HOWARD UNIVERSITY
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CAN CHANGES IN WATER PROPERTIES IMPROVE CONCRETE PERFORMANCE?

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by

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INTRODUCTION

This paper reports the research over a seven-year period, in which a goal was set up to develop an economical, uncomplicated and consistently reliable method that would significantly enhance portland cement's overall quality criteria. The research purposely began in an era of past technology—the era immediately prior to the development of synthetic admixtures, such as air entrainment, water reducers, plasticizers, super plasticizers, micro-silica, etc. Rather than modifying already-mixed cement, like many of today's admixtures, it was determined that the most promising media for enhancing the desirable properties of portland cement concrete was to modify its ***mixing water***.

In the initial studies, adding natural ingredients capable of enhancing the hydration abilities of portland cement was investigated. It was determined that certain ingredients increased the effectiveness of the mix by providing water with extraordinary molecular binding power which would allow more of concrete's so-called ***water of convenience*** to be utilized by cement hydration, rather than be evaporated. This action reduced capillary sizes, making them comparable to gel pore sizes, and created a significant increase in the concrete's impermeability.

These amazing revelations led to the development of a unique "preconditioner" to mix in water that would provide extraordinary benefits to portland cement concrete through improved conditioning of the mixing water. Research over the last five years with this mix water conditioner has proven that it increases overall quality, performance and useful lifespan of concrete, all of which means concrete with greater durability.

WHAT MAKES CONCRETE A GOOD CONCRETE?

Good concrete is durable concrete. The durability of a material is that certain property which indicates whether or not the material will endure, even though it may not be subjected to loads sufficient to destroy it. Durability of portland cement concrete, then, is defined as its ability to resist weathering, chemical attack, abrasion, or any other process of deterioration.

Durable concrete retains most of its original form, quality, and serviceability when exposed to various types of environments. Durability is one of concrete's most important properties since concrete must be capable of withstanding conditions to which it is exposed throughout the useful lifespan of the structure. Durability can be affected by factors such as alternate wetting-drying, freezing-thawing, aggressive sulfate exposure, heating-cooling, water invasion, abrasion, corrosion of embedded steel reinforcement or other embedded materials, chemical contaminant reactions, alkali-aggregate reactions, salt deposition by percolating water, dissolution of calcium hydroxide and/or certain other constituents by percolating water, etc.

Finding a consistently reproducible way to improve the durability of concrete, as well as significantly reduce its permeability, was one of two main goals that would be achieved by the successful development of a mix water conditioner. The other goal was to consistently produce defect-free, extraordinarily finely textured cement paste which is capable of improving concrete paste-aggregate contact zone areas. These areas are largely dependent on paste and microstructure quality and are known to be either the strongest or weakest part of concrete.

By preconditioning the water with the right ingredients, these goals can be achieved simply and with minimal expense. (Other methods of improving the performance and durability of concrete, such as high performance concrete, are both expensive and complicated.) It was also found that concrete can be produced with no transition between the aggregate and paste. This concrete had virtually no plastic shrinkage cracking and virtually no curling. Extensive laboratory testing indicated that the mix water conditioner's conceptual goals were consistently achievable, without necessitating use of outside mineral or chemical admixtures, synthetic agents, water-reducers, or plasticizing agents.

WHAT ROLE DOES WATER PLAY IN CONCRETE?

Water is essential to portland cement concrete since without water, the cement could not become a bonding agent. There are two ways in which portland cement and its compounds react with water. The first is hydration, in which the reaction takes place when water molecules come in contact with the dry cement. The second is hydrolysis, which results when products precipitate from solution minerals and directly combine with them. Hydrolysis and hydration are directly responsible for the production of new products or compounds that formed in concrete. These new compounds are usually referred to as ***products of hydration***. Products of hydration include calcium hydroxide, lime, calcium silicate hydrates (C-S-H), and calcium aluminate hydrates.

The quality of the products of hydration may vary greatly, depending on the quality of both the cement and the mix water. In concrete, the rate of hydration decreases continuously following the period when the formidable properties of the concrete are formed. Even after 28 days, appreciable amounts of the included cement remain unhydrated. Studies have shown that after 28 days, cement grains in constant contact with water may only hydrate to a depth of 4 micrometers, and even after a year may only hydrate 8 micrometers. Water which has been enhanced by mix water conditioner improves the cement hydration. Under field conditions, concrete made using the mix water conditioner has consistently shown a 6 to 12 percent (approximately up to one micrometer) increase in cement hydration. (The variation in the increase is contributed to the mixing efficiency.) Thus, the mix water conditioner does play an important role in providing for better hydration.

During hydration of portland cement, prolific violent actions and reactions occur as the mix water initially contacts the dry cement, splitting off molecular portions of the dry cement's compound components. These actions are vital because they result in the production of numerous forms of calcium silicate hydrates, including calcium hydroxide.

These initial hydration reactions, in combination with water dilution, temporarily lower portland cement's efficiency, causing the initially produced cement paste to be of poor quality. This includes the cement paste which is absorbed into or coated on the exterior of concrete's porous aggregates. The resultant concrete properties are affected by weak paste-to-aggregate bond, as well as the deposition of other poor quality paste, which affects permeability, and thus durability.

The mix water conditioner, however, overcomes this poor initial hydration by promoting a smoother, more gentle transition of concrete's hydration. The mix water conditioner also greatly improves the hydration/hydrolysis reactions, and results in more efficient hydration products and less unhydrated portland cement.

ROLE OF ADMIXTURES IN CONCRETE PROPERTIES

Admixtures can be used to tailor and adjust mixes to meet a wide variety of performance requirements. Most mix designs today include additional cementitious materials and chemical admixtures. Natural pozzolans, fly ash and slags supplement or replace a portion of the portland cement. Air entraining admixtures are used to improve freeze-thaw resistance. Chemical admixtures are used to accelerate or retard set, improve workability, and reduce mixing water.

Adding these ingredients requires detailed knowledge of mix design.

VARIOUS COMPONENTS OF STRENGTH CHARACTERISTICS OF CONCRETE

In a much simpler way, preconditioned mix water causes an additional 6 percent or more of the portland cement, which in turn increases the volume of the hydration products. This, in effect, is like increasing the portland cement content by 6 percent. It does this without increase of the originally designed per-cubic-yard dry cement volume, and lowers the actual water/cement ratio. This extraordinary benefit is due to the preconditioned mix water's ability to more deeply absorb portland cement particles, posturing each particle to more readily and more often shed its hydration envelopes. It then allows new envelopes to generate, causing significantly more hydration of each cement particle. It also uniquely generates additional volume of the cement paste.

ADDITIVES VS. NATURE OF WATER

The very nature of water is that when added to anything, it reduces that material's strength. The objective, then, is to transform the water into something better, i.e., a cementitious material which may produce an even lower water-cement ratio, thus avoiding this decrease in strength. As previously mentioned, introducing selected natural ingredients into the mix water will generate increased utilization of concrete's *water of convenience*, producing virtually no bleed water. An example may be presented here. In a mix, if 5 gallons of water fully hydrates 100 pounds of cement with a water ratio of 0.42, then only 2.88 gallons of normal mix water actually combines with the cement, while the remaining 2.12 gallons of water occupies capillary spaces, following the surface finish, until it is used for producing hydration products or is later evaporated, leaving void capillaries. When the mix water is preconditioned, however, virtually all of the normal mix water is used due to the increased cement particle saturation as shown in *Figure 1*.

Using the ACI-accepted standard that in a given mix design of 470 pounds of Type I portland cement, only 80% (376 pounds) of the cement is hydrated, the MWC produces a minimum of 6-8% (28-38 pounds) more cementitious material from that remaining 18-20% (84-94 pounds) of unhydrated cement and results in a very homogeneous ready mix concrete as indicated in *Figure 2*.

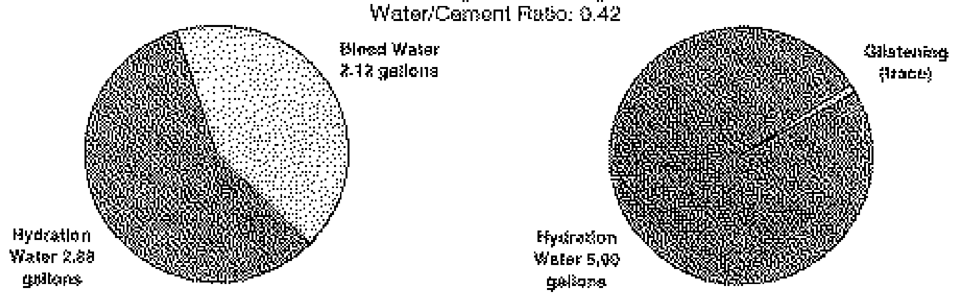
PROPERTIES OF CONCRETE

Listed below are several mix water preconditioner-derived properties gained from utilization of increased percentages of concrete mix's *already included* portland cement content:

1. The smaller than usual leftover cement particle cores increase impermeability and density. These particle cores become variously sized through increased cement utilization, and the leftover cores act as sand/aggregate.
2. The cement paste is finely textured and

Figure 1 **100 Pounds of Cement Hydrated by 5 Gallons of Water**

Water/Cement Ratio: 0.42



Normal Mix Water

Mix Water Plus Conditioner

homogenous, provided with same charge particle effect, greatly reducing potential for internal voids, shrinkage, excessive external bleed water, internal microcracking, crazing, plastic/settlement cracking, etc.

3. The concrete is extraordinarily homogenous with increased workability due to increased lubricity.

4. Cementitious material waste is reduced and water utilization increased. This results in increased volumes of cementitious material produced per cement particle, effectively lowering water-cement ratio of finished concrete.

5. Generation of more finely textured cement paste consisting of smaller-size gel pores with excellent uniformity and smaller than usual capillary pores/voids. This is due to total mix water utilization, which results in increased hydration product volumes. These actions significantly lower total void percentages and, thus, permeability.

6. It produces a true shrinkage-compensating concrete, compensated by production of increased volumes of internally generated hydration product or C-S-H, which also virtually eliminates curl.

DISCUSSION AND RESULTS

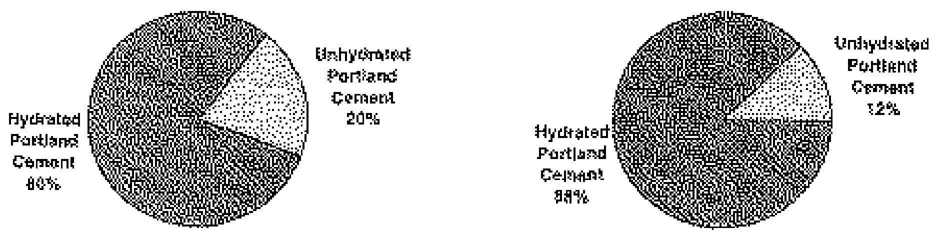
From a durability standpoint, it is of crucial importance to achieve the lowest possible permeability in the shortest period of time. Such a task is achieved uniformly when utilizing a mix water conditioner. Permeability in concrete means that pollutants or contaminants are allowed to penetrate inside its interior. The degree of permeability dictates whether these pollutants/contaminants are readily—or sparingly—allowed ingress. Therefore, permeability, as well as the degree of permeability, effectively and directly affect concrete's durability, which translates to useful lifespan.

For concrete made using normal weight aggregate, permeability is governed by cement paste porosity and pore-size distribution. In fact, concrete's permeability is generally controlled by the capillary porosity and not gel porosity. Concrete's paste capillary porosity size is governed by concrete water-cementitious material ratio and degree of hydration. Mix water conditioner was designed to significantly enhance increased cementitious material volumes and improved hydration rates and processes through reposturing the mix water's hydration abilities.

CONCLUSIONS

A mix water preconditioner added to portland cement concrete mixing water, prior to concrete manufacturing, significantly alleviates the deterioration factors in concrete. Mix water which has been preconditioned with the right mix water conditioner consistently produces concrete that is extraordinarily strong, hard and impermeable.

Figure 2 **Mix Design: 470 Pounds Type 1 Portland Cement**



Without Mix Water Conditioner — With Mix Water Conditioner