NEVADA DEPRTMENT OF TRANSPORTATION

FFY 2015 RESEARCH PROBLEM STATEMENTS

External Submission Form (Not to exceed 3 pages with font size 12)

I. PROBLEM TITLE: Phase I: Evaluation of Low Flexural Strength for Northern Nevada Concrete Paving Mixtures

II. PROBLEM DESCRIPTION: It is well-documented that difficulties are encountered when trying to obtain flexural strengths greater than 650 psi (in third-point loading) for concrete paving mixtures in Northern Nevada. An analysis of eight recently placed concrete pavement mixtures (five in Northern Nevada and three in Southern Nevada) found that on average, the Northern Nevada mixtures had 38 lbs/yd^3 more cementitious materials (696 vs. 658 lbs/yd^3), 0.03 lower water-to-cementitious materials ratio (*w/cm*) (0.386 vs. 0.417), and yet had a 12 percent lower 28-day flexural strength (664 vs. 745 psi). The use of higher cementitious contents and lower *w/cm* in an attempt to compensate for the lower flexural strengths is not only minimally effective, it is expensive and compromises the durability of the concrete pavements through an increased tendency toward shrinkage induced cracking, moisture warping, and susceptibility to materials-related distress such as alkali-silica reactivity.

The commonly stated reason for this difficulty is that the quality of aggregates in Northern Nevada is poor. Yet the problems with flexural strength persist even with the highest quality local aggregates that have absorptions of less than 1 percent and specific gravities near 2.70. Further, if the issue were one of "weak" aggregate, the mode of failure in a flexural strength beam would predominately be through the aggregate. Yet it is often observed that the failure plane passes around the aggregates through the interfacial transition zone (ITZ) that exists between the hydrated cement paste and the aggregate surface. There are a number of factors that can contribute to weakening of the ITZ including poor size distribution of cementitious materials, poor chemical compatibility between the cementitious materials, an aggregates surface chemistry that has an affinity for water, an aggregates surface chemistry with an affinity for entrained air bubbles, or dirty aggregates resulting in poor bonding. A systematic evaluation of the issues surrounding the poor flexural strength properties of Northern Nevada concrete paving mixtures is warranted to determine if cost effective strategies can be developed to increase strength while reducing the total cementitious contents to reasonable levels.

III. OBJECTIVE: The objective of this research is to determine the cause(s) of the poor strength characteristics of concrete paving mixtures in Northern Nevada and develop cost effective strategies, enforceable through specification modification, to improve strength and reduce the total mixture cementitious contents. The objective will be achieved in three phases. The Phase I objective is to synthesize the national body of knowledge on this topic and develop a research plan for conducting future phases of the research. The objective of the

Phase II laboratory investigation is to identify the cause of the problem and develop strategies to address it suitable for implementation in Nevada. The Phase III objective is to develop a prototype specification for implementation by NDOT. At the conclusion of this project, NDOT will have a fuller understanding of how to improve the flexural strength of concrete paving mixtures while reducing cementitious content and a prototype specification for Stage IV implementation as noted under Section VI.

IV. CURRENT PRACTICE and RELATED RESEARCH: As discussed, NDOT is well aware of the problem it faces in achieving adequate flexural strength for concrete paving mixtures in Northern Nevada using normal amounts of cementitious materials (6 sacks or less). A few national reports on this topic include:

- Gullerud, K., and S. Cramer. 2002. *Effects of Aggregate Coatings and Films on Concrete Performance.* WHRP #0092-00-07. September. This report details a study of aggregate coatings in Wisconsin, finding that although overall the effects were minor, clay coating were more deleterious with regards to the development of strength.
- Munoz, J.F., M.I. Tejedor, M.A. Anderson, and S. Cramer. 2007. *Expanded Study on the Effects of Aggregate Coatings and Films on Concrete Performance.* WHRP #0092-04-12. September. This follow up study specifically examined the influence of clay microfines and test methods to detect them.
- Forster, S. 2006. "Chapter 21 – Soundness, Deleterious Substances, and Coatings." *Significance of Tests and Properties of Concrete and Concrete-Making Materials.* STP 169D. Edited by J. Lamond and J. Peilert. ASTM International. April. This chapter discusses the creation and impact of aggregate coatings on concrete behavior including strength.
- Ley, T., and K. Hover. *Observations of Entrained Air Voids in Fresh Cement Paste.* PCA R&D Serial No. 2987. Portland Cement Association. Skokie, IL. This report discusses the formation of air voids in cement paste including the phenomenon of air-void clustering at the cement paste-aggregate interface.
- Vosahlik, J. 2014. *Air Void Clustering in Concrete.* M.S. Thesis at Kansas State Univerity. This thesis investigates air void clustering around coarse aggregates in concrete, identifying it as a cause of low strength.

V. RESEARCH METHODOLOGY: The research methodology is presented in the following three phases, with each subsequent phase being initiated only after successful completion of the previous phase:

Phase I: Synthesis and Phase II and III Research Plan (Duration: 9 months)
Task I-1: State-of-the-practice synthesis and current NDOT practice
Task I-2: Development of draft Phase II Research Plan
Task I-3: Phase I Report and approval of Phase II and III Research Plan

Phase II: Laboratory Evaluation of Mixtures (Duration: 18 months)
Task II-1: Selection of materials for use in study
Task II-2: Testing of initial mixtures
Task II-3: Detailed testing of revised mixtures
Task II-4: Development of Phase III Research Plan
Task II-5: Phase II Report and approval of Phase III Research Plan

Phase III: Field Trials and Implementation (Duration: 24 months)
Task III-1: Development of draft specification
Task III-2: Identification of field trials
Task III-3: Material testing
Task III-4: Construction of field trials
Task III-5: Finalization of prototype specification for Stage IV implementation
Task III-6: Final Report

Through execution of all three phases of this study, NDOT will have a prototype specification for Stage IV implementation that addresses low flexural strengths of concrete paving mixtures in Northern Nevada.

VI. IMPLEMENTATION POTENTIAL: Phase I addresses Stage I – Concept, Phase II the Stage II – Laboratory Prototype, and Phase III the Stage III – Controlled Field Demonstration. Implementation will follow successful completion of Phase III.

VII. URGENCY AND PAYOFF POTENTIAL: It is documented that achieving adequate flexural strength for paving grade concrete in Northern Nevada is difficult, and this is resulting in high cementitious content mixtures that are prone to cracking. There is an immediate need to understand the cause of this lack of strength and develop specification to reduce the risk in the future. The additional cost of high cement content concrete mixtures and compromised long-term pavement performance is enormous and thus the payoff for successfully achieving the project objective in improving concrete strength while reducing cementitious materials content is great.

VIII. ESTIMATED BUDGET: Total for three phases estimated at $420,000
Phase I: $45,000
Phase II: $250,000
Phase III: $125,000 (not including NDOT's contribution)

IX. DATE AND SUBMITTED BY: Submitted September 30, 2014 by Thomas Van Dam, Principal, NCE, 1885 S. Arlington Dr., Suite 111, Reno, NV, 89509; 775-329-4955 (p), 775-329-5098 (f); tvandam@ncenet.com.

X. NDOT CHAMPION, COORDINATION AND INVOLVEMENT
NDOT Champions are Darin Tedford, Michele Maher, and Troy Olson from the Materials Division.
Coordination with NDOT is required in all phases of the project. In Phase II, additional NDOT assistance will be required to identify materials for testing and in Phase III, NDOT will need to coordinate implementation in the field.

Five Stages of Research Deployment (Based on Caltrans Research and Innovation Stages)

1. Concept Stage (Stage I)

- First steps following Problem Statement and Proposal Development
- Includes detailed literature search
- Involves experimental design, data collection, analysis, and reporting
- Assesses results of research
- Defines barriers to implementation (e.g., policies, specifications, standards)
- Submits a Final Report and outlines a recommended implementation plan
- Includes collaboration with outside agencies or other state DOTs and US DOT
  (Applies to all Stages of Deployment)

2. Laboratory Prototype Stage (Stage II)

- Develops breadboard circuit or computer system modeling
- Demonstrates operation in laboratory setting
- May incorporate customized or one-of-a kind components
- Assesses results
- Submits Final Report and recommends design of full scale demonstration
- Potential end users are enlisted to support the field pilot stage

3. Controlled Field Demonstration Stage (Stage III)

- Prepares for full scale testing of demonstration project
- Controlled tests at specialized facilities are observed and supported by cooperating agencies, industry, and technical associations
- Potential end users are enlisted to support the field pilot stage
- Assesses results
- Submits Final Report and recommends site/conditions for first application pilot stage

4. First Application (Contract) Field Pilot Stage (Stage IV)

- Works with potential end users to select site and to conduct pilot testing under real world operating conditions
- Test specifications and standards are developed
- Research assistance given to assure proper installation and operation
- Problems are corrected and adjustments made, as necessary, to complete pilot testing
- To the extent possible, potential end users operate the project under careful research surveillance
- Assesses results
- Submits Final Report and recommends initial sites for full corporate deployment
- Potential end users are enlisted to support the field pilot stage

5. Specification & Standards with Full Deployment Stage (Stage V)

- End users select site(s) and deploy the method/process/equipment using resident management, supervision, staff, and contracting forces (where applicable)
- Deployment is without research supervision or direction
- On call assistance is available upon request
- Assesses results