

TB-0911 — DCI[®] /FORCE 10,000[®] D Concrete – Bond to Reinforcing Steel

/ concrete / mix design

Introduction

It is very important to know whether a material added to concrete increases or decreases the concrete’s bond to reinforcing steel. Flood Testing Laboratories, Inc. Chicago, Illinois was asked in 1990 to study the bond strengths of four concrete mixes containing FORCE 10,000[®] D microsilica admixture and/or DCI[®] Corrosion Inhibitor to black rebar and epoxy-coated rebar. This Engineering Bulletin will report the effect on bond strength and other mechanical properties of concrete by the addition of FORCE 10,000[®] D and DCI[®].

Table 1 — Concrete Mix Designs

	MIX A REFERENCE	MIX B DCI [®]	MIX C FORCE 10,000 [®] D	MIX D DCI [®] /FORCE 10,000 [®] D
Cement – Type I – kg/m ³ (lb/yd ³)	390 (658)	390 (658)	390 (658)	390 (658)
Sand – kg/m ³ (lb/yd ³)	840 (1,420)	840 (1,420)	840 (1,420)	840 (1,420)
Coarse Aggregate – #57 – kg/m ³ (lb/yd ³)	1,070 (1,800)	1,070 (1,800)	1,070 (1,800)	1,070 (1,800)
Total Water* – kg/m ³ (lb/yd ³)	148 (250)	148 (250)	148 (250)	148 (250)
Water/cement-ratio	0.38	0.38	0.38	0.38
FORCE 10,000[®] D				
L/m ³ (gal/yd ³)	—	—	44.5 (9)	29.6 (6)
microsilica – kg/m ³ (lb/yd ³)	—	—	29.4 (49.5)	19.6 (33.0)
% microsilica/100 kg (100 lbs)	—	—	7.5 (7.5)	5.0 (5)
DCI [®] – L/m ³ (gal/yd ³)	—	19.8	(4) —	14.8 (3)

DARACEM® 19 – mL/100 kg (oz/100 lbs)	835 (12.8)	795 (12.2)	725 (11.1)	725 (11.1)
Slump – mm (in.)	150 (6)	150 (6)	150 (6)	150 (6)
Air (%)	2.5	1.8	2.3	2.0
Unit weight – kg/m ³ (lb/ft ³)	2,435 (152.0)	2,454 (153.2)	2,437 (152.1)	2,437 (152.1)
Compressive Strength –				
MPa (psi)				
3 days	43.7 (6,345)	46.0 (6,680)	56.8 (8,235)	46.3 (6,720)
7 days	56.1 (8,135)	58.5 (8,485)	65.0 (9,430)	61.7 (8,950)
28 days	64.5 (9,350)	74.5 (10,800)	88.6 (12,850)	76.0 (11,020)
Flexural Strength – MPa				
(psi)				
3 days	5.24 (760)	5.24 (760)	6.31 (915)	5.10 (740)
7 days	6.41 (930)	6.83 (990)	8.03 (1,165)	6.17 (985)
28 days	7.41 (1,075)	7.64 (1,108)	10.53 (1,528)	9.19 (1,333)

* Total water includes added mix water, aggregate moisture, and Force 10,000®D and DCI® water.

Table 1 — Concrete Mix Designs

Concrete Mixture	STANDARD UNCOATED REBAR			EPOXY-COATED REBAR			
	Bond Strength MPa	Bond Strength (psi)	Improvement Compared to Mix A (%)	Bond Strength MPa	Bond Strength (psi)	Improvement Compared to Mix A (%)	Compared to Standard Rebar Mix A (%)
A	12.1	(1,760)	—	8.4	(1,213)	—	68.9
B	12.9	(1,878)	106.7	9.8	(1,425)	117.5	81.0
C	12.7	(1,845)	104.8	8.8	(1,275)	105.1	72.4
D	12.4	(1,808)	102.7	10.6	(1,533)	126.4	87.1

Test Data

The concrete mix design studied is a fairly common mix used for corrosion protection type concretes. The reference mix (Mix A) contains 390 kg/m³ (658 lbs) Type I cement and a water/ cement-ratio of 0.38. All mixture designs tested are shown in Table 1. Mix B contains 19.8 L/m³ (4 gal) of DCI[®] per cubic meter (yard). Mix C contains FORCE 10,000[®] D at 7.5% microsilica by weight of cement. Mix D includes FORCE 10,000[®] D at 5% and DCI[®] at 14.8 L (3 gal). The amount of water in all materials was added to maintain a constant total water content. Slump was adjusted to 150 mm (6 in.) with the use of a superplasticizer, DARACEM[®] 19. The mixtures were not air entrained. Slump, air and unit weight were measured. Compressive and flexural strengths at 3, 7 and 28 days were determined using ASTM C 39 and ASTM C 78 respectively.

Bond strength to the reinforcing steel was determined using ASTM C 234-86 “Comparing Concretes on the Basis of the Bond Developed with Reinforcing Steel”. Number 6 reinforcing steel was used in concrete specimens 150 mm x 150 mm x 300 mm (6 in. x 6 in. x 12 in.). Tension is applied to the bar in an attempt to pull it out of the concrete specimens. The bond strength in MPa (psi) is recorded throughout the test and that strength reported at a bar slippage of 0.25 mm (0.010 in.) Results of the bond test are reported in Table 2.

Conclusions

1. The addition of DCI[®] and/or FORCE 10,000[®] D increased the concrete’s bond to standard uncoated reinforcing steel by an average of 4.7% and to epoxy-coated rebar by an average of 16.3%.
2. The addition of DCI[®] and/or FORCE 10,000[®] D increased the compressive and flexural strength of concrete.
3. There was an average 22.7% reduction in bond strength when epoxy-coated reinforcing steel was used when compared to standard rebar.

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