ZALLEN ENGINEERING
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# Preventing Collapse of a Manufacturing Building Being Converted to Housing Use

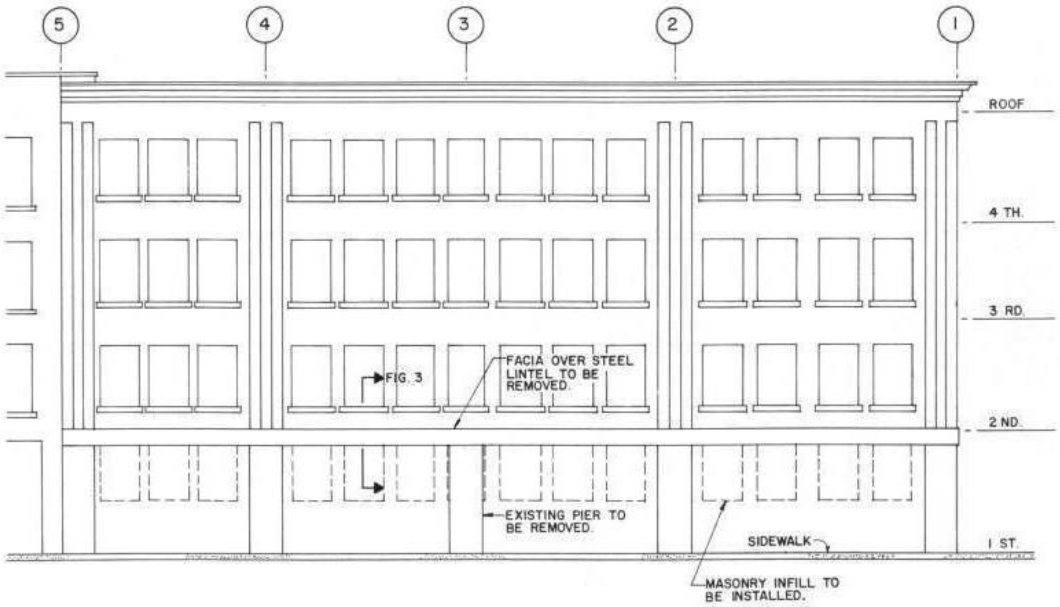


**Figure 1 Schematic elevation of southerly half of wall on Line G, where collapse was prevented, showing original conditions.**

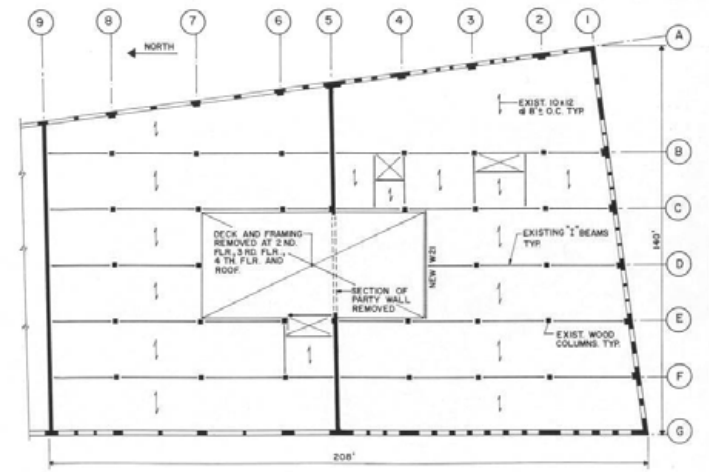


**Figure 2 Schematic plan of manufacturing building converted to urban housing, showing typical framing.**

A general contractor, acting as a developer, hired an architect to design a conversion of an old manufacturing building to urban housing in a city in Maine. The design was completed in October 1977, and construction started in early 1978.

Figure 2 shows a schematic floor framing plan of the building, as it was converted. The building was originally

composed of two structures with a common party wall on Line 5. The overall building dimensions are approximately 208 feet by 140 feet in plan. The building has four stories plus a basement story, and rises 55 feet above the sidewalk.

The exterior walls and the party walls are brick masonry bearing walls, supported on concrete foundation walls. The original floor construction consists of a 3 inch tongue and groove plank deck supported typically by 10" x 12" wood beams at approximately 8 feet on center, which in turn are supported by steel "I" beam girders. The "I" beam girders are supported by timber columns and by the brick bearing walls. Originally, there was store front construction at the first story, along Lines A, 1, and G, with steel beam lintels spanning over the store front windows and supporting the brick bearing walls above. Figure 1 is an elevation of the southerly structure along Line G, showing the original store fronts.

In the conversion, the store fronts were filled in with masonry construction and windows to match the walls above. At all locations, except one, no structural changes were required at the storefronts. The exception was on Line G, where the pier on Line 3 interrupted the pattern of windows and piers in the wall above, and needed to be removed.

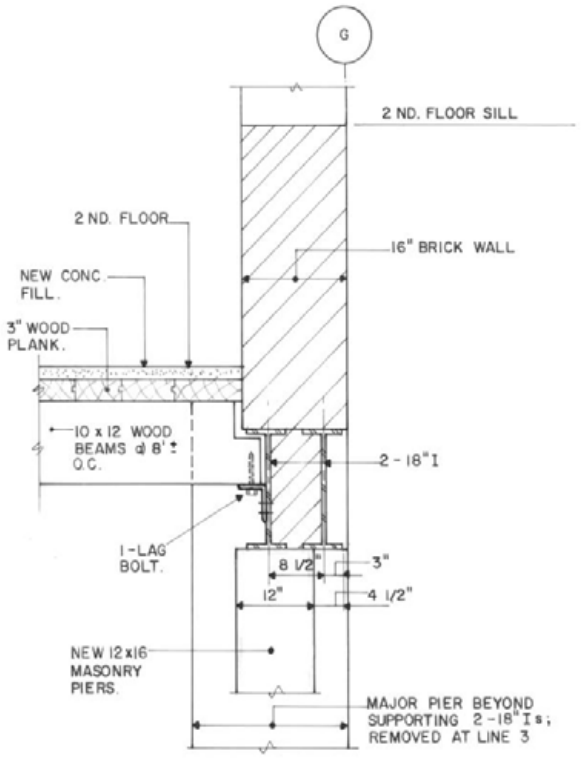


**Figure 3 Section through lintel construction on Line G.**

Figure 3 is a section through the lintel and the 2nd floor on Line G, between Lines 1 and 5. Shown is the actual lintel construction of 2-18 inch deep "I" beams which support the masonry above. These "I" beams originally spanned between the major masonry piers that divide the store front windows. As part of the renovation, new masonry piers, as shown on Figure 3, were added on Line G between the foundation wall and the bottom of the lintel (as part of the masonry infill). The major support pier at Line 3 was removed after the installation of these new piers. The new piers were constructed from 8"x16" hollow concrete chimney block with 4" brick on the outside face.

As of April 3, 1978, the structural renovations were completed. On that date, the contractor's superintendent observed that the 2nd floor piers (between the windows) of the wall on Line G were cracked on the outside face of the wall at the window sill level, and that the wall between Lines 2 and 4 had moved outward at this level. The superintendent tried to arrest the movement by various methods; however, the movements continued to increase, and by April 18th cracks opened up at the sill level of the 3rd floor.

Rubin M. Zallen Associates (a predecessor of Zallen Engineering) was retained to determine the causes of the lateral movements of the Line G wall, and to consult on remedial measures. Also, at the recommendation of Zallen Associates, an experienced shoring contractor was engaged to restore the wall to its original position.

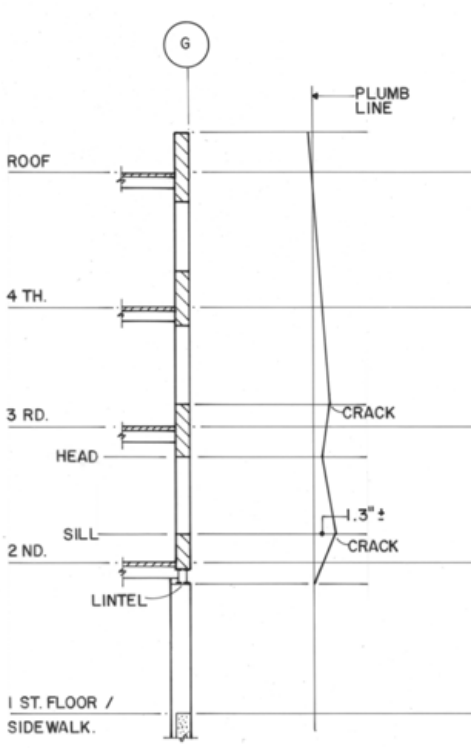


**Figure 4 Lateral displacements of wall on Line G.**

The investigation by Zallen Associates revealed that not only had the wall moved outward, but that the wall had dragged part of the 2nd, 3rd, and 4th floors outward, as well. Figure 4 shows the wall displacements. The cause of the lateral movements of the wall is that the outer 18 inch "I" beam had no stable support after the pier on Line C was removed. The new masonry piers on Line G, although numerous, were eccentric from, and inside of, the center of the outer "I" beam, causing the outer "I" beam to roll outward, which in turn caused the wall above to move outward.

The structural drawings were very limited in scope and only had requirements for new floor and roof framing, where this framing was necessary; the structural drawings had no information on the exterior brick bearing walls. Further, the structural engineer did not make a structural investigation of the existing building prior to design or construction, and was not aware of the exterior wall details until after the lateral movements of the wall occurred. The architect's drawings showed that the G-3 pier should be demolished and showed the new piers that were installed under the lintel to be located as shown in Figure 3. The architect's drawings did not show the lintel construction correctly, or provide any directions or other information on the support of the lintel. The contractor did not

question the architect or obtain instructions from him when he observed different lintel construction in the field, or observed or should have observed that the removal of Pier G-3 would leave the outer 18 inch "I" beam of the lintel without stable support.

**Remedial Shoring**

A shoring scheme was devised to first, prevent collapse of the wall and the building, and secondly, to restore the wall to its original position and tie the walls and floor framing together. Figures 5 and 6 show the shoring scheme.

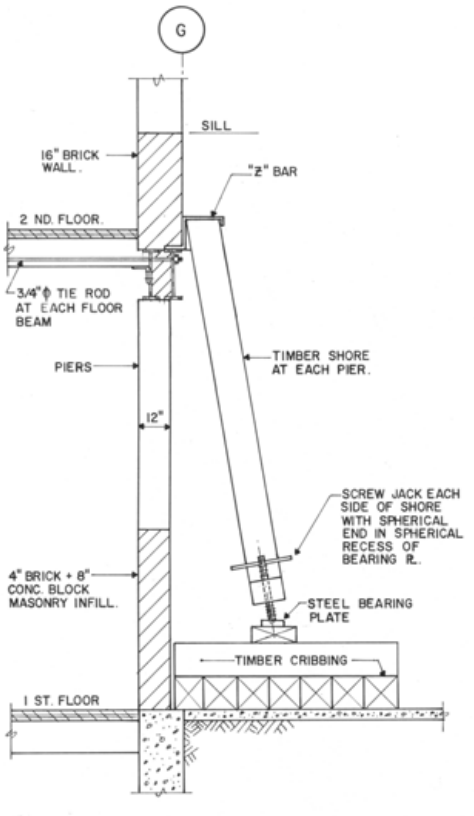


**Figure 5 Shoring scheme showing inclined shores and tie rods at the wall on Line G.**

of the building occurred at this time. 2) The 2nd, 3rd, and 4th floor brick spandrels on Line G, between Lines 1 and 5, were tied back into the building as shown in Figure 6. Temporary 6"x8" vertical timbers were placed against the

In order to prevent further movement of the wall on Line G, two measures were taken: 1) Inclined timber shores were installed to support the wall just above the lintel beams, between Lines 1 and 5, as shown on Figure 5. These shores were located opposite each pier, and were supported on timber cribbing on the sidewalk. A special "Z" bar cap on each shore was cut into the masonry. The screw jacks at the bottom of the shores were made snug, but no jacking

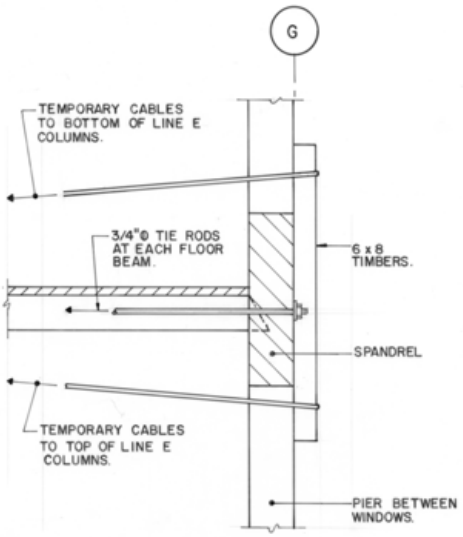


**Figure 6 Shoring scheme showing tie rods, and showing temporary timbers and cables used to laterally stabilize the masonry wall.**

outside of the spandrels, and the timbers were tied through the window openings by temporary cables to the tops and bottoms of the Line E columns.

The next step in the process was to install permanent 3/4" diameter tie rods and turnbuckles at each floor beam at the 2nd, 3rd, and 4th floors, between Lines 1 and 5, as shown on Figures 5 and 6. These rods extend from the Line G wall, through holes made in the webs of the steel girders, to the Line A wall, except that where the rods are interrupted by the court, they were terminated on Line E, and corresponding rods were run from Line C (on the other side of the court) to Line A. Also at this time, vertical shores with jacks were installed from the foundation wall on Line G to the bottoms of the double 18 inch "I" beam lintels where they terminate near Line 3 (where the pier had been removed).

To restore the wall to its original position, the screw jacks of the inclined shores were tightened to lift the wall, and simultaneously the 3/4" diameter tie rods were tightened to pull the wall inward. Also, the temporary cables attaching the 6"x8" timbers to the Line E columns were simultaneously kept tight. As the wall was lifted, the shores under the lintel beams at Line 3 were jacked to bring the lintel beams back into their original position. When the walls and lintel beams were restored to their original positions, the 12"x16" piers were removed, and 16"x16" solid brick piers, concentric with the pair of lintel beams, were installed. The last step was to repoint the brick wall and to remove the shoring and other temporary supports.

Principal Rubin M. Zallen investigated this partial collapse, consulted on the shoring and bracing of the structure, and consulted on the method of restoring the wall to its original position.

Forensic Engineering in Construction® is published by Zallen Engineering, 1101 Worcester Road, Framingham, MA 01701. Comments are welcome. Please direct comments to Rubin M. Zallen, P.E., by telephone at 508-875-1360 or by e-mail at rmzallen@zallenegineering.com.