



SAN FRANCISCO'S NEW ASIAN ART MUSEUM

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SUMMARY

The City of San Francisco's Old Main Library, a 1917 historic building constructed of structural steel and unreinforced brick masonry, was recently renovated and transformed into the New Asian Art Museum. The Museum houses an irreplaceable collection of Asian art and artifacts, including immensely valuable, brittle Ming Dynasty vases, and represents the largest non-property asset in the City of San Francisco with an estimated value of \$5 Billion. The adaptive reuse of the 180,000 sq. ft. building was orchestrated by the Milanese architect, Gue Aulenti, FAIA, known for her adaptive reuse of the Gare D'Orsay, a Parisian train station, into the internationally renowned Musee D'Orsay.

The seismic design criteria for the project was certainly to protect the brittle and vulnerable historic fabric and structure of the building. However, the primary objective was to protect the art collection on display and in storage. For both "moderate" and "severe" earthquakes, the goal was to suffer no loss in collection value.

The Museum structure and collection were seismically protected by a combination of base isolation and superstructure reinforcement. The isolation bearings were placed over a reinforced mat foundation system below the original slab on grade. A new suspended floor, above the isolation plane, supports basement loads. Reinforced concrete shear walls, from the top of the basement floor to the roof level, provided a complete and rigid lateral load path for all sections of the building. Floor diaphragm reinforcement and collector lines tied the existing and new floors into the shear walls.

Base isolation combined with superstructure reinforcement provided the most reliable protection available to the artifacts stored and displayed in the Museum. Base isolation allowed architectural freedom to manipulate the floor plate in a manner that optimized gallery space and light distribution. The seismic demands imposed on displayed artifacts were reduced to a level for which conventional artifact bracing methods could be effective.

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INTRODUCTION

The New Asian Art Museum is a monumental building located in the San Francisco Civic Center Historic District, and is recognized as one of the most notable examples of Beaux Arts architecture in the United States. See Figure 1 for exterior entry elevation. The building was designed in 1915 by the architect George W. Kelham and structural engineer H. J. Brunnier to compliment the new City Hall Building under construction. The ultimate goal of city planners was to establish a Civic Center District with government, judicial, library and arts components. With a new library commissioned and constructed within the District in the late 1990's, the renovation of the library to become a world class museum finally completes the founding planners goal.

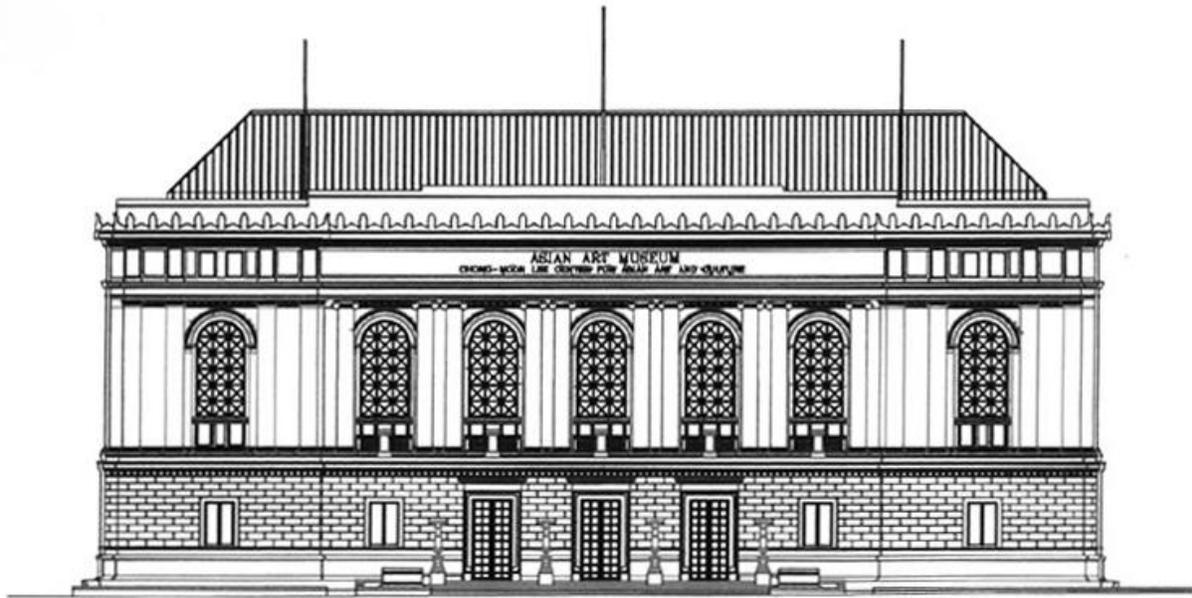


Figure 1 - Asian Art Museum, Front Elevation

The building was damaged in the 1989 Loma Prieta Earthquake, resulting in the need for repair and seismic strengthening. Due to pounding damage in the structural shell surrounding the book storage stacks, the library was no longer functional. Access to damaged regions of the building was restricted to library staff. In 1998, the library relocated to the new facility and the City searched for a new building tenant.

The Asian Art Museum was chosen as the likely candidate to occupy the Old Main Library. The Museum was previously housed in a leased space adjacent the DeYoung Museum in Golden Gate Park. The Asian Art Museum's prized "Avery Brundage" collection sustained significant damage to both stored and displayed artifacts during the Loma Prieta Earthquake. Twenty six artifacts were damaged at an estimated loss of \$3 million dollars. Monies were raised through bond initiative and private donations to relocate the Museum and to a seismically retrofit and renovate the Old Main Library at the Civic Center.

The primary seismic retrofit goal, therefore, was to protect the priceless art collection. Studies indicated that base isolation combined with shear wall superstructure enhancements, was the only method that would reduce artifact seismic demands to a level at which conventional artifact bracing methods would be effective. Conventional fixed base shear wall or braced frame solutions would solve the life safety issues but would deliver very high, potentially damaging accelerations to the gallery displays.

The New Asian Art Museum has several distinct historic elements which could not be compromised including historic facades, ceilings and walls. See Figures 2 and 3 for building sections. The transformation from library space to museum required significant infrastructure modifications which included alterations to the existing lateral load resisting system. The architects desire to open up the interior space to additional light led to long unobstructed gallery spaces and innovative interior skylights. See Figure 4 for building plan. Base isolation was the only solution which facilitated these goals and still accomplished the primary objective of art protection.

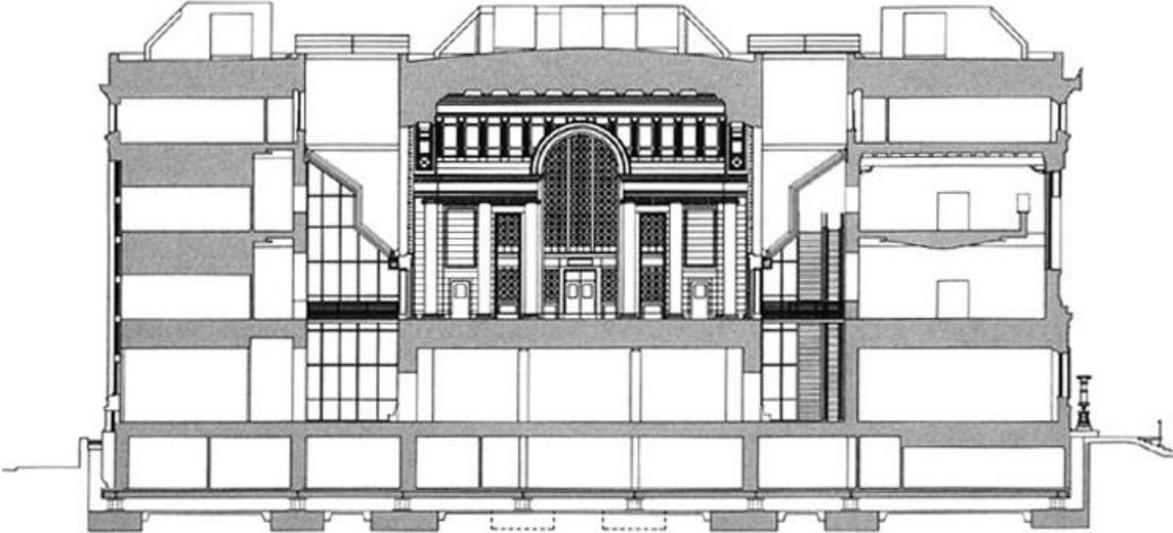


Figure 2 - Asian Art Museum, Transverse Section

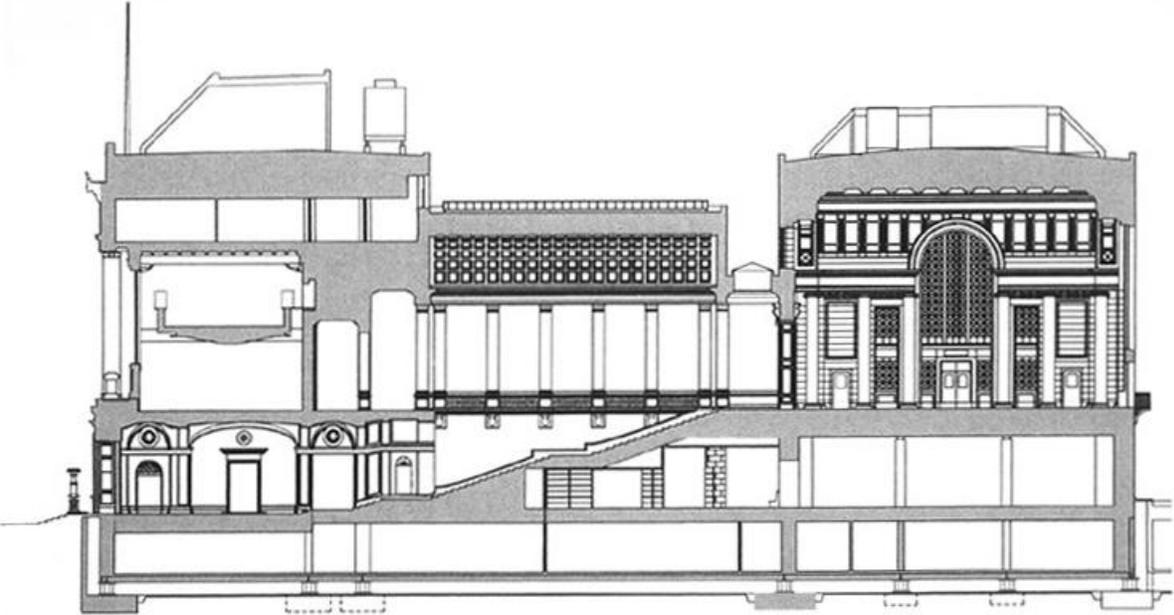


Figure 3 - Asian Art Museum, Longitudinal Section

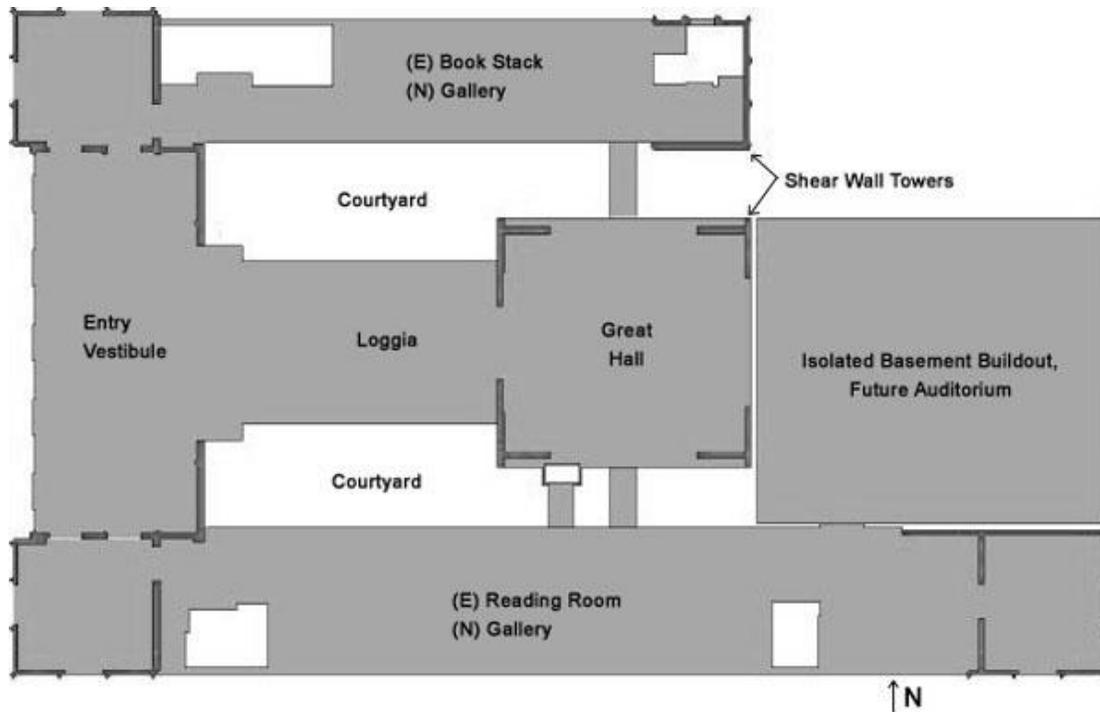


Figure 4 - Space Plan

SEISMIC CRITERIA

The primary goal of the retrofit was to protect the Asian Art Museum collection. For this reason, the various performance measures were cast in terms of collection loss, rather than superstructure damage. The Museum developed a three tier criteria which encompassed earthquake demands ranging from frequent to rare. The objectives are as follows:

- In a “Moderate” earthquake of Modified Mercalli Intensity (MMI) VI, similar to a repeat of the ground shaking of the Loma Prieta Earthquake experienced at the site; the goal is to suffer no loss in collection value.
- In a “Major” earthquake of MMI VII-VIII, similar to the ground shaking expected from a Magnitude 7 earthquake on the mid peninsula segment of the San Andreas Fault or one of the East Bay Faults (the closest point of fault rupture ± 18 km from the site); the goal is to suffer no loss in collection value.
- In a “Great” earthquake of MMI IX+, intended to represent a repeat of the 1906 San Francisco earthquake on the Northern California segment of the San Andreas fault (the closest point of fault rupture ± 12 km from the site); the goal is to have no loss in collection value in storage and a loss of less than one percent (1%) of collection value on display.

The corresponding ground motion spectra were generated by deterministic methods. In terms of equivalent probabilistic motions, the “major” earthquake is slightly greater than a code design event with a 20% probability of exceedance in 50 years. The “great” earthquake was similar to a code maximum capable event with a 2% probability of exceedance in 50 years. The governing seismic case was

continued occupancy and function at the maximum capable event. The 1995 San Francisco Building Code provided minimum requirements for the design and evaluation of structural elements.

ART PROTECTION

Collection Description

The initial Asian Art Museum collection was donated by Avery Brundage. The current collection now totals some 12,000 pieces which include bronze figurines, jade objects, stone statues, lacquerware, ceramics, swords, armor, textiles, netsuke, stone and wood wall panels and textiles. Approximately 10% of the Museum collection is on display at one time. The remaining pieces are stored, well packed in the Museum's isolated basement. The majority of these elements tend to be small, lightweight pieces. Most of the heavier pieces tend to be squat, with a relatively low center of gravity. As with most collections, a large part of the Museum's value is concentrated in a very small percentage of pieces.

Analysis Methods

To meet the Museum performance goals, each piece must be addressed with appropriate anchorage to a case rigidly mounted to the isolated structure. To estimate the seismic demands at various gallery locations, floor spectra were developed from the suite of maximum capable time histories. The spectra captured the variation in demand over the frequency domain. The governing case for gallery seismicity was midspan of the third floor south wing gallery. A comparison of fixed base demands, allowing for some superstructure non-linearity compared to the prepared floor spectra are shown in Figure 5. The analysis indicated that artifacts displayed in rigid cases will see excitation of around .33g. The analysis also showed that the demand is greater for flexibly anchored artifacts. A peak of around .7g is noted at a period of .3 seconds. The acceleration approaches 1g at periods beyond 1.25 seconds. These results compare favorably to a fixed base solution where the lateral accelerations would be from 1.2g to 2.3g. Given these results, the Museum was advised to rigidly anchor all casework and artifacts by conventional means.

Display Design

All casework was custom designed and fabricated to insure that each piece of art has a rigid, well anchored base. The lower seismic demands from the isolated structure allowed for greater architectural freedom in the quest for functional and beautiful display of art.

ADAPTIVE REUSE AND HISTORIC PRESERVATION

The conversion of the historic library to a functional museum also created significant challenges which the upgrade addressed. Several elements of the building held special historical significance. These regions include the perimeter stone clad façade, the entry vestibule, loggia, reading rooms and great hall. Bracing of these elements was incorporated into the overall retrofit as falling plaster, stone and brick pose a significant hazard to occupants and art on display.

Façade Treatments

The decorative exterior façade consisted of unreinforced masonry infill faced with integral granite blocks. The façade was cleaned and repointed. It was braced out of plane by shear wall towers- where they occurred and tube steel strongbacks at other locations. Stainless steel all thread anchors with epoxy grout were used to anchor the strongbacks to the façade. At the front entry, four steel columns were clad in fully grouted carved granite panels. To augment the entry pilaster out-of-plane anchorage, the pillars were cut

open from behind to allow the insertion of a hollow structural shape (HSS). The HSS member was welded to the existing column and the incision was repaired and regouted.

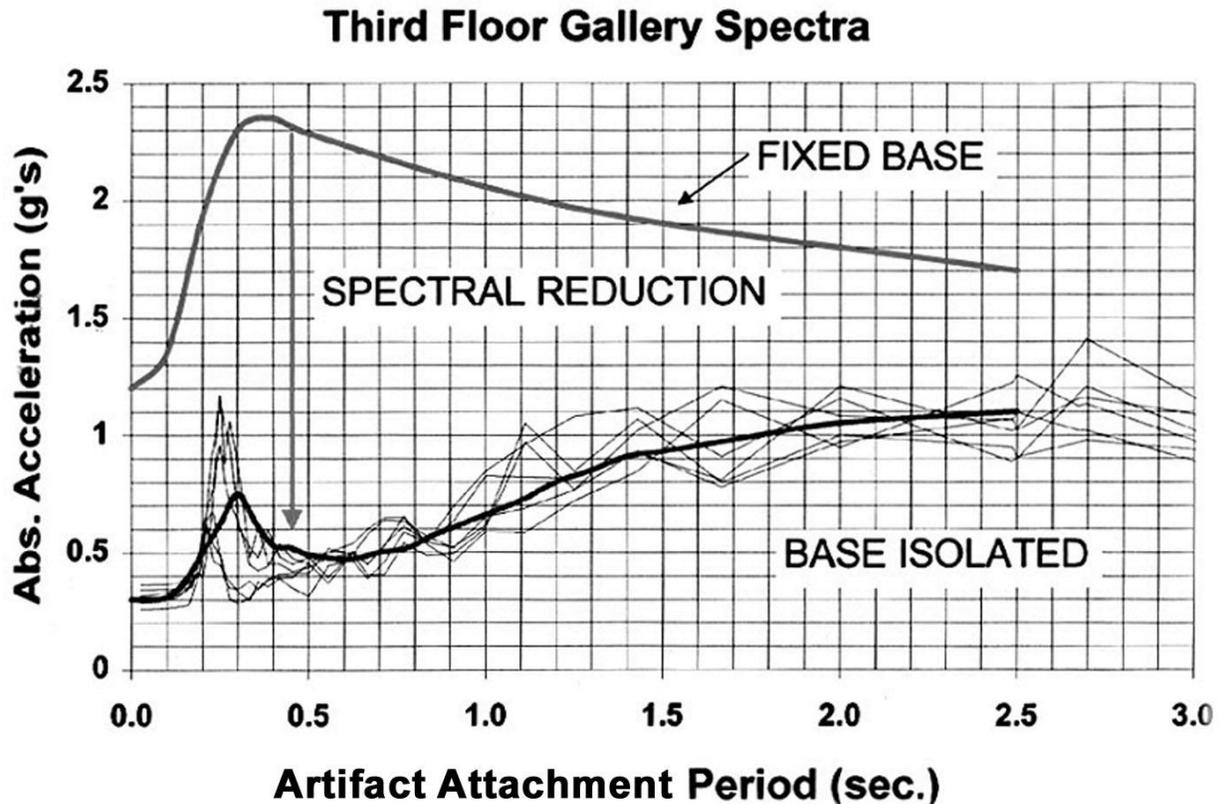


Figure 5 - Comparative Artifact Seismic Demand

Great Hall and Loggia

The great hall served as the catalogue room for the Old Main Library. The great hall was distinguished by its voluminous space, travertine tile floor, faux travertine walls and pilasters and faux travertine hexagonal ceiling. One of the key elements of the seismic upgrade called for the installation of concrete shear walls around the great hall perimeter. To hold historic finish lines, it was necessary to install the new concrete shear wall in place of the previous unreinforced masonry walls. To accomplish this task, the plaster ceiling and walls were first backed by an intricate, self supporting, self bracing steel frame system. This framing provided stability and protection for the plaster walls during construction. The brick walls were subsequently demolished and concrete was poured in their place. Mechanical ductwork was sandwiched between the plaster and concrete walls to provide humidity, air and temperature control to the gallery spaces from rooftop equipment. The final step was to attach the temporary steel frame to the surrounding shear walls.

The loggia space connected the entry vestibule to the great hall, see Figure 6. It housed a grand staircase accented with marble and travertine floors and walls. A large faux travertine barrel vault covered the monumental staircase. The architect's vision for the Museum was to open up the interior spaces to light brought in by a "V" shaped skylight at the inner courtyards. See Figure 7 for conceptual rendering. See Figure 8 for construction photograph. See Figure 9 for final condition. Gue Aulenti's design called for the removal and relocation of several large 1930's vintage murals by Gottardo Piazzoni to create large openings in the loggia walls. The removal of the murals was politically controversial, but eventually was



Figure 6 - Historic Grand Loggia

approved by the City. The loggia vault was braced with steel framing and the anchorage of faux travertine columns was reinforced top and bottom.

Reading Rooms

The Old Main Library had two historic two story reading rooms. These rooms were distinguished by their plaster covered beam ceilings with muted color stenciled polychromy. Both reading rooms also boasted several large murals by Frank DuMond which were painted for the 1915 Panoramc Exposition. To meet the Museum's gallery space requirements, the architect introduced an interstitial floor at each reading room. To maintain the historic sense of space, the new floors were held away from the perimeter windows so patrons could view the ceiling from the original floor. See Figure 10 for construction photograph. The ceilings were braced and restored in place and the murals were removed and relocated elsewhere at the Civic Center.

STRUCTURAL RETROFIT

Building Description

The five story building was generally rectangular in plan, 180 ft. by 210 ft., with a panhandle that extended 75 ft. to the east. The design called for a new rectangular basement plan to accommodate future expansion. Two large light wells dissected the interior of the rectangle to create the inner courtyards.



Figure 7 - Courtyard Skylight Architectural Rendering. Image provided by HOK Architects.

The light wells also had the effect of separating the building into three distinct wings. The northern, west and southern segments were described as the book stack, entry vestibule, and reading room regions respectively. The center section housed the grand loggia which opens up into the great hall. The entry vestibule, loggia and great hall section in total can be referred to as the historic spine of the building which houses the majority of ornamental and historically significant architectural features. The project design called for a new single story build-out which infilled the space adjacent the pan handle. This new region included back of house curator spaces but also was designed to support a future 5 story auditorium and theatre addition.

The building was originally composed of a complete steel frame with concrete slabs. The foundation system was spread footings at interior columns and strip footings at perimeter walls. The exterior granite walls were backed with unreinforced masonry laid-up integrally with the granite. The inner court walls were also unreinforced masonry walls which were faced with decorative brick. The original lateral load resisting system consisted of these unreinforced masonry infill walls acting as shear walls. All of the inner court brick walls were demolished and replaced with metal stud and modern finishes to mitigate falling hazards on displayed artifacts.

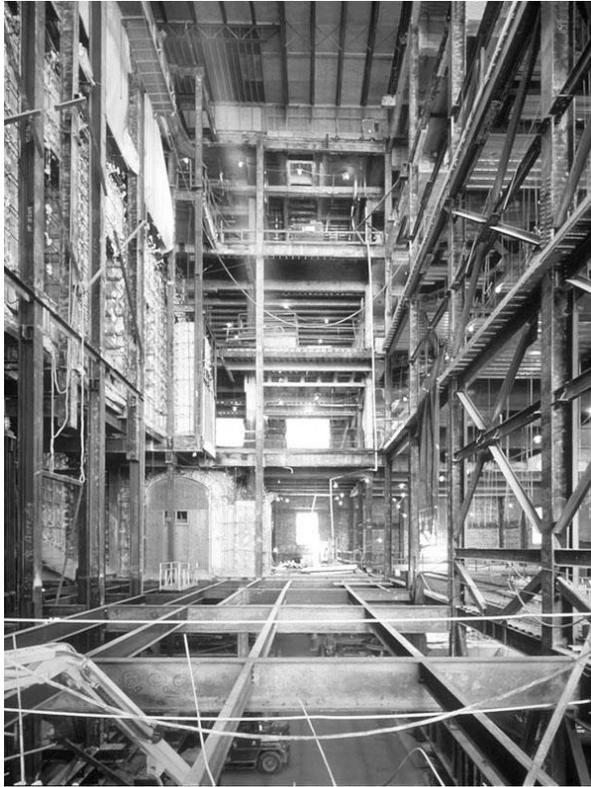


Figure 8 - Courtyard During Construction



Figure 9 - Courtyard

Retrofit Scheme

Although the use of base isolation substantially reduced the seismic forces the building will experience, some shear-resisting elements were still required to stiffen and strengthen the superstructure. Concrete shear walls were chosen in this case because they are inherently stiffer than the unreinforced masonry walls and also act to brace the existing walls against out-of-plane forces.

Analysis

SAP2000 Non-Linear was used to evaluate the isolated structural response and determine superstructure seismic loads. The design superstructure base shear was .22g. The maximum capable base shear was .33g. Due to performance restrictions imposed on the “great” earthquake, the maximum capable design loads were compared to reduced nominal capacities. The shear walls were designed using an “ $R_w=1.5$ ”. Crack width analytical studies indicated the walls would perform nearly elastically at this strength level.

Significant effort was expended to tune the isolation system response. Heavy exterior walls led to a large mass moment of inertia. Time history analysis showed the isolated structure was prone to torsional motions. To counteract this tendency, isolators with large lead cores were placed at the perimeter to increase the torsional stiffness and damping of the isolated response. Flexible natural rubber bearings were placed in the buildings interior to compensate for the stiffness added by the large perimeter bearings. Multiple studies were also conducted to demonstrate the adequacy of the isolation system following the proposed 5 story theatre addition. To match the system performance at this future condition, allowances were made to install future bearings under the new theatre columns thereby rebalancing the isolation system center of mass with the center of rotation.



Figure 10 - Reading Room with New Mezzanine Floor Framing

Base Isolation System

Two elastomeric base isolation systems were specified. Lead rubber bearings produced by Dynamic Isolation Systems, Inc., were awarded the bid and installed. The unidirectional design period for the isolated structure was 2.4 seconds which correlated to a design displacement of 16" and equivalent viscous damping of 15%. The new period provided significant load reduction benefits due to spectral shift as the existing building fixed base period was around .28 seconds. Coincidentally, the new 125 ft. diaphragm segments had a period similar to that of the existing building. The fixed base response of the renovated floor plate would likely see substantial load amplification due to resonance between the structural and diaphragm periods. The structural moat around the building perimeter was determined to be 2'-6", which allowed for a maximum total displacement of just under 28 ½".

Concrete Shear Walls

The new concrete shear walls worked in conjunction with the existing masonry piers to resist superstructure lateral loads. The walls were constructed as five discrete towers, one in each corner of the building and one surrounding the great hall. Typically, these walls were dowelled to the face of the existing brick. In the great hall, the existing brick was removed from the outside and replaced with new concrete walls. Installation of the concrete walls at this location was particularly challenging because historic finishes lined the entire interior of the hall. Steel backing members were first installed to brace the plaster and stone finishes independent of the brick wall. The brick was then demolished and new concrete cast. Large shaft spaces were created to service new mechanical duct risers which service the

new gallery spaces. Several new “out-rigger” concrete walls were constructed in the basement to distribute rocking demands uniformly over adjacent bearings and to engage additional uplift reducing dead-load.

Global Construction Sequence

Several construction related activities temporarily weakened the existing structural lateral load resisting system during construction. To install the isolators, all of the basement concrete and brick walls needed to be cut free of the foundation. As previously mentioned, all of the brick walls lining the inner court and great hall spaces were completely demolished. These walls were significant elements of the existing lateral load resisting system. The design team specified the contractor sequence maintain a minimum working stress design base shear of 10% throughout the duration of the project. The design team also developed an overall project construction sequence to demonstrate an acceptable temporary bracing configuration including bearing locking mechanisms which met the specified limits. Particular care was taken to maintain interconnectivity of the wings during construction. As the shear walls reached the upper portions of the building temporary bracing elements were removed. The most impressive of these elements was a full height inclined brace which buttressed the west end of the great hall. See Figure 11. Following the completion of all the superstructure enhancements and isolator installation, the locking devices were released symmetrically and the building was “floated”.

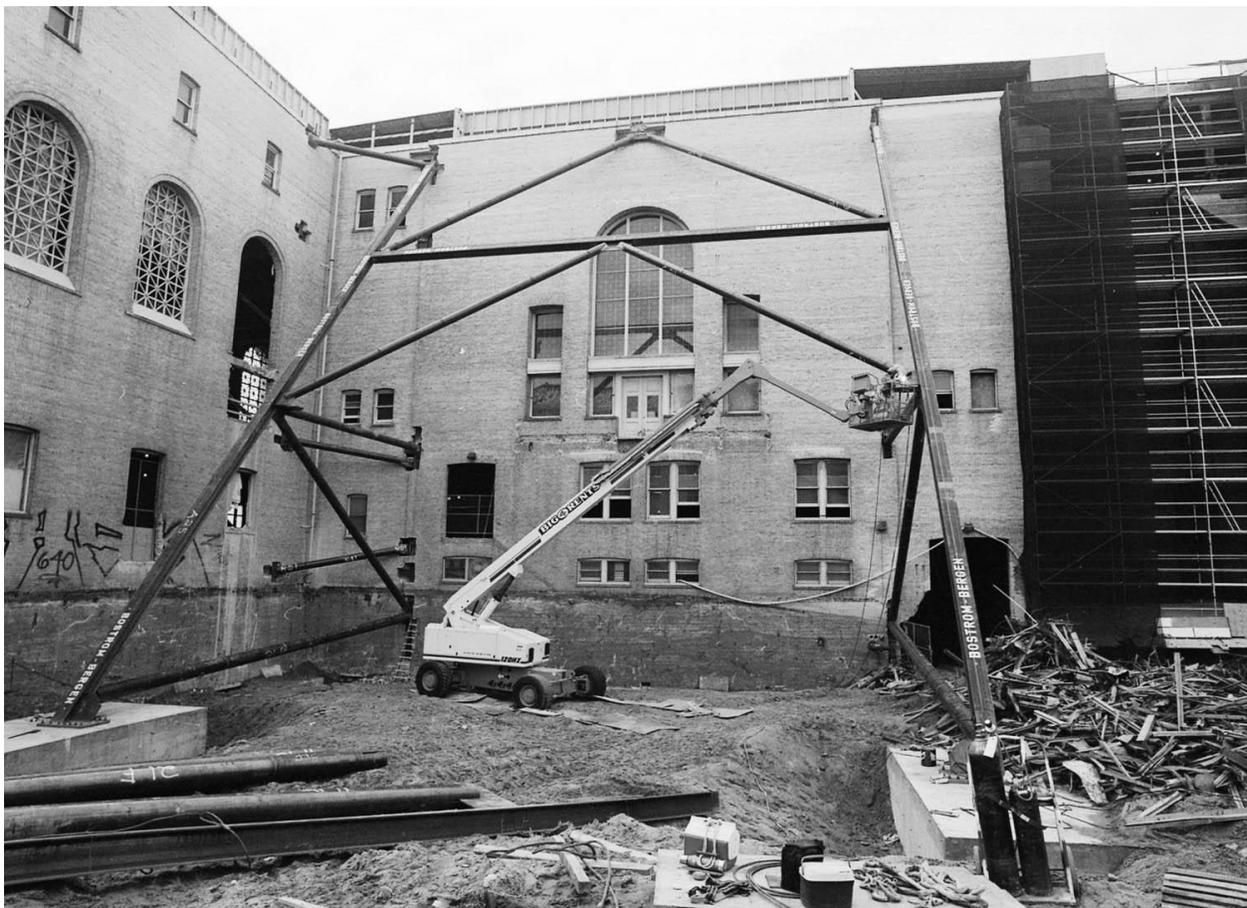
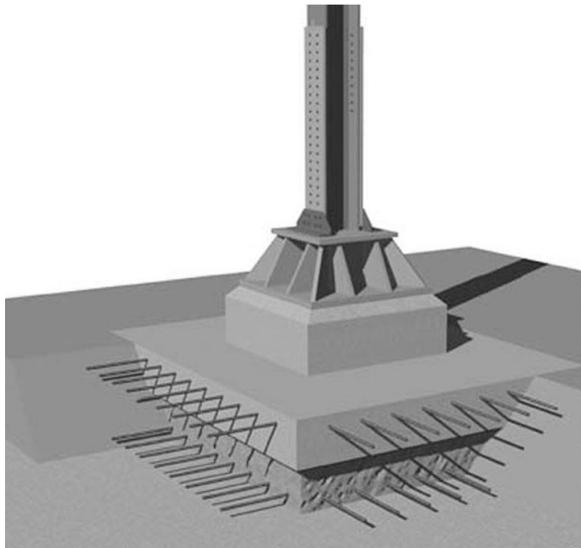


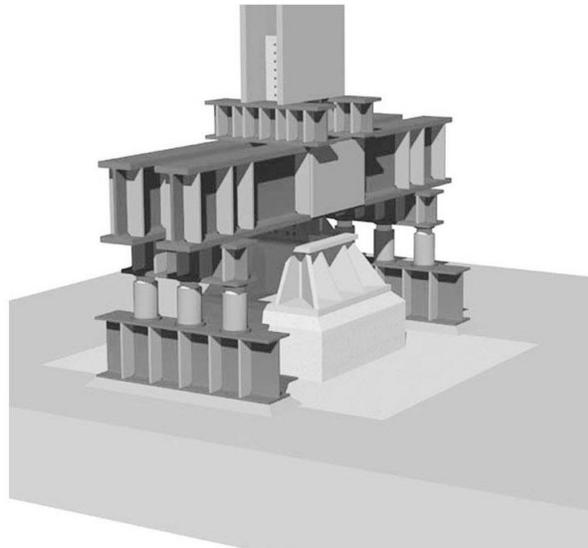
Figure 11 - Great Hall Temporary Bracing

Isolator Installation

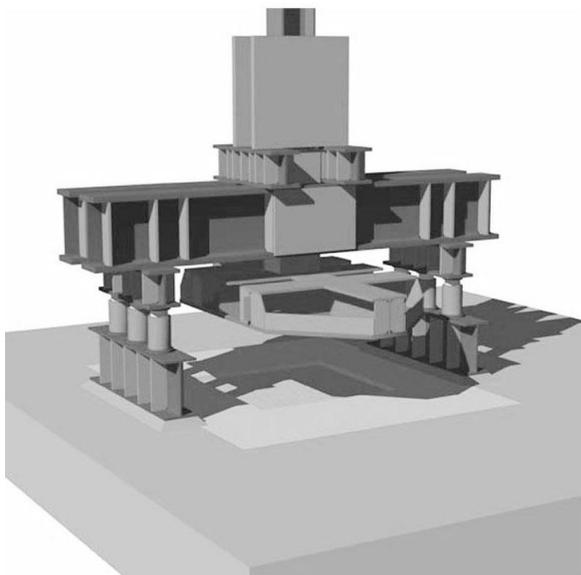
A majority of the isolators were installed directly beneath steel columns. To facilitate the installation, the shoring contractor engaged the load in each column to allow column cutting and isolator installation. The steps outlining the isolator installation are as shown pictorially in Figure 12.



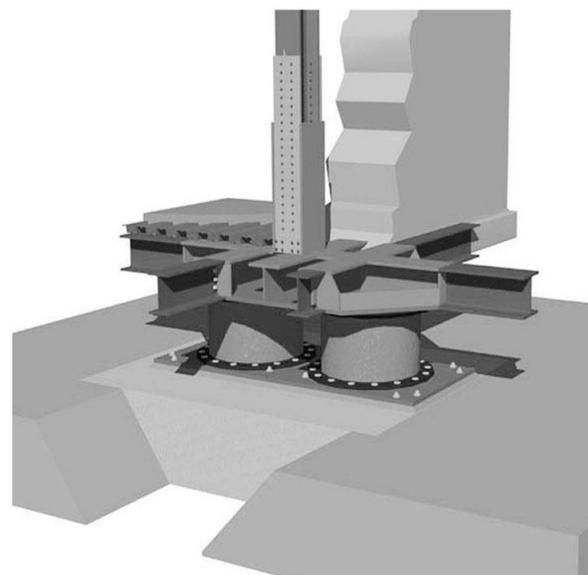
Step 1: Complete Foundation



Step 2: Shore Column



Step 3: Cut Column, Install Cruciform



Step 4: Install Bearings

Figure 12 - Isolator Installation Sequence

- Step 1- The existing slab on grade and fill were removed to expose the sides of the existing footings. The new infill mat was dowelled to the existing spread footings. The new combined mat was designed to resist future vertical and seismic loads as well as jacking point loads during construction.

- Step 2- Shoring members with carefully controlled hydraulic jacks were used to transfer the vertical load from the column onto the new foundation mat.
- Step 3- The existing column was cut and new steel cruciform weldment was installed to allow the attachment of bearing to the column and infill framing. The bearings were placed and flatjacks were used to preload the system. A flatjack is a sheet metal bladder which is pressure inflated with long pot life, low heat output epoxy.
- Step 4- The shoring haunches are removed and infill framing and walls are constructed.

It took approximately 14 days to install a bearing from the time the shoring hardware was placed until it was removed. See Figures 13 and 14 for photograph at isolator installation.



Figure 13 - Isolator Installation at Elevator Pit



Figure 14 – Installed Isolators

CONCLUSION

Site seismicity and stringent artifact protection goals made base isolation the only viable retrofit option. Although base isolation significantly reduced the lateral loads on the superstructure, shear wall and collector strengthening were required to prevent art damage. The tower walls braced the various segmented wings and allowed for long expansive gallery diaphragms. Base isolation allowed architectural freedom to manipulate the floor plate in a manner that optimized gallery space and light distribution.

The reduction in seismic demand allowed for conventional art anchorage methods to be employed. Rigid casework and cabinetry was designed to support the Museum's irreplaceable collection. Existing historical fabric was refurbished and braced in place, preserving the architecture of the Old Main Library for generations.