



Fly Ash Replacement and Performance in Concrete Pavement

Prepared for
**WHRP Rigid Pavements
Technical Oversight Committee**

Prepared by
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WisDOT Research & Library Unit**

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Topic/Problem Statement: Document literature from 2000 to the present relevant to a study of fly ash replacement of cementitious materials in portland cement concrete pavement by weight and by volume. A new Wisconsin study will evaluate fly ash as a supplementary cementitious material for replacement of cement by weight or volume in terms of performance and performance-based specifications, and will include mix proportions, admixture use, and concrete properties such as slump, air content, chloride permeability and more.

Keywords: Fly, ash, concrete, cement, pavement, performance, performance-based, weight, volume.

Summary

We found 19 published articles and reports related to fly ash and concrete pavement performance from 2000 through 2007. Another five projects are under way.

Of the 19 published documents, five articles were published in an Indian concrete industry journal, and nine in academic journals and conference proceedings; the remaining pieces were state reports and papers in TRB journals and industry journals. Five of the 19 projects were published in 2005, four in 2004, and three each in 2007 and 2003. One was published in 2002 and one in 2001, and two state reports in 2000 (one from Texas, the other from Nevada).

The research in progress includes studies by NCHRP, by transportation agencies in Arizona, Florida and Mississippi, and by Montana State University.

Citations

Results are listed chronologically, with the most recent citations shown first. Links to online copies of cited literature are provided when available. Contact the WisDOT Library to obtain hard copies of citations.

Title: Effect of a polyethylhydrosiloxane admixture on the durability of concrete with supplementary cementitious materials

Author(s): Konstantin G. Sobolev, Vladimir G. Batrakov

Date: October 2007

Source/URL: *Journal of Materials in Civil Engineering*, Vol. 19 (10), October 2007: 809-819.

Description: 11 pp.

Contents: This paper assesses durability of a high-strength concrete with large volumes of supplementary cementitious materials modified by a polyethylhydrosiloxane-based admixture and a superplasticizer. The study introduces the concept of a modified multicomponent binder, comprised of portland cement, finely ground supplementary cementitious material (fly ash, ponded ash, or granulated blast furnace slag), and a highly reactive powder component (usually silica fume), modified by a superplasticizer. The research program included tests of water permeability, freezing and thawing resistance, and the investigation of the effect of the binder on the passivation of steel reinforcement. The observations indicated that the use of the superplasticizer and polyethylhydrosiloxane admixtures yields the required air content and air void spacing factor for the freezing and thawing resistance, and the passivation of steel reinforcement. The research confirmed that the polyethylhydrosiloxane admixture has a beneficial effect on the durability of concrete with large volumes of supplementary cementitious materials. The results have important implications for offshore structures, bridges, roadways, pavements, foundations, precast concrete, and other applications.

Title: Evaluation of properties of high-volume fly-ash concrete for pavements

Author(s): Binod Kumar, G.K. Tike, P.K. Nanda

Date: October 2007

Source/URL: *Journal of Materials in Civil Engineering*, Vol. 19 (10), October 2007: 906-911.

Description: 6 pp.

Contents: The work reported in this paper is based on a laboratory study of superplasticized high-volume fly-ash (HVFA) concrete suitable for pavement construction. Three control concrete mixtures having 400 kg/ m³ of ordinary portland cement (OPC) and water-cementitious material (w-cm) ratios of 0.30, 0.34, and 0.40 were prepared. Other concrete mixtures were then prepared by substituting 20, 30, 40, 50, and 60% fly ash in all control mixtures. Compressive and flexural strengths at ages of 7, 28, 90, 180, 256, and 365 days, drying shrinkage, and abrasion resistance of concrete were measured for all the mixtures. The laboratory test results showed that HVFA concrete mixtures containing 50-60% fly ash can be designed to fulfill the requirement of strength and workability suitable for cement concrete pavement construction. At all w-cm ratios, the concrete mixture containing 60% OPC and 40% fly ash developed maximum strength at the age of 90 days and beyond. However, a maximum increase in the strength of concrete at 365 days over the 28 days strength was observed in the mixtures containing equal amount of OPC and fly ash. Drying shrinkage of concrete decreased with decreasing w-cm ratio and increasing fly-ash content. Among all the concrete mixtures, the mixture with w-cm ratio of 0.30 and containing 60% fly ash showed least shrinkage. Abrasion resistance of concrete, measured by the sand-blasting method, decreased with increasing fly-ash content and decreasing compressive strength. However, abrasion resistance of HVFA concrete mixture with 60% fly ash at 0.30 w-cm ratio was adequate from concrete-pavement considerations.

Title: Synthetic glass models for investigating fly ash reactivity

Author(s): W. Bumrongaroen, S. Swatekititham, R.A. Livingston, J.J. Schweitzer

Date: 2007

Source/URL: *Ninth CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete*, 2007: 227-242.

Description: 66 pp.

Contents: The development of performance-based standards for fly ash requires an improved understanding of reactivity of the material. The theory of the chemical durability of glass can provide a basis for this understanding in terms of the influence of the fly ash glass chemical composition. However, it is difficult to study this in real fly ashes because of the heterogeneity in chemical composition and mineralogy from one particle to another. It is not practical to isolate particles of specific glass samples with appropriate compositions. To explore this approach some calcium aluminum silicate glasses have been prepared with compositions that were selected to span the ranges measured in representative fly ashes. After characterization of the silicate specification of the glasses using Raman spectroscopy, the reactivity of the synthetic fly ashes was measured using the complementary methods of single pass

flow through leaching and nuclear resonance reaction analysis. The results showed agreement with glass durability theory and demonstrated the advantages of using a synthetic glass model for fly ashes. Synthetic fly ash glass does not completely simulate actual fly ashes, but it does make it possible to investigate the effects of chemical composition of reactivity in isolation from the effects of particle size distribution and mineral components.

Title: Deicing salt-scaling resistance: laboratory and field evaluation of concrete containing up to 70% class C and class F fly ash

Author(s): Tarun R. Naik, Rudolph N. Kraus, Bruce W. Ramme, Yoon-Moon Chun

Date: July/August 2005

Source/URL: *Journal of ASTM International*, Vol. 2 (7), July/August 2005: 93-104.

Description: 12 pp.

Contents: Laboratory mixtures, pilot mixtures, and field construction mixtures were made to evaluate salt-scaling resistance of concrete incorporating large amounts of either Class C fly ash obtained from several different sources or Class F fly ash. The laboratory mixtures that incorporated Class C fly ash up to a fly ash to cementitious materials ratio (FA/Cm) of 60% by mass exhibited very slight to moderate scaling. Results from the pilot mixtures indicate that it is possible to produce structural-grade, salt-scaling resistant concrete using up to 56% Class C fly ash. Specimens of a field mixture containing 50% Class C fly ash showed moderate to severe scaling, and specimens of a field concrete with 40% Class F fly ash showed slight to moderate scaling. These field mixtures exhibited satisfactory salt-scaling resistance in actual pavements. Comparisons of strength and scaling results suggest that it would be beneficial to allow sufficient time for high-volume fly ash concrete to develop strength before it is subjected to salt-scaling actions.

Title: Use of fly ash in structural concrete: Part II – How much?

Author(s): A.K. Mullick

Date: June 2005

Source/URL: *Indian Concrete Journal*, Vol. 79 (6), June 2005: 10-14.

Description: 5 pp.

Contents: In the first part of the paper, various reservations regarding the use of fly ash in structural concrete were addressed. It was demonstrated how a host of engineering properties of concrete, especially its durability were improved with the incorporation of fly ash. In this second part, the author discusses the modes of fly ash use—as factory-produced blended cement and as a part replacement of ordinary portland cement in ready-mixed concrete plants. Various technologies such as high volume fly ash concrete, roller compacted concrete are described along with their applications for pavements and dams.

Title: Strength properties of high-volume fly ash roller compacted and workable concrete, and influence of curing condition

Author(s): Cengiz Duran Atis

Date: June 2005

Source/URL: *Cement and Concrete Research*, Vol. 35 (6), June 2005: 1112-1121.

Description: 10 pp.

Contents: A laboratory investigation was carried out to evaluate the strength properties of high-volume fly ash (HVFA) roller compacted and superplasticised workable concrete cured at moist and dry curing conditions. Concrete mixtures made with 0%, 50% and 70% replacement of normal Portland cement (NPC) with two different low-lime Class F fly ashes, good and low quality, were prepared. Water-cementitious material ratios ranged from 0.28 to 0.43. The compressive, flexural tensile and cylinder splitting tensile strengths were measured and presented. The relationship between the flexural tensile and compressive strengths was discussed. The influence of loss on ignition (LOI) content of fly ash on water demand and the strength of concrete was also discussed. The influence of moist and dry curing conditions on the high-volume fly ash (HVFA) concrete system was assessed through a proposed simple efficiency factor. The study showed that producing high-strength concrete was possible with high-volume fly ash content. LOI content increased the water demand of fresh concrete. HVFA concrete was found to be more vulnerable to dry curing conditions than was NPC concrete. It was concluded that HVFA concrete was an adequate material for both structural and pavement applications.

Title: Development of a shrinkage performance specifications and prediction model analysis for supplemental cementitious material concrete mixtures

Author(s): David W. Mokarem, Richard E. Weyers, D. Stephen Lane

Date: May 2005

Source/URL: *Cement and Concrete Research*, Vol. 35 (5), May 2005: 918-925.

Description: 8 pp.

Contents: As concrete cures and dries, tensile stresses are created due to hydration and loss of moisture. This article reports on a study that assessed the unrestrained shrinkage and the restrained cracking tendency of concrete mixtures typically used by the Virginia Department of Transportation (VDOT). The authors were trying to establish an appropriate limit on drying shrinkage for use in a performance specification. Five existing shrinkage prediction models were assessed to determine the accuracy and precision of each model as it pertains to the VDOT mixtures used in this study. The five models assessed were the ACI 209 Code Model, Bazant B3 Model, CEB90 Code Model, Gardner/Lockman Model, and the Sakata Model. The authors conclude that the Gardner/Lockman Model performed best for the supplemental cementitious material (SCM) mixtures (those include fly ash and slag cement). The authors also conclude that the potential for cracking could be minimized by limiting the unrestrained shrinkage of the concrete mixtures. The recommended percentage length change specification limits for the supplemental cementitious material mixtures are 0.0400 at 28 days and 0.0500 at 90 days.

Title: Reducing greenhouse gas emissions in Texas with high-volume fly ash concrete

Author(s): Cindy K. Estakhri, Donald Saylak

Date: 2005

Source/URL: *Transportation Research Record No. 1941*, 2005: 167-174.

Description: 8 pp.

Contents: The objective of this study was to determine the potential for reductions in carbon dioxide emissions in Texas by substituting high volumes of fly ash in concrete production and to identify the resulting benefits and challenges. Researchers reviewed the literature and determined that high-volume fly ash can improve the properties of both fresh and hardened concrete. It can improve workability, heat of hydration, strength, permeability, and resistance to chemical attack. Researchers compiled data from 18 power plants located throughout Texas and determined that 6.6 million tons of fly ash are produced annually in Texas and about 2.7 million tons (or 40%) are generally sold for use in concrete or other end products. Researchers estimated the production of concrete in Texas and determined that if 60% of the portland cement used in Texas concrete production were replaced with fly ash, carbon dioxide emissions could be reduced by 6.6 million tons annually by the year 2015. More education is needed for design engineers and for the concrete industry regarding the performance and environmental benefits that can be realized through increased use of fly ash in concrete.

Title: Suitability of HVFA concrete for pavements

Author(s): P. Srinivasan, A.K. Tiwari, Anil Banchhor

Date: November 2004

Source/URL: *Indian Concrete Journal*, Vol. 78 (11), November 2004: 58-61.

Description: 4 pp.

Contents: Concrete pavements using 40 to 60 percent of quality fly ash can be characterised as high-volume-fly ash (HVFA) concrete pavements. The use of HVFA concrete can not only lead to the sustainable development of the cement and concrete industries but would also provide a durable and economical alternative. To obtain the desired properties of strength and durability, maintenance of a low water-to-cement ratio is essential along with the use of a superplasticiser. The pore filling effect and pozzolanic properties of fly ash improve the properties of fresh and hardened concrete. The properties such as higher flexural strength, low temperature regime, low water/gas absorption and permeability and adequate abrasion resistance can be utilised in making concrete pavements with high-volume fly ash. Economy in construction can be achieved through utilisation of fly ash and reduction of pavement thickness.

Title: Construction of HVFA concrete pavements in India: Four case studies

Author(s): J.P. Desai

Date: November 2004

Source/URL: *Indian Concrete Journal*, Vol. 78 (11), November 2004: 67-71.

Description: 5 pp.

Contents: The technology of HVFA concrete is being used for pavement construction in India. The paper describes briefly four case studies involving construction of pavements with HVFA concrete. Data are provided on the materials properties and mixture proportions used in these projects. The test results of compressive and flexural strengths of concrete are also presented together with the chloride-ion penetrability test data on cored samples from

the pavement. Performance of the HVFA concrete pavements under heavy traffic of up to 500 commercial vehicles/day was monitored for one year and the same was observed to be satisfactory. The author suggests that HVFA concrete is suitable for the construction of national, regional and rural road network in India.

Title: Performance of high-volume fly ash concrete pavements constructed since 1984

Author(s): Tarun R. Naik, Bruce W. Ramme, Rudolph N. Kraus

Date: March 2004

Source/URL: *Indian Concrete Journal*, Vol. 78 (3), March 2004: 137-143.

Description: 7 pp.

Contents: This investigation was performed to evaluate the long-term performance of concrete pavements made with high volumes of Class F and Class C fly ash. Additional recent field performance investigations (2002) are reported in this paper since the prior publication in the ACI. Six different mixtures, consisting of three mixtures with Class C fly ash having up to 70 percent cement replacement and three mixtures with Class F fly ash having up to 67 percent cement replacement, were used. Two series of tests were conducted to establish the long-term performance for all mixtures using core specimens from in-situ pavements. Long-term tests were conducted for compressive strength, resistance to chloride-ion penetration, and density. Test results revealed that both Class C and Class F fly ash contributed to high long-term compressive strength. Generally, the concrete mixtures containing Class F fly ash exhibited higher resistance to chloride ion penetration relative to mixtures containing Class C fly ash. Long-term compressive strengths of core specimens taken from in-situ pavements ranged from approximately 45 to 59 MPa. The highest long-term compressive strength was achieved by concrete mixtures incorporating 19 percent Class C fly ash at the age of 12 years (59 MPa) and 67 percent Class F fly ash at the age of 7 years (57 MPa). Visual observations revealed that the concrete pavement sections containing high-volumes of Class F fly ash (35 to 67 percent) performed well in the field with only minor surface scaling. Concrete pavement sections containing up to 70 percent Class C fly ash have experienced some surface damage due to abrasion and scaling, especially in an area where truck traffic makes a 90-degree turn.

Title: A compressive strength model for roller-compacted concrete with fly ash

Author(s): S. Tangtermsirikul, T. Kaewkhluab, P. Jitvutikrai

Date: February 2004

Source/URL: *Magazine of Concrete Research*, Vol. 56 (1), February 2004: 35-44.

Description: 10 pp.

Contents: Roller-compacted concrete (RCC) is typically used in the construction of dams and road pavements since it provides substantial benefits over conventional concrete for the construction of such structures such as faster construction, lower costs of construction and materials, etc. Incorporating fly ash into RCC can further reduce cost of materials and enhance the concrete performances. Recently, a huge fly ash RCC dam (Tha Dan Dam) project was started in Thailand. This utilises the largest the volume of RCC in the world at 5 million m³. However, one of the main problems concerns the mix proportion of RCC with fly ash. This paper presents a model for predicting compressive strength of RCC with fly ash in order to minimise the process of trial mixing. The model was formulated based on quantities of concrete ingredients, chemical compositions and physical properties of cement and fly ash. It was found that at room temperature of 28 ± 3°C the proposed model could be used to predict compressive strength of the tested mixtures of roller-compacted concrete with fly ash designed for dams and road pavements at the ages between 3 and 91 days with satisfactory accuracy.

Title: Long-term performance of high-volume fly ash concrete pavements

Author(s): Tarun R. Naik, Bruce W. Ramme, Rudolph N. Kraus, Rafat Siddique

Date: March/April 2003

Source/URL: *ACI Materials Journal*, Vol. 100 (2), March/April 2003: 150-155.

Description: 6 pp.

Contents: This investigation was performed to evaluate the long-term performance of concrete pavements made with high volumes of Class F and Class C fly ash (FA). Six different mixtures—three mixtures with Class C fly ash with up to 70° cement replacement and three mixtures with Class F fly ash with up to 67% cement replacement—were used. Long-term performance tests for all mixtures were conducted for compressive strength, resistance to chloride-ion penetration, and density using core specimens from in-place pavements. Results revealed a greater pozzolanic strength contribution of Class F fly ash relative to Class C fly ash. Generally, the concrete mixtures containing Class F fly ash exhibited higher resistance to chloride-ion penetration relative to mixtures containing Class C fly ash. Compressive strengths of core specimens taken from in-place pavements ranged from 45 to 57 MPa (6500 to 8200 psi). The highest long-term compressive strength was achieved for the high-volume fly ash mixture incorporating 67% Class F fly ash at the age of 7 years. Visual observations revealed that the pavement sections

containing high volumes of Class F fly ash (35 to 67% FA) concrete performed well in the field with only minor surface scaling. All other pavement sections have experienced very little surface damage due to the scaling.

Title: Development of some performance-based material specifications for high-performance concrete pavement

Author(s): Prasada Rao Rangaraju

Date: 2003

Source/URL: *Transportation Research Record No. 1834*, 2003: 69-76.

Description: 8 pp.

Contents: In collaboration with FHWA, the Minnesota Department of Transportation (Mn/DOT) has successfully completed its first experimental high-performance concrete pavement (HPCP) project under the Testing and Evaluation Program (TE-30). This project is one of the 22 projects funded under the TE-30 Program. With a structural design life of 60 years, this HPCP is unique in that it incorporates significant changes to the existing Mn/DOT specifications on concrete materials. Some of the new materials-related specifications developed as a part of this project are based on performance criteria that influence long-term durability of the pavement structure. The background and considerations for selecting the new performance measures are discussed, and test results are presented that evaluate the practical feasibility of establishing and achieving the performance specifications.

Title: Modeling chloride ingress in concrete: A comparative study of laboratory and field experience

Author(s): T. Callanan, M. Richardson

Date: 2003

Source/URL: *Sixth CANMET/ACI International Conference on Durability of Concrete*, 2003: 389-407.

Description: 19 pp.

Contents: This paper compares chloride resistance values from lab tests and field trials, derived solely by diffusion-based modeling. Concrete prisms were exposed to sodium chloride solutions in lab tests for 12 months. The trials included both continuous immersion and cyclical wetting and drying cycles. Chloride values were determined at 3, 6, and 12 months. Material variables included portland cement, fly ash, crushed limestone aggregate, natural sand, and natural gravels. Diffusion coefficients were derived through best-fit curves based on Crank's error function solution of Fick's 2nd law of diffusion. It was found that the lab test diffusion coefficients diminished significantly with increases in test duration and stabilized between 6 and 12 months, by which time they yielded values of a similar order of magnitude to those from the structures in service. The coefficients for gravel aggregate concrete specimens were more variable than those for crushed rock aggregate concretes and could exceed the in-service values by a factor of at least two. The beneficial influence of fly ash was reflected in the results.

Title: High-performance HVFA concrete: A solution to the infrastructural needs of India

Author(s): V. Mohan Malhotra

Date: February 2002

Source/URL: *Indian Concrete Journal*, Vol. 76 (2), February 2002: 103-107.

Description: 5 pp.

Contents: India has started a huge interstate highway-construction programme. In this paper, a case is made that high-performance, high-volume fly ash (HVFA) concrete is ideally suited for rigid pavement construction to meet the projected needs of the programme. This type of concrete is economical, environmentally-friendly and contributes to the reduced use of portland cement, reduced CO₂ emissions, reduced heat of hydration allows the use of marginal aggregates susceptible to alkali-aggregate reaction and uses large volumes of abundantly available fly ash in the country that otherwise has to be disposed of in landfills at a considerable cost. This paper* outlines the fundamentals of high-performance HVFA concrete, gives its properties and durability characteristics, and makes a case for its use in the construction of the highway system in India.

Title: Strength and durability of roller-compacted HVFA concrete pavements

Author(s): Tarun R. Naik, Yoon-Moon Chun, Rudolph N. Kraus, Shiw S. Singh, Lori-Lynn C. Pennock, Bruce W. Ramme

Date: November 2001

Source/URL: *Practice Periodical on Structural Design and Construction*, Vol. 6 (4), November 2001: 154-156.

Description: 13 pp.

Contents: This investigation was conducted to collect state-of-the-art information on the strength and durability of roller-compacted concrete (RCC) for pavement construction made with and without supplementary cementitious materials, and to describe the construction experience gained in two pavement projects (Projects I and II) recently completed in Wisconsin. Project I deals with performance of conventional high-volume fly ash (HVFA) concrete pavement having a roller-compacted, no-fines permeable base course containing fly ash obtained from an SO₂

control technology (dry desulphuring process), and Project II deals with RCC pavement (RCCP) containing 30% ASTM Class C fly ash. Past studies have shown that mechanical behavior of RCCP is similar to that of conventional paving concrete. However, nonair-entrained RCC is susceptible to freezing and thawing (F and T) damage if critically saturated when subjected to freezing actions. Laboratory testing of specimens derived from the pavements showed excellent results for conventional HVFA pavement, and satisfactory performance of the RCCP except for F and T resistance. Specimens from the RCCP performed poorly in laboratory freezing and thawing testing according to ASTM C 666, Procedure A. However, they showed adequate performance for up to 210 cycles of F and T when tested in accordance with ASTM C 666, Procedure B.

Title: Evaluating Performance-Based Test and Specifications for Sulfate Resistance in Concrete

Author(s): J.B. Stephens, R.L. Carrasquillo

Date: December 2000

Source/URL: Research Report 1706-3. http://www.utexas.edu/research/ctr/pdf_reports/1706_3.pdf

Description: 182 pp.

Contents: This research project involved an experimental evaluation of the sulfate resistance of various concretes and mortars for the purpose of establishing performance-based specifications for the durability of concrete against sulfate attack. The research is the test program portion of a long-term project that aims to establish performance-based specifications for durability for concrete mix designs for the Texas Department of Transportation. The test program described in this report consisted of two phases. The first phase was an investigation of the potential use of the standardized test, ASTM C1012-95, as a performance test. Plain portland cement mortars and mortars with cement-mineral admixture combinations were tested using three ASTM C150 types of cement, two types of fly ash, and a ground granulated blast furnace slag. The second phase involved evaluating experimentally the effect of permeability on the sulfate resistance of concrete for the purpose of determining the proper approach for specifying permeability for sulfate resistance. Concrete permeability was varied by testing different types of cement and cement-mineral admixture combinations, by using different water-to-cementitious material ratios for each cement combination, and by using various curing procedures. In the first phase mortar bars and in the second phase concrete cylinders were immersed in sulfate solution to simulate sulfate exposure. Published May 1999; Revised December 2000.

Title: High-Performance Concrete Using Nevada Aggregates

Author(s): J.J. Will, D.H. Sanders

Date: November 2000

Source/URL: RDT01-005, CCEER-00-06, Research Report.

Description: 115 pp.

Contents: The performance of concrete bridge decks depends on basic materials as well as external factors such as exposure conditions. The main objective of this research project is to develop concrete performance specifications for Nevada and determine measures which might be used to make concrete which passes those requirements. In order to do this, a series of concrete mix designs were developed and evaluated for their suitability to be used in Northern Nevada bridge decks and other structures exposed to harsh environments. In this research program, a total of 37 mix designs were completed using various combinations of three coarse aggregate sources, two Type I/II cement sources, two Class F fly ash sources, and four rates of cement replacement with fly ash. Testing of trial batches made from these materials yields data which shows how different materials and combinations of materials affect the final performance of the concrete. Laboratory testing based on tests suggested by the Federal Highway Administration's High-Performance Concrete Committee was used to evaluate the performance of each trial batch. The test program consists of chloride ion penetration, scaling resistance, shrinkage, compressive strength, modulus of elasticity, alkali-silica reactivity, and freeze/thaw durability. The results of trial batch testing show that different raw materials investigated have a significant impact on long-term performance and durability. In order to optimize concrete for the different effects of the raw materials and their proportions, the Nevada Department of Transportation (NDOT) should adopt a performance based specification system for concrete. As a part of this study, a proposed performance based specification system has been developed for the NDOT.

Research in Progress

Results are listed chronologically, with the most recent citations shown first. Links to research project Web sites or TRB Research in Progress listings are provided when available.

Title: Specifications and Protocols for Acceptance Tests of Fly Ash Used in Highway Concrete

Principal Investigator(s): n/a. Amir N. Hanna, Project Manager, (202) 334-1892 or ahanna@nas.edu

Start Date: 4/2007

RIP URL: <http://rip.trb.org/browse/dproject.asp?n=11824>

Sponsor Organization: NCHRP

Contents: Fly ash—a byproduct of coal combustion—is widely used as a cementitious and pozzolanic ingredient in hydraulic cement concrete. The use of fly ash in concrete is increasing because it improves some properties of concrete and often results in lower cost of concrete. However, the chemical and physical compositions of fly ash influence constructability, performance, and durability and may contribute to problems, such as cracking and alkali-silica reactivity in concrete pavements, bridge decks, and other highway structures. Regulatory requirements have also contributed to changes in fly ash properties that may adversely affect concrete performance. In addition, current specifications and test methods do not adequately characterize fly ash properties, address the effects of fly ash characteristics on fresh and hardened concrete properties, or consider the alkali content of the cement. For example, carbon content of fly ash is not usually determined directly, but is often assumed to be approximately equal to the loss on ignition (LOI). Such inadequate characterization may lead to unwarranted restrictions on the use of suitable materials. Although a great deal of research has been performed on the effects of fly ash characteristics on concrete properties, the research has not dealt with the applicability of current specifications to the fly ashes that currently are produced. In addition, existing test methods for sampling and testing fly ash used in concrete do not adequately address the characterization of fly ash or the performance aspects of highway concrete. Further research is needed to develop recommendations for improving fly ash specifications and test protocols and thus help highway agencies better evaluate and use fly ash that will provide acceptable structural performance and durability. The objective of this research is to recommend potential improvements to specifications and test protocols to determine the acceptability of fly ash for use in highway concrete.

Title: Evaluation of 100 Percent Fly Ash Concrete

Principal Investigator(s): Jerry Stephens, Montana State University, (406) 994-6113 or jerrys@ct.montana.edu

Start Date: 11/1/2006

RIP URL: <http://rip.trb.org/browse/dproject.asp?n=12921>

Sponsor Organization: Montana State University-Bozeman

Contents: Portland cement, the binder material in traditional concrete for construction applications, is associated with numerous environmental impacts ranging from mining the raw material required for the production of Portland cement, to the large amount of fuel required for extraction and manufacture of the raw product, to the emission of CO₂ during actual cement production. A material that resembles Portland cement both chemically and physically is Class C fly ash, which is already being manufactured as a by-product of the combustion of coals to generate electricity at coal-fired power plants. The cementitious nature of fly ash is well documented, and it has routinely been used to replace some of the Portland cement in conventional concrete mixtures. Some fly ashes such as that produced at the Corette power plant in Billings, MT, are sufficiently cementitious to completely replace Portland cement as the primary binder in concrete mixtures. Recent cost increases and shortages of Portland cement have stimulated new interest in the potential of alternate binders of this type. Previous research at Montana State University focused on fly ash available from one source—the Corette Power Plant. This work found that concrete made with Corette fly ash offered exceptional performance in workability, short term strength gain, and long term ultimate strength. Additional work validated the performance of this material in reinforced concrete applications. For this new concrete to be used in commercial applications, however, its durability and the potential cost benefits that it offers need to be further investigated. This project will evaluate remaining performance and cost issues related to using 100 percent fly ash concrete in commercial construction. It will include laboratory testing of material durability, i.e., its resistance to sulfate and hydrogen sulfide, its freeze thaw resistance, and its performance with alkali-silica reactive aggregates. Additionally, full-size precast pieces will be produced at a commercial precast plant.

Title: Economical Concrete Mix Designs Utilizing Blended Cements, Performance Based Specifications, and Rational Pay Factors

Principal Investigator(s): n/a. Christ G. Dimitroplos, Project Manager, (602) 712-7850 or cdimitroplos@azdot.gov

Start Date: 10/1/2006

RIP URL: <http://rip.trb.org/browse/dproject.asp?n=12494>

Sponsor Organization: Arizona Department of Transportation

Contents: There is a need to contain the escalating costs of construction projects through the use of economical concrete materials and rational acceptance criteria. This is a proposal to increase competitiveness among project bidders by improving the procedures for materials selection, specifications, and also pay factors for contract administration. A preliminary study conducted for joint ADOT/ARPA committee has indicated that there are significant potential cost savings through the reduction of minimum specified cement content in various grades of concrete. Such reductions however must be accomplished so that the performance of final product is not jeopardized. This project will utilize and evaluate recent advances in performance enhancing mineral admixtures and supplementary cementitious materials, in addition to QC parameters used for specification and acceptance criteria in order to develop economical concrete mixtures. This project will promote better quality and economics of using concrete materials by focusing on the: (1) mix design formulation based on economy, superior performance, quality control, and durability; (2) better utilization of mineral admixtures such as fly ash through reducing the minimum cement requirements for 2500 psi and 3000 psi concrete mixtures; and (3) evaluation of the acceptance criteria and pay factor adjustment methods based on a bonus/penalty factors in improving quality control and specification procedures.

Title: Modulus of Elasticity, Creep and Shrinkage of Concrete – Phase II

Principal Investigator(s): Mang Tia, University of Florida-Gainesville, (352) 392-6784 or tia@ce.ufl.edu

Start Date: 2/10/2006

RIP URL: <http://rip.trb.org/browse/dproject.asp?n=11480>

Sponsor Organization: Florida Department of Transportation

Contents: The main objectives of this project are to: (1) set up a concrete creep testing laboratory at the University of Florida with a minimum of 24 creep testing apparatuses; (2) conduct an extension laboratory testing program to determine the compressive strength, indirect tensile strength, modulus of elasticity, creep and shrinkage of typical Class II, IV, V and VI concrete mixes made with normal-weight and lightweight aggregates used in Florida; (3) determine the effects of aggregate properties, w/c, cement content, fly ash content, ground blast furnace slag content and curing time on the compressive strength, indirect tensile strength, modulus of elasticity, creep and shrinkage properties of Florida Class II (Bridge Deck), IV, V and VI concretes, and to determine the inter-relationships between these properties; (4) recommend values of modulus of elasticity, creep and shrinkage properties for typical Florida Class II (Bridge Deck), IV, V and VI concrete mixes to be used in structural designs; (5) conduct a laboratory study on low modulus concrete for use in concrete pavement; and (6) develop a framework for improved specifications for pavement concrete in which modulus of elasticity, along with other important properties such as flexural strength and coefficient of thermal expansion of concrete would be specified for optimal expected pavement performance.

Title: Inputs of Portland Cement Concrete Parameters Needed for the Design of New and Rehabilitated Pavements in Mississippi

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RIP URL: <http://rip.trb.org/browse/dproject.asp?n=10002>

Sponsor Organization: Mississippi Department of Transportation

Contents: Mississippi Department of Transportation is implementing the mechanistic-empirical pavement design methodology developed under NCHRP 1-37A. This pavement design method characterizes the pavement materials by fundamental properties such as modulus and Poisson's Ratio. For rigid pavement design the Portland Cement Concrete (PCC) is characterized by: (1) modulus of rupture; (2) compressive strength; (3) modulus of elasticity; (4) tensile strength; (5) coefficient of thermal expansion; (6) concrete shrinkage; (7) unit weight; and (8) Poisson's ratio. In this study PCC mixes encompassing a range of aggregate types with various blends of Type I cement, Class F or C fly ash and slag that are typically encountered in Mississippi will be evaluated for these parameter