Precast Concrete Modules Speed School Construction

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Many school districts, as well as other building owners, face a common problem. They need a building designed and constructed very quickly and available for immediate occupancy. The Boston Massachusetts School District commissioned the Josiah Quincy Upper School as a design-build project to facilitate creative solutions and rapid project delivery. The project team delivered the $1.35 million building in 108 days from contract signing to completion by using modular precast concrete elements. By combining a tightly integrated design team, along with a well-considered scheme, the project was delivered and satisfied the budget and time constraints. This article describes the design features and erection of the school and especially the role that precast modular construction played in building the project.

Many types of projects have delivery time constraints. The scheduling requirements of school construction are particularly demanding. Schools generally need to be constructed when the demand (e.g., the number of students or young families) mandates a new building. Construction or expansion of schools is often constrained to the summer recess period so that the school year is not disrupted by construction activity. Some school districts turn to pre-manufactured trailers (similar to mobile homes) to rapidly provide additional classroom space for the students.

Although trailers are widely thought to be movable, in reality, they are often difficult to move and usually are not moved. Buildings constructed of precast concrete modules could theoretically be moved by essentially reversing the

Fig. 1. West elevation of the Josiah Quincy Upper School after completion and occupancy.

Fig. 2. Overview of project looking east. Building is enclosed, site work is being completed.

erection process. However, this usually would not be needed.

Some school districts are dissatisfied with trailers as an option for classrooms for several reasons. Because of their lightweight construction, trailers do not provide the security and sound attenuation characteristics that are commonly desirable in school buildings. Trailers also have an undercarriage, which usually results in a crawlspace that can pose waterproofing, dampness and security concerns. Also, if the trailers are above a crawlspace, ramps are often needed to provide adequate access in compliance with local, state and federal accessibility laws. Because trailers are separately enclosed units, they are difficult to join together and/or integrate into an existing building or campus.

When the Boston Massachusetts School System solicited proposals for the expansion of the Josiah Quincy Upper School, the design-build team provided a proposal for the building, which was both competitively priced and addressed many of the shortcomings of the competing trailer system. It also offered a very rapid implementation scheme as compared to conventionally framed, non-precast concrete construction.

DESIGN FEATURES

The expansion of the Josiah Quincy Upper School was planned to be completed in two phases. The first phase (see Figs. 1 and 2), constructed in the summer of 1999, is comprised of six classrooms, two offices, boys' and girls' bathrooms, staff bathroom and a janitor's closet. The floor plan is approximately 9000 sq ft (840 m^2). The first phase is a single story (see Figs. 3 and 4). A second story is being added in the summer of 2000, which will double the number of classrooms and provide other amenities. The second story is being constructed of precast concrete wall panels and precast concrete slabs for the roof.

The foundation is comprised of conventional wood piles, pile caps and grade beams. The building superstructure, including the floor slab, is comprised of 30 modular precast concrete rings. The rings are four-sided, i.e., they form the walls, the roof and the floor of the building (see Fig. 5).

The rings are placed in contact directly adjacent to one another. The rings, after painting, form the finished interior and exterior surface of the building which further helps to speed construction. The rings were placed in

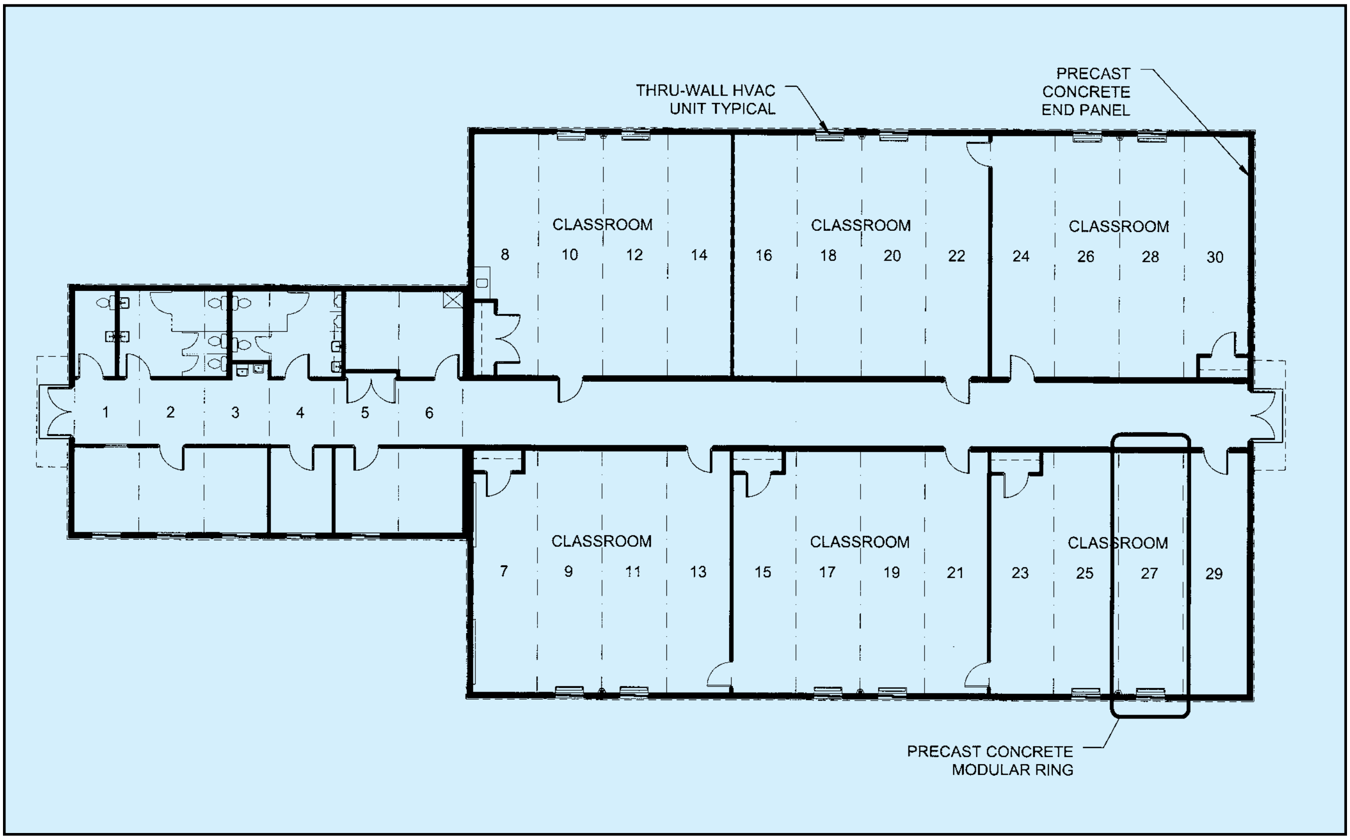


Fig. 3. Floor plan of the first phase (first floor). Administrative wing is to the left, six classrooms to the right. Number indicates the modular rings.

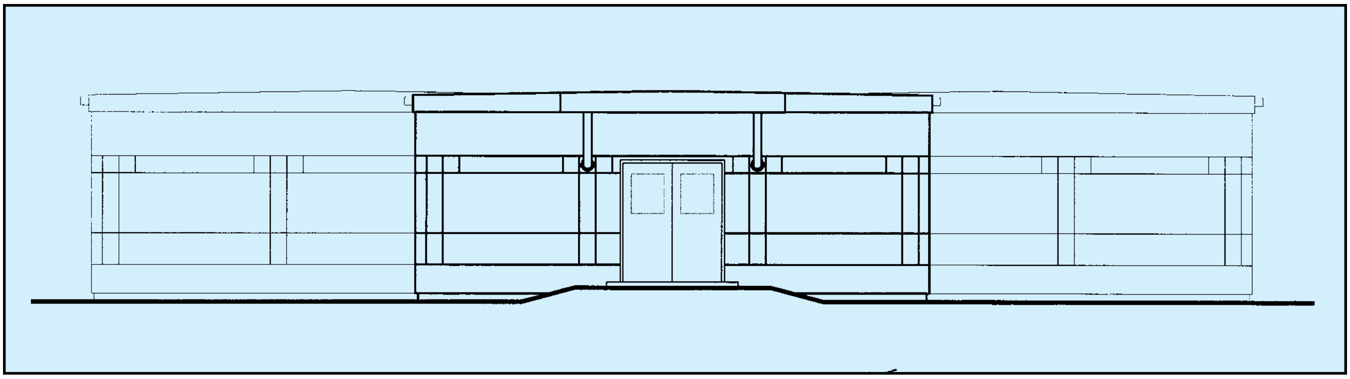


Fig. 4. West elevation of building.

an arrangement, which forms a central hallway between 24 of the rings (see Fig. 6). Six other rings form the administrative area of the building. The roof of the hallway is comprised of precast concrete slabs.

The rings were originally conceived for use in utility/communications type buildings. The design load is 60 lb per sq ft (2.87 kPa) for the roof and 150 lb per sq ft (7.18 kPa) for the floor. Because the floor and the roof are structurally similar, the excess structural capacity of the roof side of the rings provided the opportunity to readily add a second story to the building in a later phase without significant structural modification of the rings.

A second story is under construction in the summer of 2000 (see Fig. 7). The second story adds approximately 7000 sq ft (651 m^2) to the usable area of the building. A cast-in-place topping on top of the rings installed in the summer of 1999 provides a level floor for the addition. The second story is being constructed by installing precast concrete wall panels directly on the rings which form the first story. No additional floor framing is necessary. The roof is comprised of hollow-core concrete slabs.

The wall panels are cast with openings for fenestrations and unit heaters. Partitions and fixtures are added once the precast concrete pieces are added. The architect was sensitive to the intricacies of precast concrete design and erection, and the plan for the building to ultimately be expanded. Provision was made at the outset of the design for stairs and an elevator to be added. Those elements are being installed during the construction of the second story in the summer of 2000.

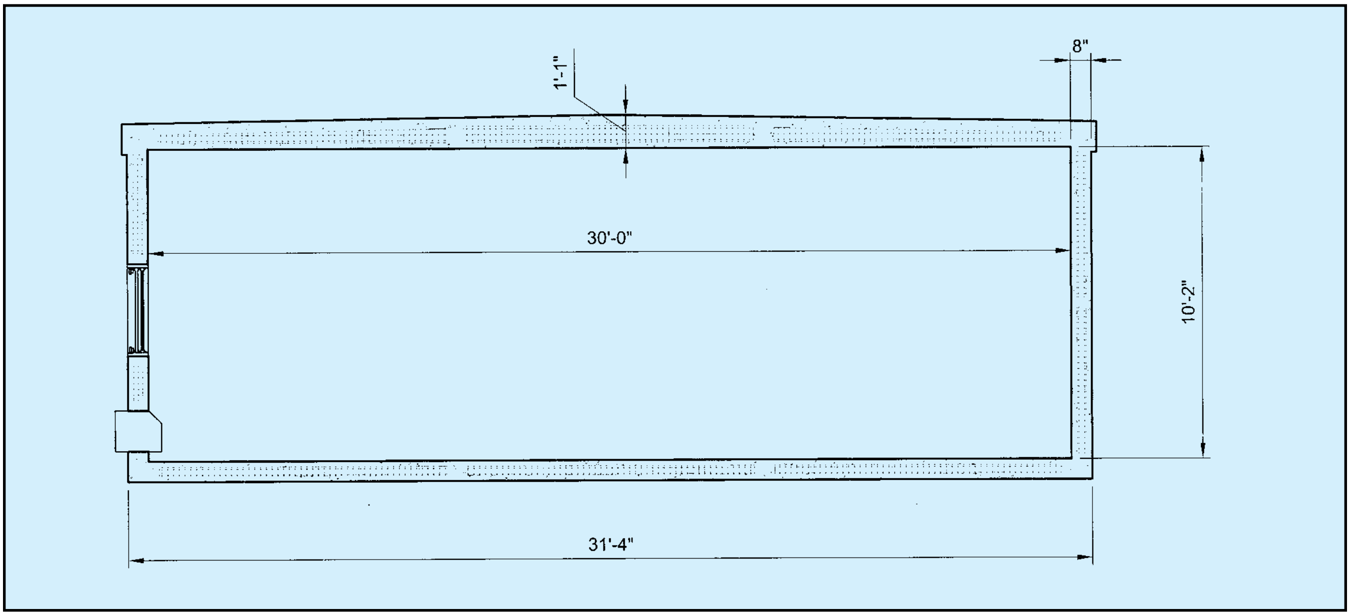


Fig. 5. Section of a typical modular ring.

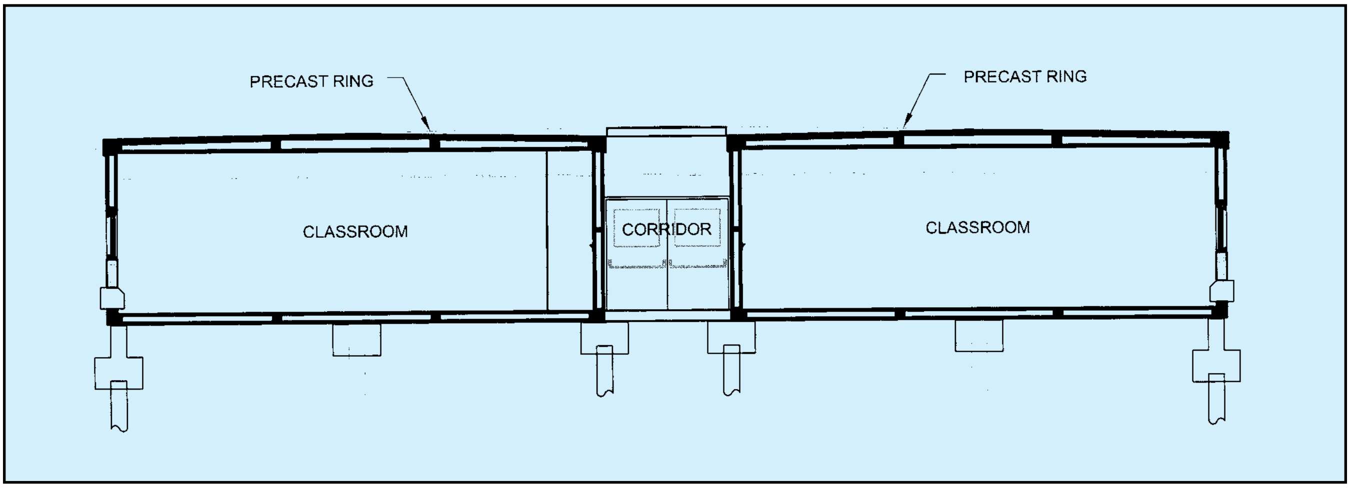


Fig. 6. Building section through classroom portion of school (Phase I).

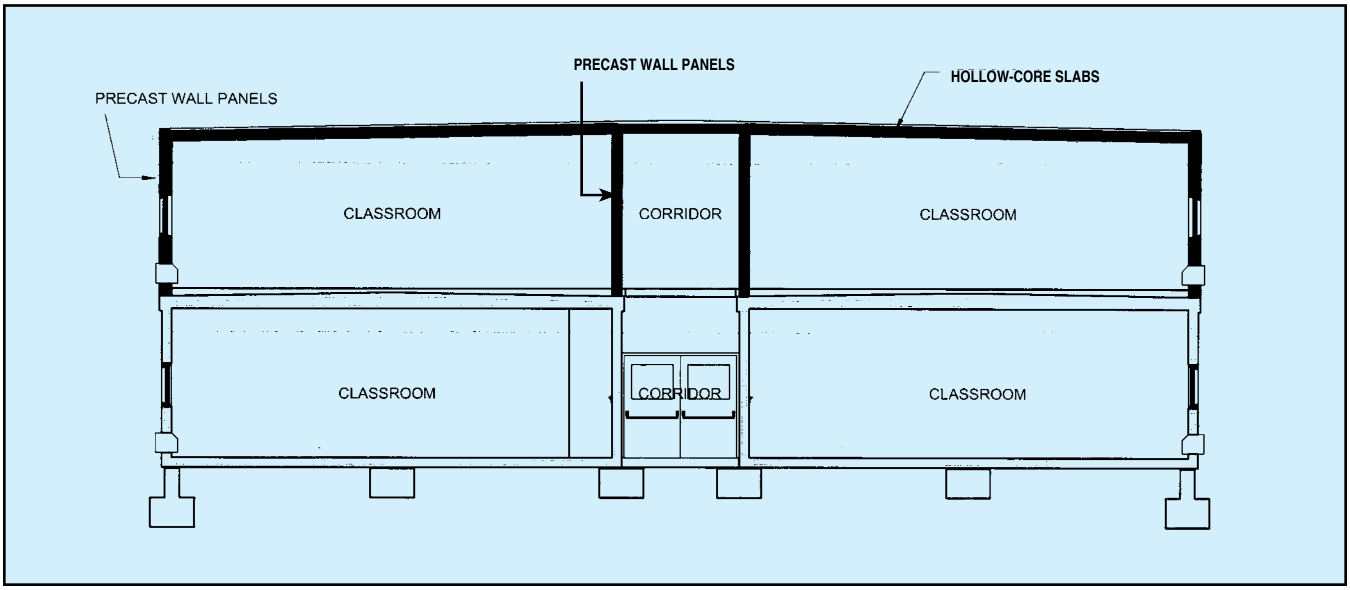


Fig. 7. Building section through classroom portion of school (Phase II).

MODULAR CONSTRUCTION

This project differs from other modular precast concrete projects in that the modules form the floor, walls and roof all in one unit. In correctional facilities, modules are used to make individual dormitory rooms. In other types of modular construction, the building structural frame and the building envelope must be constructed around the modules.

The walls and roof are separate from the modular units themselves. In the case of the Josiah Quincy Upper School, the modules form the entire building envelope. When a module is erected, so are the floor slab, walls, and roof slab. Once the pieces are set into place, interior finishing and other work can begin immediately.

The modular sections are reinforced with welded wire reinforcement. However, around the openings, additional mild steel reinforcing bars are placed. It should be mentioned that no prestressing is used in the modular rings.

The weight of the rings was controlled by making the ring sections partially hollow. As shown in Fig. 5, the floor and walls are 8 in. (203 mm) thick. The roof varies from 10 to 13 in. (254 to 330 mm) thick. The section was generally comprised of 2 in. (50 mm) of concrete, 4 in. (100 mm) of rigid insulation, and then another 2 in. (50 mm) of concrete. The inner and outer concrete faces of the rings are connected structurally with concrete ribs that are 6 in. (150 mm) wide.

End panels were used at the termination of each run of rings (see Fig. 8). The panels are made with a second face similar to that of the rings, i.e., an inner and outer concrete face surrounding a center filled with rigid insulation.

Each of the modular rings weighs approximately 90,000 lbs (41,000 kg). The rings have an interior clear opening of 30 ft x 10 ft 2 in. (9.14 x 3.10 m) wide. Window and door openings were cast directly into each module (see Fig. 9). Steel forms were used during the casting which provided tight tolerances so that field installment was not a problem.

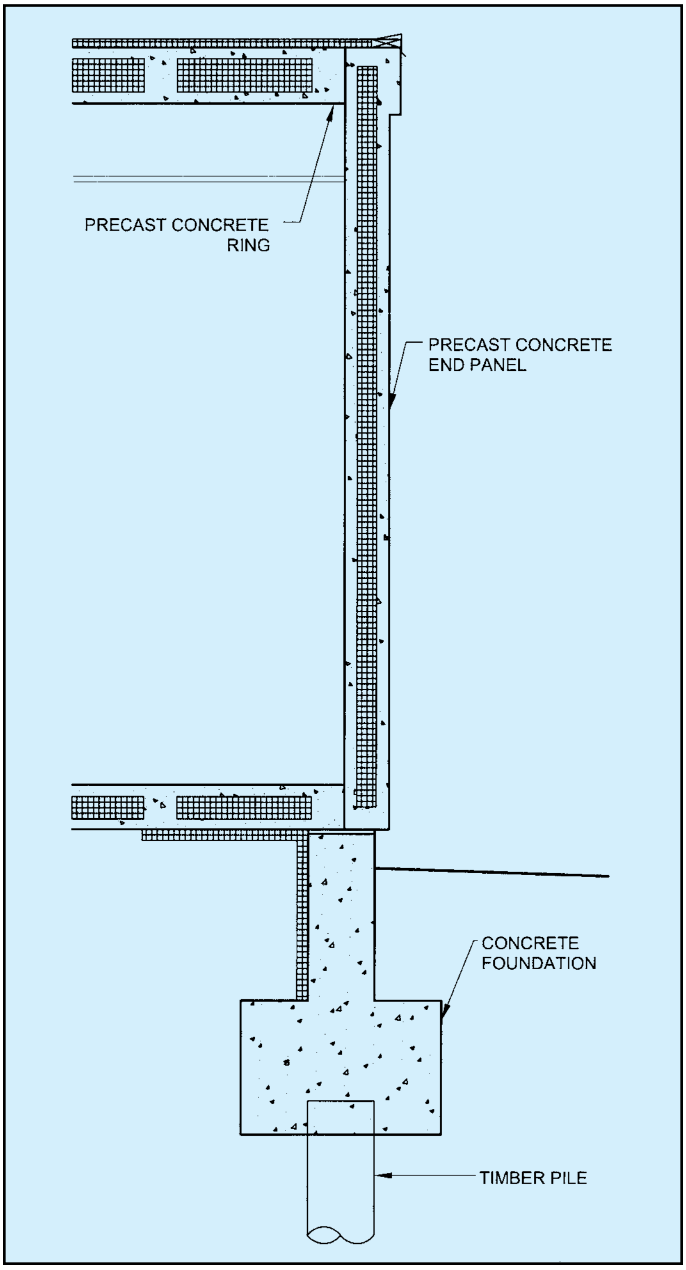
One of the benefits of modular construction is that it reduces the number of components that comprise the building wall and roof system. In this case, the wall of the precast module is the wall of the building. Only interior and exterior paint is needed to finish the wall.

The mechanical systems were designed as through-wall heating and air conditioning units, which fit in openings provided in the modular rings at the exterior side walls. Most of the electrical work and other utilities were installed in the steel stud and drywall interior partitions or the drop ceiling suspended from the overhead slab.

Although originally conceived for utilitarian type buildings, the ring design was adapted to allow for the introduction of fenestrations, surface details and reveals, and mechanical and electrical fixtures. The architect, experienced in the design of modular buildings, was able to keep the architectural design consistent with the precaster's plant practices.

Windows are amply sized, but do not exceed one-half the width of the rings. Doors and other penetrations are situated such that they can be cast into the pieces and result in rings that can be safely erected. By selecting through-wall heating and cooling units, the architect was able to largely eliminate duct work, and eliminate the need to coordinate ducts with the precast systems.

Fig. 8. Section at an end panel.



ERECTION

The Boston Public Schools awarded the $1.35 million project to the design-build team on May 24, 1999. Approximately 60 percent of the project budget was comprised of the precast concrete elements of the project. Because the precast concrete rings were variants of other designs, the specific design for this project was quickly executed which allowed fabrication to begin almost immediately.

By mid-July 1999, the foundation and grade beams had been completed and the first third of the rings (the administrative area) had been erected (see Figs. 10 and 11). All of the precast concrete components were erected by August 1, 1999. The rest of the work, i.e., roofing, interior fit-out, doors, windows, and other systems were completed from August to September 9, 1999, when the project was finished. Just 108 days had elapsed since the contract was awarded to the design-build team.

The rings were cast on their sides in the plant, and shipped to the site on their sides in trucks specially configured for hauling precast concrete rings. Because of the dense urban site, the street needed to be closed for a crane to pick the components from the truck and then rotate and place them at the installation locations.

Each of the rings were placed directly against one another. The interior and exterior joints were caulked. Because the units were cast in steel forms, the tight tolerances of the pieces allowed the building to be erected efficiently without a concern for product or erection tolerances.

PROJECT COMPLETION

Modular construction provides the opportunity for the building structural system as well as the finishes to be integrated. At the Josiah Jones Upper School, once the precast concrete rings were erected, the structure and cladding for the floor, walls and roof were in place. Completion was then just a matter of installing the roofing material, the doors and windows, and the interior and exterior wall finishes.

The exterior walls were finished

Fig. 9. Trucks transporting panels. Openings are visible in the components for unit heater and window.


Fig. 10. Erection of a precast concrete modular ring for the classroom section. The administrative area has been erected. Note the opening for the window, unit heater and door in the component being erected.


Fig. 11. Erection of a precast concrete modular ring just after it has been rotated for positioning.

Fig. 12. Finished classroom and corridor prior to furnishing.

Fig. 13. Completed classroom with furniture and fixtures.

with wall coating, the interior walls of the units with block filler and paint (see Figs. 12 and 13). Because the rings are self-supporting and form enclosures, work on interior partitions, fenestrations and fixtures can begin immediately after erection, which helps reduce overall construction time.

CONCLUDING REMARKS

The Quincy Jones School was completed in a remarkably short time, and provided the Boston School System with a high quality building that will be comfortable for its occupants and can be readily expanded.

When modular buildings are constructed using rings similar to this type of project, the rings form both the building enclosure and the building structure. That provides enormous benefits in terms of cost and time savings to the building owners, as was demonstrated by this project.

Because the design was a variant of another off-the-shelf design, it could be adapted to this specific project very quickly for rapid implementation. The efficiencies gained in the design, production and erection of the building allowed the design-build team to compete successfully against other forms of construction.

CREDITS

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