

## I. RESEARCH PROJECT TITLE: Best Practices for Concrete Pumping

**II. RESEARCH PROBLEM STATEMENT:** Good concrete air void spacing factors are required for freeze-thaw durability. Concrete pumping is known to change total air content, but it is not known how much the spacing factors are affected. Guidelines for materials, pumping equipment, and procedures would help improve durability while ensuring that concrete contractors can maintain productivity.

**III. RESEARCH PROPOSED OR RESEARCH OBJECTIVES:** Concrete pumping is known to affect the total air content and slump. Pumping is thought to reduce air content by dissolving some of the air voids into solution because of the high pressure, negative pressure created from sudden pressure decrease at the end of the hose, and impact knocking the air out of the concrete (Pleau, Pigeon, Lamontagne, & Lessard, 1995). It is thought that higher pumping pressures could correlate with higher air content loss because of these mechanisms (Jacobsen, Mark, Lee, & Haugan, 2008). Vertical pumping has been shown to lower air void contents much more than horizontal pumping, probably because of the lower pump pressures needed and less pressure difference at discharge (Yingling, Mullings, & Gaynor, 1992). Differences in concrete pumping equipment and attachments such as bladder valves can affect not just the pumping pressure but reduce the negative pressure at the end of the line and reduce the impact force (Lindquist, Darwin, & Browning, 2008). Information about how different types of attachments and pump types affect the pump pressure and air void systems will allow for durability guidelines to be developed.

Concrete material rheological properties, air entraining agents, and time from mixing to placement all influence the pumpability and finished product durability. Concrete rheology is often modeled with the Bingham Model as shown in Figure 1. The yield stress is correlated to the concrete slump, whereas the plastic viscosity can be correlated to the concrete flowability (Jacobsen, Mark, Lee, & Haugan, 2008). Pumpability has also been shown to correlate better with plastic viscosity than slump (Jacobsen, Mark, Lee, & Haugan, 2008). Measurement of not only the concrete slump, but actual concrete rheological properties will allow for guidance on mixture proportioning for pumpability for mixtures that are currently difficult to pump. Better aggregate gradations, higher fines content, and viscosity modifying admixtures have been shown to help with pumpability. It is unknown how these materials will affect the entrained air voids before and after pumping.

This project has the objectives of determining how changes in different materials allowed in low-cracking high-performance concrete (LC-HPC) mixtures affect the concrete rheology and air systems. The project will also go to concrete field placements with pumping to determine how different concrete mixtures and pumping conditions affect air void systems and slump.

**Task 1:** A literature review will be performed on the factors that affect concrete pumpability and rheology, air entrainment loss during pumping, and concrete pumping attachment options.

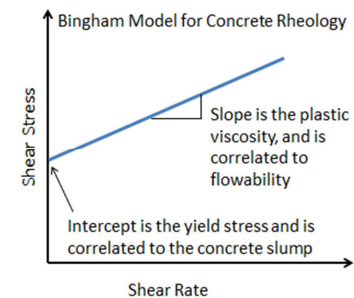


Figure 1 - Bingham model typically used for concrete rheology

**Task 2:** Laboratory mixtures to determine 1) how concrete plastic viscosity can be lowered for LH-HPC mixtures while maintaining the upper slump limit of 3.5". KSU is acquiring an ICAR rheometer that could be used to measure the true concrete rheological properties which relate to pumpability. Although it is not anticipated for this device to become a common quality control tool, it could be very useful in developing mixture guidelines to help with placement. Variables tested will include gradation, sand content, sand angularity and source, temperature, and the use of viscosity modifying admixtures. The use of nano-clay particles could also be tried as they have been shown to give concrete improved edge stability needed to prevent settlement cracking with very little effect on the flowability in pavements without the normal negative effects typically associated with clay use in concrete. These materials are also very low cost and are used in very small quantities to achieve these favorable properties.

**Task 3:** Field measurement of concrete properties before and after pumping at construction sites. Concrete air content and slump before and after pumping will be made for pumping operations conducted on KDOT construction projects. Hardened air voids samples will be made before and after pumping. Because it is not possible to sample the same exact concrete sample before and after pumping, a statistically representative number of samples for each site will be made. Sites will be selected in consultation with KDOT engineers to ensure a large variety of concrete pumping accessories, trucks, and materials are included in the study. Ideally, these sites will include both normal and LC-HPC concrete mixtures. Site access will need to be made to the KSU team by KDOT.

**Task 4:** Options for contractor and pump operator training will be evaluated in consultation with KDOT to help improve practice and implementation.

**Task 5:** Write final report.

Note: Kansas State University will be responsible for accomplishing all tasks unless noted.

**IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD:** \$68,000.00, 24 months

**V. URGENCY AND PAYOFF POTENTIAL:** Concrete pumping is used on a large percentage of structural concrete in Kansas. Improvement of pumped concrete durability will greatly decrease life cycle costs of concrete infrastructure.

**VI. IMPLEMENTATION STRATEGY:** Implementation of this study is expected to be carried out through training of contractors pump operators.

**VII. PROJECT PERSONNEL:** One graduate student will work on this project under the direction of Kyle Riding, principal investigator.

**VIII. SUBMISSION INFORMATION:** Date: 11/30/12

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