Are They Pour Lines Or Cold Joints?

When contractors detect pour lines on exposed concrete surfaces, they need to look beneath the surface to determine the implications.

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Unanticipated cold joints in concrete structures occasionally plague contractors, even though superplasticized concrete mixes and a wide range of vibrating equipment and techniques are available. But when a visible pour line is found on an exposed concrete surface, it doesn't always mean a potentially troublesome cold joint is present.

Fortunately, there are several testing methods that can be used to evaluate whether surface lines are just noncritical surface imperfections or signs of significant structural defects. By making this determination, engineers and contractors can more accurately assess the impact on the concrete’s structural integrity, function, and durability.

Pour Lines vs. Cold Joints

Both pour lines and cold joints are common in concrete construction, but cold joints have more serious consequences. Pour lines are “dark lines on the formed surface at the boundary between adjacent batches of concrete” and typically “indicate that the vibrator was not lowered far enough to penetrate the layer below the one being vibrated” (Ref. 1). Cold-joint lines, on the other hand, indicate “the presence of joints where one layer of concrete had hardened before subsequent concrete was placed” and are typically revealed by “visible lines on the surfaces of formed concrete” (Ref. 2).

To even a trained eye, the distinction between the two conditions is usually not apparent at the concrete surface. To the engineer, a surface line may indicate an unanticipated cold joint and a weakened plane for shear and tension. To the contractor, this surface imperfection may only be a pour line that will behave as if the concrete were monolithic, and the flaw can be dismissed as structurally unimportant.

The first step in evaluating a surface line is realizing that the important information does not lie at the surface. Core samples must be removed from representative locations within the structural element under consideration.

Evaluating Core Samples

Core samples should coincide with the surface line and be located such that the surface line is at the center of each core, as shown in Figure 1. Then each core must be visually examined and tested.

Visual examination of core samples should be performed both by the unaided eye and by microscope. First, visually examine each core to determine how far the line extends beyond the surface. In many instances, surface lines are caused by inadequate consolidation between the outermost reinforcement layer and the formwork and are limited to the cover concrete. In these instances, the defect is essentially aesthetic, except in cases where durability is a concern. If the surface line continues significantly beyond the surface, as shown in Figure 2, the interface between successive lifts along each core requires examination. A rough surface with some aggregate protruding between lifts and no voids or spaces at the interface indicates a pour line and not a cold joint, as shown in Figure 3.

Microscopic examination consists of sampling portions of each core and constructing thin sections for examination under a stereomicroscope. Ideally, the thin sections will be oriented with the interface along the center, allowing the greatest amount of adjacent material on each side of the line to be studied. A petrographer should examine the thin sections to identify evidence of carbonation, drying, or changes in paste microstructure along the interface. The presence of these conditions indicates a possible cold joint; a lack of them indicates that the interface is most likely a pour line. Carbonation...


**Figure 2.** Visual examination of the core sample reveals how far the line extends beyond the surface.

**Figure 3.** Signs of a pour line: Interface exhibits a rough surface with aggregate protruding between lifts and no voids or spaces.

Generally appears as a thin film detectable only with a microscope, even in a distinct cold joint. Signs of drying include microcracking perpendicular to the interface surface and/or a locally lower water-cement ratio in one layer near the interface.

Another step in core evaluation consists of performing split-cylinder tests in accordance with ASTM C 496-96 (Ref. 3). Cores must be tested with the pour line or cold-joint line oriented vertically at the center of the test machine, as shown in Figure 4. If the line does not coincide with the anticipated vertical failure surface due to an appreciable variation from the center, the test result for that core can’t be used to evaluate the tension capacity of the interface.

In addition to obtaining the split-cylinder test values, investigators should examine the fracture patterns visually. Numerous fractured aggregate particles and a roughened, fractured paste surface indicating adhesion along the failure plane are signs of monolithic concrete, not a cold joint.

The specimen’s splitting tensile strength can also be compared to the expected splitting tensile strength for concrete with the contract-specified compressive strength. ACI 318-95 (Ref. 4) and Neville (Ref. 5) present the necessary relationships between concrete compressive strength and splitting tensile strength. A statistical evaluation of the tensile test values will predict the lower-bound value, which is then compared with the expected strength of monolithic concrete. If the value exceeds the expected strength, the strength of the in-place material is considered acceptable. If this value falls below the expected strength, structural implications should be investigated.

Following are two case histories that illustrate how to apply these core test methods to real-world construction problems.

**Case Histories**

**Unnecessary grade-beam removal.** At a Texas prison, 600 linear feet of concrete grade beam were removed based only on a visual inspection of the surface, which showed a defect resembling either a cold joint or pour line (Figure 5). But the decision to remove these grade beams based solely on the limited visual survey was a mistake, as we later discovered.

The project contractor enlisted our services to determine whether it had indeed been necessary to remove the beams. Investigators inspected the concrete surfaces and removed 18 randomly selected cores at the level of the suspected cold joint for testing and visual examination. Split-cylinder test results ranged from 340 to 535 psi with a mean of 445 psi and standard deviation of 68 psi.

A statistical evaluation of these results indicated a 95% probability that the true population average was equal to or greater than 410 psi and that no single value would be less than 300 psi. Expected splitting tensile strengths for the contract-specified concrete compressive strength ($f_c$) of 3000 psi are approximately 200 to 275 psi, or less than the values indicated.

Furthermore, the fracture patterns had numerous fractured aggregate particles and a roughened paste surface, indicating adhesion along the failure plane. This is a sign of monolithic concrete, not a cold joint.
aggregate particles along the failure plane. A few specimens exhibited small areas lacking adhesion along the failure surface. Though this condition probably reduced the split-cylinder strengths, the values still exceeded the expected value for concrete with a 3000-psi compressive strength. Therefore, the in-place concrete at the pour line would have performed at least as well as monolithic concrete with the specified compressive strength of 3000 psi.

We also investigated the grade beams, assuming that their performance at the pour line would be somewhat less than monolithic concrete. The grade beams were evaluated as composite sections for horizontal shear transfer across the pour line. In accordance with ACI 318, the horizontal shear was transferred through a shear friction mechanism. The required coefficient of friction for a shear friction transfer mechanism was calculated and compared to what could conservatively be expected at the pour-line region. In all cases the capacity exceeded the required strength.

**Surface defect on a reinforced-concrete wall.** At a Massachusetts stormwater-runoff management facility, concern was raised after removal of formwork along 100 lineal feet of reinforced-concrete wall revealed a surface defect resembling either a cold joint or pour line (Figure 6). The contractor enlisted our firm to examine the defect. Investigators inspected the concrete surfaces and removed randomly selected cores at the level of the suspected cold joint for testing and visual examination.

Visual inspection of the core samples indicated that the concrete was well-consolidated, with no evidence of cold joints along the pour-line areas. The line had a rough surface, with some aggregate protruding between lifts and no voids or spaces at the interface. There were some areas of isolated honeycombing, but they were located within the cover concrete and judged as minor and easily repairable.

Split-cylinder test results ranged from 380 to 460 psi with a mean of 410 psi. A statistical evaluation of these results indicated a 95% probability that the true population average was equal to or greater than 390 psi and that no single value would be less than 330 psi. Expected split-cylinder strengths ranged from 250 to 315 psi for the contract-specified concrete compressive strength ($f_c$) of 4000 psi. Thus, based on the visual observations and results of the test data, the in-place concrete at the pour line would perform at least as well as monolithic concrete with the specified compressive strength of 4000 psi.

**Remedial Alternatives**

As the case histories illustrate, core testing and visual examination are relatively simple to implement and can save both time and money on a construction project. It's important to note, however, that cold joints may not seriously affect the performance of a concrete element, depending on the element's structural demands and service conditions. Even when testing and inspection indicate that a surface line is indeed a cold joint, each specific occurrence must be investigated to determine if the cold joint reduces the structural capacity below the structural demand of that particular element. If the structural capacity does not meet the demand, remedial repairs should be investigated as financially viable alternatives to complete concrete removal and replacement.

**Figure 5.** Saw operator removes grade beams for a Texas prison after visual inspection revealed a defect resembling either a cold joint or pour line. Core testing later determined that beam removal was unnecessary.

**Figure 6.** Core tests revealed that this surface defect in a reinforced-concrete wall was only a pour line and that the concrete would meet performance demands.
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