Florida Department of
TRANSPORTATION

Summary of Concrete Research Projects Funded by the Structures Section of the State Materials Office

Dale DeFord

Structural Materials Research Specialist

State Materials Office

Presented at the 2014 FDOT-Concrete Coalition of Florida Meeting
February 26, 2014

Active Projects

Effects of Chemical and Mineral Admixtures on Performance of Florida Structural Concrete

- Develop better understanding of the effects of chemical and mineral (supplemental cementitious materials, SCMs) admixtures on the hydration and strength development of portland cement concrete (PCC).
- Mineral and chemical admixtures are used extensively in Florida structural concrete elements.
- Physical properties of PCC are controlled by the microstructure that develops during hydration.
- To tailor the properties of concrete, need to tailor the hydration to produce the concrete microstructure needed to deliver the desired properties (performance-based specifications).

Evaluation of Alternative Pozzolanic Materials for Partial Replacement of Portland Cement in Concrete

- Need to find or develop new sources of pozzolanic materials - the future availability of high quality pozzolans currently specified by FDOT will probably become insufficient.
- Candidate materials include Class C fly ash, any highly siliceous ashes such as rice husk and sugar cane bagasse ash, and pulverized waste glass.
- Of particular interest are Class C fly ash and pulverized waste glass.
  - Class C fly ash is commercially available and is in common use in other parts of the country. Could be implemented quickly.
  - Pulverized waste glass is abundantly available - requires considerably more research and development. Implementation will depend on development of supply chain.

Long-Life Slab Replacement Concrete

- Objectives:
  - Identify the factors or parameters contributing to the cracking of concrete replacement slabs on FDOT projects.
  - Recommend changes to FDOT specifications and/or procedures that will minimize the occurrence of cracking of concrete used for Florida DOT slab replacement projects.

Goal – Reduce incidence of cracking to ≤ 1%.

Effects of Coarse Aggregate on the Physical Properties of Florida Concrete Mixes

- Investigate the effects of coarse aggregate sources on the strength, physical, thermal, and durability properties of concrete.
  - Enable Structures Design to use accurate physical property data in the design of structural concrete members
  - Provide necessary data used for inputs to the VCCTL program to predict the physical properties of any FDOT mix designs
  - Help insure the safety and durability of FDOT structural concrete
  - Aid in the development of performance-based specifications
- Recommendations will be made for revisions to the FDOT Standard Specifications for Road and Bridge Construction.

Development of Design Parameters for Virtual Cement and Concrete Testing

- Enable accurate prediction of concrete mix behavior and properties without physical testing (also known as virtual testing)
- This would greatly reduce the amount of actual physical testing needed to:
  - Develop new concrete mix designs
  - Predict performance of a concrete mix design (Performance-based specification and testing)
  - Optimize/attain a desired property value.

Corrosion Evaluation of Novel Coatings for Steel Components of Highway Bridges

- Goal is to identify corrosion coatings that have the potential to outperform currently used coatings – increase lifespan of structures and reduce maintenance costs.
- Phase I – identify promising coatings based on results of accelerated testing.
- Phase II – Evaluate long-term durability and corrosion resistance of corrosion coatings chosen from Phase I

Accelerated Slab Replacement Using Temporary Precast Panels and Self-Consolidating Concrete (SCC)

- Main goal is to develop system to improve the efficiency of concrete slab replacement
- Reusable temporary precast panels, made from SCC, for temporary slab replacement
- Benefits for concrete pavement rehabilitation projects:
  - Accelerated construction,
  - Reduced MOT, improved safety, cost savings,
  - Reduction in cracking of replacement slabs – longer cure times before opening to traffic.

The Structural and Durability Performance of Glass Modified Concrete

- Multiscale investigation of the structural properties (strength, and fracture characteristics) and durability performance (chloride ion permeability and alkali-silica reaction (ASR)) of concrete modified with micron-size glass powder.
- Develop predictive numerical models to facilitate the design of glass-modified concrete.
- Perform cost-benefit analysis pertaining to the incorporation of waste glass in concrete

Maximum Heat of Mass Concrete - Phase 2

- Build a database of rate of heat production for different cement blends used in Florida mass concrete. Use data for inputs to DIANA software for the modeling of mass concrete structures in Florida
- Evaluate typical segmental bridge pier segments used in Florida to determine if some need to be treated as mass concrete
- Determine insulating properties of different soils under various moisture conditions to use in thermal analysis of footings placed on the soils
- Further develop the user-friendly DIANA software

Development of Standard Operating Procedure for Analysis of Ammonia Concentrations in Coal Fly Ash

- Develop means of testing fly ash for ammonia content
  - Equipment economical and easy to operate
  - Methods simple and easy
- Provide method to fly ash distributors to determine the ammonia content of their fly ash

Internally Cured Concrete for Pavement and Bridge Deck Applications

- Main goal is to reduce cracking in structural applications such as bridge decks.
- Fine lightweight aggregate (LWA, expanded shale) used to partially replace normal fine aggregate.
- LWA acts as an internal water reservoir, providing water as needed for curing.
  - Faster and more complete curing due to the prevention of self-desiccation.
- Benefits include improved strengths, lower porosity, and reduced shrinkage and cracking.

Slab Replacement Maturity Guidelines

- Primary goal - determine if maturity method can identify early-age strength of pavement slab replacement concrete for opening within a 4-6 hour window
- Develop guidelines for use of maturity method to determine when opening strength attained instead of using cylinder strengths
- Develop best construction practices for using maturity method

Ground Tire Rubber (GTR) as a Component Material in Concrete Mixtures for Paving Concrete

- Determine optimum particle size or gradation of GTR for pavement concrete.
- Determine replacement % of GTR for the fine and/or coarse aggregate.
- Identify optimum moisture content, storage conditions, order of addition and mixing, w/cm ranges, air contents
- Establish effects on density, strength, elastic modulus, and thermal expansion

Impact of Aging on the Rheology of Post-Tensioning (P-T) Grouts

- Objective – Determine factors affecting the rheology of P-T grouts. Most P-T grout durability problems from unacceptable bleeding and segregation, and degradation due to aging (rheological problems)
- Goals:
  - Determine chemical and rheological effects of aging on P-T grouts
  - Quantify rheological behavior of properly formulated grouts and to establish procedures to identify improperly formulated grouts

Highly Accelerated Lifetime for Externally Applied Bond Critical Fiber Reinforced Polymer (FRP) Infrastructure Materials

- Primary goal - investigate the limits of accelerated testing for externally bonded and near-surface mounted (NSM) carbon FRP composites
- Identify limits for conditioning protocols
- Propose new conditioning protocols that can be used for accelerated testing.

Development of Laboratory Test Method to Replace the Simulated High-Temperature Grout Fluidity Test (HTGF)

- Use HTGF test and dynamic shear rheometer (DSR) tests to fully characterize grout fluidity properties
- Create test method for post-tensioning (P-T) grout that:
  - Is calibrated to the simulated HGTF test
  - Can be conducted using a DSR
  - Can be used to ensure that prepackaged P-T grouts will perform adequately.

Simulation of Prepackaged Grout Bleed Under Field Conditions

- Main objective - determine the cause of bleed and segregation problems in pre-packaged post-tensioning grouts.
- Secondary objective - determine if a relationship exists between the fluidity of the grout, as determined by the DSR, and grout bleed and segregation

Recently Completed Projects

Assessment of Potential Concerns Associated with the Use of Cement Kiln Dust in FDOT Concrete Mixes

- Particulate matter generated by cement kiln and removed from stack emissions (baghouse flue dust, BFD)
  - Most BFD recycled into kiln feed
  - Some BFD used as inorganic processing addition to cement
  - Waste (does not meet ASTM C465) is CKD
- Objective - assess potential mercury releases to air and water during the storage and handling of BFD and concrete containing BFD
- Findings – Use of BFD in Concrete:
  - Worker-safe and environment-friendly
  - Important component of plan to reduce environmental mercury

Effects of Portland Cement Particle Size on Heat of Hydration (HOH)

- Objective - identify the effect of cement fineness on heat generated by portland cement (PC)
- Findings:
  - Cement fineness correlates better to 7-day (HOH) than typically used heat index - $C_3S + 4.75\ C_3A$
  - Finer cements shrink more than a coarser cements
  - Finer cements have lower activation energies
  - For Type II moderate heat (MH) PC to be used in structural concrete elements where there is risk of thermal cracking, recommend that limits be placed on the HOH, the Blaine fineness, and heat index

Proposed Projects

Quantitative Mineralogical Characterization of Portland Cement-Based Cements and Cementitious Materials

- Need capability to analyze:
  - Supplemental cementitious material-portland cement combinations,
  - Portland-limestone cements, and
  - Blended portland cements.
- Uses:
  - QPL certifications,
  - Cement and cementitious material evaluations,
  - Forensic analyses of cementitious materials.

Permeability Evaluation of Structural Concrete Using Intrusion Porometry

- Justification - Proper quantification of permeability is important to gage anticipated durability and service life of structural concrete
- Objectives:
  - Use intrusion porometry to evaluate permeability of concrete
    - Mercury intrusion porosimetry (MIP)
    - Capillary flow porometry
  - Compare to RCP and Surface Resistivity

Development and Field Evaluation of Mix Designs for Concrete Pavement Slab Replacement

- Follow-up to Extension of Long-Life Slab Replacement Concrete project.
- Develop compositions with a range of setting times
  - Design to minimize thermal and shrinkage cracking
  - Choose mix designs based on opening time windows
  - Switch to more accelerated mix designs as approach minimum window to open