Quality Control Testing of Lightweight Insulating Concrete

By Karl A. Schaack, P.E., RRC

Lightweight insulating concrete fill, like many other components of the roofing assembly, is "manufactured" and installed in the field. Maintaining proper procedures during the batching and installation processes is essential to achieving the desired performance characteristics of the lightweight insulating concrete. Several testing procedures can be implemented during and/or after the placement in order to evaluate the properties of the lightweight insulating concrete. Wet density, fastener pull-out resistance, compressive strength, and dry density are some of the common physical characteristics determined by testing. These test procedures not only evaluate the quality of the lightweight concrete fill but also determine the adequacy of the lightweight concrete for receiving the new roof assembly.

Photo 1: A 10-quart steel pail is commonly used for the "pail test."

Photo 2: A steel vessel of known volume attached to a balance scale may be used to determine weight.

Wet Density

Determination of wet density is performed during the placement of the lightweight insulating concrete. The wet density should be determined at various times during the day as the lightweight insulating concrete is being batched and placed. The wet density should be measured at both the hopper and the point of placement. Wet density can be determined simply by placing the batched mixture in a steel container of known volume and weighing the filled container. By knowing the weight and volume of the filled container, one can calculate the wet density of the mix. A steel pail with a volume of 10 quarts is commonly used by deck applicators for performing this procedure (see *Photograph 1*). The 10-quart container equals 2-1/2 gallons or 1/3 cubic foot. After completely filling and obtaining the weight of the filled 10-quart container, multiply the weight by three to provide the weight per cubic foot or the wet density. Independent testing laboratories have a specific apparatus for determining the field density of the concrete. This apparatus consists of a steel vessel of known volume attached to a balance scale to determine the weight (see *Photograph 2*). The wet density is then calculated similar to the "pail method" described previously.

Wet density found to be greater than the specified range usually means too much cement is being used in the mix. With wet density below the specified range, the probable cause would be use of too much water. The sample of the lightweight insulating concrete used for testing purposes should be considered representative and not be collected at the beginning or at the end of the placement operation. If batching and placement methods are terminated and restarted during the workday, it is imperative that the wet density be verified when the operations are resumed.

For cellular concretes, the density of the foam should also be verified at regular intervals. The density of the foam is also checked by weighing a full container of known volume (10-quart pail). The foam density, therefore, is the weight of the foam divided by the volume of the container. During the batching process, the foam is introduced into the concrete via a manually-operated, trigger-actuated hose apparatus. Since this process depends on the experience of the operator, the rate of foam discharge from the apparatus should be measured. Again, this process simply involves discharging the foam into a container of known volume and determining the time required to fill the container.

Different types of scales can be employed to weigh the pail used to verify the densities of the foam and/or lightweight insulating concrete. Either platform or spring tension scales can be used. Platform scales are typically more accurate but more diffi-

Photos 3 and 4: A spring-type (fish) scale (left) and a custom-fabricated sheet metal holding clamp (right) may be used for pull-out resistance tests on base sheet fasteners.

cult to keep clean in the field. The spring tension scale is more portable and can also be used to perform pull-out resistance tests for the base sheet fastener.

Field Density

The field density should be verified to determine when the lightweight insulating concrete has "cured" to a point that it is suitable to receive the new roof. A common rule of thumb used by field personnel is, "If foot traffic does not leave impressions (footprints) in the lightweight insulating concrete, then the concrete is suitable to receive the new roof." However, there are more accurate and scientific test methods to evaluate the suitability of the concrete.

Fastener pull-out resistance is a relatively "quick" test to determine if the concrete has reached an adequate "age" in order to install the new roof. The fastener proposed for use in the new roof assembly should be tested in several random locations throughout the subject area. A typical test frequency is approximately four tests per 100 squares of monolithic pour. It is recommended that additional tests be performed on individual roof elevations or independent pours at the same elevation. The minimum pull-out resistance that is commonly required by membrane manufacturers for the split shank fastener is 40 pounds. When a minimum pull-out resistance of 40 pounds can be achieved, both deck and roof membrane manufacturers recommend that installation of the new roof can begin. This time frame is typically two to four days after placement, depending on the type of lightweight insulating concrete, substrate, and climatic conditions.

Care should be taken if evaluation of the lightweight concrete is determined by only performing pull-out resistance tests on fasteners. The concerns are twofold:

1) When the tests are usually performed, the concrete has not reached 28 day strength; and
2) Galvanized steel fasteners reportedly can gain additional pull-out resistance as a bond develops between the calcium hydroxide in the Portland cement and the zinc oxides in the galvanized coating on the legs of the steel fastener.

Consequently, the pull-out values can increase in time due to these factors.

The pull-out resistance test for base sheet fasteners can be performed using rudimentary tools. These tools include a spring-type (fish) scale (commonly purchased in a hardware/sporting goods store) and a custom fabricated sheet metal holding clamp (see *Photographs 3* and *4*). The scale should have a range of 0 to 100 pounds with one-pound increments. Although considered to be somewhat less than scientific, this method can provide the user with the relative quality of the lightweight fill.

A more sophisticated and reliable piece of equipment is a hand-operated tensile tester that is specifically engineered for pull-out strength testing of fasteners (see *Photograph 5*). Comten Industries of Petersburg, Florida manufactures several types of these test stands. Two types of hand-operated testers are available. The "Series 301" tester has an analog read-out and the "Series 341" tester has a digital read-out. A motorized digital fastener tester ("Series 381") is also available.[1] These testers are commonly utilized for testing screw-type fasteners. Both rigid steel and "flexible fabric" lifter feet are available for specifically testing base ply fasteners and the stress plate (see *Photograph 6*). The flexible fabric lifter foot was designed to mimic the actual movement of the base sheet and membrane as it pulls on the fastener during uplift. A national standard, ANSI/SPRI FX-1, was developed by SPRI to provide guidelines for performing pullout tests.[2]

Another easily performed test to verify the density of the "cured" lightweight insulating concrete uses a hand-held penetrometer. The penetrometer commonly utilized is one that is designed for performing field and laboratory evaluations of initial set of concrete mortars. This testing apparatus is comprised of a hand-held cylindrical tool (7 inches long x 3/4-inch diameter) with a circular probe measuring 1/20th square inch of surface area. This piece of equipment is manufactured by ELE International/Soil Test Products Division of Lake Bluff, Illinois and classified as a "Concrete Mortar Penetrometer." The test involves pushing the shaft of the penetrometer into the lightweight insulating concrete (see *Photograph 7*). The tool has a direct read scale on a range of 0 to 700 psi. A reading is obtained from forcing the shaft into the concrete at a constant rate to a known depth, approxi-

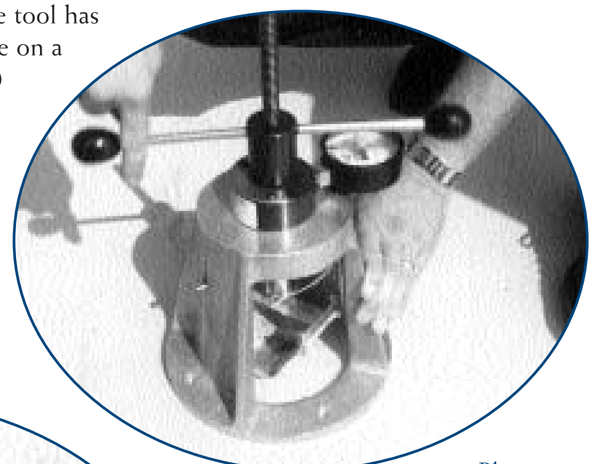

Photo 5: A hand-operated tensile tester is a more reliable piece of equipment for pull-out strength testing of fasteners.

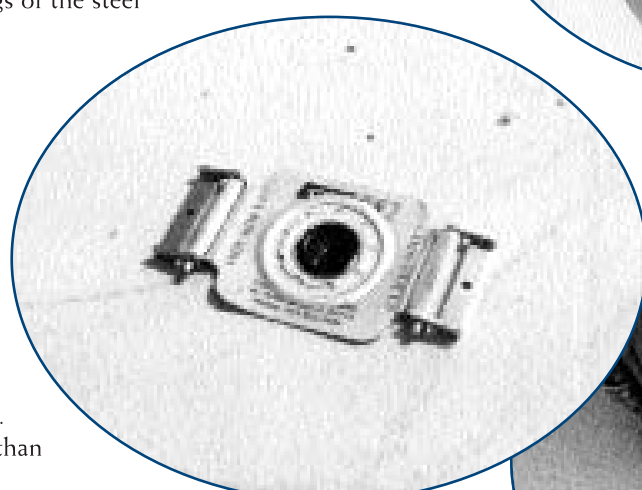

Photo 6: Both rigid steel and "flexible fabric" lifter feet are available for testing base ply fasteners and the stress plate.

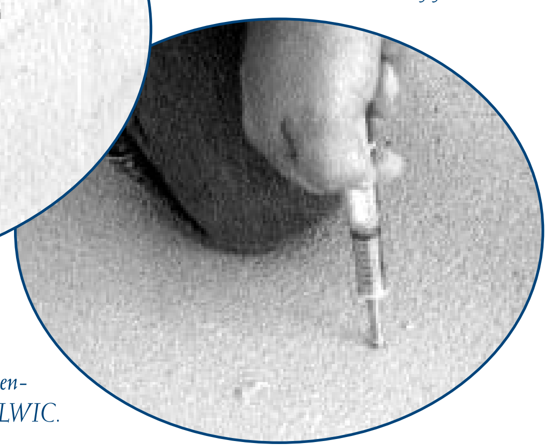

Photo 7: A hand-held penetrometer is used to verify the density of the "cured" LWIC.

Photo 8: Test specimens are molded in EPS cartons.

mately 1/4 inch. The reading is divided by three to obtain the relative compressive strength of the lightweight insulating concrete. However, the test does not provide sufficient repeatable data or the precision to use as a single source of evaluation for lightweight insulating concrete. Using this test method together with the base sheet fastener pull-out test and visual observations can provide useful information to assist project personnel in determining the "readiness" of the lightweight concrete fill.

Compressive Strength

Testing for the compressive strength of newly-installed lightweight concrete should be performed in accordance with ASTM C-495, "Standard Test Method for Compressive Strength of Lightweight Insulating Concrete." This method covers the preparation and testing of molded cylinders for lightweight concretes with oven dry weights not exceeding 50 pcf. The test specimens are molded from a sample of the lightweight concrete mixture obtained from the batching equipment prior to placement. The mixture is placed in "molds," stored, and specifically cured. The mold can be either individual, cardboard cylinders, or an EPS carton type of mold with multiple (four) cylinders per carton (see *Photograph 8*). The size of the mold and resulting cylinder varies from that commonly used for structural concrete. The mold for these cylinders is three inches in diameter by six inches long, compared to 6-inch diameter/12-inch length for structural concrete.

The molding process consists of placing the "wet" mixture in two to three approximate equal layers (lifts). After each layer is placed in the mold, the concrete should be "leveled" by either tapping the sides of the mold or lifting and gently dropping the mold until the top surface of the respective layer has subsided to a plane. The ASTM standard has specific procedures for curing which generally involve initial, moist curing followed by oven-dried curing. It is critical that the samples are dried prior to testing. The procedure is a multi-step process as follows:

Step 1: Moist cure (70 degrees Fahrenheit, +/- 10 degrees) in the mold for the first seven days.

Step 2: Strip the mold and continue moist curing in the appropriate environment (70 degrees Fahrenheit, +/- 10 degrees) for the following 18 days.

Step 3: Oven dry (140 degrees Fahrenheit, +/- 5 degrees) for the last three days of the 28-day cycle.

Step 4: The sample is then allowed to cool to the touch in ambient air prior to testing.

Several factors can affect the results of the testing of molded cylinders.

- The accuracy of the testing machine is critical. The maximum load required to break the sample of lightweight insulating concrete should be not less than 10% of the maximum load range of the testing equipment being used. Testing equipment commonly used for testing compressive strength of structural concrete has a load range of 10,000 pounds. Ten percent of this load range equals 1,000 pounds, which exceeds the anticipated maximum compressive strength of lightweight insulating concrete that ranges from 200 to 400 psi.
- Actual dimensions of the specimen should be obtained. The improper measurement/documentation of the cross-sectional area of the cylinder can have an impact on the test results. Even though the cylinder mold is commonly three inches in diameter, the actual diameter of the hardened concrete cylinder should be measured to the nearest 0.01-inch (0.3 mm). The recorded diameter should be determined by an average of two diameters measured at right angles to each other at mid height of the sample. The difference of 1/10th of an inch larger than the actual will result in a larger bearing surface which can reflect a lower compressive strength reading of approximately 6-1/2%. The actual recorded height of the sample should also be measured to the nearest 0.01-inch (0.3 mm) for volumetric/gravimetric analysis.
- Preparation of the specimens can also have an effect on the sample. The concrete should be placed in the mold in two to three lifts. After each lift is placed in the mold, the mold should be tapped or raised, and dropped approximately 1 inch to allow the lift/layer to "settle." The concrete should not be rodded, as is typically done during the molding of cylinders for structural concrete. After the cylinder is molded, it should be left undisturbed for 16 hours and kept in the mold a minimum of seven days.

Compressive strength testing can also be accomplished with casting of cubes, which is outlined in ASTM C-109, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars." The typical size of cubes is 2 inches x 2 inches. Some industry personnel indicate that cubes provide a more realistic sampling of the compressive strength compared to that obtained from cylinders. Some factors that can have a negative impact on the compressive strength test results of cubes include the following: 1) An excessive amount of mix water utilized during the batching process could wash away cement particles. 2) Performing the test before the specimen is adequately "dry" can cause moisture to act like a lubricant causing "slippage" within the matrix. This results in crushing of the specimen, likely reducing the test values. 3) Inadequate mixing can result in poor dispersion of the cement and less than desirable test results.

Testing the physical properties of existing lightweight concrete ("cured" concrete) can be performed in accordance with ASTM C-513, "Obtaining and Testing Specimens of Hardened Lightweight Insulating Concrete for Compressive Strength." This method covers obtaining and preparing samples of in-place lightweight concrete (minimum 14 days old). In general, the procedure consists of obtaining a bulk sample of the existing (cured) lightweight insulating concrete and "shaving/shaping" the sample down to the desired size and number of cubes. The bulk sample obtained should not include any cracks, spalls, or be otherwise damaged. The size of the shaped cubes is 2 inches x 2 inches (minimum), or 4 inches x 4 inches (maximum). The size of the cube is typically determined by the maximum thickness of the lightweight insulating concrete. A total of four cubes is recommended for appropriate testing. Three of the cubes are used for testing compressive strength and one is used for determining the dry density. Since the samples are manually produced, the actual dimensions of the cube should be measured to determine the true size and bearing surface. The specimens should be oven-dried (140 degrees Fahrenheit, +/- 5 degrees) for three days prior to performing the respective tests.

Dry Density

To obtain the dry density of the lightweight insulating concrete, the oven dry weight should be determined first. To determine the oven dry weight, cylinders and/or cubes (similar to those prepared for the compressive strength testing), should be molded. The molded samples are prepared and cured using the same procedures as those for the compressive strength specimens. However, after the 28-day cure, the specimens are placed in an oven at 230 + 18 degrees Fahrenheit (110 + 10 degrees Celsius) and weighed at 24-hour intervals until the loss of weight does not exceed 1%. Upon determining the oven dry weight and obtaining dimensions of the specimen, the dry density can then be calculated.

Summary

By performing each of these tests, project personnel (specifier, contractor, owner, etc.) can obtain assurance that newly-placed lightweight insulating concrete will have the desired characteristics originally intended. This comprehensive process will also ensure that the lightweight insulating concrete will provide a suitable substrate to receive the new roof assembly and provide the long-term serviceability expected.

REFERENCES

1. Comten Industries Literature
2. Choiniere, Stan, and SPRI's Fasteners Subcommittee, "Standardizing Pullout Test Procedures," *Interface*, April 1999

Also: The American Society of Testing and Materials (ASTM) ■

About the Author

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