TECH Data

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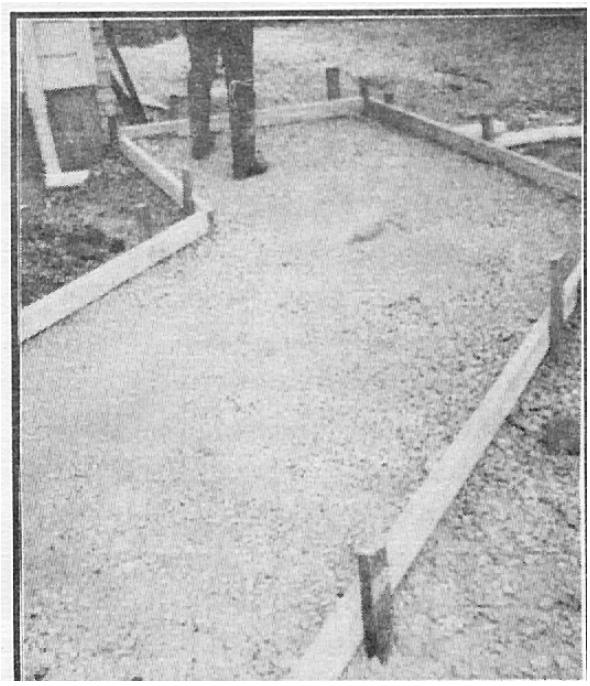
CONCRETE MOTTLING-DISCOLORATION

This TECHdata paper addresses concrete mottling-discoloration. Mottled concrete is irregular shapes of different shades of white-gray to gray-black. These blotches are restricted to the surface, normally only 1/32" to 1/8" deep. They can diminish over time but usually are permanent. The concrete is almost always sound and meets specification. The cause of mottling is the result of interaction between the concrete and its environment while it transitions from the plastic to hardened state. Mottling is a rare but unsightly occurrence. This paper will give a guideline to limit mottling.

SUB-GRADE

The sub-base is very important, but an often overlooked area, when it comes to mottling-discoloration. If the sub-base is non-uniform, the moisture from the concrete will be absorbed into the sub-base at different degrees. This causes different water/cement ratios within the concrete slab. As the concrete sets, the concrete will be darker at the lower water/cement ratios and lighter in the areas where the water/cement ratios are higher. This will cause a mottling effect on the concrete surface.



There are three areas of concern for non-uniformity of sub-bases that will cause the slab to discolor due to different water/cement ratios. One, it is critical the sub-base be uniform in its composition. For example: when 3/4" minus aggregate is used, there should not be areas that are finer than others. Two, the thickness of the sub-base must be uniform, and three, that it is leveled so the concrete will be the same thickness.

Any discrepancies in these three areas can cause the slab to be mottled-discolored. The key is to be uniform.

WATER CEMENT RATIO

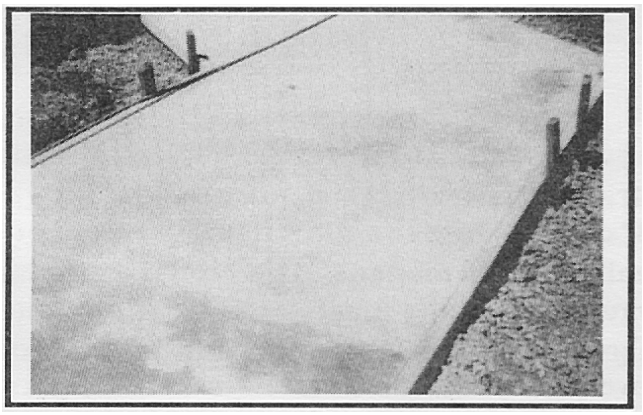
One of the more common causes of color variation in a concrete slab is variable water cement ratio. When a well mixed load of concrete arrives on a job site, the water cement ratio is very consistent. The question therefore, is how does the water cement ratio in the slab become inconsistent? There are many ways this can happen.

Discoloration most commonly occurs in residential slabs. When a load takes a long time to place, water is often added more than once during the unloading process. Each time water is added, the water cement ratio increases. More simply put, the amount of water in the concrete compared to the amount of cement in the concrete increases each time water is added. This problem can be compounded if the added water is not mixed in thoroughly. If the water cement ratio in the placed concrete varies, then the color of the slab will also vary. The best way to avoid this problem is for the dispatcher to communicate with the contractor to ensure the desired slump arrives on the job.

Many producers batch all loads at a 4" slump or less. In this case, it is important that the driver ask for the desired slump before placement begins. The driver should at this point record added water on the delivery ticket and mix the load 15-20 revolutions for late model clean drums and 30 revolutions for older drums. Concrete buildup in the drums should be kept to a minimum. Finally the crew should be able to place the entire load without adding water. As in all concrete operations, uniformity and consistency is a must.

FINISHING

Uniformity and consistency apply to all phases of concrete construction and finishing operations are no exception. Effective communication with your concrete supplier and good planning before the job starts are keys to smooth concrete placements. When the supplier, finisher and contractor have effectively planned a concrete placement, finishing and curing usually go at a consistent even pace. This will result in a slab that is of uniform color and texture and usually saves time for all parties involved. Lack of planning or too small a finishing crew can cause parts of a slab to be too hard



or soft for the next finishing operation. Spraying water on the surface will cause color variation as will burning certain areas with steel trowels. Anything that causes the concrete placement to proceed at an uneven rate has the potential to cause uneven color. Even differences in shaded and sunny areas can potentially cause areas of variable color.

CURING

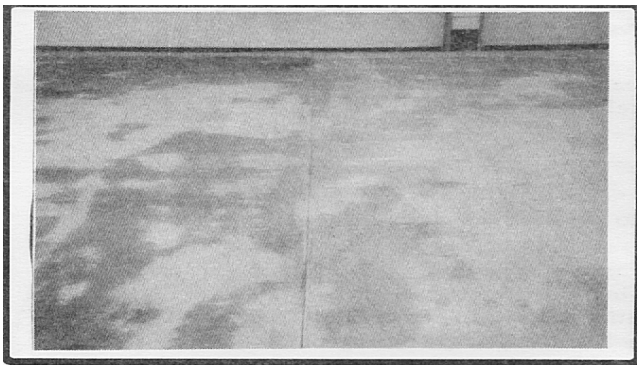
Curing is another area often neglected, especially when the weather turns cool and there is a lot of moisture in the air. It may be ideal concrete conditions, but that doesn't alleviate the need to cure the concrete. The American Concrete Institute in ACI 332, Residential Concrete, paragraph 10.1 states: "Properly mixed, placed, and finished concrete also requires proper curing. This involves preventing loss of moisture from the concrete and maintaining a temperature in the concrete-40° to 90° F (4° to 32° C) - suitable for maturing of concrete. Favorable curing conditions should be maintained as long as practical. Three to five days is considered minimum requirements for summer conditions. In the winter, favorable curing conditions should be maintained longer."

Air curing does not prevent evaporation and is not effective in preventing mottling or discoloration. Air curing causes uneven moisture loss from the concrete surface. Areas where moisture loss is greater will be darker than in areas where there is less evaporation.

Curing procedures that are most efficient in preventing evaporation from the entire concrete surface also produce the most uniform slabs. When using curing compounds, be sure to follow the manufacturer's recommendation for the correct amount to use. DO NOT FORGET TO CURE!

Polyethylene film curing will assist in moisture retainage but is also a cause of discoloration by creating the “greenhouse effect". Careless placing of plastic curing film on the surface of flatwork concrete containing calcium chloride may cause unsightly efflorescence deposits in addition to mottling discoloration.

A high ridge (any area that is not in contact with the concrete surface) in a waterproof curing sheet can serve as a little "greenhouse."



On any sunny day, the ridge becomes the location of a water evaporation-condensation cycle. The heat of the sun, aided by the heat of hydration of the concrete, evaporates water from the concrete under the ridge. The water vapor then condenses on the cool high part of the ridge and eventually runs down the sides of the film to collect at points of intersection of the concrete and film, or in low places in the concrete surface. Such localized dry and wet areas on a fresh concrete surface may cause concrete discoloration.

CEMENT CHEMISTRY

Cement is made up of many chemical compounds that in the hydration process, in rare cases, could cause mottling.

Tetracalcium aluminoferrite (C_4AF) reduces the clinkering temperature, thereby assisting in the manufacture of cement. It hydrates rather rapidly but contributes very little to strength. Most color effects are due to C_4AF and it's hydrates.

Unhydrated ferrite phases (iron compounds) in cements are blackish brown. They are primarily responsible for the dark color of unhydrated cement. Hydration lightens their color.

Thus lightening of the ferrite phase by hydration is apparently the major cause of cements and concretes becoming lighter in hue as they hydrate.

CALCIUM CHLORIDE AND REACTION WITH CEMENT

Calcium Chloride is an established accelerator" that speeds up the hydration of the silicates in cement. However, calcium chloride *retards* the hydration of the aluminate and ferrite phases in cement.
Retarded ferrite phases that remain unhydrated in cement will remain dark.

Cement Alkalies moderate the actions of calcium chloride in concrete, and will reduce the retarding effect calcium chloride has on the ferrite (iron) phase. However, high alkali cements alone tend to promote mottling.

Two major types of mottling discoloration can result from the interaction between cement
alkalies and calcium chloride, or from the separate effects of these two components:

Light spots on a dark background - characteristic of mixtures in which the ratio of cement alkalies to calcium chloride is relatively low.

Dark spots on a light background - characteristic of mixtures in which the ratio of cement alkalies to chlorides is relatively high.

In addition to the initial ratio of these two factors, certain aspects of placing, finishing and curing affect the cement alkali and calcium chloride ratio and thus influence the type, degree, and location of mottling discoloration.

Whether an area will be light or dark depends upon the amount and degree of formation and deposit of alkali chlorides and alkali carbonates at the surface, and upon the hydration of the ferrite phase in the particular area. Use non-chloride accelerators when mottling or surface discoloration is a concern.

Tech Tips

- Sub-grades need to be uniform in depth, coarseness and moisture
- Water cement ratios must be consistent through the concrete placement
- Communication and pre-planning of all parties is essential
- Proper curing is crucial
- Care should be used when using calcium chloride as an accelerator

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