CENTER OF EXCELLENCE FOR AIRPORT TECHNOLOGY

TECHNICAL NOTE

TECH NOTE NO:	17
TITLE:	PCC Mix Design Phase 1
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1. Introduction

Testing for the OMP PCC Mix Design is underway at the University of Illinois at Urbana-Champaign. This preliminary testing, known as Phase I in previous publications, addresses fresh concrete properties (air content, slump, unit weight) and mechanical properties (compressive strength at 7 days, drying shrinkage at 28 days, and flexural strength at 7 and 28 days). Data from Phase I is crucial for fine tuning mix designs to insure that the extensive testing in Phase II will be on the desired material combinations.

2. Variables Considered

Mix designs were constructed using a typical O'Hare mix design, presented in TechNote 2, as the control. This mix, called mix 688.38.ST in this report, has a water cement ratio of 0.38, a coarse aggregate top size of 0.75"., a cement content of 688lb/yd^3, and a fly ash replacement of 17%. The mix design characteristics chosen as variables for other mixes are summarized in Table 1. The fly ash replacement was kept at a constant 17% and the coarse-to-fine ratio was fixed at approximately 1.7 to be consistent with the control design but to also provide ASTM approved gradation for the combined fine and 1.5" coarse aggregate. Chemical admixtures were added during mixing as necessary.

Table 1. Independent variables and values for PCC Mix Design.

Variable	*Values*
Aggregate Size	0.75" or 1.5"
W/CM	0.38 or 0.44
Cement Content	488lb/yd^3 or 588lb/yd
Total aggregate content	Varies

3. Mix Designs

Five mixes, summarized in Table 2, were initially investigated to determine the effect of each variable on the concrete fresh and mechanical properties.

Table 2. Proposed mix designs.

	Course Aggregate Top Size				
	0.75"	1.5"			
	688.38.ST	**688.38**	**688.44**	**588.38**	**588.44**
w/cm	0.38	0.38	0.44	0.38	0.44
water (lb/yd^3)	262	261	303	217	251
cement (lb/yd^3)	588	588	588	488	488
fly ash (lb/yd^3)	100	100	100	83	83
CA (lb/yd^3)	1850	1842	1772	1982	1924
FA (lb/yd^3)	1103	1083	1042	1166	1132
AEA (oz/yd^3)	14	14	16	16	16
WR (oz/yd^3)	-	-	-	7	7

In Table 2, mix 688.38.ST is the O'Hare control mix. With the 1.5 in. maximum size coarse aggregates (MSA), both cement content and water cement ratio will be investigated, resulting in 4 additional mixes (688.38, 688.44, 588.38, and 588.44). Mix 688.38 is essentially mix 688.38.ST (note that small differences occurred due to differences in bulk specific gravity of the coarse aggregates) but with a 1.5 in. MSA rather than a 0.75 in. In the 1.5 in MSA mix designs, the total aggregate content varies allowing insight into its effect on shrinkage.

4. Mixing and Results

The mixing procedure, sampling techniques, and testing of air content, unit weight, slump, compressive strength, and flexural strength were all per appropriate ASTM standards. The fresh property results are presented in Table 3 and the mechanical properties are presented in Table 4.

Table 3. Fresh Properties for Phase I.

			Air (%)	UW (lb/cuft)	Slump (in)
Typical O'Hare Mix (CA 3/4")					
688.38.ST	w/cm = 688lb/yd^3	w/c = 0.38	7	144	3.75
Additional Laboratory Mixes (CA 1.5")					
688.38	w/cm = 688lb/yd^3	w/c = 0.38	6	147	4.75
688.44	w/cm = 688 lb/yd^3	w/c = 0.44	3	150	9
588.38	w/cm = 588 lb/yd^3	w/c = 0.38	5.5	147	3
588.44	w/cm = 588 lb/yd^3	w/c = 0.44	4	151	6
Excepcted Values of Typical O'Hare Mix			5-8	-	3 +/- 1

Table 4. Mechanical Properties for Phase I.

			fc' 7 (psi)	ε 28 (um)	fr 7 (psi)	fr 28 (psi)
Typical O'Hare Mix (CA 3/4")						
688.38.ST	w/cm = 688lb/yd^3	w/c = 0.38	3690	-80		
Additional Laboratory Mixes (CA 1.5")						
688.38	w/cm = 688lb/yd^3	w/c = 0.38	3000	-60		
688.44	w/cm = 688 lb/yd^3	w/c = 0.44	2720			
588.38	w/cm = 588 lb/yd^3	w/c = 0.38	2400			
588.44	w/cm = 588 lb/yd^3	w/c = 0.44	2280		768	790
Excepcted Values of Typical O'Hare Mix			~6300			

The fresh properties (air content, unit weight, and slump) were mostly as desired. The two 588lb/yd^3 mixes easily met slump requirements (Table 3) at a lower cement content and therefore the mid-range water reducer was not used for the 688lb/yd^3 mixes, since the additional cement at a constant w/c would increase the slump. As expected, the larger coarse aggregate increased slump and unit weight while also reducing air content.

The results for the fresh propertied from the 688.38.ST test agreed well with the expect values for the typical O'Hare mix from field measured data. However, the laboratory strength is lower than that predicted by converting the available MOR to an expected compressive strength value (this value is likely for a 28 day MOR and thus a 28 day compressive strength).

Seven day compressive strength trends (Table 4) were as expected, with strength increasing for an increased cement content and decreased water/cement ratio. Shrinkage results showed that for the same cement content, a larger coarse aggregate can decrease autogenous shrinkage by about 25% at 28 days. A 7 day flexural test was conducted on 588.44 as it is the lowest cement content and highest w/c ratio. The MOR at 7 days was over that typically specified at 28 days, showing that a lean mix with a relatively high w/c ratio and large course aggregates is capable of meeting early age strength specifications. The 28 day flexure showed only a 3% increase over the 7 day, indicating that strength development was quick in the first 7 days (not enough values are available to discuss overall strength gain trends).

Phase II mixes will include these 5 mixes as well as to two new mixes and will be tested for the following variables: compressive strength (f_c' at 7 and 28 days), modulus of elasticity (E at 7 and 28 days), splitting tensile strength (σ_{sp} at 7 and 28 days), modulus of rupture (σ_{fl} at 28 days), autogenous and drying shrinkage (ε_{as} and ε_{sh} at 1, 2, 3, 4, 5, 6, 7, 8, 11, 14, 18, 21, 25, and 28 days), and fracture energy development (G_f at 6, 8, 12, and 24 hours and 7, 14, and 28 days).