

Shrinkage Characteristics of Force 10,000[®] Concrete

Introduction

Force 10,000[®] concrete is typically used in applications where cracking may be a major concern. These include environments that are highly corrosive, chemically saturated, or very abrasive and where less permeable, more durable concrete is required. For these applications concrete needs to be designed and constructed to produce the least amount of cracking.

A series of tests was conducted by Grace Construction Products to examine the shrinkage characteristics of Force 10,000 concrete as it relates to aggregates, plain concrete and length of curing. The evaluations included several mix designs with silica fume dosage rates ranging from 0 to 10.8% by weight of cement. The concrete was sampled, prepared, cured and tested in accordance with ASTM C157, "Length Change of Hydraulic Cement Concrete."

Test Series 1: The Effect of Aggregate Type on Shrinkage of Force 10,000 Concrete

Coarse Aggregate Type	River Gravel		Crushed Limestone	
Coarse aggregate	1090 kg	1837 lbs	1051 kg	1771 lbs
Type II cement	332 kg	560 lbs	332 kg	560 lbs
Class F fly ash	59 kg	100 lbs	59 kg	100 lbs
Force 10,000	42.4 kg	71.5 lbs	42.4 kg	71.5 lbs
HRWR	1174 mL/100 kg	18 oz/100 lbs	1174 mL/100 kg	18 oz/100 lbs
W/C + P ratio	0.35	0.35		
Slump	102 mm	4 in.	102 mm	4 in.
Air content, %	2.0		2.0	
% Length change, shrinkage, drying age (after 7 days wet cure)	River Gravel		Crushed Limestone	
7 days	0.040		0.025	
28 days	0.078		0.038	
56 days	0.080		0.035	
90 days	0.075		0.036	

Note: Values do not represent all limestone and gravel aggregates.

Test Series 2: The Effect of Force 10,000 on Shrinkage at Equal Paste Content

Mix Description	with Force 10,000		without Force 10,000	
	SI	US	SI	US
Type II cement	332 kg	560 lbs	392 kg	600 lbs
Class F fly ash	59 kg	100 lbs	59 kg	100 lbs
Force 10,000	42.4 kg	71.5 lbs	0 kg	0 lbs
HRWR	1174 mL/100 kg	18 oz/100 lbs	1174 mL/100 kg	18 oz/100 lbs
W/C + P ratio	0.35	0.34		
Slump	127 mm	5 in.	127 mm	5 in.
Air content, %	3.0	3.0		
% Length change, shrinkage, drying age (after 7 days wet cure)	with Force 10,000		without Force 10,000	
7 days	0.040		0.038	
28 days	0.078		0.075	
56 days	0.080		0.079	
90 days	0.075		0.076	

Test Series 3: The Effect of Curing on Shrinkage of Force 10,000 Concrete

Mix Description	Midwest Gravel	Northeast Gravel	Midwest Limestone
W/C + P ratio	0.37	0.37	0.37
Force 10,000	27.2 kg (46 lbs)	27.2 kg (46 lbs)	27.2 kg (46 lbs)
HRWR	652 mL/100 kg (10 oz/100 lbs)	652 mL/100 kg (10 oz/100 lbs)	652 mL/100 kg (10 oz/100 lbs)
Slump	165 mm (6.5 in.)	165 mm (6.5 in.)	165 mm (6.5 in.)
Air content, %	6%	6%	6%
% Length change (shrinkage) wet cure time, days			
3 days	0.075	0.084	0.051
7 days	0.061	0.068	0.045
28 days	0.040	0.048	0.038

Conclusions

1. The type of aggregate used in the mix will influence the amount of shrinkage.
2. Force 10,000 has little effect on shrinkage when compared to concrete made without silica fume with equal paste content. ACI 234 indicates that the dry shrinkage of silica fume concrete is generally comparable to that of control concrete regardless of the water/cementitious ratio.
3. Curing is essential. Longer, co

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TB-0708 Printed in USA 2/06 FA/PDF



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