# Saving Millions While Preserving a Vital Local and National Asset

*By Raymond Pugliesi and Michael Allen*

*Degenbolb Engineers received an Outstanding Project Award for the UCSF Medical Sciences Buildings and Moffitt Hospital Separation project in the 2010 NCSEA Annual Excellence in Structural Engineering awards program (Category – Forensic/Renovation/Retrofit/Rehabilitation Structures).*

*University of California, San Francisco MSB/ Moffitt Separation Project.*

The University of California San Francisco Medical Center faced a serious challenge when California's Senate Bill 1953 mandated that, by 2008, all hospitals remain life-safe after an earthquake. As prime consultant, Degenkolb Engineers employed state-of-the-art analysis techniques and designed a creative solution to retrofit this important asset by separating two 15+ story buildings, the Medical Sciences Building (MSB) and Moffitt Hospital, and seismically strengthened the MSB, while allowing the buildings to remain fully occupied and operational during construction.

Moffitt Hospital and MSB are both composite steel and shearwall buildings, with Moffitt also having an extensive pier-spandrel system along its perimeter. Both buildings were built in the early 1950s.

From Degenkolb's experience with non-linear analysis, it was understood that conventional linear analysis would not accurately capture the hospital's strength and ductility. They long suspected that the hospital itself was quite robust and should not require the strengthening as well as the major disruption and cost that conventional linear analysis indicated. Therefore, the owner was provided with two directions to proceed: a brute force approach of strengthening the two buildings together using typical conventional elastic analysis, or proceed with more in depth analysis using non-linear investigations to better understand the behavior. The owner opted for the deeper analysis because it could minimize disruption to services and risk to patients, as well as save the hospital millions in lost operations and construction.

Degenkolb implemented a state-of-the-art seismic evaluation procedure of the fifteen-story asymmetric hospital attached to the fifteen-story L-shaped lab building. Due to its irregular plan configuration and height, a complex 3-dimensional mathematical model was developed and validated. In what is believed to be one of the first applications ever outside of university research, Degenkolb employed and further developed a new non-linear static analysis procedure, termed Modal Pushover Analysis (MPA). Unlike the FEMA 356 Nonlinear Static Procedure, the MPA procedure explicitly considers higher mode effects. In each direction, two modes were considered in the pushover analyses. Lateral force patterns for each mode were determined from the corresponding building mode shapes, and included not only lateral forces but also torsional moments. The building was pushed to the target displacement for each mode using a site-specific response spectrum. With the contribution of the structural steel considered explicitly in the development of the inelastic flexural and shear properties of all composite members, plastic hinge rotations of each structural element for each mode were combined to evaluate and determine the buildings performance.

Through a subsequent 3 year process of further developing and refining through the OSHPD review process, a design criteria was finalized to utilize the procedure and specify acceptance criteria of the structural elements. The analysis was then completed and reviewed by OSHPD and a third party plan checker to show the building satisfies the SPC2 Life-Safety Criteria.

After analyzing the buildings behavior together and as separate units, it was clear that both buildings had better seismic behavior separately then attached. In fact, Moffitt Hospital satisfied the life-safety performance criteria with no strengthening. In essence, the connection between the stiff cruciform shaped Moffitt Hospital to the largely torsionally irregular L-shaped MSB building was hugely problematic. MSB was retrofitted primarily by improving the torsional behavior by strengthening and stiffening one end of the building with shotcrete shear walls, and on other end weakened by cutting and removing horizontal coupling spandrel beams. Diaphragm drags were also provided on select floors to improve the re-entrant corner conditions.

There were, however, some significant design hurdles to install the seismic joint in an operating building(s). Structurally, Degenkolb re-supported the floor with "propped" cantilever framing in the majority of areas, but five of the floors had major telecommunication rooms where the joint would be. All the telecommunication rooms serving the hospital were meticulously rerouted while preserving all data and minimizing disruption.

Additionally, on the fifteenth floor, the seismic joint was immediately adjacent to the Neonatal Intensive Care Unit (NICU). Disruptive noise and vibrations could disturb the critically ill infants in the unit. Together with acoustical engineer, Charles Salter Associates, Degenkolb developed an in-situ test program to determine the noise and vibration response of the building to a suite of typical construction activities, including rotohammering, chipping and saw-cutting using electric, pneumatic and hydraulic equipment types. A procedure was developed to first re-support the floors using details requiring minimal disturbances, then saw cut all the floors, and finally, completed the demolition of the floor slab and construction. This best reduced the structure-transmitted vibrations from the operating hospital and, in particular, the NICU.

By using advanced MPA analysis, Degenkolb was able to capture the inherent strength and ductility of the building, and was able to avoid a costly and unnecessary strengthening of the hospital. Additionally, the project is a great example of the flexibility and innovation that performance-based engineering gives to clients and designers.▪

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