

Gymnasium Wall Study

**BOLTON CENTER SCHOOL
TOWN OF BOLTON, CT**

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SUBMITTED TO:

Town of Bolton

222 Center Street
Bolton, CT 06043

Tel 860.649.8066
Fax 860.643.0021

PREPARED BY:

CME Associates, Inc.
333 East River Drive, Suite 400
East Hartford, CT 06108

Tel 860.290.4100
Fax 860.290.4114



Introduction

The Town of Bolton engaged CME Associates to investigate the exterior wall condition of Bolton Center School near the Gymnasium. Visual observations of the apparent displacement of the upper portion of this wall generated concerns about its condition and deterioration. The Town of Bolton requested that CME Associates provide short-term recommendations, long-term recommendations and an estimate for recommended work. CME Associates visited the site on April 29, 2014 to photo document the wall, take measurements of the wall displacement and conduct a visual inspection of the exterior walls and adjacent interior spaces. This investigation was limited to the problems associated with the main gymnasium walls. Other issues with the masonry such as cracking and closing of expansion joints is not included in this study.

Review of Existing Plans and Previous Studies

The Town of Bolton provided a complete set of building drawings to CME Associates, which included both architectural and structural drawings dated August 1992. In addition, the Town of Bolton provided the Exterior Masonry Wall Study dated June 29, 1998, which they conducted to determine the cause of other vertical cracking in the masonry façade that appeared shortly after construction of the building.

Steel beams, open web steel joists and steel columns provide the primary structural support system, and an exterior masonry wall system clads the building. It is important to note that the masonry system does not support vertical loads from the roof. The masonry provides a building envelope and transmits wind loads to the adjacent steel framing. The cracking found does not affect the ability of the primary structural support system to support loads. At the gymnasium, the composition of the wall system includes backup concrete masonry units [CMU], followed by 2 inches of rigid insulation a $\frac{3}{4}$ inch air space and the exterior façade masonry which alternates between 4-inch CMU and standard-sized brick. Figures 1 and 2 show the two wall types used in the construction of the east wall of the gymnasium.

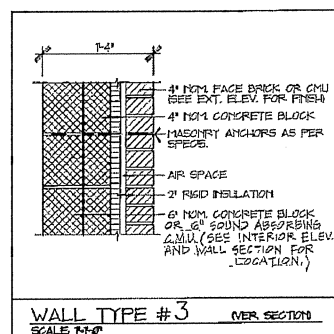


Fig. 1

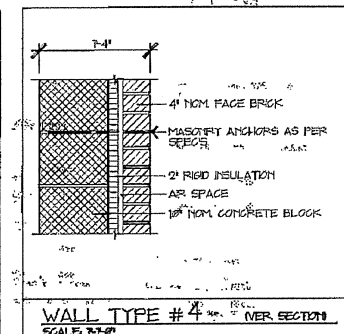


Fig. 2

This type of wall, referred to as a cavity wall, provides a drainage path for moisture in the wall to weep holes located at the base of the wall. The wall types show a $\frac{3}{4}$ -inch air space, which is significantly

smaller than the current industry standard of a 2-inch air space. The backup CMU forms the interior face of the gymnasium wall and varies along the length of the wall. Acoustic CMU, which has openings in the interior face shell and sound dampening material in the hollow cores, composes a portion of the wall (See Figure 3). The location of the acoustic CMU corresponds to area of greatest deterioration in the exterior façade.

The wall type sections in Figures 1 and 2 do not include a moisture barrier in the wall system. Photos taken of the destructive wall tests done for the previously mentioned exterior study revealed that the face of the rigid insulation had an adhered moisture barrier material. It is unknown whether this material is an air barrier, vapor retarder, weather-resistive barrier or a combination thereof.

The wall at the gymnasium extends two stories tall. It does not contain any window openings, but does have openings for mechanical louvers. The architectural wall section in Figure 4 shows the construction of the wall. However, it neglects to show a structural steel tube at elevation +14'-0". The steel framing plans show this tube and include it in a section detail. The tube transmits wind forces from the wall to the adjacent steel columns. This wall section also does not provide information about the construction of the wall between roof joist seats (red circle). The wall does not contain any relieving angles that would interrupt the air space, but the airspace and insulation terminate below the bottom of the parapet. The air space that would allow moisture to drain in the wall does not appear to extend the full height of the wall.

The wall section indicates that the parapet is composed of 6-inch backup CMU supported by a steel beam and 4-inch façade CMU vertically supported by the masonry below. The architectural detail appears to show mortar between the 6-inch backup CMU and the 4-inch façade CMU. In this detail, the mortar restricts the 4-inch façade CMU from moving up and down independently from the

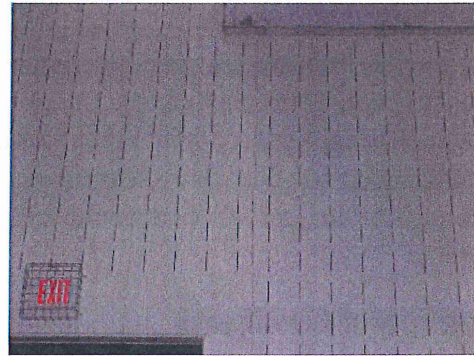


Fig. 3

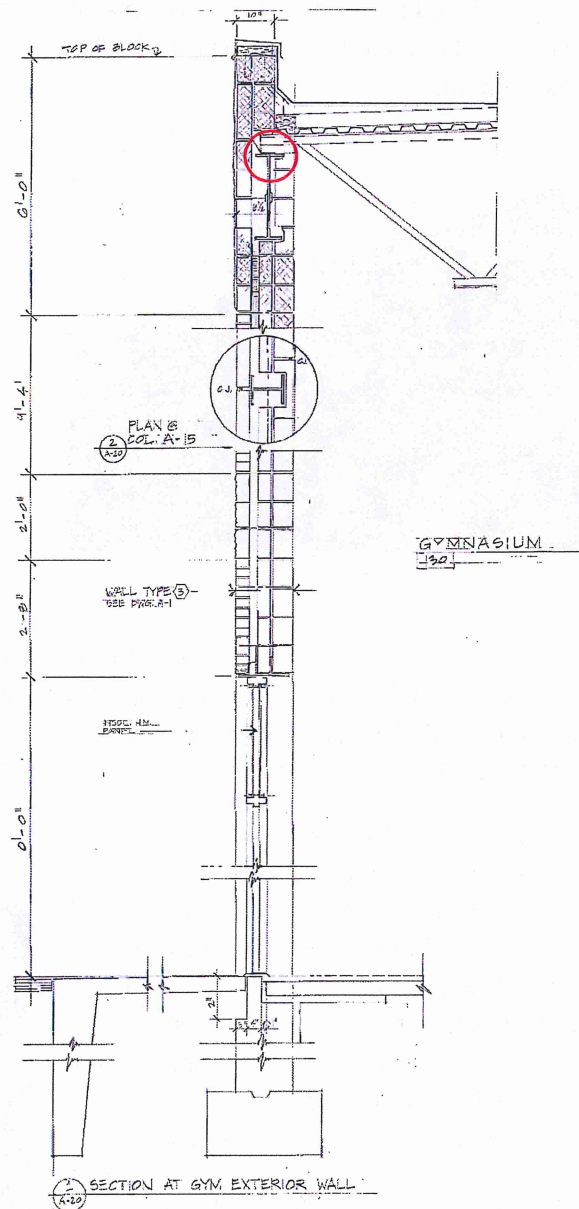


Fig. 4

6-inch CMU supported by the steel beam, which will deflect due to snow load on the roof.

As mentioned previously, the building experienced significant cracking in the masonry façade shortly after construction. Subsequent to the Exterior Masonry Wall Study, the Town of Bolton undertook repair work to the facade. As part of that repair work, the contractor applied “breathable” water repellent to the brick and split-faced masonry. Manufacturers label their products “breathable” if the water repellent acts to prevent rain from penetrating the masonry, yet also allows moisture to escape from the interior.

Description of Conditions

The upper portion of the east wall of the gymnasium shows signs of significant deterioration of the outer 4-inch façade layer of the wall. The masonry, covered by a layer of pargeing (a thin coating), contains both horizontal and vertical cracks through the masonry joints and the masonry units (See Figures 5 and 6).



Fig. 5



Fig. 6

The vertical cracks are consistent with movement due to expansion and contraction in the material in the horizontal length of the wall. The horizontal cracks indicate that the masonry has experienced tension in the exterior face of the unit in the vertical direction.

Figure 6 also shows the presence of efflorescence and staining. Efflorescence is white staining, caused by water moving through a wall, which transmits dissolved salts from the masonry materials to the surface. When the water evaporates, the salts are left behind causing white staining. Both efflorescence and staining are indications of moisture movement through the façade masonry and joints.

Near the top of the wall at approximately two feet to three feet below the coping, the wall

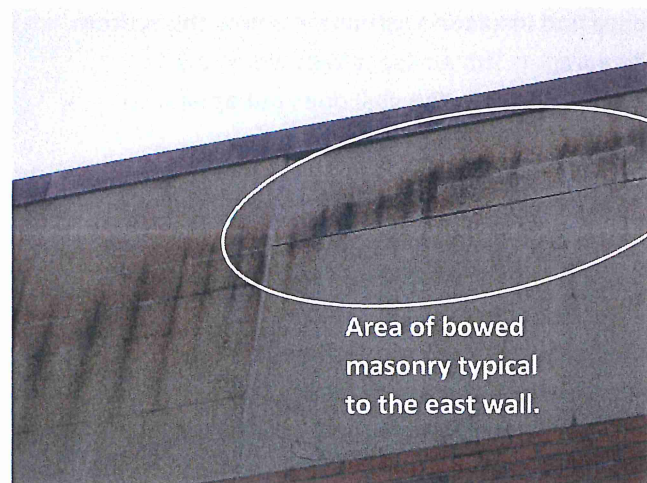


Fig. 7

bows outward (See Figure 7). This location corresponds to approximately the top flange of the steel beam supporting the roof joists and the backup CMU of the parapet. Cracking, staining and protrusion of the mortar in the horizontal joints accompany the bowed masonry.

Measurements of the displaced masonry indicate that the greatest protrusion occurs horizontally for approximately 80 feet starting approximately 25 feet from the southeast corner. The horizontal distance from the top of the wall to the face of the bulge is approximately $\frac{1}{2}$ inch to $\frac{3}{4}$ inch. The wall below the pargeted CMU does not exhibit any bowing or concavity.

At both the north and south corners of the east gymnasium wall, the exterior façade contains spalls or masonry that appears to be unstable. This masonry requires repair to prevent it from becoming a falling hazard (See Figures 8 and 9). The damaged areas occur in the pargeted CMU and accompany a loss of mortar at the joints. The damaged areas do not extend into the brick below.

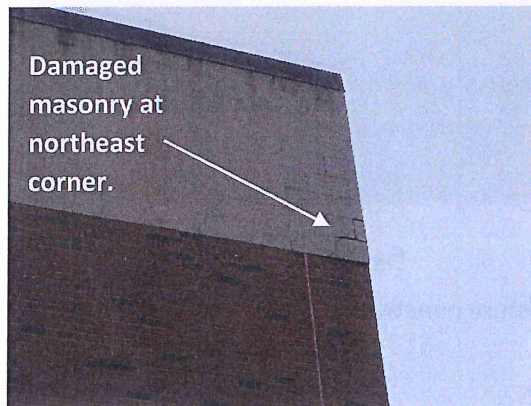


Fig. 8

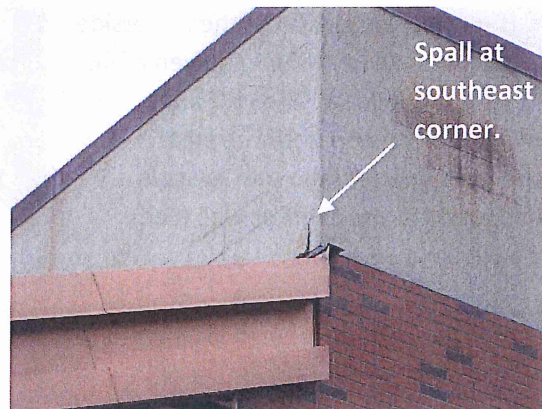


Fig. 9

As noted in the previous Exterior Masonry Wall Study, the weep holes at the east wall are below grade. Per discussions with facilities staff, CME understands that during construction, the Town of Bolton addressed the problem of the location of the weep holes. In lieu of relocation of the weep holes, they agreed to place free draining material in this area to allow water to escape below grade.

Similar cracking, staining and efflorescence are present at the north gymnasium wall in the pargeted CMU above the brick (See Figure 10). The south wall above the sloped roof also has cracking. However, these walls do not exhibit the same bowing outward that the east wall does. In addition, the upper portion of each of the walls terminates at a lower roof with weep holes located just above the lower roof.

A recently performed thermal scan of the gymnasium roof revealed several areas along the parapet in which there is moisture below



Fig. 10

the roof membrane. The thermal scan detected areas of moisture along the north, east and south parapets. The east gymnasium wall had the largest section. It measured approximately 65 feet and corresponded to the area of greatest deterioration in the exterior wall. Inspection of the roof showed that there were no standing puddles of water and drains were clear.

In addition to exterior observations and measurements, CME conducted an inspection of the interior of the building both at the gymnasium and at areas adjacent to the gymnasium. Inspection of the underside of the deck in a portion of the classroom wing at the exterior wall adjacent to the gymnasium showed no evidence of water. However, inspection of the underside of the deck in the gymnasium showed areas of light rust and mildew. The rust and mildew was located on both the steel acoustic roof deck and the roof joists in areas adjacent to the exterior wall (See Figure 11).

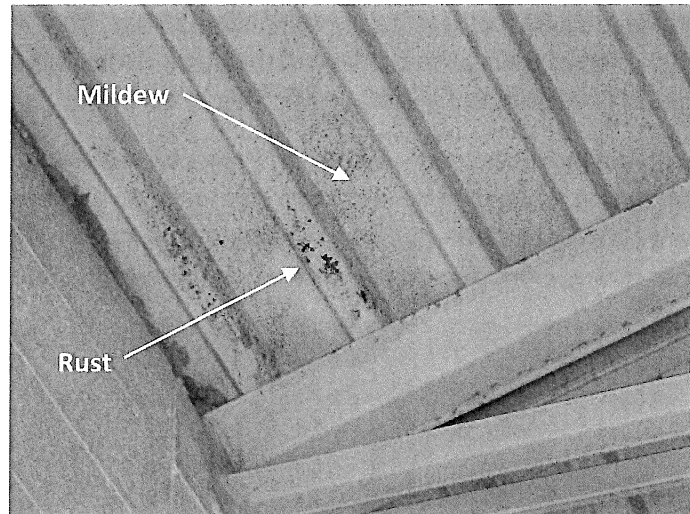


Fig. 11

These areas also correspond with the marked locations of moisture penetration at the roof from the thermal scan.

Cause of Deterioration

There are four potential sources of water penetration in the wall. The first source is water vapor from the interior of the building drawn into the cavity and then condensing when reaching a cooler portion of the wall. In an informative article in *Masonry* magazine on moisture management, Kami Farahmandpour and Joshua Summers wrote, "Research and experience has shown that the vast majority of moisture condensation within wall assemblies is caused by movement of moist air from the warm side of the assembly to the cold side."¹ CME completed a previous investigation of a pool structure at Palmer High School in Palmer, Massachusetts with similar construction. The investigation showed that acoustic CMU with an opening in the face shell, similar to acoustic CMU installed at the Bolton gymnasium, allowed a high level of water vapor to move through the wall.

The second source is exterior water penetration from rain. Water resistive sealant helps to prevent water penetration, especially in driving rain. However, in locations where the sealant cannot bridge the larger cracks, rain will be able to penetrate the crack and move into the cavity through capillary effects.

Another source of moisture is water from the roof. The architectural detail of the parapet at the roof indicates that the roof deck extends below the masonry backup at the parapet. Moisture trapped at the back of the parapet below the roof membrane could potentially move through the joint between the roof deck and the CMU into the cavity of the wall.

The last source of moisture in the wall is localized condensation. This could occur anywhere a thermal bridge exists. A thermal bridge is an interruption in the insulating material by a non-insulating material.

The potential locations for thermal bridges in east gymnasium wall are at the steel tube at elevation +14'-0", the flanges of the steel beam and the CMU at the parapet. At these localized cold spots, moisture in the air can condense and enter the cavity in the wall.

In cavity walls, water can move down through the air space, through a pea stone or similar material at the base of the wall and out through weep holes to the exterior of the building. The water in the cavity needs to move quickly out of the cavity wall. Water prevented from leaving, absorbed into the masonry or held by surface tension in small spaces in the cavity wall will freeze and expand under cold conditions. The wall construction at the gymnasium has two potential restriction on the flow of water out of the wall system. The first is the buried weep holes. If soil clogs these holes, it impedes the movement of water to the exterior. The location of the weep holes below grade also prevents ventilation of the cavity. The second restriction on the flow of water is the size of the air space. An air space of $\frac{3}{4}$ " does not give the mason enough room to clean excess mortar out of the air space during construction, and the excess mortar will intrude on the air space. During destructive testing as part of the Exterior Wall Study partial removal of block revealed that there was minimal or no air space.

CME also investigated the potential movement of the steel structure as a cause of the bowing masonry. Steel roof joists in the gymnasium deflect under snow load. Since the span of these joists is approximately 80 feet, the vertical movement due to snow load could potentially reach over 2 inches and still be within permissible limits of the building code. However, the corresponding horizontal movement at the supporting steel beam at the exterior gymnasium wall is not large enough to cause the bowing out of the masonry. Flexing of the wall system at its base can accommodate minor lateral movement of the steel framing. As the wall flexes, the upper portion of the wall simply moves with the steel framing. The cracking and deterioration patterns are not consistent with this type of movement.

The observations made with regard to the cracks in the masonry facade, efflorescence, mildew, rust and thermal scans demonstrate that moisture infiltration in the wall played an important role in the deterioration of the wall. Given the evidence of the presence of moisture and the possible restriction to drainage present in the construction of the wall, expansion and contraction caused by freeze-thaw cycles of water trapped in the masonry wall is another likely source of masonry deterioration. The restriction to differential movement of the façade masonry in relation to the backup masonry at the parapet further complicates the conditions caused by excess moisture.

The general conclusion is that the details and methods used for the construction of the wall are the most likely cause of the problems noted. Several details in the wall are not consistent with current industry practice leading to improper moisture management in the wall cavities.

Short-Term Recommendations (Implemented in approximately 3-24 Months)

In the short-term, CME proposes the following recommendations:

1. Repair to the roof membrane at the parapets to ensure a moisture barrier from rain and snow on the roof.
2. Repair the two small areas of masonry with spalls at the southeast and northeast corners of the gymnasium wall.

3. Initiate a destructive investigation of the masonry at the bowed area below the parapet to determine the condition of the masonry ties. This work could be scheduled during cold periods in order to determine the presence of ice in the wall cavity.
4. Conduct visual inspection of the masonry at two-month intervals to check for spalls, excessive cracking, additional joint movement and loss of mortar at joints.

If it is determined that the masonry ties are no longer effectively restraining the masonry or a visual inspection reveals additional problems, additional short-term measures will need to be taken and may include stabilization of the exterior masonry façade or local repointing and repair.

It should be noted that the only immediate repair that is necessary is item number 2. There is a slight risk that the loose masonry could fall onto passing pedestrians. The area below these spalls should be barricaded off with safety tape prior to this repair. The other recommendations noted should be completed in the next two years.

Intermediate Recommendations (Implemented in approximately 3-5 years):

Subsequent to the short-term recommendations, CME proposes the following intermediate recommendations:

1. Completion of an in-depth study of the wall system and building envelope to:
 - a. Determine the as-built condition of the wall.
 - b. Design and detail the replaced portion of the wall façade and parapet.
 - c. Evaluate the possibility of sealing the face shell openings in the acoustic block.
 - d. Evaluate, design and detail the relocation of weep holes above grade.
 - e. Evaluate, design and detail weep holes at the top of the wall for ventilation.
 - f. Comment on the continued application of water resistive sealants.
2. Removal of the upper portion of the 4" façade of the wall composed of CMU and covered by parget at the east and north gymnasium wall. This portion is the 6-foot tall off-white band at the top of the wall.
3. Relocation of the weep holes above grade. This work would involve incremental removal and replacement of small sections of masonry. Grout would be placed behind the masonry veneer below grade to fill the cavity. This work would be followed by installation of new flashing and new weeps, and replacement of the removed masonry. Relocation of weeps below grade would be accompanied by installation of weeps at the top of the wall to improve both drainage and ventilation.

While the weeps at the bottom of the wall play a part in the overall function of the drainage of the cavity, it is not a direct cause of the deterioration of the wall in the 6-foot tall off-white band at the top. This deterioration is due to moisture trapped at the top of the wall. Relocation of the weeps can improve the overall function of the wall, but will not resolve the larger issues of deterioration at the top of the wall.

4. Replacement of the removed façade with a non-masonry wall cladding.

Long-Term Recommendations (Implemented in approximately 20+ years)

CME advises the Town of Bolton to view the above recommendations as an intermediate solution. Measures taken to improve the drainage and ventilation of the cavity wall may significantly improve the performance of the wall and extend its life. The lower portion of the wall does not exhibit the same level of deterioration as the upper portion of the wall. It generally is free of spalls, mortar joint loss and staining, although some efflorescence is present. However, in areas in which there is minimal to no air space, trapped water will continue to cause deterioration through freeze-thaw cycles. Long-term deterioration has the potential to damage the façade and require the replacement of the outer façade portion of the wall.

In the future, it may be necessary to replace the entire wall face masonry. The interior masonry wall could potentially be salvaged. Replacement of the entire wall face can address all of the potential deficiencies noted in this report.

Cost Estimate

The tables below provide estimated costs for the short-term and intermediate recommendations. This estimate represents an order of magnitude for the cost of implementing the recommendations.

Short-Term Recommendations

Item	Units	Cost per Unit	Estimated Cost	Remarks
1. Repair to the roof membrane	n/a	n/a	n/a	This is work undertaken apart from the wall study.
2. Repair or replacement of the two noted areas at the southeast and northeast corners	2 Locations	\$1000	\$2000	
3. Destructive investigation of the masonry at the bowed area	Lump	\$2000	\$2000	
4. Visual inspections	n/a	n/a	n/a	Visual inspections can be performed by Town of Bolton facilities staff
Total Cost Estimate			\$4000	

Intermediate Recommendations

Item	Units	Cost per Unit	Total Estimated Cost	Remarks
1. Demolition setup & material disposal	Lump sum	\$31,000	\$31,000	
2. Demolition of masonry and removal of existing coping	230 LF	\$250	\$57,500	
3. Installation of EIFS & new coping	230 LF	\$170	\$39,100	
4. Relocation of weeps	90 LF	\$250	\$22,500	
Subtotal			\$150,100	
10% General Conditions			\$15,000	
15% Design Costs			\$22,500	
10% Contingency			\$15,000	
10% Overhead and Profit			\$15,000	
Total Cost Estimate			\$217,600	

Work Cited

¹Rarahmandopour, Kami and Joshua J. Summers. "Air Barriers, Vapor Retarders and Weather-resistive Barriers: Are They All the Same?" *Masonry*, July 2007.