UTC Project Information	
Project Title	Investigation of the Relationship between Formation Factor and Water Content of Fresh Concrete
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Funding Source(s) and Amounts Provided (by each agency or organization)	University of Washington PacTrans $7,500 Oregon State University $7,500
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Agency ID or Contract Number	DTRT13-G-UTC40
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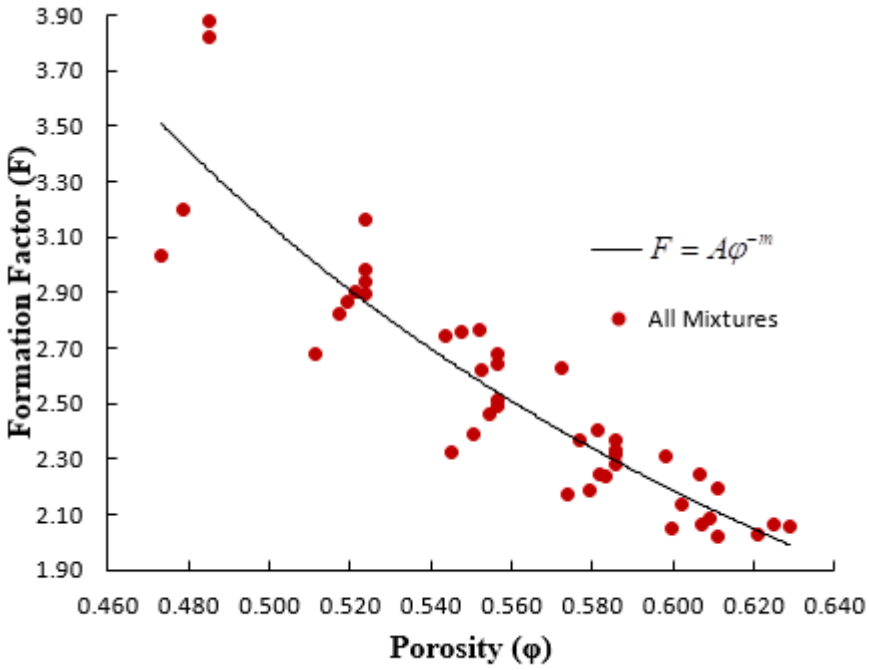
Brief Description of Research Project	Formation factor of concrete is directly related to critical performance indicators such as water-to-cementitious material ratio or porosity of concrete and provide information about both durability and mechanical performance of structures during their service life. The main objective of this research is to investigate the relationship between the formation factor and water content of fresh ordinary Portland cement concrete. This research will establish the groundwork for the future development of an in-situation measurement device for measuring formation factor of fresh concrete mixtures at job sites for improved QC and QA protocols. These protocols will provide significant improvements in the quality of the concrete used in transportation structures.

Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	Formation factor of fresh cementitious pastes was investigated experimentally as a function of time from initial mixing and mixture design properties such as supplementary cementitious material (SCM) replacement level, water-to-binder ratio (w/cm), and superplasticizer dosage. SCM types included fly ash, slag and silica fume. A total of 54 paste mixtures were studied. The formation factor of each fresh paste was determined at the 30th, 60th, and 90th minutes from initial mixing. It was shown that the formation factor of fresh cementitious pastes were strongly correlated with porosity, tortuosity and w/cm. Slag and fly ash considerably decreased tortuosity of the pastes, whereas silica fume did not have a significant effect. Superplasticizer addition increased tortuosity through a better distribution of the solid particles. A new model for the formation factor of fresh cementitious pastes was proposed. The model can be used to determine the initial setting time of cement-based materials. Figure below shows the relationship between the formation factor and the proposed model.  The main outcomes of this project have led to the next stage of this ongoing work to correlate formation factor to w/cm. In the future we hope to develop tools to obtain w/cm of the mixtures from fresh concrete that are delivered by ready-mix concrete trucks. This implementation was beyond the scope of this project, but it I expected that such tools will be available for engineering community.

Impacts/Benefits of Implementation (actual, or anticipated)	Each year approximately 10 billion tons of concrete is produced, making concrete the largest manufactured product globally [1]. The majority of this production is in the form of ready-mix concrete — it is estimated that the value of ready-mixed concrete produced in the US is approximately $35 billion per year. There are about 5,500 ready mixed concrete plants and approximately 55,000 ready-mixed concrete mixer trucks that deliver concrete to the point of placement. The quality control (QC) and quality assurance (QA) of this large operation have major economic, social and environmental implications. The quality of concrete is the most important factor that determine the long-term performance of a reinforced concrete structure. Achieving high quality concrete in construction projects involves the strict adherence to the established standards for specifying, ordering, mixing, delivering and curing, such as those defined by ASTM C94, the Standard Specification for Ready-Mixed Concrete. Despite all efforts and streamlined procedures, many newly constructed structures suffer from performance and long-term durability problems due to low-quality concrete. The issue can be traced back to existing QC/QA protocols of concrete production. Current QC protocols via ASTM C94 measure slump, unit weight and air content of the fresh concrete. While these measurements may have value, they do not provide the critical information to directly link to performance. They do not measure water content, porosity, strength or long-term transport properties that are related to durability. The absence of a QC protocol that directly assesses performance at the time of delivery is a major limitation. In the future, we expect that the outcomes of this project will open door for future work with the main objective of the development of an in-situ measurement device/protocol for formation factor of fresh concrete mixtures at job sites for improved QC and QA protocols. The device will provide a fast (within a couple of minutes) and direct (out-of-the-box) measurement of the formation factor of the fresh mixture right out of the concrete truck before placement, which then can be used to determine w/cm or other performance indicators of concrete. Currently no funding for such project was obtained; however, we are exploring opprtunities.
Web Links • Reports • Project Website	**Report:** O. Burkan Isgor, Hossein Sallehi, Pouria Ghods, Investigation of the relationship between formation factor and fresh properties of concrete, Final Report, Pacific Northwest Transportation Consortium, 2017, 44 pp. **Journal Paper:** Sallehi, H., Ghods, P., Isgor, O.B. (2018) Formation factor of fresh concrete pastes, Cement and Concrete Composites, 91: 174-188.