SERVICE INDUSTRY NEWS

Reprinted from March 15, 2004 Issue

Making Pool Plaster More Durable

By David Dickman

We've heard it time and again – veteran pool professionals insist that the plaster in today's swimming pools does not hold up as well as the plaster applied 20, 30, or 40 years ago.

Is there a difference in the way pools are plastered today? And if so, could it affect the durability of the plaster?

These questions were at the heart of a recent experiment carried out by Kim Skinner of onBalance, an independent research group that has done extensive research into the nature of pool plaster.

Skinner observed that 30 years ago, some plasterers would allow a newly plastered swimming pool to sit for about six hours after final troweling before it was filled.

Now, he says, normal practice is to begin filling up the pool within 30 minutes after final troweling. What effects, he wondered, does this practice have on the plaster?

Another changing practice, Skinner notes, is in the amount of calcium chloride (an accelerator) being used in the plaster mix. Calcium chloride is used to speed up the time that plaster will set and harden.

A survey of some plastering firms indicates that calcium chloride use 30 years ago was approximately .5 percent to 1.5 percent, Skinner says. Recent studies indicate that the average is now approximately 1.5% to 3%. So what effect, he asks, does adding higher amounts of calcium chloride have on the quality of the plaster?

And with the increasing amounts of calcium chloride being used to speed up the setting of the plaster, it also appeared to Skinner that extra water is being added to the plaster mix to insure that the plaster doesn't get hard until it is applied. So what effect, he wondered, does the extra water in the plaster mix (a high water-to-cement ratio) have on the quality of the plaster coating?

Along with these changes, Skinner also noted that pool-plastering consultants are now claiming that spot etching problems are a result of the dissolution of calcium hydroxide from the plaster surface. This, they claim, can only be accomplished by aggressive water (which is low in alkalinity and low in calcium hardness), and that if the water were balanced with sufficient alkalinity and calcium hardness, then no dissolution would occur.

Skinner decided to design an experiment to investigate the spot etching theory and to answer the questions mentioned above and determine the solubility of pool plaster.

The Experiment's Purpose

Skinner outlined six goals of his experiment:

- To determine if there are soluble components in swimming pool plaster in balanced pool water conditions.
- To determine how placing newly finished pool plaster in balanced water at different time successions affects the solubility of the plaster finish.
- To determine how different water-to-cement ratios affects the solubility of pool plaster in balanced water conditions.
- To determine how much calcium hydroxide in pool plaster will dissolve into balanced swimming pool water with the above varying conditions. (Calcium hydroxide is a by-product from the hydration (hardening) of cement.)
- To determine if calcium chloride affects the solubility of swimming pool plaster components in balanced water conditions.
- To determine how much calcium chloride dissolves from the plaster into balanced pool water after filling.

How The Experiment Was Conducted

Thirty-two plaster samples (known to plaster researchers as "coupons") were formed, each 4 inches by 4 inches, three-fourths inches thick, one-part cement to one-and-a-half parts aggregate. No color was added to the mix. The variables for the plaster coupons were as follows:

- Two different water-cement ratios were used. Sixteen plaster coupons were made with a .44 ratio and sixteen coupons with a .56 ratio, simulating a low and high water-cement ratio, respectively.
- Four different calcium chloride amounts were used. Eight plaster coupons were each made with 1%, 2%, 3%, and 4% calcium chloride contents respectively. Four of each eight were made with the water-cement ratio of .44 and the other four with a .56 ratio.

The plaster coupons were each placed separately in a five-gallon tank of balanced water for 30 days. Four different water placement times were used. Once the plaster coupons had sufficiently hardened, eight were each placed in the water tanks after 30 minutes, 2 hours, 6 hours, and 24 hours.

The water in each tank was balanced according to the Langelier Saturation Index, meaning that the water was neither aggressive nor scaling. Each water tank had an initial pH of 7.7, alkalinity of 110 ppm, calcium of 180 ppm, and temperature of 70 degrees.

The water in each tank was analyzed every 24 hours for the first 7 days, then twice a week for 30 days to determine pH increase, alkalinity changes, calcium (expressed as calcium carbonate) increase, and chloride increase. Adjustments to water included nitric acid being added to lower pH, and sodium bicarbonate to replenish alkalinity. At the end of 30 days, the plaster coupons were removed and acid was added to the water tanks to dissolve all precipitated calcium carbonate (plaster dust). The water was then tested for the calcium content to determine the amount of calcium increase. Note: Nitric acid was used because it does not contain chloride, which muriatic acid does.

The plaster coupons were minimally troweled, and troweling is not considered a variable factor in this experiment.

Observations and Results

Obviously, the plaster coupons with 4% calcium chloride set (hardened) faster than the coupons with 3% calcium chloride added, which hardened faster than the coupon with 2%, and so forth. But it was also observed that the low water-cement ratios coupons set faster than high water-cement ratio coupons.

The pH change

After placement of all plaster coupons in water at the succession times mentioned above, it was observed that the pH of the water in each tank began to rise immediately despite the water being balanced according to the Saturation Index. Although the pH rose in every case, the amount of increase varied from one water tank to another. The pH increased generally to at least 8.5 and went as high as 9.5 within 24 hours.

The Effect of the Time Placement (In Water) On pH

The water where plaster coupons were placed first (30 minutes) reached a higher pH than the water where coupons were placed at 2 hours. Likewise, the 2-hour coupons raised the pH higher than the 6-hour coupons, which was also higher than the water that had coupons placed in water after 24 hours.

The Water-To-Cement Ratio Effect On pH

The plaster coupons with the high water-cement ratio (.56) consistently had higher pH results as compared to its counterpart coupons with the low water-cement ratio (.44).

It was observed that the combination of the high content of calcium chloride (4%), the high water-cement ratio plaster coupons (.56) and placement of them in water the earliest (30 minutes and 2 hours) proved to cause the pH to rise the highest and caused the greatest cloudiness (plaster dust) to develop.

After testing the pH, acid was added to lower pH to 7.7. For several days, the pH would begin to rise again although not quite as high as before. But as before, the pH rose higher in the same water tanks as mentioned above and as compared to the other tanks. After a few days the increase of the pH slowed down significantly. Only minor adjustments to the pH and alkalinity were necessary after one week.

Calcium Testing & Results

The calcium content increased in all water tanks. The major source of calcium increase came from the dissolution of calcium hydroxide, with a lesser amount being contributed by calcium chloride contained in the plaster coupons. For this discussion, Skinner discussed calcium only in terms of the dissolution of calcium hydroxide.

The water tank with the greatest increase of calcium came from the coupon that had the high water-cement ratio, and was placed in water the earliest (30 minutes). The water tank with the least amount of calcium increase came from the coupon that had the low water-cement ratio and that was placed in water the latest (after 24 hours).

After curing for 30 days, plaster has a carbonated surface, and approximately 10% of the total weight of the cement is calcium hydroxide. It was determined that as much as 15% of this calcium hydroxide can be dissolved away from the plaster coupon by balanced water if the coupon is made with the high water-cement ratio and placed first in the water tank.

At the other end of the spectrum, the coupon with the low water ratio and placed in water after 24 hours had less than 2% of the calcium hydroxide dissolved by balanced water. The other water tanks had readings between these two percentages.

Equating the above 15% figure to an average size residential swimming pool (20,000 gallons), it is estimated that the equivalent of 25 pounds of calcium carbonate can be dissolved from (the calcium hydroxide in) the plaster surface of a balanced pool.

Chloride Testing and Results

The chloride content of the water increased in all water tanks. The source of the chloride increase from calcium chloride added to the plaster. (Calcium is also contributed to the water from this chemical compound, but by testing the chloride content, we can determine the total amount of calcium chloride that dissolves into the water).

Notwithstanding the other variables, the water tanks with the greatest increase of chloride obviously came from the coupons that had the highest amount (4%) of calcium chloride added, and the least came from the coupons that had only 1% added. However, the coupon that was made with the high water-cement ratio (.56) and placed in water first, allowed slightly more chloride to be leached from the plaster as compared to its counterpart (the .44 water-cement ratio coupon and place in water last).

It was determined that regardless of whether 1%, 2%, 3%, or 4% of calcium chloride was added to the plaster mix, approximately 15% to 25% of that amount added dissolved from the plaster and into the water depending on the other variables. As stated before, the highest increase (25%) of calcium chloride came from the coupon that had the high water-cement ratio and was placed in water the earliest. The lowest increase (15%) came from the coupon with the low water-cement ratio (.44) and placed in water after 24 hours. The other tanks had readings between these two percentages. Equating these percentages to an average size residential swimming pool (20,000 gallons) means that using 2% calcium chloride in the plaster mix can result in the loss of about 8 pounds of this material from the plaster on the high side, and about 5 pounds on the low side.

Conclusions

The increase of the pH in the water tanks is due primarily to calcium hydroxide being dissolved from the plaster coupons and into the water. (It is the hydroxide portion of this compound that raises the pH).

The coupons that were placed in water earliest apparently had not sufficiently hydrated and hardened which results in greater amounts of cement compounds (calcium hydroxide and calcium chloride) being dissolved. Also, the high water-cement ratio coupons create a higher porosity in the plaster, which results in the dissolving of more of these compounds from the surface. When these two conditions are combined, about ten times more plaster material is dissolved away. From a pool water maintenance perspective, this causes pool service technicians and personnel greater difficulty in balancing the water in freshly filled swimming pools.

Based on the results of this experiment, the higher amounts of calcium chloride in the plaster mix also increased the percentage of calcium hydroxide dissolved.

It is most likely that the majority of these plaster materials are lost from the surface, not deep from within the matrix. The dissolving (technically known as leaching) of these plaster components adds to the existing porosity of the plaster finish, creating even a more porous surface, and affecting its long-term esthetics and durability.

As mentioned before, it has been stated by plaster consultants that spot etching is from the dissolution of calcium hydroxide, which can only be caused by low alkalinity and low hardness, and therefore, spot etching is caused by a water imbalance. It is evident from this experiment that the basis of their contention is untrue – plaster has components that will be dissolved away despite being placed in balanced water. However, if the plaster is made with a low water-cement ratio and allowed to harden sufficiently, then far lower amounts of calcium hydroxide will be leached away from the plaster surface.

It should be understood that the Langelier Saturation Index is a standard designed to predict the precipitation or dissolution of calcium carbonate, (a much more durable and less soluble material), not calcium hydroxide or calcium chloride. In other words, higher Index values (greater than +0.5) predict calcium carbonate precipitation, where lower values (lower than –0.3) predict dissolution of calcium carbonate. Balanced water (between –0.3 and +0.5) will dissolve both calcium hydroxide and calcium chloride.

This experiment demonstrated that plaster with a low water-cement ratio creates a more dense material, which does not allow as much movement of the calcium hydroxide and calcium chloride and therefore, less is dissolved away. In addition, waiting 24 hours before placing coupons in water also allowed the coupons to develop a denser and harder surface, and thus a greater resistance to the dissolving action of water.

Recommendations

According to the Portland Cement Association (PCA), using a low water-to-cement ratio for mixing cement-based materials is superior and recommended for optimum strength and durability of cementitious products.

It is also documented (by the PCA) that a high water-cement creates a more porous matrix. As demonstrated by this experiment, using a high water-to-cement ratio for plaster (that is subject to underwater conditions), is much more detrimental to a plaster surface.

While it is recognized that a .44 water-cement ratio is a very stiff and difficult mix to use, Skinner recommends a plaster mix with a water-cement ratio no higher than .50, which has a good workability and is a reasonable standard to follow.

The Portland Cement Association advises against adding more than 2% calcium chloride, and that adding high amounts of calcium chloride (above 2%) is detrimental to a cement product. If plasterers use less water, then less calcium chloride would be needed. A stiff mix (low water-cement ratio) helps speed up the set time and therefore, less calcium chloride would be needed to speed up the setting and hardening of the plaster mix. Pool plasterers could also heat the water used for mixing the plaster, which would speed up setting time.

This experiment has also shown that plasterers should not turn on the water to fill the pool immediately after plastering (troweling) is finished. The turning on of the fill water should be delayed for at least 8 to 24 hours depending on temperature and weather conditions. This would be an additional important step to improve the quality of their product.