Caltrans Experience with Ternary Mix for Long-performing Concrete

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Introduction and Background

Ternary Mix is a concrete mixture containing three cementitious materials, typically Portland cement and two SCM's (1). Ternary mixtures can be designed for high strength, low permeability, corrosion resistance, sulfate resistance, ASR resistance, and elimination of thermal cracking.

Properties of ternary mixtures are more difficult to generalize than for binary mixtures. The properties will vary greatly depending on which SCM is used, how much of each SCM is used, and the amount of cement used. Ternary mixes should be thoroughly tested prior to placement on any job to determine these characteristics. The standard Caltrans mix is 75 percent Portland cement (ASTM C150) with 25 percent Class F fly ash.

The Study

A study performed by Caltrans (2) presents the results of a series of preliminary trial batches performed to evaluate the potential of using high volumes of supplementary cementitious materials (SCMs) in concrete mixtures. Currently, Caltrans uses 25 percent class F fly ash in most concrete mixtures. However, the Department is seeking to specify much higher volumes of SCMs. Based on this study, it was concluded that the long-term strengths of some of the tested ternary mixtures were significantly better than the control mixture, from a statistical point of view. Most of ternary mixtures, however, had statistically significantly lower short-term strengths than the control mixture. Concrete mixtures with high volumes of SCMs need to be carefully designed for each application. The use of special admixtures may be crucial for good concrete performance, depending on the intended application.

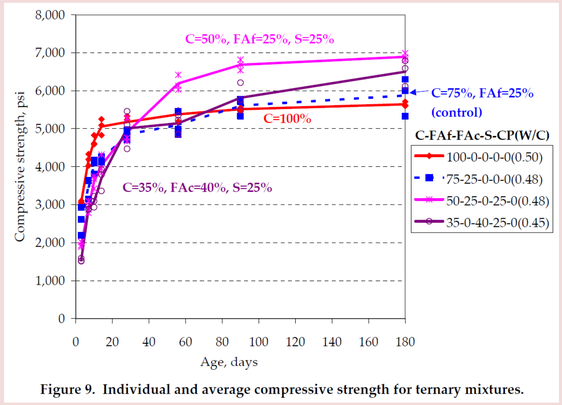


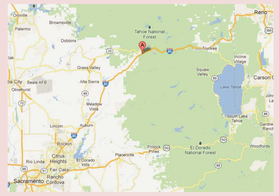
Figure 9. Individual and average compressive strength for ternary mixtures.

The Project

Interstate 80 Emigrant Gap - Contract 03-2C8604

This was a 90 million dollar contract to reconstruct 43 lane miles of Interstate 80 at Emigrant Gap. The project is in a very harsh environment. Annually this construction site receives 20ft of snow and nearly 8ft of rainfall. The resistance to chain wear is one of the most demanding in the nation. The project site is 10 miles long and goes from 5,200' Elevation on West end to 5,975' on the East end. The project started in 2011 and is still under construction with an anticipated finish time of 2014. The following is a general description of work:

-Jointed Plain Concrete Pavement (JPCP)172,000 CY
-Continuously Reinforced Concrete Pavement (CRCP) 32,100 CY
-Ternary "Slag" Concrete Mix Design with onsite concrete batch plant
-Original mix contains 35% slag and 8% Fly ash



The Concern

The Contractor did not favor ternary mix from the beginning and preferred to use a straight 7 sack "traditional" mix. The Contractor stated that the strength gain with high slag was slow. Per CT 559, the best result showed 550 psi in 21 days. It was argued that this was too slow to allow the project to be constructed within the seasonal timeframe available.
The problem was exacerbated by the specified Grade 120 slag being a sole source product. The producer coupled the purchase of slag with their specific cement, which is known to gain strength slower than other cements.
To address the problem, it was recommended that the slag content be reduced to 25%.

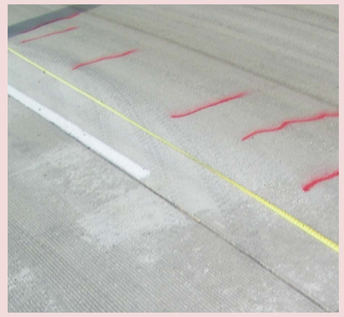
MIX USED: [illegible]		SPECIFIED FLEXURAL STRENGTH: 570 PSI at 28 Days of age.				
NUMBER OF BEAMS CAST:	20	SPECIFIED COMPRESSIVE STRENGTH:	-----			
DATE CAST:	05/24/2011	NOMINAL BEAM SIZE: 6" x 6" x 21" or 150 mm x 150 mm x 533 mm				
TIME BATCHED:	09:55 AM	INITIAL TIME: 10:10 AM (FOR SPECIFICATION OF TESTING AGE)				
MEASURED SLUMP, in/mm:	-----	-----	MEAS. PEN., in/mm:	1.00"		
MEASURED AIR CONTENT,	4.6		UNIT WT., pcf/(Kg/cu.m):	148.75		
AMBIENT TEMP., ºF / ºC:	62		CONCRETE TEMP., ºF / ºC:	65		
INITIAL SETTING TIME:	-----		FINAL SETTING TIME:	-----		
MADE BY:	C. MARTIN & M. STACKS					
AGE (Test Time as reported)	10 DAYS	10 DAYS	10 DAYS	10 DAYS	10 DAYS	
TEST TIME	-----	-----	-----	-----	-----	
TEST DATE	06/03/2011	06/03/2011	06/03/2011	06/03/2011	06/03/2011	
BEAM I.D.	1	2	3	4	5	
AVERAGE WIDTH (b), in.	5.94	5.97	5.97	5.81	5.99	
AVERAGE DEPTH (d), in.	6.11	6.14	6.08	6.10	6.08	
SPAN LENGTH (L), in.	18	18	18	18	18	
MAX. APPLIED LOAD (P), lbf	6385	5850	6675	5495	6005	
M.O.R. (R) , psi	544	491	572	480	513	
M.O.R. (R) , MPa	3.8	3.4	3.9	3.3	3.5	
TESTED BY	C. Martin	C. Martin	C. Martin	C. Martin	C. Martin	
AVERAGE @ AGE OF:	520 PSI at 10 Days					

The Result

After a relatively mild winter season, cracks with more that expected width and narrower than expected spacing (1 to 2 ft compared to 3 to 5 ft) were noticed in CRCP with ternary mix. Some of the wide cracks have shown spalling at the edges. Apparently no JPCP section was built with ternary mix. The JPCP sections with seven sack Portland cement mix did not show any unusual cracking or spalling.

The early failure of CRCP portion of the project with the ternary mix (modified 25% slag) seems to be more material related than a design issue.

Wide cracks with spalled edges



Frequent wide cracks under wheel path, and surface wearing

Conclusion

Caltrans is still analyzing the case to find the reason for premature wear of ternary mix. Samples of material are also sent to CP Tech Center for further investigation. The candidates for failure are climate, abrasive environment, workmanship, and incompatibility of material. At the meantime, Caltrans has decided to eliminate this mix for the rest of project and use the seven sack mix to avoid similar issues.
Lessons learned:

1. Should try in less harsh environment to reduce variables.
2. Having more than one source of material is important.
3. Give Contractor more flexibility to mix and match the cement, fly ash, and slag content.

References

•Guidelines for the Design & Inspection of Concrete, Caltrans, April 2010
•Preliminary Testing of Concrete with High Volume of SCMs, Caltrans, September 2008