Antiquated Structural Systems Series

Part 3

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This article is the third in a series that is intended to provide a resource of information to structural engineers for projects that involve the repair, restoration or adaptive reuse of older buildings for which no drawings exist. Part 2 of the series can be found in the December 2007 issue of STRUCTURE® magazine (**www.STRUCTUREmag.org/archives**).

The purpose of this series is to compile and disseminate a resource of information to enable structural engineers to share their knowledge of existing structural systems that may no longer be in use, but are capable of being adapted or reanalyzed for safe reuse in the marketplace of today and the future.

One- and Two-Way Clay Tile and Unit Masonry Joist Systems

In one- and two-way clay tile and unit masonry joist systems, individual units were laid in such a way as to form trenches that allowed reinforcing bars to be placed in the bottom of the resulting joist cross sections. This method of construction is very similar to the more recent pan joist system; however, unlike steel pans, the clay and masonry units were left in place for added strength and fire resistance, and to provide a flat ceiling surface.

Proprietary one-way floor systems included the Natcoflor and Republic Slagblock systems. Proprietary two-way floor systems included the Schuster, Smooth-Ceiling, Sandberg and Republic Slagblock systems. All of these employed regularly shaped units of varying size and depth that resulted in a uniform modulation of joist sizes and spacings. However, during the 1930s, a patented "wide-center" system was introduced for both one-way and two-way framing that allowed for wider clay tile units to be placed at the center of the span and narrower units to be placed at the end of the span. This resulted in wider joists near the supports, which in turn resulted in greater shear capacity at the end of the span, similar to the more recent tapered end pan joist system.

With the exception of the Smooth-Ceiling and Sandberg systems, the clay tile and unit masonry could be constructed to span between steel beams, concrete beams or loadbearing walls. In addition, most of the systems could be placed with or without a concrete topping. When a monolithic concrete topping was used, the thickness typically varied from 1½ inches to 3 inches. Joists were typically analyzed as T-beam sections when a monolithic topping was used. With the exception of the Natcoflor system, joist widths typically varied from 4 inches to 6 inches.

Typically, ¾-inch clear cover was provided between the square or round deformed reinforcing bars and the adjacent tile or masonry units or the top and bottom of the exposed concrete surface of the joist. It was typical to use straight bottom bars and trussed top bars bent down to align with the bottom bars near the center of the span. When a concrete topping was used, it was typical for temperature/shrinkage reinforcement to be provided orthogonal to the joist span. The amount of this steel was typically 0.0025 times the gross cross-sectional area of the topping, and it was spaced at no more than 18 inches on center.

One-way systems were very efficient for spans over 12 feet, and were used very frequently for spans up to 24 feet with loadings that ranged from 40 to 125 PSF, and up to 18- and 20 foot spans for heavier loadings. For two-way systems, and at the end of the span for one-way systems, it was common for the open webbed ends of clay tiles (or masonry units) to be filled with cardboard or metal inserts to prevent concrete from flowing into the voids, in order to minimize the dead load of the slab.

The Natcoflor system used specially manufactured clay tiles with curved flanges that allowed only the bottom of the tiles to be exposed as the ceiling soffit. Other one- and two-way clay tile systems could be formed and cast either with the bottom of the concrete joist exposed or with tile soffit pieces along the bottom of the trenches that resulted in a uniform tile ceiling soffit. The Natcoflor joists were no more than 2 inches in width, spaced at 13 inches on center, with a depth that varied from 4 inches to 12 inches (*Figure 1*). The joists were typically cast using cement grout consisting of one part cement and two and one-half parts sand. A composite concrete topping was not required above the tiles, in order to attain the maximum load-carrying capacity of the system.

The Schuster two-way system (*Figure 2*), which was patented in 1915, used clay tiles that were 12 inches x 12 inches, or 16 inches x 16 inches, and had depths of 4, 6, 8, 10 or 12 inches. The joists were typically spaced at 16 inches on center or 20 inches on center; however,

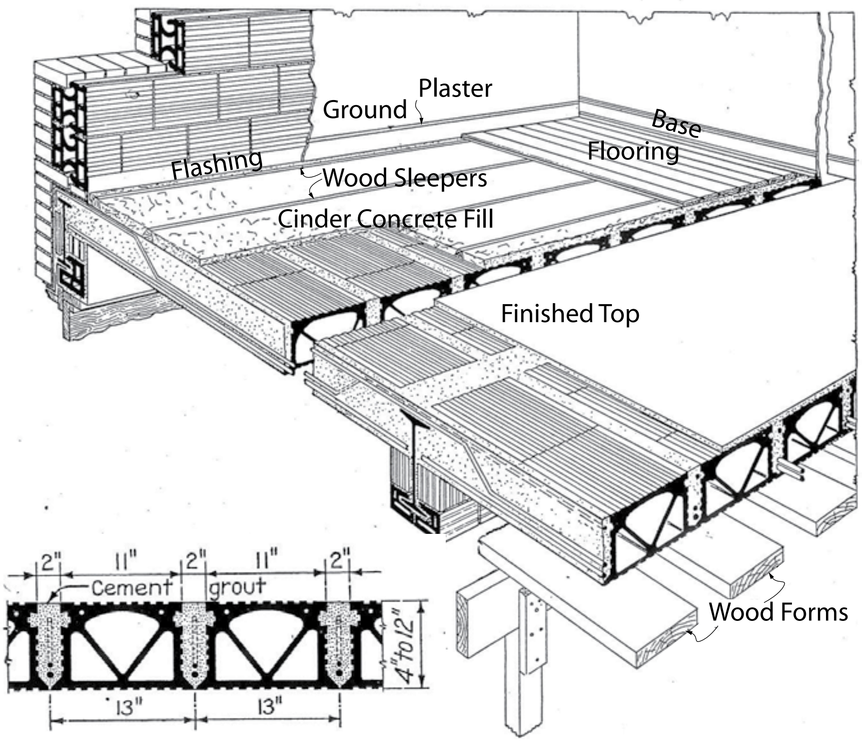

Figure 1.

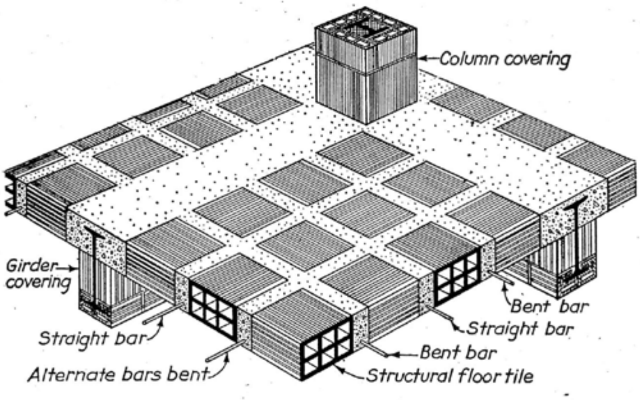

Figure 2.

tiles could be doubled up to allow for joist spacings of 28 or 30 inches on center. This two-way system was typically used in square bays or rectangular bays in which the longer span was not more than 50% greater than the shorter span.

The Republic Slagblok system could be installed in either a one-way or two-way configuration. The Slagblok unit measured 8 inches x 16 inches, and came with one open end and one closed end. Each unit was placed in combination with another Slagblok to form closed cells that were 16 inches x 16 inches. Slagbloks came in 3-, 4½-, 6-, 7- and 8-inch depths. The concrete ribs or joists were typically 4 inches in width and spaced at 20 inches on center. Typical spans for this system varied from 15 to 25 feet. The author has seen similar one-way joist systems constructed as recently as the 1970s using regular concrete masonry units.

The Smooth-Ceiling system, which was patented in the 1930s, and the similar Sandberg system both eliminated the need for beams or drop panels by employing embedded internal steel shear reinforcement around either structural steel or reinforced concrete columns. As with other two-way systems, standard tile units were placed in a modular layout in order to establish a uniform two-way grid of concrete joists. Typically, both systems eliminated all tiles from around the column to enable this area to be cast as solid concrete.

Although load tables, which included considerable factors of safety, were provided by the manufacturers of most of the above systems, the actual design of the joists was accomplished using conventional working stress methods of analysis that were available at the time. Moment and shear coefficients were typically employed to establish the maximum positive and negative moment and end shear design envelopes; however, continuous beam analysis was also used to establish the required design parameters. Moment and shear coefficients were also used for two-way analysis.

Even though load tables and methods of analysis are available for all of the above clay tile and unit masonry systems, when one encounters any of these same systems in an existing building, and there are no original drawings available, it is difficult to determine what the internal reinforcement is, and subsequently the load-carrying capacity of the system. However, hopefully this article, by identifying the many different types of systems that were in use at one time or other, will assist readers in their investigation of the structural framing when any of the above-described systems are encountered in an existing building.▪

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Example of an existing one-way clay tile joint system.

References

"Analysis and Testing of Archaic Floor Construction", John P. Stecich, Standards for Preservation and Rehabilitation, ASTM STP 1258, 1996, John Wiley & Sons, Inc., 1925

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Architects' and Builders' Handbook, 18th Edition, Frank E. Kidder, Harry Parker, John Wiley and Sons, 1956

Future installments of the archaic structural systems series will cover one- and two-way clay tile and unit masonry joist systems; prefabricated clay tile and concrete block framing systems; precast concrete framing systems; antiquated post-tensioning systems; and outdated structural steel stub-girder construction. If there are other topics along these lines that you would like to see addressed, please send your suggestions and any relevant information that you have to the author (**mstuart@cmxengineering.com**).