**Off-Site Construction Case Study:**

**Lexington High School Modular Addition**

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### General Information

- **Building Name:** Modular Addition to Lexington High School, Phase 1
- **Building Location:** Lexington, Massachusetts, USA
- **Project Size:** 16,800 sf., 16,000 sf. modular
- **Building Type:** High School Classroom addition, type VB construction
- **Project Type:** Addition
- **Delivery Method:** Modular
- **Total Building Costs:** $4.9 million
- **Cost/ft²:** $297 / sf
- **Off-Site Construction Methods Used,** Percentage of Overall Construction:
  - Owner: 95%
- **Building Architect/Project Team:** TBA Architects, Norian Siani Engineering, VGNA, LandTech Consultants, Triumph Modular
- **Off-Site Construction Component Provider:** Mark Line Industries
- **Project Contact Person:** Cliff Cort, Triumph Modular

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### Description

In order to meet increasing enrollment and changing student needs, Lexington High School required the addition of 10 new classrooms and a series of special education spaces. TBA Architects studied the existing site and working closely with the Town determined the best location on the campus was a three-sided courtyard along the south east side of the existing building. Lexington High is a campus made of several buildings, some linked through enclosed corridors and some by exterior canopies and arcades. Three sides of the site are bordered by two-story classroom, library, and cafeteria spaces and the fourth side by a parking lot. Given the severe time constraints to get the building operational and the need to construct while school was in session, modular construction was chosen as the delivery method. By working in a controlled environment, construction activities could happen concurrently, rather than consecutively, compressing the construction timeline. Site work involved relocation of several utilities and storm drainage service to the existing building. Additionally, the site and building had to be kept operational given that school was in session.

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*Photos Courtesy of Terry Siegrist of Mark Line Industries*
Overall Project Goals/Philosophy

**SECURE/SAFE**

The new building sits in a prominent location of the existing campus. The building needed to allow the students to continue to access the way they were familiar with the rest of the campus, but also able to meet the schools safety and emergency response requirements. This was accomplished by incorporating circulation planning into the overall design process.

**SUSTAINABLE**

Lexington is a Massachusetts Green Community so the building was designed to meet and exceed the requirements of the “Stretch Code” for energy use and mechanical ventilation. One of the ways this was done was by moving the insulative and air barrier layers to the exterior of the wall assembly. This creates a more air tight envelope and prevents moisture from building up in the wall cavity. Large windows and operable windows were used to take advantage of natural daylight and air. Skylights were used in interior corridor and office spaces to reduce the need for artificial lighting and continue the connection goal of having a connection with outside throughout the building as a number of studies have correlated adequate daylighting and an increase in student performance (+4-5%). The controlled environment of the off-site fabrication facility allowed waste to be held under 2% with off-falling being reused and recycled. Wall, roof, and floor assemblies were built indoors, protecting open assemblies from the elements and helping to preserve indoor environmental quality.

**FUNCTIONAL**

The modular building needed to provide ten new full sized classrooms, and five other specialized classrooms, and all required restrooms and building services on a very tight site. A double loaded corridor flooded with natural light was employed to provide access to the classrooms and punctuated to create gathering and wayfinding spaces for students and visitors. A site-building corridor connects the modular to the existing building and its configuration allowed the creation of an enclosed courtyard for recreation and educational use. Modular construction allowed the school to accomplish the project across multiple phases, scaling their physical infrastructure proportionally to their enrollment.

**ACCESSIBLE**

Accessibility is not only required, but was intended to make the experience of the building better for all users. Sloped walkways without the need for ramps are used for access to the modular from the exterior and interior. The floor elevation of the modular was set between the existing building floor and exterior grade to allow a gentle slope from all directions. All restrooms are fully accessible, corridors are wide and bright, and windows are low, allowing views for all users.

**AESTHETICS**

Lexington intends the building to be a solution for 10 to 15 years, but wanted a building that looked permanent and contemporary. TBA designed a rhythmic façade that used colors to accentuate the rhythm of the modular units and further animated the long sides with windows in alternating directions and depths. The idea was not to compete with the bays of the modular units, but to use them to create a building that looked as though it was part of the plan and reference the rhythm of the bays expressed in the existing school.

**COST-EFFECTIVE**

Modular was utilized mostly for the benefits of time and to ease challenging site logistics. However general conditions costs were minimized using this method, as standard construction would have struggled to be as continuous with the school needing to stay in operation and area for staging being limited. The connection to the existing building was designed to minimize the need for renovations to the existing building and the resultant spaces were taken advantage of as much as possible.

**PRODUCTIVE**

The building was designed and fabricated to meet all the same goals as a conventional build but using modular opened up additional options such as the ability to dismantle and reassemble in another location in the school district in the future as student demographics shift and flex. Utilizing modular construction was one means to improve productivity and meet the school's short timeline. The Bureau of Labor Statistics identifies the construction sector as the only non-farm industry where productivity has fallen since the Second World War, and the National Research Council is currently quantifying the productivity gains delivered by prefabrication.

**Other Significant Aspects of the Project**

This project was intended to be the first of two phases. The timeline was very short from planning through completion of the building and occupancy. Modular construction was a perfect match for the required speed to occupancy and the ability to phase the project.
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**PROCESS**

**Overview of Process**

The two-phased modular building solution was the end result of several months of collaborative space planning, programming, and site evaluation. TBA prepared design documents for Lexington Town Meeting for approval of funds for both phases. Once the Town approved the funds, the first phase was fully designed and out to bid in four months. Once the contract was awarded the site work and installation of the modular building was completed in five months. In under a year 16,800 sf. of classroom addition was completed from conceptual design to occupancy.

**Pre-Design/Planning Activities**

TBA worked closely with various members of the school department to program and space plan the two phases. Studies of the existing building were done, including space utilization for time and area. A number of locations on the campus were studied as well. Drawings, cost estimates, and schedules were assembled for presentation to a Town Meeting.

**Design Activities**

Once programming was complete and the Town had approved the money, TBA began design work. Believing modular construction is a means to delivering the same high quality product as one would expect in standard construction, but in a shorter timeframe, TBA designed as they would any other project. Using modular units as a source of inspiration and embracing technology suitable to unitized construction in a factory they assembled RFP documents with complete architectural, mechanical, electrical, fire protection, and civil engineering drawings. It was the intent to use modular as a delivery method to get the building the Town desired. Design and RFP were completed in a few short months.

**Construction Activities**

The building needed to be ready for occupancy by the start of the 2014 school year. There were only six months from contract signing to occupancy. Site work began in April, modular units were delivered in late June and mid-July, and the building was ready in time. Many latent conditions were uncovered when site-work began—gas lines, water lines, and storm drains not in the previously documented locations; a 10,000 gallon grease trap not known of; and needing to relocate the entire building due to utility company timelines—but the entire team worked together to devise solutions quickly and Triumph was able to keep the project on track. The use of modular construction reduced timelines by 30-40% in comparison to conventional construction approaches where the school would be constructed in situ.

**INFORMATION AND TOOLS**

A great deal of research was done into the modular construction process. TBA had meetings with different modular contractors, reviewed modular procurement laws (MA Ch 149 E) and procedures, and designed the building with modular in mind.

**Tools**

Vectorworks, Sketchup and AutoCad were used for development of documents.

**PRODUCTS AND SYSTEMS**

Materials and systems were chosen with an eye to balancing cost, modular friendly design, and durability for the educational use. The entire wall section was designed to meet the stretch energy code while still maximizing the amount of construction in the factory and minimizing time on site. Corrugated and smooth metal panels were specified for the exterior in a pattern intended to facilitate installation in the factory. The entire insulative and air/vapor barrier layers were moved to the outside of the walls, leaving clear stud cavities for infrastructure and minimizing the chance of water infiltration to the wall cavity. Low and no-VOC materials were chosen for the interior.

**ENERGY ISSUES**

**Energy Use Description**

Access to post occupancy data or utility cost is not available, but the HVAC system and lighting were designed to be efficient.

**INDOOR ENVIRONMENT**

**Indoor Environment Approach**

A single Energy Recovery Ventilator ensures a continuous supply of fresh tempered air and provides air circulation. The fresh air is delivered based on CO2 levels continuously monitored by the system and is filtered to clean the outside air. Heating and ventilation is provided by...
ceiling mounted mini-split and ductless units that the school system is familiar with controlling and maintaining. These units allow for individual control of spaces. Quiet operation meets ANSI standards for quiet classrooms.

OFF-SITE CONSTRUCTION PROCESS

Advantages and Disadvantages

Overlapping construction shortens overall time to meet the need for fall 2014. Units were built simultaneously with site work and quick on-site assembly. Units were built primarily in a climate and quality controlled environment, the factory. Assembly on site and exterior finishes were installed on site creating interiors in keeping with existing building. Building is designed to meet the stretch energy code and provide an environment that is equal to or better than that provided by the existing High School. Materials and systems are all in keeping with the school and are familiar to maintenance staff. Full insulated perimeter foundation wall and footing with a heated and humidity controlled crawl space eliminates mold and mildew problems arising due to water and moisture rising from below and creating warmer floor. Connecting corridor to existing building is enclosed. Exterior wall system has continuous rigid insulation on the outside of the stud cavity over a full air/vapor barrier taped to all openings and continuous with the air/vapor barrier at the roof. Corrugated metal siding and panels were completed on site assuring a complete weatherproof exterior.

Windows are thermally broken aluminum frame, dual pane insulating glass. Skylights and operable windows are large and flood the interiors with natural light, providing both natural ventilation and natural light.

PVC roof over tapered rigid insulation above the roof deck is applied on site assuring water tightness is not a patch job of individual units. Air circulation is provided by a single Energy Recovery Ventilator, ensuring a continuous supply of fresh tempered air. The fresh air is delivered based on CO2 levels continuously monitored by the system and is filtered to clean the outside air prior to delivery. Heating and ventilation is provided by ceiling mounted mini-split and ductless units that the school system is familiar with controlling and maintaining. They allow for individual control of spaces. Quiet operation meets ANSI standards for quiet classrooms. Interior finishes are in keeping with existing building. Rubber and VCT flooring, tiled restroom walls, acoustic tile ceilings were provided. Fluorescent lighting is on occupancy sensors. Classrooms are wired with data and smart boards. Wireless network is extended. Classrooms are sized with current MSBA standards. ILP spaces are designed to meet needs of population while providing for integration with school.

Schedule

Using offsite construction methods shortened the construction schedule and still allowed the team to have a complete design.

Total Project Duration:

Design Duration: Triumph was awarded the project post design.

Construction Duration: Only six months from contract signing to occupancy.

Factory Time: 12 weeks

Erection Time: Set was in 2 phases – 2 days each phase, for a total of 4 days.

Cost Data:

Vertical Construction Cost (excludes site work, land acquisition, utility improvements, mechanical and electrical improvements, etc.): $1.8MM

Design Cost: Architect hired by owner

Offsite Construction Contract: $3.0MM

PROJECT RESULTS

Lessons Learned

This project proved what the team had hypothesized—that modular construction is a viable delivery method to achieve a high quality building. The Town has used this building as an example in thinking of other projects as well as touting it to other Towns interested in exploring alternate delivery methods.

Awards:

- Honorable Mention: Modular Building Institute's 2015 Awards of Distinction, Permanent Education 10,000 to 20,000 sf. Category.