movement to be differentiated from the rotary movement of the stump. The displacement was then calculated at 30 cm above the estimated point of germination. Stump height, strap height and stump diameter were measured prior to each test. The diameter at breast height (dbh) (outside bark) was estimated using formulas which account for stump height, stump diameter, and species (Omule and Kozak, 1989).

Plots of force vs lateral displacement were generated for each each test. The maximum load required to pull the stump from the ground (regardless of displacement), and the maximum load achieved prior to a displacement of 12.5 mm, at 30 cm above the point of germination, were summarized along with the dbh estimate.

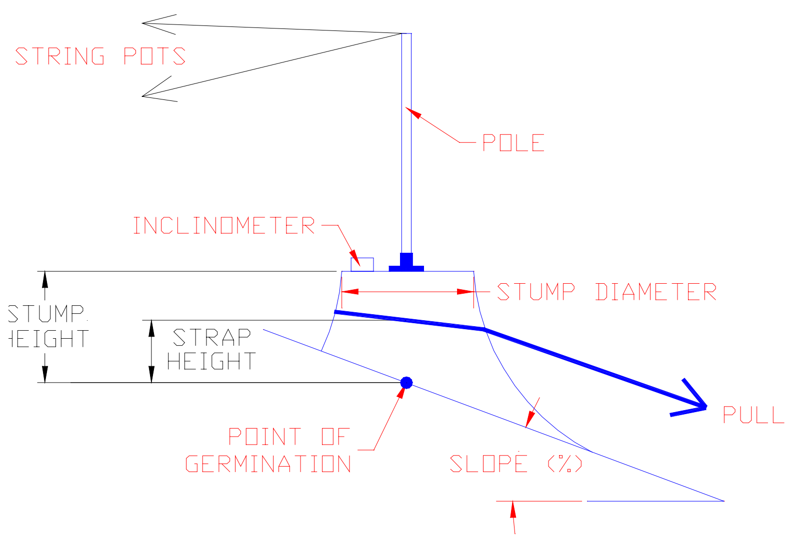

Figure 3. Measured Stump Parameters.

RESULTS AND DISCUSSION

Most stumps exhibited an elastic loading relationship up to a critical load level as illustrated by Figure 4. In this example, the stump was pulled a number of times at increasing levels with the load released after each pull. Following the first three low level pulls, the stump returned to virtually its same position at zero load. However after the fourth pull the deformation was more substantial when the yield level was reached as some of the more major roots were strained. In this example, the ultimate load occurred at a significant lateral displacement.

The majority of the stumps had an estimated DBH between 81 cm and 111 cm, with one stump less than this range at 62 cm DBH (Table 1). Generally stump strength increased with stump DBH. The ultimate load required to pull the stump out of the ground ranged from a minimum of 308 kN to a maximum of 834 kN (Figure 5). The ultimate load often occurred at significant lateral displacements up to 77 mm, therefore ultimate load is probably not a suitable parameter for road fill design. A more appropriate design strength may be the load that is achieved prior to a lateral displacement of 12.53 mm (@ 30 cm stump height from the point of germination). Stump #5 had a much lower ultimate strength than others of a similar size — field observations (no bark, weathered appearance) indicated that this stump was likely dead prior to cutting. This illustrates the degree to which root strength is lost over time and as a result this stump is not included in the graphs of diameter verses strength.

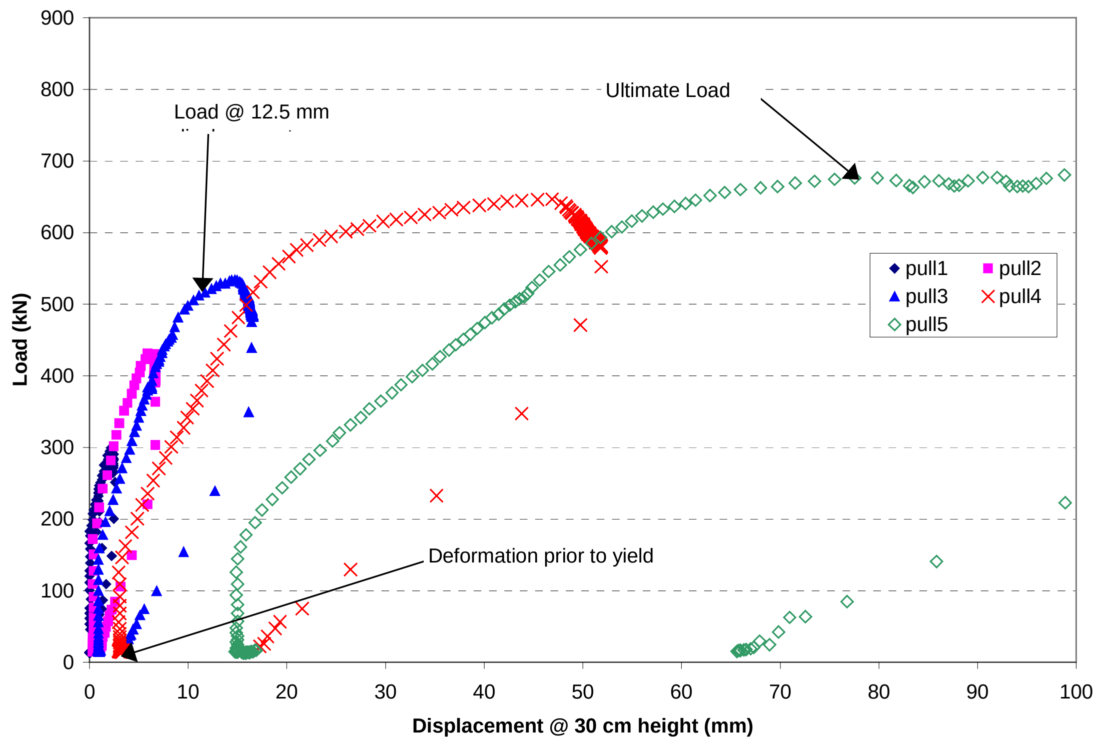

Figure 4. Sample Load verses displacement plot

The ultimate strength of these stumps were greater than second growth stumps previously tested in Washington and Oregon (Pyles et al. 1991), where the ultimate strength ranged from 50 to 275 kN and from 150 to 450 kN for Douglas-fir and Hemlock stumps respectively. This was likely due to the less developed root structure found in the smaller second growth stumps relative to the old growth stumps evaluated in this trial.

The force required to move the stump 12.5 mm (Figure 6), ranged from 295 kN for a 62 cm DBH stump to 718 kN for a 98 cm DBH stump. Note that only a portion of the relationship between pulling force and stump DBH is explained by the regression equations shown in Figures 4 and 5. The variability of stump strength is also likely due in part to variations in soil composition and depth, and root architecture throughout the site. These tests can therefore

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3 This level of displacement was selected as the maximum level of fill displacement that can be tolerated, and generally corresponds to the elastic load limit of the stump.

only provide rough site-specific guidelines for utilizing stumps to support road fills on temporary roads. More statistical confidence in these results can only be obtained through further testing.

Table 1. Summary of test data.

Test #	Species	Slope Gradient (%)	DBH (cm)	Ultimate Load (kN)	Displacement @ Ultimate Load (mm)	Load @ 12.5 mm Displacement (kN)	Deformation prior to yield (mm)	Failure type
1	Douglas-fir	45	111	676	77	525	3.6	Rotational
2	Douglas-fir	45	98	801	35	718	1.8	Rotational
3	Hemlock	45	87	627	36	587	1.1	Rotational
4	Douglas-fir	40	99	565	13	565	NA	Rotational
5	Douglas-fir	40	87	358	13	358	NA	Rotational/Sliding
6	Douglas-fir	40	98	842	60	671	NA	Rotational/Sliding
7	Douglas-fir	40	81	640	47	640	9.1	Rotational/Sliding
8	Douglas-fir	30	86	603a	17	594	0.6	Rotational
9	Douglas-fir	30	62	308	29	295	2.6	Rotational

a Ultimate load was not achieved due to 2 part pull and crawler tractor's winch capacity maximized

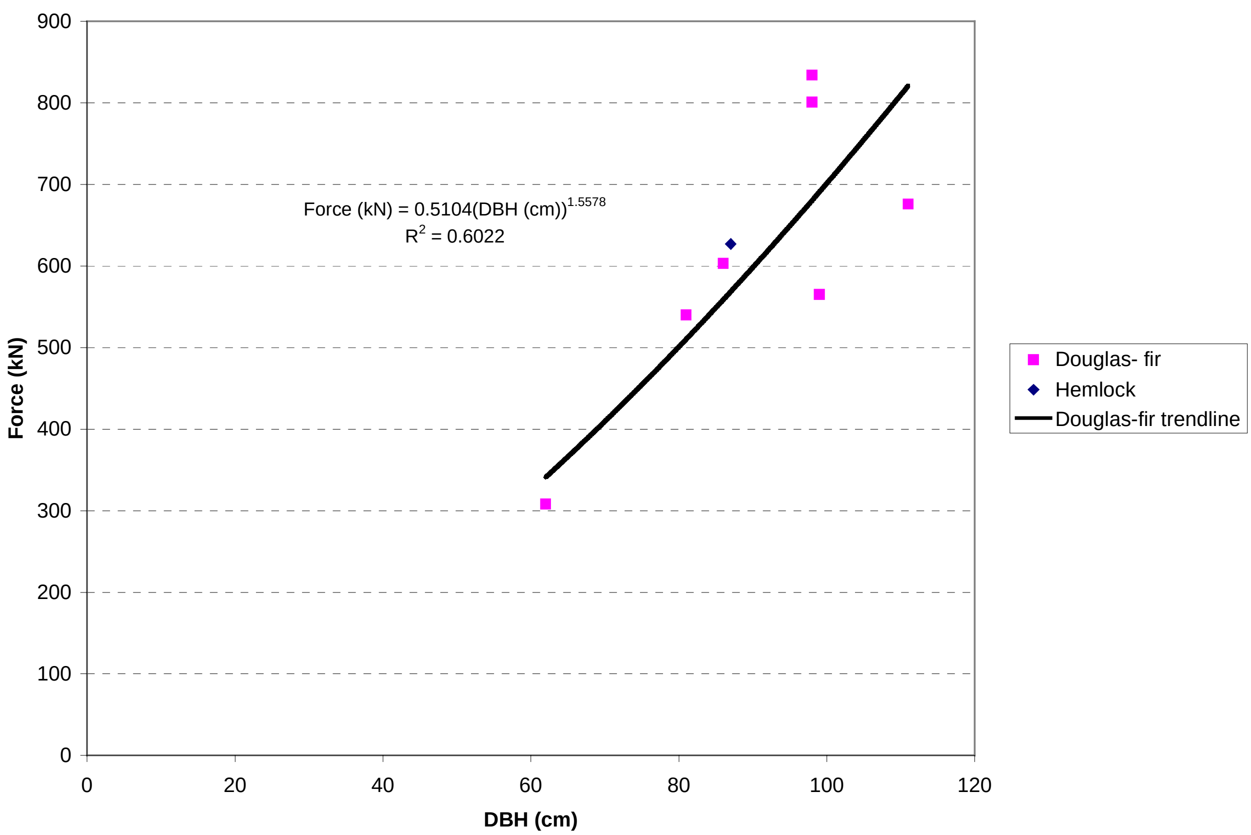

Figure 5. Relationship of Ultimate stump strength with estimated DBH

The failure mode was predominantly rotational (Figure 7). There were three cases where some surface sliding also occurred. Deformation was minimal in most cases (Table 1), with the greatest initial deformation of 9.1 mm for stump #7, which was mostly due to sliding.

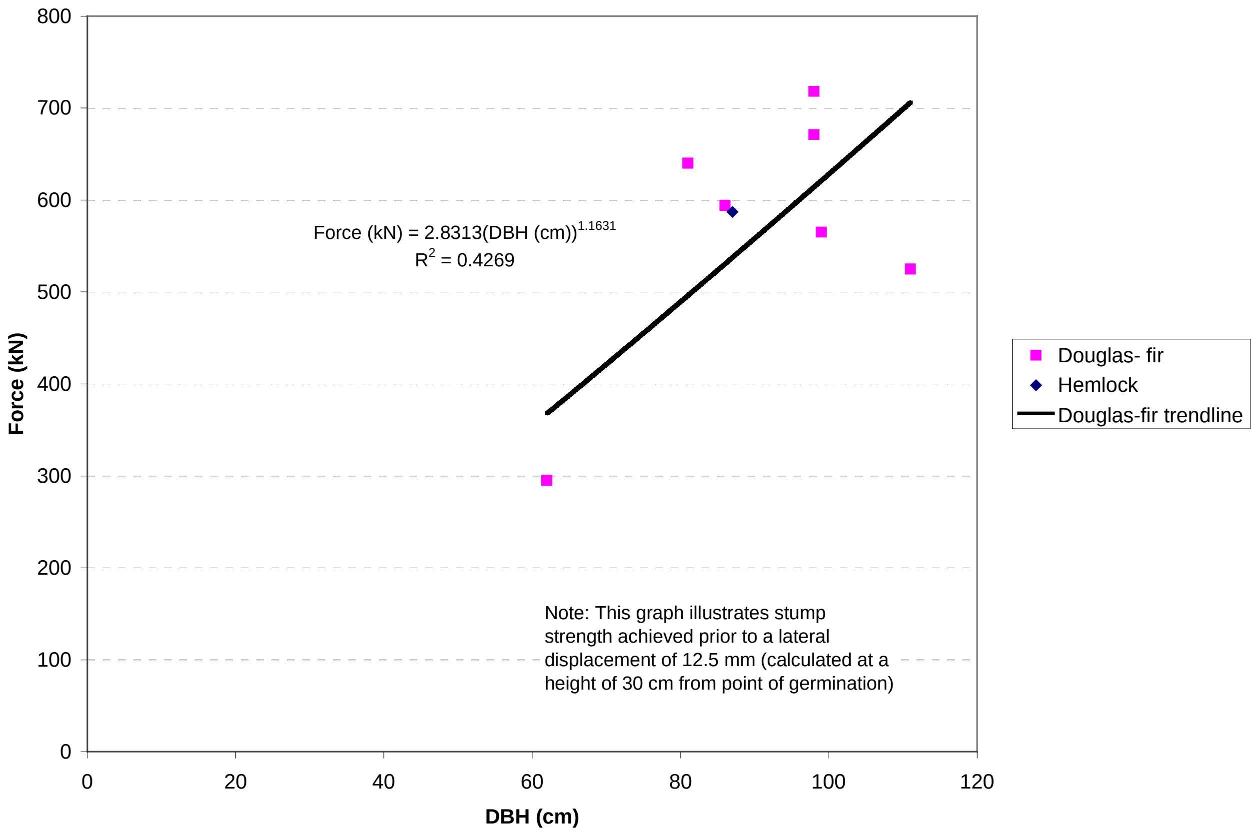

Figure 6. Relationship of stump strength at 12.5 mm lateral displacement with estimated DBH

CONCLUSIONS

1. This method presents a cost effective means of measuring stump strength to support short term roadfills.

2. The ultimate load required to pull the stump out of the ground ranged from a minimum of 308 kN to a maximum of 842 kN. The ultimate loads often occurred at significant lateral displacements (up to 77 mm).

3. A more appropriate design strength may be the load that is achieved prior to a lateral displacement of 12.5 mm. This load ranged from 295 kN to 718 kN.

4. The failure mode was predominantly rotational, with some surficial sliding, with deformations minimal in most cases

5. These tests provide rough site specific guidelines for utilizing stumps to support road fills, due to the variability of the data and limited number of samples.

Figure 7. Stump being pulled

RECOMMENDATIONS

Conduct further tests to obtain greater confidence in suitable design criteria for using stumps to support road fills on temporary roads.

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REFERENCES

Omule, S.A.Y., A. Kozak. 1989. *Stump and Breast Height Diameter Tables for British Columbia Tree Species.* Ministry of Forests Research Branch FRDA Victoria, 67 pp.

Peters, P.A. and C.J. Biller. 1986. *Preliminary Evaluation of the effect of vertical angle of pull on stump uprooting failure.* Proceedings of the 9th Annual Council on Forest Engineering , Mobile, AL. Sept. 29-Oct. 2, 1986, pp 90-93.

Pyles, M.R., J.W. Anderson and S.G. Stafford. 1991. *Capacity of second growth Douglas-fir and Western hemlock stump anchors for cable logging.* Journal of Forest Engineering, Vol. 3, No. 1, July 1991. pp29-37.

Smith, J. and S. McMahon. 1995. *Stump anchorage capacity on two contrasting soil types.* Logging Industry Research Organization Report, Vol. 20, No. 22, Rotorua, NZ. 6 pp.