SEISMIC RETROFIT OF THE AFRICAN AMERICAN UNITY CENTER CHURCH

By Dilip Khatri, Ph.D., S.E.

A unique approach to seismic retrofit has been completed in the City of Los Angeles. A 100-year-old structure, comprised of unreinforced masonry elements, has been seismically retrofit using a system of internal moment frame beam-column design to facilitate the upgrade of the structure.

Coring Operation in Brick Wall. Courtesy of Cintec North America.

The building was constructed in 1901 and utilized as an assembly facility for over 80 years. In 1994, the Northridge Earthquake almost completely destroyed much of the unreinforced masonry elements and collapsed a portion of the roof.

The key issues associated with designing a retrofit for this project included:

1) Soil Liquefaction: The site is in a designated California Hazard Zone with known soil liquefaction.
2) Historic Structure: The building is listed on the National Historic Register.
3) City of Los Angeles Building Requirements: Any retrofit "system would have to comply with the strict requirements of the LADBS.

The ability to obtain approvals from the City of Los Angeles proved to be the most formidable issue because, the City required a thorough test program to establish the design value of the retrofit system.

After 7 years of multiple attempts to procure building permits, the owner decided to contract with Khatri International and Cintec America to prepare a unique approach to the seismic retrofit.

Cintec America and Khatri International developed the first internal moment resisting frame system to be installed "inside" the unreinforced masonry structure. Moment frames are a standard lateral load resisting system commonly utilized in a variety of multi-story structures. The concept of the moment frame structure embedded into an unreinforced masonry (URM) shear wall building sounds farfetched, but was developed and constructed at the African American Unity Center. The concept involves the following stages:

1) Core drilling vertically to establish 6-inch diameter holes for placement of structural tubes.
2) Placement of 4x4x½ Structural Tubes inside the vertical core holes.
3) Core drilling horizontal 6-inch holes to place horizontal 4x4x¼ beam tubes.
4) Seismic moment frame connections are welded at the horizontal beam and vertical column connections. These are proprietary moment frame connections designed by SidePlate.
5) Diagonal reinforcement is placed in a similar fashion. The 2-inch diameter holes are drilled, reinforcement is inserted, and then the holes are grout filled with low pressure.

The risks of performing this type of retrofit are apparent and required the use of highly specialized subcontractors to perform the core drilling. Pointe Construction was selected to do this delicate task.

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This project was funded by a grant from FEMA and the Brotherhood Crusade. The project Architects are R.F. McCann & Company and JGM Architects. The project structural engineer and contractor is Khatri International, Inc.

Interior Showing Roof Truss and Prior Retrofit Posts and Wall Anchors.

After completing a typical vertical core, the HSS 4x4x½ was lowered using a crane, and then grouted with a proprietary grout to secure it within the core. The moment frame connections were then welded to the horizontal beams using the SidePlate connection system.

Before construction could commence, design issues had to be resolved through the City of Los Angeles Department of Building and Safety. Since a project of this kind had never been completed before, there were many questions and technical issues that required explanation, and a protocol developed to satisfy the City of Los Angeles. The project was plan checked and approved in four months. The City Engineers required the following items:

(a) Three-dimensional finite element model with dynamic analysis.
(b) Steel moment frame connections that satisfy the highest standards prescribed by FEMA and the City of Los Angeles.
(c) Lateral drift analysis to demonstrate that the interior moment frame elements would not cause excessive cracking of the URM walls.
(d) Demand-Capacity analysis of the walls to show they were enhanced by inserting the moment frame.
(e) Piles to address the liquefaction issues.

Each of these items was addressed. The City review enhanced the design process by requiring a superior product at the end of the plan check process.

In order to prove the system to the City of Los Angeles, the finite element model of the church was created using the RISA-3D program. Two finite element models were prepared: (a) Unreinforced/as-built FEM, and (b) Retrofit FEM. The idea was to compare FEM (a) with (b) and show that structure's performance was enhanced with internal frame elements. To further complicate the issues, an increased base acceleration was required both by the City of LA and as a result of local liquefaction conditions. The design acceleration of 0.11g is the specified minimum value from the City of Los Angeles Division 88 requirements. (For those non-California residents, Division 88 is the section of the City of LA Building Code that covers URM buildings in this class.) But since this site is in a liquefaction zone, the design acceleration was 0.30g as provided by Earth Systems Southwest (ESSW), the project's Geotechnical Engineer. An increase to 0.30g creates three times the seismic loads as compared to a typical Division 88 requirement. This leads to a higher demand and consequently higher capacity seismic retrofit structure.

Another hurdle was the requirement to utilize a City of LA approved moment frame connection. Recall that before 1994, moment frame connections were standard design elements from the American Institute of Steel Construction (AISC) and were designed following established code procedures learned in our academic training. After the Northridge Earthquake, the City of LA required all steel moment frame structures to comply with the latest FEMA requirements, and also be tested to City of LA standards for strength and post-cracking ductility. This became a supplementary requirement over and above the Division 88 standards. The bottom line, all of the steel moment frame connections were required to satisfy FEMA and the City of LA requirements.

To meet all of these conditions, Khatri International, Inc. worked with SidePlate to utilize their proprietary moment frame connection for tube-tube design. This eliminated the need for additional testing, and cut the project schedule down to two months for plan approval. The overall plan check process took 4 months from submittal to approval.

Khatri International, Inc. engaged Earth Systems Southwest to perform the geotechnical testing, and then created a detailed pile design system to support the structure. The pile system supports the entire building. The internal moment frames are connected to the pile elements via a grade beam structure.

Structure drift limits are set at 0.5% of height (i.e., 0.005h) and are checked in the FEM using the 0.30g design acceleration. All steel is grade 50, HSS 4x4x½ for vertical columns, and HSS 4x4x¼ for horizontal beams. The 12-inch diameter pipe piles are concrete encased 8-inch diameter pipe using a proprietary grout compound for exterior protection of the pipe.

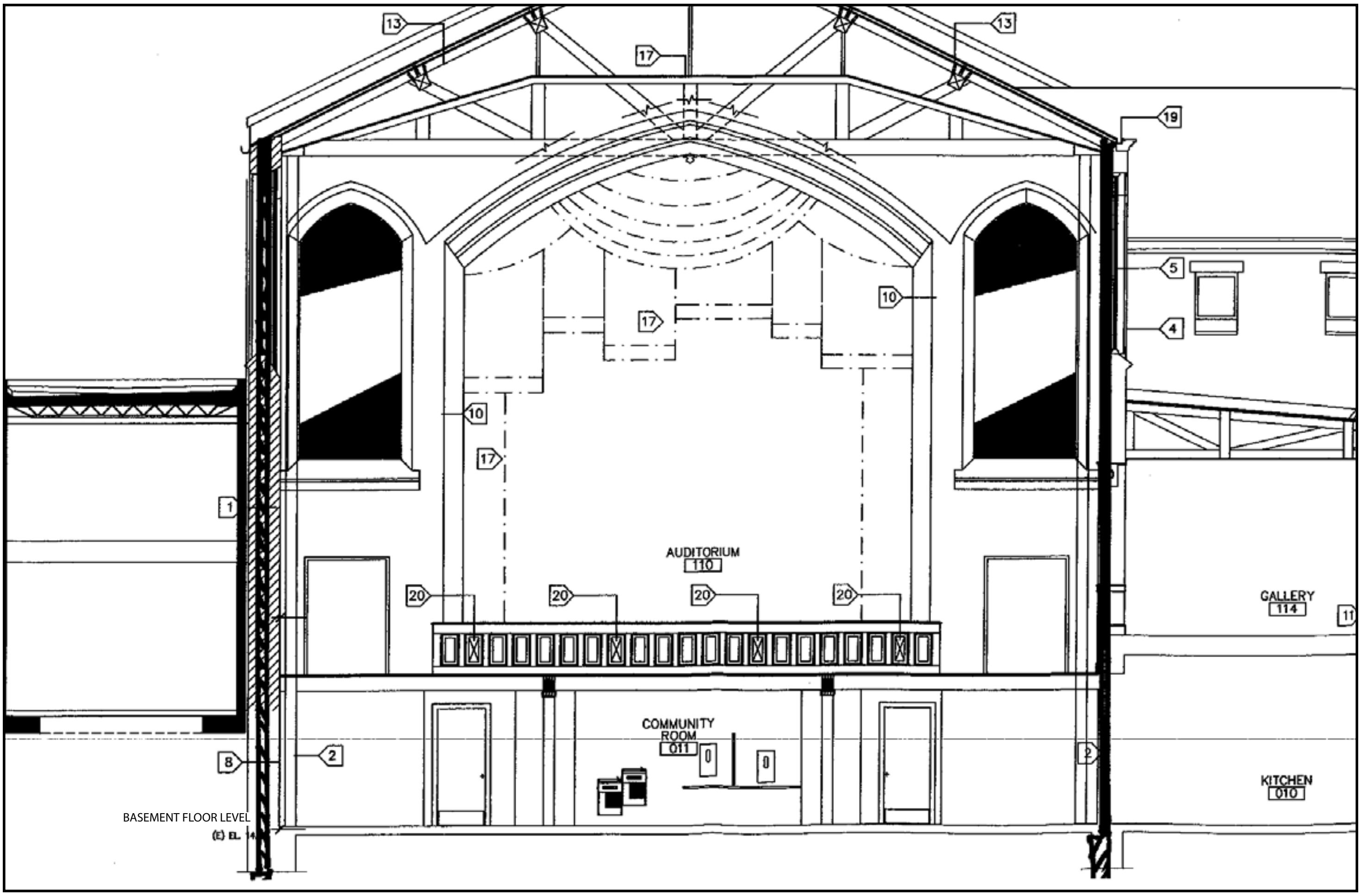
In addition to the internal moment frame elements, diagonal steel bracing with internal reinforcement is utilized on all wall elevations. The 2-inch diameter holes were drilled at diagonal angles (approximately 45 degrees), grade 70 stainless steel rebar was placed, and then the holes were filled with grout. The diagonal reinforcement created an internal shear resisting element for the URM shear walls.

The architectural advantages of the Internal Moment frame system are:

A) No visible appearance of the steel elements.
B) All seismic moment frame connections are inside the unreinforced masonry wall, and then interconnected to a new grade beam system below the foundation.

In addition to the seismic moment frame, a new grade beam was installed below the existing foundation and connected a system of 40-foot deep vertical pipe piles.

Formwork for New Foundation.



Schematic Cross Section of Church Sanctuary.

The project construction commenced in January, 2005, and proceeded with the core drilling of the exterior masonry walls. A specialized crane, installed to assist with the vertical core drilling, was required to have a lifting capacity of 6,000 pounds with a total reach of 140 feet. This allowed the crane to pick up core material from the furthest corner of the building. It was also necessary to place the vertical steel tubes using the crane.

The horizontal drilling was by far the most challenging aspect of this project. The potential of vertical sections of masonry collapsing during the horizontal core drill were addressed by the author and project team. To alleviate this potential, an innovative shoring mechanism was installed using horizontal plates with vertical tubes. This temporary shoring redistributed the vertical loads away from the exposed section of the core and allowed for the horizontal drilling to proceed unabated. No problems were encountered, and the horizontal drilling proceeded without incident.

Rigid Moment Resisting Joint. Courtesy of SidePlate Systems, Inc.

Installation of the pipe piles in the basement had many complicated facets of their own. A new grade beam was required to resist high seismic loads, and the beam had to connect to the vertical pipe piles. The 40-foot deep piles consist of an 8-inch steel pipe (⅜-inch thick, Grade 50). The entire pipe was encased within a 12-inch diameter concrete core. Placing the pipes posed several construction difficulties that included a height clearance in the basement area, machinery access, pipe assembly problems, and difficult work/site conditions. A specialized drill rig was utilized to drill the vertical pile holes, and pipes had to be connected in 8-foot segments to work within the access requirements.▪

Khatri International Inc. has prepared a DVD presentation of approximately 40 minutes that shows the highlights of this project, and would be pleased to provide this to interested parties (*dkhatri@aol.com*, www.khatrinternational.com).

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