Can You Pass the Strength Panel Test?

By Oscar Duckworth

Often Overlooked Requirements That All Nozzlemen Need to Know

Author's note: The purpose of this article is to provide insight on the proper placement and care of test panels required for strength development testing only. *Test panels are used in a number of varying situations, and it is important to note that this article does not address the particular concerns for all panels shot for other purposes. Although practices presented within this text should not be overlooked, test panels shot for core grading purposes, such as for the ACI Nozzleman Performance Evaluation, require far more discussion of nozzle techniques than could be responsibly covered in this article. This topic will be covered in a future Nozzleman Knowledge article.*

Nearly everyone in the shotcrete industry is familiar with test panels. To the shotcrete professional, it is simply a compulsory ritual of our daily routine. We shoot the panels, cores are extracted from panels, and the cores are tested for strength compliance. Numbers are always good. But what if something goes wrong? Do the nozzleman and crew share responsibility for strength values?

Many shotcrete workers possess little knowledge about the proper handling and storage of a typical test panel. Casual research seems to indicate that most workers know that, once shot, panels should not be moved…or dropped.

How much do you actually know about the proper care of a typical test panel? Are you confident that you are currently creating and handling test panels in an approved manner? If not, don't worry. A few low-strength test panels are sure to draw plenty of attention to your company's test panel protocol.

"Produce a material test panel for each mixture and each work day or every 50 yd^3 (38 m^3) placed, whichever is less." (Typical specification)

Studying for the Test Panel Test

Experienced shotcrete craftsmen know that the ultimate quality of in-place shotcrete is largely dependent on the skill and knowledge of the placement crew. Shotcrete must be carefully placed, consolidated, and cured to gain its full design strength. When we shoot the test panel, placement techniques and materials should mirror the in-place work. Many times after a test panel is shot, however, it is generally forgotten. Mishandling, improper storage, or insufficient curing can result in test panels with less than half their strength potential. When test results come up low, it can be difficult to determine if low core strengths are caused by poor test-panel shotcrete placement, handling practices, or other factors.

"Using techniques that assure a repeatable standard of care for each test panel should be a component of every shotcrete worker's education program."

Test panel placement, early-age handling, and protection techniques are crucial to allow the maximum strength development of shotcrete test specimens. But many shotcrete workers lack specific knowledge about these important practices. Currently, various ACI and ASTM documents provide guidance on the proper care, handling, and storage of shotcrete test panels.

The First Step: Correctly Shoot the Panel

Any test panel used to determine a shotcrete mixture's compliance with job specifications should closely match the actual placement condition. This is one of the reasons we derive strength data from cores extracted from test panels rather than cast concrete cylinders. If a mixture is to be pneumatically applied, the mixture's properties should be tested following placement by the same procedure. Unfortunately, the act of shooting a test panel may introduce unexpected variables that can dramatically affect test results. A nozzleman who is responsible for shooting a test panel must be able to correctly place material in a manner that will not significantly alter its hardened properties.

Poorly shot panels are susceptible to various internal flaws that will negatively affect strength. Similar to other difficult-to-shoot areas, placement of the test panel requires precise nozzle techniques to attain satisfactory results. Skilled nozzlemen are aware that the size of the test panel

Fig. 1: Poor placement techniques have produced sand lens or encased rebound trapped within test specimen

Fig. 2: Nozzleman initially places material into the panel's lower corners while close in

Fig. 3: As the panel fills, the nozzleman adjusts the angle and backs away to avoid displacing in-place material. Note continuous use of a blow pipe

affects placement difficulty. This is primarily due to the placement accuracy required to fill small elements. Nozzle orientation, angle, material volume, air flow, slump, and blow-pipe techniques become more critical when filling small areas.

Whereas nozzle velocity is a primary element in material consolidation and compaction, excessive velocity can shove, displace, or fold material when placing a test panel. Poorly chosen placement angles, distance, or incorrect nozzle flow can disturb in-place material within the panel. Internal cracks, voids, laminations, or sand lenses can result. Additionally, because test panels have formed perpendicular edges, the potential for trapped rebound pockets or sand lenses within the in-place material can intensify if panels are not placed skillfully (refer to Fig. 1).

Prior to placement of any test panel, nozzlemen should ensure that the panel is sufficiently rigid to withstand placement pressures without movement. Nozzlemen should reduce placement volume and make other material adjustments before shooting the panel. Adjust placement equipment to attain a smooth, controllable nozzle flow that is free of slugging or air bursts. Due to the panel's size, steady filling, free of irregular, high-energy bursts of material, is crucial to producing a test specimen that is properly consolidated. Initially, come close and direct the nozzle flow into the lower corners and then build from the bottom. When shooting wet-mix shotcrete with a coarse aggregate, use a blow pipe to keep the receiving surface free of rebound or loose sand. As the panel fills, back away slowly to keep excess energy from disturbing previously placed material within the panel until it reaches its full thickness (refer to Fig. 2 and 3).

If a nozzleman is unsure of the placement quality of material within a panel, it should be cleaned out and shot again.

After placement, do not trowel, sweep, or otherwise work the shotcrete surface. Movement by troweling can bring water to the surface or disturb the test panel's compaction and consolidation. Never allow panels to be worked, troweled, or finished. This unnecessary step can affect strength values. Specifications require that after panels are cored, ends of the cores will be prepared for uniformity by the testing facility.

Next Step: Do Not Disturb

Moving a freshly placed test panel will never increase its strength; however, it can certainly diminish it. Like any concrete, freshly placed test panels are extremely susceptible to damage from external sources. Movement or large temperature fluctuations will influence panel integrity. Early-age shotcrete has not developed sufficient strength to withstand handling or thermal stresses during the first 24 hours or more. Test panels should always be positioned and shot in a location where they can remain *undisturbed and protected from the elements* for 24 hours or more.

Moisture's Influence on the Test Panel

Shotcrete does not harden by drying; it hardens by a complex chemical reaction called hydration. Moisture is required for the hydration process to occur. With time, shotcrete will grow progressively stronger if sufficient moisture is available for hydration (refer to Fig. 4). If internal concrete moisture drops to below roughly 80%, hydration will stop and concrete will no longer continue to gain strength.

ACI and ASTM specifications require that "The test panel shall be kept moist and at 70 ± 10°F (21 ± 5°C) until moved to test laboratory. The panels shall be covered and tightly wrapped (as soon after fabrication as is safe to prevent damage) with a sheet of material to prevent evaporation of water from the material."

Test panels left unprotected are subject to excessive moisture loss that can disrupt hydration and slow strength development. Low or erratic test values can occur anytime exposure allows panels to lose a significant amount of moisture. Curing practices implemented by the nozzleman and placement crew are crucial to the strength development of shotcrete test specimens.

After test panels are moved to a testing facility, they are stored under carefully controlled conditions within a "moist cabinet or room." Specifications require a temperature of 70 to 77°F (21 to 25°C) and a relative humidity of not less than 95% be maintained to diminish curing variables that may reduce strength development during storage. Unfortunately, panels kept within ideal conditions at the lab will not reverse damage to the panel caused by improper handling or curing practices at the job site during the critical initial hours.

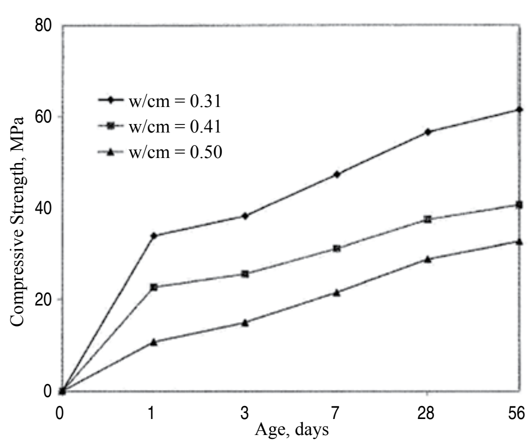

Fig. 4: Development of compressive strength of concrete with different w/cm *(RHA content = 10%) (Originally from Fig. 2-4 of ACI 232.1R-00 [Zhang and Malhotra]) (Note: 1 MPa = 145 psi)*

Summary

Actions of the nozzleman and shotcrete crew have a powerful influence on the strength development of specimens drawn from a shotcrete test panel. Training and education are required to diminish strength-test variables. A training program that draws attention to approved methods of creating, handling, and the proper care of shotcrete test panels is absolutely necessary to attaining representative strength values. Using techniques that assure a repeatable standard of care for each test panel should be a component of every shotcrete worker's education program.

References

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