Bay Area Pervious Concrete
Technical Services Division

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Pervious Concrete: The Evolution of Mix Design

New developments and advances over the past decade have rapidly changed pervious concrete technology. As a result, pervious mix designs have trended toward lower cement contents and higher moisture (w/c) content. Experience with regular concrete tells us that less cement and increased water would reduce the performance of the pavement, but with pervious concrete we have found the opposite to be true.

Cement Content and Mix Design Results

Pervious concrete is not traditional concrete; instead, it is a concrete with intentionally created voids, the design target being approximately 20% interconnecting voids. In order to create those voids the quantity of cement paste needs to be carefully proportioned according to the available space in the aggregate.

With traditional concrete more cement equates to stronger concrete, and it seems logical to apply this thinking to pervious concrete as well. This being the case, in the past it was not unusual to see pervious concrete mix designs calling for 600 or more lbs cement per cubic yard, believing that this would produce stronger pervious concrete. Pervious concrete however is limited to a particular maximum quantity of cement ***paste*** (cement + water) based on the available voids in the aggregate being used; too much paste and the voids needed for porosity are no longer interconnected and water will not flow through the pavement. Because of the paste volume restriction, the use of higher quantities of cement can only be achieved by lowering the volume of water in order to keep the overall paste volume consistent. As a result, these 1st generation pervious concrete mixes with 600+ lbs of cement were restricted to water cement ratios in the 0.22-0.28 range. Since cement requires water in the ratio of approx. 0.42 in order to fully hydrate, these early mixes were severely compromised before they even arrived at the jobsite.

This high cement, low w/c approach also produced heavy, dry, sticky mixes that discharged from the truck at a painfully slow rate, were difficult to place and finish, and required considerable compactive effort to obtain even moderate consolidation. Due to the slow placement times, much of the little water that was in the mix to begin with, was lost to evaporation. By the time the curing cover is applied to a cement heavy 1st generation pervious mix, what water remains is far from sufficient for adequate hydration. The result is low paste density, low strength and weak aggregate bonding that together resulted in pavements with both unacceptable aesthetics (raveling) and performance.

In an effort to find a solution to these challenges BAPC, along with several other leaders in the field, begin to make the move towards lighter wetter mixes in the 2010-12-time frame. These new mixes, which now we refer to as 2nd generation pervious, represented a shift in thinking away from the belief that equated high cement contents with better performance. Dropping the cement content allowed us to increase the quantity of water while maintaining the same paste volume. Water cement ratios were now in the .29-.33 range. Where previously 2 men were required to "work the chute" or pull the dry pervious concrete down the chute, now the concrete would almost make it down on its own, was more workable, and had a greater quantity of moisture remaining when the curing cover went down.

Instead of lower strengths due to less cement, we experienced increases in strengths and performance due to higher rates of hydration associated with more water in the mix. We still had to carefully monitor and manage the mix water throughout the process from batching to covering, but it was now possible for an experienced crew to install a higher quality product on a more consistent basis.

In the more recent past BAPC has led the way to a 3rd generation of pervious mixes using super absorbent polymers that allow for even higher water cement ratios that now approach the ideal hydration range* while dramatically increasing ease of installation, production rates and quality.

Only a few hundred nanometers in diameter an SAP particle is capable of absorbing and holding many times its weight in water. When used in a pervious concrete mix, SAP's act as tiny reservoirs that and can hold an extra supply of water without thinning, or lowering the viscosity of, the paste to the point where it would run off the aggregate and seal the bottom of the slab. This additional water greatly increases workability and speed of installation allowing curing to start sooner while also providing ample water for hydration. For several years now BAPC have been creating and installing pervious concrete mixes with w/c ratios in the .39-.42 range and cement contents as low as 400lbs that are consistently out-performing 2nd generation mixes due to reduced evaporative water loss, and the resulting increase in hydration.

The evolution of pervious concrete mix designs has, and continues to, advance at a rapid pace. The vast improvements in 3rd generation pervious mixes, along with advances in installation techniques and equipment, have positioned pervious concrete for continued growth and acceptance among produces, installers and owners.

**The consensus among the scientific community is that the ideal w/c ratio for maximum cement hydration is in the low to mid 40's. Below that level the water in the cement matrix will be depleted before the hydration process is complete, leading to self-desiccation, high rates of autogenous shrinkage, warping and cracking. Above that level excess water results in greater size and number of capillary pores that raise permeability while lowering density and strength.*