Drying Concrete

Excess moisture in concrete slabs has caused many flooring failures, disrupting building operations and necessitating expensive repairs. Consequences can be particularly serious in sensitive manufacturing facilities, such as those for semiconductors and biopharmaceuticals, where tens of millions of dollars' worth of production potential may be at stake.

Moisture In Concrete

Cement particles adhere to one another because of surface forces. More surface area means more available force-and stronger concrete. When water molecules react with cement molecules, the cement's surface area increases. For example, when crushed for cement, a typical pea-sized piece of cement clinker yields a surface area of about 2,000 cm^2. When water is added, the surface area increases nearly a thousand times, to 2,000,000 cm^2. Surface forces, acting over this very large area, provide the adhesion between particles that gives concrete its strength.

Without sufficient water, the surface area of the cement particles would be too small to ensure proper adhesion. For the same reason, the surface of concrete that dries prematurely will contract and pull apart, forming cracks just as mud does when it dries. If the water deficit is extreme, the surface crumbles because the shrinkage forces are not balanced by strong surface attraction between cement particles. To avoid such damage, concrete is kept wet until sufficient adhesion develops. Problems can occur if the excess water volume is large, however. The concrete will hold the water tenaciously, slowing drying times and, in some instances, preventing on-time completion.

How Much And When

A typical yard of concrete mix might consist of 1555 kg (34251bs) of aggregate (stone and sand), 250 kg (550 lbs) of cement, and 125 kg (275 lbs) of water. The water first serves as a vehicle for pouring the mix, then is partly consumed by the hydration reaction. During hydration (better known as the "curing" phase), about half of the water becomes part of the concrete, leaving a roughly equal amount of free water in the material's pores. Thus, a typical yard of "newly cured" concrete will have an excess moisture content of approximately 3.5 percent by weight [62.5 **-** (1555 + 250) = 0.035].

If it were distributed evenly throughout the concrete, a moisture content of 3.5% would not interfere with proper adhesion and cure of most coatings and flooring adhesives. To ensure complete curing, however, the contractor must continue to add water after the concrete is placed. In addition, rainwater and ground water can enter the slab. These post-pour water sources usually raise the excess water content of "cured" concrete to well above 7 percent, which translates to a weight of roughly 300 kg/m^3 to 360 kg/m^3 (500 lb/yd^3 to 600 lb/yd^3), or a volume of 225 L to 265 L (60 gal to 72 gal).

Many coating and flooring manufacturers will not guarantee their products if there is more than 5 percent free water in the concrete. Some prohibit more than 3 percent. So extra moisture, amounting to 3 to 5 percent of the weight of the concrete, must be removed. In other words, 115 L to 225 L (30 gal to 60 gal) of water must be removed from every yard of concrete in the slab before coating operations can begin or flooring can be laid. Industry sources agree that in most cases strength is sufficient at 70 percent hydration to allow drying to begin. How long it takes to achieve this percentage depends on the concrete mix.

At a constant 20°C (68°F) with relative humidity (RH) in the cement kept close to 100 percent by the regular addition of water, ASTM Type III cements cure rapidly, achieving 40 percent hydration after one day, 60 percent after three days, and 70 percent after seven days.

In comparison, Types I and II achieve 30 percent hydration within one day, 50 percent within three days, 60 percent after seven days, and 70 percent after 28 days.

Rules Of Thumb

The factors affecting concrete drying rates are numerous and interact in ways that are specific to the concrete element's shape and internal structure. Drying does not progress at a constant rate. The first water comes out relatively easily, because it is bound loosely to the other water molecules filling the concrete's pores. The last water is more difficult to remove because it is tightly bound to the surface of the concrete; more energy and usually more time are required to break the bonds.

Rules of thumb for estimating drying times have been around for years. One of these is that slabs usually dry to an acceptable moisture content for most flooring at a rate of about 25 mm (1 in.) of concrete thickness per month. Thus, a 150 mm (6 in.) slab will probably require six months to dry after 28 days of curing to 70 percent strength, or a total time from pouring to finishing of roughly seven months. Speeding the drying rate is possible with modern equipment, but it is important to understand the drying process.

Drying Rates

The primary variables that affect drying are moisture content, porosity, and temperature of the concrete (and temperature of the excess water the concrete contains); temperature and moisture content of the surrounding air; and velocity of the air flowing over the concrete. According to a monograph published by the American Concrete Institute, "typical" concrete will lose water at a rate of l.lkg/m^2/hour (0.23lb/ft^2/hour), provided that air temperature is 32°C (90°F), RH is 60 percent (74°F dew point), concrete temperature is 32°C, and air velocity is 24km/h (15 mph) (see Figure A). If there is no air movement (velocity = 0), the drying rate may fall by a factor of 10, to 0.1 kg/m^2/hour (0.025lb/ft^2/hr). If the air is dehumidified to 10 percent (26°F dew point), the drying rate should essentially double, to 2.2 kg/m^2/hour (0.45 lb/ft^2/hour).

In theory, then, the fastest drying rates should occur when the concrete and the air are both warm and when the air is also very dry and moving rapidly. Actual field observations appear to support this conclusion. For example, T. K. Greenfield, a concrete coating inspector, has reported that maintaining an air dew point at least a 11°C (20°F) below the coldest surface temperature allowed very rapid drying rates on a large project involving repair of concrete water tank linings.

Coating contractor Steven Mainello reported similar results for an aquarium tank repair project in Baltimore in the summer of 1994. To maintain the high drying rate that allowed the project to be commercially practical from a contractor's perspective, Mainello found it necessary to use the desiccant dehumidification equipment as well as heaters for the concrete. Air ducts were placed carefully to maintain high velocity at the concrete surfaces.