Technical Bulletin

BORAL MICRON³™

Workability, Shrinkage Crack Resistance, and High Strength Concrete

Workability

Micron³ reduces water and high range water reducing (HRWR) admixture demand and improves concrete workability. This is in contrast to most highly reactive pozzolans. Figure 1 is a summary of the water and HRWR reductions due to the use of Micron³.[1] The concrete slump was maintained between 6.5-8.0 inches and the air content was between 5.0-6.5%. It can clearly be seen that at equivalent slump levels, silica fume increases HRWR demand and Micron³ reduces it. Even when the concrete mixtures with Micron³ had 10-16% lower amounts of water, the HRWR dosages were still lower than that of the silica fume concrete mixture. These results have been confirmed repeatedly using various materials, and have been proven in cement paste rheology testing as well.

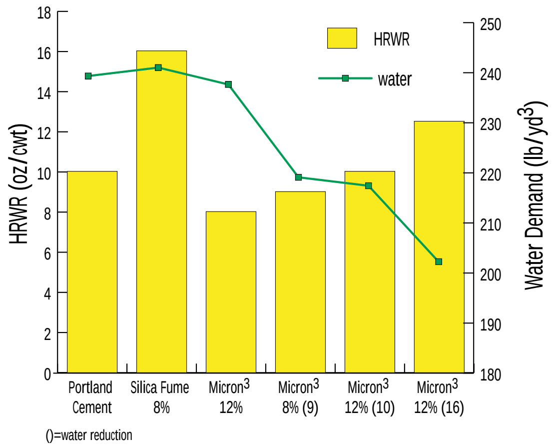

Figure 1. Impact of Micron³ on Water and HRWR Demand

Micron³ tends to lower the yield stress and viscosity of concrete so that it is easier to place, move and consolidate, as compared to concrete with silica fume. Contractors report that concrete containing Micron³ is easier to finish, and may be floated and troweled without the normal stickiness associated with the use of other high performance pozzolans.

Plastic Shrinkage Crack Resistance

Plastic shrinkage occurs when moisture evaporates from the surface of freshly placed concrete faster than it is replaced by bleedwater. This shrinkage, which is restrained by more stable concrete below the surface layer, may lead to plastic shrinkage cracking. In testing conducted at Rutgers University, concrete containing Micron³ displayed a reduced incidence of plastic shrinkage cracking as compared to concrete made with silica fume. During plastic shrinkage testing, concrete slabs were subjected to rapid drying and the weighted crack area was measured.[2] Four mixtures were cast for plastic shrinkage testing and each had a cementitious content of about 800 pounds per cubic yard (no air entrainment was used). The concrete slumps ranged from 9 to 10 inches.

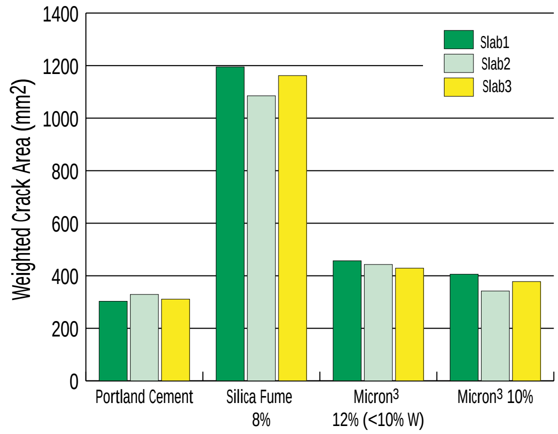

Figure 2. Plastic Shrinkage Cracking Test Results

The plastic shrinkage cracking test results are shown in Figure 2. The weighted crack areas are obtained by multiplying the crack lengths by the weighted crack width. The silica fume concrete mixture shows significantly more plastic shrinkage cracking (366% over control) as compared to Micron³ (130% over control).

Boral Material Technologies
BORAL

Autogenous and Drying Shrinkage

Drying shrinkage occurs due to loss of moisture from the cement paste system within the concrete. Autogenous shrinkage (also known as chemical shrinkage) is defined as the macroscopic volume reduction of cementitious materials during hydration after setting. When shrinkage is restrained tensile stresses develop, and when these stresses exceed the fracture resistance of the concrete, cracking occurs. Restrained shrinkage test results show that Micron[3] delays the onset of cracking. In these tests, a 35mm thick annulus of concrete was cast around a rigid steel cylinder (300mm in diameter by 140mm in height.) The concrete ring contracts due to moisture loss and autogenous shrinkage, but is restrained by the rigid steel ring. Tensile stresses develop, leading to eventual cracking. In the experimental program, each concrete mixture had a w/cm of 0.40, aggregate volume factor of 0.71, and a cementitious content of 400 kg/m^3. After one day in a normal laboratory environment (22^{0}C and 50% relative humidity), the specimens were transferred to a controlled test environment of 86^{0}F and 40% relative humidity. Three ring specimens were cast for each mixture. Individual test results are plotted in Figure 3.

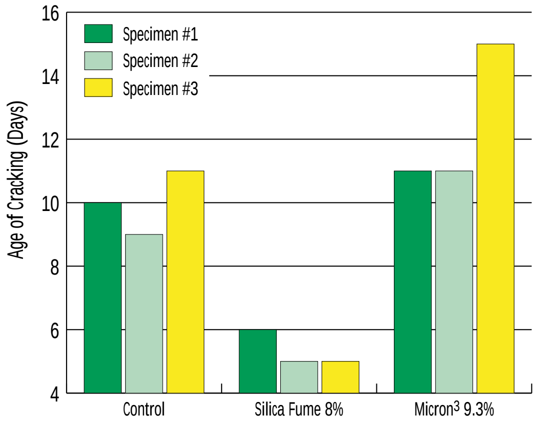

Figure 3. Drying Shrinkage Cracking Test Results

It can be observed that the concrete containing Micron[3] cracked at a slightly later age (12.3 days) as compared to the control concrete mixture (10 days). The silica fume concrete mixture cracked at a much earlier age (5.3 days). Further investigation by researchers at Northwestern University[3] showed that the fracture resistance, elastic moduli, and drying shrinkage values are similar for all three mixtures; however, the silica fume mixture has a much higher rate of increase in autogenous shrinkage at early ages (Figure 4). This suggests that the rate of stress development in this early age is very high in the silica fume mixture, at the same time as the material is still relatively weak. Since the fracture resistances of all mixtures are comparable, the silica fume mixture has the highest potential for failure due to early cracking.

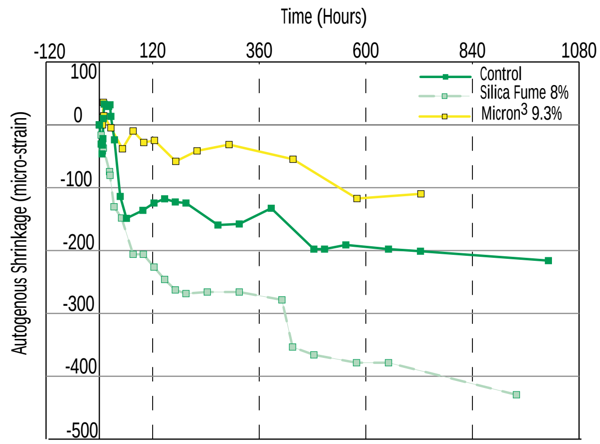

Figure 4. Autogenous Shrinkage Test Results

Boral Micron3

High Strength Concrete

High strength concrete is used for various applications such as columns for high rise structures, prestressed concrete bridge girders, bank vaults etc. In columns, the increased compressive strength may be used to reduce the cross sectional area, and also reduce the amount of steel reinforcement. Another benefit of smaller columns in buildings is increased office rental space. In beams, high strength concrete can be utilized to reduce the number of bridge girders and also increase span lengths.

Micron^3 may be used to manufacture high strength concrete in excess of 15,000 psi at 28 days. The high strength is primarily achieved by reduction in porosity, made possible by the pozzolanic reaction as well as an increased packing density. Table 1 summarizes several test programs conducted in various parts of the country where high strength concrete was achieved using local materials.

Table 1. High Strength Concrete Test Results

Location	Denver, CO 15,000 psi		Salt Lake City, UT 10,000 psi			Austin, TX 12,000 psi		Pascagoula, MS 10,000 psi
Type I/II Cement	750	800	700	600	520	677	673	672
Class F Fly Ash	150	200	0	100	100	147	143	118
Micron^3	100	100	100	100	72	100	100	100
Max Aggregate Size, in.	3/8	3/8	3/4	3/4	3/4	5/8	5/8	3/4
Water	249.5	244.9	251	267	225	225	250	220
w/cm	.255	.230	0.314	0.334	0.33	0.24	0.27	0.33
Type A	-	-	3	3	-	5	4	4
Type F	10	10	15	15	19	15	15	18
Slump, in	10.50	10.25	5.25	9.25	6.25	8.50	10.75	9.75
Air, %	1.5	2.3	-	1.5	7.2	0.5	-	-
Unit W., lb/ft^3	150.9	150.2	-	-	-	152.8	149.6	-
Temperature, F	70	72	88	88	60.7	70	60	75
Compressive Strength, psi								
1 day	1190	-	-	-	-	4630	-	-
3 day	9090	10380	-	-	5773	9530	6760	-
7 day	11340	12930	8465	7525	7195	10980	8950	8540
14 day	-	-	-	-	-	11855	10740	10365
28 day	16000	15590	11590	11385	10185	14800	12450	12143
56 day	17730	18410	12425	12860	-	16430	14680	13650
90 day	-	-	-	-	-	18700	17020	-

- Cement, fly ash, Micron^3, water weights are in lb/yd^3; 1 lb/yd^3 = 0.593 kg/m^3
- Admixture dosages are in oz/100lb of cementitious; 1 oz/100lb = 65.46 ml/100kg
- Mixtures tested in Denver had low alkali cement and also had hydration control agent at 4 oz/100 lb
- All mixtures had crushed rock as coarse aggregate except the 3/8 inch rock used in Austin that was river gravel

Boral Material Technologies

Boral Micron³

Summary

1. The use of Micron³ enhances concrete workability and makes concrete more worker-friendly as compared to concrete made with other highly reactive pozzolans. Therefore, concrete containing Micron³ will have less chance of being abused in the field with excess water addition.

2. Due to its high potential for plastic and drying shrinkage cracking, concrete made with silica fume must be cured during and after finishing operations. Concrete with Micron³ on the other hand, is more resilient and will have less tendency to crack even when curing conditions are less than optimal.

3. Improved workability and reduced cracking ensures that concrete containing Micron³ placed in the field achieves durability properties closer to those achieved in the laboratory.

References

1. Obla, K.H., Hill, R., Thomas, M.D.A. and Hooton, R.D., "Ultra-Fine Fly Ash - A Premium Material to Achieve High Performance Concrete," *Proceedings: 14th International Symposium on Management and Use of Coal Combustion Products (CCPs)*, San Antonio, TX, USA, 2001, Vol.1, p. 35-1.
2. Obla, K.H., Hill, R.L., Thomas, M.D.A., Balaguru, P.N. and Cook, J., "High Strength High Performance Concrete Containing Ultra Fine Fly Ash," *Seventh CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete*, Supplementary Volume, July 22-27, 2001, Chennai, India.
3. Subramaniam, K., Gromotka, R., Shah, S.P., Obla, K.H., and Hill, R.L., "Mechanical and Shrinkage Characteristics of Concrete Containing Ultra-Fine Fly Ash," Presented at the Session on Research in Progress at the ACI Spring convention, Philadelphia, PA, March 25, 2001.

Boral Material Technologies

BORAL™

BMT 1127 Printed in USA * Boral Material Technologies Inc. * Date Issued 5/02 * 1M