Evaluation of Grade 120 Granulated Ground Blast Furnace Slag

by

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ABSTRACT

This study evaluates Grade 120 Granulated Ground Blast Furnace Slag (GGBFS) and its effect on the properties of hydraulic cement concretes used in structural and pavement construction. Several mix designs, structural and pavement, were used for this evaluation with varying amounts of GGBFS used as a substitution for cement. These substitutions were a percentage by weight substitution. This study looked at the effects of slag on workability, constructability, durability and the compressive strength of the concrete. How GGBFS affected the concrete's set times was also critical in establishing the maximum substitution amount for DOTD concrete structures and pavements.

In addition, an informal telephone survey was taken with other state DOT's concerning their use and experience using GGBFS in concrete. This further assisted DOTD in the development of their own specifications for GGBFS concretes.

Test results indicate that concretes with GGBFS substitutions displayed delays in set times and exhibited delays in compressive strengths at an early age, as compared to conventional concrete mixes. However, at later ages the compressive and flexural strengths markedly surpassed those of conventional concrete mixes as the cement content increased. Permeability was greatly reduced in those concretes that incorporated GGBFS as opposed to the conventional mixes.

At this time, the use of GGBFS has already been implemented into the specifications of Louisiana concrete mixes. Conclusions from this study are to be incorporated into the specifications of Louisiana concrete mixes. Restrictions are for an allowable substitution of Grade 120 GGBFS up to 50 percent, and an ambient pouring temperature of 50°F and rising.

IMPLEMENTATION STATEMENT

At the writing of this report, the use of GGBFS has already been implemented into the specifications of Louisiana concrete mixes. A quality control program was devised and implemented by the Materials and Testing Section. Additional specifications concerning allowable substitution amounts and ambient temperature restrictions were suggested by LTRC and adopted for use on DOTD projects.

Currently there are two projects using GGBFS in their concrete mixes. The Charenton Canal Bridge (SP. 241-02-0040) has a deck containing a class AA mix design with 50 percent substitution of GGBFS concrete. The new alignment of LA 14 pavement project (SP. 055-05-0048) is using a class B concrete mix design with a 50 percent substitution of GGBFS also.

It is anticipated that the inclusion of GGBFS into DOTD concrete mix designs will have the practical values of enhancing the physical properties of concrete along with long-term economical and ecological benefits.

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INTRODUCTION

Because of an increasing awareness of waste material disposal methods, particularly those waste materials that may pose environmental hazards, increasing attention has been given to providing safe and practical use of these materials. One such material is Granulated Ground Blast Furnace Slag GGBFS.

The use of GGBFS as a constituent of concrete was first recorded in 1905. GGBFS is made from iron blast furnace slag. It is non-metallic and consists essentially of silicates and aluminosilicates of calcium and other bases developed in a molten form with iron in a blast furnace. Molten slag, at a temperature of 2730° F, is rapidly chilled by quenching it in water to form a glassy sand-like granulated material. This material is then ground to less than 45 microns. The rough and angular shaped slag hydrates and sets in a manner similar to cement. This is accomplished in the presence of water and an activator, such as NaOH (sodium hydroxide) or CaOH (calcium hydroxide), supplied by cement.

To maximize the hydraulic (cementitious) properties, the molten slag must be chilled rapidly as it leaves the blast furnace. Quenching minimizes crystallization and converts the molten slag into fine aggregate sized particles (less than a #4 sieve), composed mainly of noncrystalline material. The cementitious action of GGBFS is dependent largely on the glass content. Slowly quenched slags are predominantly crystalline (non-glass) and therefore do not possess significant cementitious properties. The properties of GGBFS, therefore, are dependent on the production process.

Recently, a facility producing GGBFS was built in the New Orleans area. The manufacturer, Lone Star Cement, reports that the cost of GGBFS is less than that of

cement and that it possesses excellent cementitious properties. In addition, the use of GGBFS as a partial replacement for cement will decrease the burden on naturally occurring raw materials needed in the production of cement.

The primary concern over using GGBFS is delayed set times, and hence, delayed early strength gain. This can present a problem in the time management of sawing joints in concrete pavement. It could also present a problem in developing the necessary minimum early strengths required at the time strands are cut in prestressed members. This study addresses the amount of the delay in set time and strength gain and the effect on the time between initial and final set as compared to non-GGBFS concrete.

ASTM C 989 (Standard Specification for GGBFS for use in Concrete and Mortars), adopted in November 1982, provides for three strength grades of GGBFS depending on their mortar strengths when blended with an equal mass of portland cement. Grades 120, 100 and 80 are expressed as:

SAI = (SP/P x 100)

where:

SAI = slag-activity index, %

SP = average compressive strength of slag-reference cement mortar cubes, psi

P = average compressive strength of reference cement mortar cubes, psi

This study evaluates only Grade 120 GGBFS.

OBJECTIVE

This study will determine the characteristics of paving and structural concrete made with varying amounts of GGBFS as a percentage by weight substitution. Specifically, the study focused on the effects of slag on workability, constructability, durability, and the effect of GGBFS on the compressive strength of concrete. Standard American Society for Testing and Materials (ASTM) tests and some non-ASTM tests were employed. Secondary objectives were to poll other state (DOT's) that allow the use of GGBFS to gain their experiences as it pertained to the economic and performance characteristics of GGBFS.

The ultimate objective was to determine how GGBFS affects set times and the maximum percent substitution of GGBFS in DOTD concrete structures and pavements.

SCOPE

The LTRC Concrete Laboratory was the site of the testing program. Control mixes (those containing no GGBFS) and GGBFS mixes were made and then tested using standard ASTM test procedures and one AASHTO test, the rapid chloride permeability test to determine the effect of GGBFS on permeability.

In addition, an informal telephone survey of states that have used GGBFS was undertaken (see appendix A). An inquiry into their work experiences using GGBFS proved valuable. The experience of other states and the laboratory-testing program performed at LTRC were beneficial in specification development for GGBFS.

METHODOLOGY

(TESTS)

Through a series of standard ASTM tests, LTRC evaluated the effects of GGBFS on Louisiana concrete mixtures at various substitution rates. The tests determined the properties of plastic GGBFS concrete as well as volume stability, strength, durability and workability of GGBFS concrete so that substitution rates and specifications can be developed. Additionally set times at temperatures of 40°F, 50°F, 60°F, and 73°F were examined.

The following tests were conducted:

1) ASTM C 143 Slump of Fresh Concrete - 1 specimen
2) ASTM C 148 Air Content and Unit Weight - 1 specimen
3) ASTM C 403 Set Time of Fresh Concrete - 2 specimens
4) ASTM C 39 Compressive Strength - 3 specimens
5) ASTM C 78 Flexural Strength - 3 specimens
6) ASTM C 469 Static Modules of Elasticity and Poisson's Ratio - 2 specimens
7) ASTM C 666 Resistance to Rapid Freezing and Thawing - 3 specimens
8) ASTM C 157 Length Change - 2 specimens
9) ASTM C 512-87 Creep Test of Concrete in Compression - 3 to 5 specimens
10) ASTM C 672-92 Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to De-icing Chemicals - 2 specimens
11) ASTM C 944-90a Standard Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating Cutter Method - 3 specimens
12) AASHTO T 227 Rapid Chloride Permeability Test - 2 specimens

(MIX DESIGNS)

Concrete mixes conformed to DOTD Standard Specifications for Roads and Bridges and were representative of concrete used in pavement and structures in Louisiana. Both paving and structural mixes were evaluated.

(Paving Mixes)

(Reference mix:)

* Cement content: 5.4 bags of cement per cubic yard when crushed limestone is used as the coarse aggregate; 5.8 bags of cement per cubic yard when gravel is used as the coarse aggregate.

* 60/40 ratio of coarse to fine aggregate.

* Coarse aggregate gradation "B".

* water/cementitious material ratio: not to exceed 0.40.

* Use of admixtures; air entrainment and water reducers to achieve air content and slump within DOTD Standard Specifications for Roads and Bridges for each mix type.

* Same water/cementitious material ratio for similar mixes.

Slag mixes were identical to the reference mix with the exception that various percentages of cement, by weight, will be replaced with GGBFS.
The percentage substitutions were 15 percent, 30 percent, and 50 percent.

(Structural Mixes:)

(Reference mix:)

* Cement content: 6.0 bags of cement per cubic yard when crushed limestone is used as the coarse aggregate; 6.5 bags of cement per cubic yard when gravel is used as the coarse aggregate.
* water/cement ratio: not to exceed 0.45
* 60/40 ratio of coarse to fine aggregate
* Coarse aggregate gradation "A"
* Use of admixtures; air entrainment and water reducers to achieve air content and slump within DOTD Standard Specifications for Roads and Bridges for each mix type.
* Same water/cementitious material ratio for similar mixes.

Table 1 presents the test factorial used for this study. Because of the anticipated slower set times and strength development, two test temperatures were originally chosen. For this purpose, 40°F was chosen as the lower bounds temperature and 73°F as the standard. For the 40°F samples, the plan was to chill all components to 40°F before mixing and to cure the specimens at 40°F for 28 days. This plan was changed for several reasons. Temperatures do reach 40°F in Louisiana but have never stayed at that level for 28 days, as such the researcher felt that this was an unrealistic test for this region. Additionally, the space required to chill components and cure specimens at 40°F was too great; only one mix per month would have been possible. This would have delayed the study by at least one year, which was unacceptable to all concerned. Additionally, the average temperature in Louisiana for the months of November, December, January, and February is 50°F. So the decision was made to modify the study to reflect realistic temperature conditions in Louisiana. Components would be chilled to 50°F and 60°F prior to mixing and cured for seven days at that same temperature (50°F and 60°F) then allowed to cure for the remainder of the 28 days at 73°F in the 100 percent humidity room. These changes were

approved by the Project Review Committee.

One mix design, the paving mix for limestone and gravel at 70°F, will consist of 10 percent fly ash and 15 percent slag. This is to address the possibility that a fly ash hopper used for a previous pour may contain some residual fly ash. This could contaminate the GGBFS supply when it is added to the same hopper on a job requiring GGBFS. Since its not likely that the Department would allow the intentional use of both slag and fly ash in concrete until a fundamental understanding of concrete containing GGBFS only is achieved, it was prudent to determine how the two admixtures, when combined, performed in a standard DOTD concrete mix design.

All mixes, except the fly ash and slag mixes, were tested with their components having been cooled to 40° F to address the set time and strength gain delay. The combination of fly ash and slag will be tested at 70° F only. Mixes will not be made and tested at high a temperature (90° F). Based on previous experience, at higher temperatures, set time and early strength are not as negatively impacted as they are at lower temperatures.

Table 1

Test Factorial

% SLAG		0%				15%				30%				50%			
TEMP. °F		40	50	60	73	40	50	60	73	40	50	60	73	40	50	60	73
5.4 BAG MIX	GRAVEL																
	STONE				X				X				X				X
5.8 BAG MIX	GRAVEL	X			X	X			X	X	X	X	X	X			X
	STONE																
6.0 BAG MIX	GRAVEL																
	STONE	X			X	X			X	X	X	X	X	X			X
6.5 BAG MIX	GRAVEL				X				X				X				X

	STONE																

DISCUSSION OF RESULTS

Tested mixes consisted of a reference without slag and substitutions (slag for cement) by weight of 15 percent, 30 percent, and 50 percent. All mixing was performed at 73°F; however, for some mixes components were chilled to 40°F, 50°F, and 60°F prior to mixing and cured for seven days at one of the mentioned temperatures. As previously mentioned, the original plan was to cure at reduced temperature for 28 days, but this was unrealistic for southern conditions and the curing protocol was modified to reflect a more realistic test.

All blends met or exceeded the required compressive strength specifications and compared favorably to the reference mix in most tests performed (see appendix B). Set times were fairly consistent and can be controlled by monitoring ambient temperature at the time of placement and the percentage of GGBFS used in the concrete mix. Although no testing of set accelerating admixtures was done in the course of this study, it may be possible to decrease set times by the use of these types of admixtures. Even though permeabilities were considerably lowered, freeze thaw test (ASTM C 666 method B) results indicated that GGBFS had little or no impact on a mix's ability to resist deterioration due to freezing and thawing.

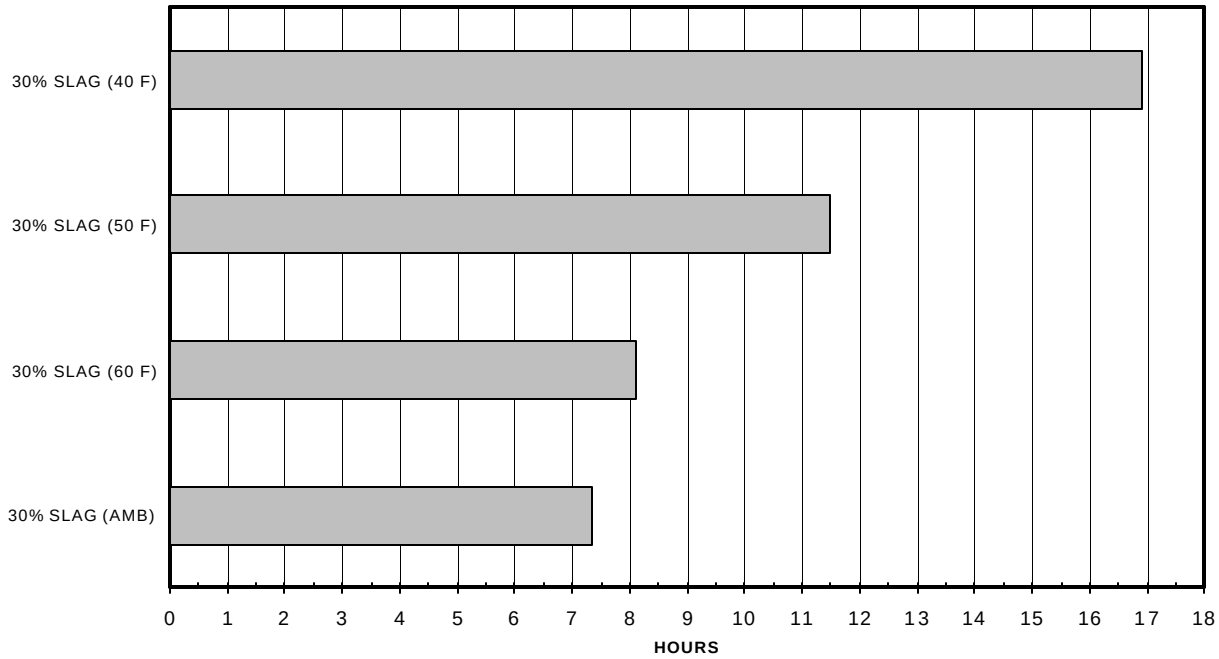
No testing above 73°F was performed, as such no information is available regarding set time or any other test parameter above the reference temperature. However, it can be expected that higher temperatures will lower the time necessary to achieve initial and final set.

The Slag Activity Index and chemical composition has remained consistent from 10/15/97 to 7/12/97 and should remain so as long as the source of slag remains constant.

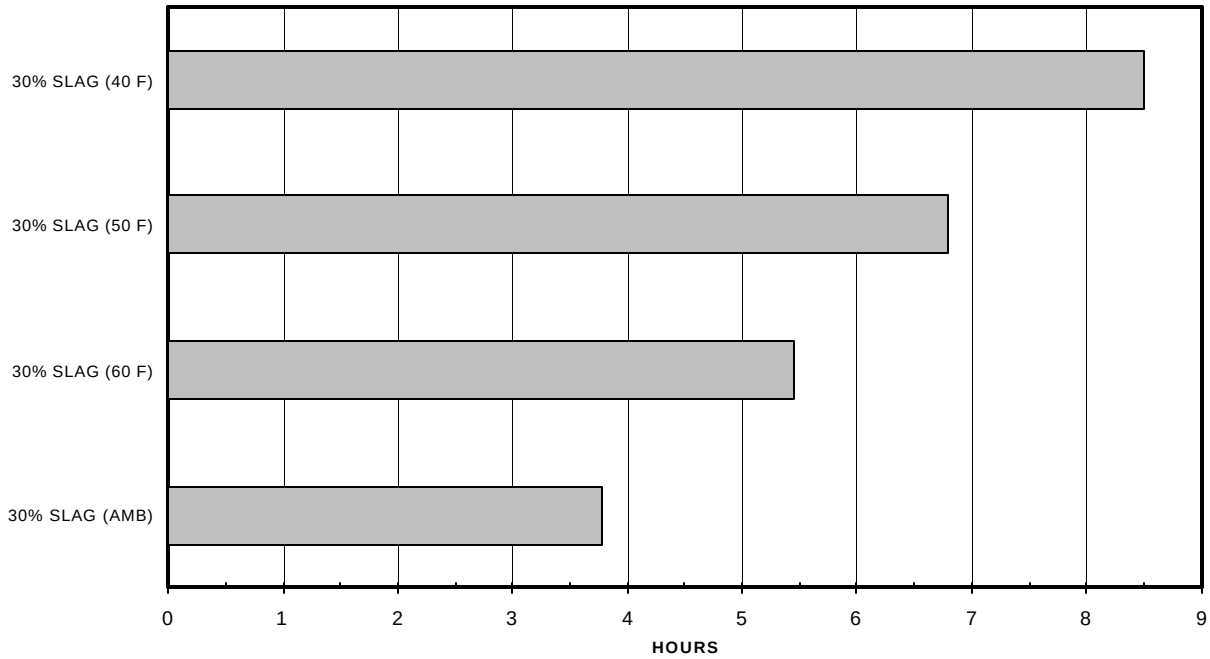
CONCLUSIONS

The conclusions were drawn based on the limitations of the factorials used in testing grade 120 GGBFS. Laboratory results indicate that when slag is blended into the concrete mixture we can expect comparable or increased compressive strengths, lower permeability, and consistent set times (set times can be controlled with admixtures). Based on test results at 73°F, the LTRC Concrete Laboratory has no objections to the use of GGBFS from Lonestar Cement in our concrete mixes. However, it is recommended that trial batching should be required to demonstrate the compatibility of the blended materials used and a required temperature of 50°F and rising for placement. The temperature restriction is based on the delayed set at lower temperatures (See following graphs). Finally, quality control testing should be used to insure the consistency of the product.

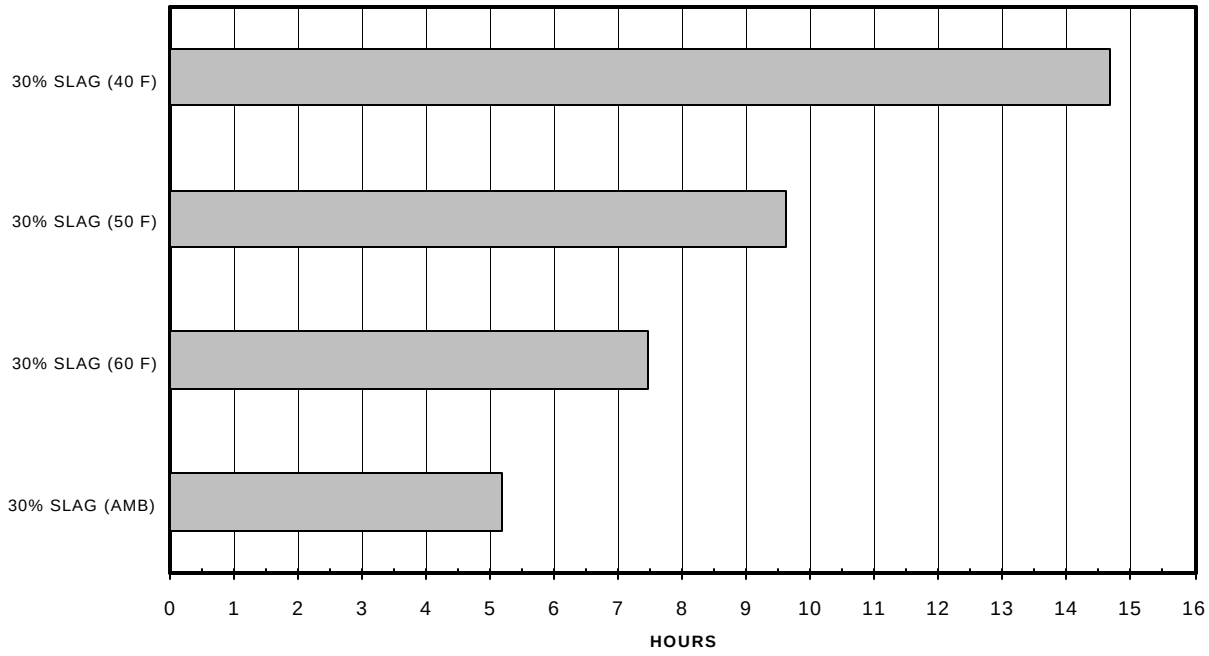
5.8 BAG MIX: FINAL SET



6.0 BAG MIX: INITIAL SET



6.0 BAG MIX: FINAL SET



RECOMMENDATIONS

Based on the attached laboratory results, the LTRC Concrete Section sees no reason to restrict GGBFS and its use in our concrete mixtures, providing the existing quality control program, developed by the Materials and Testing Section, is followed and proper specification modifications are implemented.

When blended at the redi-mix plant, the substitution rate should be limited to 30 percent and a separate hopper provided for the storage of slag. Although, the results of the 50/50 cement/slag blend were good, it is recommended that mixtures with these proportions be blended at the point of origin to decrease the possibility of an error in proportioning.

Mixing of slag and fly ash or any cement containing fly ash should not be permitted. It is also suggested that trial batches be required to demonstrate the compatibility of the mix components before accepting the mix design. Additionally, during trial batching, the producer should be required to demonstrate that satisfactory set times can be achieved when slag is included in the mix design.

Only slag with a Slag Activity Index (SAI) of 120 should be allowed for use in LA DOTD concrete mixes at this time since it is the only grade tested to date. Grade (SAI) 100 will be tested in 1999-2000 for consideration of incorporation into the specifications.

The consistency and performance of GGBFS is source dependent. Lonestar Cement intergrinds materials from several sources and has a contract with each slag supplier for five years. Louisiana should require notification of any change in source material.

Appendix A

COMPARISON OF USAGE OF GGBFS BY OTHER STATES

COMPARISON OF USAGE OF GGBFS BY OTHER STATE DOT'S

this information was collected in 1995 and may have changed

	USE YES OR NO	**NATURE OF USAGE**	**SUBST. RATE (%)**	**# YEARS**
FLORIDA	YES	STRUCTURAL	50% TO 70%	12 YEARS
INDIANA	NO	----------	------	--------
N. CAROLINA	YES	PAVEMENT	UP TO 50%	N.A.
GEORGIA	ALLOWED?	NOT STATED	* SEE ADD. COMM.	N.A.
MICHIGAN	ALLOWED	----------	UP TO 40%	N.A.
OHIO	YES	STRUCTURAL?	* SEE ADD. COMM.	2 YEARS
NEW YORK	NO	NONE YET	TO BE DETERMINED.	0
VIRGINIA	YES	MOSTLY PAVEMENT	35 TO 50%	10 YEARS
MARYLAND	YES	PAVEMENT AND STRUCTURES	25% TO 50%	13 YEARS
PENN.	YES	STRUCTURES	25% TO 50%	N.A.
MASS.	YES	ROADS AND STRUC.	UP TO 40%	N.A.
DELAWARE	YES	ROADS AND STRUCTURES	35% TO 50%	4 YEARS
ALABAMA	NO	----------	------	---------
KENTUCKY	NO	----------	------	---------
MISSOURI	NO	----------	------	---------
MONTANA	NO	----------	------	---------
NEW JERSEY	NO	----------	------	---------
S. CAROLINA	YES	MAINLY STRUCTURES	UP TO 50%	8 YEARS.

NEW HAMP.	YES	MAINLY STRUCTURES	UP TO 50%	N.A.
ILLINOIS	ALLOWED	N.A.	25%	N.A.

	SPECS DEVELOPED HOW?	**ADDITIONAL COMMENTS**
FLORIDA	IN HOUSE RES. AND WORK DONE BY JACKSONVILLE PORT AUTHORITY	PRIMARILY USED TO ENHANCE CORROSION RESISTANCE IN STRUCTURES; NOT USED IN PAVEMENT; ALSO USED IN COMBINATION WITH MICROSILICA AT 50% TO 55% SUBST.
INDIANA	----------	NO WORK EXPERIENCE WITH YET; THOUGHT TO HAVE DURABILITY PROBLEMS
N. CAROLINA	N.A.	NOT USED IN HIGH EARLY STRENGTH APPLICATIONS OR COMBINED WITHIN TYPE 1P AND 1S CEMENTS. HOWEVER, EXPERIMENTAL USAGE FROM DEMO PROJECT INDICATES ACCELERATED STR. GAIN @ HIGH TEMPERATURES
GEORGIA	N.A.	SHALL MEET REQ. OF AASHTO M302, GRADE 120. NOT TO BE USED IN COMBINATION WITH FLY ASH OR TYPE 1P CEMENT. 50% SUBST. IF T > 60 DEG. F. IF 40 < T < 60, SUBST. UP TO 30%. IF T < 40, NOT PERMITTED.
MICHIGAN	N.A.	NOT USED BECAUSE IT'S CONSIDERED TOO EXPENSIVE; USE NOT ALLOWED BETWEEN OCT. & APR.
OHIO	BASED ON RESULTS FROM CONSULTANT MAT. LAB	SHALL CONFORM TO ASTM 989 GRADE 100 OR 120. FROM OCT. 15 TO APR. 1, 25% SUBST. FROM APR. 1 TO OCT. 15, 40% MAX. USED TO ACHIEVE LOW-PERMEABILITY AND SHRINKAGE.
NEW YORK	N.A.	RESEARCH CURRENTLY BEING CONDUCTED FOR USE IN HIGH -PERF. CONC.
VIRGINIA	FEDERAL GUIDELINES	NOT TO BE USED WITH TYPE 1P CEMENT. USE W/TYPE II ONLY IF ALKALI > 0.40%. NO CRACKING PROBLEMS ASSOCIATED W/USE. SLAG OR F.A. SUBT. MANDATORY. SHALL CONFORM TO ASTM C989. GRADE 100 OR 200.
MARYLAND	EXPERIENCE OF OTHER	DECREASES PERMEABILITY; MITIGATES

	STATE DOT'S	ASR; CONTRACTOR MUST FURNISH TRIAL BATCH; APPROVED ON AN AS NEED BASIS JOB TO JOB; VERY FAVORABLE OPINION OF. NO CRACKING PROBLEM IN PAVEMENT BUT THEY USE CRCP. SHALL CONFORM TO AASHTO M302, GRADE 120.
PENN.	N.A.	THOUGHT TO HELP MITIGATE ASR; USED ACCORDING TO SPECIAL PROVISION
MASS.		USED IN ALL PRECAST MIXES AND SOME READY MIX PLANTS; USED FOR COST SAVINGS.
DELAWARE	EXPERIENCES OF OTHER STATE DOT'S.	SHALL CONFORM TO ASTM C989; USED INITIALLY BECAUSE OF LOW COST; NOW PRIMARILY TO MITIGATE ASR; DID GREATLY RETARD SET IN PAVING CONC.-18 HR. JOINT SAWING TIME NOT SEEN AS A PROBLEM, THOUGH. DELAWARE USED 22,000 TONS IN '93.
ALABAMA	N.A.	----------
KENTUCKY	N.A.	POSSIBLE FUTURE CONSIDERATION FOR USE
MISSOURI	N.A.	----------
MONTANA	N.A.	----------
NEW JERSEY	N.A.	----------
S. CAROLINA	N.A.	VERY LITTLE WORK EXPERIENCE WITH, ESPECIALLY IN PAVEMENT; SLAG "POLICY" DEVELOPED 1986; CONFORMANCE TO ASTM 989; MIX DESIGN SUBMITTAL BY CONTRACTOR REQUIRED
NEW HAMP.	N.A.	USED IN BRIDGE DECKS TO DECREASE PERMEABILITY AND RESIST REBAR CORROSION
ILLINOIS	N.A.	USE BETWEEN APRIL AND OCT. ONLY SHALL CONFORM TO ASTM 989 AND AASHTO M 302 GRADES 100 OR 120.

NOTE: ASTM C 989 AND AASHTO M 302-91 ARE THE (SAME) STANDARD SPECIFICATION FOR GROUND IRON BLAST-FURNACE SLAG FOR USE IN CONCRETE AND MORTARS.

NOTE: TYPE 1S CEMENT IS PORTLAND BLAST FURNACE SLAG CEMENT (BFS CONTENT BETWEEN 25% AND 70% BY WEIGHT. TYPE 1P CEMENT IS PORTLAND POZZOLAN CEMENT. POZZOLAN CONTENT 15 TO 40% BY WEIGHT. POZZOLAN MAY OR MAY NOT BE SLAG.

APPENDIX B

TEST RESULTS

COMPONENTS OVEN DRIED AND CHILLED TO 50°F or 60°F PRIOR TO MIXING.
SAMPLES CURED IN SEALED 50°F or 60°F ENVIRONMENT FOR 7 DAYS & THEN STORED IN 100%RH AT 73°F FOR FINAL CURING.
CEMENT USED: HOLNAM TYPE I PORTLAND with a **30% SUBSTITUTION** of LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
MIXING SEQUENCE: (1) 3 MIN - COARSE+2/3 WATER+AEA., (2) 3 MIN - TOTAL COMPONENTS, (3) 3 MIN - REST, (4) 2 MIN - FINAL MIX

	CLASS A	**CLASS A**	**TYPE B**	**TYPE B**
LTRC LAB NO.	C-2185	C-2189	C-2187	C-2188
DATE MIXED	06/03/98	06/23/98	06/09/98	06/17/98
TEMPERATURE OF CURING	50°F	60°F	50°F	60°F
TYPE AGGREGATE	LIMESTONE	LIMESTONE	GRAVEL	GRAVEL
WATER/CEMENT RATIO	0.43	0.43	0.40	0.40
BAG MIX (sks/yd)	6.0	6.0	5.8	5.8
CEMENT (lbs/yd)	395	395	382	382
SLAG (lbs/yd)	169	169	163	163
WATER (lbs/yd)	243	243	218	218
COARSE AGGREGATE (lbs/yd)	2039	2039	1979	1979
FINE AGGREGATE (lbs/yd)	1103	1103	1135	1135
DARAVAIR 1000 (oz/100ct)	2	2	1	1
WRDA w/ HYCOL (oz/100ct)	3	3	4	4
AIR TEMPERATURE (°F)	73.0°	69.0°	73.0°	73.0°
CONCRETE TEMP.(°F at batch)	68.0°	68.0°	62.0°	69.0°
SLUMP (inches)	3.75"	3.25"	3.50"	2.25"
AIR CONTENT (percent)	4.2%	5.6%	4.8%	5.0%
UNIT WEIGHT (lbs/cu.ft.)	145.6 lbs	144.0 lbs	142.4 lbs	140.8 lbs
ASTM C 403 TIME OF SET				
initial	06 hrs 48 mins	05 hrs 27 mins	07 hrs 30 mins	06 hrs 06 mins
final	09 hrs 38 mins	07 hrs 28 mins	11 hrs 30 mins	08 hrs 22 mins
ASTM C 39				
7 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	3832	3385	2881	3199
cylinder #2 psi	3738	3891	3017	3168
cylinder #3 psi	3754	3774	2951	3185
average psi	**3774**	**3683**	**2950**	**3184**
28 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	5889	5622	5498	4734
cylinder #2 psi	5904	5595	4816	4422
cylinder #3 psi	5748	5528	5028	3349
average psi	**5847**	**5582**	**5114**	**4168**
ASTM C 78				
7 DAY FLEXURAL STRENGTH				
beam #1 psi	611	580	652	546
beam #2 psi	644	645	566	579
beam #3 psi	635	601	575	477
average psi	**630**	**608**	**598**	**534**
28 DAY FLEXURAL STRENGTH				
beam #1 psi	890	928	833	801
beam #2 psi	945	848	745	754
beam #3 psi	944	852	770	779
average psi	**927**	**876**	**782**	**778**
ASTM C 469				
28 DAY MODULES OF ELASTICITY				
cylinder #1				
cylinder #2	6291497	5153556	5552101	5563745
average	5306892	5034190	5455594	5415978
28 DAY POISSON'S RATIO	**5799194**	**5093873**	**5503848**	**5489862**
cylinder #1				
cylinder #2	0.24	0.20	0.12	0.17
average	0.30	0.19	0.13	0.17
	0.27	**0.19**	**0.13**	**0.17**

COMPONENTS OVEN DRIED AND CHILLED TO 50°F or 60°F PRIOR TO MIXING.

SAMPLES CURED IN SEALED 50°F or 60°F ENVIRONMENT FOR 7 DAYS & THEN STORED IN 100%RH AT 73°F FOR FINAL CURING.
CEMENT USED: HOLNAM TYPE I PORTLAND with a **30% SUBSTITUTION** of LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
MIXING SEQUENCE: (1) 3 MIN - COARSE+2/3 WATER+AEA., (2) 3 MIN - TOTAL COMPONENTS, (3) 3 MIN - REST, (4) 2 MIN - FINAL MIX

DESCRIPTION	CLASS A	CLASS A	TYPE B	TYPE B
LTRC LAB NO.	C-2185	C-2189	C-2187	C-2188
DATE MIXED	06/03/98	06/23/98	06/09/98	06/17/98
TEMPERATURE OF CURING	50°F	60°F	50°F	60°F
TYPE AGGREGATE	LIMESTONE	LIMESTONE	GRAVEL	GRAVEL
WATER/CEMENT RATIO	0.43	0.43	0.40	0.40
BAG MIX (sks/yd)	6.0	6.0	5.8	5.8
CEMENT (lbs/yd)	395	395	382	382
SLAG (lbs/yd)	169	169	163	163
WATER (lbs/yd)	243	243	218	218
COARSE AGGREGATE (lbs/yd)	2039	2039	1979	1979
FINE AGGREGATE (lbs/yd)	1103	1103	1135	1135
DARAVAIR 1000 (oz/100ct)	2	2	1	1
WRDA w/ HYCOL (oz/100ct)	3	3	4	4
AIR TEMPERATURE (°F)	73.0°	69.0°	73.0°	73.0°
CONCRETE TEMP.(°F at batch)	68.0°	68.0°	62.0°	69.0°
SLUMP (inches)	3.75"	3.25"	3.50"	2.25"
AIR CONTENT (percent)	4.2%	5.6%	4.8%	5.0%
UNIT WEIGHT (lbs/cu.ft.)	145.6 lbs	144.0 lbs	142.4 lbs	140.8 lbs
ASTM C 666 & ASTM C 215				
FREEZE and THAW				
beam #1 DF @ CYCLES	89.4 @ 300	75.9 @ 300	16.1 @ 105	34.9 @ 190
beam #2 DF @ CYCLES	92.9 @ 300	72.9 @ 300	39.1 @ 171	28.0 @ 157
beam #3 DF @ CYCLES	89.2 @ 300	77.9 @ 300	47.4 @ 187	19.4 @ 132
average DF @ CYCLES	**90.5 @ 300**	**75.5 @ 300**	**34.2 @ 154**	**27.4 @ 159**
ASTM C 157				
LENGTH CHANGE (air storage)				
beam #1 (percent +/-)	-0.024	-0.036	-0.309	-0.126
beam #2 (percent +/-)	-0.033	-0.030	-0.296	-0.121
average (percent +/-)	**-0.029**	**-0.033**	**-0.202**	**-0.124**
ASTM C 672				
SCALING after 50 test cycles				
block #1 rating	5	0	5	3
block #2 rating	5	0	4	3
average rating	**5**	**0**	**5**	**3**
interpretation	**severe**	**no scaling**	**severe**	**moderate**
ASTM C 944				
ABRASION RESISTANCE				
block #1 grams lost/cm5	0.0214	0.0114	0.0143	0.0050
block #2 grams lost/cm5	0.0143	0.0136	0.0122	0.0093
block #3 grams lost/cm5	0.0143	0.0136	0.0172	0.0079
average grams lost/cm5	**0.0167**	**0.0129**	**0.0146**	**0.0074**
ASTM C 1202				
CHLORIDE PENETRABILITY				
core #1 coulombs/rating	1642/LOW	2228/MODERATE	3250/MODERATE	2585/MODERATE
core #2 coulombs/rating	2401/MODERATE	2350/MODERATE	3428/MODERATE	3145/MODERATE
core #3 coulombs/rating	1791/LOW	2384/MODERATE	2470/MODERATE	3011/MODERATE
core #4 coulombs/rating	1786/LOW	1624/LOW	3103/MODERATE	2496/MODERATE
average coulombs/rating	**1905/LOW**	**2146/MODERATE**	**3063/MODERATE**	**2809/MODERATE**

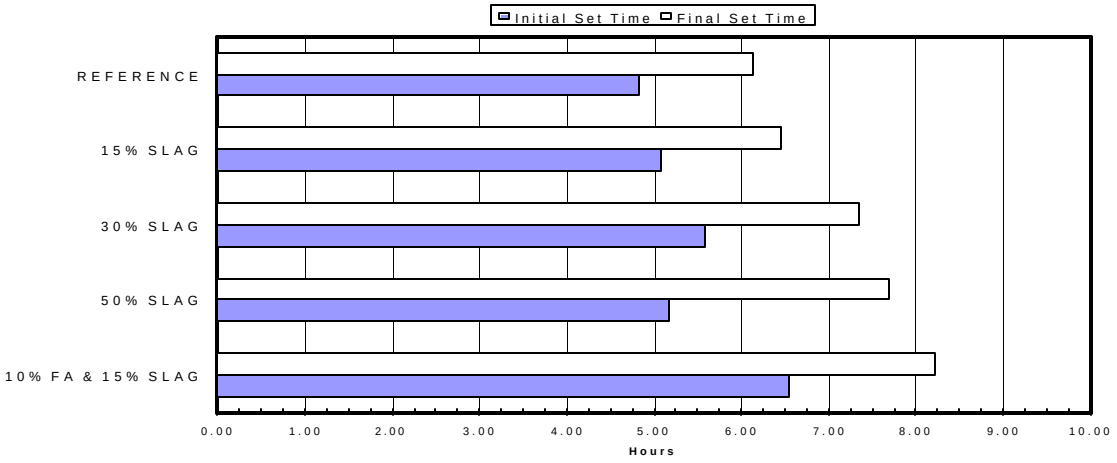
5.8 BAG TYPE "B" PAVEMENT CONCRETE MIXES
GRADE "B" GRAVEL @ AMBIENT TEMPERATURE (73°F)
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.40

DESCRIPTION	**REFERENCE**	**15% SLAG**	**30% SLAG**	**50% SLAG**	**10% FLY ASH 15% SLAG**
LTRC LAB NO.	C-2144	C-2154	C-2156	C-2159	C-2160
DATE MIXED	07/01/97	11/13/97	11/17/97	12/09/97	12/11/97
CEMENT (lbs/yd)	545	463	381	273	409
SLAG (lbs/yd)	0	82	164	273	82
FLY ASH (lbs/yd)	0	0	0	0	54
WATER (lbs/yd)	218	218	218	218	218
COARSE AGGREGATE (lbs/yd)	1964	1964	1964	1964	1964
FINE AGGREGATE (lbs/yd)	1135	1135	1135	1135	1135
DARAVAIR 1000 (oz/100ct)	3	3	3	3	3
WRDA-19 (oz/100ct)	4	4	4	4	4
AIR TEMPERATURE (°F)	70°	66°	67°	70°	68°
CONCRETE TEMPERATURE (°F)	74°	72°	69°	68°	71°
SLUMP (inches)	2.00"	1.00"	1.50"	3.50"	3.00"
AIR CONTENT (percent)	5.4%	5.0%	5.5%	6.4%	7.4%
UNIT WEIGHT (lbs/cu.ft.)	141.6 lbs	140.0 lbs	140.8 lbs	138.0 lbs	138.0 lbs
ASTM C 403					
TIME OF SET					
INITIAL	04 hrs 50 mins	05 hrs 05 mins	05 hrs 35 mins	05 hrs 11 mins	06 hrs 33 mins
FINAL	06 hrs 08 mins	06 hrs 27 mins	07 hrs 21 mins	07 hrs 42 mins	08 hrs 13 mins
ASTM C 39					
7 DAY COMPRESSIVE STRENGTH					
cylinder #1 psi	3754	3073	3408	2489	2829
cylinder #2 psi	3570	3339	3679	2569	2866
cylinder #3 psi	3609	3195	3234	2494	2635
average psi	**3644**	**3202**	**3440**	**2517**	**2777**
28 DAY COMPRESSIVE STRENGTH					
cylinder #1 psi	5066	4416	4904	4429	3521
cylinder #2 psi	4730	4321	4757	4491	3407
cylinder #3 psi	4547	4189	4788	4509	3709
average psi	**4781**	**4309**	**4816**	**4476**	**3546**
ASTM C 78					
7 DAY FLEXURAL STRENGTH					
beam #1 psi	568	565	615	513	467
beam #2 psi	545	549	603	496	461
beam #3 psi	530	605	592	490	493
average psi	**548**	**573**	**603**	**500**	**474**
28 DAY FLEXURAL STRENGTH					
beam #1 psi	623	661	687	705	595
beam #2 psi	654	697	734	636	521
beam #3 psi	653	641	734	686	504
average psi	**644**	**666**	**718**	**676**	**540**
ASTM C 469					
28 DAY MODULES OF ELASTICITY					
cylinder #1	5322988	4831975	5352596	4799747	4974733
cylinder #2	4936830	5286386	5516965	5247730	5229663
average	**5129909**	**5059180**	**5434780**	**5023738**	**4974733**
28 DAY POISSON'S RATIO					
cylinder #1	0.0479452	0.2133713	0.0952381	0.2222222	0.1818182
cylinder #2	0.1118012	0.2384868	0.0702006	0.2406015	0.2666667
average	**0.0798732**	**0.2259290**	**0.0827193**	**0.2314118**	**0.2242424**

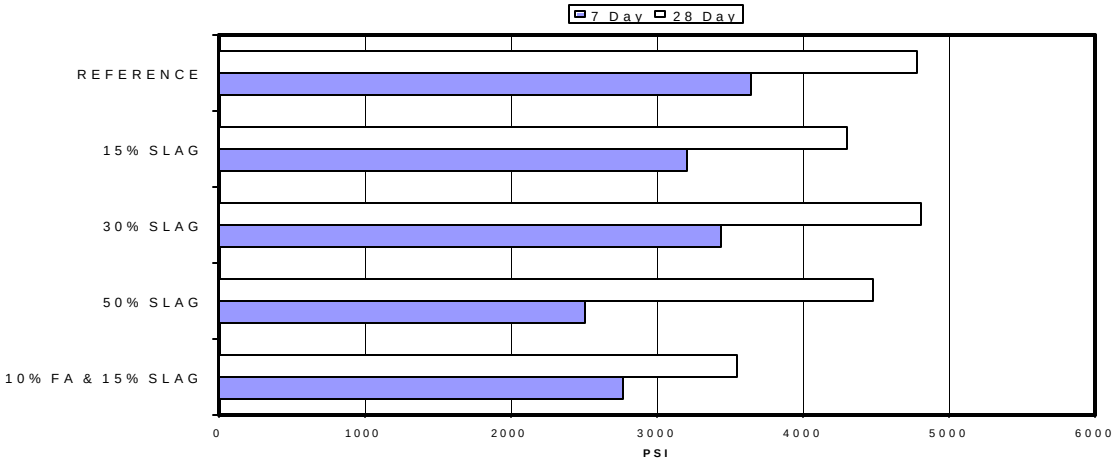
5.8 BAG TYPE "B" PAVEMENT CONCRETE MIXES
GRADE "B" GRAVEL @ AMBIENT TEMPERATURE (73°F)
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.40

DESCRIPTION	**REFERENCE**	**15% SLAG**	**30% SLAG**	**50% SLAG**	**10% FLY ASH 15% SLAG**
LTRC LAB NO.	C-2144	C-2154	C-2156	C-2159	C-2160
DATE MIXED	07/01/97	11/13/97	11/17/97	12/09/97	12/11/97
CEMENT (lbs/yd)	545	463	381	273	409
SLAG (lbs/yd)	0	82	164	273	82
FLY ASH (lbs/yd)	0	0	0	0	54
WATER (lbs/yd)	218	218	218	218	218
COARSE AGGREGATE (lbs/yd)	1964	1964	1964	1964	1964
FINE AGGREGATE (lbs/yd)	1135	1135	1135	1135	1135
DARAVAIR 1000 (oz/100ct)	3	3	3	3	3
WRDA-19 (oz/100ct)	4	4	4	4	4
AIR TEMPERATURE (°F)	70°	66°	67°	70°	68°
CONCRETE TEMPERATURE (°F)	74°	72°	69°	68°	71°
SLUMP (inches)	2.00"	1.00"	1.50"	3.50"	3.00"
AIR CONTENT (percent)	5.4%	5.0%	5.5%	6.4%	7.4%
UNIT WEIGHT (lbs/cu.ft.)	141.6 lbs	140.0 lbs	140.8 lbs	138.0 lbs	138.0 lbs
ASTM C 666 & ASTM C 215					
FREEZE and THAW					
beam #1 DF @ CYCLES	41.8 @ 209	36.2 @ 181	40.8 @ 204	27.0 @ 135	19.4 @ 97
beam #2 DF @ CYCLES	48.6 @ 243	28.0 @ 140	42.4 @ 212	28.0 @ 140	22.2 @ 111
beam #3 DF @ CYCLES	33.8 @ 169	24.0 @ 120	39.2 @ 196	29.2 @ 146	17.8 @ 89
average DF @ CYCLES	**41.1 @ 207**	**29.4 @ 147**	**40.8 @ 204**	**28.1 @ 140**	**19.8 @ 99**
ASTM C 157					
LENGTH CHANGE (air storage)					
beam #1 (percent +/-)	-0.017	-0.075	-0.018	-0.021	-0.008
beam #2 (percent +/-)	-0.019	-0.076	-0.017	-0.012	-0.054
average (percent +/-)	**-0.018**	**-0.076**	**-0.018**	**-0.016**	**-0.031**
ASTM C 672					
SCALING after 50 test cycles					
block #1 rating	2	4	4	4	4
block #2 rating	2	4	5	4	3
average rating	**2**	**4**	**4**	**4**	**3**
interpretation	**SLIGHT-MOD**	**MOD-SEVERE**	**MOD-SEVERE**	**MOD-SEVERE**	**MODERATE**
ASTM C 944					
ABRASION RESISTANCE					
block #1 grams lost/cm^5	0.0379	0.0257	0.0179	0.0257	0.0264
block #2 grams lost/cm^5	0.0307	0.0250	0.0250	0.0272	0.0214
block #3 grams lost/cm^5	0.0172	0.0264	0.0250	0.0257	0.0257
average grams lost/cm^5	**0.0286**	**0.0257**	**0.0226**	**0.0262**	**0.0245**
ASTM C 1202					
CHLORIDE PENETRABILITY					
core #1 coulombs/rating	2417/MOD	4066/HIGH	2454/MOD	1243/LOW	1301/LOW
core #2 coulombs/rating	3162/MOD	2913/MOD	2511/MOD	3088/MOD	3189/MOD
core #3 coulombs/rating	4070/HIGH	5379/HIGH	2403/MOD	3086/MOD	3178/MOD
core #4 coulombs/rating	3455/MOD	2306/MOD	1447/LOW	3262/MOD	4612/HIGH
average coulombs/rating	**3276/MOD**	**3666/MOD**	**2204/MOD**	**2670/MOD**	**3070/MOD**

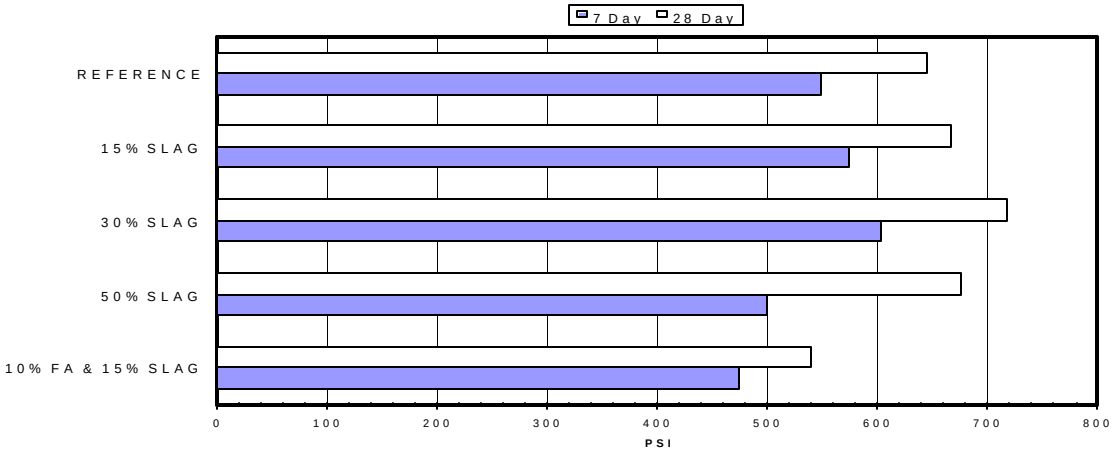
SET TIMES: 5.8 Bag Type 'B' Pavement Mix (Grade B Gravel @ 73F)



COMPRESSIVE STRENGTH: 5.8 Bag Type 'B' Pavement Mix (Grade B Gravel @ 73F)



FLEXURAL STRENGTH: 5.8 Bag Type 'B' Pavement Mix (Grade B Gravel @ 73F)



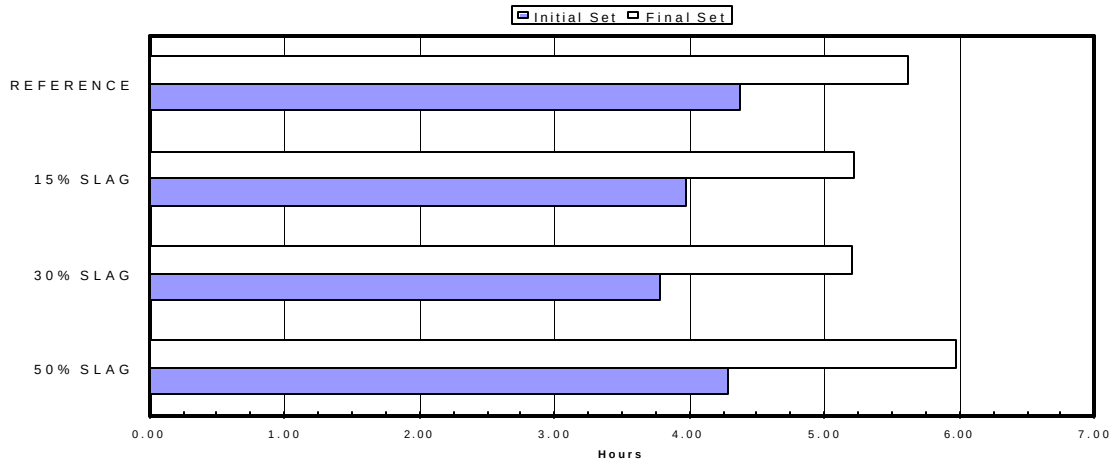
6.0 BAG CLASS "A" STRUCTURAL CONCRETE MIXES
GRADE "A" LIMESTONE @ AMBIENT TEMPERATURE 73°F
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.43

DESCRIPTION	REFERENCE	15% SLAG	30% SLAG	50% SLAG
LTRC LAB NO.	C-2082	C-2091	C-2092	C-2090
DATE MIXED	04/25/96	07/22/96	07/31/96	07/15/96
CEMENT (lbs/yd)	564	479	395	282
SLAG (lbs/yd)	0	85	169	282
WATER (lbs/yd)	243	243	243	243
COARSE AGGREGATE (lbs/yd)	2024	2024	2024	2024
FINE AGGREGATE (lbs/yd)	1103	1103	1103	1103
DARAVAIR 1000 (oz/100ct)	2	2	2	2
WRDA w/ HYCOL (oz/100ct)	3	3	3	3
AIR TEMPERATURE (°F)	72°	74°	72°	73°
CONCRETE TEMPERATURE (°F)	75°	76°	76°	75°
SLUMP (inches)	2.00"	2.25"	0.75"	0.50"
AIR CONTENT (percent)	4.9%	4.3%	3.8%	3.0%
UNIT WEIGHT (lbs/cu.ft.)	146.0 lbs	146.8 lbs	149.6 lbs	149.6 lbs
TIME OF SET				
INITIAL	04 hrs 22 mins	03 hrs 58 mins	03 hrs 47 mins	04 hrs 17 mins
FINAL	05 hrs 37 mins	05 hrs 13 mins	05 hrs 12 mins	05 hrs 58 mins
7 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	4201	4668	4901	5856
cylinder #2 psi	4184	4562	5063	5940
cylinder #3 psi	4307	4485	5036	5584
average psi	**4231**	**4571**	**5000**	**5793**
28 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	5325	6435	6594	7071
cylinder #2 psi	5300	5563	6214	7021
cylinder #3 psi	5147	5680	5835	6805
average psi	**5257**	**5892**	**6214**	**6966**
7 DAY FLEXURAL STRENGTH				
beam #1 psi	631	665	638	825
beam #2 psi	587	637	631	841
beam #3 psi	642	638	607	817
average psi	**620**	**647**	**625**	**828**
28 DAY FLEXURAL STRENGTH				
beam #1 psi	854	753	894	780
beam #2 psi	756	704	810	840
beam #3 psi	731	767	980	846
average psi	**780**	**741**	**894**	**822**
28 DAY MODULES OF ELASTICITY				
cylinder #1				
cylinder #2	5038727	5388475	5986260	5576352
average	5098357	5301519	5956097	6019432
	5068542	**5344997**	**5971178**	**5797892**
28 DAY POISSON'S RATIO				
cylinder #1	0.1988304	0.2584270	0.2294118	0.1886792
cylinder #2	0.1952663	0.2122905	0.2232558	0.2268041
average	**0.1970483**	**0.2353587**	**0.2263338**	**0.2077416**

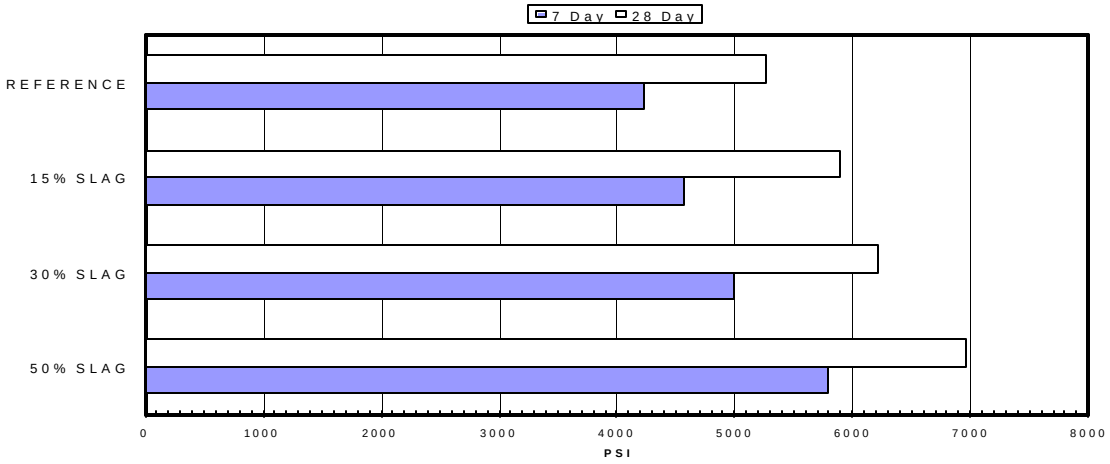
6.0 BAG CLASS "A" STRUCTURAL CONCRETE MIXES
GRADE "A" LIMESTONE @ AMBIENT TEMPERATURE 73°F
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.43

DESCRIPTION	REFERENCE	15% SLAG	30% SLAG	50% SLAG
LTRC LAB NO.	C-2082	C-2091	C-2092	C-2090
DATE MIXED	04/25/96	07/22/96	07/31/96	07/15/96
CEMENT (lbs/yd)	564	479	395	282
SLAG (lbs/yd)	0	85	169	282
WATER (lbs/yd)	243	243	243	243
COARSE AGGREGATE (lbs/yd)	2024	2024	2024	2024
FINE AGGREGATE (lbs/yd)	1103	1103	1103	1103
DARAVAIR 1000 (oz/100ct)	2	2	2	2
WRDA w/ HYCOL (oz/100ct)	3	3	3	3
AIR TEMPERATURE (°F)	72°	74°	72°	73°
CONCRETE TEMPERATURE (°F)	75°	76°	76°	75°
SLUMP (inches)	2.00"	2.25"	0.75"	0.50"
AIR CONTENT (percent)	4.9%	4.3%	3.8%	3.0%
UNIT WEIGHT (lbs/cu.ft.)	146.0 lbs	146.8 lbs	149.6 lbs	149.6 lbs
FREEZE and THAW				
beam #1 DF @ CYCLES	79 @ 300	74 @ 300	N/A	55 @ 277
beam #2 DF @ CYCLES	83 @ 300	75 @ 300	54 @ 268	51 @ 256
beam #3 DF @ CYCLES	80 @ 300	47 @ 236	36 @ 181	48 @ 240
average DF @ CYCLES	**81 @ 300**	**65 @ 279**	**45 @ 224**	**52 @ 258**
LENGTH CHANGE (air storage)				
BEAM #1 (percent +/-)	-0.025	-0.023	-0.021	-0.004
BEAM #2 (percent +/-)	-0.022	-0.013	-0.016	-0.016
AVERAGE (percent +/-)	**-0.024**	**-0.018**	**-0.019**	**-0.010**
SCALING after 50 test cycles				
block #1 rating	1	1	2	3
block #2 rating	1	1	2	3
average rating	**1**	**1**	**2**	**3**
interpretation	**SLIGHT**	**SLIGHT**	**SLIGHT-MOD.**	**MODERATE**
ABRASION RESISTANCE				
block #1 grams lost/cm^2	0.0093	0.0157	0.0057	0.0264
block #2 grams lost/ cm^2	0.0143	0.0193	0.0050	0.0293
block #3 grams lost/ cm^2	0.0129	0.0200	0.0064	0.0279
average grams lost/ cm^2	**0.0122**	**0.0183**	**0.0057**	**0.0279**
CHLORIDE PENETRABILITY				
core #1 coulombs/rating	4324/HIGH	3424/MOD	1858/LOW	1191/LOW
core #2 coulombs/rating	4079/HIGH	3519/MOD	1917/LOW	1270/LOW
core #3 coulombs/rating	3879/MOD	3180/MOD	1998/LOW	1493/LOW
core #4 coulombs/rating	4235/HIGH	2353/MOD	2288/MOD	1355/LOW
average coulombs/rating	**4129/HIGH**	**3119/MOD**	**2015/MOD**	**1327/LOW**

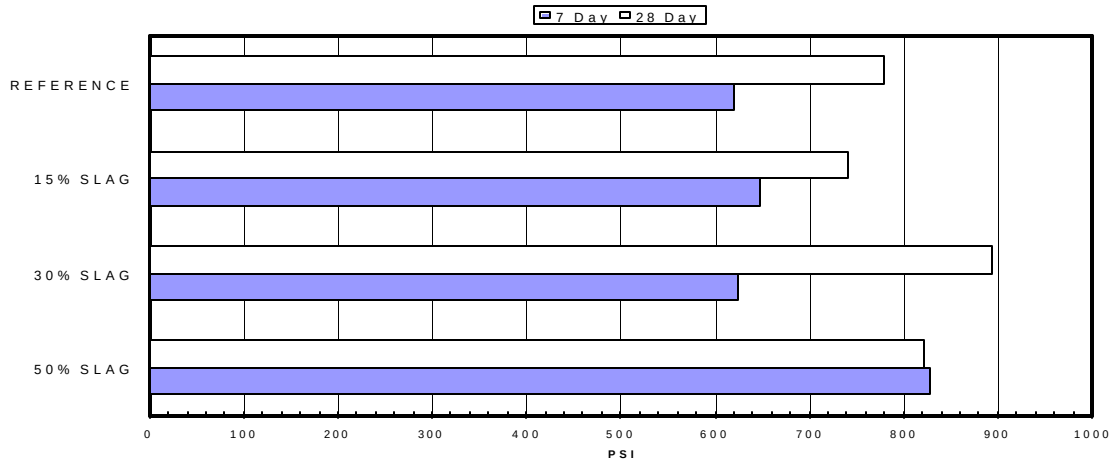
SET TIMES: 6.0 Bag Class 'A' Structural Mix (Grade A Limestone @ 73F)



COMPRESSIVE STRENGTH: 6.0 Bag Class 'A' Structural Mix (Grade A Limestone @ 73F)



FLEXURAL STRENGTH: 6.0 Bag Class 'A' Structural Mix (Grade A Limestone @ 73F)



6.5 BAG CLASS "AA" STRUCTURAL CONCRETE MIXES
GRADE "A" GRAVEL @ AMBIENT TEMPERATURE 73°F
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.43

DESCRIPTION	REFERENCE	15% SLAG	30% SLAG	50% SLAG
LTRC LAB NO.	C-2073	C-2074	C-2076	C-2083
DATE MIXED	02/08/96	02/13/96	04/18/96	05/02/96
CEMENT (lbs/yd)	611	519	428	306
SLAG (lbs/yd)	0	92	183	305
WATER (lbs/yd)	263	263	263	263
COARSE AGGREGATE (lbs/yd)	1879	1879	1879	1879
FINE AGGREGATE (lbs/yd)	1066	1066	1066	1066
DARAVAIR 1000 (oz/100ct)	2	2	2	2
WRDA w/ HYCOL (oz/100ct)	3	3	3	3
AIR TEMPERATURE (°F)	66°	65°	73°	65°
CONCRETE TEMPERATURE (°F)	74°	72°	76°	69°
SLUMP (inches)	3.50"	3.75"	3.50"	3.50"
AIR CONTENT (percent)	5.8%	6.0%	5.9%	4.6%
UNIT WEIGHT (lbs/cu.ft.)	138.0 lbs	138.8 lbs	139.2 lbs	141.6 lbs
TIME OF SET				
INITIAL	05 hrs 53 mins	05 hrs 00 mins	04 hrs 52 mins	04 hrs 48 mins
FINAL	07 hrs 07 mins	06 hrs 27 mins	06 hrs 27 mins	06 hrs 20 mins
7 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	3353	3437	1714*	3400
cylinder #2 psi	3377	3479	3283	3508
cylinder #3 psi	3316	3300	3299	3401
average psi	**3349**	**3405**	**3291**	**3436**
28 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	3957	4538	4729	5271
cylinder #2 psi	3987	4373	4923	5218
cylinder #3 psi	3901	4578	4389	5320
average psi	**3948**	**4496**	**4681**	**5270**
7 DAY FLEXURAL STRENGTH				
beam #1 psi	534	591	501	572
beam #2 psi	536	571	557	531
beam #3 psi	536	579	591	584
average psi	**535**	**580**	**550**	**563**
28 DAY FLEXURAL STRENGTH				
beam #1 psi	606	632	756	691
beam #2 psi	574	725	733	720
beam #3 psi	553	695	691	720
average psi	**578**	**684**	**726**	**710**
28 DAY MODULES OF ELASTICITY				
cylinder #1				
cylinder #2	3882803	4916944	5221920	4927092
average	4084662	4873984	5199510	4948103
	3983733	**4895464**	**5210715**	**4937598**
28 DAY POISSON'S RATIO				
cylinder #1	0.1279070	0.0555556	0.0811594	0.1511628
cylinder #2	0.1992136	0.0821918	0.0977778	0.1136364
average	**0.1635603**	**0.0688737**	**0.0894686**	**0.1323996**

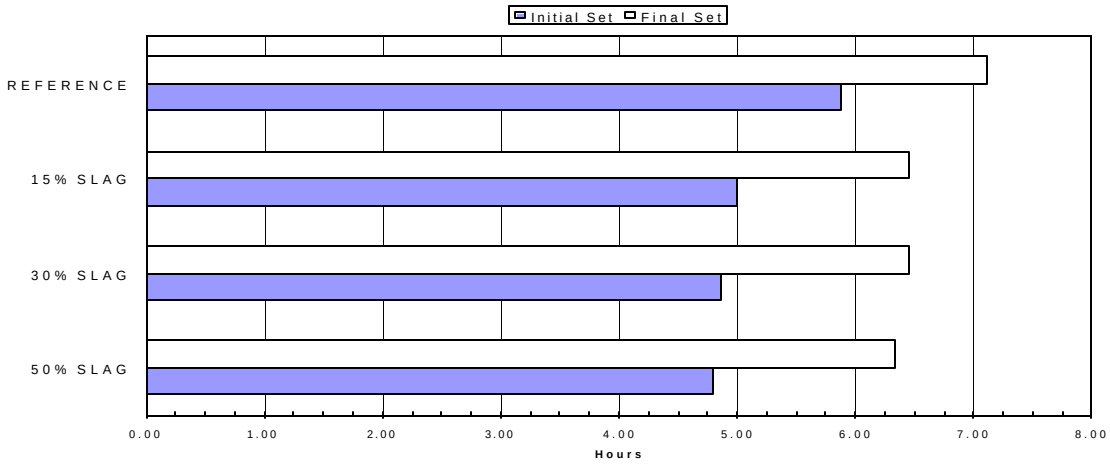
(*) denotes test not included in the overall average due to abnormal failure.

6.5 BAG CLASS "AA" STRUCTURAL CONCRETE MIXES
GRADE "A" GRAVEL @ AMBIENT TEMPERATURE 73°F
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.43

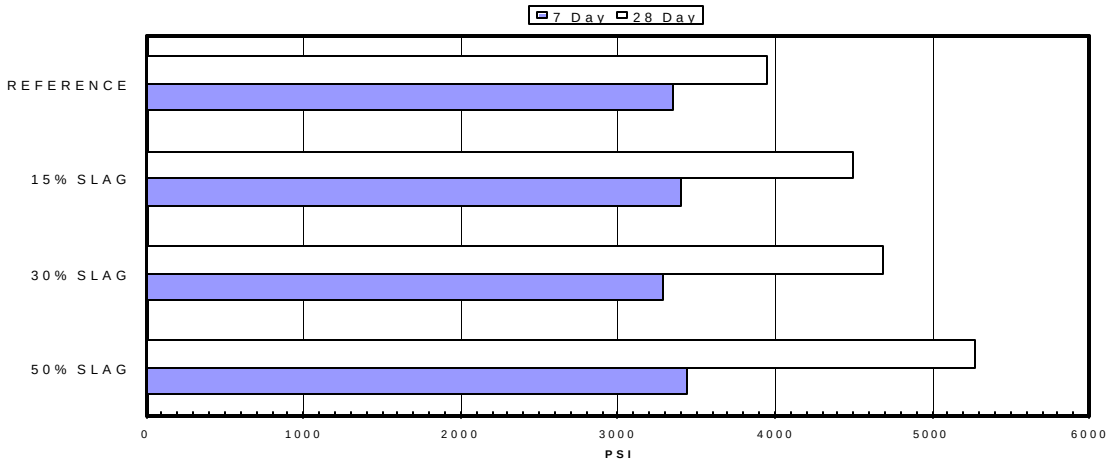
DESCRIPTION	**REFERENCE**	**15% SLAG**	**30% SLAG**	**50% SLAG**
LTRC LAB NO.	C-2073	C-2074	C-2076	C-2083
DATE MIXED	02/08/96	02/13/96	04/18/96	05/02/96
CEMENT (lbs/yd)	611	519	428	306
SLAG (lbs/yd)	0	92	183	305
WATER (lbs/yd)	263	263	263	263
COARSE AGGREGATE (lbs/yd)	1879	1879	1879	1879
FINE AGGREGATE (lbs/yd)	1066	1066	1066	1066
DARAVAIR 1000 (oz/100ct)	2	2	2	2
WRDA w/ HYCOL (oz/100ct)	3	3	3	3
AIR TEMPERATURE (°F)	66°	65°	73°	65°
CONCRETE TEMPERATURE (°F)	74°	72°	76°	69°
SLUMP (inches)	3.50"	3.75"	3.50"	3.50"
AIR CONTENT (percent)	5.8%	6.0%	5.9%	4.6%
UNIT WEIGHT (lbs/cu.ft.)	138.0 lbs	138.8 lbs	139.2 lbs	141.6 lbs
FREEZE and THAW				
beam #1 DF @ CYCLES	70.0 @ 300.0	55.4 @ 277	28.8 @ 144	44.6 @ 223
beam #2 DF @ CYCLES	33.0 @ 165.0	67.0 @ 300	27.8 @ 139	48.6 @ 243
beam #3 DF @ CYCLES	42.4 @ 212.0	40.0 @ 200	51.0 @ 255	37.4 @ 187
average DF @ CYCLES	**48.5 @ 225.7**	**54.1 @ 259**	**35.9 @ 179**	**43.5 @ 218**
LENGTH CHANGE (air storage)				
beam #1 (percent +/-)	-0.012	-0.002	-0.031	-0.018
beam #2 (percent +/-)	-0.004	-0.021	-0.033	-0.023
average (percent +/-)	**-0.008**	**-0.011**	**-0.032**	**-0.020**
SCALING after 50 test cycles				
block #1 rating	4	5	4	4
block #2 rating	4	3	4	4
average rating	**4**	**4**	**4**	**4**
interpretation	**MOD/SEV**	**MOD/SEV**	**MOD/SEV**	**MOD/SEV**
ABRASION RESISTANCE				
block #1 grams lost/ cm^2	0.0143	0.0186	0.0220	0.0164
block #2 grams lost/ cm^2	0.0143	0.0186	0.0200	0.0179
block #3 grams lost/ cm^2	0.0143	0.0207	0.0160	0.0229
average grams lost/ cm^2	**0.0143**	**0.0193**	**0.0190**	**0.0191**
CHLORIDE PENETRABILITY				
core #1 coulombs/rating	4674/HIGH	3819/MODERATE	2561/MODERATE	1384/LOW
core #2 coulombs/rating	4102/HIGH	2906/MODERATE	3155/MODERATE	1186/LOW
core #3 coulombs/rating	6682/HIGH	3180/MODERATE	2757/MODERATE	1395/LOW
core #4 coulombs/rating	4984/HIGH	3089/MODERATE	2703/MODERATE	1456/LOW
average coulombs/rating	**5110/HIGH**	**3248/MODERATE**	**2794/MODERATE**	**1355/LOW**

(*) denotes test not included in the overall average due to abnormal failure.

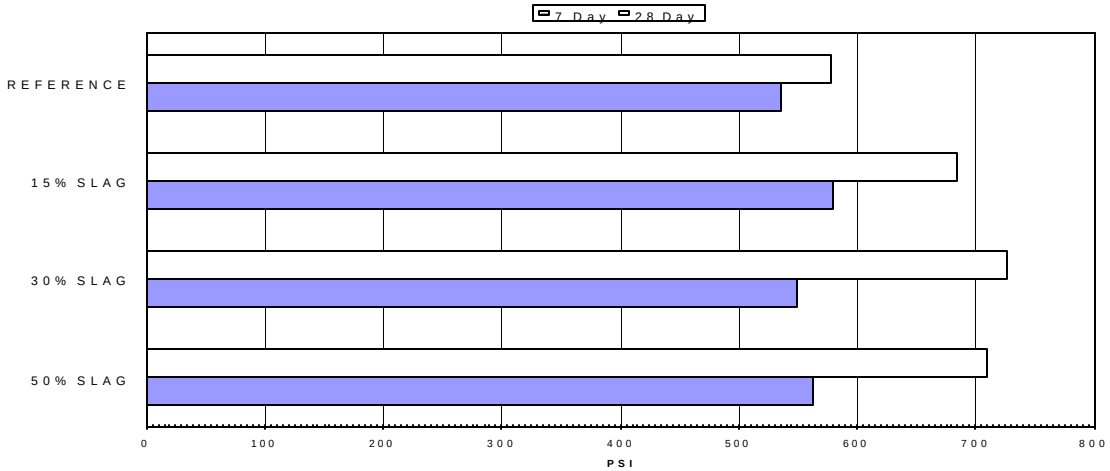
SET TIMES: 6.5 Bag Class 'AA' Structural Mix (Grade A Gravel @ 73F)



COMPRESSIVE STRENGTH: 6.5 Bag Class 'AA' Structural Mix (Grade A Gravel @ 73F)



FLEXURAL STRENGTH: 6.5 Bag Class 'AA' Structural Mix (Grade A Gravel @ 73F)



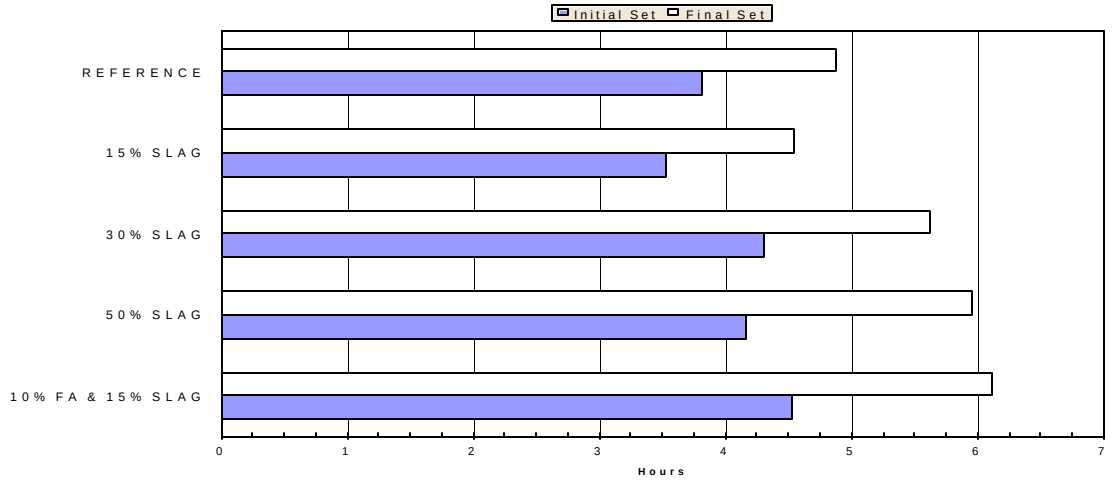
5.4 BAG TYPE "B" PAVEMENT CONCRETE MIXES
GRADE "B" LIMESTONE @ AMBIENT TEMPERATURE 73°F
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.40

DESCRIPTION	REFERENCE	15% SLAG	30% SLAG	50% SLAG	10% FLY ASH 15% SLAG
LTRC LAB NO.	C-2093	C-2095	C-2096	C-2102	C-2103
DATE MIXED	09/10/96	09/17/96	09/24/96	02/20/97	03/11/97
CEMENT (lbs/yd)	508	431	356	254	381
SLAG (lbs/yd)	0	76	152	254	76
FLY ASH (lbs/yd)	0	0	0	0	51
WATER (lbs/yd)	203	203	203	203	203
COARSE AGGREGATE (lbs/yd)	2116	2116	2116	2116	2116
FINE AGGREGATE (lbs/yd)	1163	1163	1163	1163	1163
DARAVAIR 1000 (oz/100ct)	3	3	3	3	3
WRDA-19 (oz/100ct)	12	12	12	12	12
AIR TEMPERATURE (°F)	74°	72°	74°	72°	71°
CONCRETE TEMPERATURE (°F)	75°	78°	68°	75°	76°
SLUMP (inches)	2.00"	1.50"	2.75"	1.50"	2.75"
AIR CONTENT (percent)	3.8%	3.9%	3.9%	3.0%	3.2%
UNIT WEIGHT (lbs/cu.ft.)	151.6 lbs	151.6 lbs	151.2 lbs	150.8 lbs	148.8 lbs
ASTM C 403					
TIME OF SET					
initial	03 hrs 49 mins	03 hrs 32 mins	04 hrs 18 mins	04 hrs 10 mins	04 hrs 32 mins
final	04 hrs 53 mins	04 hrs 33 mins	05 hrs 37 mins	05 hrs 57 mins	06 hrs 07 mins
ASTM C 39					
7 DAY COMPRESSIVE STRENGTH					
cylinder #1 psi	5018	5881	4880	6056	4716
cylinder #2 psi	4923	5110	4839	6361	4652
cylinder #3 psi	5063	5447	4856	6219	4695
average psi	**5001**	**5480**	**4858**	**6212**	**4688**
28 DAY COMPRESSIVE STRENGTH					
cylinder #1 psi	6183	6113	5769	6883	5858
cylinder #2 psi	6125	5701	5604	7300	6369
cylinder #3 psi	6081	5645	5696	6696	5904
average psi	**6130**	**5820**	**5690**	**6960**	**6044**
ASTM C 78					
7 DAY FLEXURAL STRENGTH					
beam #1 psi	806	719	761	852	713
beam #2 psi	738	721	840	851	717
beam #3 psi	808	762	763	818	775
average psi	**784**	**734**	**788**	**840**	**735**
28 DAY FLEXURAL STRENGTH					
beam #1 psi	847	841	905	905	725
beam #2 psi	845	791	905	866	785
beam #3 psi	818	786	824	894	843
average psi	**837**	**806**	**878**	**889**	**784**
ASTM C 469					
28 DAY MODULES OF ELASTICITY					
cylinder #1	6021988	5541828	5718631	6331081	6038550
cylinder #2	5869812	5487916	5434445	6288407	6148388
average	**5945900**	**5514872**	**5576538**	**6309744**	**6093469**
28 DAY POISSON'S RATIO					
cylinder #1	0.2857143	0.2083333	0.1842752	0.2021277	0.2228916
cylinder #2	0.2558140	0.2559524	0.1744186	0.1914894	0.2261905
average	**0.2707641**	**0.2321428**	**0.1793469**	**0.1968085**	**0.224541**

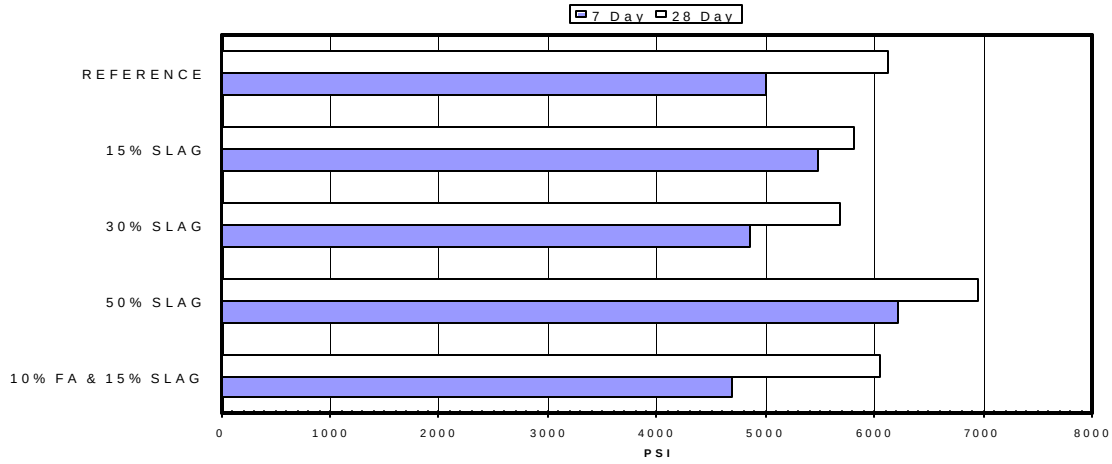
5.4 BAG TYPE "B" PAVEMENT CONCRETE MIXES
GRADE "B" LIMESTONE @ AMBIENT TEMPERATURE 73°F
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG
WATER / CEMENT RATIO = 0.40

DESCRIPTION	**REFERENCE**	**15% SLAG**	**30% SLAG**	**50% SLAG**	**10% FLY ASH 15% SLAG**
LTRC LAB NO.	C-2093	C-2095	C-2096	C-2102	C-2103
DATE MIXED	09/10/96	09/17/96	09/24/96	02/20/97	03/11/97
CEMENT (lbs/yd)	508	431	356	254	381
SLAG (lbs/yd)	0	76	152	254	76
FLY ASH (lbs/yd)	0	0	0	0	51
WATER (lbs/yd)	203	203	203	203	203
COARSE AGGREGATE (lbs/yd)	2116	2116	2116	2116	2116
FINE AGGREGATE (lbs/yd)	1163	1163	1163	1163	1163
DARAVAIR 1000 (oz/100ct)	3	3	3	3	3
WRDA-19 (oz/100ct)	12	12	12	12	12
AIR TEMPERATURE (°F)	74°	72°	74°	72°	71°
CONCRETE TEMPERATURE	75°	78°	68°	75°	76°
(°F)	2.00"	1.50"	2.75"	1.50"	2.75"
SLUMP (inches)	3.8%	3.9%	3.9%	3.0%	3.2%
AIR CONTENT (percent)	151.6 lbs	151.6 lbs	151.2 lbs	150.8 lbs	148.8 lbs
UNIT WEIGHT (lbs/cu.ft.)					
ASTM C 666 & ASTM C 215					
FREEZE and THAW					
beam #1 DF @ CYCLES	19 @ 96	24 @ 118	24 @ 121	69 @ 300	29 @ 143
beam #2 DF @ CYCLES	17 @ 86	26 @ 130	20 @ 102	63 @ 300	30 @ 149
beam #3 DF @ CYCLES	19 @ 93	13 @ 66	24 @ 118	60 @ 300	34 @ 169
average DF @ CYCLES	**18 @ 92**	**21 @ 105**	**23 @ 114**	**64 @ 300**	**31 @ 154**
ASTM C 157					
LENGTH CHANGE (air storage)					
beam #1 (percent +/-)	-0.018	-0.015	-0.003	-0.012	-0.021
beam #2 (percent +/-)	-0.017	-0.018	-0.025	-0.012	-0.023
average (percent +/-)	**-0.018**	**-0.016**	**-0.014**	**-0.012**	**-0.022**
ASTM C 672					
SCALING after 50 test cycles					
block #1 rating	1	3	2	2	1
block #2 rating	2	3	3	1	2
average rating	**2**	**3**	**3**	**2**	**2**
interpretation	**SLIGHT/MOD**	**MODERATE**	**MODERATE**	**SLIGHT/MOD**	**SLIGHT/MOD**
ASTM C 944					
ABRASION RESISTANCE					
block #1 grams lost/ cm^2	0.0172	0.0172	0.0272	0.0207	0.0214
block #2 grams lost/ cm^2	0.0172	0.0200	0.0222	0.0200	0.0222
block #3 grams lost/ cm^2	0.0164	0.0114	0.0236	0.0229	0.0200
average grams lost/ cm^2	**0.0169**	**0.0162**	**0.0243**	**0.0212**	**0.0212**
ASTM C 1202					
CHLORIDE PENETRABILITY					
core #1 coulombs/rating	3760/MOD	1544/LOW	1437/LOW	996/V.LOW	2617/MOD
core #2 coulombs/rating	2500/MOD	2239/MOD	1650/LOW	1045/LOW	2446/MOD
core #3 coulombs/rating	3132/MOD	1648/LOW	1348/LOW	997/V.LOW	2977/MOD
core #4 coulombs/rating	3209/MOD	1662/LOW	1563/LOW	997/V.LOW	2555/MOD
average coulombs/rating	**3150/MOD**	**1773/LOW**	**1500/LOW**	**1009/LOW**	**2649/MOD**

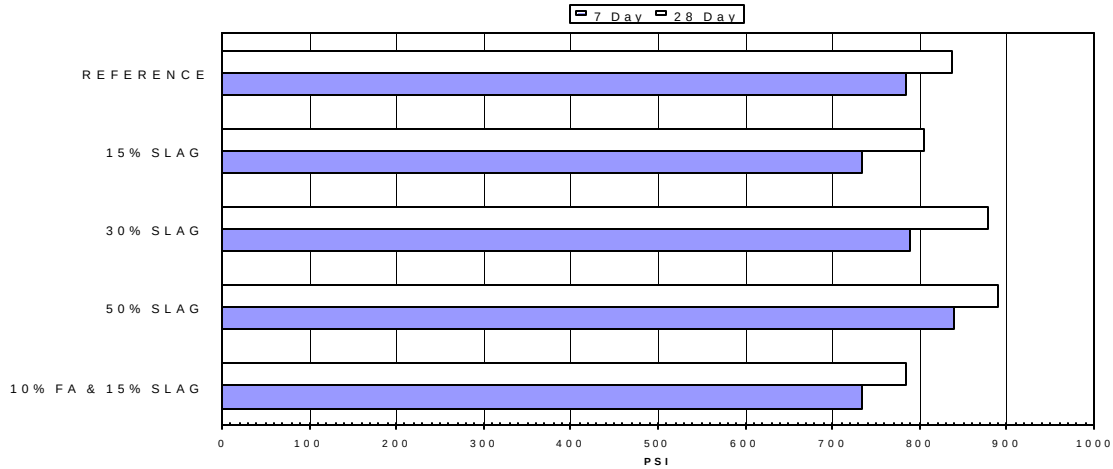
SET TIMES: 5.4 Bag Type 'B' Pavement Mix (Grade B Limestone @ 73F)



COMPRSEEIVE STRENGTH: 5.4 Bag type 'B' Pavement Mix (Grade B Limestone @ 73F)



FLEXURAL STRENGTH: 5.4 Bag Type 'B' Pavement Mix (Grade B Limestone @ 73F)



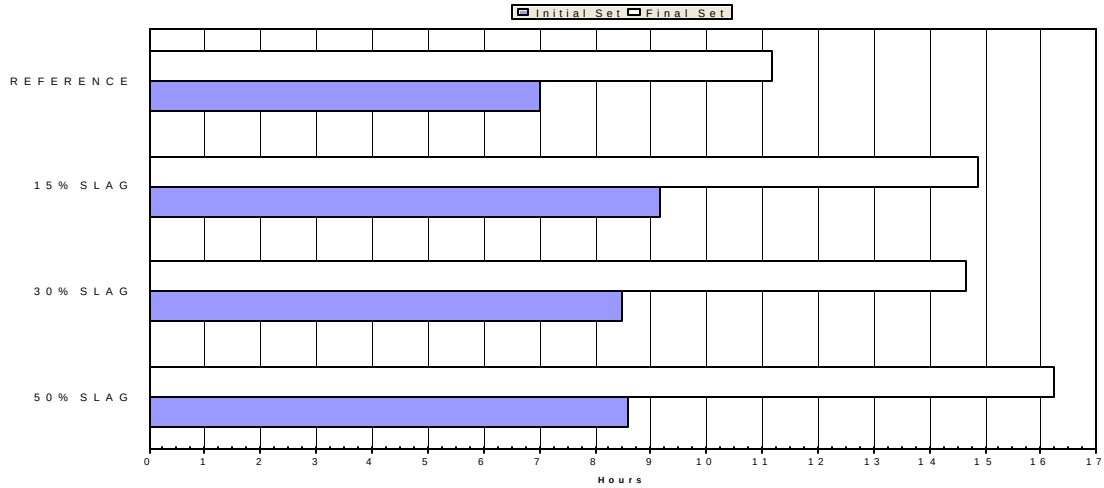
6.0 BAG CLASS "A" STRUCTURAL CONCRETE MIXES. WATER / CEMENT RATIO = 0.43.
GRADE "A" **LIMESTONE**. COMPONENTS DRIED AND CHILLED TO 40°F PRIOR TO MIXING. SAMPLES CURED IN SEALED 40°F ENVIRONMENT.
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG

DESCRIPTION	REFERENCE	15% SLAG	30% SLAG	50% SLAG
LTRC LAB NO.	C-2173	C-2180	C-2176	C-2170
DATE MIXED	03/17/98	04/21/98	04/07/98	03/05/98
CEMENT (lbs/yd)	564	479	395	282
SLAG (lbs/yd)	0	85	169	282
WATER (lbs/yd)	243	243	243	243
COARSE AGGREGATE (lbs/yd)	2039	2039	2039	2039
FINE AGGREGATE (lbs/yd)	1103	1103	1103	1103
DARAVAIR 1000 (oz/100ct)	2	2	2	2
WRDA w/ HYCOL (oz/100ct)	3	3	3	3
AIR TEMPERATURE (°F)	63°	69°	69°	66°
CONCRETE TEMPERATURE (°F)	53°	61°	62°	48°
SLUMP (inches)	2.50"	3.50"	2.75"	1.00"
AIR CONTENT (percent)	5.6%	5.6%	5.5%	3.3%
UNIT WEIGHT (lbs/cu.ft.)	143.2 lbs	144.4 lbs	144.0 lbs	136.8 lbs
ASTM C 403 TIME OF SET				
initial	07 hrs 00 mins	09 hrs 09 mins	08 hrs 30 mins	08 hrs 36 mins
final	11 hrs 11 mins	14 hrs 52 mins	14 hrs 40 mins	16 hrs 15 mins
ASTM C 39				
7 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	3337	3230	3317	1484
cylinder #2 psi	3239	3422	3396	2258
cylinder #3 psi	3391	3462	3381	2419
average psi	**3322**	**3371**	**3365**	**2054**
28 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	4268	4607	4766	4870
cylinder #2 psi	4382	4380	4520	5179
cylinder #3 psi	3390	4708	3907	5908
average psi	**4013**	**4565**	**4398**	**5319**
56 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	5067	5772	5293	6859
cylinder #2 psi	5084	5741	5430	6029
cylinder #3 psi	4649	4930	3096	6752
average psi	**4934**	**5481**	**4603**	**6547**
ASTM C 78				
7 DAY FLEXURAL STRENGTH				
beam #1 psi	477	620	501	512
beam #2 psi	616	602	493	484
beam #3 psi	471	634	475	473
average psi	**422**	**619**	**490**	**490**
28 DAY FLEXURAL STRENGTH				
beam #1 psi	665	641	680	885
beam #2 psi	671	586	741	865
beam #3 psi	671	635	774	903
average psi	**669**	**621**	**732**	**884**
ASTM C 469				
28 DAY MODULES OF ELASTICITY				
cylinder #1	5072420	4633297	4574719	5078395
cylinder #2	N/A	4552163	4588500	5398227
average	**5072420**	**4592730**	**4581610**	**5238311**
28 DAY POISSON'S RATIO				
cylinder #1	0.17	0.20	0.19	0.22
cylinder #2	N/A	0.22	0.20	0.22
average	**0.17**	**0.21**	**0.19**	**0.22**

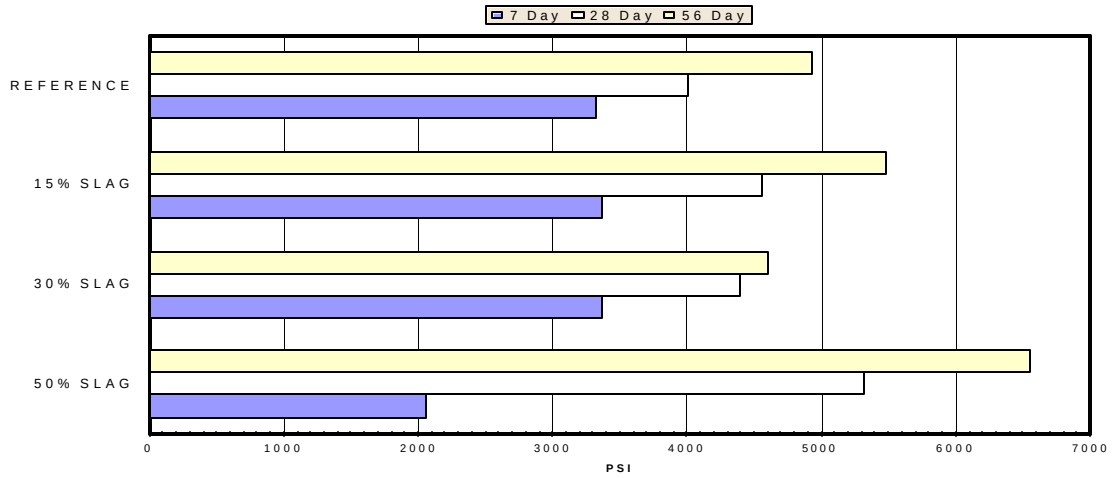
6.0 BAG CLASS "A" STRUCTURAL CONCRETE MIXES. WATER / CEMENT RATIO = 0.43.
GRADE "A" **LIMESTONE**. COMPONENTS DRIED AND CHILLED TO 40°F PRIOR TO MIXING. SAMPLES CURED IN SEALED 40°F ENVIRONMENT.
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG

DESCRIPTION	**REFERENCE**	**15% SLAG**	**30% SLAG**	**50% SLAG**
LTRC LAB NO.	C-2173	C-2180	C-2176	C-2170
DATE MIXED	03/17/98	04/21/98	04/07/98	03/05/98
CEMENT (lbs/yd)	564	479	395	282
SLAG (lbs/yd)	0	85	169	282
WATER (lbs/yd)	243	243	243	243
COARSE AGGREGATE (lbs/yd)	2039	2039	2039	2039
FINE AGGREGATE (lbs/yd)	1103	1103	1103	1103
DARAVAIR 1000 (oz/100ct)	2	2	2	2
WRDA w/ HYCOL (oz/100ct)	3	3	3	3
AIR TEMPERATURE (°F)	63°	69°	69°	66°
CONCRETE TEMPERATURE (°F)	53°	61°	62°	48°
SLUMP (inches)	2.50"	3.50"	2.75"	1.00"
AIR CONTENT (percent)	5.6%	5.6%	5.5%	3.3%
UNIT WEIGHT (lbs/cu.ft.)	143.2 lbs	144.4 lbs	144.0 lbs	136.8 lbs
ASTM C 666 & ASTM C 215				
FREEZE and THAW				
beam #1 DF @ CYCLES	85.0 @ 300	100.0 @ 300	79.5 @ 300	55.2 @ 276
beam #2 DF @ CYCLES	94.7 @ 300	96.1 @ 300	94.2 @ 300	52.6 @ 263
beam #3 DF @ CYCLES	93.4 @ 300	100.0 @ 300	93.5 @ 300	63.0 @ 300
average DF @ CYCLES	**90.9 @ 300**	**98.7 @ 300**	**89.0 @ 300**	**56.9 @ 280**
ASTM C 157				
LENGTH CHANGE (air storage)				
beam #1 (percent +/-)	-0.038	-0.031	-0.034	-0.021
beam #2 (percent +/-)	-0.038	-0.029	-0.038	-0.012
average (percent +/-)	**-0.038**	**-0.030**	**-0.036**	**-0.016**
ASTM C 672				
SCALING after 50 test cycles				
block #1 rating	4	2	5	5
block #2 rating	5	4	5	5
average rating	**4**	**3**	**5**	**5**
interpretation	**MODERATE to SEVERE**	**MODERATE**	**SEVERE**	**SEVERE**
ASTM C 944				
ABRASION RESISTANCE				
block #1 grams lost/ cm^2	0.029	0.025	0.010	0.014
block #2 grams lost/ cm^2	0.021	0.023	0.019	0.013
block #3 grams lost/ cm^2	0.028	0.026	0.013	N/A
average grams lost/ cm^2	**0.026**	**0.025**	**0.014**	**0.013**
ASTM C 1202				
CHLORIDE PENETRABILITY				
core #1 coulombs/rating	4877/high	4327/high	2513/moderate	2232/moderate
core #2 coulombs/rating	4674/high	5175/high	3416/moderate	1865/low
core #3 coulombs/rating	4235/high	5203/high	3348/mioderate	2153/moderate
core #4 coulombs/rating	4324/high	N/A	N/A	N/A
average coulombs/rating	**4528/high**	**4902/high**	**3092/moderate**	**2083/moderate**

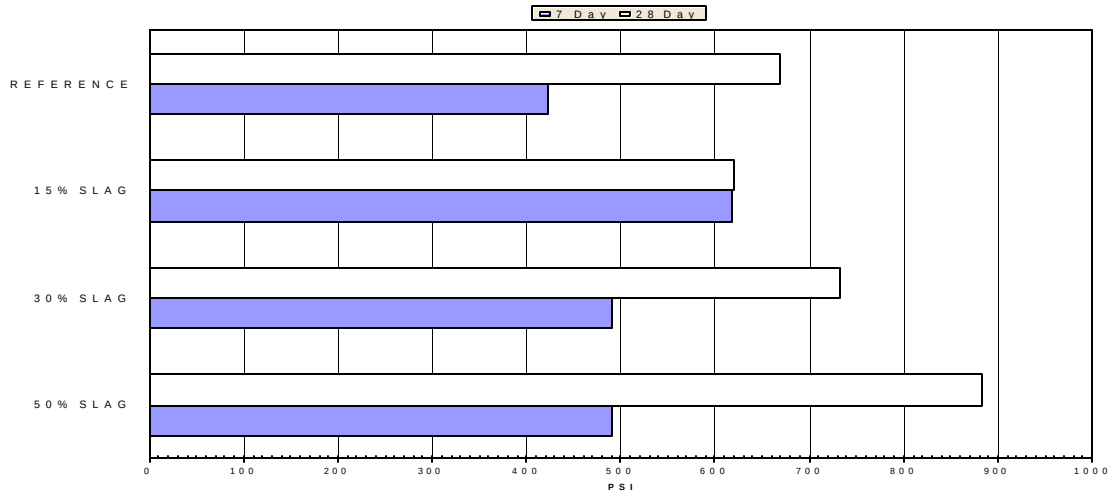
SET TIMES: 6.0 Bag Class 'A' Structural Mix (Grade A Limestone @ 40F)



COMPRESSIVE STRENGTH: 6.0 Bag Class 'A' Structural Mix (Grade A Limestone @ 40F)



FLEXURAL STRENGTH: 6.0 Bag Class 'A' Structural Mix (Grade A Limestone @ 40F)



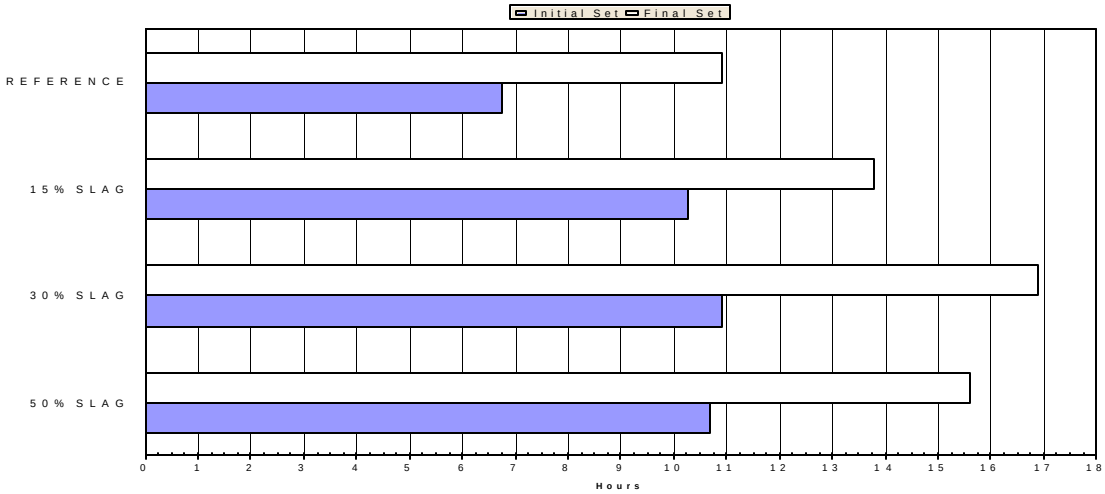
5.8 BAG TYPE "B" PAVEMENT CONCRETE MIXES. WATER / CEMENT RATIO = 0.40.
GRADE "B" GRAVEL. COMPONENTS DRIED AND CHILLED TO 40°F PRIOR TO MIXING. SAMPLES CURED IN SEALED 40°F ENVIRONMENT.
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG

DESCRIPTION	REFERENCE	15% SLAG	30% SLAG	50% SLAG
LTRC LAB NO.	C-2143	C-2163	C-2172	C-2169
DATE MIXED	06/25/97	01/21/98	03/10/98	02/25/98
CEMENT (lbs/yd)	545	463	382	272
SLAG (lbs/yd)	0	82	163	272
WATER (lbs/yd)	218	218	218	218
COARSE AGGREGATE (lbs/yd)	1979	1979	1979	1979
FINE AGGREGATE (lbs/yd)	1135	1135	1135	1135
DARAVAIR 1000 (oz/100ct)	1	1	1	1
WRDA w/ HYCOL (oz/100ct)	4	4	4	4
AIR TEMPERATURE (°F)	69°	65°	66°	68°
CONCRETE TEMPERATURE (°F)	60°	57°	55°	57°
SLUMP (inches)	2.00"	3.50"	3.00"	3.50"
AIR CONTENT (percent)	5.4%	5.8%	4.9%	5.8%
UNIT WEIGHT (lbs/cu.ft.)	141.2 lbs	139.6 lbs	142.0 lbs	142.0 lbs
ASTM C 403 TIME OF SET				
initial	06 hrs 45 mins	10 hrs 17 mins	10 hrs 55 mins	10 hrs 42 mins
final	10 hrs 55 mins	13 hrs 48 mins	16 hrs 54 mins	15 hrs 37 mins
ASTM C 39				
7 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	3380	2677	2258	1823
cylinder #2 psi	3474	2710	2305	1772
cylinder #3 psi	3317	2724	2323	1830
average psi	**3390**	**2704**	**2295**	**1808**
28 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	4677	1407*	3342	3167
cylinder #2 psi	4538	3870	3455	3171
cylinder #3 psi	4782	3941	3501	3061
average psi	**4666**	**3906**	**3433**	**3133**
56 DAY COMPRESSIVE STRENGTH				
cylinder #1 psi	N/A	N/A	3913	3922
cylinder #2 psi			4085	4005
cylinder #3 psi			3970	4002
average psi			**3990**	**3976**
ASTM C 78				
7 DAY FLEXURAL STRENGTH				
beam #1 psi	594	568	561	408
beam #2 psi	565	553	538	411
beam #3 psi	575	529	484	441
average psi	**578**	**550**	**528**	**420**
28 DAY FLEXURAL STRENGTH				
beam #1 psi	561	683	559	636
beam #2 psi	562	731	597	651
beam #3 psi	641	713	598	627
average psi	**588**	**709**	**585**	**638**
ASTM C 469				
28 DAY MODULES OF ELASTICITY				
cylinder #1	5594303	4109923	4465071	4052836
cylinder #2	5417395	3046711	4068476	3992779
average	**5505849**	**3578317**	**4266774**	**4022808**
28 DAY POISSON'S RATIO				
cylinder #1	0.12	0.23	0.49	0.13
cylinder #2	0.17	0.54	0.14	0.10
average	**0.14**	**0.38**	**0.32**	**0.11**

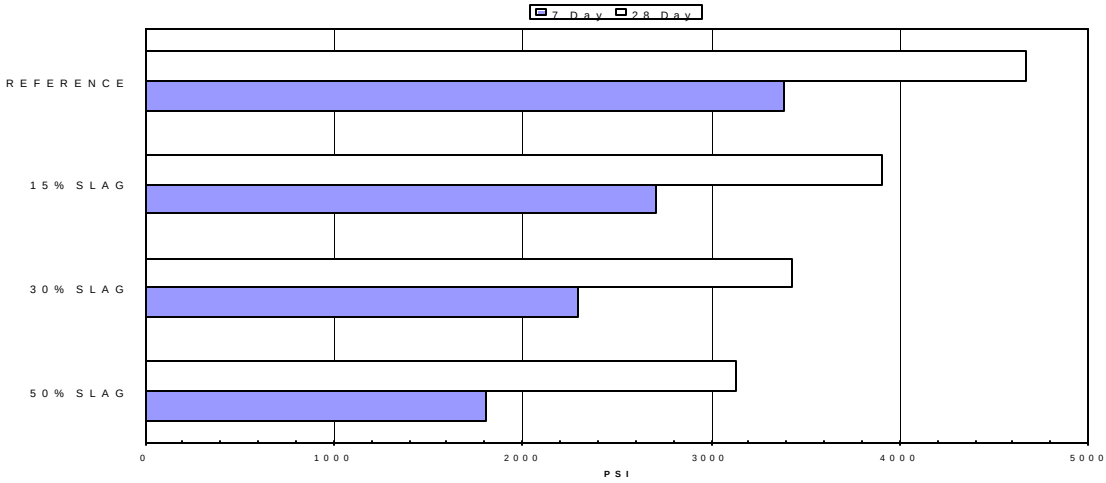
5.8 BAG TYPE "B" PAVEMENT CONCRETE MIXES. WATER / CEMENT RATIO = 0.40.
GRADE "B" GRAVEL. COMPONENTS DRIED AND CHILLED TO 40°F PRIOR TO MIXING. SAMPLES CURED IN SEALED 40°F ENVIRONMENT.
CEMENT USED: HOLNAM TYPE I PORTLAND and LONESTAR AUCEM GRANULATED GROUND BLAST FURNACE SLAG

DESCRIPTION	REFERENCE	15% SLAG	30% SLAG	50% SLAG
LTRC LAB NO.	C-2143	C-2163	C-2172	C-2169
DATE MIXED	06/25/97	01/21/98	03/10/98	02/25/98
CEMENT (lbs/yd)	545	463	382	272
SLAG (lbs/yd)	0	82	163	272
WATER (lbs/yd)	218	218	218	218
COARSE AGGREGATE (lbs/yd)	1979	1979	1979	1979
FINE AGGREGATE (lbs/yd)	1135	1135	1135	1135
DARAVAIR 1000 (oz/100ct)	1	1	1	1
WRDA w/ HYCOL (oz/100ct)	4	4	4	4
AIR TEMPERATURE (°F)	69°	65°	66°	68°
CONCRETE TEMPERATURE (°F)	60°	57°	55°	57°
SLUMP (inches)	2.00"	3.50"	3.00"	3.50"
AIR CONTENT (percent)	5.4%	5.8%	4.9%	5.8%
UNIT WEIGHT (lbs/cu.ft.)	141.2 lbs	139.6 lbs	142.0 lbs	142.0 lbs
ASTM C 666 & ASTM C 215				
FREEZE and THAW				
beam #1 DF @ CYCLES	43.0 @ 215	31.6 @ 158	56.8 @ 284	49.4 @ 247
beam #2 DF @ CYCLES	19.0 @ 95	32.4 @ 162	30.0 @ 150	48.8 @ 244
beam #3 DF @ CYCLES	28.6 @ 143	31.4 @ 157	13.4 @ 67	49.2 @ 246
average DF @ CYCLES	**30.2 @ 151**	**31.8 @ 159**	**33.4 @ 167**	**49.1 @ 246**
ASTM C 157				
LENGTH CHANGE (air storage)				
beam #1 (percent +/-)	-1.814	-0.834	+0.188	+0.103
beam #2 (percent +/-)	-1.602	-0.786	+0.064	+0.764
average (percent +/-)	**-1.708**	**-0.810**	**+0.126**	**+0.434**
ASTM C 672				
SCALING after 50 test cycles				
block #1 rating	3	3	5	4
block #2 rating	3	4	5	5
average rating	**3**	**3**	**5**	**4**
interpretation	**MODERATE**	**MODERATE**	**SEVERE**	**MOD/SEVERE**
ASTM C 944				
ABRASION RESISTANCE				
block #1 grams lost/ cm^2	0.0100	0.0185	0.0107	0.0207
block #2 grams lost/ cm^2	0.0207	0.0229	0.0193	0.0286
block #3 grams lost/ cm^2	0.0129	0.0114	0.0207	0.0336
average grams lost/ cm^2	**0.0145**	**0.0176**	**0.0169**	**0.0276**
ASTM C 1202				
CHLORIDE PENETRABILITY				
core #1 coulombs/rating	4329/HIGH	8564/HIGH	3034/MODERATE	5629/HIGH
core #2 coulombs/rating	4714/HIGH	7216/HIGH	4324/HIGH	6513/HIGH
core #3 coulombs/rating	4868/HIGH	8503/HIGH	4534/HIGH	7470/HIGH
core #4 coulombs/rating	4877/HIGH	1131/LOW	1709/LOW	1149/LOW
average coulombs/rating	**4697/HIGH**	**6354/HIGH**	**3400/MODERATE**	**5190/HIGH**

SET TIMES: 5.8 Bag Type 'B' Pavement Mix (Grade B Gravle @ 40F)



COMPRESSIVE STRENGTH: 5.8 Bag Type 'B' Pavement Mix (grade B gravel @ 40F)



FLEXURAL STRENGTH: 5.8 Bag Type 'B' Pavement Mix (Grade B gravel @ 40F)