Elegant Solution

Viscous Dampers Allow Retail and Hospitality to Share Space and Energize a Historic Building

By Blake Patsy, P.E., S.E., and Bryan Starr, P.E., S.E.

Situated at the center of a city nationally renowned for its thriving urban core, the historic Meier & Frank Building is in the midst of a complex renovation. This 14-story structure's successful revitalization is a key to maintaining Portland, Oregon's downtown vibrancy. The project will consolidate the existing department store on the first five floors and reconfigure the upper nine floors into a 332-room luxury hotel called "The Nines", a property in Sage Hospitality Resources' preferred hotel portfolio.

Dampers Accommodate Diverse Programs

Meier & Frank's presence in the city's center dates back nearly 100 years. Beginning as a quarter-block 11-story structure in 1909, it was not long before the department store covered the full block. Additions in 1915 and 1932 created two adjacent 14-story towers and brought the size of the building up to 600,000 square feet.

Knowing that the May Company and the City of Portland were interested in renovating and consolidating the store, the designers explored how to brace the building seismically even before the project was born. The proposed idea was developed on the back of a napkin over lunch. They sought a solution to reinforce the existing steel frame, concrete floors and terra cotta skin while allowing the store to remain open for business. Viscous dampers presented great potential for this application, since the city building department required that the existing building frame not be weakened during the renovation.

The tremendous appeal of the viscous dampers lies in their flexibility. As opposed to traditional bracing that needs to be aligned throughout the height of the building, the dampers can be strategically placed to absorb energy and reduce the demands on the existing system in a seismic event without being stacked uniformly.

Sage took advantage of this independence by cutting an atrium down the building's center to the sixth floor and arranging the interior-facing hotel rooms around it. The team is re-constructing the lobby level floor using new long-span steel beams. This will create the base of the atrium at the eighth floor and a large, column-free ballroom on the sixth floor.

Another design consideration was the building's exterior terra cotta facade. The preservation of the facade required an in-depth investigation into the condition of the terra cotta and its anchorage to the building's structural elements, including review of existing shop drawings from the original construction. The viscous damper system reduced the earthquake accelerations of the building and lessened the story drifts, thereby allowing the existing facade to meet life safety requirements with minimal retrofit.

Original terra cotta façade. Courtesy of Pete Eckert, Eckert & Eckert Photography.

The System

The team reviewed other seismic solutions, but viscous dampers remained the best alternative from a programming and cost perspective. The dampers were installed in the building by constructing new steel frames between existing columns at each floor, with four to eight frames each direction at each level. These frames look like conventional chevron braced frames, typically with an "A" configuration. At the bottom, the braces are connected to the existing beam and column with gusset plates. At the top, the braces are connected to an assembly that may move horizontally along a channel. The channel is connected to the existing beam, and the channel and brace assembly are connected by the damper units.

The damper units are comprised mainly of a large cylinder with a piston. One end of the damper unit is connected to the adjacent floor, and the other end to the brace assembly that connects to the floor below. As

Close-up view of installed damper frame. Courtesy of Harold Hutchinson, Ackroyd Photography.

the floors move relative to one another, they engage the damper units. By having one end of each unit connected to the adjacent floor, and the other end connected to the floor below via the diagonal braces, the relative velocity of the floors drives the dampers to dissipate energy. The piston is forced through viscous fluid, and the unit is designed to operate with a particular relationship of force and velocity ($F = C * V^a$, with "C" as the damping coefficient and "a" as the velocity exponent). For the Meier & Frank building, the velocity exponent was set to unity.

Time History Analysis

The decision to utilize the damper system created significant challenges. Although dampers have been used in limited building applications, at the time of design there was no code provision for viscous damper systems. The team chose FEMA 356 as the guideline for design with approval from the City of Portland, using the non-linear time history analysis procedure. The process required a peer review, and SIE Inc., a firm that specializes in seismic isolation and energy dissipation, was brought in early in the process.

Obtaining the right geotechnical data was essential and two firms, GeoDesign and URS, joined forces to provide the ground motion input. The period of the existing structure was unusually long, and it was necessary to develop pertinent data for the long-period range of the response spectrum. The long-period transition period, T_L, was found in the 2003 NEHRP Provisions (now in ASCE 7-05) as 16 seconds for the Portland area, which was much greater than the building period. If the FEMA 356 General Response Spectrum was used explicitly for the site-specific study, it would have resulted in unrealistically high accelerations for the long building period. To take advantage of the displacement range of the response spectrum and produce a more cost-effective solution, further study was necessary.


Interior demoliton of upper floors creates a new hotel atrium. Courtesy of Harold Hutchinson, Ackroyd Photography.

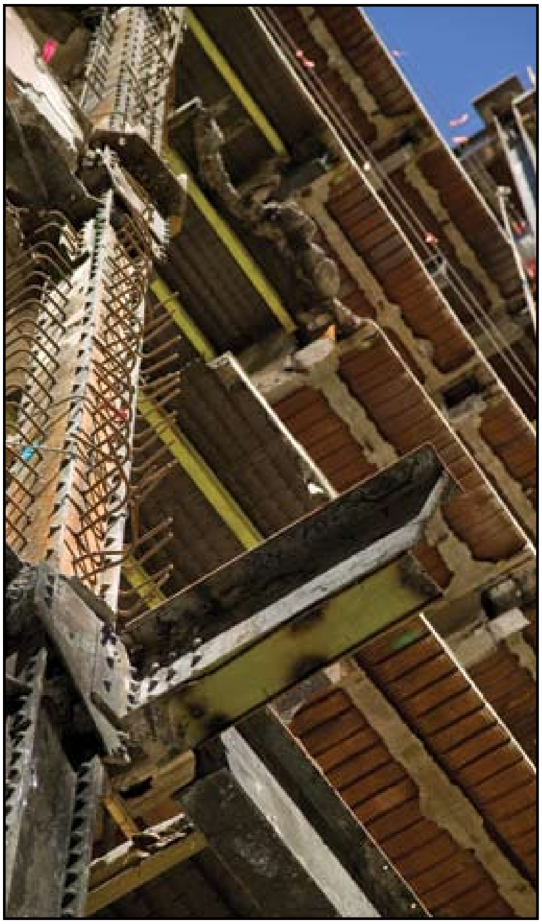
Using geophysical wave propagation models, URS simulated fault ruptures along the Cascadia subduction zone (CSZ), located off the Oregon Coast. URS tracked the propagation of earthquake energy from the CSZ, through the Earth's crust, to the Portland area and determined that a more appropriate value of T_L for the project site is five seconds, rather than the published value of 16 seconds. This reduced the accelerations at the building period by approximately 30 percent. Representative historic earthquake acceleration records were then scaled in the amplitude and frequency domains to obtain design ground motions corresponding to the target design spectra.


Building exterior in downtown Portland, Oregon. Courtesy of Harold Hutchinson, Ackroyd Photography.

Flexible Connections

The complicated existing structure was constructed in three main phases. The majority of the structure used steel beams encased in concrete for fire protection, and steel columns encased in either concrete or masonry, with a combination of riveted and rolled sections.

One of the most difficult design tasks was to assign stiffnesses to the partially restrained moment connections of the floor beams to the columns. These relatively flexible connections played a significant role in the dynamic



Dowels installed on existing columns for concrete retrofit. Courtesy of Pete Eckert, Eckert & Eckert Photography.

behavior of the building. To comply with FEMA 356, the non-linear properties of the existing joints needed to be determined by experiment. After reviewing multiple research studies, the design team selected experiments performed at the University of Washington as the most representative.

The tested connections were riveted top and bottom clip angles encased in concrete. Several years of testing are summarized in a 1994 NSF report and a 1996 ASCE paper. The commentary of FEMA 356 references FEMA 355D for the experimental data on partially restrained connections, which includes a method to determine the failure moment of the connection, M_{fail}. The joint can be assumed to remain essentially linear to a joint rotation of 1 percent, with a stiffness of $M_{fail}/0.01$. The design team combined the procedure of FEMA 355D with the methods presented in the 1994 and 1996 publications to develop a flow chart for the determination of M_{fail}.

Test curves from the experimental data showed that the connections remained essentially linear to 1 percent rotation, with an average stiffness of $M_{fail}/0.01$, which matched the recommendations of FEMA 355D. The design team selected these values for the primary analysis of the building. Due to the unusually long period of the existing building, the City of Portland asked for the exploration of a shorter building period. Using the experimental results, an initial joint stiffness of $M_{fail}/0.003$ was selected as an upper bound. The time history analyses were performed with both the lower and upper values for connection stiffness.

The analysis showed that the joint rotations remained essentially elastic, using the FEMA 355D recommendation of 1 percent rotation and comparing to the experimental data. Therefore, the joints were modeled as linear elements. The building frame was designed to remain elastic, with retrofit of the existing members where required. This allowed the time history analyses to be performed with linear elements, with the exception of the damper units.

Conclusion

In all, 372 viscous dampers will be added to the building, which represents the highest quantity of dampers in any building in the United States. Taylor Devices supplied the viscous dampers, with a phased procurement that closely aligned with the construction schedule to ensure the on-time delivery of so many dampers. The dampers provided an elegant solution to an array of challenges. Using FEMA 356, an extensive geophysical study, and past experimental data, the team provided a cost-effective alternative for the building retrofit that preserved the historic terra cotta exterior of a landmark building. In addition, the damping system allowed two unique programs to share one prominent space and maintain the vibrancy of downtown Portland.▪

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