Structural Lightweight Concrete Offers Benefits for High-rise Construction

Many architects and engineers think of lightweight concrete as a material strictly used for floor slabs poured on steel decking. That is one common and excellent application, but it's an unnecessarily limited view of lightweight concrete's capabilities.

In fact, lightweight concrete has a long and successful track record as a structural material, and it works particularly well for structural floor slabs in concrete frame buildings. Furthermore, its benefits are multiplied in high-rise buildings, which can be constructed using less material for each floor.

Using Material Efficiently

The material saving results in part from reduced dead loads on the structural frame; floor slabs that weigh less allow a designer to reduce the size of concrete columns and beams. In seismic zones, lighter weight also reduces seismic loading. In some cases, lightweight concrete also can achieve required fire ratings with a thinner slab. This allows a reduction in floor-to-floor height, which affects not only the quantity of frame material needed, but also the amount of exterior cladding, as well as the length of electrical, plumbing, and mechanical services running vertically through the building. The more stories involved, the greater the potential savings.

These savings are achieved without compromising quality. The reduction in weight comes from the use of expanded shale, clay, or slate for part of the concrete aggregate. These ceramic materials form an exceptional bond to the cementitious matrix, which enhances the concrete's durability. Structural lightweight concrete achieves strengths comparable to normal weight concrete, but with 20% to 30% lower density.

Lightweight concrete offers other desirable properties as well: compared with regular concrete, it has better thermal properties, higher fire ratings, better shock and sound absorption, less autogenous shrinkage, and less micro-cracking.

Marina City: Lightweight Landmark

The iconic corncob-shaped Marina City towers in Chicago are an example of a structural lightweight concrete project that has stood the test of time. At 60 stories each, they were the world's tallest apartments and the tallest reinforced concrete buildings when constructed in the early 1960s. In a structurally innovative design, each tower's lightweight concrete floor slabs and supporting beams radiate from a slip-formed cylindrical concrete core. Architect Bertrand Goldberg intended the structures to be visually striking, but also efficient and economical to build. The Marina City complex was designated as a historic landmark in 2016.

Market Square Tower: Meeting Demand

A more recent project that makes the most of structural lightweight concrete is Market Square Tower, a high-rise apartment that recently opened in downtown Houston. Jackson & Ryan Architects designed the project, which is adjacent to an existing 12-story parking structure and across from Market Square Park. It was originally planned as a 36-story tower with normal-weight reinforced concrete for colum-

ns, walls, and floor slabs, but the developer opted to add more apartments in response to strong demand.

That led to some further changes, as the structural engineer, Tim Santi of Walter P. Moore and Associates, explains: "When the owner asked that we add four more floors to the building, we had to do something to minimize the weight of the tower. In an area like downtown Houston, where you have softer soils and no rock, mat foundations are commonly used for high rise buildings, and you're limited in the amount of weight you can put on that mat footprint. If we were to add more weight to the building by adding 4 more levels without digging another basement level to relieve more soil weight, then we'd be overstressing the soils supporting the mat. Another alternative was to use lightweight concrete to make the entire building lighter.

"Normally we see lightweight concrete costing about $20 to $30 more per cubic yard than normal weight, but here the additional cost was less than we would have incurred by digging a deeper basement," Santi says.

The engineer had frequently used lightweight concrete for floor slabs supported on metal deck, but this project has post-tensioned, 8-inch-thick formed slabs instead. Santi says: "Typically we don't use lightweight concrete for flat slabs due to a variety of reasons, one of which is the reduced shear strength. Inadequate shear strength at slab-to-column joints can compromise the integrity of the connection resulting in what is known as punching shear. Fortunately, at Market Square Tower the columns were very large which in fact increases resistance to punching shear, allowing us to comfortably use lightweight concrete."

"Column spacing was 26 feet 8 inches in one direction, and either 32 feet or 25 feet in the other direction. The column dimensions varied depending on their location in the building, but some were 18 inches by 6 feet long, and others were 36 by 36 inches at the base of the building."

Santi says they took special care at a couple of points because they were using lightweight concrete for the slabs.

"[Because] we used post-tensioning strands within the slab that are gradually 'draped' between columns, it was important that Harvey Builders, the general contractor for the project, positioned the strands carefully and at the specified heights within the slabs. This is of course important for any project, but our awareness was heightened more than normal on this project due to the somewhat unconventional use of lightweight concrete within the slabs."

Recent Projects Rising Higher

Any number of recent skyscrapers have made use of lightweight concrete for floor slabs placed on metal decking. Among them is a 54-story office tower on Lake Street in Chicago and, most notably, the Wilshire Grand Center in Los Angeles. This multi-use project will contain office and retail space, as well as a 73-story InterContinental Hotel tower that will be the tallest building in the western United States.

The efficient construction of these and other projects have required large volumes of lightweight concrete to be pumped over long distances. In the case of the Wilshire Grand Center, pumps conveyed concrete 1,300 feet, 1,100 of which was vertical. Their success should dispel any misconception that pumping lightweight concrete is problematic.

Paying proper attention to recommended procedures for pre-soaking lightweight aggregate before it is used to batch concrete is the key to successfully pumping the material. These procedures are well known and well documented, so problems rarely occur these days. As long as concrete producers and contractors follow these best practices, they can expect a trouble-free placement. And if ever questions arise, lightweight aggregate producers can quickly provide the answers.