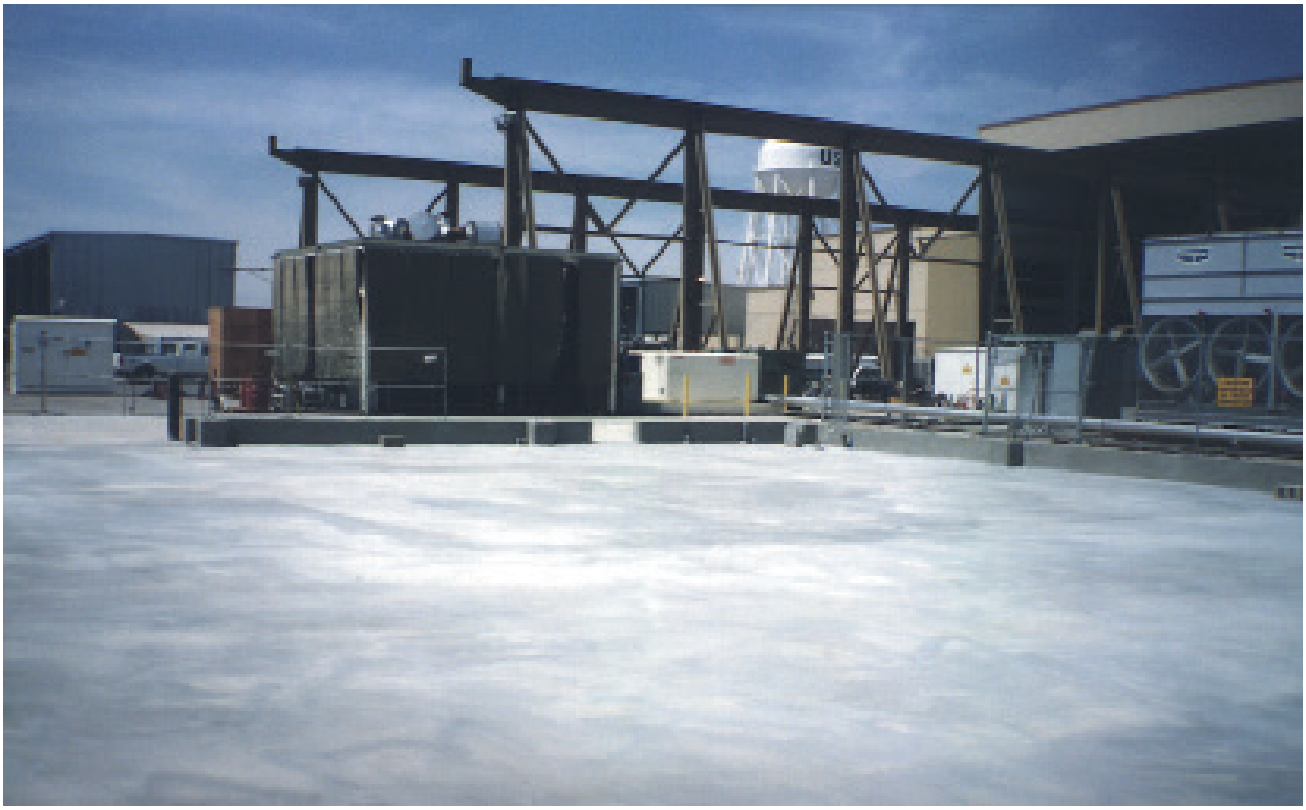
Eclipse® Floor
Shrinkage-reducing admixture



A major drawback associated with concrete as a building material is its volume instability over time. In other words, its propensity to shrink and ultimately crack as it dries.

Eclipse® Floor shrinkage-reducing admixture blocks concrete shrinkage, providing super-flat surfaces with as much as 80% shrinkage reduction at 28 days.

In collaboration with a team of scientists and chemical engineers from Lyondell (formerly ARCO) Chemical Company, GCP Applied Technologies has developed the solution to reducing 28-day concrete shrinkage by 50 to 80%, with reductions in ultimate shrinkage on the order of 25 to 50%. The solution is Eclipse Floor shrinkage-reducing admixture. Eclipse Floor alters the basic mechanism of shrinkage without adding any expansive materials to the concrete.

Large scale testing has shown that the use of Eclipse Floor resulted in the elimination of drying shrinkage cracks in fully restrained 10.7m long slabs exposed to severe drying conditions (see next page). Eclipse Floor should be specified for all construction projects where concrete shrinkage and resultant cracking cause durability, functional, or aesthetic concerns:

- High-Performance Industrial Floors
- Bridge Decks
- Parking Garages
- Marine Structures
- Hydraulic Structures
- Waste Water Treatment Facilities
- Primary and Secondary Containment

Eclipse Floor has received certification by the National Sanitation Foundation (NSF) stating that it conforms to the requirements of NSF 61 – Drinking Water System Components – Health Effects. NSF is an important consideration when designing containment structures for potable water.

Why Concrete Cracks

In order to understand the full impact of this innovative concrete admixture and how it will change the way concrete is specified, it is important to review the properties of concrete and why concrete cracks, or until now, why it was always believed that all concrete cracks.

The Mechanism of Shrinkage and Cracking

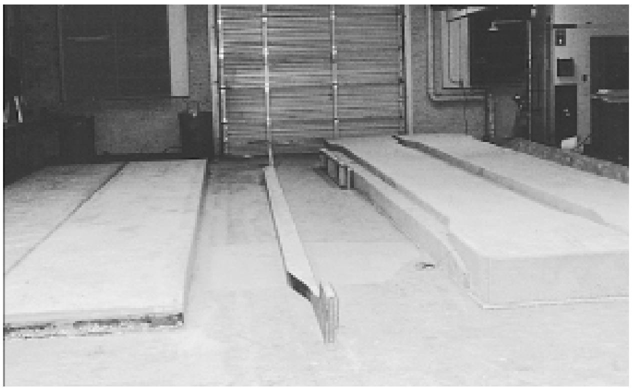
The portion of the concrete that shrinks is the cement paste. Certain porous aggregates may experience small amounts of drying shrinkage on their own (i.e., the aggregate as a separate component will undergo some minor shrinkage as it dries out), but the magnitude of this shrinkage is minor in comparison to that of the paste and is not an issue for normal weight concrete. Cement paste shrinks as it loses moisture due to the surface tension of water and the menisci that are formed in the pore spaces in the paste, as illustrated in Figures 1A, 1B, and 1C.

The surface tension of water in partially filled pores pulls inward on the walls of the pore spaces, as shown in Figure 1C. The concrete responds to these internal forces by shrinking. The amount of shrinkage for any cement paste is primarily a function of the water-to-cement ratio of the paste, but it may also be affected by cement type, cement fineness, and any other ingredients which alter the pore size distribution. Eclipse Floor works to reduce shrinkage by reducing the surface tension of the water in all the filled spaces in the concrete.

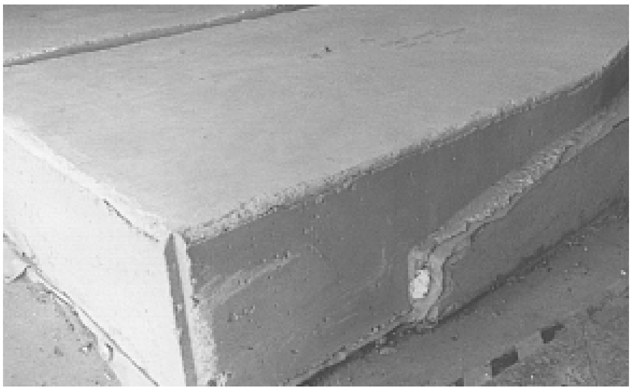
Aggregate in concrete actually acts as an internal restraint to the shrinkage of the paste. The amount of shrinkage in concrete is a function of the shrinkage of the paste, the volume fraction of paste, the stiffness of the aggregate and the strength of the bond between the paste and aggregate. So although the shrinkage of the paste is the primary cause of concrete shrinkage, the restraining properties of the aggregate can have a substantial impact. Cases have been documented where, in otherwise identical mixtures, the substitution of one aggregate type will result in twice as much concrete shrinkage as another aggregate type of exact same size and grading.

Whether or not concrete cracks due to shrinkage is a very complex matter involving the rate of shrinkage, the level of restraint, the creep properties, the modulus of elasticity, and the tensile strength of the concrete. The ultimate level of shrinkage alone is rarely sufficient for predicting cracking performance, although it can be a key indicator.

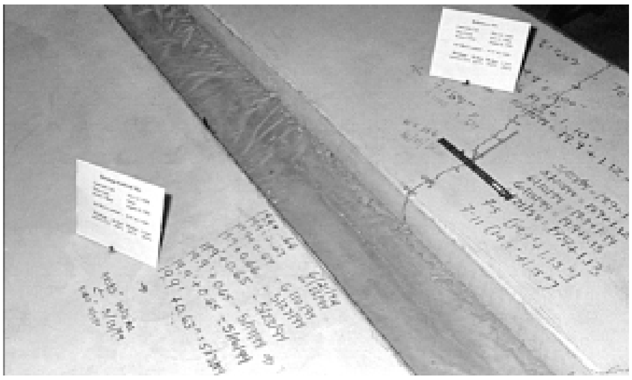
Ice Cream Factory — Comparison Testing



A converted 1920s ice cream factory in Cambridge, MA was the site for a full-scale restrained shrinkage test in a controlled environment. Two highly restrained slabs of identical composition, with the exception of Eclipse Floor, were placed and monitored for over 36 months.

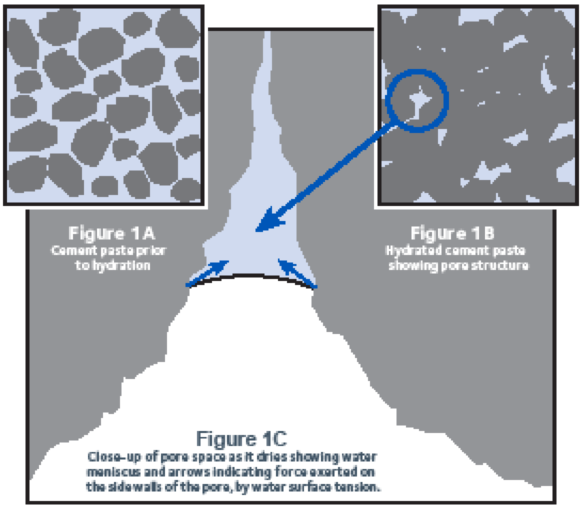


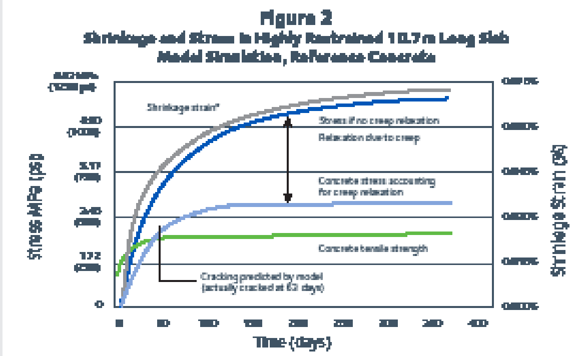
This close-up shows how test slabs were restrained by heavy steel-reinforced pre-conditioned bottom bases.

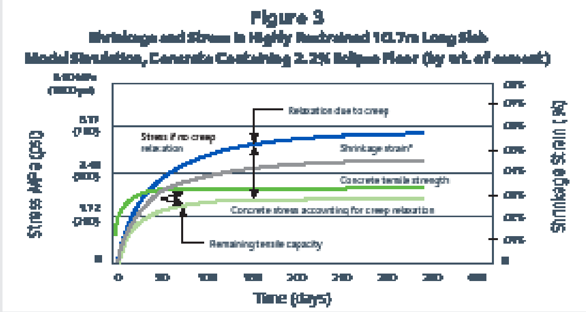


Side-by-side comparison (after 24 months) shows long-term performance of Eclipse Floor vs. the reference. The reference cracked in 2 months (at right). The slab containing Eclipse Floor is crack free (at left) after more than three years of continuous drying.

GCP Applied Technologies and Lyondell Chemical Company have co-sponsored research currently underway at Northwestern University, and the University of Illinois (administered by NSF Centre for Science and Technology Advanced Cement Based Materials – ACBM). The objective is to develop a computer model that accounts for all the variables mentioned above and utilises fracture mechanics methods to predict cracking due to shrinkage. GCP's R&D team has developed a precursor to this model based on previously published work done at Northwestern. Though this model may not be appropriate for predicting cracking for actual jobs, it can be used to gain insight into the mechanics of cracking of restrained concrete due to drying shrinkage. Figures 2 and 3 show the results of this preliminary model in predicting the buildup of stresses in two highly restrained concrete slabs. The two 10.7m long slabs were constructed of identical concrete except for the addition of Eclipse Floor to one of the mixtures, which resulted in a long-term shrinkage reduction of more than 40%. The model results were consistent with actual observed results. The mixture containing Eclipse Floor has not cracked after more than 36 months whereas the reference slab cracked after 63 days. The primary conclusion from this test (and augmented by the model) is that even in an extremely dry environment (40 to 50% relative humidity), it is possible to produce highly restrained concrete that does not crack due to drying shrinkage. A secondary conclusion revealed by the model is that creep of concrete plays a very large role in relieving the stresses that build up due to restrained shrinkage. Without adequate information on the creep characteristics of a particular concrete mixture, it is very difficult to use any model to predict cracking performance for an assembly containing that mixture.







* Shrinkage strain measured on unrestrained speciment.
Actural large scale members were restrained causing stress to build up.

What Shrinkage to Specify?

How does one determine the appropriate level of shrinkage to specify?

Because of the variability of performance of materials from location to location, no universal standard exists for an acceptable, achievable level of concrete shrinkage. The first step in controlling shrinkage is to determine what can be consistently achieved with the locally available materials. Once this baseline is established the impact of adding Eclipse Floor can be quantified.

With this information the specifier will then know the full range of possibilities with the materials available to the local concrete producers. The next, much more difficult step, is to understand the impact on cracking for different structures and environments of these different levels of shrinkage performance.

Given all the variables that affect cracking, in addition to shrinkage, the appropriate design tools do not exist today to accurately predict project specific cracking performance. GCP is working to overcome this limitation. Currently the best course of action where cracking is a concern is to minimise the shrinkage as much as possible both through mixture and material optimisation and the inclusion of Eclipse Floor. Although this course of action cannot be guaranteed to eliminate cracking, it is clearly the most effective way to minimise cracking due to drying shrinkage.

Putting Eclipse Floor to the Test

Shrinkage Performance

All of the shrinkage results quoted in this document are based on testing performed in accordance with ASTM C 157-93, which calls for 28-day moist curing. However, ASTM C 494-92 for chemical admixtures refers to C 157 for shrinkage testing and only calls for a 14-day curing period. GCP feels that 28 days of moist curing is rarely indicative of actual field conditions and has therefore based its testing on curing periods ranging from 1 to 14 days.

The Results

Eclipse Floor, when added to concrete at 2% by weight of cement, provides long-term shrinkage reductions on the order of 25 to 50% across a broad range of mix designs and materials. For 28-day results, which are the basis of many specifications, reductions of 50 to even +80% have been documented. So the product not only reduces long-term shrinkage, it slows down shrinkage in the early stages when concrete is most vulnerable to cracking.

Water-to-Cementitious Ratio

As previously stated, results vary from mix design to mix design. The primary reason for this variability is the water-to-cementitious ratio. Generally speaking, the relative performance (percent shrinkage reduction) is better for lower water-cement ratio concrete as confirmed in Figures 4-6, which summarise a round of testing for three different classes of concrete. (Figures 7-9 show compressive strength performance of these mixes.) These tests showed that for mixes with water-cement ratios of less than 0.60, reductions in 28-day shrinkage of +80% and reductions in 56-day shrinkage of 70%, were achieved at the 1.5% by weight of cement dosage level. With a water-cement ratio of 0.68 and a cement factor of 280kg / m³, the level of shrinkage reduction at 28 days and 56 days were 37% and 36% respectively.

Cement

A second factor that can impact concrete performance is the cement. Different cements behave differently with virtually all admixtures. The same is true with Eclipse Floor. In a mortar study of nine different cementitious materials (seven different cements, one cement combined with fly ash, and the same cement combined with slag) with no curing applied, long-term shrinkage results varied from 25 to 38%. This reinforces the need to establish shrinkage levels with local materials.

Figure 4 — ASTM C 157 Shrinkage
3 Day Cure, 280kg / m³ Cement

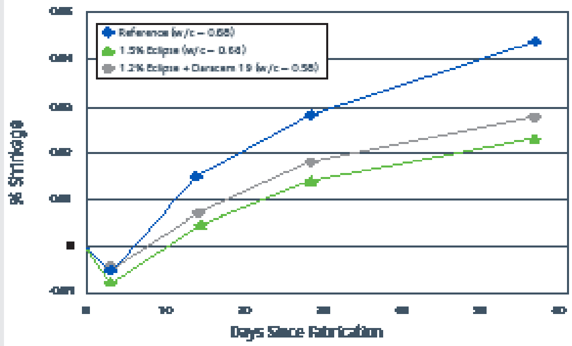


Figure 5 — ASTM C 157 Shrinkage
3 Day Cure, 325kg / m³ Cement

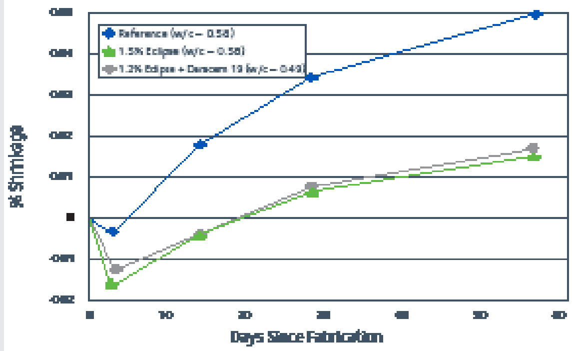
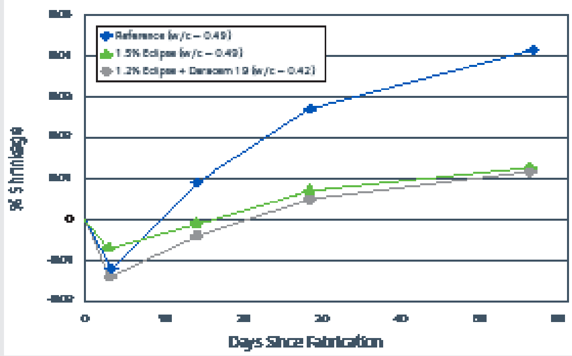


Figure 6 — ASTM C 157 Shrinkage
3 Day Cure, 385kg / m³ Cement



Curing

The third very important factor which affects both absolute shrinkage levels and the percent reduction (especially in the early ages) is the level of curing. Figures 10 and 11 contrast the performance of a 390kg / m^3 cement factor and 0.40 water-cement ratio mixture with and without curing. At 28 and 56 days the percent reductions due to Eclipse Floor were dramatically increased for the condition with 14-day curing. Beyond 90 days, the percent reductions due to Eclipse Floor tended to be equal for the two conditions, but the absolute levels of shrinkage were reduced at all ages by the longer wet curing condition.

Impact of Compressive Strength

The inclusion of Eclipse Floor shrinkage-reducing admixture at the 2% dosage level results in a reduction in compressive strength on the order of 0 to 10% at 28 days. In general, the strength reduction is minimised (i.e., a lower percent reduction) for lower water-cement ratio concrete. In many low water-cement ratio mixtures, that are commonly used in durability applications, the actual concrete strengths are significantly higher than the design strengths. In these mixes, the strength reduction due to the addition of Eclipse Floor can be easily accommodated. In other situations a strength reduction of 5 to 10% is not acceptable and the mix design must be adjusted. The recommended method for adjusting a mixture to counteract the strength reduction effect of Eclipse Floor is to use a superplasticiser (or additional superplasticiser such as Daracem® 19 or ADVA®) to provide for a water cut of 7 to 10% relative to the established mixture without Eclipse Floor. Figures 7-9 show the effect on strength with a 15% water cut and reduced Eclipse Floor content. This method resulted in 6 to 7% increases in strength relative to the reference without compromising the shrinkage performance of Eclipse Floor alone (see Figures 4-6 for shrinkage performance).

What is the ASTM Status for Eclipse Floor?

Table 1 (see back page) shows the results of ASTM C 494-92 testing for Eclipse Floor. Eclipse Floor does not qualify as any specific admixture type, as per C 494; but this is not surprising, since this is the first shrinkage-reducing admixture to be commercialised in North America and no ASTM designation yet exists. However, by going through the process of ASTM qualification testing, independent confirmation of a broad range of concrete properties can be documented. Of primary importance for this product are the shrinkage test results. ASTM criteria allow an admixture to have as much as 35% greater shrinkage than the reference at 28 days and still be deemed to be "shrinkage". By contrast, concrete containing Eclipse Floor at 1.5% resulted in a 54% reduction in 28-day shrinkage, and concrete containing 1.25% Eclipse Floor plus 0.25% Daracem 19 superplasticiser exhibited a 71% reduction in 28-day shrinkage.

Figure 7 — Compressive Strength 280kg / m³ Cement

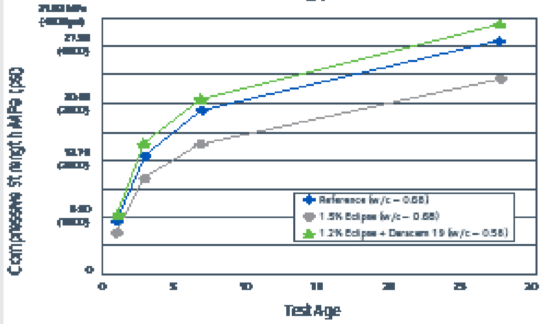


Figure 8 — Compressive Strength 325kg / m³ Cement

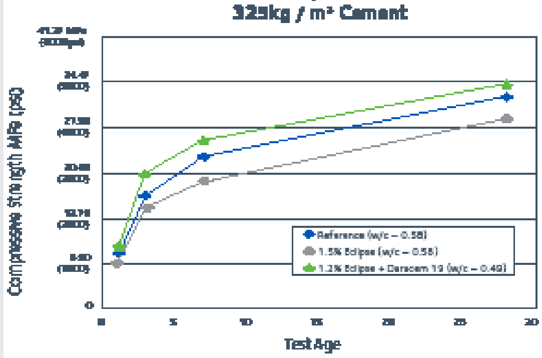
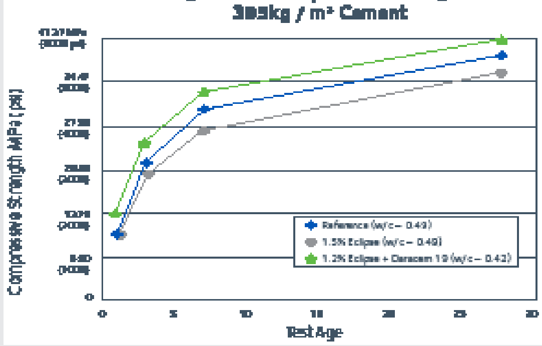


Figure 9 — Compressive Strength 385kg / m³ Cement



Does Eclipse Floor Help Block Curling?

A key consideration in high quality flatwork is the amount of curling that will take place at joints and cracks due to the moisture gradient in the concrete slab. The top surface of a slab dries out first and shrinks, while the concrete below is still saturated. The slab responds to this differential shrinkage across the thickness by curling up at the edges. For super-flat floors, curling is the least controllable variable affecting final flatness. Restrained curling (due to dowels at joints or gravity loads) is also one of the key reasons for cracking of otherwise unrestrained slabs on grade.

With Eclipse Floor shrinkage-reducing admixture, slabs curl less because the top surface shrinks less as it dries. In addition, Eclipse Floor alters the way water migrates through concrete, resulting in a more uniform moisture profile. The end result is even greater reduction in curling than would be predicted based on the reductions in shrinkage. So far this effect has only been quantified in small laboratory specimens, but tests are ongoing to confirm the effect on larger slabs more representative of field concrete.

Does Eclipse Floor Reduce Thermal Cracking?

Although most cracks occurring in hardened flatwork are attributed to drying shrinkage, a large percentage are actually due to thermal effects. There are two basic types of thermal cracks. The first is due to temperature differences within a section of concrete. A temperature differential of 19°C within 300mm is usually considered enough to cause cracking. The second type is due to the volume change that concrete goes through as it cools. Within 24 hours of placing, concrete temperatures can reach anywhere from 11 to 28°C hotter than ambient temperatures. Concrete sets and gains strength in this hot condition. As the concrete cools it contracts. In extreme conditions concrete may contract as much in three days due to thermal conditions as it does in a year due to drying shrinkage. This thermal contraction is an undiagnosed cause of cracking in many conditions where the cracking appears within the first weeks after placement.

Eclipse Floor shrinkage-reducing admixture does not alter the coefficient of thermal expansion (contraction) of concrete, but it does alter the rate of heat generation due to hydration, resulting in lower peak temperatures and less postpeak thermal contraction. This reduced hydration activity is manifested in the lower concrete strengths observed when using Eclipse Floor. For mixtures where additional water must be cut (or cement added) to regain the strength, the effect of this heat reduction is counteracted. For the types of mixtures used in bridge decks, parking garages, and marine structures, where low water-cement ratios are dictated by durability concerns, the concrete is often substantially over designed for strength. In these cases the heat reduction induced by Eclipse Floor can be a significant factor in reducing the likelihood of cracking.

Figure 10 — ASTM C 157 Drying Shrinkage – NO Curing
Cement= 390 kg/m³, w/c = 0.40

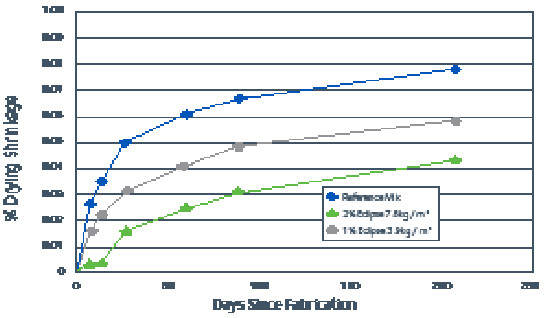


Figure 11 — ASTM C 157 Drying Shrinkage – 14 Day Cure
Cement= 390 kg/m³, w/c = 0.40

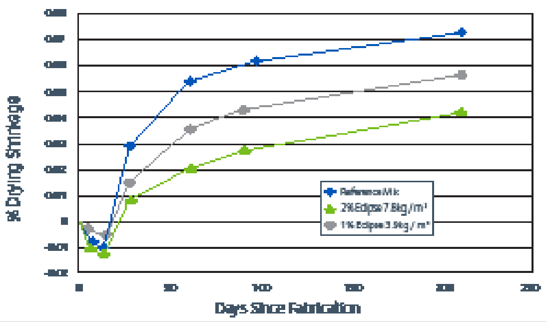


Table 1 - ASTM C 494 Results

Mix	Reference	Eclipse Floor (1.5%)	Eclipse Floor (1.25%) + HRWR (0.25%)
Water to cement ratio	0.52	0.48	0.45
% Water Cut		8%	14%
Slump mm	100	90	75
% Entrained Air	5.4	5.7	5.4
Initial Set Time (min.)	210	244	262
Final Set Time (min.)	462	485	574
1 Day Compressive Strength MPa (psi)	11.00 (1595)	10.52 (1525) 96% of ref	10.96 (1590) 100% of ref
3 Day Compressive Strength MPa (psi)	19.27 (2795)	20.75 (3010) 107% of ref	24.27 (3520) 126% of ref
7 Day Compressive Strength MPa (psi)	28.23 (4095)	27.72 (4020) 98% of ref	31.82 (4615) 113% of ref
28 Day Compressive Strength MPa (psi)	39.68 (5755)	40.96 (5940) 102% of ref	43.86 (6365) 111% of ref
3 Day Flexural Strength MPa (psi)	3.16 (458)	3.14 (456) 99% of ref	3.57 (518) 102% of ref
7 Day Flexural Strength MPa (psi)	4.01 (582)	3.97 (576) 99% of ref	4.41 (640) 110% of ref
28 Day Flexural Strength MPa (psi)	4.78 (693)	4.87 (706) 102% of ref	4.71 (683) 99% of ref
28 Day Shrinkage (%)	0.028	0.013 54% reduction	0.008 71% reduction
56 Day Shrinkage (%)	0.056	0.038 32% reduction	0.032 43% reduction
120 Day Shrinkage (%)	0.063	0.046 26% reduction	0.039 38% reduction

Conclusion

Eclipse Floor shrinkage-reducing admixture is an exciting new advancement in concrete technology, offering a cure to one of concrete's major flaws: drying shrinkage. Summarised in Table 2 are the properties and performance characteristics of Eclipse Floor shrinkage -reducing admixture.

Table 2 - Performance Characteristics of Eclipse Floor

Property	Performance
Shrinkage	50 to 80% reductions at 28 days 25 to 50% reductions in ultimate
Curling	Reductions greater than corresponding shrinkage reductions (Tested in small scale to-date)
Heat Generation	No adverse effects
Compressive Strength	0 to 15% reductions in 28 day strengths (can be offset with superplasticiser usage)
Freeze-Thaw Durability	Contact your GCP representative for restrictions in freeze-thaw environments
Set Time	Neutral to slightly retarding
Water Demand	2 to 4% reductions (can be as high as 8%)
Finishability	Neutral to slight improvement

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