

Paradigm Shift

In an era of tight budgets and sophisticated digital tools, architects take modular construction beyond the single-family house.

By Joann Gonchar, AIA

AMERICAN ARCHITECTS have long been infatuated with the notion of prefabricated housing—not only as a solution for the single-family dwelling but also as a way to provide affordable and dense housing in mid-rise or high-rise buildings. But, with the exception of mostly architecturally nondescript projects, such as barracks, jails, and no-tell motels, the modular multistory approach hasn't yet gained a sturdy foothold in the U.S. That situation could be on the verge of changing, hastened by increasingly constrained client budgets and advances in technology, like the growing sophistication of building-information-modeling (BIM) tools.

Two projects on opposite coasts illustrate this emerging popularity among architects. One is a 102-unit studio-apartment building in Los Angeles. It will stack off-site-fabricated wood-framed units up to four stories above a stepped base that incorporates an existing one-story retail and parking structure into its volume. According to its designer, Michael Maltzan Architecture (MMA), the building will be the city's



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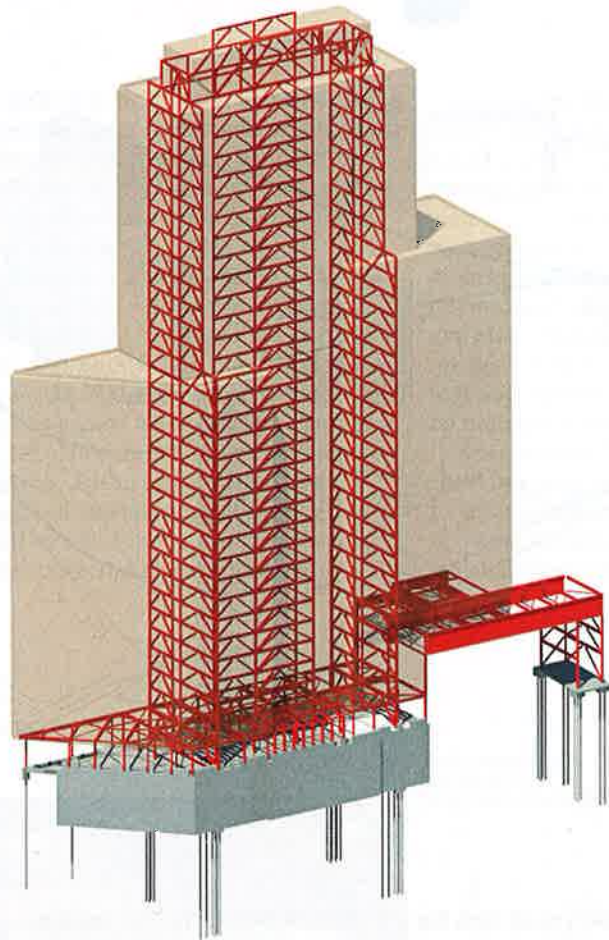
Learning Objectives

- 1 Discuss the advantages of modular construction for multi-unit, multistory buildings.
- 2 Discuss some of the obstacles to constructing multiunit, multistory buildings modularly.
- 3 Describe the construction process for the Star Apartments and the proposed B2 Tower, outlining which work will be performed on site and in the factory.
- 4 Describe the role of building information modeling (BIM) in the construction of complex modular projects.

AIA/CES Course #K1210A

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**ATLANTIC YARDS,
BROOKLYN, NEW YORK**

The developer's preferred scheme for building the 350-apartment B2 tower includes 930 modules (right), each with a steel-framed chassis. According to the plan, the modules, including bathrooms, m/e/p services, and finishes, will be assembled in a factory not far from the site. They will be lifted into place by crane around a steel-brace frame (above, in red) that will serve as the building's primary lateral-load-resisting system.



first multiunit residential project employing such a strategy. The other project—part of Forest City Ratner Companies' \$4.9 billion redevelopment of Atlantic Yards in Brooklyn, New York—is a 350-unit, 322-foot-tall tower designed by SHoP Architects, made of steel-framed modules. According to the developers, the 32-story building will be the world's tallest modular structure.

Maltzan's project is the firm's third for the Skid Row Housing Trust, a nonprofit organization that owns and manages housing for formerly homeless individuals. The building, called the Star Apartments, is already under construction. A terraced slab that will support living-unit modules is now nearly complete.

The fate of the Brooklyn modular project is less certain. It hinges in large part on the outcome of negotiations with the unions representing the local construction trades. "We expect the unions to cooperate, although we don't have an agreement yet," says Robert Sanna, Forest City Ratner's director of construction and design development. If all goes well, ground will be broken for the tower, referred to as B2, by the end of 2012 on a site that sits directly adjacent to Barclays Center. That just-completed arena, which has a facade by SHoP, will serve as home court for the National Basketball Association's Nets.

In case negotiations with the unions don't work out, Forest City Ratner has a backup plan to construct the high-rise conventionally. The modular B2 and its alternate would look identical: Both schemes call for a predominantly metal-and-glass-clad tower broken up into four volumes, each articulated by panels of different hues, patterning, and reflectivity.

At 340,000 square feet, the B2 tower will be more than three times the size of the Star Apartments. But though the scales of the projects are different, the goals are the same: By minimizing on-site construction, the teams behind both buildings say they will shorten project schedules, deliver high-quality housing, and save money. Forest City Ratner claims that using the approach will move 60 percent of the work off site and shave at least four months off an 18-month construction timeline. The developer also estimates that the modular B2 tower would cost 20 percent less than a conventionally constructed building with a concrete flat-slab structure (the typical construction method for high-rise residential buildings in New York).

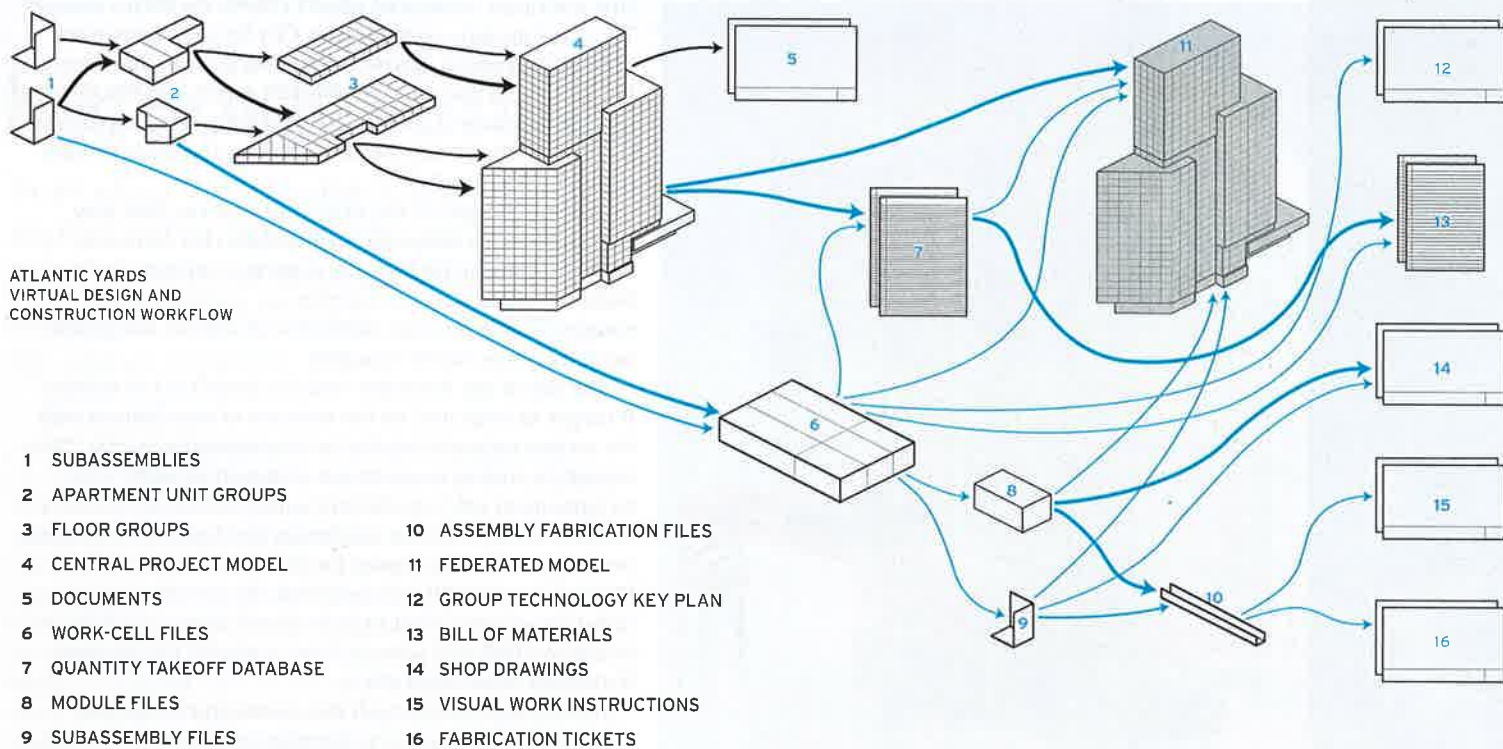
These savings are especially significant since the Atlantic Yards site, which covers 22 acres, is ultimately projected to include 14 residential buildings. Of the 6,430 planned rental and condominium apartments, 2,250 are reserved for low- or middle-income households. As each tower is built, the developer anticipates that its modular-construction process would improve. "We expect to find even greater levels of efficiency," says Sanna.

Similarly, the Skid Row Housing Trust, which has a portfolio of 1,600 units in 23 buildings in Los Angeles, sees modular building as an economically viable alternative to conventional construction. "We want to continue to develop housing even in the context of a tough fiscal environment," says Mike Alvidrez, the organization's executive director.

The trust expects Star to be completed in April 2013, approximately 14 months after workers began retrofitting

The developers of Atlantic Yards hope to build the B2 tower (this photo) from preassembled units. It is the first of three residential towers expected to rise directly adjacent to the new arena, Barclays Center (right), and one of 14 planned for the 22-acre development.

IMAGES: COURTESY SHoP ARCHITECTS, EXCEPT PHOTOGRAPHY



the reinforced-concrete-and-masonry structure that will serve as the apartment building's base, converting it into space for retail tenants, social-service providers, and recreation, including a running track and basketball court. A more typical construction timeline would be 18 to 24 months, says Theresa Hwang, community designer for the organization. She also points out that the residential floors represent only about 25 percent of the \$19.7-million construction cost, even though they make up more than half of its 95,000 square feet. "Our per-unit costs are dramatically lower," she says.

Proponents of modular construction say the efficiencies are realized by performing work in a factory environment, where labor costs are lower and the construction is not subject to weather-related delays. The savings also come from the ability to perform foundation construction and other site-bound work simultaneously with unit assembly. Advocates of the approach also tout benefits such as reduced noise and less construction-related disruption in the neighborhood surrounding the building site, as well as improved job-site safety, since so much of the work normally done outdoors, many stories in the air, is performed on the factory floor. And they cite green advantages, like reductions in construction waste and the potential for better energy performance, which they attribute to tighter quality control. (Both project teams hope to achieve LEED certification, with the B2 targeting Silver and Star seeking Platinum.)

For the Star Apartments project, Guerdon Modular Buildings began assembling four prototypes of the units, which typically are 12 feet wide, 30 feet long, and 10 feet 6 inches tall, at its 225-employee factory in Boise, Idaho, in late August. According to Lad Dawson, the company's CEO, Guerdon has the capacity to build between four and six of

Star's units each day and plans to deliver the first modules to the site by the middle of October. Meanwhile, workers from Westport Construction, the project's general contractor, have been reinforcing the existing building's structure and forming the multilevel, moment-framed concrete deck that will receive the modules.

It should take Guerdon about 20 working days to lift the modules by crane and install all of Star's units, stacking them in clusters of nine to 12 modules around outdoor spaces and joining them to each other with a variety of connection types.

The Star Apartment modules are built to withstand the loads of transport as well as the forces they will sustain once the project is completed and occupied. Their frames are made primarily of wood, but they have wall assemblies that include a composite material combining sheet steel and gypsum board to help the units resist shear forces, explains Tim Williams, MMA managing principal. Binding the units to each other also improves performance, explains Brad Smith, principal of BW Smith Structural Engineers, the firm's structural consultant. "Together they are seismically stronger," says Smith.

After they are in place, Star's clustered modules will receive stucco facades, applied by Westport, whose workers will also install the building's open-air, steel-framed corridors. In addition to providing the main circulation infrastructure for the building's residents, the walkways serve as the distribution channels for utility lines that will connect above each dwelling unit's entrance to the factory-installed electricity, gas, and water services in individual apartments.

Forest City Ratner plans to build the modules for the B2 tower in Brooklyn, not far from the Atlantic Yards site, in a

ATLANTIC YARDS

As part of the BIM workflow for the modular B2 project, the architect and engineer are creating virtual subassemblies, inserting those into a module, and grouping the modules into apartments and floors. The team will be able to use the model to generate documents such as shop drawings, a bill of materials, and fabrication tickets.

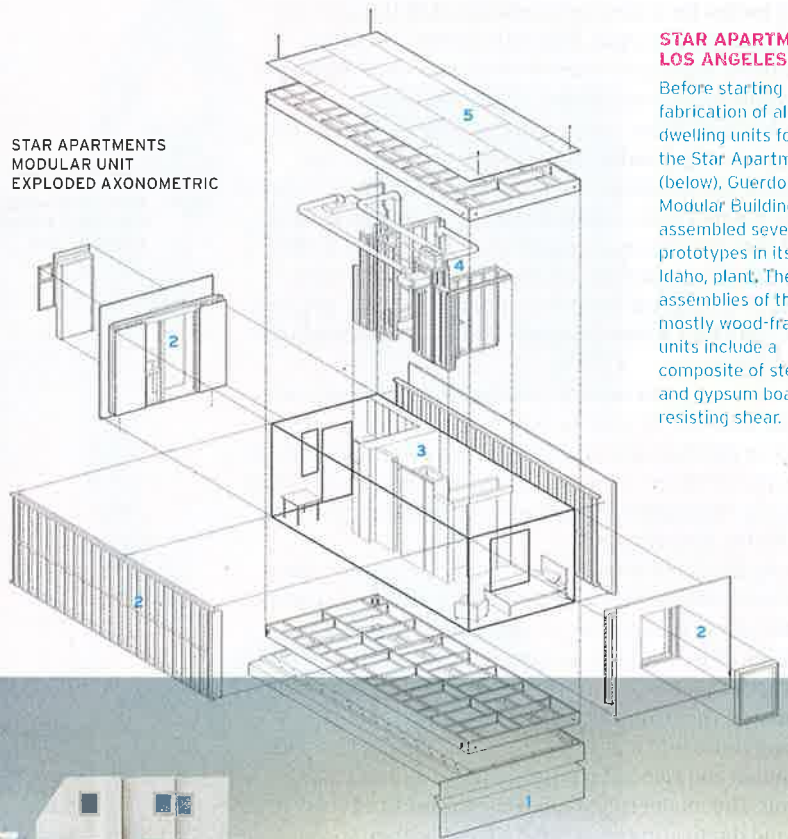
factory it is setting up with XSite Modular, a modular-building consulting firm. Because the larger apartments will be made of multiple modules, fabricators will need to assemble 930 in all. Although very few are exactly the same, there will be about 24 “families” of similarly configured modules, says Jonathan Mallie, a SHoP principal.

Each module in the B2 tower will have a tubular steel chassis that will be fabricated outside the city and delivered to the Brooklyn factory assembled. The chassis, which are 15 feet wide, 10 feet tall, and up to 45 feet long, are made up of Vierendeel trusses, which are distinguished by fixed joints and the absence of diagonal members. The configuration facilitates placement of openings between the modules, explains David Farnsworth, a principal at Arup, the B2 modular project’s structural and mechanical engineer. However, diagonals will be added in some locations where they won’t obstruct the connections between rooms.

Carpenters, plumbers, and electricians will perform almost all the fit-out work of the B2 chassis in the factory, building a floor and ceiling assembly for each module and adding partitions, finishes, and subassemblies, including bathrooms, cabinets, and m/e/p services. Only one hallway in each apartment will be left incomplete, to allow contractors to make riser connections between units in the field without disrupting already in-place finishes. The building’s metal-and-glass cladding will also be installed at the factory. Each module’s section of exterior skin will mate to the one next to it with self-sealing joints, much like those typically used on unitized facade systems.

After transporting the modules to the site and stacking them by crane, workers will connect the ceiling of one B2 module to another from the outside, creating a structural diaphragm that is tied to a steel-brace frame. The frame, which serves as the building’s primary lateral-load-resisting

- | | |
|-----------------------|--------------------|
| 1 FLOOR ASSEMBLY | 4 M/E/P CORE |
| 2 WALL ASSEMBLY | 5 CEILING ASSEMBLY |
| 3 INTERIOR COMPONENTS | |



**STAR APARTMENTS,
LOS ANGELES**

Before starting fabrication of all 102 dwelling units for the Star Apartments (below), Guerdon Modular Buildings assembled several prototypes in its Boise, Idaho, plant. The wall assemblies of the mostly wood-framed units include a composite of steel and gypsum board for resisting shear.



system, will be erected on site, with erection advancing a few levels ahead of module stacking.

One important advantage of using modular construction methods to build B2 would be a reduction in weight, says the team. According to Arup's estimates, the superstructure would be about 40 percent lighter than that of a concrete flat-slab building. The reduction translates into the need for a less hefty foundation system, a particular boon at the Atlantic Yards site, which straddles a busy transportation hub. "Every pile costs much more than it would on a green-field site," says Farnsworth.

Multistory modular construction does pose special challenges. For instance, the depth of the floor-and-ceiling sandwich tends to be greater than with common site-built construction methods, since each module has its own, structurally stable lid and base. At Star, for example, the dimension from the underside of the ceiling to the top of the floor is just over 26 inches, compared with a depth of about 14 to 16 inches for a similar wood-framed building in the same fire-resistance class. The extra inches can prove problematic, especially when dealing with building-height restrictions set by zoning laws.

Resolving modular construction's complex architectural and engineering puzzles, like trying to maximize the number of stories while minimizing overall height, requires intense collaboration among project-team members, close attention to tolerances, and careful orchestration of fabrication and construction sequences, especially since every decision is multiplied hundreds, if not thousands, of times. "There can't be a screw that hasn't been thought through," says Williams.

To facilitate the necessary coordination, the teams for both the modular B2 and the Star Apartments have relied heavily on BIM for tasks like identifying potential conflicts among the modules' many small components, construction scheduling, estimating the quantity of specific materials, and creating cost estimates.

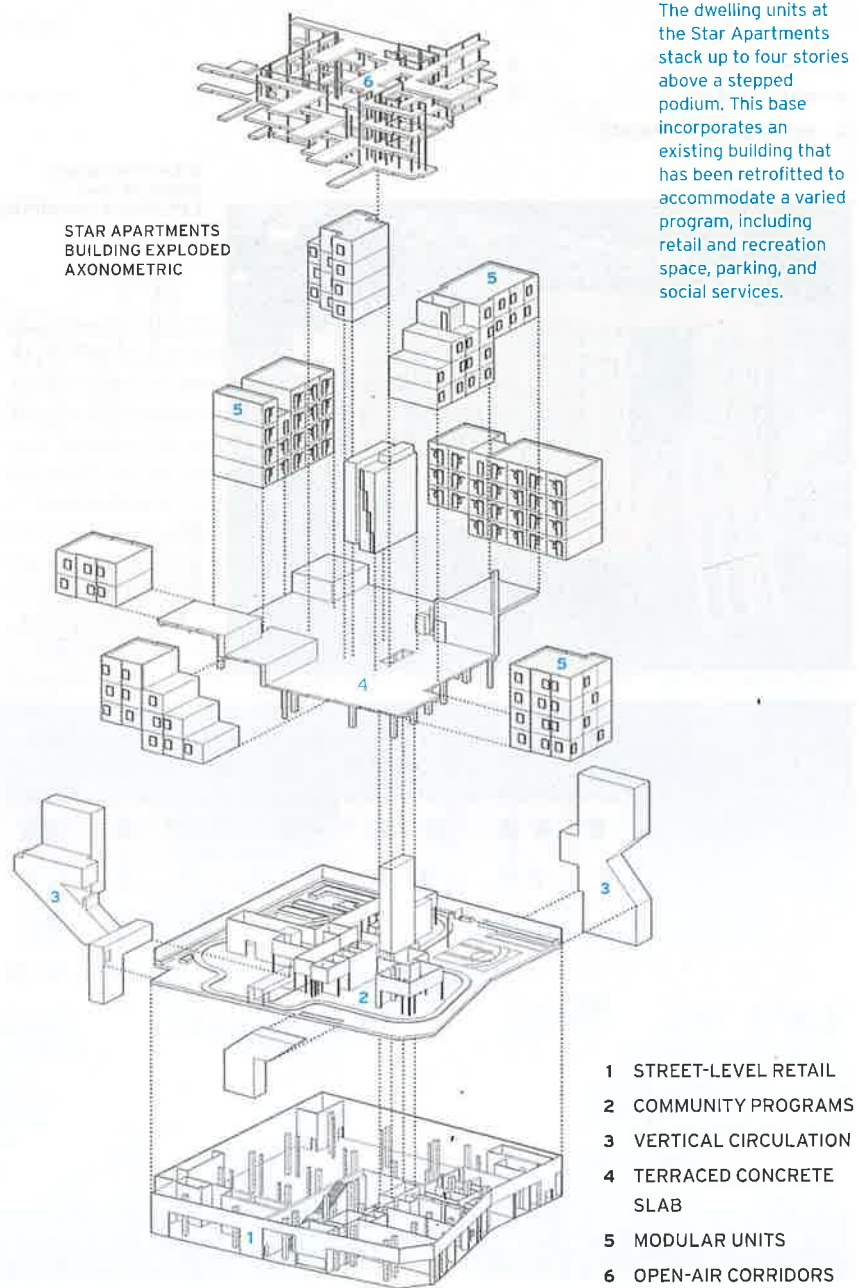
For the Brooklyn project, the architect, engineer, and others are working with a cloud-based "federated" model—one that allows consultants to input and share discipline-specific models. With the architect's affiliate, SHoP Construction, serving as virtual design and construction coordinator, the team is modeling B2's subassemblies, inserting those into a module, grouping the modules into apartments and floors, and then placing those in the building. The model should help contractors and subcontractors avoid duplicating work, since it can be used to generate documents like a bill of materials, shop drawings, and fabrication tickets. "The project is not so much about product innovation," says Mallie, "as it is about supply-chain integration."

Whether the new design and construction paradigm proposed by the modular B2 and the Star Apartments projects will become commonplace remains to be seen. But Forest City Ratner, at least, seems to be envisioning demand well beyond New York for the modules it hopes to build in Brooklyn. "We could even ship the modules overseas," says Sanna. His comments suggest that modular construction could be more than just an efficient way to build. It might be the key to the revival of a moribund manufacturing sector. ■



STAR APARTMENTS

The dwelling units at the Star Apartments stack up to four stories above a stepped podium. This base incorporates an existing building that has been retrofitted to accommodate a varied program, including retail and recreation space, parking, and social services.



- 1 STREET-LEVEL RETAIL
- 2 COMMUNITY PROGRAMS
- 3 VERTICAL CIRCULATION
- 4 TERRACED CONCRETE SLAB
- 5 MODULAR UNITS
- 6 OPEN-AIR CORRIDORS