PCI PRECAST/PRESTRESSED CONCRETE INSTITUTE
TECHNOTES
TN-2

REFLECTION OF REINFORCING STEEL

Reinforcing steel in some finishes may show up as light shadow lines usually directly over the steel depending on mix, vibration of reinforcement, placing, etc. In a few cases, a dark shadow pattern is displaced from the steel above. In order to modify manufacturing procedures to eliminate shadow lines, it is necessary to understand the possible causes.

Using intermediate or high vibration frequencies (6000 to 12000 vpm) with low amplitude (less than 0.005 in.), only the fine particles in the mix are agitated. These fine particles (material passing No. 4 sieve) move rapidly and independently of each other giving the mix mobility and providing a paste coating over the larger aggregates. No displacement or disturbance of the larger aggregates occurs. On the other hand, although effective on stiff, dry mixes, low frequency and high amplitude consolidation agitates the coarser aggregates, causing excessive mobility in the mix and a tendency to segregate.

During high frequency vibration of concrete, the agitation is much more vigorous near the surface of the form under the steel. The agitation tends to cause greater concentrations of cement or fine particles of the aggregate at the form interface under the steel. These fines scatter light better and tend to give the area a light color. This is, therefore, only a "skin deep" change in the concrete. However, the lighter concrete skin is likely to be less dense and have a higher water absorption. The concrete beneath the steel surface at the ghosting is the same as the balance of the concrete. In some cases, the light and dark zones representing the zone of influence of vibration may be reversed. This type of shadowing may be related to lack of compaction in areas where steel concentrations prevent full vibration of the covering concrete. This ghosting problem may be aggravated by excess form-release agent being folded into the surface of the concrete during vibration. This folding motion will be greater under mesh wires or reinforcing bars.

Displacement of the shadow from the reinforcement pattern, with a resultant darker grid outline, may occur with low frequency vibration. The intersection of the longitudinal and transverse steel may be centered in the shadow area rather than directly below the shadow lines.

Steel reflection may be more likely to occur when minimum cover is used over the steel and a rigid steel cage is used. The cage will vibrate as an assembly in phase (resonates) during the intense vibration used to compact the low-slump concrete of precast concrete. Welded wire fabric or tack welding of steel will stiffen the steel cage and is more likely to produce reflection. Tied steel assemblies should not have this problem.

The following are approaches to alleviate shadowing:

❶ High frequency rather than low frequency vibration should be used.

❷ Reduce fines by 5 percent or to minimum necessary to obtain desired finish.

❸ Cages should be tied and not tack welded to reduce rigidity.

❹ To avoid settlement of the steel reinforcement with consequent loss of steel cover, it would be expedient to use chairs or suspend steel from above. If external vibration is used, steel support should be isolated from the mold by rubber pads to prevent vibrations being transmitted into the cage.

❺ Increase cover on the steel to 2 to 2 1/2 in. If the shape of the panel or the type of mix allow, a 2 in. (preferable) layer of low slump concrete (slump as low as can be reasonably compacted) should be placed and consolidated without the steel in place. Then place steel and the balance of the concrete. If chairs are not used, the 2 in. layer of concrete should be allowed to stiffen (adequate bond must be obtained between concretes) until the initial lift is capable of keeping the steel grid from settling. When vibrating the top layer of concrete, care must again be taken to avoid vibrating the steel. If internal vibration is used, extra care must be taken to avoid vibration of the steel caused by touching the cage with the vibrator.

If shadowing does occur, sandblasting with the smallest available gun and nozzle and using fine grit can reduce the reinforcement outline to a reasonably uniform tone. However, portions of the surface immediately over the reinforcement may be less dense than areas away from the reinforcement, making it extremely difficult not to over-erode the surface over the reinforcing steel.

Another cause of steel reflection on the surface of a panel is the use of galvanized reinforcement and/or the use of galvanized and nongalvanized reinforcement together in fresh concrete unless the steel surface of the galvanized reinforcement is passivated.

The reactions of zinc in concentrated alkaline material (concrete prior to setting has a pH of 12.5 to 13.5) liberate hydrogen gas, forming bubbles of gas at the zinc coated surface during initial stages of hydration. These bubbles or voids may cause local porosity of the concrete and increase the water absorption of the concrete over the steel resulting in steel reflection.

When galvanized and nongalvanized reinforcement or steel forms are in contact in fresh concrete, galvanic cell problems may arise during the initial processes of hydration. An electrochemical reaction occurs in which zinc is consumed to form either zincate ion or zinc hydroxide on the anodic galvanized steel, and hydrogen gas may be liberated on the cathodic nongalvanized steel or locally on cathodic areas of the zinc. This reaction tends to be more active where there is a low ratio of galvanized surface area relative to nongalvanized steel surface area, or when the fresh concrete is more strongly alkaline as with cements containing considerable free alkalies, and where cement and other concrete constituents are low in chromate ion. In this case, rows of hydrogen bubbles may form along nongalvanized reinforcement in contact with galvanized welded wire fabric, or occasionally on smooth black steel form surfaces resulting in steel reflection.

Although not a steel reflection problem, discoloration or surface distress may occur with some form oils or mold release agents (for example, a neutral oil with 10 percent fatty acid, which may not function effectively), and concrete may stick in places to the black steel form if galvanized steel is in electrical contact with the form surface. Form oils such as the one described utilize a negatively charged polar chemical which is attracted to positively charged anodic steel surfaces and holds the oil film to the steel. The black steel becomes cathodic or negatively charged by contact (galvanic coupling) with the galvanized steel. The polar compound is repelled by the like charge, and the form oil does not efficiently wet or cover the steel form so concrete sticks to the form.

All of these galvanizing problems may be prevented by passivating the surface of the galvanized steel reinforcement by using a chromate treatment or by adding chromic oxide to the concrete mix. This inhibits reaction between zinc and the alkalies of the concrete. Chromate coating of galvanized surfaces can be readily done in most galvanizing plants and consists of either dripping the galvanized elements for 10 to 20 seconds in an aqueous solution having 150 gm per liter (20 oz per gallon) of potassium or sodium dichromate and 5 to 10 cc per liter of sulfuric acid with a sp.gr. 1.84 or in a 5 percent chromic acid solution. At the precasting plant brushing or spraying with 0.3N potassium dichromate ($K_2Cr_2O_7$) + 0.4N nitric acid (HNO_3) and then rinsing with water passivates the galvanized steel and suppresses hydrogen liberation. The addition of chromium trioxide (at a pH level of 12.5, chromium trioxide is reduced to CrO_3-chromic acid anhydride) to the concrete mix (150 parts per million based on weight of mixing water or about 8 oz of a 10 percent solution per cu yd of concrete) may also be effective in eliminating reflection of steel and sticking of concrete. Portland cements in the U.S. contain an average of 52 ppm of CrO_3 based on weight of mixing water per cu yd of concrete with a range of 10 to 156 ppm. Therefore, some cements may have adequate chromium to passivate the surface of the galvanized steel and prevent the problems. *Precautions in handling concrete containing chromic acid (as CrO_3) are necessary to avoid dermatitis and chromic acid is considered to be a potential carcinogen.*

Weathered or aged galvanized steel is less susceptible to the problems described, since the zinc is less active.