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Timelines and Techniques: Finishing Practices for Structural Lightweight Concrete Floor Slabs

by William H. Wolfe

The use of lightweight aggregates in concrete extends well into antiquity and through multiple cultures.[1] Some of the earliest lightweight concrete mixtures incorporated naturally porous materials like pumice. And since the 1920s, structural lightweight concrete has been used for concrete floors in well over 500,000 buildings.[2] With strengths comparable to normalweight concrete yet typically 25 to 35% lighter, this material helps reduce the building's structural dead load. Not only does this allow for more design flexibility and reduced construction costs over an entire structure but it also contributes to improved seismic resilience by reducing the forces a building endures during an earthquake.

Likewise, structural lightweight concrete, when it incorporates expanded shale, clay, or slate (ESCS) lightweight aggregates, can be specified in thinner floor slabs without compromising required fire ratings. This is due in part to the material's ability to transmit heat at a slower rate than normalweight concrete. Lightweight concrete has a higher insulating value due to the pore structure within the lightweight aggregate.

If the lightweight aggregate is preconditioned by prewetting prior to batching, the processes for batching and placing this material can be similar to those for normalweight concrete.[3] With all these benefits and no specialized knowledge necessary for placement, the question becomes: Why isn't structural lightweight concrete used more often? The answer may be tied to concerns with finishing techniques and timelines.

What Are ESCS Aggregates?

In modern construction, lightweight aggregates are produced by expanding minerals like shale, clay, and slate. These materials are fired in a rotary kiln at temperatures around 2000°F (1648°C). During this process, the material softens and forms air bubbles that remain as non-interconnected pores when it cools. As these pores increase the sizes of aggregate particles, they reduce the density of the particles without compromising the strength of the concrete containing them.

After the ESCS has cooled, it is crushed and screened to the size appropriate for its use. Because ESCS is a manufactured material, it provides a consistent gradation and density that allows predictable properties in concrete mixtures.

Concrete Finishing

When using structural lightweight concrete made with ESCS, the most critical issue for contractors is determining when to begin finishing. While this is an important consideration for all concrete types, it has added significance with structural lightweight concrete slabs on metal decks. Finishing this material too early can lead to delamination and more-than-necessary compaction and deflection across the floor deck. These issues are not insurmountable, especially when contractors and engineers understand how the material works, where it is most reasonable to specify it, the proper finishing timelines, and the differences in how finishing tools interact with structural lightweight concrete compared to normalweight concrete.

ESCS Mixtures

As with all types of concrete, the mixture should be proportioned to ensure proper workability, pumpability, finishing characteristics, and setting times and to prevent mixture segregation. Overworking a concrete mixture with ESCS aggregates may bring the lightweight aggregates to the surface.

One of the most important requirements with lightweight concrete mixtures is that lightweight aggregates must be saturated prior to batching so the water-cement ratio (*w/c*) of the paste can be consistent, and the pump pressures don't drive water and air into the aggregates only to come back out of the aggregates at the point of placement. If the degree of saturation varies, this has a large impact on the bleed and setting behavior of the concrete and can complicate finishing.

Also, structural lightweight concrete made with ESCS aggregates is commonly specified with an air content between 4 to 7% to meet density and fire rating requirements. The air content should be tested in accordance with ASTM C173/C173M.[4] It is not always necessary to use a high amount of air entrainment to meet the density requirements; therefore, calculating the equilibrium density is recommended.[5] If measured during placement, the required unit weight of the fresh concrete must be adjusted to account for the weight of the saturation water. Because lightweight aggregates are lighter, the concrete results in less bleed water and bleed air, and less risk of blisters and delaminations. However, there is still risk, and the lower the entrained air content, the lower the risk.

Lightweight concrete deck being placed *(photo courtesy of William H. Wolfe)*

Bleed water coming to the surface prior to finishing *(photo courtesy of Arcosa Lightweight)*

What to Avoid

Floor slabs in office, commercial, multi-unit residential, and institutional buildings are typically specified with floor coverings for foot traffic. Because these floors are covered, they need neither higher flatness tolerances (unless specifically called for in design requirements) nor an overly smoothed surface. Likewise, the troweling recommendations for this class of flooring (Class 2 per ACI 302.1R-15[6]) are not the same as what is recommended for other commercial or industrial flooring. With that in mind, contractors can avoid overworking a floor slab by understanding the right timelines and by using trowels that exert the optimum force for floors of this class.

This can be easier said than done, as calls for faster construction and flatter tolerances have become a norm. To meet these calls, many contractors have achieved desired flatness, reduced wait times, and minimized labor by using ride-on power trowels that impart more energy to the concrete surface than walk-behind power trowels. While this practice can be beneficial to normalweight or non-air-entrained concrete floors, lightweight concrete provides some complications. Therefore, it is important that concrete contractors do not treat lightweight concrete floors as they would normalweight ones.

It may seem that lightweight concrete can make finishing concrete floors needlessly complex. However, avoiding the dangers of overworking can be simple when contractors observe proper finishing techniques, use the appropriate tools, and maintain an ideal finish window.

Techniques and Tools

Power trowels with float pans or float blades exert a much lower surface pressure than those without them. This can sometimes entice contractors to commence finishing sooner than when is ideal. While this can be feasible for slabs-on-ground or slabs made from normalweight concrete, it can cause delamination and deflection when used prematurely on lightweight concrete floors. It is recommended that finishers use walk-behind machines with float blades for the first pass during the proper window for finishing. After the first pass with the walk-behind equipment is completed, ride-on finishing equipment can be used.

Although the right equipment and proper timelines can help contractors easily finish concrete floors, the ambient conditions also play a part. For example, cold weather can prolong bleeding time on unheated decks, increasing delamination risks from mistimed finishing. For this reason, concrete crews should be aware and take action during colder weather and during weather that may speed up surface drying times, as these environments may cause disparities between surface stiffness and adequate time to set.

Time and Weather

When it comes to finishing any concrete floor, timing is essential. Premature finishing is a major cause of delamination (including blistering). Finishing a floor too late, even one that will be covered, can result in poorly textured surfaces and floor flatness/levelness that are outside of design specifications. To determine the window of finishability, it is important for contractors to consider a wide range of variables.

The first of these variables is the concrete itself. For years, finishers have had two tests for determining when to start finishing operations—examining for visible bleed water and measuring the depth of footprints. After placement, the sheen of bleed water should disappear from the concrete's surface. This indicates that sealing the top layer will not lead to trapped water and subsequent delamination. However, sometimes the bleed water evaporates quicker than it rises to the surface, which can fool the finisher into thinking it's done. This is especially true with slower bleeds, which can result from using lightweight aggregate. Additionally, finishers can step on the concrete and measure the depth of their footprints to ascertain the readiness of a floor. If a footprint is no deeper than 1/8 or 1/4 in. (3 or 6 mm) in some cases,[7] then it's likely that the concrete is ready to be finished with the proper equipment. However, if "crusting" occurs (setting of the surface faster than the slab interior), the footprint determination may not be accurate.

However, these tests are not infallible. Cool or damp weather can lead to prolonged bleeding, and hot, windy, or dry conditions can lead to premature surface stiffness. In the latter case, a floor may pass the sheen and footprint tests without actually being ready for finishing. With this in mind, concrete contractors should consider the ambient environment when determining the window of finishability.

Premature finishing may cause a dense sealed layer on the concrete. If bleeding of the concrete has not finished, this low-permeability top layer can trap rising air and water to form a plane of weakness directly under the impermeable layer. This weakness plane can have a higher *w/c* and a higher air content, and it could lead to delamination in the future.

To avoid possible delamination, it is recommended that finishers start troweling as late as possible based on the concrete and environmental conditions, crew size, and equipment availability.

Crossing the Finish Line

As previously noted, structural lightweight concrete typically will not need a finish as dense as that of other types of concrete floor slabs requiring a higher floor flatness/levelness. On the one hand, this can reduce the effort necessary for finishing crews to reach specified densities and surface flatness/levelness—allowing finishing to be completed within a potentially smaller window of finishability. On the other hand, it can increase the finesse needed to finish a floor because unintentional overworking can cause several problems that would be costly and time-consuming to correct.

Project design professionals and concrete suppliers can help avoid these issues by making sure the concrete is designed to achieve the required equilibrium density with a minimum required entrained air. In addition, batch plants should verify that the aggregates are consistently at a saturated surface-dry (SSD) condition prior to batching, so the bleed and setting characteristics are consistent. And finishing crews can avoid these issues by first and foremost commencing finishing processes as late as possible within the window of finishability. Further, if the specified tolerances allow, they can sideline potential finishing problems by using equipment that exerts less pressure on the slab surface. In doing so, the project team can help a project reap all the benefits of structural lightweight concrete without compromising the overall cost and completion timelines.

Almost all lightweight concrete used in elevated floor slabs is pumped *(photo courtesy of William H. Wolfe)*

Additional ACI Resources

- On-Demand Course: Guide to ACI 213R-14 Structural Lightweight-Aggregate Concrete (three-part series)
- On-Demand Course: Internal Curing: Improving Concrete Durability with Use of Lightweight Aggregate
- On-Demand Course: Contractor's Guide: Concrete Placement and Finishing
- On-Demand Course: Concrete Floor and Slab Construction (302.1R-15, Chapter 5)

Visit **www.concrete.org/education/aciuniversity.aspx** for more information.

References

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7. Suprenant, B.A., and Malisch, W.R., "The True Window of Finishability," *Concrete Construction*, Oct. 1998, 3 pp.

Selected for reader interest by the editors after independent expert evaluation and recommendation.

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