Gap Mountain Consulting Engineers, PLLC

April 7, 2024

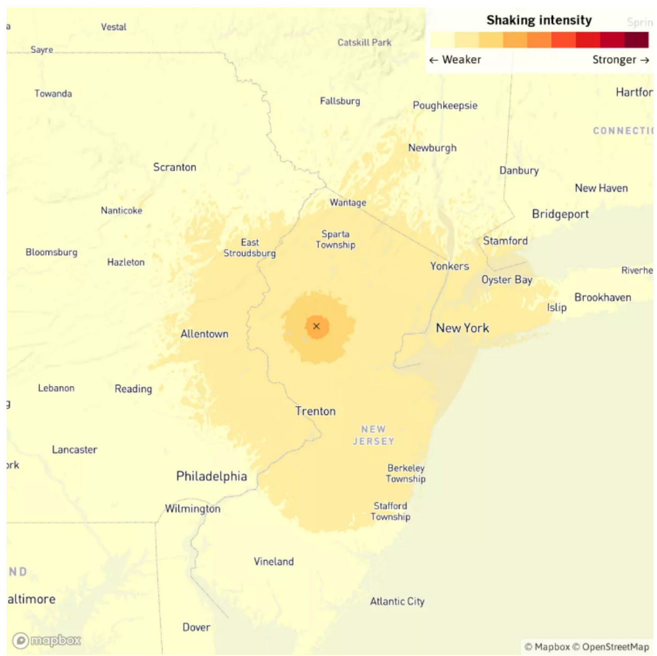
Director of School Facilities
Mr. Daniel Watson
Greenwich Public Schools
290 Greenwich Avenue
Greenwich, CT 06730

Subject: **GREENWICH CENTRAL MIDDLE SCHOOL**
POST-EARTHQUEST STRUCTURAL CONDITION INSPECTION

Dear Watson,

Per your request we conducted a structural condition assessment to determine whether there was structural damage to the building following the 04.04.2024 earthquake.

EARTHQUAKE



A magnitude 4.8 earthquake occurred at 10:23 AM on 04.04.2024 with the epicenter located in Oldwick, NJ. The figure to the right is a map showing the epicenter of the earthquake. Shaded bans illustrate the dissipation of seismic energy as the intensity decreased from moderate at the epicenter to mild in Greenwich, CT. We estimate that the Richter reading for Greenwich was less than 1.5 magnitude based on extrapolated data from NYC.

Magnitude of an earthquake is reported using the Richter scale where damage is predicted using the Mercalli scale. For purposes of this report we discuss the earthquake in terms of Richter because of public general knowledge and applicability.

The Richter scale derives a specific number for the magnitude of an earthquake. The number ranges from 0.0 to 9.9 and is dimensionless. The formula used to derive this number is a logarithmic analysis of wave amplitude measured from Wood-Anderson seismographic field data. Because the scale is logarithmic, vibration energy increases exponentially with increases in the number. For example, an increase in Richter from 1.0 to 1.2 is a 100% increase in wave energy. Earthquakes with Richter readings lower than 1.5 are generally not observable with exceptions to unique soil conditions such as dense soils or rock or high ground water levels. Enclosed is a scholarly discussion on Richter for further reading. Richter is a convenient method for communicating the severity and potential for damage. Neither Richter nor Mercalli are used for the design of buildings and the take away from Richter is that Greenwich experienced a very mild earthquake.

Contemporary buildings are designed to respond to and withstand earthquake energy in context with a facilities risk to human life and the frequency / intensity of earthquake potential in a geographic zone. Designers consider life safety and not the condition of the building following an earthquake. In other words, contemporary buildings are designed to be damaged during an earthquake, remain standing, and not be so strong and rigid as to induce injury to occupants or bystanders. Contemporary and historic design practices do not use Richter or Mercalli.

Risk to public safety is categorized numerically from 1 to 4. Geographic zones are categorized alphabetically from A to F. Generally accepted practice in CT is to apply published ASCE[1] engineering algorithms, formulae, and methods to convert design earthquake energy to equivalent lateral forces, and to study and design structural response to this seismic energy using equivalent static lateral forces[2].

Risk category 1 represents low to no risk to human life, while risk category 4 applies to hospitals, first responders, shelters, and other uses that pose significant risk to the public. Most public K-12 schools fall into risk category 3. Some are category 4 because they are also designated shelters.

Earthquake zone categories are a more involved study that guide designers. For purposes of this report most K-12 schools in CT are Zone B which we assume for Greenwich Central Middle School.

EXISTING STRUCTURE

Greenwich Central Middle School was constructed in 1958, prior to State building codes. It has a small addition circa 1999 serving as a library with offices. The addition is connected by a narrow sallyport and both the sallyport and library would have been design under the CT State Building Code not inclusive of the 2000 amendment. The basic structural system of the original building and addition is structural steel frame with masonry walls. The 2nd level and roof of the original building are not design as diaphragms[3] and do not act to distribute lateral loads to the CMU walls that are rigid but were not designed as structural cords. CMU block walls carry their self-weight and are laterally supported by steel frames and their assembly at foundation walls. The sallyport is similarly designed. The 2nd level of the addition was designed as a diaphragm and acts in composite with it's CMU walls to distribute lateral loads to steel frames. Thus the original building and sallyport respond to seismic loads with structural steel framing while the library is more rigid and responds with a structural steel frames, diaphragm, and cords.

There unique conditions in the design of the building that should be noted.

> **Theater**. It is structurally steel framed but the walls are brick and CMU. The brick walls are structural while the CMU walls are partitions similar to the rest of the original building. We believe the design acts in composite with structural steel frame and brick, while it's hexagonal geometry resists rotational effects associated with seismic. The theater responds more robustly to seismic forces and is a relatively rigid design.
>
> **Sallyport**. This smaller, weaker structure is sandwiched between the heavier and more rigid library and strong (long) axis of a wing to the existing building. The sallyport is prone to damage with any lateral movements to the overall building along the centerline of its axis. Reaction to seismic forces is dynamic. Lateral vibration or shaking of the existing building and library can and are likely to be opposite to one another at the same time. This places large compression and tension forces on connections with the sallyport making the sallyport prone to damage during a seismic event.
>
> **Groundwater**. The library and sallyport are constructed in a depression with high ground water levels. Ground water introduces buoyancy forces to a soil's structure which significantly reduces the soil's internal friction. This reduction in internal friction reduces the soils ability to resist lateral pressure. This phenomenon is most typically associated with retaining walls. However, buildings whose foundation walls are exposed to high ground water levels lose their ability to resist lateral pressure under seismic forces. Buildings with submerged foundation walls will move. The risk that the library pushes it's weight against or pulls away from the sallyport during a seismic event increases with high ground water levels.

[1] American Society of Civil Engineers 7-XX circa the applicate State Building Code.
[2] This method is not typically used for taller and more complex buildings.
[3] Horizontal floors or rigid plates that transfer lateral wind and seismic loads to walls or rigid cords.

INSPECTION

We performed interior and exterior observations of the building on 04.06.2024. Observations include facades, hallways, randomly selected classrooms, the sallyport to the library, library, stair towers, dining facility, gymnasium, theater, basements, tunnel / plenum, roof, and a brick chimney. We did not perform destructive inspection or testing but were able to observe conditions above the suspended ceiling.

Our inspection focused on those structural members designed to brace the building during lateral earthquake loads. For the original building and sallyport this focus was on structural steel and concrete foundations. We observed the physical condition of structural steel beams, columns, base plates and anchor bolts, foundation walls, bolted assemblies, welds, and where structural steel and concrete foundations interact. We also observed the condition of CMU and brick walls. Because we performed prior condition inspections of this same building, we are familiar with pre-earthquake conditions. Enclosed are photographic records with captioned notes from our inspection.

Our findings are that the basic structure was not observably impacted by the earthquake. The building appears to remain in serviceable condition and is suitable for continued use as a K-12 school.

Some minor repairs and maintenance to CMU partition walls in the sallyport are recommended. Reference earlier reports and discussions with the Town regarding differential settlement[4]. During earlier inspections we observed that the building experienced some differential settlement following construction of the 1999 addition. Contributing factors are ground and surface water conditions surrounding the library and sallyport coupled with their geotechnical subgrade conditions. The observed result is cracking in CMU walls acutely in the sallyport connecting existing to new. These conditions predate the earthquake.

We believe that designers of the addition accounted for differential settlement using an expansion joint. However, the expansion joint was either not design or constructed correctly. The flaw is that joint in the floor does not align with the joint in CMU walls. The results are: 1) natural expansion joints are formed in walls of the sallyport; and 2) uncontrolled cracking. During our above ceiling inspection, we observed that uncontrolled cracking extends to the roof and beam pockets. Some cracks are indicative of lateral loads such as wind and seismic. Cracks are more extensive where the sallyport abuts the existing building at the roof and beam pockets, which is where forces concentrate and the sallyport structure is confined by the existing building. We observed fine cracks at and above the ceiling which is indicative of response to seismic loading. These cracks may have formed or been exacerbated by the earthquake but they are not a structural or life safety concern.

We observed the condition of facades that were repaired earlier under our design and resident engineering of the construction project. We observed no cracking or failure in the façade and find that the retrofit wall ties performed as designed for seismic response. Facades do not appear to have been impacted by the earthquake or extreme winds. We did not test or measure whether there has been any movement.

[4] Condition that occurs when soils supporting footings for a portion of a building consolidate at a faster rate than soils supporting footings for other portions of a building. This is a common condition for additions to existing buildings because all newly constructed buildings cause soils to consolidate. The addition was completed roughly 42-years after the original building was constructed and the designers of the addition accounted for this with an expansion joint.

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RECOMMENDATION

Recommend that the Town program a minor maintenance and repair project to “stich” uncontrolled cracks in CMU walls abutting the existing building in the sallyport. Do not stitch what are now naturally formed expansion joints in the walls as these are now expansion joints. The joint can be caulked for aesthetic and weather proofing purposes. The caulk needs to be elastic while stich repairs are rigid and structural. Stitch repairs to masonry construction are retrofit mechanical devices that structurally connect cracked CMU or brick, permanently restoring a masonry wall to its original structural condition. We would be pleased to provide you with SK level drawings and performance specifications for a minor project that can be performed sometime during summer months.

Again, our overall findings are that the building requires minor maintenance and repairs in the sallyport, and the basic structure was not impacted by the earthquake. The building remains in serviceable condition and is suitable for continued use as a K-12 school.

Please call me at 603-400-5455 if you have any questions or need more information.

Very truly yours,

GAP MOUNTAIN CONSULTING ENGINEERS, PLLC

STATE OF CONNECTICUT BRODERICK C. ATTRA No. 21845 LICENSED PROFESSIONAL ENGINEER

04.07.2024

B. Cory Attra, PE, MBA, SI, M.ASCE
Engineer in Responsible Charge

Enclosures: 1. The Richter Magnitude Scale
2. Photographic records with captioned notes.

APPENDIX G

THE RICHTER MAGNITUDE SCALE

Earthquake Severity

Magnitudes	Earthquake Effects
Less than 3.5	Generally not felt, but recorded.
3.5-5.4	Often felt, but rarely causes damage.
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1-6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0-7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

Information above found at: http://www.seismo.unr.edu/ftp/pub/louie/class/100/magnitude.html

The Richter Magnitude Scale

Seismic waves are the vibrations from earthquakes that travel through the Earth; they are recorded on instruments called seismographs. Seismographs record a zig-zag trace that shows the varying amplitude of ground oscillations beneath the instrument. Sensitive seismographs, which greatly magnify these ground motions, can detect strong earthquakes from sources anywhere in the world. The time, locations, and magnitude of an earthquake can be determined from the data recorded by seismograph stations.

The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included for the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

At first, the Richter Scale could be applied only to the records from instruments of identical manufacture. Now, instruments are carefully calibrated with respect to each other. Thus, magnitude can be computed from the record of any calibrated seismograph.

Earthquakes with magnitude of about 2.0 or less are usually call microearthquakes; they are not commonly felt by people and are generally recorded only on local seismographs. Events with magnitudes of about 4.5 or greater - there are several thousand such shocks annually - are strong enough to be recorded by sensitive seismographs all over the world. Great earthquakes, such as the 1964 Good Friday earthquake in Alaska, have magnitudes of 8.0 or higher. On the average, one earthquake of such size occurs somewhere in the world each year. The Richter Scale has no upper limit. Recently, another scale called the moment magnitude scale has been devised for more precise study of great earthquakes. The Richter Scale is not used to express damage. An earthquake in a densely populated area which results in many deaths and considerable damage may have the same magnitude as a shock in a remote area that does nothing more than frighten wildlife. Large-magnitude earthquakes that occur beneath the oceans may not even be felt by humans.

Above information can be found at: http://neic.usgs.gov/neis/general/handouts/richter.html

Enclosure 2

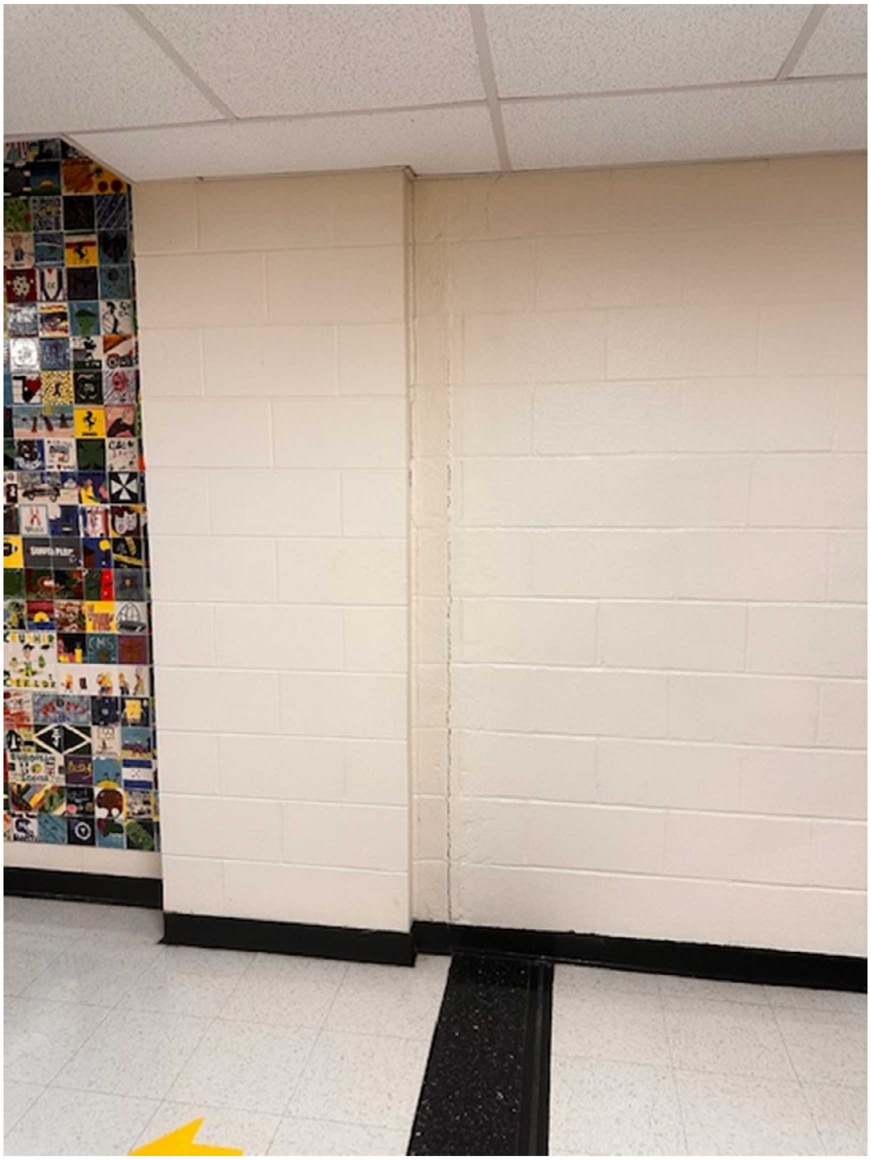

Figure 1 - expansion joint in the floor is covered with vinyl strip while the naturally formed expansion joint in the wall is off-set and formed through CMU block and joints. The abutting pilaster remains in serviceable condition.

Figure 2 - stepped cracking typical of differential settlement. Note the expansion joint in the wall is not aligned with one in the floor and is not functioning.

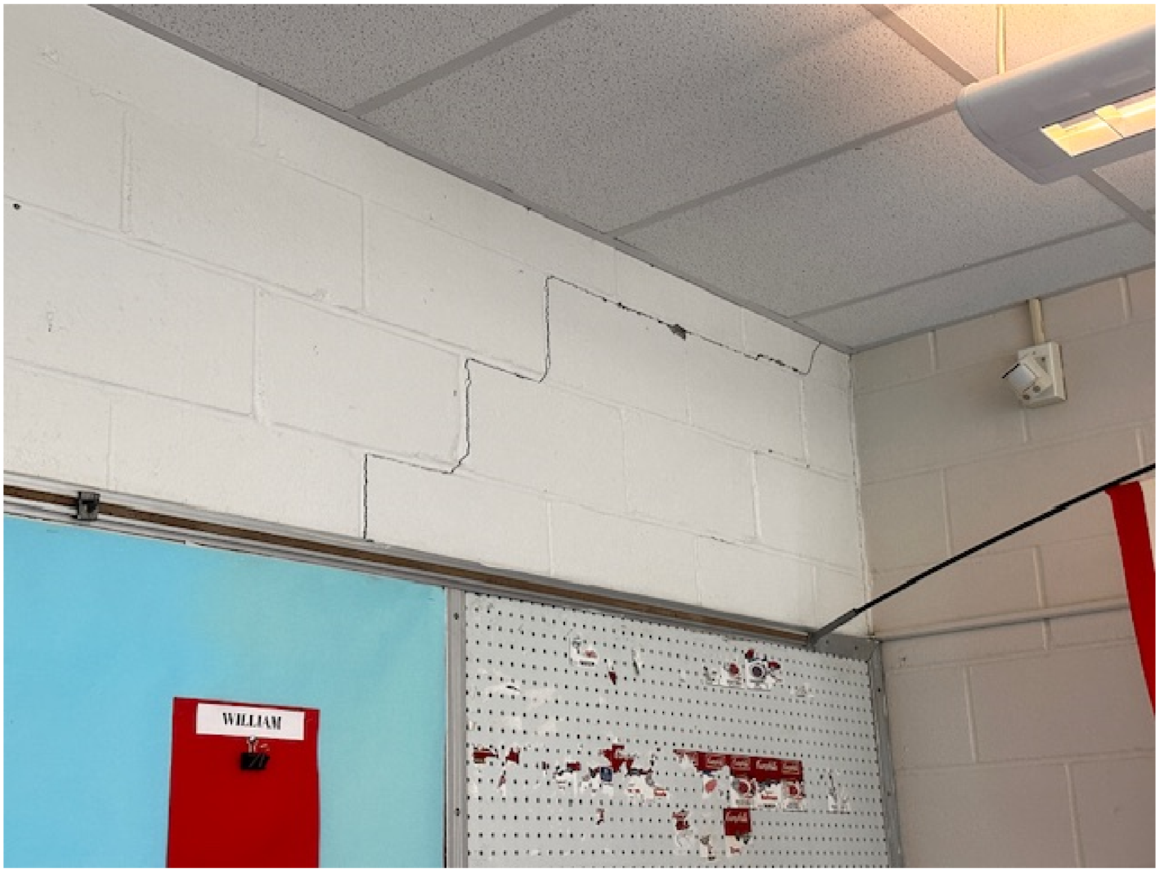

Figure 3 - opposite side of the wall in Figure 2 showing that the stepped cracking carries through the wall. This is typical of differential settlement conditions in non-structural CMU walls.

Figure 4 - Uncontrolled cracking above the ceiling in the area of the expansion joint of the sallyport.

Figure 5 - different angle on Figure 4 where we observed fine hairline cracks around the beam pocket which is consistent with the response of CMU block under seismic loads.

Figure 6 - Above ceiling and opposite side of the hallway from Figure 5 which is consistent with differential settlement. Fine hairline cracks around beam pockets cannot be seen in this photo but were observeable.

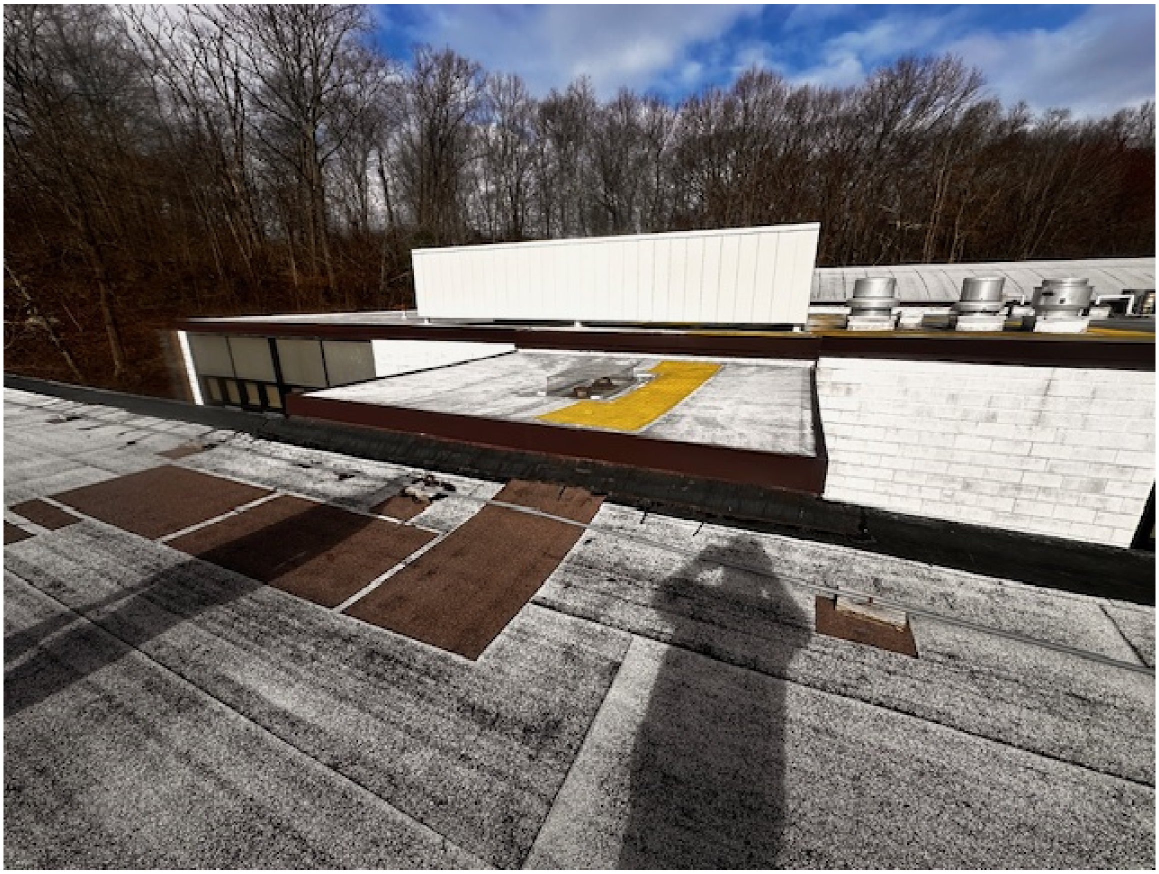

Figure 7 - Perspective of standing on the roof looking down on the cracked CMU walls of the sallyport, where it abuts the existing building. Photo is taken from the existing building with the library in the background.