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Quality Increase and Cost Reduction by Controlled Concrete Curing Conditions

"...as simple as possible, but not simpler." This quote from Albert Einstein may be carried over to the concrete paver and block industry. Today's hardscape customer demands not only short delivery times, but also a high quality product – not only one that meets the strength requirements, but an aesthetically pleasing product with bright, consistent and durable colors. The goal of every producer must be to produce the lowest cost product, available within 24 hours, with consistent and bright colors, without efflorescence and without damage to corners and edges. It is as simple and as complicated as that! The role of curing in meeting these goals is as fundamental as it is overlooked.

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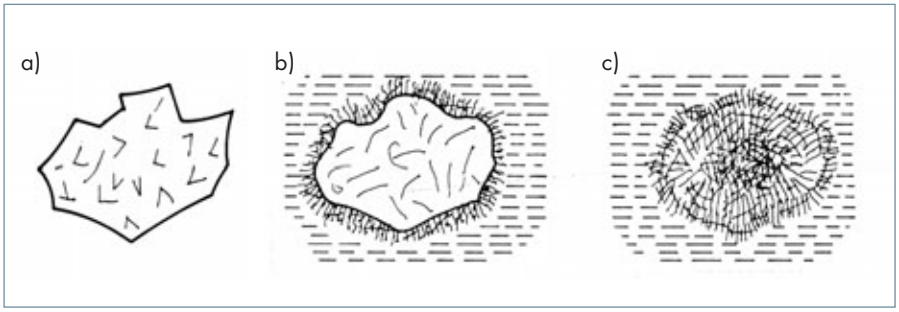
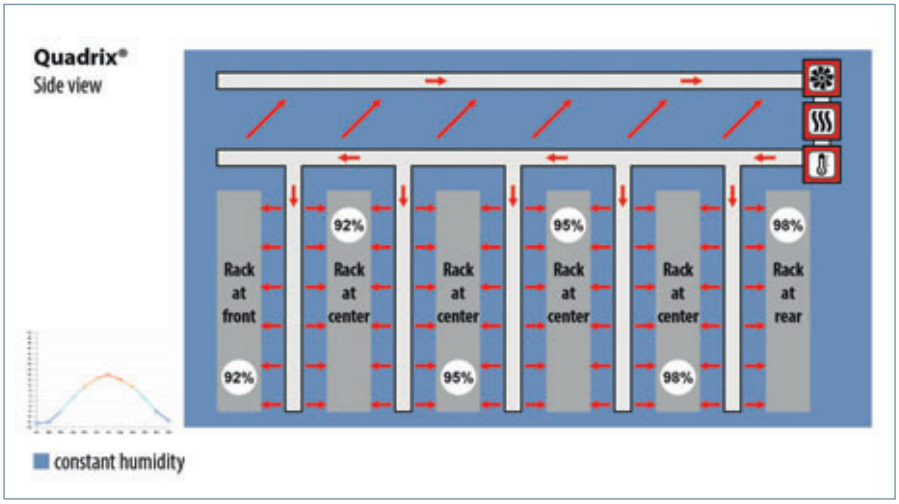
What is concrete, but for sand, stone, cement and water mixed and formed into a concrete pave stone, block or some variant thereof. In order to make the end product more valuable and, thus, more desirable, most producers add pigment for color. In many cases, the addition of pigment simply makes the product look worse due to lack of control of the concrete hardening process. Either curing temperature too high, too low or inconsistent, curing humidity too high, too low or inconsistent, natural air drafts or drafts created due to poorly designed air circulation systems cause weak corners and edges, poor durability, poor abrasion characteristics, inconsistent colors and efflorescence.



Chemical Cement Hydration Process: seen here, the importance of moisture on cement hydration.
a) Cement grain prior to the addition of water
b) Cement grain shortly after the addition of water. Dashed lines indicate water. Follicles indicate the presence of cement gel.
c) Cement has been greatly dissolved by the water to form a large quantity of cement gel. The center of the cement grain is not completely hydrated.



Indication of consistent humidity distribution through proper concrete curing with humidity control in a single atmosphere curing chamber.

Here is a look at curing conditions, how they affect concrete quality and how they may be enhanced to provide higher quality for less money.

Hydration

Concrete achieves its strength through a hydraulic process known as hydration. With the addition of the correct amount of water and time, cement gels into a paste that glues sand and aggregates together to form hardened concrete. For our purposes here today, this process begins in the mixer and continues throughout the time the concrete product is stored in the racks. In most concrete production facilities too little is understood about the affect of curing conditions – temperature, relative humidity and air circulation – on concrete quality.

Curing Climate

The climate during concrete hardening in the racks is of enormous importance to the quality of hydration and strength gain. Let us look at the three most important aspects of the curing climate and the role they play in increasing quality and reducing costs.

Temperature

In uncontrolled curing environments, the ambient temperature plays an important role in determining the speed of the hydration process. The warmer the air, the warmer the concrete and the quicker the concrete strength gain. The difference in the concrete hardening duration is experienced with every change in season – slower in cold weather and faster in warm weather. There are several economic benefits achieved through control of the air temperature and acceleration of the hardening process: elimination of season-based mix designs (a cement content driven mix design based on the ambient temperature)

and an overall reduction in cement and, therefore, pigment content. The addition of controlled curing in the design of a green-field production plant reduces the requirement and, therefore, cost of rack space, pallets, building and land by reducing the required production board storage capacity.
It is important to keep in mind, that, by increasing the air temperature in the curing area, the relative humidity will drop, thereby increasing the rate of evaporation of moisture from the paver surface. The ambient temperature in the curing area should never be raised without the addition of external moisture. Having control of the air temperature, means raising it to a minimum of 35°C (100°F) with a corresponding increase in the amount of external moisture added (in order to maintain a relative humidity over 95%).
A key economic benefit of accelerated curing is the opportunity to secondary process concrete pavers within 14 to 16 hours after production – in line. The products may be immediately cubed and shipped without a reduction in 28-day strength, eliminating packaging and storage costs of unprocessed products and allowing for shorter delivery times to the end-user.

Relative Humidity

As previously mentioned, the moisture level of concrete is of utmost importance. A lack of moisture results in incomplete hydration of the existing cement, resulting in unnecessary cost.
The following is an example of this condition in an uncontrolled curing environment.

Situation

- A rectangular paver with a cement content of 12.5%.
- A concrete paver weighing 3,800 g, the cement content is equal to 475 g.
- A water-cement ratio of 0.38 works-out to 180 g of water per paver.
- Within 24 hours after production 70 g of water evaporate from each paver.
- The remaining 110 g per paver are equal to a water-cement ration of 0.23.
- A minimum w-c ratio of 0.27 is required for complete cement hydration.

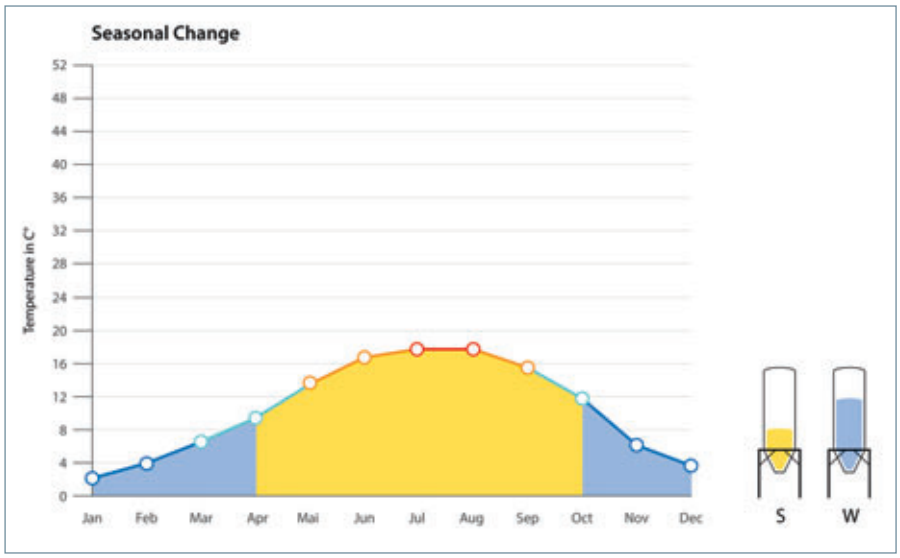
Result

- 110 g water can hydrate a maximum of 410 g of cement.
- 65 g cement per paver are not hydrated

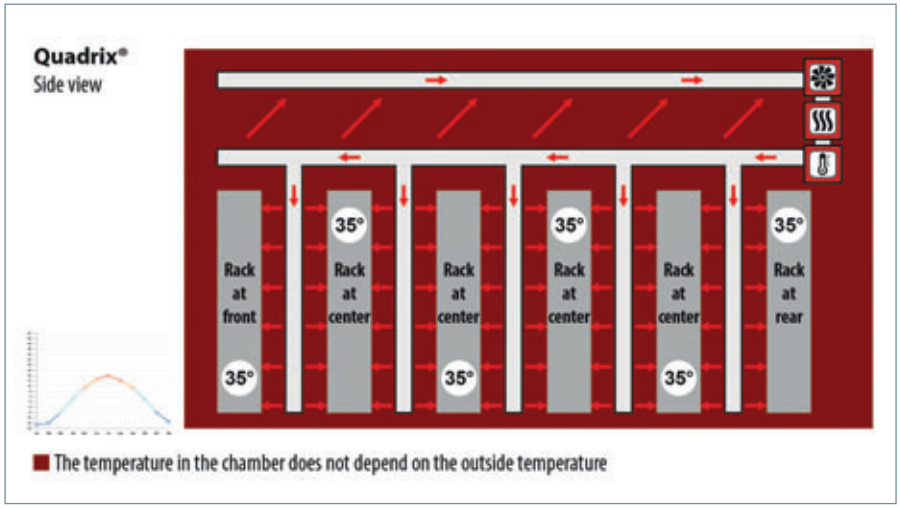
Conclusion

- If evaporation is eliminated, 410 g would be the cement requirement.
- Relative humidity control during curing provides a 15% cement savings.

The humidity experienced in an uncontrolled curing environment – most rack systems, is due to the evaporation of moisture from the fresh concrete paver. Concrete producers often exclaim that there is enough humidity in the curing area. What they fail to understand is that this is moisture that is lost from the paver. Only an external source of moisture can create a relative humidity that prevents moisture loss.
From a quality perspective, the evaporation of moisture from the paver plays a critical roll in the ultimate strength of the edges, corners and surface. The moisture loss from these areas is, due to the ratio of surface area to concrete volume, is the greatest and causes strength loss and surface porosity. Aesthetic problems include rounded corners and edges, reduced resistance to wear and an



Due to seasonal changes in the ambient temperature and its affect on the speed of concrete hardening, cement content is raised/lowered in order to achieve the necessary early strength in order to cube.



Indication of consistent temperature distribution through proper concrete curing with temperature control in a single atmosphere curing chamber.

increase in the likelihood of secondary efflorescence.

Control over the relative humidity in the curing area will reduce binding agent costs, while increasing the aesthetic appearance of the concrete product.

Air Circulation

The effect of uncontrolled temperature and humidity in the curing environment manifests itself negatively not only as "lack of" causing drying or "over-abundance of" causing efflorescence and condensation, but also as "inconsistent" causing variations in color and quality. Without proper air circulation within a curing environment, several concrete quality issues are created, including:

- stratification of air from top to bottom of the curing environment as heat rises,
- the creation of cold and hot areas of the chamber as heat stagnates furthest away from elevator, lowerator and transfer car areas
- relative humidity becomes inconsistent as a results of the air temperature inconsistency (at 35°C or 100°F, a 1° temperature change results in a 3% relative humidity change)

Not only is air circulation critical to the reduction in production cost and increase in quality of concrete pave stones and blocks, but so is the velocity at which the air is circulated throughout the curing environment. The speed of the air flow through the curing area has a direct effect on the level of evaporation of moisture from the concrete surface. The higher the air speed the greater the evaporation of moisture and the more detrimental to product quality – see the previous subject: Relative Humidity.

Curing Environment Design

The Single Atmosphere Curing Environment, also known as the Big Room System, is the system of today and the future. It is efficient, economical to build, operate and maintain and offers the simplest design to guarantee a consistent curing environment for repeatable concrete quality every production day of the year. Other benefits of this curing chamber design is the elimination of condensation on building, rack and equipment components and the elimination of fog.

Through intelligent design via the partnership between concrete producer and curing specialist, the operating cost of a curing system is reduced to between 3 and 5 cents per m^2 of production with a resulting return-on-investment equal to between 1 and 3 years.

The addition of a controlled curing environment to the concrete production process will provide significant improvements in quality while allowing for a reduction in production costs.

Concrete Curing by Specialists

In order to obtain the correct curing environment for your concrete products, look to the experience and knowledge of an established supplier of concrete curing equipment, not a company that sees curing as a sideline. How do you find such a company? Check a curing company's references through case studies and industry contacts, ask for written temperature consistency guarantees, ask how a suppler proves the guaranteed consistency.

FURTHER INFORMATION

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