UltraFiber Technical Bulletin
UFTB #7
Freeze/Thaw Durability

TESTING PURPOSE:

To measure the freeze/thaw durability of concrete containing Solomon UltraFiber 500™ compared to plain concrete.

TESTING CONCLUSIONS:

The following studies compare the freeze/thaw durability of concrete containing Solomon UltraFiber 500™ to plain concrete. The results of these studies show that at dosages of 1.0 and 1.5 lb/yd^3, UltraFiber 500® concrete reinforcing fiber provides a substantial improvement to freeze/thaw durability over plain concrete.

Durability Factor	**Plain Concrete**	**Concrete with UltraFiber 500®**	**Improvement**
Middle Tennessee State University	68.5 %	96.4 %	41%
Solomon Concrete Lab	60.0 %	77.6 %	29%
Stork Twin City Testing Corporation	36.1 %	54.9 %	52%
Swelling Factor	**Plain Concrete**	**Concrete with UltraFiber 500®**	**Improvement**
CERIB Lab	2.4 mm/m	0.3 mm/m	87%

RESEARCH METHODOLOGY:

Two concrete mixes were formed for each study: plain concrete (no fiber) and fiber reinforced concrete (FRC). The mix designs used for each study are outlined below.

Ingredient	**MTSU Lab**	**Solomon Lab**	**Stork Lab**	**CERIB Lab**
Portland Cement, lb/yd^3 (kg/m^3)	540 (320.4)	517 (306.8)	517 (306.8)	506 (300)
Coarse Aggregate, lb/yd^3 (kg/m^3)	2000 (1186.6)	1700 (1008.9)	1700 (1008.9)	1517 (900)
Fine Aggregate, lb/yd^3 (kg/m^3)	1200 (712.0)	1365 (810.1)	1365 (810.1)	1517 (900)
Water, lb/yd3 (kg/m^3)	280 (166.1)	289 (171.5)	290 (172.1)	263 (156)
Superplasticizer, lb/yd^3 (kg/m^3)	---	---	---	0.76 (0.45)
Air Entrainment, fl oz/cwt	---	---	4.1 (158.5)	---
Fiber, UltraFiber 500®, lb/yd^3 (kg/m^3)	1.5 (0.890)	1.0 (0.590)	1.0 (0.590)	1.5 (0.884)

RESEARCH METHODOLOGY (continued):

Each lab determined the air content on the fresh plain concrete and fiber reinforced concrete using the appropriate standards for their location. Those results are summarized in the following table:

Testing Location	MTSU Lab		Solomon Lab		Stork Lab		CERIB Lab	
Sample Type	Plain	FRC	Plain	FRC	Plain	FRC	Plain	FRC
Air (%)	2.0	1.9	4.1	4.7	6.0	5.6	2.0	3.0

Samples were tested according to the appropriate ASTM or French standard method for Freeze/Thaw Durability. ASTM C 666 – 97, Procedure A, was used for the samples tested at MTSU, Solomon, and Stork labs. For Procedure A, each sample was subjected to water during the freezing and thawing cycles. Samples were moist cured for 14 days. An initial measurement was then taken at 40°F. Samples were cycled from 40°F to 0°F and back to 40°F. At intervals of 36 cycles or less, the fundamental transverse frequency was determined for each specimen. Fundamental transverse frequencies were measured by the use of a sonometer with an oscilloscope resonance frequency tester according to the specifications listed in ASTM C 215.

Solomon Lab Freeze/Thaw Chamber

The test ended when either 300 cycles elapsed, the dynamic modulus of elasticity reached 60% of the initial modulus, or 0.10% expansion was measured.

The CERIB specimens were tested according to French standard P 18 – 425. These samples were subjected to part of the freezing in air and part of the thawing in water. This standard is similar to Procedure B of the ASTM method. For Procedure B, specimens are completely surrounded by air during the freezing phase of the cycle and by water during the thawing phase of the cycle. Testing then proceeds in the same manner as for Procedure A. The American and French test methods each specify 300 Freeze/Thaw cycles.

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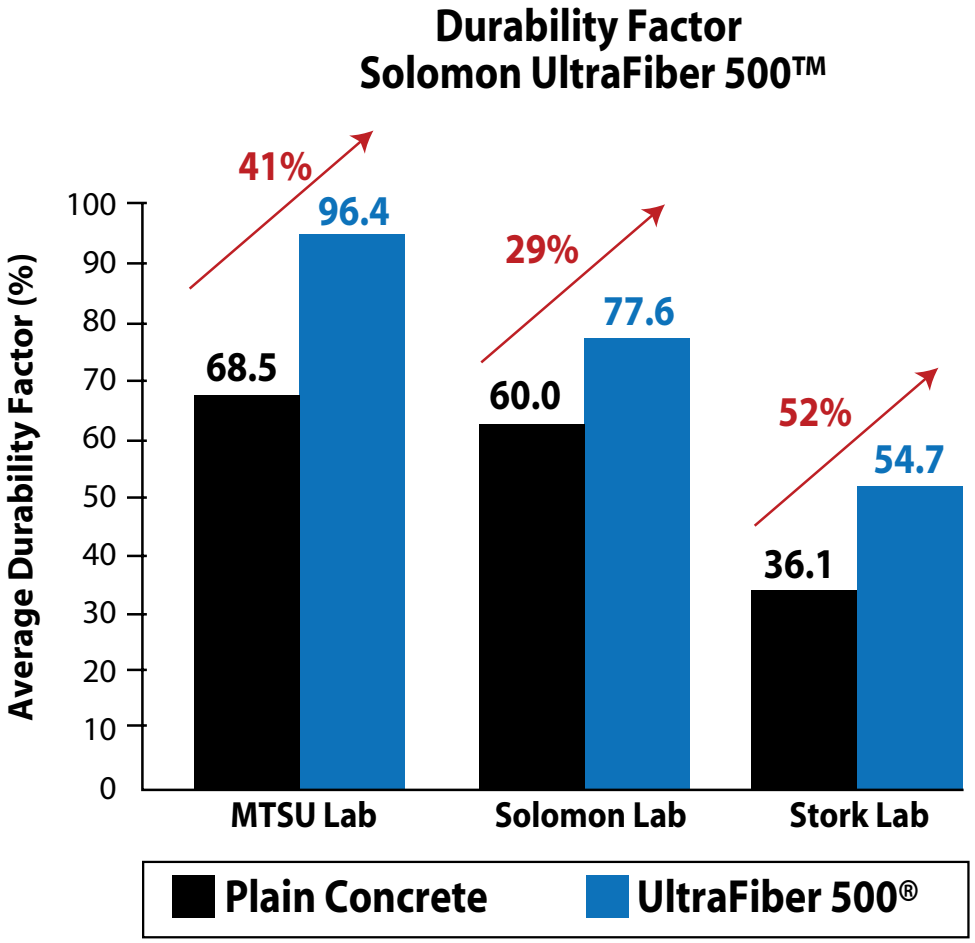
RESEARCH RESULTS:

For the MTSU lab testing, 1.5 lb/yd^3 of UltraFiber 500® improved the durability by 41% over the plain concrete. The testing conducted at the Solomon Concrete Lab showed that 1.0 lb/yd^3 of UltraFiber 500® improved the durability by 29%. Testing at the Stork lab using 1.0 lb/yd^3 of UltraFiber 500® showed a durability improvement of 52%. In each study, the inclusion of UltraFiber 500® substantially improved the freeze/thaw durability factor over plain concrete. A bar chart of these results is shown below.



The laboratories at CERIB in France measure the concrete swelling factor to determine the durability of concrete exposed to a freeze/thaw environment (expressed as millimeters of swell per meter length of specimen). Concrete that swells 0.4 mm/m or greater after 300 cycles is not considered durable by French standards. CERIB's testing of identical mix designs showed that the plain concrete had a swelling factor of 2.4 mm/m at 300 cycles which represents failure. Concrete containing UltraFiber 500® dosed at 1.5 lb/yd^3 had a swelling factor of 0.3 mm/m at 300 cycles and is considered freeze/thaw resistant. The swelling factor for the concrete containing 1.5 lb/yd^3 UltraFiber 500® was 87% lower than the plain concrete. A chart of the swelling factor for the plain concrete and UltraFiber 500® samples through all 300 cycles is shown on the following page.

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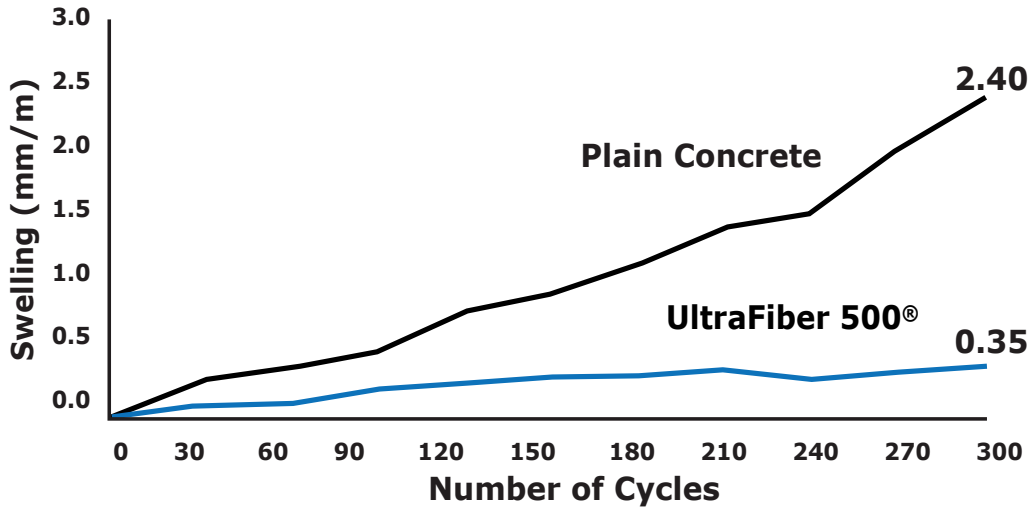
RESEARCH RESULTS (contined):



Using 1.0 lb/yd³ of UltraFiber 500® Compared to Corresponding Plain Concrete
AVERAGE IMPROVEMENT IN FREEZE/THAW DURABILITY = 41%

Using 1.5 of lb/yd³ UltraFiber 500® Compared to Plain Concrete
IMPROVEMENT IN FREEZE/THAW DURABILITY = 41%
CONCRETE SWELLING FACTOR REDUCTION = 87%

CONCLUSIONS:

Compared to plain concrete that exhibits poor performance in freeze/thaw resistance, the use of UltraFiber 500® concrete reinforcing fiber has been shown to improve the freeze thaw durability between 30% and 50% when tested by ASTM C666 at 1.0 and 1.5 lb/yd³ fiber loadings. Using French standard P18-425, 1.5 lb/yd³ of UltraFiber 500® has been shown to substantially reduce the swelling factor of plain concrete exposed to freeze/thaw conditions.

REFERENCES
Middle Tennessee State University, Murfreesboro, TN
• July 2003

Buckeye Technologies Inc Concrete Lab, Memphis, TN
• All testing supervised by a licensed Professional Engineer (PE)

Stork Twin City Testing Corporation, St. Paul, MN
• Project No.: 034051, March 8, 2005

CERIB, Material Division, France
• Test Report Reference: 04 DM 207, April 29, 2004

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