From Darkness to Light

Converting a Warehouse

One of the major changes in converting the warehouse (right) into an office building (above) was the addition of 32 new windows.

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Constructed in 1914, the warehouse was originally used as a leather producing shop in Boston's leather district. The building was built with brick bearing walls on the periphery with wood girders, joists, and wood decking forming the floors. Wood columns on the interior for the upper four stories and steel columns at the lower two stories and the basement support the floors, while columns rest on piers with granite stone pile caps. The two-story appendix was built at a later date with exterior masonry bearing walls and steel columns supporting the floor and roof, which comprised of steel girders supporting wood joists and wood decking. Deterioration had occurred in the brick walls and the wood structural elements on the southeastern corner of the building.

The intent of the new architecture was to provide more natural light for the new office spaces in the six floors of the building. The western side of the building is constructed with a solid brick-bearing wall with no openings, creating a dark space along the interior west side of the building. The architectural firm, The Stubbins Associates, Architects, prepared the new architectural plans. Vice President, Scott Simpson, AIA, Principal, Youngjo Sul, Vice President, and Fred Clark, Project Architect, required cutting 32 new openings on the west wall for installation of new windows. Discussions and final decisions were made with the architects to select the size of the openings in a way to leave adequate space between the openings for the existing bearing brick walls to carry the gravity load of the building with adequate factors of safety.

Effect of Lateral Loads

Cutting the new openings in the western wall would considerably reduce the lateral load carrying capacity of the wall in the long direction. Provision had to be made to reinforce the wall to avoid X cracking at remaining portions of the wall due to lateral loads and also to restore the lateral load carrying capacity of the wall to its original condition. Several options were considered for reinforcing the wall to increase its strength and ductility, such as introduction of steel reinforcement around the openings or installing carbon fiber reinforced plastic laminates on the interior face of the wall. Installation of steel reinforcing around the opening was labor intensive, and reinforcing with carbon fiber reinforced plastic sheets would hinder the desired architectural look of the wall and the interior space. An internal steel reinforcing frame was chosen as the most cost effective and easy solution.

Steel Frame Reinforcing

A steel frame was designed and installed in the new openings to compensate for the loss of strength from removal of the bricks and to produce a continuous path for the lateral loads around the opening along the wall to the base of the building. The loss of stiffness of the solid wall to introduction of the new openings was compensated by installation of the steel frames throughout all new openings. Double angles were installed at the top working as a new lintel, and three single angles were installed at the sides and the bottom all anchored to the brick for transfer of vertical and lateral loads through the wall. The whole assembly was then welded providing a rectangular steel frame inside the opening.

Earthquake and wind load calculations were performed, assuming

After window openings were cut, they were reinforced with steel frames consisting of double angles at the top and single angles on the bottom and sides. The new frames were anchored to the brick for transfer of vertical and lateral loads through the wall.

that the exterior walls act as shear walls, and the wind stresses were calculated to govern.

The unit horizontal shear stress, *q*, due to wind acting on the base of the wall where the shear force is a maximum, was calculated as a maximum of 2 psi. The lateral wind load h on the new opening was then assumed to act uniformly along the width (*d*) of the window on the periphery of the newly installed window frame and calculated as 2psi multiplied by the width of the wall and the length of the new opening. The epoxy anchors would have to be able to resist this load.

The openings were saw cut in the walls from the top story to the bottom. Alternate bays were cut where the frame was installed before proceeding with cutting the remaining openings. The masonry was completely restored and long embedment lengths were used to ensure the epoxy anchors would be effective in transferring the loads. Architecturally, the steel frames provided a smooth surface for an easy installation of the window frames.

Shown above is an interior view of the converted office space. Pictured opposite is a new stairway.

Stabilizing the Building

Design calculations required strengthening of the main building in the short direction. From various options discussed, using an X-bracing midway between the end walls of the building was considered to be the most effective solution.

The building was comprised of three bays along the short direction where the X-braced bay was going to be installed. It was decided to install the X-brace system on the middle bay, where the lateral load from the exterior walls would be transferred from the exterior walls through the wood beams and the floor to the middle bay braced frame. Installing seismic clip angles and additional connection hardware therefore strengthened the floor beam connection to the braced frame.

The X-braced bay was constructed by attaching and through bolting channels to the top and bottom of the wood floor girders and lag bolting vertical channels on the inner side of the wood columns on all floors. The floorboards around the wood beams were cut, and steel gusset plates were inserted through the cut and welded to all the steel channels. Steel diagonal members were welded to gusset plates forming the X-bracing system.

Other Strengthening Considerations

The 10" x 12" wood girders were tied to the brick walls by using steel angles bolted to the wood beams and epoxy anchored to the brick walls. The corners of the building were tied using connection angles bolted to the brick masonry walls at all floor levels on all corners.

Steel columns and girders in the area where new mechanical units and the new elevator were installed replaced the top story wood columns and girders supporting the roof structure.

A portion of the two-story building that was used as a covered loading dock/parking garage was converted to a new classroom by constructing a new raised steel floor structure resting on minipiles. The roof structure was reinforced to support new mechanical equipment and accommodate the installation of new heavy folding partitions. Existing steel lintels at the loading dock openings were reinforced to accommodate new larger openings connecting the classroom area to the rest of the structure.

Improvements to the building also included exterior masonry cleaning, replacement of the roof with new insulated membrane system, allowance for a steel/glass canopy main entrance, renovation of one existing and construction of a new fire stair, and two new elevators.

Using steel for reinforcing and rehabilitation of the building and selection of T.R. White Co. Contractors, with a past experience of using steel for rehabilitation of buildings, helped to achieve a well-coordinated project. AISC-member Mill City Iron Works served as the fabricator and detailer. The project was completed according to the required schedule bypassing the hassle of cold weather concreting and lengthy operational procedures.

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