ACI 360R-06 Brings Slabs on Ground Design into the 21st Century

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ACI Committee 360, Design of Slabs on Ground, recently completed a comprehensive update of their 360-92 document. All chapters from the existing document were extensively rewritten and new chapters were added on fiber reinforcing, slabs in refrigerated buildings, and structural slabs.

General Considerations

Over the past fourteen years, there has been a broad increase of the industry’s ability to place and finish high quality surfaces that are, at least initially, flat and level. The key drivers have been the Face Flatness and Levelness Numbering System for evaluating the surface, the laser screed, pan floats and early entry dry cutting saws. These developments permit the placing, finishing, and surface tolerance control of high quality floors at significantly higher daily production rates than in the past.

A serviceable slab is almost always defined by reference to only the exposed surface: a flat, level, dense finished surface with stable joints and limited cracking. However, the slab must be capable of supporting the applied loads by bearing on the ground. ACI Committee 302 (Construction of Concrete Floors) concentrates on the construction techniques required to achieve such a surface. ACI Committee 360 concentrates on the design considerations to achieve a stable platform for the serviceable surface.

The Committee’s goal is to provide guidance for designers in planning, analyzing, specifying, and detailing slabs on ground which will provide the expected serviceability under the anticipated loadings and conditions of use. For a successful solution, it should be noted that even the best design requires reconciliation with the actual means, methods, materials and site conditions.

Design Choices

With an eye to these expectations, ACI 360R-06 presents four basic design choices:

1. Unreinforced concrete slab
2. Slabs reinforced to limit crack widths
3. Slabs designed to minimize cracking
   o Shrinkage compensating concrete
   o Post-tensioned
4. Structural slabs

These choices are each developed in specific chapters, preceded by general considerations, soil support system requirements and jointing options.

It is important to frame any design discussion with the acknowledgement that ACI considers slabs on ground as non-structural. Slabs on ground are generally modeled as an elastic slab supported by a field of linear springs. Stresses from applied loads can be calculated using this or similar models. Slab on ground design should result in sufficient strength to support the loads applied to the finished surface. Of course, an adequate soil support system is critical to the performance of the slabs.

Slabs on ground are typically designed as unreinforced sections. The moment and shear stresses are calculated in working stress, and an appropriate safety factor against first cracking (Modulus of Rupture) is applied to determine the required section modulus and thickness. The first three design choices all use this approach. Under choice three, post-tensioned slabs evaluate the net tensile stress including the effective p-t compression, while shrinkage compensating concrete allows extended joint spacing independent of slab thickness.

The reason for the stress limiting approach to slab design is serviceability. Reinforced concrete is designed as a cracked section, but cracking of slabs on ground is generally contrary to Owner expectations.

Slabs on ground, working stress, section modulus — nothing could be simpler — right? Browse on, gentle reader.

The second choice only adds reinforcing steel to limit crack widths. The presence of reinforcing does not prevent cracking. Such reinforcing has negligible effect prior to cracks forming. The goal is to limit crack widths when and if cracking occurs.

The use of reinforcement to limit crack width received significant attention from the Committee. In the previous edition, the Subgrade Drag Formula provided a ready solution for using reinforcement to extend the contraction joint spacing. This formula yielded very low reinforcing ratios (suggesting the ubiquitous use of 6 x 6 x 10/10 welded wire fabric). The formula considers only subgrade friction, but the industry now recognizes the primary role warping (curling) plays in slab cracking.

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Conventional wisdom has been that, when reinforcing is used, it should be discontinued at the contraction joints. The concern here was that the reinforcing could “blind” the slab to the presence of the sawn joint and cracking would occur away from the saw cut. The use of light reinforcing (0.10%), not more, not less, is presented. This reinforcing, while continuous through the contraction joints, is provided only to hold the activated joints in effective contact for load transfer. If properly positioned, even light reinforcing would provide some resistance to crack widening. However, to reiterate, joint spacing should follow Figure 5.6.

**Fiber Reinforcing**

The new chapter on fiber reinforced slabs on ground provides useful insights on using fibers to enhance slab performance. Fine monofilament fibers (denier less than 100) are useful in controlling bleed water channel formation and plastic shrinkage. They have limited effect after the concrete takes initial set.

Macropolymeric fibers (denier greater than 1000) help control cracking due to drying shrinkage. Steel fibers can increase impact resistance and other properties.

In general, the Committee believes that fibers should be treated as an enhancement. The notion that fibers contribute to ductility was resisted. Fibers typically fail by progressive bond failure. This may mimic tensile ductility, but would not justify extending joint spacing or reducing slab thickness. Further research and development may build better confidence in this area.

The structural slab chapter, while brief, draws attention to the requirement that load bearing elements must bear on foundations. Slabs on ground can be designed as foundations; however the design criteria would then be mandated by ACI 318 (Building Code Requirements for Structural Concrete). This can be a gray area and the chapter is intended to draw attention to the issue and act as a placeholder for future elaboration.

**Conclusion**

The new 360 document reflects current research and analysis, addresses significant changes in design thinking, and embraces new materials and technologies. For industrial applications, slabs on ground are the working surface for all activities. As someone said, “The roof only leaks when it’s raining — a floor problem is there all day, every day.”

Design should provide adequate thickness. Joints should be closely spaced with adequate provision for load transfer — or joints should be minimized by shrinkage compensating concrete or eliminated by post-tensioning or heavy continuous reinforcing. And finally, the design must be reconciled with the actual means, methods, materials and site conditions of the project.

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**REFERENCES**

ACI 360R-06 Design of Concrete Slabs on Ground will be available from ACI in November, 2006.


McKinney, A.W.: Persistent Problems with Concrete Slabs in the USA, 5th International Colloquium, Industrial Floors, Technische Akademie Esslingen, Ostfildern, Germany, January, 2003.