CONCRETE CITATIONS
Robert "Concrete Bob" Higgins

1) Moisture-Related Cracking Effects on Hydrating Concrete Pavement - Texas Transportation Institute Published 2006, Report No. FHWA/TX-05/0-1770-6: proof of surface deterioration due to uneven curing. "The incidence of this distress type is strongly correlated to pre-existing horizontal delamination that occur within 25 mm of the pavement surface and can later grow into a spall due to a variety of causes. The cause of the shallow, horizontal delamination that occur within the top 25 mm of the pavement surface is primarily from early-age nonlinear shrinkage strains in addition to temperature variations through slab depth. Thus, the factors of the most importance are those related to the effectiveness of the curing medium in minimizing moisture loss during the hydration of the concrete and the bond strength between the aggregate and the paste."

2) Sun Damage to Concrete: What's the Story? TRP Ready Mix, August 11, 2018: Proof of surfaces drying faster than remainder of the concrete. Damage to Curing Concrete - Freshly poured concrete is susceptible to excessive damage from solar radiation. Direct sunlight causes water to evaporate from the concrete prematurely. As a result, concrete will not have enough time (and water) to strengthen its structure before it dries out. And once it has dried out, it will experience shrinkage and cracking.

3) No More Low-Alkali Cement? Why? VRMCA , Summer 2019 Issue. Beginning in 2019 there will no longer be "low-alkali cement"! What? Has the Portland cement manufacturing process changed such that low-alkali cement doesn't exist anymore? The answer is NO. But in June of 2019 ASTM C150 Standard Specification for Portland Cement will eliminate the "low- alkali".

NOTE: This article deftly never answers the question as to why. The REAL answer is in the next reference.

4) Cement Kiln Dust Waste, EPA.gov - Introduction Cement kiln dust (CKD) is the fine-grained, solid, highly alkaline waste removed from cement kiln exhaust gas by air pollution control devices. Because much of the CKD is actually unreacted raw materials, large amounts of it can and are recycled back into the production process. July 25, 2002— EPA publishes a notice of data availability (NODA) in the Federal Register (67 FR 48648). In addition to announcing the availability of new data to the public, the NODA explains that EPA is considering a new approach to CKD management whereby it would finalize the proposed CKD management standards as a RCRA Subtitle D (solid waste) rule and temporarily suspend the proposed RCRA Subtitle C (hazardous waste) portion of the proposed rule for 3 to 5 years to assess how CKD management practices and state regulatory programs evolve.

NOTE: The tie-in between references 3 and 4 have to do with the cement kilns not being able to produce low alkali cement due to EPA regulations requiring the recovery of flue gases. Reference #3 is basically "damage control".

5) Effects of High Alkalinity on Cement Pastes, ACI Materials Journal, May-June 2001. This study indicated higher alkalinity has a deleterious effect on cement hydration. SUMMARY AND CONCLUSIONS Increasing the alkali content of cement pastes by the addition of a 1M NaOH solution greatly accelerates the initial hydration reaction. After the first day, however, high alkalinity retards hydration. Sodium hydroxide increases cracking and decreases the rate of length change at 50% RH,

6) Maximum Concrete Temperature, Concrete Construction Magazine, Problem Clinic, August 1, 2003. The simple truth of the matter is that concrete placed and cured at a moderate temperature (60° to 80° F) will outperform +90° F concrete in strength and durability. If you are looking for superior concrete, control the temperature.

NOTE: The "other simple truth" is that the warmer temperatures that guarantee a lower quality concrete, also produces a higher 28-day compressive value, which is the basis for nearly 100% of the specifications and requirements in any given jobsite. So, this advice is routinely ignored.

7) Concrete Durability in a Free Market System, Concrete International, October 1986 - During the past 35 years the strength of Portland cement in the UK has increased by 75 percent. As strengths went up, cement contents dropped by 34 percent, water-cement ratio increased by over 50 percent, and capillary porosity increased by 500 percent.

8) Behavior of capacitive humidity sensors in monitoring the drying of concrete walls - MATEC Conference (2019). Based on the study, reliable measurement of relative humidity of the pore air in concrete using continuous measurements in above 90% RH moist concrete with capacitive humidity sensors is difficult and the measurement results may contain significant flaws.

NOTE: There are three other studies, conducted independently and in other countries that had similar to nearly identical issues. I chose this specific test because it dealt with drying of walls, which would be encountered by restoration contractors, whereas the other three studies were conducted on horizontal exterior concrete (bridge decks).

9) Even in a closed container, humidity can vary if distribution of salts within that container are not consistently mixed: From: e2b Calibration (e2b calibration is an ISO/IEC 17025 accredited calibration laboratory) "Depending on the size of the container used, it can take anywhere from 6 up to 20 hours for the humidity conditions within the container to stabilize.

In larger containers without circulation, there will be slight variations in the temperature at various levels as the air in the container is not a very efficient heat transfer medium and therefore, variations in the humidity will exist at those levels." The measurable humidity varies by salt types, with some of the alkaline salts within concrete, too variable to be useful for calibration purposes while the more popular and consistent salts, dramatically demonstrate how concentration of salts, not volume of water dictates the measurable humidity: "When mixed with distilled water, the chemical properties of certain salts produce a known relative humidity value. Sodium Chloride, or table salt, is the most widely used salt and will provide a reading of roughly 75% RH. Other popular salts that are used to produce different humidity levels include Lithium Chloride for 11%, Magnesium Chloride for 33%, Potassium Carbonate for 43%."

10) Super absorbent polymers are even being investigated to reduce the inevitable autogenous cracking experienced with HPC (High Performance Concrete): On the Interaction between Superabsorbent (December 2017) Hydrogels and Cementitious Materials Abstract of a dissertation at the University of Miami. Dissertation supervised by Dr. Ali Ghahremaninezhad. No. of pages in text. (140) Autogenous shrinkage induced cracking is a major concern in high performance concretes (HPC), which are produced with low water to cement ratios. Internal curing to maintain high relative humidity in HPC with the use of an internal water reservoir has proven effective in mitigating autogenous shrinkage in HPC. Superabsorbent polymers (SAP) or hydrogels have received increasing attention as an internal curing agent in recent years. A key advantage of SAP is its versatility in size distribution and absorption/desorption characteristics, which allow it to be adapted to specific mix designs. Understanding the behavior of superabsorbent hydrogels in cementitious materials is critical for accurate design of internal curing.

NOTE: Superabsorbent polymers are basically a "one-trick pony" in that the sole beneficial function is to provide a "water reservoir" for continued cement hydration without disruption of the designed water to cement ratio of the concrete mix. This focuses ONLY on autogenous cracking and none of the other benefits that are realized by the use of nano colloidal silica or absorptive aggregate.

11) Determination of Moisture Diffusion Coefficient of Concrete at Early Age from Interior Humidity Measurements, Jun Zhang; Dongwei Hou; Yuan Gao; Sun Wei, Key Laboratory of Structural Engineering and Vibration of China Education Ministry, Department of Civil Engineering, Tsinghua University, Beijing, China, Jiangsu Key Laboratory of Construction Materials, School of Materials Science and Engineering, Southeast University, Nanjing, China. Online publication date: 29 April 2011 "Concrete shrinks as moisture is lost to the environment or by self-desiccation. The magnitude of shrinkage strain is normally proportional to the amount of moisture lost.

As concrete shrinks, a certain amount of tensile stress will develop in the structure due to restraints from adjunct materials or connected members. The stresses may achieve the tensile strength and lead to concrete cracking. Drying shrinkage strain develops near the drying surface much faster than that in the center of concrete element." This indicates that the moisture content inside the concrete differs from the surface to the center and a moisture gradient exists before the hygrometric equilibrium with the surroundings is reached. Local shrinkage is directly related to the pore humidity. The relationship between free shrinkage strain and moisture content is approximately linear.

Note: Thus, a gradient of shrinkage strain should exist throughout the moisture loss process.

12) "Wireless sensor networks for temperature and humidity monitoring within concrete structures." Norberto Barroca, Luís M. Borges, Fernando J. Velez, Filipe Monteiro, Marcin Górski, João Castro-Gomes. Instituto de Telecomunicacoes, Department of Electromechanical Engineering, University of Beira Interior, 6201-001 Covilhã, Portugal.

C-MADE, Centre of Materials and Building Technologies, Department of Civil Engineering and Architecture, University of Beira Interior, 6201-001 Covilhã, Portugal. Department of Structural Engineering, Silesian University of Technology, Gliwice, Poland. 2012

From this study: "Temperature is an important parameter during the curing and hardening of the concrete since the concrete cannot be too cold or too hot. When the temperature decreases, the hydration reaction slows down. Hence, if the concrete temperature increases the reaction accelerates, creating an exothermic reaction (which produces heat), causing temperature differentials within the concrete. This temperature gradient can lead to cracking. Moreover, during the initial phase of the life of the concrete, it is essential to avoid cracking caused by the rapid drying due to increased temperature and the on-going hydration reaction.

"Since the curing process is the process that defines the concrete quality, if the values of humidity and temperature are known, the premature drying of the concrete surface can be avoided by hydrating it."

The temperature readings from the SHT21S sensor have been successfully performed during the first 16h of the experiment, while the humidity values were successfully obtained for the first 21h. After this period, the sensor went off. The initial sets of results were very promising, although SHT15 and SHT21 sensors went off after some time inside concrete. This is explained by the fact that the components of the sensors do not resist concrete high relative humidity alkaline environment.

NOTE: In every result, the RH within the top surface of the concrete fell to below 80%, which is the lowest humidity needed to allow cement formation. Again, even though the study recognizes the high alkalinity in concrete tends to damage, even destroy the sensors. The RH in this alkaline environment drops below 80%, the conclusions reached are actually incorrect since part of the deterioration is blamed on high humidity, even though the humidity isn't high. In each step, the sensors became damaged within hours and simply stopped working.

13) Properties of water change with sodium hydroxide concentration: Sodium hydroxide is the most common and voluminous alkali in most concrete. The concentration of alkalinity dictates the measurable humidity. The concentration also changes the freezing point of water in a distinctly non-linear and in fact opposing manner. In lower concentrations alkalinity acts as an anti-freeze, whereas in higher concentrations, the same alkalinity can become a freeze initiator where the water becomes increasingly cohesive and resistant to drying as would be experienced when unadulterated water approaches atmospheric freezing.

14) Wool Safe Study: The Wool Safe Study was conducted in the mid 1990's, shortly after a seminar I gave where I was asked about the damaging effects of high pH on materials and fabrics. I stated that alkalinity was a bigger issue, to which I received a roomful of puzzled looks. I went on to explain there is a distinct difference between high pH and high alkalinity.

NOTE: This study was conducted which confirmed that a high pH cleaner was no more damaging than a neutral cleaner (which came as a complete surprise to the researchers). As the alkalinity increased, THEN the high pH cleaners began to show significant damage as the higher pH, along with concentration had near linear damage to the fabrics.

15) NFCA (National Floor Covering Association): "Concrete Moisture Testing Best Practice," October 18, 2024. Outlines factual and practical data to encourage accurate moisture testing and interpretation of data. 29 pages of best practices accompanied by 40 pages of appendices/references.

16) Sweating Slab Syndrome, 14th Central European Congress on Concrete Structures, September 22-24, 2024. Identifies the role of ambient air as a moisture source for concrete surfaces, particularly for alkaline surfaces.

17) Water molecule discovery is forcing textbooks to be rewritten: Earth.com/Nature - Science - Life. A group of researchers discovered that the molecules at the surface of salt water organize themselves in a way that's different than we ever thought.

> "Our work demonstrates that the surface of simple electrolyte solutions has a different ion distribution than previously thought," Litman explained.

NOTE: "At the very top, there are a few layers of pure water, followed by an ion-rich layer, and then the bulk salt solution." As is the case with concrete. Salt water develops gradients.

18) **Taken from the Introduction of: Effect of curing techniques on compressive strength of concrete**

Curing may be described as the process of controlling the relative humidity and temperature of newly poured concrete for a certain amount of time after it has been cast or finished to ensure that the cement has been properly hydrated and the concrete has hardened [1].

Once curing is finished, the concrete can no longer grow strength since the cement can no longer be able to hydrate. The process requires adequate moisture, temperature, and time [2]. If any of these parameters is missing in the early period of hydration of concrete, the desired strength of concrete cannot be obtained[3].

Hydration is the most significant part in the process of curing. Without enough water, hydration cannot occur, and
the final concrete could not be as strong and impermeable as desired. Additionally, due to premature concrete drying,
microcracks or shrinkage cracks would appear on the concrete's surface [4].

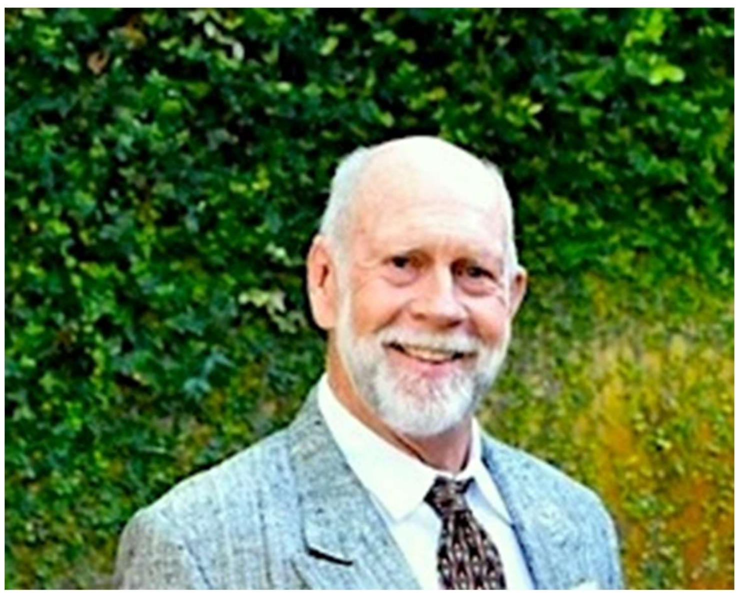
When concrete is exposed to the environment, water evaporates, and the original water-to-cement ratio is reduced. This causes the cement to only partially hydrate, degrading the quality of the concrete [5]. The increase in compressive strength of concrete is governed by a number of variables, including wind speed, relative humidity, air temperature, water-to-cement ratio, and kind of
cement used in the mix [6].

Because cement paste and particles are thermally incompatible, fractures emerge in conventional concrete when temperatures rise (7).
High-temperature-cured concrete often has greater early strength than concrete made and cured at lower temperatures, but typically exhibits less strength beyond 28 days.

Concrete's strength increases with time; hence, a longer wet curing period is preferable if hydration of cement particles is to continue unabated (8). The fact that moisture curing only affects the outer 30 to 50 mm of a concrete element's surface is emphasized.

NOTE:

- That last sentence CONFIRMS just how important the surface testing is since the curing does NOT affect the body of the concrete, only the surface gradient.
- This was published two years ago and follows the challenge I have put out internationally as well as domestically.
- While I do not agree with some of the conclusions within this report, since this was STILL conducted in a carefully controlled environment, it is a huge step in the right direction.
- My biggest disagreement is supported by field studies where the curing effect is actually limited to within the first 19-25mm, NOT the first 30-50 mm



Robert “Concrete Bob” Higgins

Bob Higgins has expertise in moisture-related concrete issues, having been involved with waterproofing, technical committees, professional groups, lecturing, teaching, and construction defect litigation. Bob Higgins is equally involved in product and process development, having developed most of the products manufactured and marketed by his former company SINAK Corporation, as well as owning or co-owning patents for moisture testing. Bob has authored articles in local and national publications, lectured in regional and national conventions. Bob has contributed to, used as an expert resource, or written over 100 papers involving moisture-related concrete issues including deterioration mechanisms, testing protocols, diagnosis, inspection, and repair.

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Construction Defect - expert opinion and testimony

Inspection - **Before Installation**: How to rigorously evaluate, analyze and determine what-if steps may be needed prior to floor installation.

When Problems Arise: Determine what went wrong, why, and how to evaluate and analyze correctly and accurately; determining root-cause.

Specifications - Assisting in Architects/Engineers/Designers to develop sound concrete specifications for the ever-changing environmental restrictions and product changes.

Professionally - Bob has been involved with waterproofing since 1976 and has functioned as an expert in construction litigation since 1985. Bob was Vice President and Chemist/Product Development for SINAK Corporation for 30 years (1979-2009).

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