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Technology Brief

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CERATECH™ Cement Concrete Offers a Self Drying, Integral Moisture Solution

CeraTech's ekkomaxx™ has emerged as the market leader for durable, sustainable concrete all while providing an integral solution to concrete moisture issues that affect fast track construction.

BACKGROUND

The flooring industry continues to introduce a broad range of materials to satisfy the demands for design, durability, and sustainability. Many of these materials have lower levels of breathability, and utilize adhesives sensitive to moisture and alkalinity typically found in portland cement concrete (PCC). Adhesive manufacturers are also challenged to address lower standards for Volatile Organic Components (VOC) proliferating from a number of agencies including the Environmental Protection Agency (EPA), the Southern California Air Quality Management District (SCAQMD), etc. These changes in adhesive composition may dramatically impact the performance of flooring systems, particularly as related to moisture and alkalinity tolerance. Moisture moving through an open capillary system often with high alkalinity, attacks low permeability flooring and adhesives, leading to warping, blistering, telegraphing joints, re-emulsifying of adhesives, leaching adhesives through joints, odors from mildew, and ultimately bond failure. The end result of this moisture driven alkalinity attack is a failed floor system requiring costly remediation, replacement, operational down-time and litigation.

In the past, prevailing opinion associated moisture issues with flooring to slab-on-grade construction having inadequate and/or damaged moisture barriers. Failed vapor barriers can lead to water migration through the concrete slab as the moisture attempts to gain equilibrium with a lower humidity, climate controlled environment above the slab. However, in today's construction market, new evidence has demonstrated that moisture issues, and the failure of flooring installations are not limited to slab-on-grade construction.

The demands of fast track construction have elevated the issue of moisture (including vapor transfer, moisture content, relative humidity within concrete) to the forefront of any critical path planning process for construction schedules. In most cases, the issue starts with water used in concrete placement. In new construction (including elevated slabs) it is not uncommon to find standard PCC mixes that do not meet flooring manufacturers' moisture requirements for more than 12 months after placement.

Traditional Concrete Technology is Fundamentally Susceptible to Moisture and Alkalinity Issues that Lead to Flooring Failures

Typical PCC placements utilize a water to cement (W/C) ratio of approximately .45 W/C with many mixes exceeding a .50 W/C ratio. Efforts to reduce the W/C ratio typically utilize costly admixtures to drive the ratio to lower levels, while maintaining workability for placement and finishing. In any case, there is additional water in PCC (as much as 50% by volume) than required for hydration of the cement. During hydration, this excess water (often referred to as water of convenience) creates a open capillary structure allowing moisture to migrate out of the curing concrete and evaporate. This process ensures the open capillary structure remains a part of the concrete, leaving pathways for future moisture and alkaline migration through the hardened concrete. Water of convenience can take many months to dissipate, and excess moisture often leads to costly remediation when significant delays to the installation of a flooring system are not possible or acceptable.

Many manufacturers of moisture control systems attempt to address the issue by specifying low water to cement ratios, (.40 to .45), along with mitigation coatings. This specification typically requires admixtures, and the concrete still may not reach necessary moisture levels earlier than 28 days, and fail to address the issue of alkalinity. Typical PCC has a pore water pH of 13 when placed, with a significant excess of highly alkaline Ca(OH)2 (calcium hydroxide) and soluble alkali hydroxides such as Sodium and Potassium. Under the influence of moisture, these alkali chemicals migrate through concrete's capillary system or go into solution in the condensate layer and provide a means to attack sensitive adhesives. Open capillary systems, excess alkalinity, and high moisture content combine to slow construction schedules and set the stage for flooring failures. In all cases, flooring failures lead to costly shutdowns and remediation efforts.

The need to keep construction schedules on track and ensure freedom from moisture, and/or alkalinity related flooring failures, has spawned a variety of mitigation approaches. These approaches include utilizing admixtures in the concrete, or application of specialty materials to the cured concrete. Such treatments and their associated additional costs are as follows:

- *Admixtures* (Ranges from \$30 - \$45 a yd^3 to the concrete).
- *Topical reactive silicates or specialty adhesives* (Ranges from \$ .75 - \$2 ft^2).
- *High solids epoxies* (Ranges from \$3 to \$7ft^2).

These mitigation approaches are required to address the fundamental chemical and structural challenges of interfacing modern floor coverings on standard concrete mixes.

CERATECH™ CEMENT TECHNOLOGY SOLUTION

In contrast to the variety of mitigation approaches, concrete made with CERATECH™ Cement (in this case ekkomaxx™) offers a natural, inherent solution to the aforementioned moisture and alkalinity issues demonstrating the capability for installation of moisture sensitive flooring systems from 3 to 21 days after placement, without the need for admixtures. ekkomaxx™ cement concrete meets ASTM C1157 classifications for a hydraulic cement system with 95% recycled fly ash and 5% rapidly renewable proprietary activators, producing an engineered concrete with the following attributes:

Dense crystalline structure free of excess CA(OH)2. The ekkomaxx™ Calcium-Aluminum-Silicate (CAS) structure is much denser and more durable than portland cement's CSH (Calcium Silicate Hydrate) gel structure, in addition, it is free of excess Ca(OH)2. The migration of excess CA(OH)2 is the major contributor to alkalinity related failures of adhesives placed over PCC.

The formation of crystalline stratlingite consumes water within the mix during hydration, contributing to the rapid internal drying of the ekkomaxx™ (see Appendix).

Utilizes a very low W/C ratio. It is well documented that PCC uses much more water than is required for hydration of the cement. ekkomaxx™ cement typically utilizes a W/C ratio of .18 to .24 W/C (while providing desired slump and workability), approximately half that of PCC. Essentially, all of the water used in placement of ekkomaxx™ cement concrete is consumed in the hydration reaction leaving no excess water to produce a continuous capillary system. Without a continuous capillary system, the impact of moisture migration is eliminated and the timeline for installing flooring systems is greatly reduced, reducing jobsite delays and potentials for failures.

Requires no water of convenience for ease of placement. The well known "ball bearing effect" of fly ash provides exceptional workability even at designs of .18 to .24 W/C ratios.

EVALUATION OF ekkomaxx™ CEMENT

To validate the cure time required prior to ekkomaxx™ receiving flooring, CeraTech, Inc.'s (CTI) Laboratory in Baltimore, Maryland, performed the following tests:

- ASTM F 1869: *"Standard Test Methods for Measuring Moisture Vapor Emissions Rate of Concrete Subfloor using Anhydrous Calcium Chloride."*
- ASTM F 2170: *"Standard Test Methods for Determining Relative Humidity in Concrete Floor Slabs using in situ Probes."*
- ASTM F 2659: *"Standard Guide for Preliminary Evaluation of Comparative Moisture Condition of Concrete Cement and other Floor Slabs and Screeds using a Non Destructive Electronic Moisture Meter."*

Evaluations continued until the flooring industry's most stringent requirement of a Moisture Vapor Emission Rate (MVER) of 3.0 lbs. was achieved. Data was collected for moisture content and relative humidity at the same testing intervals. Measuring relative humidity near the center of the slab, a more accurate view of the actual moisture content of the concrete was achieved. The ekkomaxx™ sample placed was 8" in thickness. Ambient temperatures during the test cycle were between 80 - 87°F, with ambient humidity from 32 - 49%.

TEST RESULTS

Research of standard industry requirements and review of ASTM documentation indicate the general requirements represented in *Table 1* on page 4:

TABLE 1

Age	1 day	1 day	1.5	3	7	10	14	21
MVER	6.89	6.64	5.88	4.53	NT	4.10	3.3	2.81
RH%	NT	NT	NT	74.2	61.3	52.7	47.3	48.8
MC %	5.9	5.7	5.4	5.3	4.5	3.2	3.1	3.0

NT - not tested
MVER – Moisture Vapor Emission Rate; RH – Relative Humidity; MC % - Moisture Content as a percentage
MC% - The Moisture Content data is provided as a point of reference. This data is not typically cited by North American flooring manufacturers.

Verify Requirements with Adhesive or Material Manufacturer. Typical Industry Standard requirements are as follows:	
New Adhesive Technologies Requirements	8 -10 lbs MVER, RH < 90%
Traditional Minimum Requirement	5.0 lbs MVER, RH < 85%
Most Stringent Requirement	3.0 lbs MVER, RH < 75%

When following industry standard practices and protocols, CeraTech's ekkomaxx™ cement concrete demonstrates the ability to accept moisture sensitive adhesives and flooring as early as 72 hours, and between 14-21 days for the most sensitive systems. This is achieved with the assurance of a discontinuous capillary system, freedom from future attack by alkalinity, and without additional admixture(s). It is clear that ekkomaxx™ provides the capability to construct as fast as is reasonably possible, and assures that if moving at a more typical speed of 30 - 90 days from placement of the slabs and superstructure to placement of flooring - no costly and schedule consuming moisture mitigation will be required. The lack of free $Ca(OH)_2$ within ekkomaxx™ also provides the assurance that alkaline sensitive adhesives will be free from future alkaline attack.

CONCLUSION

ekkomaxx™ inherently provides a solution to moisture related issues facing the flooring industry today, whether it be:

- *Avoiding construction delays generated by excess water content during placement,*
- *Protection from future moisture problems typically suffered by slab-on-grade construction,*
- *Failure of adhesives due to the alkaline attack from the migration of excess $Ca(OH)_2$.*

When compared to portland cement concrete, ekkomaxx™ clearly provides a superior concrete system, combining additional durability, segment defining sustainability, speed and capability to integrally solve moisture related challenges.

APPENDIX

THE SCIENCE OF THE CRYSTALLINE STRUCTURE DEVELOPMENT WITHIN ekkomaxx™

Utilizing a .18 -.24 W/C, ratio, ekkomaxx™ requires very little water for hydration. The majority of water within an ekkomaxx™ mix (typically > 90%) is consumed through the hydration process. However, moisture tests show ongoing drying of the concrete over a 21 day span. It is relevant to look at the hydration process within the ekkomaxx™ cement system to understand what is taking place with water during the initial days.

During hydration of ekkomaxx™ cement, stable crystalline hydrates are formed (vs. gels which portland cement hydration creates), binding the water of hydration within their structure. This crystalline formation greatly reduces available moisture that can leave the system as vapor, or remain within the system as relative humidity or measurable moisture content.

Portland cement hydration creates at best 10% crystalline material (of which 50% is water), while virtually all ekkomaxx™ hydration products are crystalline. In the ekkomaxx™ system, approximately 50% of the cement is hydraulically reactive (the remaining material within the ekkomaxx™ system is uniformly dispersed reactive silica available to mitigate ASR). Approximately 43% of this reactive component is water, which means 21 grams (gm) per 100 gm ekkomaxx™ paste is crystalline bound water (compared to 5 gm in a portland cement system).

In summary, the net result of the hydration means that 100 gm. of hydrated portland cement paste contains 5 gm. of crystalline bound water, compared to 100 gm. of hydrated ekkomaxx™ cement paste containing approximately 21 gm., crystalline bound water. The primary crystal development within ekkomaxx™ is stratlingite, a very stable $C2ASH_8$ formation.

Given that the ekkomaxx™ system starts with a 0.18- 0.24 W/C ratio, about half of which is used in a portland system (0.45 +/-), and virtually all the water used to mix ekkomaxx™ is tied up in crystalline hydrates and not available to evaporate, the “drying” advantage of the ekkomaxx™ system is clear.

In summary, while the moisture testing of ekkomaxx™ does indicate modest evaporation of moisture over the fist 21 days, the majority of water within the cement system is bound in the crystalline stratlingite formation.