



Evaluation of Binary and Ternary Mixes

Nebraska Department of Roads

Research Project:
**Evaluation of Binary
 and
 Ternary Mixes**

Location: Genoa East & North

Project Number: S-22-5 (1013)

Starting Date: 08/25/2005

Completion Date: 05/11/2007

Purpose of the Research Project:

The Nebraska Department of Roads began one of the several evaluations of binary and ternary mixes in June 2005. This evaluation consisted of a new type of mix design containing combination of Class F fly ash and Ground Granulated Blast Furnace Slag (GGBFS). The project location is in Genoa, Nebraska. NDOR, Paulsen Construction Concrete Company, Inc, Lafarge North America Cement and Overland Sand & Gravel worked together on this study.



Purpose of this Project:

- To determine the effect of substituting GGBFS in blended cement as cementitious materials meeting the chemical and physical properties in concrete mixes.
- To ensure workability and constructability so that the mixes can be easily used in engineering applications.
- To evaluate concrete mixes for mechanical properties and durability characteristics that is compatible with NDOR mix concrete design.

Plan of Action in the field and Laboratory:

Sections Evaluated:

Mix Design used: NDOR 47B Mix Design

1. Control Section:
Tested one section that followed the NDOR standard mix design with Type I/II cement and 25% Class F fly ash cementitious materials. The section length is 10% of the total project, located at Elm Street.
2. Tested one section using Type I/II cement with 35% GGBFS replacement. The section length is 10 % of the project.
3. Tested one section using Type I/II cement replaced with 20% Class F fly ash and 20% GGBFS. The test section length is the remaining 80% of the project at Elm Street. Table 1 show the three mixes used in the project.



Field Workability



Field Workability



NDOR Field Sampling



NDOR Field Sampling



NDOR Field Sampling

Table 1. Description of the Paving Blend

Paving Blend	Cement Type	Supplementary Cementitious Materials Cement Replacement Percentage by weight		
		Class C Fly Ash % replacement	Class F Fly Ash % Replacement	GGBFS (Slag) % Replacement
47B	Type I/II	-	25	-
47B	Type I/II	-	20	20
47B	Type I/II	-	-	35

Plan of Action in the field and Laboratory by Tasks:

Conducted in the Field:

Sampling & Testing

At Delivery:

1. Slump Test
2. Unit Weight
3. Checked Air:
 - i. As delivered by Truck
 - ii. Behind the paver in the vibrator path and vibrator gap testing for air content by the pressure method (ASTM C 231)

Conducted in the Laboratory:

1. Standard Test Method for Microscopic Determination Parameters of The Air Void System in Hardened Concrete by the Linear Traverse Method (ASTM C457-90)
2. NDOR Wet and Dry Test
3. ASTM C 1567 Expansion
4. ASTM C 1202 Permeability
5. ASTM C 666 Freeze & Thaw Durability
6. ASTM C 157 Shrinkage
7. Mechanical Properties:
 - i. ASTM C39 Compressive Strength
 - ii. ASTM C293 Flexural Strength
 - iii. ASTM C469 Modulus of Elasticity

Project Results to Date:

Each mix was evaluated and compared for mechanical and durability characteristics toward the current NDOR 47B paving mix design. The following Table 2. is shown test results for durability properties and Table 3. is shown test results for mechanical properties for each mix tested in the Genoa project in October 2005

Table 2. Test Results for Durability Properties

Paving Blend	ASTM C 1567 % Expansion	ASTM C 666 Freeze & Thaw Durability (%)	ASTM C 1202 Permeability	NDOR Wet & Dry Flexure (Psi @ 18 months)	Shrinkage Based on 16.5 Inches Slab
47B I/II 25F	0.03	72	725	950	-0.1617
47B I/II 20F/20S	0.03	71	546	874	-0.1393
47B I/II 35S	0.17	85	1400	816	-0.1241

Table 3. Mechanical Properties Test Results

Paving Blend	Compressive Strength @ 14 Days (Psi)	Flexure Strength @ 28 Days (Psi)
47B I/II 25F	5687	679
47B I/II 20F/20S	6520	780
47B I/II 35S	4467	639

Highlights of the Project to Date:

Based on the field performance the GGBFS blends improved:

- Workability
- Finishing
- Improved consistency plastic and hardened properties
- Lower permeability
- Improved compressive strength and flexure strength

Conclusions:

- The curing temperature has a significant influence when using GGBFS.
- Ternary cement will reduce compressive strength at early age.
- The study showed that properties of the 20% slag replacement exceed the NDOR flexure strength design.

The initial field and laboratory results have showed good comparison with the current 47B paving mix design. Therefore based on the results to date NDOR is confident that IPF cement up to 20% GGBFS replacement. This blend will have a very good performance in the field. As a result, NDOR has a new mix design in the Standard Specification called 47BFS which can be used for paving and bridge deck operations. This is a result from a collaboration effort with the industry.