CMC Newsletter

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CMC Construction Materials Consultants, Inc.

Serving the Industry through Testing, Investigation, Evaluation, & Research

Welcome to CMC's Newsletter. In this section, we discuss everyday issues of our industry from our past and present projects, materials characterization and failure investigation, relevant topics, questions and answers, and how we can be of service to you. This can be a good discussion forum for you. We welcome your comments, criticism, and any ideas you wish to share with us, which will not only be beneficial in understanding the behavior and properties of construction materials but also be helpful for the success of our industry. We hope you find our newsletter informative.

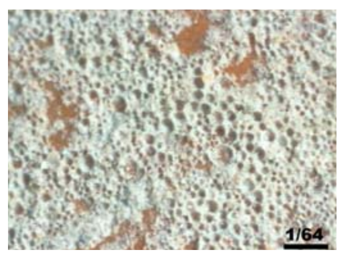
Low Breaks: Why & How to Diagnose?

Compressive strength is an important parameter of concrete quality. Many times a field-made, laboratory-cured concrete cylinder or a concrete core from a structure does not achieve the designed (or desired) strength at a specified age, which requires a detailed investigation, commonly by petrographic examinations, to diagnose the causes. Petrography can determine many factors that are responsible for low strength, such as:

- Too much water in the mix
- Too much air in the mix
- Too much water and air in the mix
- Low cement content; high pozzolan content
- High water plus low cement content
- Inadequate consolidation of concrete
- Inadequate moist curing of concrete
- Clustering of air voids along aggregate-paste interfaces
- Restricted cement hydration due to various reasons such as freezing of concrete in the plastic state
- Adverse physicochemical reactions in concrete that can cause strength loss such as lime leaching, acid attack, sulfate attack, fire attack, etc.

Improper sampling, handling, care of cylinders, test procedures, and testing machines can add errors that should be evaluated.

For field-made cylinders, a common reason for low strength is excessive air in the concrete and clustering of air-voids along aggregate-paste interfaces. Many new generation air-entraining chemicals (e.g., tall oil, fatty acid, petroleum distillates, gum rosin) stabilize many fine air voids (less than 100 microns in size) in concrete. Use of these chemicals at a dosage similar to that of the common vinsol resin-type agent can introduce more bubbles than are actually needed and hence clustering of voids along interfaces. Therefore, the dosage rate of new chemicals should be adjusted and reduced from that of vinsol resin to reduce the possibility of excessive air-entrainment, void clustering, and strength loss.



Excessive air voids are a common cause of low strength of concrete.

Floor Covering Failures

In recent years, occurrences of floor covering failure are increasing at an alarming rate. Moisture emissions, entrapment, and condensation; high alkalinity (pH) at the concrete surface; and alkali-silica reaction are the common causes of floor covering failures. Blistering, debonding of covering from the substrate, and adhesive failure are the common consequences. Improper or inadequate preparation of the concrete surface on which the covering is placed and improper mixing and/or installation of flooring adhesives are also the culprits.

A detailed petrographic examination of a core from a distressed (e.g., blistered) area encompassing the floor cover and the substrate is helpful in diagnosing the cause of failure. Usually cores from distressed and relatively sound areas are taken for comparative studies. Future issues will provide some case studies of diagnosis of floor covering failures by petrography.

CMC is involved in various floor covering failure projects across the nation. Information obtained from comprehensive failure analysis by petrography is valuable not only in preventing future failures but also in designing an appropriate repair scheme.

Upcoming Events:

- *Dec. 9-12: ACI India Chapter Silver Jubilee Celebration*
- *Jan 17-21: World of Concrete 2005*
- *Mar 12-14: NRMCA Annual Conv.*

Future Issues:

- *Concrete Exposed to Fire*
- *Concrete Exposed to Acid*
- *ASR and DEF in Concrete*
- *Failure of gypsum products*
- *Floor covering failures—Case studies*
- *Failure of anchoring grouts*

Past Issues:

- *Driveway & Pavement Scaling*
- *Delamination of Indoor Slab*
- *Frozen Concrete*
- *Water Leakage in Masonry*
- *Mortar Matching*
- *Stone Failure*
- *De-bonding of Ceramic Tile*

Inside this issue:

Why Does Concrete Crack?

Concrete cracks when stresses due to volume changes or loading exceed its tensile strength. Volume changes can occur either due to expansion or shrinkage in restrained or unrestrained conditions.

Cracking due to expansion of concrete includes various mechanisms such as alkali-aggregate reaction (AAR), corrosion of reinforcing steel in concrete, hydration of free lime or magnesia in concrete, internal or external sulfate attacks, salt hydration distress, fire attack, and frost attack.

Cracking due to shrinkage occurs due to loss of water from concrete, which can be drying shrinkage due to loss of water that was adsorbed on the surfaces of the cement hydration products; plastic shrinkage due to rapid evaporation and loss of mix water from the surface of the concrete in plastic state on a hot, dry, windy, sunny day (where the rate of evaporation exceeds the rate of bleeding); or carbonation shrinkage due to loss of moisture generated by carbonation.

Beside inherent expansion or shrinkage, other common causes of cracking that are related to unaccommodative drying shrinkage of concrete due to design error are: lack of control joints in a slab-on-grade, inadequate amount and/or depth of control joints, wide spacing of joints, delay in installation of joints, lack of expansion joints between the concrete components, lack of reinforcement in a slab-on-deck to control crack width, etc.

Common map or polygonal-shaped cracks on the concrete surface can be due to drying shrinkage of concrete or due to expansion such as by AAR, which requires detailed petrographic examinations of cores from the cracked locations to diagnose the cause. Usually cracks associated with white exudes of gel are indicative of AAR or salt effect. Cracks due to sulfate attacks may contain gypsum or ettringite—the products of such reactions. The patterns and configurations of the cracks vary depending on the type of the mechanism that causes the crack.

Fig: Map cracking of concrete can occur both by expansion and shrinkage mechanisms.

Carbonation—The Good, The Bad & The Ugly

Carbonation is the reaction between the carbon dioxide and cement hydration products. It occurs best at a relative humidity of 50 to 70% (diffusion of CO_2 is fast through a partially moist pore system of concrete). Carbonation produces calcium carbonate ($CaCO_3$) and releases moisture. Calcium-silicate-hydrate, the main component of a portland cement concrete, carbonates at a rapid rate (due to its high surface area), which is followed by calcium hydroxide and calcium sulfo-aluminate hydrates. The product (calcite) being larger in solid volume than the reactant (calcium hydroxide) causes sealing of pore spaces, especially at the surface and forms an impermeable barrier to aggressive external chemicals—this is the good side of carbonation. A carbonated concrete surface is also less prone to alkali-sensitive adhesive failures in floor coverings than a non-carbonated concrete surface.

Excessive carbonation, however, softens the paste, makes it porous, and causes a loss of strength due to decomposition of calcium silicate hydrate—the bad side of carbonation.

Carbonation down to the depth of reinforcing steel causes a drop in alkalinity, corrosion of reinforcing steel, and spalling of concrete—the ugly side of carbonation

A dense, well consolidated, well-cured, low water-cement ratio concrete carbonates much less than a porous, poorly consolidated, inadequately cured or high water-cement ratio concrete.

During repair of an old slab and placement of a cementitious topping, the carbonated skin of the substrate should be removed down to the sound concrete to achieve a strong bond.

Unlike portland cement based products, lime mortar (used in the old days) gains strength very slowly and progressively by carbonation and remains strong and durable for many years.

Cement & Concrete Burns

Up to second or even third degree burns to skin can occur from prolonged exposure to fresh concrete juices. It is the highly alkaline or caustic nature of the cement or concrete solution that causes dryness to skin and the resultant burn. Proper precautions in clothing and boots are essential to prevent direct contact of fresh concrete to any part of the bare skin. Although the alkalinity of concrete causes the burns but don't blame the concrete for the burns if you don't take adequate precaution in handling it.

Common warnings on cement bags like "causes skin irritation" are an understatement of the severity of the burns that can occur from prolonged exposure. So take adequate precaution in concreting—even if it is the placement of a small patio in front of your house.

Prolonged contact and friction of skin to clothing and shoes saturated with plastic concrete often causes burns.

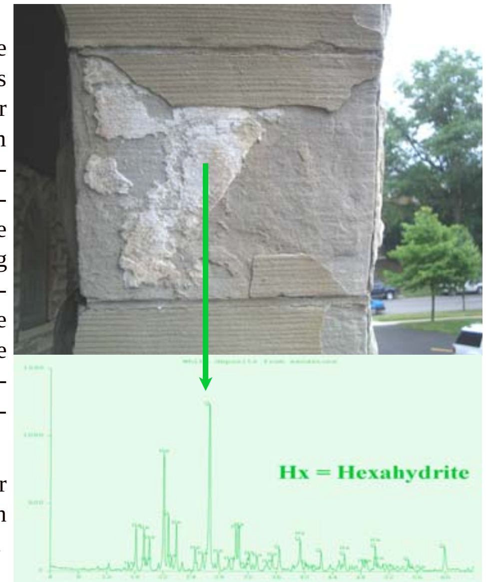
Skin in contact with concrete should be rinsed with water, followed by rinse with diluted vinegar and then again with water.

It is the highly alkaline nature of the concrete that causes the skin to burn—beware of it and take adequate protection in handling it! It is not the concrete but the negligence in handling concrete that causes the injury

Masonry Efflorescence

The presence of water-soluble salts in masonry units and/or in jointing mortars, migration of water through the masonry, dissolution of salts and cement hydration products (from mortars and concrete masonry units), followed by the evaporation of solution at the surface, and precipitation of dissolved solutes as white deposits on the surface are the conditions that cause efflorescence. Efflorescence deposits are soft, powdery, white, and typically contain calcium carbonate, calcium sulfate, or rarely (depending on the situation) alkali sulfate hydrate, alkali-carbonate-hydrate, or calcium-alkali-sulfate-carbonate hydrate double salts. Lack of or improper installation of flashing commonly leads to a moisture transmission problem through the masonry wall and subsequent efflorescence. Upward migration of sulfate solution through a masonry wall can cause salt hydration distress (discussed in the previous issue). Application of deicing salts on brick or stone pavers can cause efflorescence simply from the salts that were applied. Addition of disinfectants to fountain water (e.g., calcium hypochloride) can provide the salts and calcium carbonate to form efflorescence on drying of the surrounding pavers. The presence of some impurities in masonry units (such as hexahydrite in the sandstone masonry unit in the right photo) can also cause efflorescence. Petrographic examination of a sample along with a sample of efflorescence can determine the source of efflorescence.

ASTM C 67 describes a test of masonry units for efflorescence by partially immersing the units in water and exposing the top surface to evaporation.



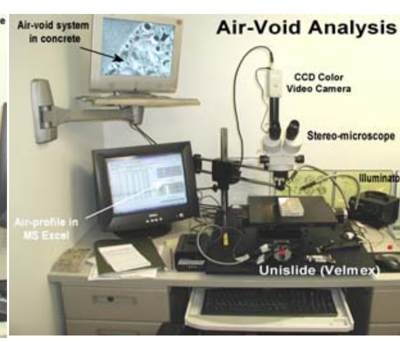
Petrographic Laboratory at CMC

CMC specializes in petrographic examinations of construction materials. CMC has a state-of-the-art petrographic laboratory that houses the latest optical microscopes, fluorescent-light microscopes, metallurgical microscopes, stereomicroscopes, scanning electron microscope with EDS attachment, x-ray diffractometer for qualitative and quantitative analyses, computerized automated air-void analysis, various in-house equipment for sample preparation (sectioning, lapping, grinding, polishing, staining, blue dye or fluorescent dye mixed epoxy impregnated large-area thin-sectioning, and pulverizing), video-microscopy, digital photomicrography, and advanced image analysis facilities. Depending on the purpose of the examination various techniques are used, sometimes in conjunction with chemical analysis (facilities on chemical analyses will be discussed in a future issue). CMC has all the facilities needed for detailed petrographic examinations.

CMC is also evaluating the prospect and applications of other new-generation microscopical methods in the study of cement and concrete. Fourier transform infrared microscopy and x-ray microscopy are the two major areas where CMC explores the possible future advancements in organic microanalysis and early-age cement hydration studies, respectively.

CMC has a state-of-the-art, automated, air-void analyzer that can perform rapid air void analysis by image analysis and by the ASTM C 457 method. Consider CMC's petrographic services for: (a) a comprehensive professional report; (b) quick (1 to 2 week) turnaround; (c) competitive cost; (e) in-depth knowledge and expertise on the science of petrography and its applications on various construction materials; (f) understanding the impact of various construction methods and environmental exposures on the behavior, property and durability of construction materials; and (g) applications of petrography in quality assurance and failure investigation.

Petrography has been used in the investigation of: low strength, various forms of surface distress (scaling, cracking, spalling, delamination, blistering, covering failure), chemical attacks from acids, sulfates, and salts, extent of frost or fire damage in concrete, low strength gain or slow setting, alkali-aggregate reactions, corrosion of reinforcing steel in concrete, floor covering failures, masonry failures, mortar proportioning for repointing of historic structures, deteriorations of natural or cast stones, deviations from project specifications, and many others.



CMC's Latest Industry Publications

Jana, D., Techniques used in petrographic examinations of construction materials – A state-of-the-art review, Abstract for Symposium on Petrographic Techniques for examining hydraulic cements and concretes, ASTM International, Dec. 2004.

Jana, D., Concrete, Construction, or Salt – Which Causes Scaling? Part II: Importance of finishing practices, Concrete International, Dec. 2004, pp. 51-56.

Jana, D., Concrete, Construction, or Salt – Which Causes Scaling? Part I: Importance of air-void system in concrete, Concrete International, Nov. 2004, pp. 31-38.

Jana, D., and Lewis, Richard. Acid attack on PCCP mortar coating, In "Pipeline Engineering and Construction – What's on the Horizon?" John J. Galleher, Jr., and Michael T. Stiff (eds) ASCE Publication, 2004.

Erlin, B., and Jana, D., So, what about chloride chemicals applied to concrete surfaces too soon? Some truths and fantasy about chloride deicing chemicals, Concrete Construction, September 2004, pp. 35-40.

CMC -Construction Materials Consultants, Inc.

CMC is a full-service, independent consulting and testing firm dedicated to providing materials characterization and failure investigation services of construction materials. We have extensive experience in evaluation and forensic investigations of products related to portland cement and other cementitious materials, aggregates, concretes and concrete-products, natural and building stones, grouts, plasters, clay, stone and concrete masonry units, masonry mortars, and ceramic, quarry, porcelain, mosaic and vinyl tiles. Visit us at www.cmc-concrete.com for a complete listing of services or call us with your questions or concerns at 724-834-3551.

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This newsletter is freely distributed to our clients as an acknowledgment to their support in better understanding the behavior and properties of various construction materials that are discussed here. To receive future issues of the CMC Newsletter online, please include yourself in our mailing list by sending an email to jana@cmc-concrete.com with your name, address, and email address. If you do not want to receive this newsletter, please let us know.

Q & A
From readers through emails

Q: *Can I apply deicing salt to my concrete?*

A. If your concrete has been placed recently, stay away from salt for the first winter. If it is old and has performed satisfactorily in the past, you may apply salt with your fingers crossed—it will resist the effect of salt if it is a good quality concrete and is properly placed, finished and cured. Stay away from magnesium based salts, urea, potassium chloride, or other chemicals that may have an adverse chemical effect on concrete. If you can live without salt (except for your food, of course) then stay away from it.

Q. *When should I start finishing a slab?*

A. When your footprint impression on the surface is less than 1/4 in. and when no bleed water appears on the surface or no bleed water sheen is present on the surface—if the surface dries out quickly an intermediate period of curing before finishing is needed.

Q. *What would be a suitable and durable repointing mortar for a historic masonry structure?*

A. Usually a Type N portland cement—lime mortar or a masonry cement mortar with similar sand as in the original mortar. An actual match will depend on the project and the environment to which the mortar will be exposed.

Q. *How important is it to test the air content in a freshly placed concrete?*

A. Measuring air in plastic concrete should be a mandatory requirement in a good construction project. In outdoor concrete lack of air can cause surface scaling during cyclic freezing. On an indoor slab air can cause delamination if the slab is machine trowel-finished. It is always judicious to test air at the early stage so that future costly repair can be avoided. Air should be tested on every batch of concrete placed.

Q. *Why does a slab made using 1-in maximum size stone curl less than a slab made with 1/2 in. size stone?*

A. Possibly because a concrete made with larger stone does not require as much water per cubic yard to produce the same workability as one made with smaller stones. The lower water content reduces shrinkage and thereby curling.

Q. *What surface sealers are good for water and oil repellence*?

A. A silane and/or siloxene based sealer is good for water repellency; a low-solid (10-15%) acrylic or urethane sealer will provide oil repellence.

Construction Materials Consultants, Inc.
Berkshire Center, Suite 104, Rt. 30 East, Greensburg, PA 15601 Tel: 724-834-3551; Fax: 724-834-3556
Email: jana@cmc-concrete.com Web: www.cmc-concrete.com

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