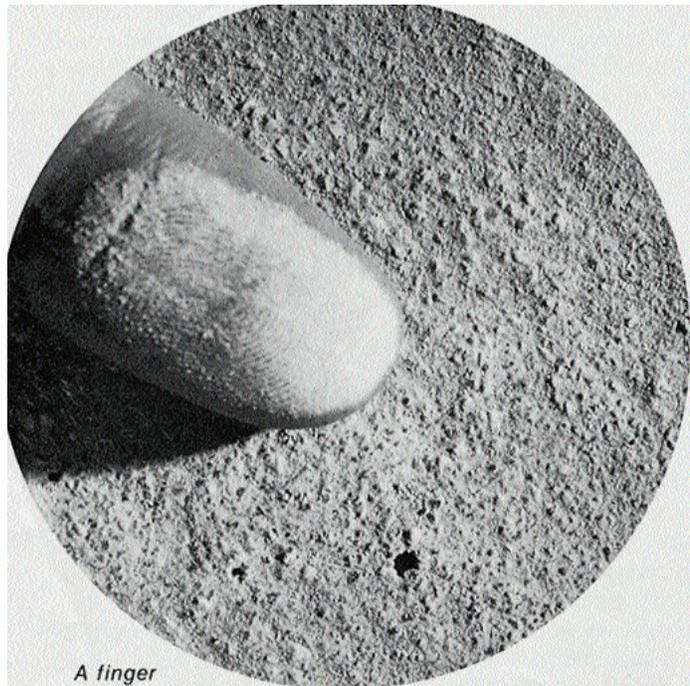


The basic facts about Carbonation of fresh concrete floor surfaces

Causes and chemistry

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A finger drawn across a floor slab offers a quick test for dusting caused by carbonation of fresh concrete.



Some time after moving into a new building, the occupant may find that foot or wheel traffic is creating a lot of dust on the concrete floors. Investigation shows that the floor surface is soft and easily scratched.

This is another example of an old problem—the carbonation of fresh concrete that causes dusting of concrete surfaces. The problem was identified and discussed 70 years ago, and the construction industry has been warned about it many times since then. However, the lesson has not yet been learned by everyone involved. Each new generation of craftsmen must be made aware of the phenomenon of carbonation and how to avoid the problems it can cause.

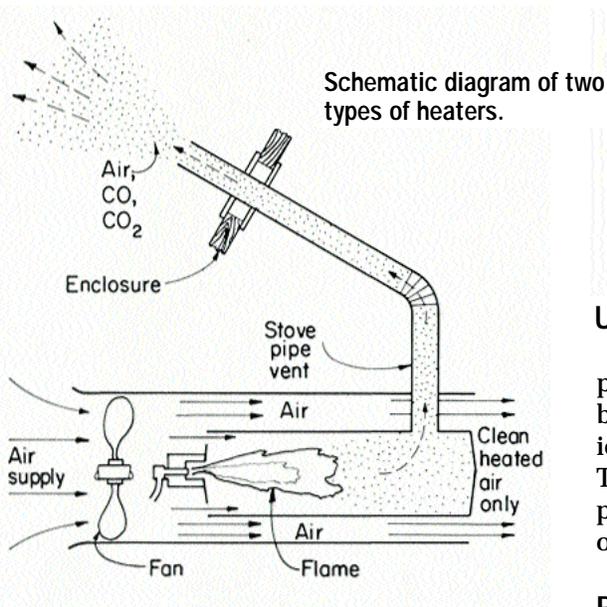
Causes and chemistry

Combustion heaters—those that burn wood, oil, gas, coal or coke—are the principal cause of soft, dusty concrete floor surfaces. Used during winter to protect fresh concrete from freezing, these heaters emit exhaust gases that contain, among other things, carbon dioxide (CO₂), which is harmful to fresh concrete. If the air is still,

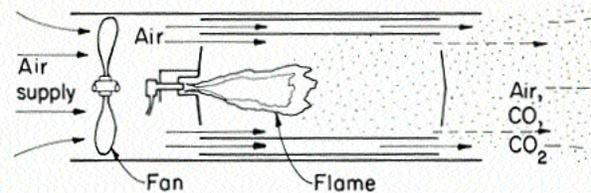
the CO₂ will settle and concentrate near the floor, rather than distributing itself evenly throughout the air, and do more damage than otherwise. Once the carbon dioxide enters the work area, it reacts with the moisture on the fresh concrete surface to form carbonic acid (H₂CO₃). This acid then combines with the hydrated lime (calcium hydroxide or Ca(OH)₂) created during the hydration of cement to form weak calcium carbonate (CaCO₃) rather than the calcium silicate hydrate that normally would be formed as a product of hydration. In normal cement paste, calcium silicate hydrate forms dense bonded aggregations between the other crystalline phases and the remaining unhydrated cement grains. It is thus chiefly responsible for the setting, hardening and strength development of cement paste. When it is replaced by weak calcium carbonate, the concrete loses strength and wear resistance.

The soft layer caused by carbonation usually develops only a fraction of an inch^{(1)*} deep at the surface of the floor; the concrete immediately below that level will not be noticeably affected. The approximate depth of the carbonation can be determined by applying phenolphthalein to a fractured face of the floor surface. The color of the carbonated layer does not change in response to

* Numbers in parentheses refer to metric equivalents listed with this article.



VENTED, INDIRECT-FIRED HEATER



UNVENTED, DIRECT-FIRED HEATER

UNVENTED, DIRECT-FIRED HEATER

phenolphthalein; the unaffected concrete below the carbonated layer, however, contains free calcium hydroxide, which reacts with this chemical to form a pink stain. This test reportedly shows the depth of carbonation, provided the moisture content of specimen is 15 percent or less (Reference 1).

Prevention

To prevent the formation of destructive carbonic acid, there are two alternatives:

- immediately sealing the fresh concrete with liquid curing membrane
- using vented heaters or other sources of heat

Curing membranes. Several authors have reported success at the jobsite by applying curing compound as soon as the concrete surface has been finished. As reported in Reference 2, the result was an “excellent and hard” surface—though the same report showed that laboratory specimens treated with curing compound and exposed to a 4.5 percent concentration of CO_2 for 24 hours were carbonated to a depth of 0.025 inch.⁽²⁾

If the intention is to produce the final surface finish by grinding, the liquid membrane could be applied as soon as the concrete is bull-floated thus reducing time of exposure to the CO_2 . The practice of grinding floors to achieve a smooth finish is a planned operation by some builders as it saves finishing time and removes surface blemishes. The early application of curing compound minimizes exposure to CO_2 ; any soft carbonate that does develop will be removed during grinding. This procedure would also minimize exposure to CO_2 fumes from a power trowel.

Vented heaters and alternative sources of heat. Use of vented, or indirect-fired heaters eliminates carbonation problems. The figure shows flow of combustion gases and fresh air in vented and unvented heaters. In a vented heater, heat is generated in a fire box that acts as a heat exchanger for the fresh air flowing over it; only warmed fresh air, free of combustion gases, is blown into the enclosure where the floor is located.

Other sources of heat can be used to avoid the carbonation problem. They include electric heaters, electric heating blankets, steam, or the permanent heating sys-



Close-up view of a severely dusted concrete floor slab scratched with a sharp instrument.

tem of a building or house. The use of straw or insulating blankets to contain the hydration heat of the concrete, but without supplying additional heat, may not be adequate to cure slabs less than a foot⁽⁹⁾ thick. When air temperatures drop below the freezing point, additional heat may be required.

What to do about surfaces that dust

If a surface has been damaged by CO₂ it can possibly be repaired by grinding or by applying a surface hardener. The grinding should be done deeply enough to remove all soft, powdery concrete and expose the harder material below.

The soft surface may alternatively be treated with a floor hardener within the first week after the floor has been cast. The longer the hardener treatment is delayed, the less successful it will be because of continued slow carbonation. Some commonly used chemical hardeners contain sodium silicate or magnesium or zinc fluosilicate. Chemical hardeners depend on the generation of Ca(OH)₂ by the cement. There usually will be some Ca(OH)₂ remaining after carbonation to react with the hardener. Also, some hardeners contain some hydrochloric acid which regenerates the soluble calcium ion.

General effects of CO₂

Carbonation of fresh concrete is considered to be a problem only for about the first 24 hours. There are no reports of research showing exactly when the danger point is past, but the consensus of technical reports is that at normal working temperatures of 50 degrees F⁽⁹⁾ or more concrete can safely be exposed to CO₂ starting about 24 hours after the concrete is mixed.

The amount of CO₂ found in normal air is on the order of 0.03 to 0.04 percent. On the other hand the CO₂ content maybe 0.08 percent near a heavily traveled expressway. The CO₂ concentration may be as high as 0.12 percent in unventilated rooms. Values as high as 4 percent have been reported near chimneys at factories where the air circulation was unfavorable. Therefore it may be wise to check the air purity with a CO₂ meter. Three percent CO₂ in the air is considered dangerous to humans and 6 percent can increase the acidity of the blood enough to cause death within an hour.

There is no reported threshold for the amount of CO₂ that will damage fresh concrete. Kauer and Freeman (Reference 2) ran tests at CO₂ concentrations of 18, 16, 10 and 4.5 percent. For the last value, carbonation was reported to a depth of:

- 0.025 inch₍₂₎ for a liquid-membrane cure
- 0.057 inch₍₅₎ for a burlap cure
- 0.075 inch₍₆₎ for a moist cure

This confirms results of other researchers that a liquid membrane curing compound or polyethylene sheet, when applied early, will significantly reduce car-

bonation. Note that some carbonation did nevertheless occur.

Flue gases from older propane-fueled heaters have been reported to contain 5 to 8 percent CO₂; flue gases from oil-burning salamanders may contain 12 to 15 percent CO₂. Some modern propane heaters rated at 4 million Btu per hour⁽⁷⁾ discharge only 0.15 percent CO₂ as determined by tests in the field.

Other effects of carbon dioxide

What perhaps has confused cement users is that carbonation has different effects on fresh concrete and on hardened concrete. While carbon dioxide has a harmful effect on fresh concrete during the first 24 hours, it has a beneficial effect on hydrated hardened concrete after the age of 24 hours. The chemical reactions of CO₂ with hydrated cement are more complex than those with unhydrated cement.

Carbonation of fresh concrete can occur to a depth of 1/8 to 1/4 inch,⁽⁸⁾ but carbonation of hydrated concrete over a period of years in natural atmosphere has been known to reach a depth of 1 inch⁽⁹⁾ or more. The progress of carbonation is affected by the permeability of the concrete and the relative humidity.

Carbonation of hardened concrete by the air has the adverse effect of causing surface crazing and neutralizing the protection of reinforcing bars against corrosion.

It is reported that the rate of carbonation of hardened concrete decreases at low temperatures and completely ceases at 18 degrees F.⁽¹⁰⁾ Researchers report the rate of carbonation to be a maximum at a relative humidity of 60 or 90 percent.

Summary

Fresh concrete floor surfaces may be damaged by carbon dioxide in the exhaust gases of unvented heaters within the first 24 hours but the chemistry is not well enough understood to explain why it happens sometimes and not others. Liquid membrane-forming curing compounds or plastic sheeting can be used to help protect the surface, thereby reducing the carbonation. Very efficient direct-fired heaters produce little CO₂ and may be effective but the effectiveness of these preventive measures is not fully understood.

The state of the art requires careful monitoring of carbon dioxide and construction operations coupled with seasoned judgment, or the use of vented heaters, if good hard concrete floor surfaces are to be built in the wintertime. 

Metric equivalents

- (1) Up to several millimeters
- (2) 0.64 millimeter
- (3) 300 millimeters
- (4) 10 degrees C
- (5) 1.4 millimeters

- (6) 1.9 millimeters
- (7) 4 gigajoules per hour
- (8) 0.3 to 0.6 millimeter
- (9) 25 millimeters
- (10) -8 degrees C

(3) Leas F. M., The Chemistry of Cement and Concrete, Third edition, Chemical Publishing Company, Inc., 1970.

(4) White, Alfred H., "Disintegration of Fresh Cement Floor Surfaces by the Action of Smoke Gases at Low Temperatures," Engineering News, Volume 62, Number 4, July 22, 1909, page 102.

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(1) Properties of Cement Paste and Concrete: Proceedings of the Fifth International Symposium on the Chemistry of Cement, Volume III, Tokyo, 1968, pages 362 and 394.

(2) Kauer, J. A., and Freeman, R. L., "Effect of Carbon Dioxide on Fresh Concrete," Journal of the American Concrete Institute, December 1955, page 447. Discussion: Journal of the American Concrete Institute, December 1956, Part 2, page 1299.

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