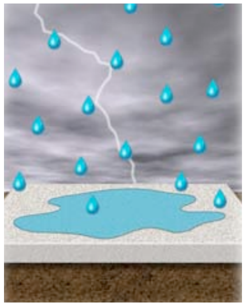
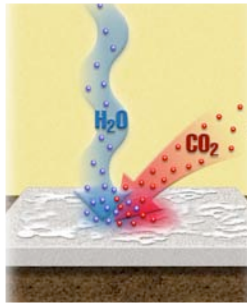
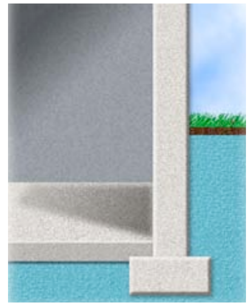
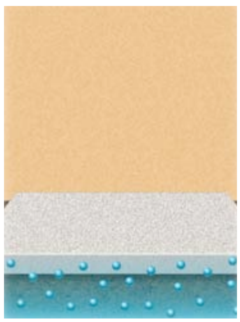


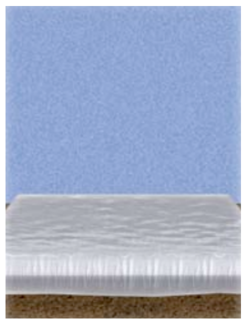


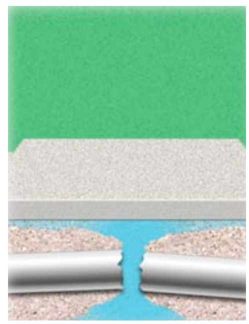


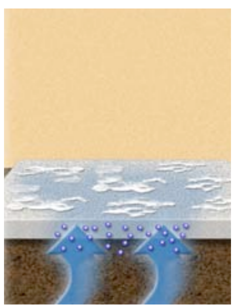
Concrete Floors and Moisture

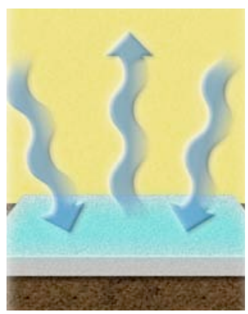
Howard Kanare

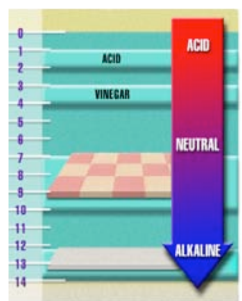












Concrete Thinking for a sustainable world
PCA Portland Cement Association
National Ready Mixed Concrete Association

ENGINEERING BULLETIN 119

Concrete Floors and Moisture

by Howard M. Kanare

PCA

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The National Ready Mixed Concrete Association is the leading industry advocate working to expand and improve the ready mixed concrete industry through leadership, promotion, education and partnering, ensuring that ready mixed concrete is the building material of choice.

Abstract: Unwanted moisture in concrete floors causes millions of dollars in damage to buildings annually in the United States. Problems from excessive moisture include deterioration and debonding of floor coverings, trip-and-fall hazards, microbial growth leading to reduced indoor air quality, staining and deterioration of building finishes. Understanding moisture in concrete leads to design of floors and flooring systems that provide excellent service for many years. This book discusses sources of moisture, drying of concrete, methods of measuring moisture, construction practices, specifications, and responsibilities for successful floor projects.

Keywords: Alkalies, concrete floors, construction practices, floor coverings, flooring, mildew, moisture, moisture-proofing, mold, vapor retarders

Reference: Kanare, Howard M., *Concrete Floors and Moisture,* EB119, Portland Cement Association, Skokie, Illinois, and National Ready Mixed Concrete Association, Silver Spring, Maryland, USA, 2005, 168 pages.

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WARNING: Contact with wet (unhardened) concrete, mortar, cement, or cement mixtures can cause SKIN IRRITATION, SEVERE CHEMICAL BURNS (THIRD DEGREE), or SERIOUS EYE DAMAGE. Frequent exposure may be associated with irritant and/or allergic contact dermatitis. Wear waterproof gloves, a long-sleeved shirt, full-length trousers, and proper eye protection when working with these materials. If you have to stand in wet concrete, use waterproof boots that are high enough to keep concrete from flowing into them. Wash wet concrete, mortar, cement, or cement mixtures from your skin immediately. Flush eyes with clean water immediately after contact. Indirect contact through clothing can be as serious as direct contact, so promptly rinse out wet concrete, mortar, cement, or cement mixtures from clothing. Seek immediate medical attention if you have persistent or severe discomfort.

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PREFACE

We work, play, shop, and dine on concrete floors every day. They are often covered with finishes ranging from spectacular to merely pedestrian, but we rely on the implicit understanding that they are doing their duty as platforms for our activities with little or no change in the substrate itself. Nothing could be further from the truth. Concrete is born of water, stone and cement. Without water, we simply would not have concrete floors. Yet unrestrained moisture can lead to failures of floor finishes, reduced indoor air quality, and hazards to movement of people, goods, and equipment.

The purpose of this book is to explain how to control moisture in concrete floors so that they can provide years of reliable service with minimal costs for maintenance and repair. Unfortunately, such expenses have become very large in recent decades. It is much easier and more cost-effective to keep a floor dry through proper design, material selection, and construction practice, than to dry a wet floor after a building is occupied. Newer materials and construction equipment make it possible for smaller crews to place larger floors with great efficiency. New methods of measuring moisture in concrete using relative humidity probes hold the promise of better understanding and prediction of moisture trends in floors. However, the rapid pace of construction and pressures to reduce construction costs can impede delivery of high-quality, long-term dry floors.

Two fundamental concepts permeate this writing: the floor is part of a building envelope, but also is in itself a system comprising many elements. For a floor to function successfully, specifiers, builders, owners, and finish flooring installers all must understand the factors for floor performance, especially moisture.

ACKNOWLEDGMENTS

This book grew out of many years of troubleshooting moisture-related floor performance problems across North America. The author is grateful to his colleagues at Construction Technology Laboratories who worked on these projects and provided excellent technical insights and support, including CTL microscopists, chemists, physical testers, and technicians. I would like to thank especially Scott Tarr, Terry Willems, John Gajda, and Martha Vangeem for many insightful discussions about the causes of field problems; Ron Sturm, Linda Hills, and Ann Caffero, whose microscopy techniques revealed hidden gems of understanding; Don Broton, Bill Rebel, and the entire analytical chemistry group, whose analyses often explained why floor system components performed in mysterious ways; and Kathy Merlo and Linval Williams for extensive technical support during research into moisture testing methods.

I would like to recognize Steve Kosmatka of the Portland Cement Association for his wisdom in agreeing to support the efforts to make this book a reality, and his patience to see it through to completion over many years. Ward Malisch, American Concrete Institute, spent countless hours with me discussing moisture issues and the need to clear the air of myths and inaccuracies. I hope this book accomplishes that.

I am indebted to Vagn Johansen who drafted the first versions of chapters 4 and 5. Thanks are due, also, to Dr Goran Hedenblad and colleagues at Lund University who graciously shared their knowledge.

For ten years, fellow members of ASTM Committee F-6 on Resilient Flooring have shared their experiences with commercial flooring systems and moisture problems. I am grateful for their frank disclosures of jobsite situations that have led to better understanding of moisture issues and better solutions to those problems.

At the Portland Cement Association, Rick Bohan, Bill Burns, Terry Collins, Jamie Farny, Connie Field, Beatrix Kerkhoff, and Martin McGovern, have been an immense help in locating all sorts of written materials, suggesting sources of information, and providing contacts at foreign organizations. This book would not have the authoritative references listed without their considerable skills and pluck.

I deeply appreciate the careful reviews of the entire manuscript performed by representatives of many organizations with vested interests in floor moisture issues, including Joe Audino, National Wood Flooring Association, Bill Freeman, Resilient Floor Covering Institute, Colin Lobo, National Ready Mixed Concrete Association, Ken McIntosh, The Carpet and Rug Institute, Joe Nasvik, Hanley-Wood, Bruce Newbrough, Ardex, Inc., and Ray Thompson, Armstrong World Industries, along with Bill Panarese, Consultant to PCA, and PCA and CTL staff.

Mitch Lopata and Cheryl Taylor provided many wonderful drawings to illustrate the points I struggle to convey with words. Finally, this book would not be a reality without the efforts of Ben Bradley, editorial assistance, Michelle Wilson, editor, and Cheryl Taylor's exceptional design.

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CHAPTER 6

MEASURING MOISTURE IN CONCRETE

INTRODUCTION

Test methods used to measure moisture in concrete can be classified as qualitative or quantitative. Qualitative tests provide a general indication of moisture, while quantitative tests produce a numerical result. Both types of tests can provide useful information. However, qualitative tests should not be relied on to determine if a floor moisture level is acceptable. Although a qualitative test result that indicates excessive moisture is a strong indication that the floor is not ready to receive adhesive and floor covering, a qualitative test result that does not indicate excessive moisture must be followed by a quantitative test to assure that the floor is in fact acceptably dry. In other words, qualitative tests usually do not give false positive results but can give misleading negative results.

Proper preparation prior to testing for moisture is essential. Rooms and floors must be at service temperature and relative humidity for at least 48 hours before performing any moisture test. If the room air and floor are not at service conditions, test results can be misleading. Moisture vapor emission from a concrete surface, and relative humidity within the upper region of the slab, are strongly dependent on the relative humidity and temperature of the ambient air over the concrete surface.

QUALITATIVE MOISTURE TESTS

Plastic Sheet Test

ASTM D 4263, *Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method*, involves taping a 460-mm (18-in.) square of 0.1-mm (4-mil) thick polyethylene film onto a concrete surface and allowing it to rest for at least 16 hours, then examining the underside of the sheet and the concrete for signs of moisture. If condensed moisture is present under the sheet, or if the concrete has darkened noticeably, then excessive moisture is present and the concrete is not ready to receive a moisture-sensitive covering. Some flooring manufacturers specify a 24-hour test period using heavy-duty polyethylene film.

The presence of observable moisture below the plastic sheet depends on the dew point. There must be enough moisture to condense at the surface temperature of the concrete. A typical positive test result is shown in Figure 6-1. Darkening of the concrete surface is obvious and there might even be moisture droplets visible on the underside of the plastic sheet. However, it is possible to get a negative result – showing no apparent moisture – simply because the temperature of the slab surface is above the dew point temperature for the amount of moisture in the slab (Figure 6-2).

Figure 6-1. Plastic sheet test, ASTM D4263, can show positive results when excessive moisture is present in a concrete floor slab. (IMG15993)

Some flooring installers place a heat lamp over the plastic sheet in an attempt to "draw out" moisture from the concrete. This variation of the test is not recognized in the ASTM method and is not likely to provide reproducible results.

The plastic sheet test on concrete is a good example of a qualitative test that can be misleading. If the floor looks damp below the plastic sheet, excessive moisture is present. But, this test does not reveal whether moisture might be entering the slab from below, for example, if no vapor retarder is present under the slab. Even if the floor looks

Figure 6-2. False negative results from the Plastic Sheet Test can indicate a floor is dry simply because the concrete surface temperature is above the dew point conditions within the slab. (IMG15992)

Figure 6-3. The Mat Bond Test is a short-term test installation that does not reveal moisture conditions deep within the floor slab. (IMG15991)

dry under the plastic sheet, moisture might still be present below the surface, and the floor may not be dry enough to proceed with a successful flooring installation.

Mat Bond Test

To perform the Mat Bond Test, a 1-m (3-ft) square sample of resilient sheet flooring specified for the jobsite is adhered to the concrete floor using the manufacturer's recommended adhesive and installation procedure, and the edges of the flooring are taped to the concrete. After 72 hours the flooring is pulled up by hand. The force required to remove the flooring is judged, and the condition of the adhesive is examined. If the adhesive is emulsified or obviously wet, or if the bond is unacceptably weak, then the slab is not dry enough to receive flooring. This technique obviously requires judgement and experience to evaluate the quality of adhesive bond. A well-bonded sample suggests that the floor is suitable for installation of the flooring (Figure 6-3).

This procedure is described in some floor covering installation manuals and actually is a short-term test installation. There are two variations of the test: in one, the adhesive is allowed sufficient open time to develop tack, and a piece of flooring is then installed just as it would be for the actual installation. In a second variation, suitable only for water-based adhesive, the adhesive is spread on the surface of the concrete and covered immediately with a piece of low-permeability resilient sheet flooring (vinyl or rubber) and the edges are sealed with tape. Moisture in the adhesive is initially trapped between the flooring and the concrete. If the concrete has a curing compound, sealer, or dense surface, then the moisture from the adhesive will move into the concrete very slowly or not at all. When examined, the adhesive may still be wet, indicating that the concrete surface must be treated to remove the moisture-resistant substance. This is one method of checking for a sealer on the concrete that might not otherwise be visible to the naked eye.

Like the plastic sheet test, the Mat Bond Test indicates moisture problems that might occur within the first few days after installation due to moisture near the concrete surface. Problems that might develop over a longer period, for example, moisture vapor migration from the subbase into the slab, will not be detected by this test.

Electronic Instruments

The following electronic tests produce numerical results but are listed here as qualitative rather than quantitative because they provide indirect, comparative indications of moisture in concrete. These instruments generally are not recognized by any standards or flooring manufacturers for the purpose of accepting or rejecting a floor. However, they can be useful as survey tools to broadly evaluate the relative moisture conditions across a floor and to select locations for quantitative moisture tests.

Electrical Resistance Test. To conduct the electrical resistance test, handheld meters with sensing pins or probes are placed in contact with the concrete surface and the meter reading is noted (Figure 6-4). This type of meter was developed for moisture in wood and is widely used for that purpose. These meters are delivered from the manufacturers calibrated for various wood species and read directly in percent moisture content. Pin-type meters that only contact the concrete surface cannot assess the moisture deep within the slab. Such pin-type surface electrical resistance tests can be misleading and are not recommended for any serious floor moisture testing. Some resistance meters use probes or nails placed into holes drilled into the concrete. While these instruments can be accurate and useful for wood, the electrical resistivity of concrete depends

Figure 6-4. Electrical resistance testing may not relate to the true condition of available moisture within a concrete slab. (IMG15964)

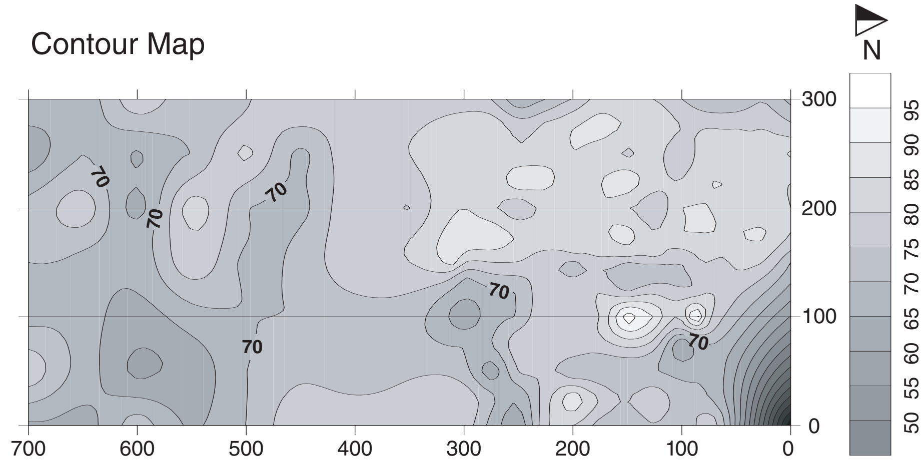

Figure 6-6. Impedance devices can be used as survey meters to create moisture maps showing areas of comparatively higher and lower moisture across a large floor area.

on many factors besides moisture content, such as the extent of cement hydration, composition of hydration products, and the presence of alkalies, carbonation, and chlorides.

Electrical Impedance Test. Electrical impedance meters are handheld devices placed on a concrete surface (Figure 6-5). A transmitting antenna on the meter emits a radio-frequency alternating-current field that is received by another antenna on the meter. The electrical field created by the instrument is attenuated by the dielectric nature of the concrete and moisture in the concrete. Such instruments can provide useful information on relative differences in moisture conditions to a depth of 50 mm (2 in.). They are simple and quick to use across a floor and are useful as survey tools for troubleshooting investigations and to help determine where to place quantitative moisture tests. An electrical impedance meter can be used to read concrete moisture through some types of thin floor coverings and floor coatings. However, comparisons of meter readings should not be made across different types of floor coverings. An example of a concrete floor moisture map based on impedance meter readings is shown in Figure 6-6.

Nuclear Moisture Gauge. Nuclear moisture gauges are portable meters that contain a radioactive source that emits gamma rays and high-speed neutrons (Figure 6-7). The neutrons are slowed by interactions with hydrogen atoms in concrete and water, being converted into "thermal" neutrons, which are backscattered and detected by a sealed gas counter in the instrument. A digital display on the instru-

Figure 6-5. Electrical impedance devices can provide comparative measures of moisture in the upper region of a slab. (IMG15963)

Figure 6-7. Requirements of nuclear moisture gauges for training, licensing, handling, and transport make them less desirable for routine floor testing. (IMG12233)

ment indicates the number of counts collected over a fixed time, generally 10 to 60 seconds per measurement. A nuclear moisture gauge can read concrete moisture through flooring and floor coatings; however, polypropylene-backed flooring can give false high readings due to the concentration of hydrogen in the polymer.

This type of instrument can provide useful information on relative differences in moisture conditions to a depth of 100 mm (4 in.). Like electrical impedance meters, the nuclear gauge is relatively simple and quick to use. However, because the instrument contains radioactive material, users must be trained and licensed; the owner must be licensed; documents are required to be kept with the instrument; and special fees and travel documents must be obtained for interstate transport. The nuclear instrument must be kept locked and placarded with warning signs when not in use.

Nuclear Magnetic Resonance. Nuclear magnetic resonance (NMR) is based on the interaction of a transmitted radio frequency field and the magnetic properties of nuclear particles (hydrogen nuclei) contained in a static magnetic field. The nucleus of the hydrogen atom – the proton – possesses significant magnetic moment and, therefore, provides the best effect. A hydrogen NMR experiment measures the proton density in the sample volume and also the molecular mobility of the proton environment. Therefore, in a porous solid the amount as well as the binding state of a hydrogen bearing liquid, as water, can be determined.

Conventional NMR instrumentation encloses the sample; however, in the case of a large specimen, sampling is required. Although the method is, in principle, nondestructive, in this case, traditional NMR instrumentation does not allow application without damaging the specimen.

One-Side Access Nuclear Magnetic Resonance (OSA NMR) is used to measure the one-dimensional water distribution (moisture profile) in building materials. An OSA NMR device can be applied to the specimen surface from one side, which allows information about water transport during capillary absorption and pressure driven permeation to be determined in-situ.

Using OSA NMR to monitor water invasion into a porous structure offers the possibility of determining moisture storage and moisture transport quantities of concrete. In contrast to traditional methods for moisture transport characterization (gravimetrical methods), OSA NMR does not require sampling; it represents a tool for in-situ service-life estimation of building components. This method could provide a deeper understanding of moisture damage mechanisms in building materials.

QUANTITATIVE MOISTURE TESTS

Gravimetric Moisture Content

In the Gravimetric Moisture Content Test, the weight percent of free moisture in concrete can be determined from a representative sample of the floor slab. The best sample is a full-depth core with diameter at least three times the aggregate top size. The core should be dry-cut to avoid introducing additional water from the coring operation. Alternatively, pieces of concrete can be stitch-drilled and chiseled from the floor, being sure to go deep enough to represent the bulk of the slab, not just the top surface. The sample must be wrapped immediately in an impermeable foil so its moisture content does not change during transport and storage. Next, the concrete is weighed in a laboratory, heated at 105°C (220°F) until the loss in mass is not more than 0.1% in 24 hours of drying (Figure 6-8). The weight loss is calculated and expressed as percent of the dry weight. This technique can produce a very accurate measure of the weight percent of free moisture in concrete. However, there are several reasons not to use this test: (1) free moisture determined by this method does not correlate well with field performance of adhesives and floor coverings; (2) most concrete cores are wet-drilled and cannot be used for this test; (3) obtaining sufficiently large and dry samples is labor intensive and time-consuming. While gravimetric moisture measurement is an indispensable tool for assessing the moisture content of aggregates, soil, and subbase materials, it is a not very useful test for assessing the readiness of a concrete floor to receive a floor covering.

Figure 6-8. Gravimetric moisture analysis determines weight percent of free moisture by heating a concrete specimen to constant weight. Wet-cored cylinders obtained from in-place floors cannot be used for this purpose. (IMG15990)

Moisture Vapor Emission Rate (MVER) (Calcium Chloride Kit Test)

The Moisture Vapor Emission Rate (MVER) test (ASTM F 1869-04 *Test Method for Measuring Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*) is the most commonly used test in the United States and is recommended by the Resilient Floor Covering Institute (1995) and the Carpet and Rug Institute (1996). More than 300,000 of these tests are performed annually. The Rubber Manufacturers Association first publicized the test in the early 1960s. Most flooring and adhesive manufacturers specify maximum limits for moisture vapor emission from concrete floors based on the MVER test expressed as pounds of moisture emitted from 1000 sq ft in 24 hours. Specification limits vary by flooring manufacturer and material type. Typical limits are:

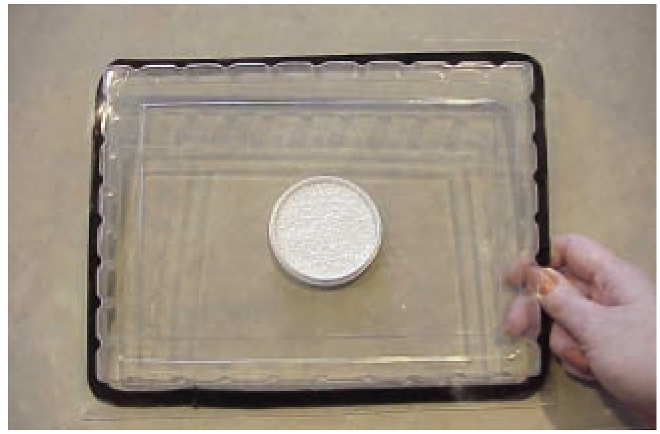

Figure 6-9. Moisture vapor emission rate is determined according to ASTM F1869 using commercially available calcium chloride kits that absorb moisture from a specific test area over a known length of time. (IMG15989)

Table 6-1. Typical Limits for MVER Test*

MVER	Materials
5 lb/1000 sq ft/24 hr	Vinyl composition tile Felt-backed resilient sheet flooring Porous-backed carpet Linoleum
3 lb/1000 sq ft/24 hr	Solid vinyl sheet flooring Vinyl-backed carpet Nonporous-backed carpet Cork Direct glue-down wood flooring

* Resilient Floor Covering Institute 1995.
Note: To convert to SI (µg/sec · m^2), multiply by 56.51

MVER test kits (Figure 6-9) are available from several vendors in the United States (see *Sources of Supplies* in the Appendix). Each kit consists of:

- A plastic dish with lid approximately 75 mm (3 in.) diameter containing 16 g (0.56 oz) anhydrous calcium chloride; pressure sensitive adhesive (PSA) tape to seal the lid around its circumference; a paper label to record data on the top of the lid; and a moisture-resistant, heat-sealable bag to contain the dish during storage until needed.
- A flanged, clear plastic cover, called the “dome,” 30 mm (1.2 in.) in height with 460 cm^2 (0.5 ft^2) inside the flanges; the dome is made of low permeability plastic such as polyethylene terephthalate (the same plastic used for soda pop bottles); and a caution label fixed inside the cover.
- Preformed sealant strip used to form a hermetic seal between the flanges of the dome and the concrete floor.

The building must be enclosed with its HVAC system operating, and the room and floor of interest must be at anticipated service conditions 48 hours before performing the test or 24°C ± 5°C/50 ± 10% RH (75°F ± 10°F/50 ± 10% RH). Ambient relative humidity and temperature can significantly affect test results. Test areas should be selected that represent the entire floor, including the center and perimeter of the floor. The test area is prepared by scraping or brushing to provide a clean surface slightly larger than the area of the dome. Care must be taken to remove all material from the slab surface including any curing compounds or surface sealers prior to performing the test as these materials will inhibit the moisture vapor emission rate. Light grinding has been found effective at removing such sealers. A calcium chloride dish is weighed to the nearest 0.1 g (0.0002 lb), including the lid, label, and sealing tape. The starting date, time, weight, and test location are noted on the label. The dish is opened and placed on the floor; the sealing tape is temporarily secured against the inner side of the plastic dome; and the dome is fastened to the floor using the sealant strip. After 60 to 72 hours, the dome is cut open to remove the dish, and the lid is replaced on top of the dish and sealed with the tape. Then the dish is weighed and the net weight gain calculated in grams. Finally, the moisture vapor emission rate in lb/1000 ft^2/24 hours is recalculated as shown in the kit manufacturer’s instructions. Because ambient air humidity and slab temperature can significantly affect the reported MVER, it is useful to measure and report these data along with the MVER results.

For most concretes (w/c < 0.6) the MVER test determines moisture emitted from the upper two centimeters (less than an inch) of a concrete slab and is not a good indicator of moisture deep in the slab. Figure 6-10 shows how the MVER test gains nearly all its moisture from just a narrow region near the top of the slab.

Users should interpret the MVER test results with caution. The test yields only a snapshot-in-time of moisture emission from the upper portion of the concrete and cannot predict the long-term performance of a floor, especially if there is no vapor retarder below the slab. As with the

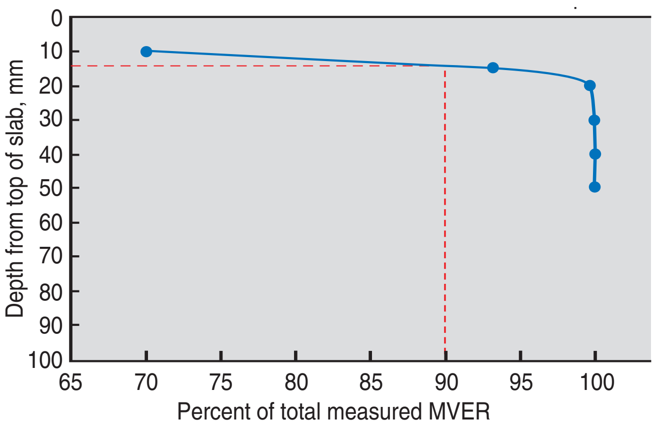

Figure 6-10. ASTM F 1869 Source of Measured Moisture Cumulative Percent of Total MVER at Various Depths. Graph shows that 90% of the moisture measured by a calcium chloride kit comes from the upper 12 mm (½ in.) of the concrete slab.

qualitative tests discussed previously, a high MVER result indicates a floor is not ready to receive flooring, but a low MVER result only indicates that the moisture level in the upper portion of the concrete may be acceptable.

Relative Humidity Measurement

In several countries outside the United States, standards for floor moisture were developed in the 1980s based on measuring relative humidity (RH) within, or in equilibrium with, the concrete floor slab. This practice has several advantages over other concrete moisture measurement techniques:

- RH probes (Figure 6-11) can be placed at precise depths in a concrete slab to determine the relative humidity below the surface or to determine the RH profile as a function of depth.
- RH probes placed close to mid-depth actually measure the relative humidity within the slab and are less sensitive to short-term fluctuations in ambient air humidity and temperature above the slab.
- Moisture moves through concrete in a partially adsorbed or condensed state by diffusion, not simply as unbound, free water vapor or liquid. The rate of moisture transmission depends on the degree of saturation, which is a function of the relative humidity on each side of the concrete. Therefore, the driving force for water vapor movement through a slab is the relative humidity differential through the slab's depth, not simply the vapor pressure differential (Powers 1958 and BRAB-FHA 1958). RH probes are a method of directly measuring this property.
- Relative humidity is a measure of equilibrium moisture level. When a floor covering is placed on top of a slab, it restricts evaporation from the top surface of the slab; moisture within the slab then distributes itself to achieve an equilibrium due to temperature and chemical interactions from the top to the bottom of the slab. In the long run, adhesive and flooring are then exposed to the equilibrium moisture level at the top of the slab. The calcium chloride kit artificially pulls moisture out of the top few centimeters of the slab and does not reflect the long-term moisture situation that will be established by equilibration. RH probes can measure the relative humidity that will exist well after the floor is covered.
- RH probes can be connected to electronic data loggers to record changes in relative humidity within a slab over time (Figure 6-12). Such measurements can be very useful to determine whether a floor is getting wetter or drier, and to predict how long it might take to reach an acceptable level of moisture.

Figure 6-11. RH Probes containing moisture sensors directly determine relative humidity in holes drilled into concrete floor slabs. (IMG15962)

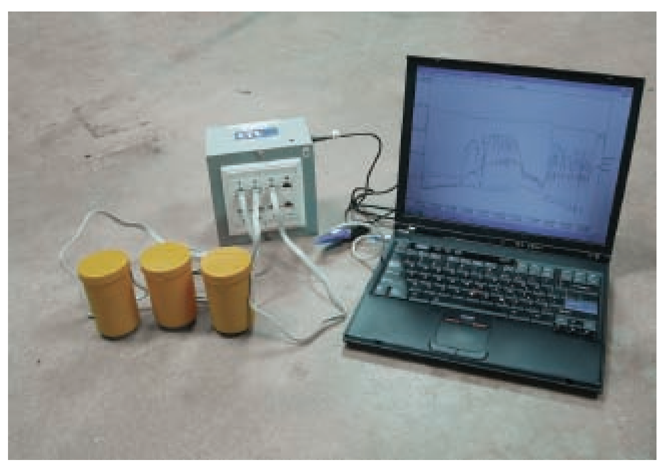

Figure 6-12. RH Probes can be connected to data loggers to record trends in floor moisture and predict when a floor will be dry enough for installation of finish flooring systems. (IMG15961)

Worldwide RH Standards. Two British standards, BS5325:1996, *Code of Practice for Installation of Textile Floor Coverings,* and BS8203:1996, *Code of Practice for Installation of Resilient Floor Coverings,* use the same method: a hygrometer or relative humidity probe is sealed under an insulated, impermeable box to trap moisture in an air pocket above the floor (Figure 6-13). The box is sealed to the concrete using preformed butyl sealant tape. The hygrometer or probe is allowed to equilibrate for at least 72 hours before taking the first reading. Equilibrium is achieved when two consecutive readings at 24-hour intervals agree within the precision of the instrument, generally ±3% RH. Under these two British standards, floors are acceptable for installation of resilient or textile floor coverings when the relative humidity is 75% or less.

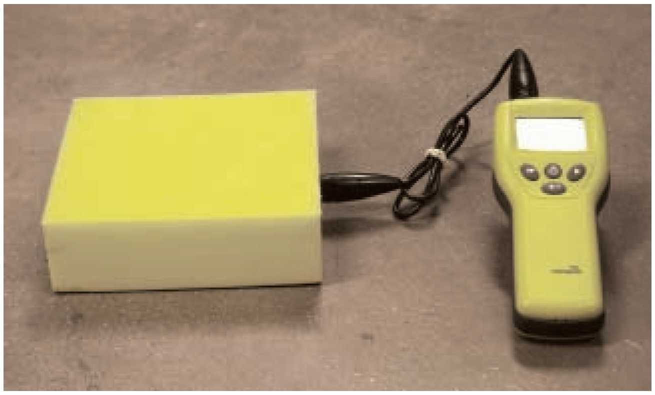

Figure 6-13. Method BS8203 used in the United Kingdom and parts of Europe involves placing a relative humidity probe in an insulated hood that is sealed to the surface of the concrete floor. (IMG15960)

The New Zealand Federation of Master Flooring Contractors (1984) published a method similar to BS5325 and BS8203 using a hygrometer (Edney Gauge) sealed directly to the concrete floor and covered by an insulated box.

In Sweden and Finland, relative humidity measurements are made by drilling holes in the concrete floor slab and placing probes into the holes (Nordtest NT Build 439, 1995). For a floor slab drying from its top surface only, a probe placed at 40% of the slab depth (measured from the top of the slab) will determine the relative humidity that will eventually be achieved in the slab at equilibrium after a floor covering is installed (Figure 6-14).

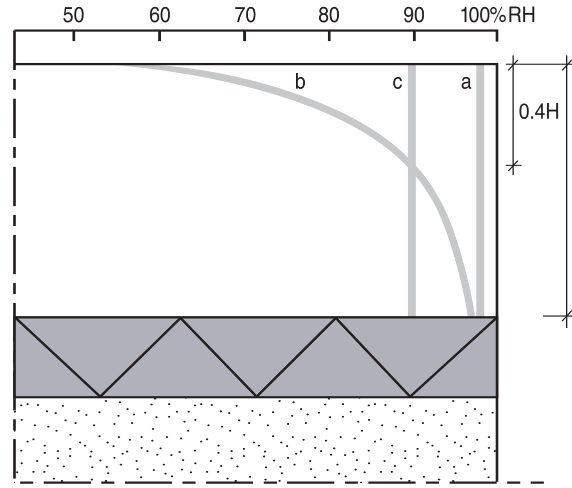

Figure 6-14. The moisture gradient formed as concrete dries will redistribute itself after a floor covering or coating is applied to the surface of a slab. For 180-mm thick slabs drying from one side, the eventual relative humidity will be equal the RH at 40% of slab depth before flooring installation (Hedenblad 1997).

In 2002, ASTM International approved a new test method modeled on the Scandinavian Nordtest method, titled ASTM F 2170, *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes*.

Installing RH Probes. RH probes must be set into sleeves that isolate the walls of the drilled holes from the probe so that the probe reads only the bottom of the hole. The drilled hole must be allowed to achieve thermal and moisture equilibrium before making a measurement; it is best to leave a probe in the hole for this period, but the probe can be placed into a previously drilled hole and allowed to equilibrate. When a hole is drilled, heat from friction between the drill bit and the concrete drives moisture away from the hole and into nearby concrete. RH measurements made shortly after drilling will be inaccurate until equilibrium is restored after about 72 hours for 16-mm (⅝-in.) diameter holes. Time, temperature, dust, alkalies, and other factors affect accurate RH measurements in concrete; strict attention must be paid to details of the test procedures. (Molina 1990 and Hedenblad 1997).

An advantage of this method is that once a hole is drilled in the concrete, it can be used repeatedly to check the progress of slab drying. Holes also can also be cast into the concrete for this purpose.

Relative humidity probes based on various principles are available (see *Sources of Supplies* in the Appendix).

Acceptable RH Levels. What percentage of relative humidity is acceptable in an interior concrete floor slab? Various levels can be appropriate depending on the uses of the occupied space and applied floor finishes. Relative humidity at mid-depth in bare concrete floors – such as those found in manufacturing facilities and warehouses – can be quite high if there is no vapor retarder below the slab. Moisture vapor passes through the slab and evaporates at top the surface with no detrimental effect most of the time. However, dew point condensation can occur on or within the slab if the temperature and relative humidity of the air are right. To minimize the opportunity for dew point condensation, relative humidity in the upper centimeter of a slab should be less than approximately 85%. Dense, hard-troweled slabs or slabs with an applied sealer and no vapor retarder can have greater than 95% RH in the upper centimeter. Abrading the floor, for example by shotblasting, can remove a portion of the dense surface and allow the slab to "breathe," thus lowering the relative humidity in the upper region. However, removing a densely troweled wearing surface may reduce the wear resistance of the floor.

Acceptable RH levels using in situ probes have been established and published in Finland and Sweden. These maximum permissible values are given in the following tables:

Table 6-2. Maximum Value of Relative Humidity in Concrete*

Max. %RH	Cover Material
85%	Plastic carpet with felt or cellular plastic base Rubberized carpet Cork tile with plastic film barrier Textile carpet with rubber, PVC or rubber-latex coated Textile carpet made of natural fibers
90%	Plastic tiles Plastic carpet with no felt or cellular plastic base Linoleum
60%	Parquet board with no plastic film between wood and concrete
80%	Mosaic parquet on concrete

* The Finnish SisaRYL 2000 Code of Building Practice.

Table 6-3. General Material and Workmanship Specifications for Buildings*

Max. %RH	Cover Material
80%	Wood and wood-based materials
80%	Vinyl floor coverings with a backing which may provide nutrients for mycological growth
	Bonded floor coverings which do not tolerate degradation of floor adhesive by alkali in the concrete
90%	Layered products
85%	Homogeneous vinyl materials
	Cork tiles
80%	Without vinyl layer on the underside
85%	With a vinyl layer on the underside

* Swedish HusAMA83.

RH Probe Calibration. Calibration of relative humidity probes is not a trivial matter. It is best to send the probes to their manufacturer annually, or more often if needed. The manufacturer should provide a calibration certificate traceable to a national standard (in the United States such certificates are traceable to the National Institute of Standards and Technology, NIST). Although some publications suggest users can recalibrate RH probes using saturated salt solutions in accordance with ASTM E 104-04, it is difficult in practice to achieve the stability and moisture homogeneity within a calibration chamber required for high accuracy calibration. However, users can easily check performance by placing a probe into a chamber over an appropriately saturated salt solution.

Powders or Crushed Concrete. Another method of determining relative humidity in concrete is to obtain sufficient representative pieces of the concrete from a slab by chisel or hammer drill, place them into a bottle, then measure relative humidity using a probe sealed through the cap (Nordtest NT Build 490, 1999). This method requires that the bottle, RH probe, and concrete pieces come to thermal and moisture equilibrium, a process that typically requires at least overnight. Do not use concrete powder drilled from a hole for this purpose, since much of the moisture in the concrete is lost due to frictional heat from the drilling.

Accuracy and Precision of RH Measurements. RH measurements typically are quite precise, ±2% being commonly achieved in the field when attention is paid to all the measurement details. This means that repeated measurements yield similar values. However, accuracy of RH measurements (that is, how close the measurement is to the "true value" of RH in the concrete) depends on careful calibration of the sensor and on achieving thermal equilibrium before recording the measurement. A "safety margin" of several percent should be one of the considerations in establishing RH specification limits. For example, if a flooring manufacturer believes that RH must not exceed 85% for the performance of a particular floor covering and adhesive system, then the maximum permissible RH measured in the field (and specified in the installation instructions) should not exceed 80% to 82% for the floor to be considered ready for installation.

EARLY RH MEASUREMENTS IN PCA LABORATORIES

The measurement of relative humidity in concrete floor slabs for the purpose of evaluating readiness to receive floor coverings goes back to at least the 1950s. Menzel (1955) describes in considerable detail methods for measuring the relative humidity of concrete slabs and concrete block. He stated, "Knowledge of the moisture content of concrete slabs [is important]… in determining the effectiveness of vapor barriers on wall or floor slabs; and in determining when a concrete floor slab is dry enough for the application of paint or covering with rugs, asphalt or rubber tile, linoleum, wood flooring, etc." Menzel, and later Monfore (1963), credit Gause and Tucker (1940) with first using hygrometers to measure relative humidity in concrete specimens.

Two types of apparatus developed at the PCA laboratories for this purpose in the 1950s are shown in Figure 6-15 (Menzel 1955). One apparatus is very similar to the current British standard method (BS8203) which uses a hygrometer in a container sealed to the surface of the concrete slab; the other method is very similar to the current Nordtest NT Build 439 and ASTM F 2170, first published in 2002. Menzel also discussed using saturated salt solutions to calibrate hygrometers and humidity sensors, standard practice today.

Monfore (1963) developed a miniature (2.5 mm diameter) electronic sensor for measuring relative humidity in concrete; it used a Dacron thread attached to a fine Advance wire (tempered nickel copper alloy) that was read using a DC strain bridge. The "Monfore Gage" became a standard tool in the PCA laboratories for measuring the relative humidity in concrete floor slabs and other structural concrete members being conditioned for fire testing (Abrams and Monfore 1965) (Figure 6-16).

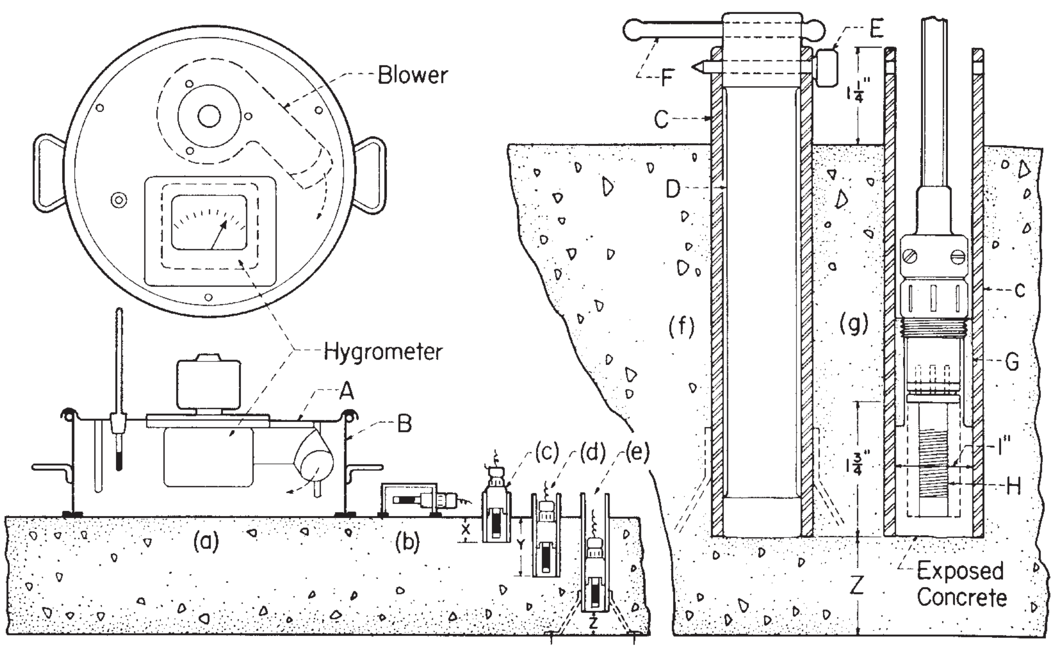

Figure 6-15. In the 1950s and 1960s, researchers at the Portland Cement Association developed tools to assess moisture in concrete floor slabs using hygrometers and relative humidity sensors. These methods presaged our modern standard test methods used in Europe and the U.S. (Menzel 1955).

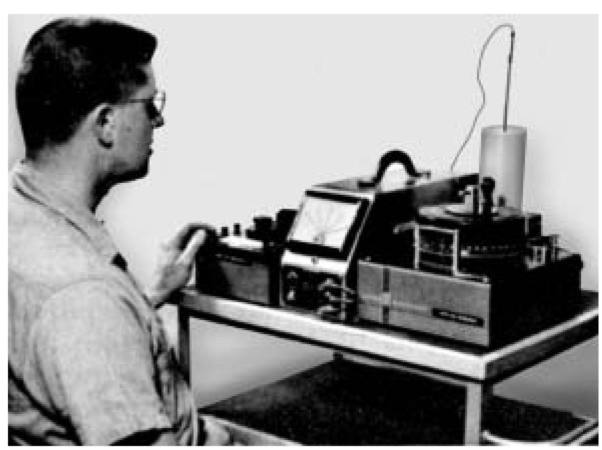

Figure 6-16. The 1960s-era Monfore gauge was a miniature relative humidity sensor that required a table top full of electronic equipment to produce a readable output. Today, pencil-sized RH sensors plug into handheld meters with digital displays. (IMG16041)

GLOSSARY

A

Absorption—see *Water absorption*.

Accelerating admixture—admixture that speeds the rate of hydration of hydraulic cement, shortens the normal time of setting, or increases the rate of hardening, of strength development, or both, of portland cement, concrete, mortar, grout, or plaster.

Acrylic—a glassy thermoplastic made by polymerizing acrylic or methacrylic acid or a derivative of either and used for cast and molded parts or as coatings and adhesives.

Addition—substance that is interground or blended in limited amounts into a hydraulic cement during manufacture—not at the jobsite—either as a "processing addition" to aid in manufacture and handling of the cement or as a "functional addition" to modify the useful properties of the cement.

Admixture—material, other than water, aggregate, and hydraulic cement, used as an ingredient of concrete, mortar, grout, or plaster and added to the batch immediately before or during mixing.

Aggregate—granular mineral material such as natural sand, manufactured sand, gravel, crushed stone, air-cooled blast-furnace slag, vermiculite, or perlite.

Air content—total volume of air voids, both entrained and entrapped, in cement paste, mortar, or concrete. Entrained air adds to the durability of hardened mortar or concrete and the workability of fresh mixtures.

Air entrainment—intentional introduction of air in the form of minute, disconnected bubbles (generally smaller than 1 mm) during mixing of portland cement concrete, mortar, grout, or plaster to improve desirable characteristics such as cohesion, workability, and durability.

Air-entraining admixture—admixture for concrete,mortar, or grout that will cause air to be incorporated into the mixture in the form of minute bubbles during mixing, usually to increase the material's workability and frost resistance.

Air-entraining portland cement—– portland cement containing an air-entraining addition added during its manufacture.

Air void—entrapped air pocket or an entrained air bubble in concrete, mortar, or grout. Entrapped air voids usually are larger than 1 mm in diameter; entrained air voids are smaller. Most of the entrapped air voids should be removed with internal vibration, power screeding, or rodding.

Alkali—usually a hydroxide of potassium or sodium, contributing to the increased pH (basicity) of portland cement concrete.

Alkali-aggregate reactivity—production of expansive gel caused by a reaction between aggregates containing certain forms of silica or carbonates and alkali hydroxides in concrete.

Ambient— existing or present on all sides; ambient air conditions include relative humidity and temperature.

Architectural concrete—concrete that will be permanently exposed to view and which therefore requires special care in selection of concrete ingredients, forming, placing, consolidating, and finishing to obtain the desired architectural appearance.

Asbestos—any of several minerals (as chrysotile) that readily separate into long flexible fibers, that have been implicated as causes of certain cancers, and that have been formerly used in fireproof insulating materials.

Asphaltic—a type of composition used for pavements and as a waterproof cement.

Autoclaved cellular concrete—concrete containing very high air content resulting in low density, and cured at high temperature and pressure in an autoclave.

B

Batching—process of weighing or volumetrically measuring and introducing into the mixer the ingredients for a batch of concrete, mortar, grout, or plaster.

Blast-furnace slag—nonmetallic byproduct of steel manufacturing, consisting essentially of silicates and aluminum silicates of calcium that are developed in a molten condition simultaneously with iron in a blast furnace.

Bleeding—flow of mixing water from a newly placed concrete mixture caused by the settlement of the solid materials in the mixture.

Bleedwater—water that has bled through to the surface of freshly placed concrete.

Blended hydraulic cement—cement containing combinations of portland cement, pozzolans, slag, and/or other hydraulic cement.

Bulking—increase in volume of a quantity of sand when in a moist condition compared to its volume when in a dry state.

C

Calcined clay—clay heated to high temperature to alter its physical properties for use as a pozzolan or cementing material in concrete.

Calcined shale—shale heated to high temperature to alter its physical properties for use as a pozzolan or cementing material in concrete.

Carbonation—reaction between carbon dioxide and a hydroxide or oxide to form a carbonate.

Capillary break—a layer of coarse crushed stone installed on subgrade to prevent wicking of liquid water due to fine grained soils

Cellular concrete—high air content or high void ratio concrete resulting in low density.

Cement—see *Portland cement* and *Hydraulic cement*.

Cement paste—constituent of concrete, mortar, grout, and plaster consisting of cement and water.

Cementitious material (cementing material)—any material having cementing properties or contributing to the formation of hydrated calcium silicate compounds. When proportioning concrete, the following are considered cementitious materials: portland cement, blended hydraulic cement, fly ash, ground granulated blast-furnace slag, silica fume, calcined clay, metakaolin, calcined shale, and rice husk ash.

Chemical admixture—see *Admixture*.

Chemical bond—bond between materials resulting from cohesion and adhesion developed by chemical reaction.

Clinker—end product of a portland cement kiln; raw cementitious material prior to grinding

Chloride (attack)—chemical compounds containing chloride ions, which promote the corrosion of steel reinforcement. Chloride deicing chemicals are primary sources.

Coarse aggregate—natural gravel, crushed stone, or iron blast-furnace slag, usually larger than 5 mm (0.2 in.) and commonly ranging in size between 9.5 mm and 37.5 mm (⅜ in. to 1½ in.).

Cohesion—mutual attraction by which elements of a substance are held together.

Colored concrete—concrete containing white cement and/or mineral oxide pigments to produce colors other than the normal gray hue of traditional gray cement concrete.

Compaction—process of inducing a closer arrangement of the solid particles in freshly mixed and placed concrete, mortar, or grout by reduction of voids, usually by vibration, tamping, rodding, puddling, or a combination of these techniques. Also called consolidation.

Compressive strength—maximum resistance that a concrete, mortar, or grout specimen will sustain when loaded axially in compression in a testing machine at a specified rate; usually expressed as force per unit of cross sectional area, such as megapascals (MPa) or pounds per square inch (psi).

Concrete—mixture of binding materials and coarse and fine aggregates. Portland cement and water are commonly used as the binding medium for normal concrete mixtures, but may also contain pozzolans, slag, and/or chemical admixtures.

Consistency—relative mobility or ability of freshly mixed concrete, mortar, or grout to flow. (See also *Slump* and *Workability*.)

Construction joint—a stopping place in the process of construction. A true construction joint allows for bond between new concrete and existing concrete and permits no movement. In structural applications, their location must be determined by the structural engineer. In slab on grade applications, construction joints are often located at contraction (control) joint locations and are constructed to allow movement and perform as contraction joints.

Contraction joint—weakened plane to control cracking due to volume change in a concrete structure. Joint may be grooved, sawed, or formed. Also known as a "Control joint."

Corrosion—deterioration of metal by chemical, electrochemical, or electrolytic reaction.

Creep—time-dependent deformation of concrete, or of any material, due to a sustained load.

C-S-H— calcium silicate hydrate.

Curing—process of maintaining freshly placed concrete mortar, grout, or plaster moist and at a favorable temperature for a suitable period of time during its early stages so that the desired properties of the material can develop. Curing assures satisfactory hydration and hardening of the cementitious materials.

Cutback—asphaltic adhesive used extensively until the 1980s to adhere resilient floor coverings to concrete; some formulations contain asbestos fibers.

D

Dampproofing—treatment of concrete, mortar, grout, or plaster to retard the passage or absorption of water, or water vapor.

Debonding—the detaching or separation of materials

Deflection—the departure of a material from equilibrium position.

Degrade—erode, bring to lower quality.

Density—mass per unit volume; the weight per unit volume in air, expressed, for example, in kg/m3 (lb/ft3).

Deterioration—the process in which a material goes from complete and high quality to incomplete and low quality.

Discoloration— a change in color for the worse.

DPM—damp-proofing membrane.

Durability—ability of portland cement concrete, mortar, grout, or plaster to resist weathering action and other conditions of service, such as chemical attack, freezing and thawing, and abrasion.

E

Efflorescence—to change to a powder from loss of water of crystallization, to form or become covered with a powdery crust.

Early stiffening—rapidly developing rigidity in

freshly mixed hydraulic cement paste, mortar, grout, plaster, or concrete.

Emulsion—a system consisting of a liquid dispersed in an immiscible liquid usually in droplets of larger than colloidal size.

Entrapped air—irregularly shaped, unintentional air voids in fresh or hardened concrete 1 mm or larger in size.

Entrained air—spherical microscopic air bubbles—usually 10 µm to 1000 µm in diameter—intentionally incorporated into concrete to provide freezing and thawing resistance and/or improve workability.

Epoxy resin—class of organic chemical bonding systems used in the preparation of special coatings or adhesives for concrete or masonry or as binders in epoxy-resin mortars and concretes.

Epoxy terrazzo—finish flooring system comprising epoxy, decorative aggregates, pigments, and fillers installed on concrete structural floors, ground flat to expose the aggregate particles and polished.

Ettringite—needle like crystalline compound produced by the reaction of C_3A, gypsum, and water within a portland cement concrete.

Expansion joint—a separation provided between adjoining parts of a structure to allow movement.

F

Ferrocement—one or more layers of steel or wire reinforcement encased in portland cement mortar creating a thin-section composite material.

Fibers—thread or thread like material ranging from 0.05 to 4 mm (0.002 to 0.16 in.) in diameter and from 10 to 150 mm (0.5 to 6 in.) in length and made of steel, glass, synthetic (plastic), carbon, or natural materials.

Fiber concrete—concrete containing randomly oriented fibers in 2 or 3 dimensions through out the concrete matrix.

Fine aggregate—aggregate that passes the 9.5-mm (3/8-in.) sieve, almost entirely passes the 4.75-mm (No. 4) sieve, and is predominantly retained on the 75-µm (No. 200) sieve.

Fineness modulus (FM)—factor obtained by adding the cumulative percentages of material in a sample of aggregate retained on each of a specified series of sieves and dividing the sum by 100.

Finishing—mechanical operations like screeding, consolidating, floating, troweling, or texturing that establish the final appearance of any concrete surface.

Fire resistance—that property of a building material, element, or assembly to withstand fire or give protection from fire; it is characterized by the ability to confine a fire or to continue to perform a given structural function during a fire, or both.

Flexural strength—ability of solids to resist bending.

Fly ash—residue from coal combustion, which is carried in flue gases, and is used as a pozzolan or cementing material in concrete.

Forms—temporary supports for keeping fresh concrete in place until it has hardened to such a degree as to be self supporting (when the structure is able to support its dead load).

Freeze-thaw resistance—ability of concrete to withstand cycles of freezing and thawing. (See also *Air entrainment* and *Air-entraining admixture*.)

Fresh concrete—concrete that has been recently mixed and is still workable and plastic.

Fungi—any of a major group (Fungi) of saprophytic and parasitic spore-producing organisms usually classified as plants that lack chlorophyll and include molds, rusts, mildews, smuts, mushrooms, and yeasts.

G

Galvanic—of, relating to, or producing a direct current of electricity.

Geotextile—permeable fabric used to prevent infiltration of fine particles into drainage stone around the perimeter of a building; also used to separate subgrade soil and fine subbase material from capillary break layer beneath a floor slab.

Grading—size distribution of aggregate particles, determined by separation with standard screen sieves.

Grout—mixture of cementitious material with or without aggregate or admixtures to which sufficient water is added to produce a pouring or pumping consistency without segregation of the constituent materials.

H

Hardened concrete—concrete that is in a solid state and has developed a certain strength.

High-density concrete (heavyweight concrete)—concrete of very high density; normally designed by the use of heavyweight aggregates.

High-strength concrete—concrete with a design strength of at least 70 MPa (10,000 psi).

Hemihydrate—a hydrate (as plaster of paris) containing half a mole of water to one mole of the compound forming the hydrate.

Honeycomb—term that describes the failure of mortar to completely surround coarse aggregates in concrete, leaving empty spaces (voids) between them.

Hydrated lime—dry powder obtained by treating quicklime with sufficient water to satisfy its chemical affinity for water; consists essentially of calcium hydroxide or a mixture of calcium hydroxide and magnesium oxide or magnesium hydroxide, or both.

Hydration—in concrete, mortar, grout, and plaster, the chemical reaction between hydraulic cement and water in which new compounds with strength-producing properties are formed.

Hydraulic cement—cement that sets and hardens by chemical reaction with water, and is capable of doing so under water. (See also *Portland cement*.)

Hydraulic limes—calcined limestone containing clay having cementitious compounds that that react with water.

Hydrostatic—related to fluid pressure; hydrostatic head refers to the height of water above a given point such as the floor or footing of a building.

I

IAQ—indoor air quality.

Inch-pound units—units of length, area, volume, weight, and temperature commonly used in the United States during the 18th to 20th centuries. These include, but are not limited to: (1) length—inches, feet, yards, and miles; (2) area—square inches, square feet, square yards, and square miles; (3) volume—cubic inches, cubic feet, cubic yards, gallons, and ounces; (4) weight—pounds and ounces; and (5) temperature—degrees Fahrenheit.

Isolation joint—separation that allows adjoining parts of a structure to move freely to one another, both horizontally and vertically.

J

Joint—see *Construction* joint, *Contraction joint*, *Isolation joint*, and *Expansion joint*.

K

Kiln—rotary furnace used in cement manufacture to heat and chemically combine raw inorganic materials, such as limestone, sand and clay, into calcium silicate clinker.

L

Lath—a thin narrow strip of wood nailed to rafters, joists, or studding as a groundwork for slates, tiles, or plaster.

Lateral strength—resistance to stress applied in the same direction of material.

Lightweight aggregate—low-density aggregate used to produce lightweight (low-density) concrete. Could be expanded or sintered clay, slate, diatomaceous shale, perlite, vermiculite, or slag; natural pumice, scoria, volcanic cinders, tuff, or diatomite; sintered fly ash or industrial cinders.

Lightweight concrete—low-density concrete compared to normal-density concrete.

Lime—general term that includes the various chemical and physical forms of quicklime, hydrated lime, and hydraulic lime. It may be high calcium, magnesian, or dolomitic.

M

Masonry—concrete masonry units, clay brick, structural clay tile, stone, terra cotta, and the like, or combinations thereof, bonded with mortar, dry-stacked, or anchored with metal connectors to form walls, building elements, pavements, and other structures.

Masonry cement—hydraulic cement, primarily used in masonry and plastering construction, consisting of a mixture of portland or blended hydraulic cement and plasticizing materials (such as limestone, hydrated or hydraulic lime) together with other materials introduced to enhance one or more properties such as setting time, workability, water retention, and durability.

Mass concrete—cast-in-place concrete in volume large enough to require measures to compensate for volume change caused by temperature rise from heat of hydration in order to keep cracking to a minimum.

Metakaolin—highly reactive pozzolan made from kaolin clays.

Metric units—also called System International (SI) Units. System of units adopted by most of the world by the 21st Century. These include but are not limited to: (1) length—millimeters, meters, and kilometers; (2) area—square millimeters and square meters; (3) volume—cubic meters and liters; (4) mass milligrams, grams, kilograms, and megagrams; and (5) degrees Celsius.

Microbial—an organism of microscopic size

Mildew—common term for combination of fungal, bacterial, and/or algal growths on building surfaces due to high humidity.

Mineral admixtures—see *Supplementary cementitious materials*.

Modulus of elasticity—ratio of normal stress to corresponding strain for tensile or compressive stress below the proportional limit of the material; also referred to as elastic modulus, Young's modulus, and Young's modulus of elasticity; denoted by the symbol E.

Moist-air curing—curing with moist air (no less than 95% relative humidity) at atmospheric pressure and a temperature of about 23°C (73°F).

Mold—a fungus (as of the order Mucorales) that produces mold.

Mortar—mixture of cementitious materials, fine aggregate, and water, which may contain admixtures, and is usually used to bond masonry units.

Mortar cement—hydraulic cement, primarily used in masonry construction, consisting of a mixture of portland or blended hydraulic cement and plasticizing materials (such as limestone, hydrated or hydraulic lime) together with other materials introduced to enhance one or more properties such as setting time, workability, water retention, and durability. Mortar cement and masonry cement are similar in use and function. However, specifications for mortar cement usually require lower air contents and they include a flexural bond strength requirement.

N

Normal weight concrete—class of concrete made with normal density aggregates, usually crushed stone or gravel, having a density of approximately 2400 kg/m^3 (150 lb/ft^3). (See also *Lightweight concrete* and *High density concrete*.)

No-slump concrete—concrete having a slump of less than 6 mm (¼ in.).

O

Organic carbon—carbon formed from the decomposition of plant-life.

Osmosis—movement of a solvent through a semipermeable membrane into a solution of higher solute concentration that tends to equalize the concentrations of solute on the two sides of the membrane

Overlay—layer of concrete or mortar placed on or bonded to the surface of an existing pavement or slab. Normally done to repair a worn or cracked surface. Overlays are seldom less than 25 mm (1 in.) thick.

P

Passivation— to protect (as a solid-state device) against contamination by coating or surface treatment.

Pavement (concrete)—highway, road, street, path, or parking lot surfaced with concrete. Although typically applied to surfaces that are used for travel, the term also applies to storage areas and playgrounds.

Pavimentum—ancient Roman interior floor

Permeability—property of allowing passage of fluids or gases. Permeance per unit thickness of material

Perched water—local, man-made temporary or permanent water table above the natural water table due to compaction of subgrade soil, inadequate drainage, or shifted natural water supply.

Percolate—to diffuse through.

Permeance—vapor transmission rate in units of mass per area per time per pressure differential; usually expressed as PERMS equivalent to grains/h·sq ft·in. Hg

Pervious concrete (no-fines or porous concrete)—concrete containing insufficient fines or no fines to fill the voids between aggregate particles in a concrete mixture. The coarse aggregate particles are coated with a cement and water paste to bond the particles at their contact points. The resulting concrete contains an interconnected pore system allowing storm water to drain through the concrete to the subbase below.

pH—chemical symbol for the logarithm of the reciprocal of hydrogen ion concentration in gram atoms per liter, used to express the acidity or alkalinity (base) of a solution on a scale of 0 to 14, where less than 7 represents acidity, and more than 7 alkalinity

Plastic cement—special hydraulic cement product manufactured for plaster and stucco application. One or more inorganic plasticizing agents are interground or blended with the cement to increase the workability and molding characteristics of the resultant mortar, plaster, or stucco.

Plasticity—that property of freshly mixed cement paste, concrete, mortar, grout, or plaster that determines its workability, resistance to deformation, or ease of molding.

Plasticizer—admixture that increases the plasticity of portland cement concrete, mortar, grout, or plaster.

Polymer-portland cement concrete—fresh portland cement concrete to which a polymer is added for improved durability and adhesion characteristics, often used in overlays for bridge decks; also referred to as polymer-modified concrete and latex-modified concrete.

Polyurethane—any of various polymers that contain NHCOO linkages and are used especially in flexible and rigid foams, elastomers, and resins (as for coatings).

Popout—shallow depression in a concrete surface resulting from the breaking away of pieces of concrete due to internal pressure.

Portland blast-furnace slag cement—hydraulic cement consisting of: (1) an intimately interground mixture of portland-cement clinker and granulated blast-furnace slag; (2) an intimate and uniform blend of portland cement and fine granulated blast-furnace slag; or (3) finely ground blast-furnace slag with or without additions.

Portland cement—Calcium silicate hydraulic cement produced by pulverizing portland-cement clinker, and usually containing calcium sulfate and other compounds. (See also *Hydraulic cement*.)

Portland cement plaster—a combination of portland cement-based cementitious material(s) and aggregate mixed with a suitable amount of water to form a plastic mass that will adhere to a surface and harden, preserving any form and texture imposed on it while plastic. See also *Stucco*.

Portland-pozzolan cement—hydraulic cement consisting of an intimate and uniform blend of portland cement or portland blast-furnace slag cement and fine pozzolan produced by intergrinding portland cement clinker and pozzolan, by blending portland cement or portland blast-furnace slag cement and finely divided pozzolan, or a combination of intergrinding and blending, in which the amount of the pozzolan constituent is within specified limits.

Pozzolan—siliceous or siliceous and aluminous materials, like fly ash or silica fume, which in itself possess little or no cementitious value but which will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Precast concrete—concrete cast in forms in a controlled environment and allowed to achieve a specified strength prior to placement on location.

Prestressed concrete—concrete in which compressive stresses are induced by high-strength steel tendons or bars in a concrete element before loads are applied to the element which will balance the tensile stresses imposed in the element during service. This may be accomplished by the following: Post-tensioning—a method of prestressing in which the tendons/bars are tensioned after the concrete has hardened; or Pretensioning—a method of prestressing in which the tendons are tensioned before the concrete is placed.

Primer—liquid substance applied to a concrete substrate to improve adhesive bond of coatings and applied floor coverings

Q

Quality control—actions taken by a producer or contractor to provide control over what is being done and what is being provided so that applicable standards of good practice for the work are followed.

R

Reactive-powder concrete—high-strength, low-water and low-porosity concrete with high silica content and aggregate particle sizes of less than 0.3 mm.

Ready-mixed concrete—concrete manufactured for delivery to a location in a fresh state.

Recycled concrete—hardened concrete that has been processed for reuse, usually as an aggregate.

Reinforced concrete—concrete to which tensile bearing materials such as steel rods or metal wires are added for tensile strength.

Relative density—a ratio relating the mass of a volume of material to that of water; also called specific gravity.

Relative humidity—the ratio of the quantity of water vapor actually present in the atmosphere to the amount of water vapor present in a saturated atmosphere at a given temperature, expressed as a percentage.

Retarder—an admixture that delays the setting and hardening of concrete.

Roller-compacted concrete (RCC)—a zero slump mix of aggregates, cementitious materials and water that is consolidated by rolling with vibratory compactors; typically used in the construction of dams, industrial pavements, storage and composting areas, and as a component of composite pavements for highways and streets.

S

Scaling—disintegration and flaking of a hardened concrete surface, frequently due to repeated freeze-thaw cycles and application of deicing chemicals.

Screed—a leveling device drawn over freshly placed concrete.

Segregation—separation of the components (aggregates and mortar) of fresh concrete, resulting in a nonuniform mixture.

Self-compacting concrete—concrete of high workability that require little or no vibration or other mechanical means of consolidation.

Self-desiccation—hydrated concrete consumes water leaving empty pores once filled with water.

Set—the degree to which fresh concrete has lost its plasticity and hardened.

Silica fume—very fine noncrystalline silica which is a byproduct from the production of silicon and ferrosilicon alloys in an electric arc furnace; used as a pozzolan in concrete.

Shear strength—resistance to stress applied in opposite directions.

Shotcrete—mortar or small-aggregate concrete that is conveyed by compressed air through a hose and applied at high velocity to a surface. Also known as gunite and sprayed concrete.

Shrinkage—decrease in either length or volume of a material resulting from changes in moisture content, temperature, or chemical changes.

Shrinkage-compensating concrete—concrete containing expansive cement, or an admixture, which produces expansion during hardening and thereby offsets the contraction occurring later during drying (drying shrinkage).

Slab— a thick plate or slice.

Slag cement—hydraulic cement consisting mostly of an intimate and uniform blend of ground, granulated blast-furnace slag with or without portland cement or hydrated lime.

Slump—measure of the consistency of freshly mixed concrete, equal to the immediate subsidence of a specimen molded with a standard slump cone.

Slurry—thin mixture of an insoluble substance, such as portland cement, slag, or clay, with a liquid, such as water.

Soil cement—mixture of soil and measured amounts of portland cement and water compacted to a high density; primarily used as a base material under pavements; also called cement-stabilized soil.

Specific gravity—see *Relative density*.

Stucco—portland cement plaster and stucco are the same material. The term "stucco" is widely used to describe the cement plaster used for coating exterior surfaces of buildings. However, in some geographical areas, "stucco" refers only to the factory-prepared finish coat mixtures. (See also *Portland cement plaster*.)

Subbase—infill material, such as graded stone placed on top of existing subgrade to support a concrete floor slab.

Subgrade soil—natural soil existing at a construction site.

Sulfate attack—most common form of chemical attack on concrete caused by sulfates in the groundwater or soil manifested by expansion and disintegration of the concrete.

Superplasticizer (plasticizer)—admixture that increases the flowability of a fresh concrete mixture.

Supplementary cementitious (cementing) materials—Cementitious material other than portland cement or blended cement. See also *Cementitious material*.

T

Tensile strength—stress up to which concrete is able to resist cracking under axial tensile loading.

Tuff—a rock composed of the finer kinds of volcanic detritus usually fused together by heat.

U

UBC—Uniform Building Code, published by the International Conference of Building Officials, Whittier,California.

Unit weight—density of fresh concrete or aggregate, normally determined by weighing a known volume of concrete or aggregate (bulk density of aggregates includes voids between particles).

V

VAT—vinyl asbestos tile.

Vapor Retarder—material in sheet form placed under a concrete floor slab to inhibit movement of moisture into the slab.

VCT—vinyl composition tile.

Vibration—high-frequency agitation of freshly mixed concrete through mechanical devices, for the purpose of consolidation.

VOC— volatile organic compounds.

Volume change—Either an increase or a decrease in volume due to any cause, such as moisture changes, temperature changes, or chemical changes. (See also *Creep*.)

W

Water absorption—(1) The process by which a liquid (water) is drawn into and tends to fill permeable pores in a porous solid. (2) The amount of water absorbed by a material under specified test conditions, commonly expressed as a percentage by mass of the test specimen.

Water to cementitious materials ratio (w/cm)—ratio of mass of water to mass of cementing materials in concrete, including portland cement, blended cement, hydraulic cement, slag, fly ash, silica fume, calcined clay, metakaolin, calcined shale, and rice husk ash.

Water to cement ratio (w/c)—ratio of mass of water to mass of cement in concrete.

Water reducer—admixture whose properties permit a reduction of water required to produce a concrete mix of a certain slump, reduce water-cement ratio, reduce cement content, or increase slump.

Water vapor transmission (wvt)—rate of moisture movement through a material in units of mass per area per time.

White portland cement—cement manufactured from raw materials of low iron content.

Workability—That property of freshly mixed concrete, mortar, grout, or plaster that determines its working characteristics, that is, the ease with which it can be mixed, placed, molded, and finished. (See also *Slump* and *Consistency*.)

Y

Yield—volume per batch of concrete expressed in cubic meters (cubic feet).

Z

Zero-slump concrete—concrete without measurable slump (See also *No-slump concrete*).

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