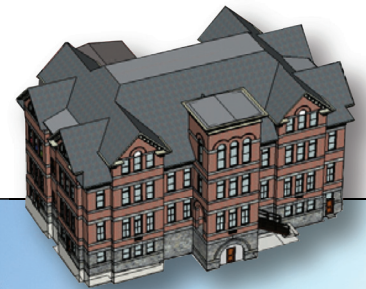


Lord Strathcona Elementary School - Heritage Classroom Building - Base Isolation Seismic Upgrade



Submitted by: **Ausenco**

Client/Owner:



Vancouver Board
of Education
School District #39
(Vancouver)

Prime
Consultant:

THE
COLBORNE
ARCHITECTURAL
GROUP
Pacific Inc.

Contractor: Heatherbrae

Isolator

Subcontractor: Dynamic Isolation Systems (DIS)
via Teratec Inc. (isolators)

Sub Consultants to Ausenco:

- Seismic Isolation Engineering (analyses support)
- Forell/Elsesser Engineers (analyses support)

Other Consultants:

- MMM Group (mech/elec)
- aDB Engineering (shoring)
- exp. (geotechnical)
- McGrath Engineering (material testing)
- Jensen Hughes (code)
- Associated Engineering (civil)
- PWL Partnership (landscape)
- Morrison Hershfield (envelope)
- ACM Environmental (hazmat)



Canadian Consulting Engineering Awards 2017

PROJECT INFORMATION

Project Name: Lord Strathcona Elementary School
Heritage Classroom Building – Base Isolation Seismic Upgrade

Location of Project: 592 E Pender St, Vancouver, BC, Canada V6A 1V3

Completed By: December 2016

Category: Buildings

Entering Firm Name: Ausenco
Address: 855 Homer Street, Vancouver, BC, V6B 2W2

Role on Project: Structural and earthquake engineering: analysis, design, isolator testing requirements, witness isolator testing, construction related services including flat-jacking procedure.

Member of ACEC: Yes

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P.Eng: Yes

Project Summary

Lord Strathcona Elementary School - Heritage Classroom Building Base Isolation Seismic Upgrade

The Vancouver Board of Education needed to seismically upgrade their High risk 1897-vintage heritage classroom building. Ausenco provided analysis, design and construction-related services for the innovative solution - the first base isolated building in Canada.

Non-linear analyses involved 21 earthquake records. First-in-Canada use of “flat-jacking” raised the building 3mm onto 30 new isolators; custom details accommodate 250mm of during-earthquake lateral movement at an “isolation plane”.

The upgrade achieves resilience, post-earthquake “immediate-occupancy” performance, and heritage preservation.



Project Highlights

Innovation

The base isolation seismic upgrade converted a high seismic risk 120 year old brick-and-stone building to one with post-earthquake “immediate-occupancy” performance and heritage preservation.

This is the first base isolated building in Canada, further unique and cost effective with the isolation plane above ground, compared to below-grade isolation projects elsewhere.

The non-linear analyses carried out are a Canada-first following all-new national code provisions. Four different computer models accounted for variations in concrete, soil, and isolator properties, each analyzed for 21 different earthquakes. Custom software was developed to post-process the tremendous amount of data. Numerous iterations realized a 12 bearing/18 slider isolator design with a predicted lateral movement of 250mm at the isolation plane, during which the isolators will support 100% of the building load.

The design included: demolition of basement slab and replacement with a new ‘rigid’ foundation, critical to ensure the lateral deformation is focused in the isolators; demolition of the central three storey load bearing brick wall (while shoring floors and attic to deformation tolerances of 4mm) – this accommodated new architectural layouts and circulation; demolition of basement portions of four load bearing brick walls (while shoring the upper storeys, again to stringent deformation tolerances); demolition of the elevated timber floor – for a new concrete floor stiff enough to transfer all vertical and horizontal load to the isolators; new columns/beams in the upper floors to complete the new vertical load path.

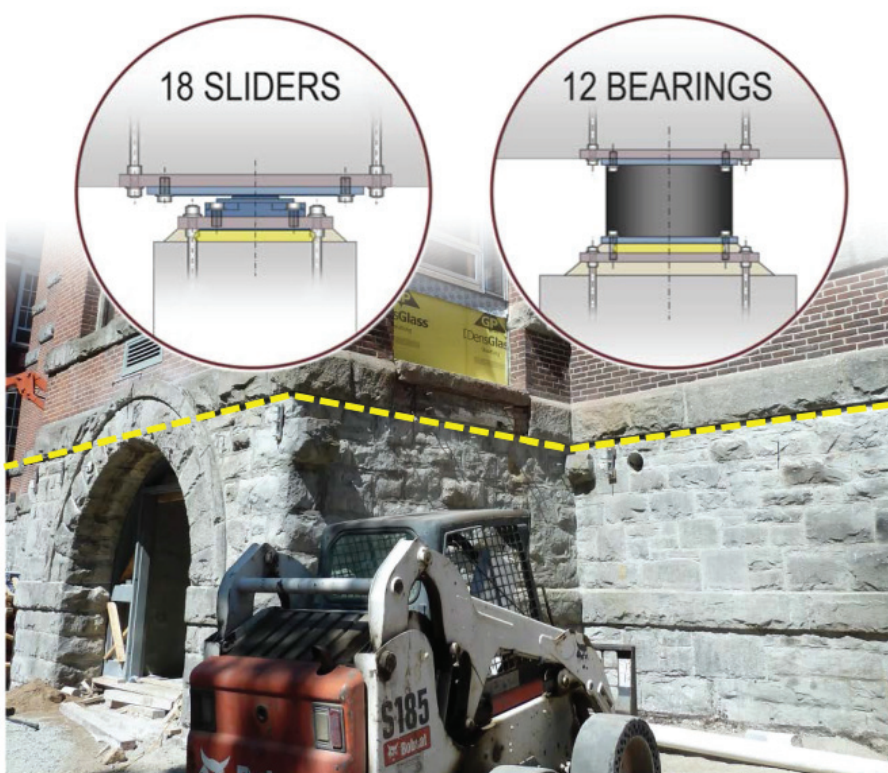
New upstand concrete beams at the main floor were critical to ensure load transfer from the upper exterior brick walls into the isolators; a ‘triple-redundant’ design resulted in essentially no movement of the walls during load transfer. Transferring vertical load to the 30 isolators was a Canada-first use of ‘flat jacks’; these were placed beneath every isolator and expanded only 3mm to transfer the load; a unique system was developed to first pressurize using fluid, then re-balance the loads/deformations, and finally transfuse high strength epoxy into the jacks making them permanent vertical load carrying components. This involved 9 set-up locations, 22 loading increments, and 22 surveys and visual inspections to ensure load/deflection criteria was met and no damage was occurring to the heritage exterior.

Sawcutting the basement stone wall completed the isolation plane and ensured no load was carried by the walls but rather was transferred fully to the isolators.

Architectural components and mechanical/electrical services crossing the isolation plane were custom designed to accommodate the 250mm movement.

Innovative Project

At the recent ACEC-BC Awards Competition, the Lord Strathcona Elementary School Seismic Upgrade Project received the Award of Excellence in the category of "Buildings". The Project also received the Lieutenant Governor's Award for Engineering Excellence.



Complexity

The project involved a complex construction sequence, involving custom shoring, demolition of existing load bearing walls, a new 'rigid' foundation, critical load transfer beams and a new floor slab to transfer all load to 30 new isolators, the Canada-first use of flat jacks to transfer such load with less than 3mm vertical movement, and basically "slicing the building in two" by sawcutting exterior walls to complete the isolation plane.

The construction included an uncommon "top down" sequence, where the isolators in the basement were the last components constructed, allowing finishing to commence early in both upper floors.

Every isolator was tested to full earthquake demand; however, they did not meet specification requirements. All non-linear analyses were completely repeated using tested properties to re-confirm the design intent was met. This enabled the fabricated isolators to be used, avoiding re-fabrication which would have delayed the project by months.

While extensive investigations and material testing were completed, they could not capture all the variations of this archaic building.

The team cost-effectively addressed significant 'surprises' during construction: 'garbage' soil required replacement with concrete; weak rubble foundations required carefully sequenced excavation with new reinforcing; lead paint needed mitigation; water damaged brick mortar needed repointing; wood nailing strips in brick walls that totally compromised their capacity were removed and replaced with custom designed 1897-quality mortar.

The extent of delay and cost extras due to the 'surprises' were mitigated by the team's creative solutions combined with very timely and collaborative work with all consultants, Owner and contractor.

Social and Economic Benefits

The students, parents, teachers and community treasure this 120 year old building and it was their strong desire to retain and seismically upgrade and renew it; this project achieved that and preserved its heritage exterior.

The project provided 'swing space' on the site while this and two other buildings were upgraded one at a time. No students or teachers were displaced from their normal school location. This was accomplished not in portables, but in existing buildings on site, in modified spaces fully meeting current teaching requirements.

Base isolation very significantly reduces earthquake demand to the structure above the isolation plane such that the structure may remain elastic (undamaged) – a solution ideally suited for seismic upgrades of weak, brittle, heritage structures that preserves their heritage aspects and will enable immediate use of the building after the earthquake. By comparison, 'conventional' seismic upgrades that dissipate energy by controlled damage (ductility) may have residual drift (not re-center), may not be repairable or useable after an earthquake, and are very difficult to effectively ensure heritage preservation.

After an earthquake this building will contribute to a resilient community. Parents will be able to drop off their children to continue to attend school, and will themselves be able to continue working (if possible at their workplace). Teachers will be able to continue working. The economic benefit is virtually no cost impact due to disruption of 'business continuity'. There will be no economic burden due to the requirement of temporary shelters, repair, or replacement of the building.

Environmental Benefits

By retaining and upgrading the existing building, some 2000 tonnes of brick, stone and other material was saved from demolition and likely disposal to landfill. Furthermore, the energy to produce and install a further 2000 tonnes of material for a replacement school was avoided.

All timber removed from the building, some 450m³ (16,000 ft³) from the main floor, was recycled. In fact, the structural engineer of record is in the process of making two coffee tables out of just one 6m old growth floor joist. There were some 40 tonnes of steel shoring used during construction. All steel was removed for reuse on other projects, or recycled.

All hazardous material in the building, including asbestos and lead paint, was removed leaving a 'hazardous material free' building.

The renewal of classrooms and washrooms, plumbing and electrical services, and architectural finishes is intended to provide at least a further 50 year life to this 120 year old building.

The nature of a base isolation seismic upgrade is that it can sustain earthquake after earthquake without damage and without the need to replace any of the isolators. Thus, in the future after minor, moderate or significant earthquakes there will not be a need to demolish and move materials to landfill, nor replace the building, nor spend significant effort or money to repair it. This cannot be said for even new code-compliant buildings that are designed to be 'life safe' but will need repair and may need replacement after the design level earthquake.

Meeting Client Needs

Lord Strathcona Elementary School, owned by the Vancouver Board of Education, has been operating since 1891, is one of the oldest elementary schools in BC, and is an important neighborhood focal point.

As part of BC's Ministry of Education (MEd) Seismic Mitigation Program four heritage buildings at the school were assessed and rated as High seismic risk; MEd provided \$25.6 million (plus reserve) for the seismic upgrade and renewal for three heritage buildings retained for school purposes.

For one building, the Class A heritage, 1897, three storey timber/brick/stone classroom building, the seismic upgrade was achieved using base isolation, a solution never before attempted in Canada.

The Owner's and MEd's objectives were to respect the community's desire to retain the oldest heritage school building in Vancouver, while implementing an innovative seismic upgrade that achieved at least life safety performance and if possible preserved the heritage exterior aspects of the building. Furthermore, the project needed to include 'renewal' of teaching spaces and a new Neighborhood Learning Centre, improve classroom and circulation layouts, make the previously underutilized basement fully functional, and improve accessibility (which eliminated two sets of 'unattractive' exterior non-original timber stairs). The MEd provided additional funding during the project to remove, refurbish, and reinstall the original wood framed windows.

All of the above needs were achieved, within budget, while the earthquake performance was exceeded. The base isolation upgrade will enable this building to be fully functional after the design earthquake, and provides heritage preservation of this 120-year old neighborhood gem.



Critical temporary shoring to support upper two levels of load-bearing brick walls and timber floors above demolished basement.



New 'rigid' concrete foundation and concrete main floor in progress.

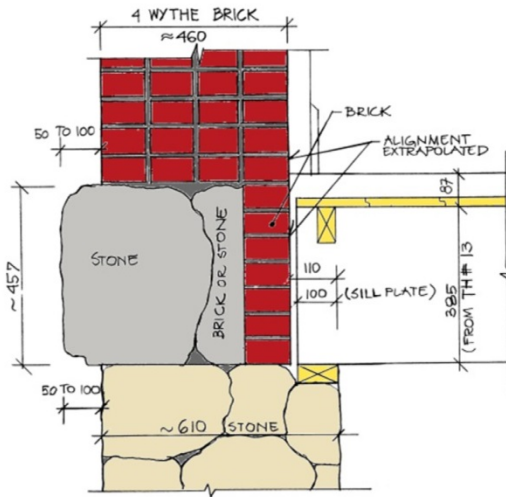


1st installation in Canada to use flat jacks to transfer entire building weight to new isolators. Flat jacks, located beneath every isolator, transferred all load to isolators with only 3mm vertical movement.



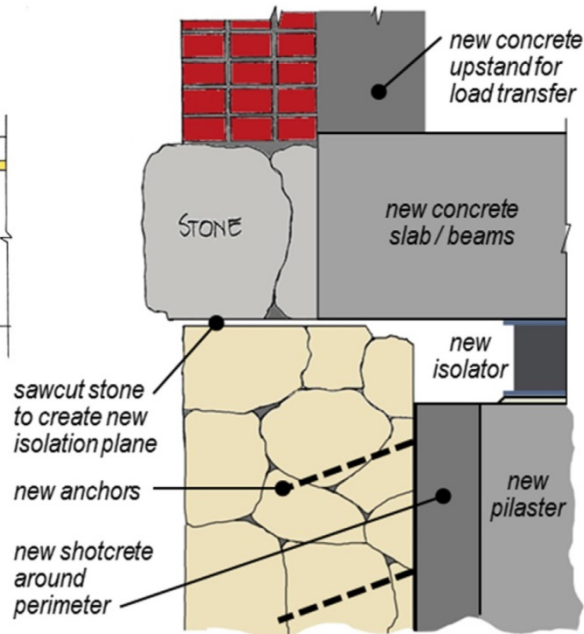
Sawcutting stone around entire perimeter of building to complete isolation plane.

Original Construction

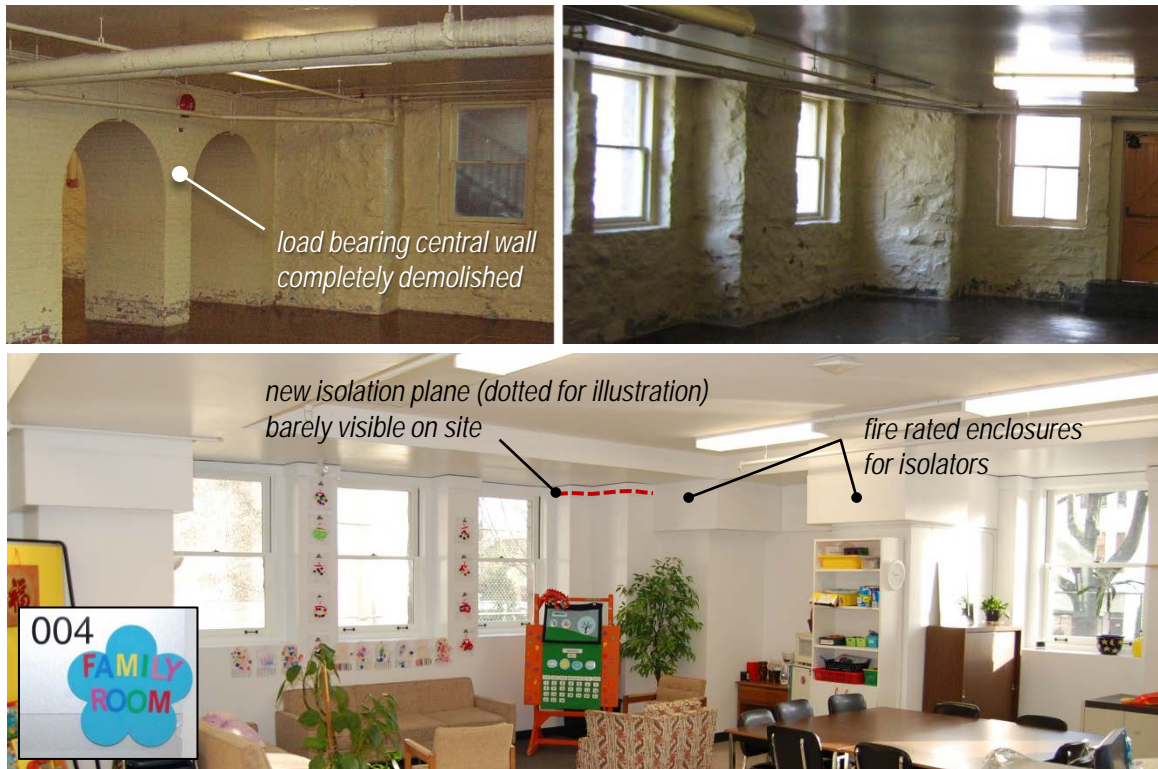


No useful information of original construction was available. Extensive investigation and material testing provided many details.

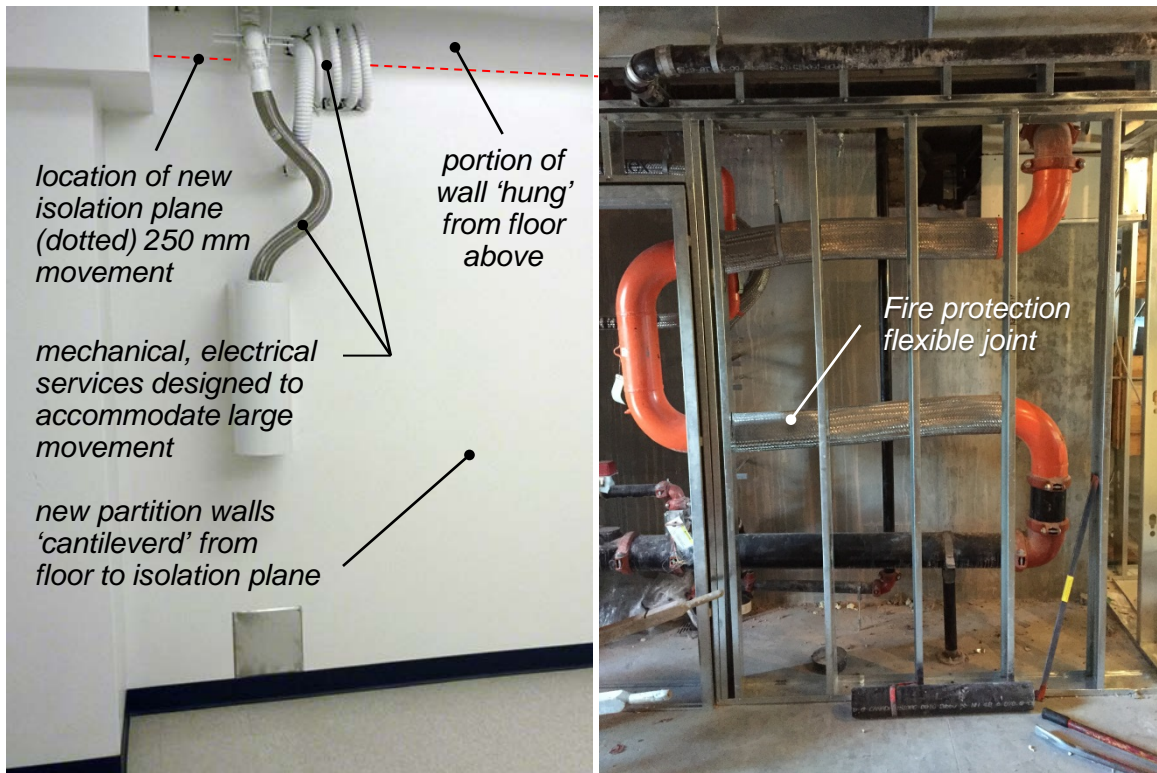
Modified



Exterior wall before and after modifications.



Renewed basement (original underutilized basement shown above).

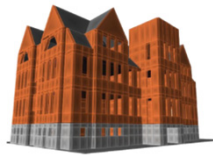


Custom basement partition wall design, and over 40 special joints for services installed to accommodate during-earthquake 250 mm movement at isolation plane.



Threshold plate at main entrance; a sample of architectural details to accommodate during-earthquake 250 mm movement at isolation plane.

Lord Strathcona Elementary School Heritage Classroom Building Base Isolation Seismic Upgrade



This project involved turning a brittle 120 year old heritage High seismic risk building, into a very Low seismic risk building, achieving post-earthquake "immediate occupancy" performance, and heritage conservation, using base-isolation technology - the first such use in Canada for any building existing or new.

The project involved a complex but carefully planned construction sequence, involving demolition of existing load bearing walls, custom shoring, a new 'rigid' foundation, critical and stiff load transfer beams and new floor slab to transfer all load to 30 new isolators with effectively no deformation, Canada-first use of flat jacks to transfer such load with less than 3 mm vertical movement, and basically "slicing the building in two" just above the basement windows using special sawcutting equipment to complete an isolation plane.

Extensive non-linear analyses of four models, 21 earthquake time history records, met newest code requirements of 'mean plus one standard deviation' results to design the overall system. The design involved custom architectural, mechanical, and electrical details to accommodate the 250 mm of lateral movement predicted at the new, unique, above-ground isolation plane.

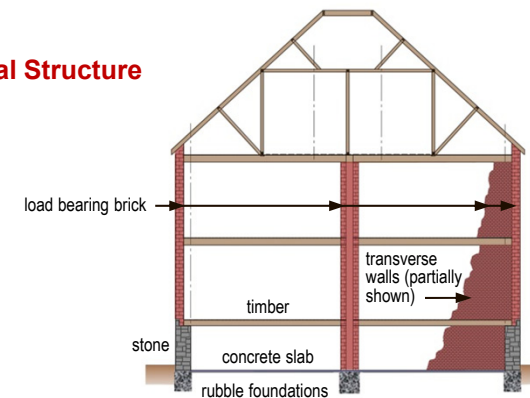


Sawcut stone foundation walls around entire building to create new isolation plane just above basement windows



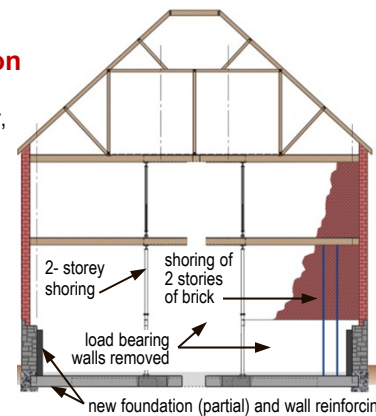
Construction Sequence

Original Structure



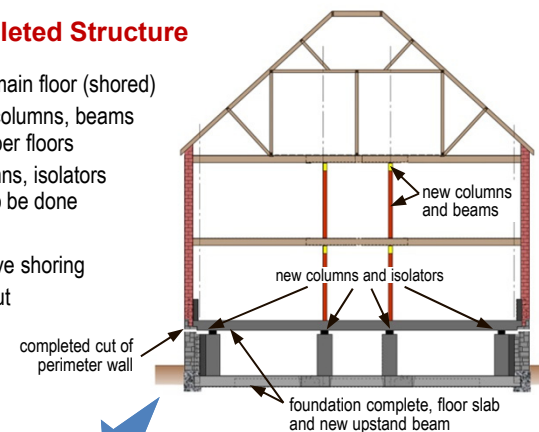
During Construction

- demolish basement floor, new foundations, new shotcrete on perimeter walls
- demolish main floor, central brick wall, and basement level of transverse walls

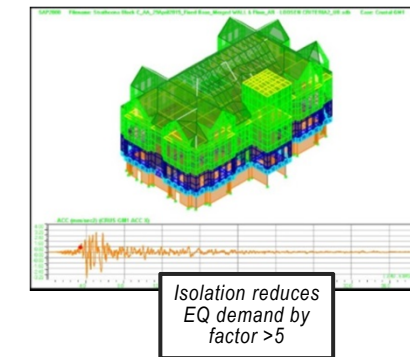


Completed Structure

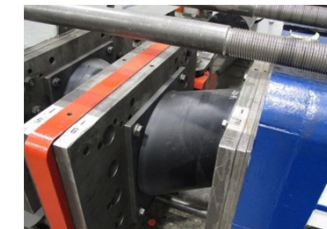
- new main floor (shored)
- new columns, beams in upper floors
- columns, isolators last to be done
- jack
- remove shoring
- sawcut



Extensive Iterative Non-linear Analyses and Re-analyses

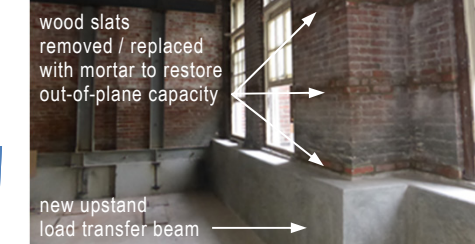


- Four different building models to account for variation in building, soil, isolator properties
- 21 time history records to simulate subduction, crustal, in-slab earthquakes that can affect this building
- Every isolator tested per very prescriptive specifications to full earthquake demand; all witnessed; results used in 2 sets of re-analyses

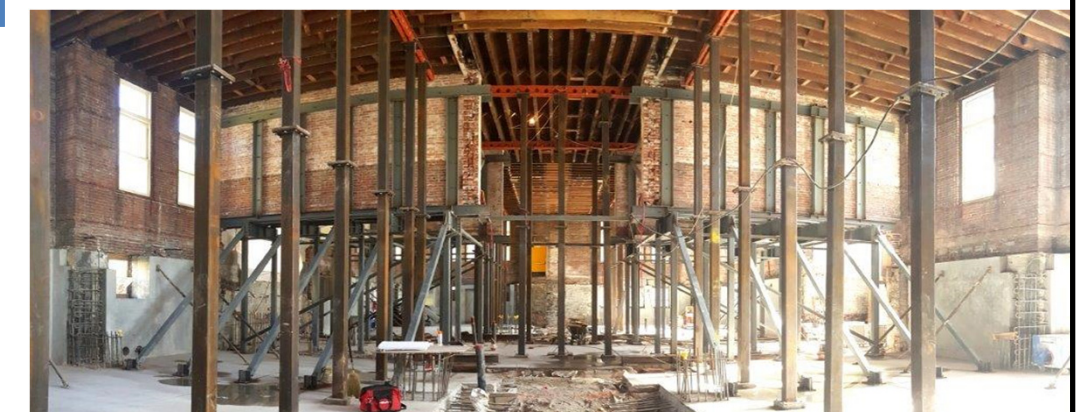
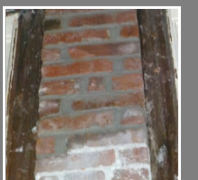


Isolator testing in pairs (bearings)

Discovered Conditions

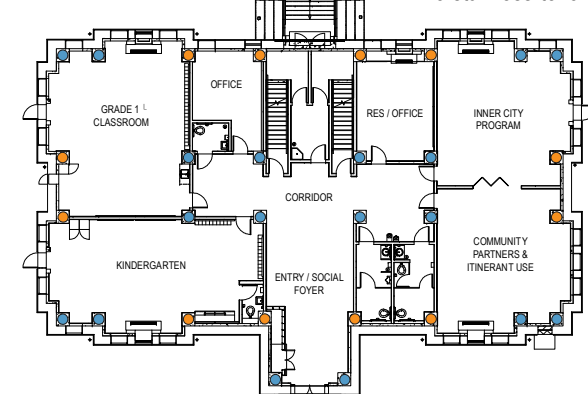


Deteriorated mortar replaced with specially designed mortar to match archaic properties, to achieve uniform behavior.



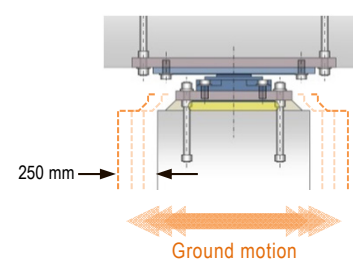
Critical temporary shoring to support upper two levels of load-bearing brick walls and timber floors above demolished basement.

BASEMENT PLAN

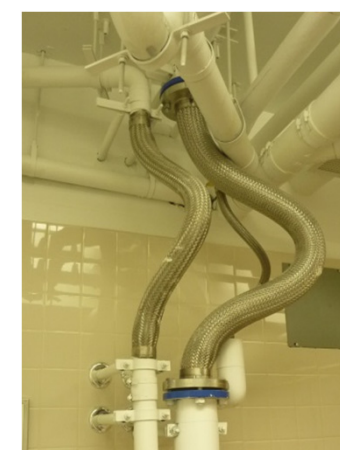
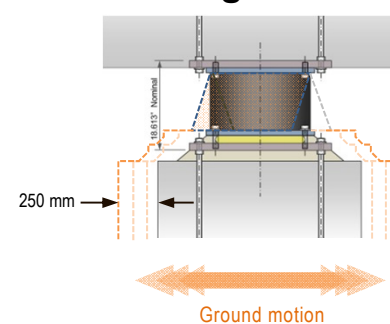


Extensive iterative analyses to determine unique mix of sliders and bearings; to ensure no movement during wind, but appropriate movement and energy dissipation during an earthquake.

Slider

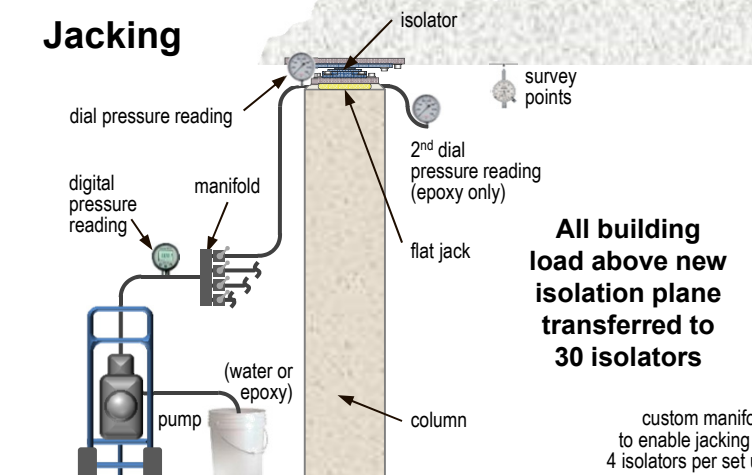


Bearing



Flexible joints
custom designed mechanical, electrical, architectural components to accommodate 250 mm movement

Jacking



25 mm flat jack expands 3mm to lift 100 t load - very tight space (170 mm) to assemble slider and flat jack



custom manifold to enable jacking at 4 isolators per set up

2-stage Jacking (water followed by transfusion with epoxy)

9 set up locations; 22 increments of jacking; surveys and extensive visual inspections at every increment