Impact of Hydrated Cement Paste Quality and Entrained Air-Void System on the Durability of Concrete

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Background

- Concrete mixtures have undergone numerous changes in recent years
- As the mixtures have changed, the research linking air-void system parameters to performance has not been updated
- The research used to establish the current air content requirements was predominately conducted prior to 1970
- Changes that have occurred (e.g. lower *w/cm*, use of SCMs, synthetic AEAs) affect not only the quality of the hydrated cement paste but also the characteristics of the entrained air-void system

Objectives

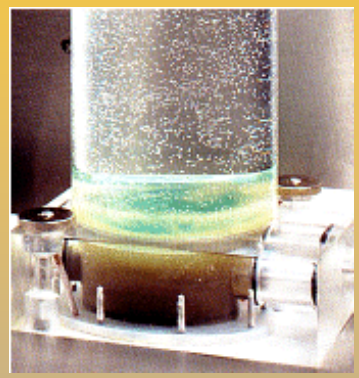
- Review the current accepted relationship between the quality of HCP and the air-void system and how it affects the F-T durability of concrete
- Conduct a phased laboratory study to evaluate how recent changes impact the quality of HCP and air-void system and how this influences the F-T durability of the concrete
- Make recommendations to improve the F-T durability and cost effectiveness of concrete mixtures currently being used in Michigan
- Utilize newly available equipment to assess the *w/cm* and air-void system in fresh concrete, correlating the results with those obtained using accepted analytical techniques
- Based on this research, recommendations will be made regarding potential implementation of promising equipment to improve construction quality control and quality assurance

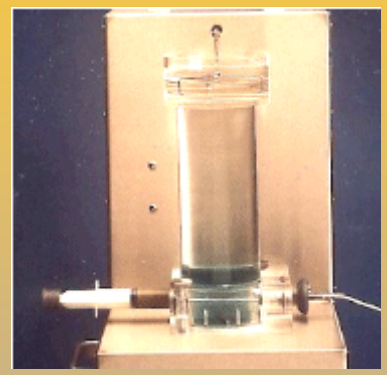
Approach

- *Review of Existing Literature*
  - How the durability of concrete is affected by the quality of the hydrated cement paste (HCP) and the presence of a properly entrained air-void system
  - Recent work focusing on the use of SCMs and non-vinsol resin air entrainers will be examined
  - Emerging laboratory test equipment and protocols will be reviewed for use in this study

Approach

- *Emerging Methods to Evaluate*
  - AVA
  - Calorimetry
  - Cementometer
  - Automated CTE
  - Microwave Water Content





Approach

- *Phase II Experiment: Combined Full- and Partial- Factorial*
  - One cement type: a Lafarge Type I/II
  - Two cement factors: 564 lb/yd^3 and 470 lb/yd^3
  - Three SCMs: none, Class C fly ash, and a Grade 100 ground blast furnace slag
  - Two AEAs: one vinsol resin and one synthetic
  - One coarse aggregate: a durable carbonate
  - Two aggregate gradings: gap gradation and optimized
  - Fine aggregate volume will be altered to adjust yield with changes in *w/cm*
  - Two *w/cm*: 0.45 and 0.55
  - Two fresh air contents: 3 ± 1% and 6 ± 1%

Approach

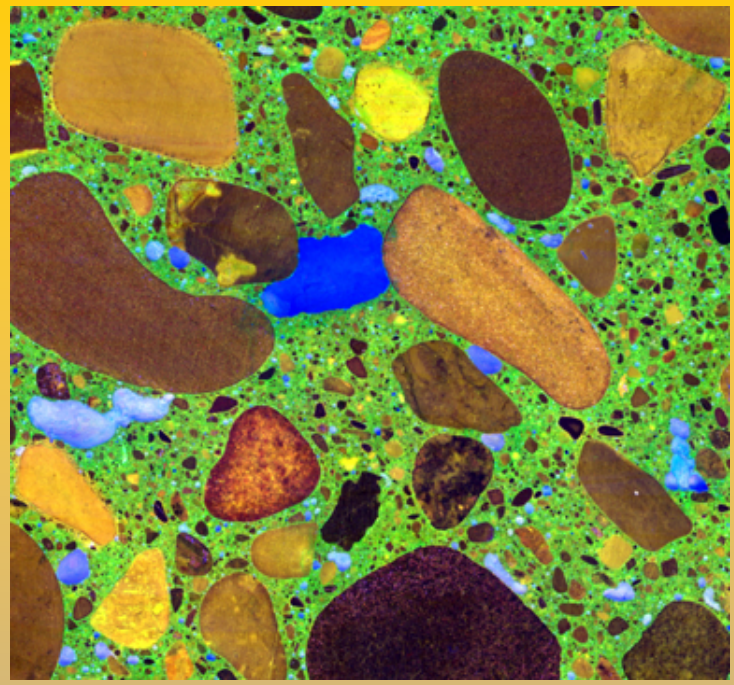
- *The testing conducted will be used to assess a number of fresh concrete properties including:*
  - Slump (ASTM C143)
  - Determination of air content using the pressure (ASTM C231), volumetric (ASTM C173) and gravimetric method (ASTM C138)
  - Air-void system parameters using the AVA
  - Unit weight and yield (ASTM C138)
  - Calorimetry to determine heat signatures of concrete and additional supplemental testing on mortar
  - Maturity (ASTM C1074)
  - Water content by microwave method (AASHTO T 318) and Cementometer

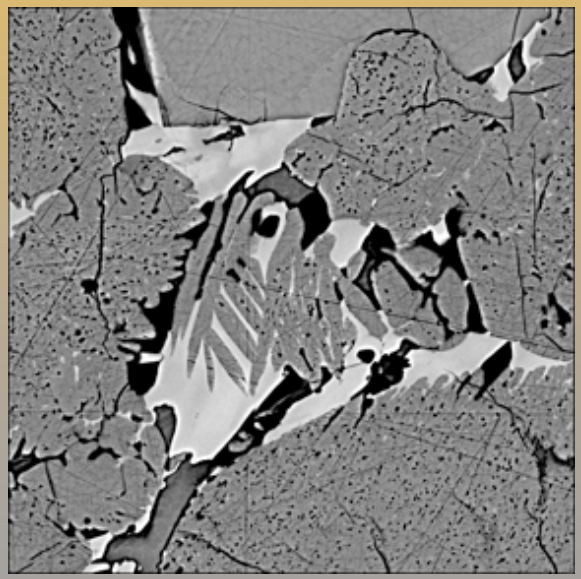
Approach

- *The testing conducted will be used to assess a number of hardened concrete properties including:*
  - Compressive strength (ASTM C39) at 7, 28, and 90 days
  - Determination of air-void system parameters using ASTM C457
  - Sorptivity after 56 days (ASTM C1585)
  - F-T durability (ASTM C666B)
  - Limited analysis of thin sections to estimate *w/cm* content of concrete

- Benedict Laboratory - AMRL Accredited
  - 15,000 ft^2 laboratory space for concrete research
  - Mixing, curing, physical testing - laboratory and large scale testing

Materials Characterization





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Approach

- *Purpose of the testing is to assess how:*
  - Changes in the concrete mixture (e.g. *w/cm*, type of SCM, type of AEA, reduced cementitious content, etc.) affect the fresh and hardened concrete properties
  - Changes in the cementitious system (cement, SCM), *w/cm*, cement content, AEA, air content, and air-void system parameters impact the freeze-thaw durability of the concrete
  - Emerging technologies can be used to test the properties of fresh concrete
  - Results from emerging technologies relate to the properties of hardened concrete

Follow-Up

- *Phase III Testing*
  - Additional experiments to fill in the gaps that are observed
  - Examine correlations between fresh and hardened properties
  - Test additional materials as identified in previous testing
- *Recommendations will be made with regards to implementing the results as justified and for future work as needed to fill in any remaining knowledge gaps*

Summary

- *New baseline information regarding the hardened cement paste systems in today's paving concrete*
- *Project will provide valuable information to help establish the effectiveness of new testing methods*
- *Provide information to augment and support the mix design track being discussed*

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