PRACTICAL SEISMIC RISK EVALUATION

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SUMMARY

Potential loss due to earthquake is evaluated for commercial buildings in Memphis, Tennessee. Five typical existing structures are analyzed for their seismic resistance: a four-story reinforced concrete frame, a four-story steel structure with vertical trusses, a 13 story steel frame, and two multistory reinforced concrete frames. An elastic analysis is performed to determine the moments and shear forces caused by selected earthquakes. Two widely publicized accelerograms are used: El Centro and Taft earthquakes. The member forces are also calculated due to lateral (seismic) loads specified by BOCA and UBC codes. The potential damage is evaluated on the basis of the analyisis and by comparison to reported performance of similar buildings in the past earthquakes.

INTRODUCTION

The paper deals with a practical method for estimating potential loss due to earthquakes. The analysis performed ia for commercial buildings in Memphis, Tennessee. With respect to the style and construction of its buildings, Memphis is typical of the cities in the southern United States. It is situated in the New Madrid fault region; this is potentially active seismic zone (Ref.1).

Statistical evaluations were made of the entire population of commercial buildings in the city to determine the distribution functions for various parameters, such as building height, floor area, age, type of construction, and assessed value (Ref. 2). The most common is a masonry, low-rise structure; however only about 20% of such buildings are assessed at over $50,000 and only about 2% at over $500,000. Most of the high-valued buildings are steel or reinforced concrete multistory frames, located in the downtown area. The age of the existing commercial structures reflects the city development stages; a gradual growth from the end of the last century through the 1920's, then a sudden drop, followed by a recovery in the 1950's and a gradual drop since then.

Over 30 buildings representing typical structures in the area were selected for site examination. The quality of design, materials, and construction was found to be surprisingly good, especially in those structures built since 1900.

Five buildings were selected for the anlaysis of their seismic resistance. They are: a 4-story, reinforced concrete frame with slab

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flooring (1930's); a 4-story, steel frame with lateral resistance provided by vertical trusses (1970's); a 10 story, reinforced concrete flat slab framing system with recessed central slab panels (1920's); a 13 story steel frame with concrete slabs (1920's); and a 13-story, reinforced concrete frame with ribbed flooring (1930's). Equivalent lateral forces are calculated for two reecorded strong motion events (El Centro and Taft), and also for two code-specified forced (UBC and BOCA). The resulting moments, shears and axial forces are used to evaluate the building performance.

REFERENCE GROUND MOTIONS

The city of Memphis falls withing the intensity MM VIII or IX zone (Ref. 3). Because no strong motion accelerogram records for the Central United States are available, two California earthquakes are used in the analysis: El Centro (Imperial Valley Earthquake of May 18, 1940) and Taft (Lincoln School Tunnel, Kern County Earthquake of July 21, 1952). They are widely publicized and may be used for comparison. The maximum MM intensities are estimated at VIII to X for El Centro and at IX to XI for Taft.

For comparison, moments and shear forces in frame members are also calculated using the seismic code provisions from the 1979 Uniform Building Code and 1981 BOCA Code. According to the UBC Memphis is in zone 3, and according to BOCA code - in zone 2.

Spectra for the two selected earthquakes, plotted as spectral acceleration vs. period, are shown in Figure 1.

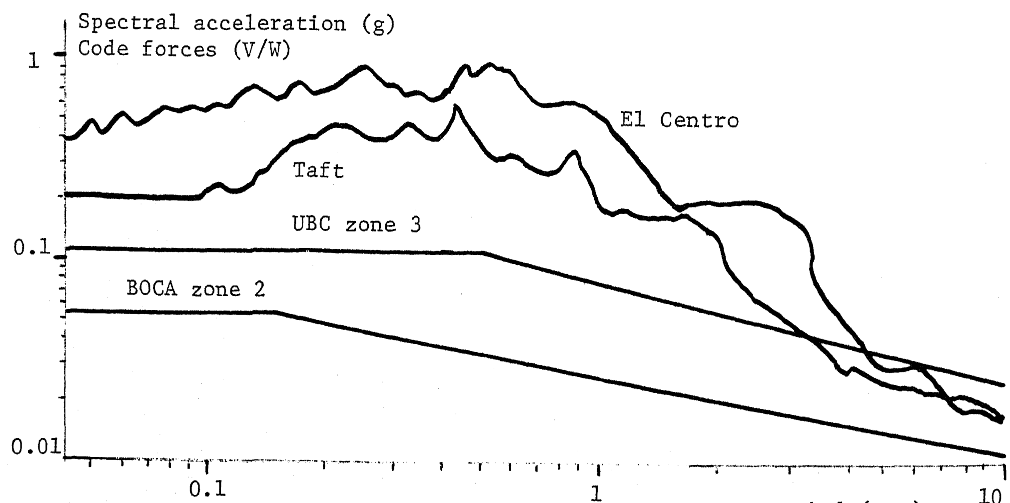

Fig. 1 Acceleration spectra and code seismic forces.

SEISMIC STRENGTH EVALUATION

The analysis is based on the following procedure.

For each building considered, a representative bent is selected. Moments of inertia and moment capacities are calculated for all members in the frame. Inertia masses are calculated and apportioned, using the building plans along with photographs and observations. The bents are analyzed as weightless frames with the masses lumped at each floor; the tributary mass is considered to be from mid-height of adjacent stories. Mode shapes, frequencies, periods and base shear equivalent masses are calculated using a Stodola iteration procedure.

The equivalent lateral forces for the two California earthquakes (El Centro and Taft) are calculated using response spectrum techniques, with damping assumed to be 5% of critical. The effects of these lateral forces are calculated for each bent using rigid frame analysis considering flexural deformations only. The results include lateral displacements, joint rotations, end moments and shears, and column axial forces.

Dead and live load are considered as uniformly distributed. In accordance with the codes (UBC and BOCA), a load combination factor of .75 was applied to the joint effect of the earthquake, dead, and live loads. The moment capacity was compared with the total load effect for each of the four lateral force conditions.

Building 1:

The structure is a low-rise building (three stories and a basement), built in the 1930's, consisting of a reinforced concrete frame system with slab flooring and very few partitions. There are four bays in each direction, with columns spaced at about 6 m. The interior bent selected for analysis is shown in Figure 2. Moments of inertia were calculated for columns and beams based on the gross concrete sections.

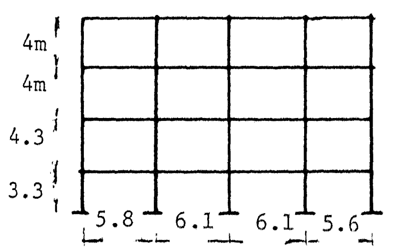

Fig. 2 Bent selected for analysis in Building 1.

End moments, M, resulting from the application of the lateral forces were calcualted for each of the four sets of forces (El Centro and Taft earthquakes, UBC and BOCA codes). For each column and beam the nominal ultimate moment, M_n, was calculated using the ACI code. The resulting ratios of M to M_n are shown in Figure 3.

Building 2:

Building 2 is a 13-story steel frame, built in 1923. It has brick walls, concrete floors and numerous exterior and interior walls (partitions). The beams are standard I sections and the columns typically consist of four angles, two flange plates and a web plate. All beams and columns are encased in concrete. Columns are spaced at about 5 m, with 9 longitudinal bays and three transversal bays.

The interior bent depicted in Figure 4 was selected for analysis. Column and beam moments of inertia were calculated using transformed area principles. The resulting ratios of M to M_n are presented in Figure 5.

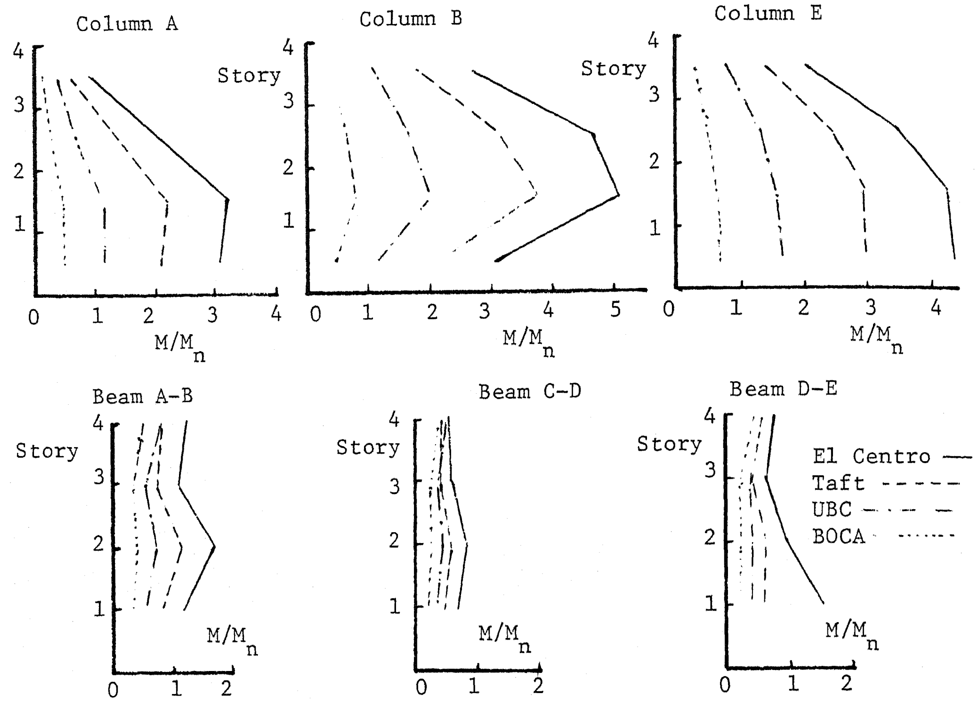

Fig. 3 Ratios of M to M_n in Building 1.

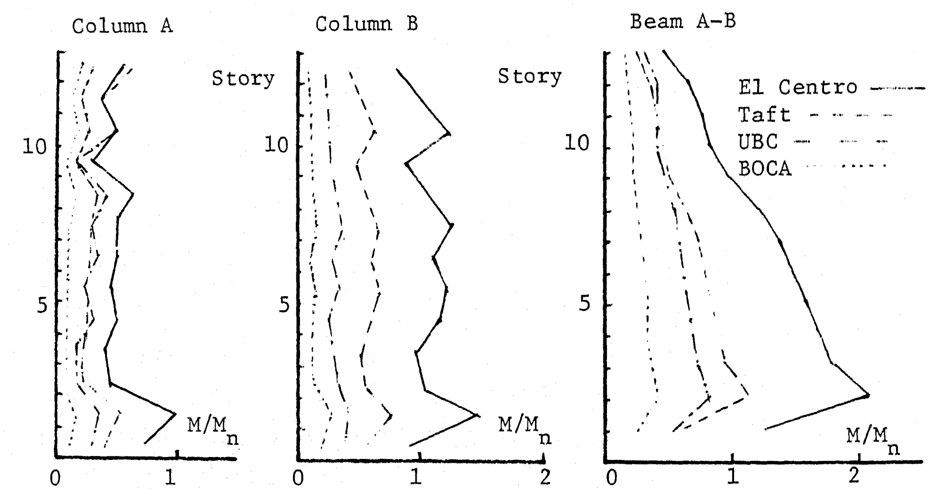

Fig. 5 Ratios of M to M_n in Building 2.

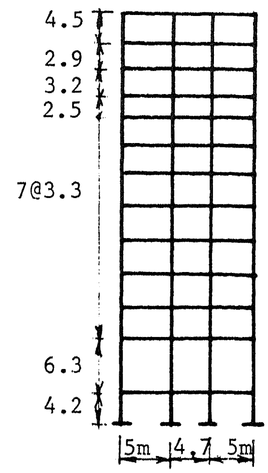

Fig. 4 Bent selected for analysis in Building 2.

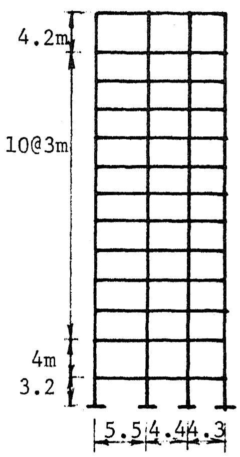

Fig. 6 Bent selected for analysis in Building 3.

Building 3:

Building 3 is a 13-story reinforced concrete frame, with concrete ribbed floors and roof, built in the 1930's. This is a regular structure, rectangular in plan, with numerous shear walls: exterior and interior, longitudinal and transverse. It has 7 bays in the longitudinal direction (about 6.4 m each) and three in the transverse direction. Figure 6 shows the exterior frame that was analyzed. The resulting ratios of M to M_n are presented in Figure 7.

Building 4:

Building 4 is 10 stories high and has a reinforced concrete flat slab framing system with recessed central slab pannels, column capitals, and

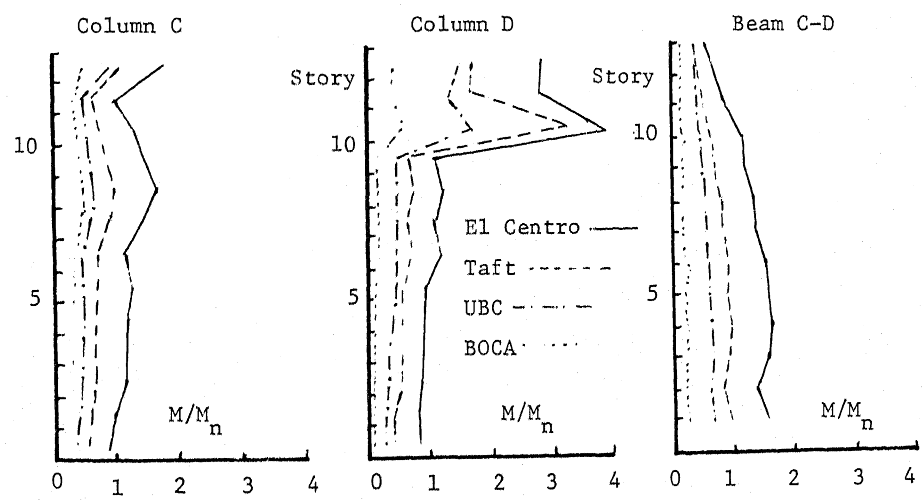

Fig. 7 Ratios of M to M_n in Building 3.

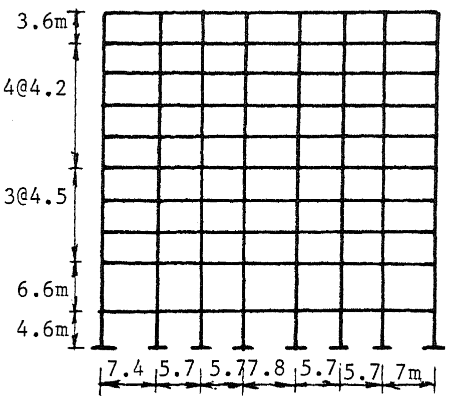

Fig. 8 Bent selected for analysis in Building 4.

deep beams around the building periphery. It was built in the 1920's.

The interior frame shown in Figure 8 was analyzed. The resulting ratios of actual and moments, M, to capacities, M_n, are presented in Figure 9.

Building 5:

Building 5 is a four story office, constructed in 1976. The structure consists of steel columns and beams and concrete floor slab. Lateral stiffness is provided by four vertical trusses, two in each direction. Outside walls are precast concrete panels attached to exterior columns and beams.

There are three types of vertical trusses used in the building: truss A in the longitudinal direction and trusses B and C in the transverse direction. The trusses are shown in Figure 10.

The ratios of the calculated member force, P, to the member load carrying capacity, P_n, are presented in Figure 11. The capacities were calculated using AISC specification.

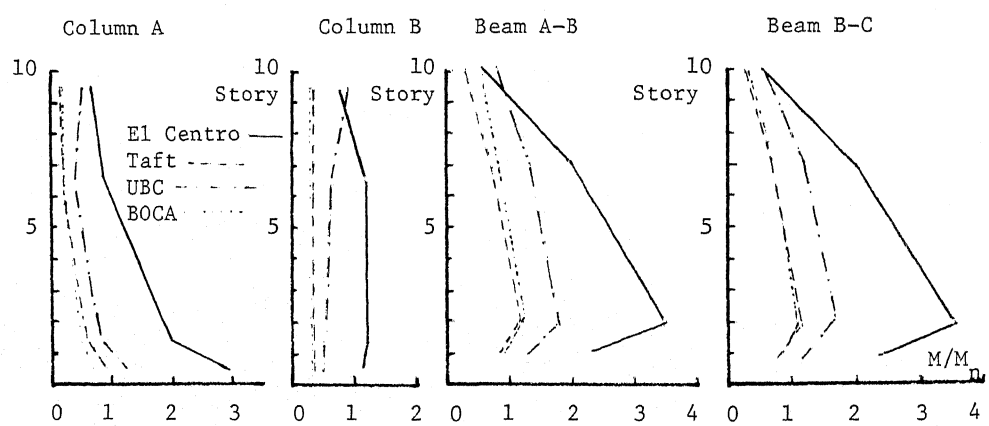

Fig. 9 Ratios of M to M_n in Building 4.

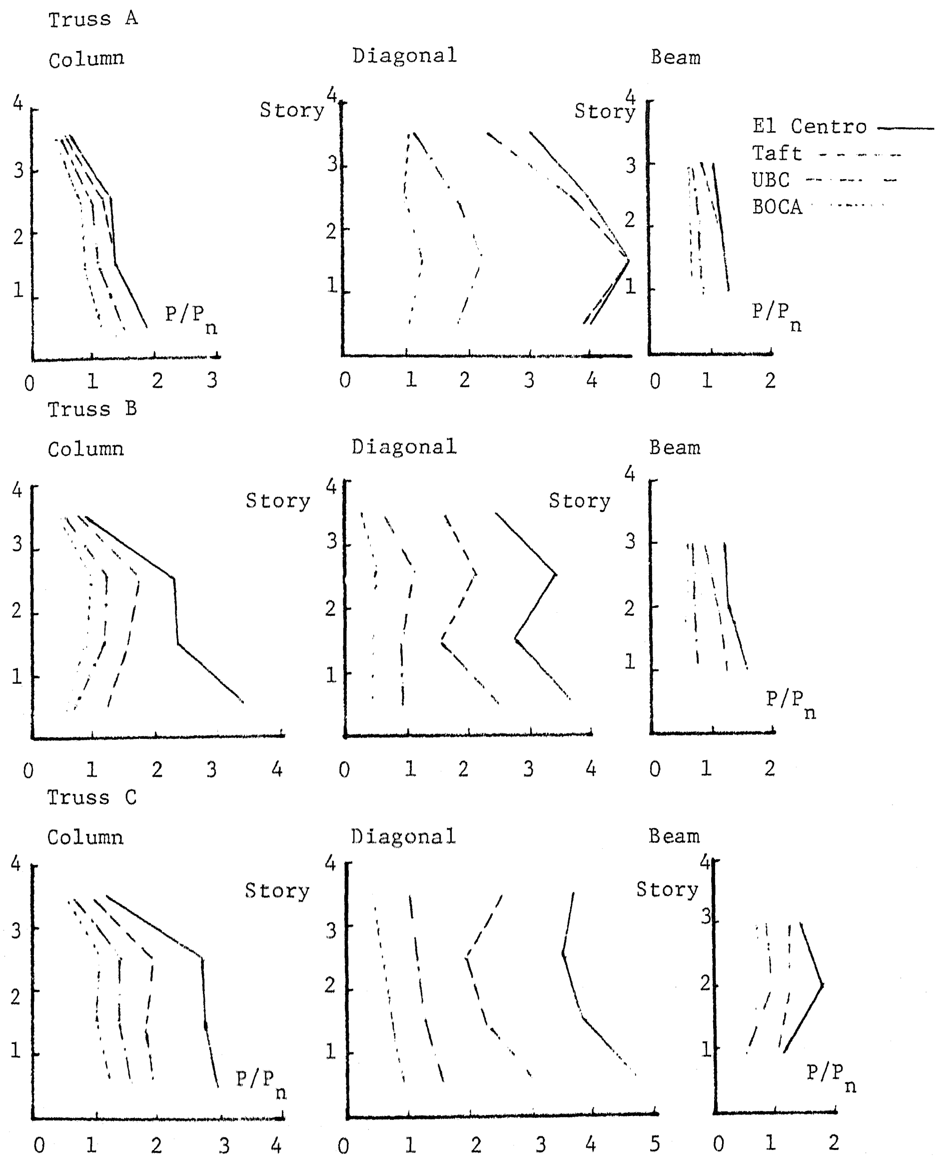

Fig. 11 Ratios of P to P_n in Building 5.

EVALUATION OF POTENTIAL LOSS

The calculated load effect to nominal capacity ratios may be used as an indication of the expected performance under seismic loading. However the elastic analysis is conservative; the actual earthquake-induced lateral

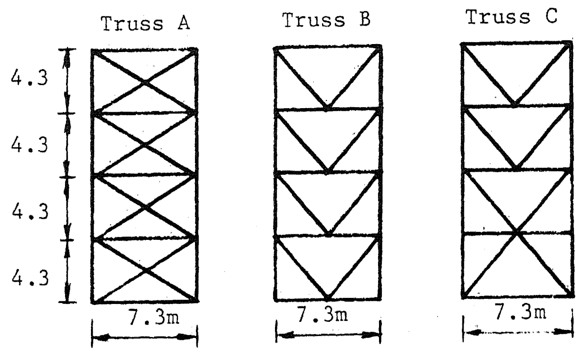

Fig. 10 Types of trusses in Building 5.

forces may be considerably lower than those calculated, due to ductility of the structure. Also non-structural members (walls, partitions) are important in evaluation of the seismic response of multistory frames. Finally, the nominal capacity used in this analysis constitues a lower percentile of the strength distribution.

Therefore the expected percentage of damage for the analyzed buildings is evaluated as given below:

Building	El Centro	Taft
1	60	20
2	30	20
3	25	0
4	10	0
5	15	10

ACKNOWLEDGMENTS

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