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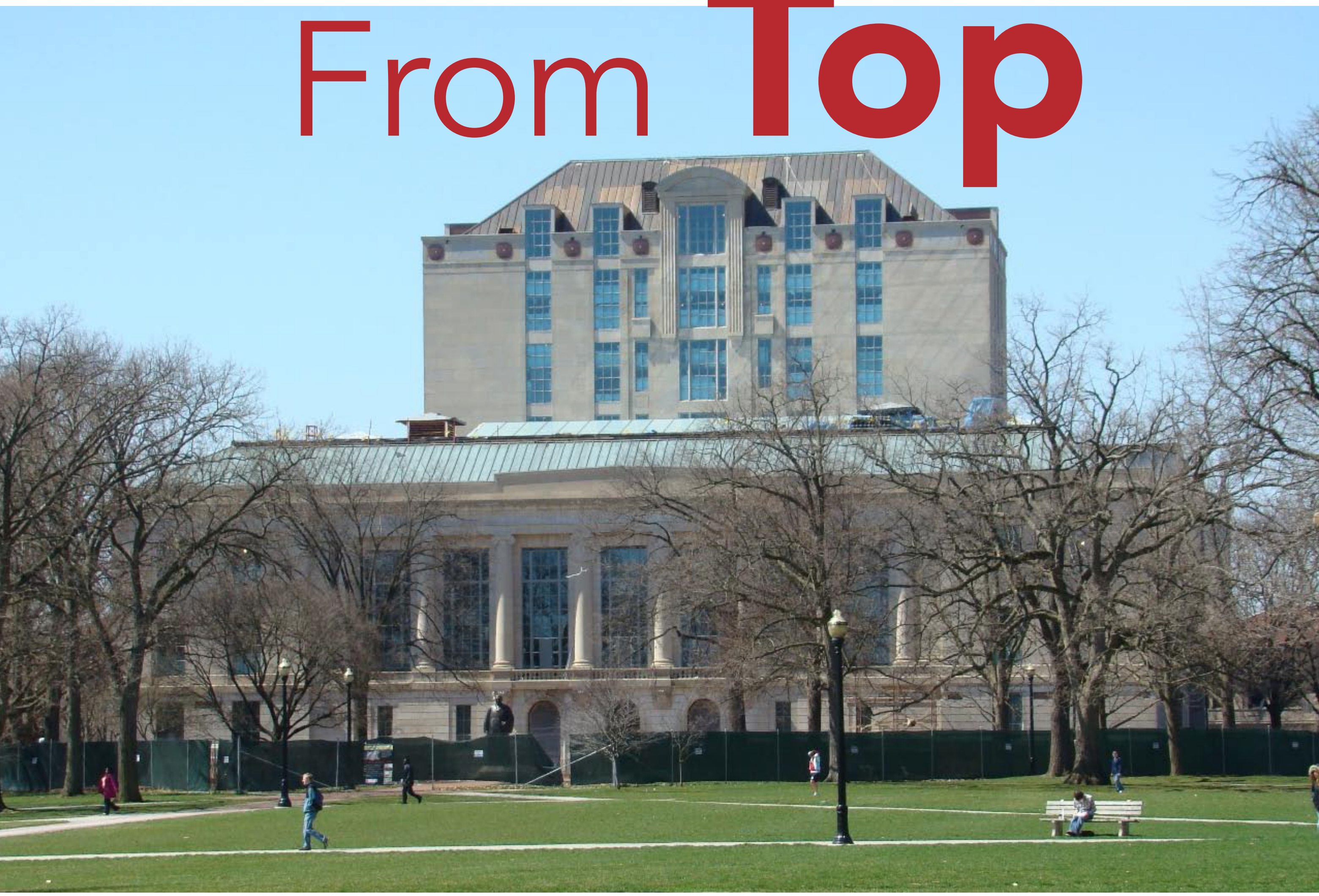


BY STEPHEN METZ, P.E.

to Bottom

Ohio State's main library receives a structural upgrade, from the basement to the attic.

ONE OF THE HALLMARK STRUCTURES for any university or college is the library, and it's not uncommon for the library to be one of the oldest buildings on a campus. Over the years, the weight of time—and books—can take its toll, thus making renovation necessary.

One such library, The Ohio State University's William Oxley Thompson Library, recently underwent a $105 million renovation, including a complete renovation of the existing buildings, partial historic renovation and preservation of the original building, and a four-story addition.

Reviving the Revival

Occupying extremely visible and high-profile real estate on the campus, the library is located on the west end of the historic Oval green space in the middle of campus. Originally constructed in 1913, the library was designed in the Second Italian Renaissance Revival style. The structure of the three-story building was a combination of exterior and interior brick bearing walls and a steel frame. Steel trusses were used to support the roof.

The 11-story stacks tower was added to the west of the original library in 1952 to provide additional study and stack space. The structure of the stacks addition was a combination of structural steel and concrete. The interior columns were composite steel and concrete while the floors are typically a 10-in. two-way concrete slab. Steel channels were welded to the columns to transfer shear from the slab to the columns. A third floor was added in 1966, which divided the reference hall in half. In 1977, because of the continued growth of the university, a three-story addition was added to the west side of the stack tower.

All of these various additions created a space that was not unified. Much of the original grandeur of the 1913 structure had been lost and the space had become dark and uninviting. Recognizing that the library was in need of a major transformation to restore its beauty and function, the university embarked on a feasibility study in 2001 followed by the start of design work in 2003. The architect developed a comprehensive plan that would provide an open and unified space and restore some of the historic elements.

Seismic Retrofit

Early in the design process, a seismic analysis of the additions was conducted, revealing a deficiency in the 1952 addition that resulted in the need for a seismic retrofit. The university decided that the lateral load resisting system should be retrofitted to meet the current building code requirements, the 2005 Ohio Building Code. Floors two through ten, with the exception of the mechanical floor at the fifth floor, were programmed to continue being used as book stack space. This resulted in very closely spaced shelving units to provide an efficient use of storage space. The use of conventional braced frames or shear walls would have reduced the number of volumes that could be stored on each floor, due to the size of the members. Hence we opted for steel plate shear walls (SPSWs).

By using the ¼-in.-thick SPSWs, the same number of volumes could be stored on each floor as before the retrofit, which was a tremendous asset to the university. In the end, the SPSW proved to be a cost-effective solution because the university would have had to build additional, unprogrammed space to make up for the lost shelving.

Removing the Bearing Walls

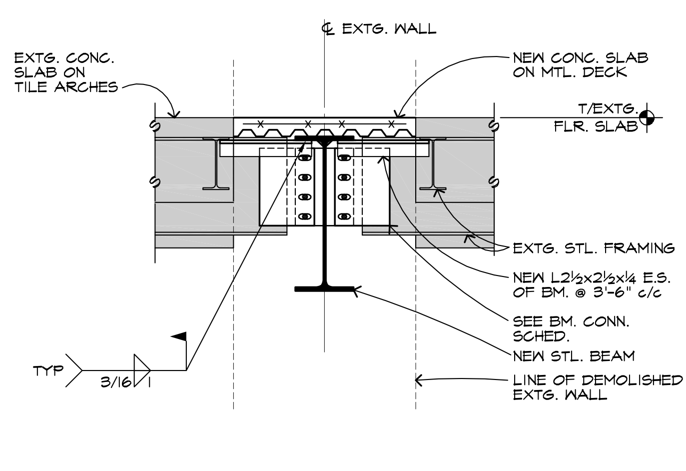
In the 1913 structure, all three of the floors and the basement were partitioned into smaller areas by the interior brick bearing walls, some more than 2 ft thick. The new design of the space called for the basement and first floor to be entirely free of the bearing walls. The walls at the upper floors also had to be removed to allow for the new four story high atrium in the middle of the space. To open the space and allow for the atrium, the bearing walls and large areas of the floors were entirely removed. Temporary shoring was installed during construction to support the floor and roof framing that was left in place. Steel framing was inserted into the building at the locations of the brick bearing walls. The new framing supports the existing floor and roof framing while allowing for the openings at the new atrium.

The north and south walls of the second floor reading room were also brick bearing walls. The historic renovation portion of the project dictated that these walls remained in place so that the original plaster details could remain and be restored. However, the brick walls at the first floor and the basement had to be removed. To accomplish this, temporary shoring was erected to support 30-ft-long W24×94 needle beams that were spaced at four feet on center. After the walls were removed, double W30×235 beams were placed tight to the underside of the needle beams. The W30 beams were supported on new wide flange columns. New masonry was added around the needle beams and the beams were cut off on each side of the wall, leaving a piece of the needle beam in the wall.

Constructability was the primary reason why steel framing was selected; it would have been nearly impossible to place concrete in the renovated portions of the building. Further, the selection of steel aided the schedule. Steel was able to be erected faster than concrete could be placed. It also provided the necessary flexibility for attaching to the existing framing. Because of the existing steel members bearing on the brick walls, the exact location of the ends of the members could not be determined until after demolition was complete. By using steel, adjustments were able to be made during construction, based on the actual conditions (see Fig. 1).

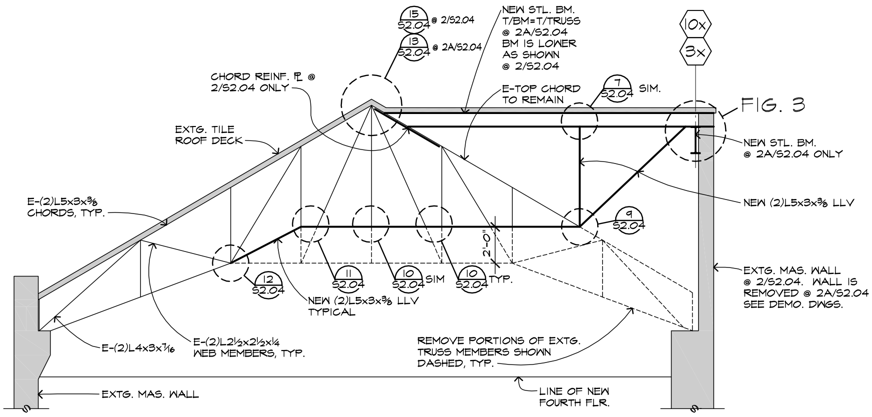
Modifications to the existing trusses in the library's attic.

New floor framing at the library's east atrium.



SECTION FIG. 1
¾" = 1'-0"

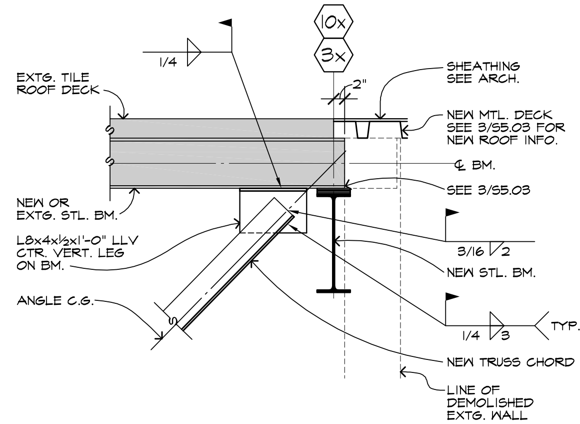
Photos: Courtesy Dave Lee with Acock Associates; Details: Courtesy Shelley Metz Baumann Hawk



TRUSS ELEVATION FIG. 2

¼"=1'-0"

NOTE: ALL NEW MEMBERS SHALL BE COMPLETELY INSTALLED PRIOR TO REMOVAL OF ANY PORTIONS OF THE EXISTING TRUSS



SECTION FIG. 3

¾" = 1'-0"

Cleaning Out the Attic

The original 1913 building had an attic above the third floor. The architect wanted to transform the space to house mechanical equipment and allow for office space to add a fourth floor. In this space, the bearing elevation of the roof trusses was approximately 4 ft above the new fourth floor elevation. The 13-ft truss spacing allowed for the offices to be built such that the office walls aligned with the trusses. However, the corridor outside of the offices was impossible if the truss bearing elevation was not modified. An additional challenge was that the existing copper roof had to be maintained. To accomplish this, we modified the trusses in place (see Fig. 2). The bottom chords of the trusses had to be reconfigured to allow for the required headroom over the new corridor. The existing trusses were made up of double angles with gusset plate connections. New gusset plates and double angle members were added before the existing members were removed. Since the end of the truss was bearing on the brick walls that were removed, new connections between the existing truss members and the new steel framing were designed (Fig. 3).

In addition to the original structure, the attic in the stacks tower was also transformed. The attic was originally used for mechanical space, which was programmed to be placed elsewhere in the building. One of the highest points on campus, the space features beautiful views. To capitalize on this, it was decided to transform the space into

Skylight trusses at the east atrium.

Needle beams for temporary support of the reading room walls.

an honors student study area that can also be used for events. Windows and dormers were added to the space to provide views of the Oval. The steel-framed, hipped roof over this space is supported by two interior column lines. The steel framing bears on the attic slab at the perimeter. To provide a more open space for campus events, four interior columns had to be removed. W30x148 girders were added to support the roof framing in the area of the removed columns. To provide openings for the new windows and dormers, portions of the existing roof framing had to be removed and reframed. Curved HSS members and trusses were used to frame the roof over the new dormer areas.

In all, the project includes 340 tons of new steel and is expected to be done in time for the fall quarter this year. It demonstrates a complete transformation of space and gives new life to what has always been a focal point of the campus. A dark, enclosed environment has yielded to bright, airy space, not only enhancing the building itself but also the entire experience of going to the library. MSC

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A Note on SPSWs

Examples of steel plate shear walls (SPSWs) as a seismic retrofit solution for low- and medium-rise structures can be found in the United States starting in the 1970s. Today, the system is being applied to a number of mid-rise and high-rise steel structures primarily on the west coast of the United States. In this area of the country, many structures are undergoing seismic retrofitting to meet current codes, and SPSWs are extremely effective in resisting seismic and wind loads. However, though applicable, the system is not widely used in other parts of the country.

Typical steel plate shear wall systems consist of a steel plate wall, boundary columns, and floor beams. The steel plate wall and boundary columns jointly act similar to a vertical plate girder. The steel plate wall itself acts as the web and the horizontal floor beams act as transverse stiffeners in a plate girder. When loaded, the plate will experience large inelastic deformations, while the VBEs (vertical boundary elements) and HBEs (horizontal boundary elements) must remain elastic. This also needs to be the case under forces generated by fully yielded webs. Thus, the actual-versus-theoretical plate yield strength becomes extremely important in the design of the system. Recent studies have shown that the ratio of expected yield stress to specified minimum yield stress, R_y, for ASTM A36 plate material is 1.3 rather than 1.1, as specified in previous codes. These new findings significantly increase design loads on the system's VBEs, anchor bolts and foundations.

A SPSW in the library's stack tower.