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EVALUATION OF EARTHQUAKE RESISTANCE OF EXISTING BUILDING PRACTICE IN NEW YORK CITY

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SUMMARY

There is a growing concern in the eastern United States (US) regarding the potential for damaging moderate earthquakes. A study funded by the National Center for Earthquake Engineering Research of the State University of New York at Buffalo was conducted by the authors to assess the applicability of western US seismic code to the New York City context and begin to evaluate the inherent resistance of existing construction to the ground motion levels considered possible.

INTRODUCTION AND SETTING

We are presented in the eastern United States with a steadily growing accumulation of evidence pointing to the possibility and even likelihood of damaging earthquakes. Unfortunately the evidence is largely statistical and cannot, as in California, be corroborated and constrained by measurable tectonic features and mechanisms. A number of hypotheses have been proposed (Ref. 1) but as of yet, as compared to our colleagues along plate boundaries, we are more or less in the dark.

We do possess a historical record dating back to the 1638 St Lawrence River Canada earthquake. There have been sizable earthquakes in 1755 (Cape Ann near Boston, Massachusetts), 1812 and 1813 (New Madrid, Missouri) and 1886 (Charleston, North Carolina) with magnitudes estimated to be in excess of 7.0. In 1884 an earthquake with an estimated magnitude of 5.0 to 5.5 occurred off shore near Coney Island, New York causing large cracks in masonry walls in Jamaica, Queens. There have been numerous small earthquakes as well. If we extrapolate from this historical data (using the standard b-value Gutenberg-Richter recurrence model) we are led to believe that moderate earthquakes are quite possible. In fact, as stated in a clarification issued by the US Geological Survey in response to a query from the Nuclear Regulatory Commission, the risk may be even greater than the direct evidence suggests.

> "Because the geologic and tectonic features of the Charleston region are similar to those in other regions of the eastern seaboard, we conclude that although there is no recent or historical evidence that other regions have experienced strong earthquakes, the historical record, is not of itself sufficient ground for ruling out the occurrence in these other

regions of strong seismic ground motions similar to those experienced near Charleston in 1886. Although the probability of strong ground motion due to an earthquake in any given year at a particular location on the eastern seaboard may be very low, deterministic and probabilistic evaluations of the seismic hazard should be made for individual sites in the eastern seaboard to establish the seismic engineering parameters for critical facilities." (Ref. 2)

A committee of seismologists and engineers convened in New York City (NYC) in 1984 to consider the need for seismic design requirements concluded that

> "Earthquakes with intensity of about MM Intensity VII have occurred every 100 years in the NYC area.
>
> Regional seismicity indicates that earthquakes of MM Intensity VII are likely to occur on average every 100-200 years.
>
> Larger earthquakes, with MM Intensity VIII-IX or magnitude 5.75 to 6.75 (probable upper bound range) may occur. Even larger magnitude and/or higher intensities, at very low levels of probability, cannot be excluded.
>
> NYC seismicity is very similar to that of the Boston area, where seismic design requirements are in effect."

One need only recall the damage caused last October (1987) in Whittier, California (M5.9, MMI VII-VIII) to realize the hazard.

CONSIDERATION AND EVALUATION OF SEISMIC CODES AND NYC CONSTRUCTION PRACTICE

The seismological evidence presents us with a most difficult and sensitive problem. We have begun to review the basic aspects of this problem as follows

Exceedence Ratio In California we design structures on the basis of ground motions with an average return period of about 500 years. The most extreme event thought possible will not exceed these design basis values by more than a factor of 1.5 to 1.8. Based on current estimates the corresponding exceedence ratios of events with a 500 year average return period against the maximum credible event are closer to 3 to 5 in the NYC area (Ref. 3). In effect we stand to be wrong by a very large factor in New York. This of course reflects the relative infrequency of earthquakes coupled with the possibility of damaging ones. It suggests that we need more, not less ductility in our structures.

Frequency Content and Duration Current earthquake design practice in the western US has incorporated response spectra representative of local earthquakes. We have reviewed the work of Atkinson, Boore, Joyner and others (Ref. 4,5,6). From this it would appear that for eastern, "intraplate" conditions the design response spectra that might best reflect a local seismic setting where moderate magnitudes predominate will be of a narrower bandwith than is typical in the west. Figures 1 and 2 give some indication of this trend. The duration of ground motion is also likely to be lesser in the eastern US, though there is as yet little but indirect evidence to support this.

Inherent Earthquake Resistance of Current and Past Construction Practices We have attempted to quantify in general terms the relationship between wind and seismic effects in order to evaluate the capacity for elastic resistance to earthquakes that is inherent in the wind resistant design practice presently applied in NYC. For this purpose we have developed the relation

$$v = \frac{0.1875\ \rho\ H^{1.5}}{C_t^{2/3}\ \beta}$$

Where

v = base shear per foot of plan "width"
ρ = building density
H = building height
C_t = period equation coefficient = 0.030 for reinforced concrete and = 0.035 for steel moment frames
β = building height to plan "depth" ratio

Using the wind pressures calculated by the provisions of ANSI A58.1 (Ref. 7) and the response spectral shape suggested in the 1988 Uniform Building Code for NYC as well as a spectral shape developed specifically for NYC (NYC-Mod; Ref. 8) we are able to compare total elastic demands of wind and seismic (see Figures 3-6). We have plotted the results of several trial design comparisons as well. However approximate, these figures illustrate clearly the influence of density and assumed spectral shape as well as the potentially large exceedence of design basis wind loads for the types of earthquakes considered possible in NYC.

Equally uncertain is the "supply" side of the equation. Existing buildings include rather tall structures reliant in many cases on the infill masonry facades for stability against wind. Many modern apartment buildings are constructed of reinforced concrete flat plate with infill masonry cladding that will contribute to the overall stiffness and energy dissipating capacity of the structures. It is of course quite difficult to predict the details of response of these systems since they tend to be strength and stiffness degrading. Nevertheless in an environment where earthquakes are moderate, such structures may in fact be able to survive collapse. One need only recall the behavior of the steel frame/masonry infill buildings in San Francisco in 1906.

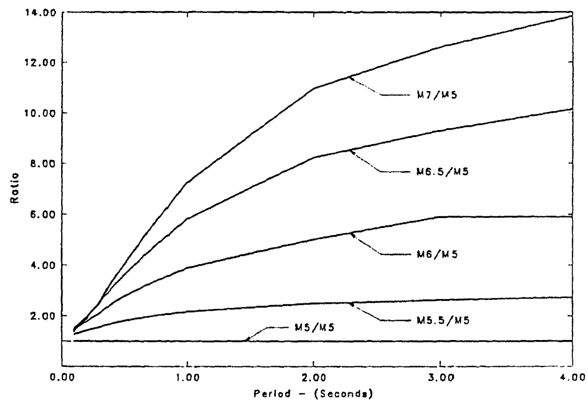
CONCLUSION

There is a great deal of research needed on both the demand and supply side of this problem if we are to mitigate the earthquake hazards in NYC. The recurrence basis and shape of the design response spectra should reflect the specific environment. A careful evaluation of structural systems such as frame/infill structures that respond in a degrading yet possibly sufficiently stable manner is warranted. This can include both analytical and experimental study. Finally interim code measures should include provisions for the type of "total" design practiced in seismic zones, including effective bonding and tying of the building elements (structure, collectors, cladding etc), capacity design etc.

REFERENCES

1. Jacob, K., ed Seismic Hazards, Ground Motions, Soil-Liquefaction and Engineering Practice in Eastern North America, NCEER Symposium, Sterling Forest, NY, October 20-22 1987.
2. Nuclear Regulatory Commission. "Division of Engineering Geosciences Plan to Address USGS Clarification Relating to Seismic Design Earthquakes in the Eastern Seaboard of the United States", Memorandum from Richard H Vollmer to Harold R. Denton, March 2, 1983.
3. Nordenson, G.J.P., "Some Limitations of Current Seismic Codes for Eastern US Earthquake Resistant Design," in K. Jacob ed, op. cit., NCEER

Symposium Sterling Forest, NY, October 20-22 1987.
4. Boore, D.M. and Atkinson, G.M., "Stochastic Prediction of Ground Motion and Spectral Response Parameters at Hard-rock Sites in Eastern North America," Bulletin of the Seismological Society of America, v. 77, no. 2, pp. 440-467, April 1987.
5. Joyner, W.B. and Boore, D.M., "Prediction of Earthquake Response Spectra," Proc.of the 51st Annual Convention of the Structural Engineers Association of California, Sacramento, CA, (1982).
6. Joyner W.B. and Boore, D.M., "Ground Motion Prediction for Design: Progress and Issues," ATC-10-1, Critical Aspects of Earthquake Ground Motion and Building Damage Potential, Applied Technology Council, Palo Alto, CA, (1984).
7. American National Standard Minimum Design Loads for Buildings and Other Structures, American National Standards Institute, A58.1-1982, National Bureau of Standards, (1982).
8. Statton, C.T., personal Communication, (1987).



SPECTRAL ORDINATE RATIOS NORMALIZED TO M5

After Joyner & Boore 1982

Figure 1

NORMALIZED RESPONSE SPECTRA

ROCK SITE - 5% DAMPING

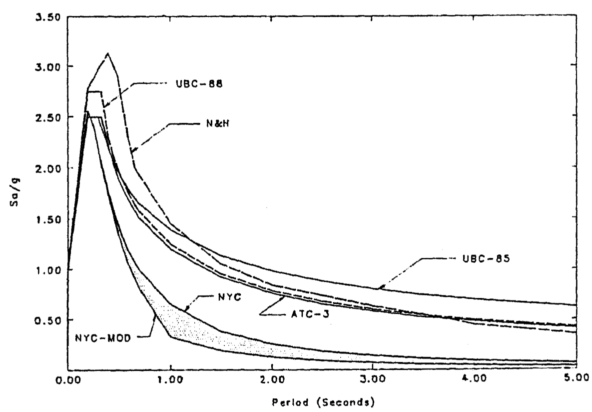


Figure 2

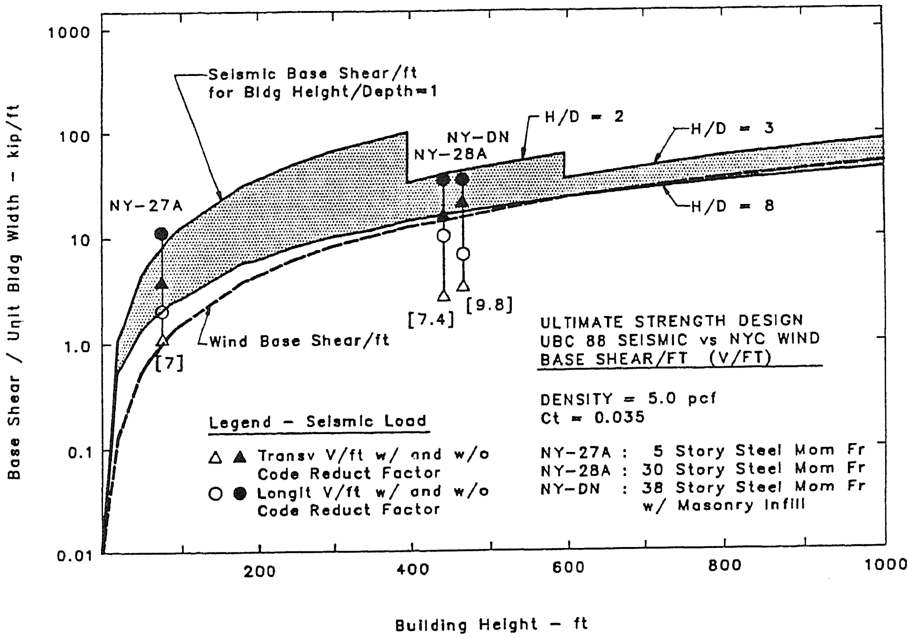


Figure 3

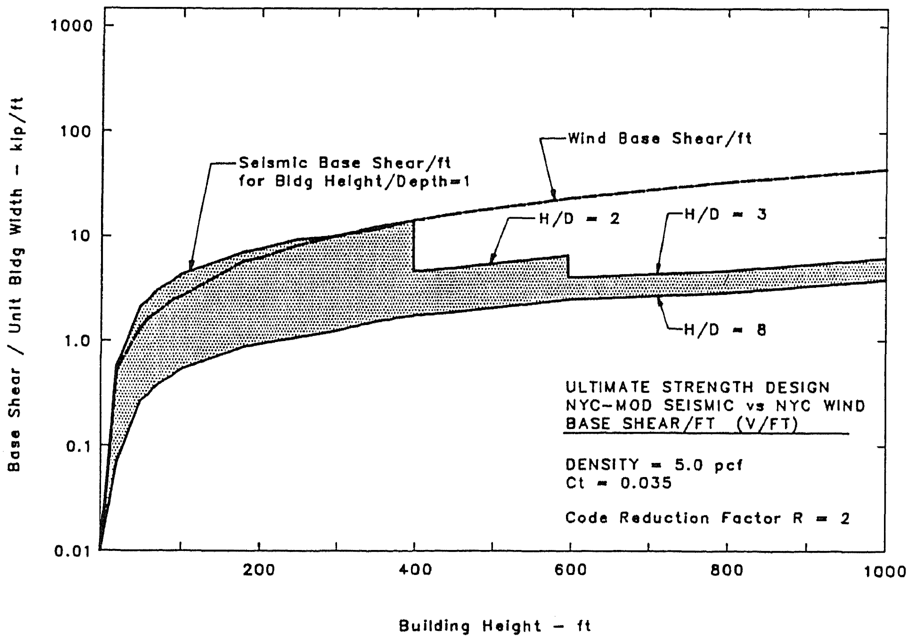


Figure 4

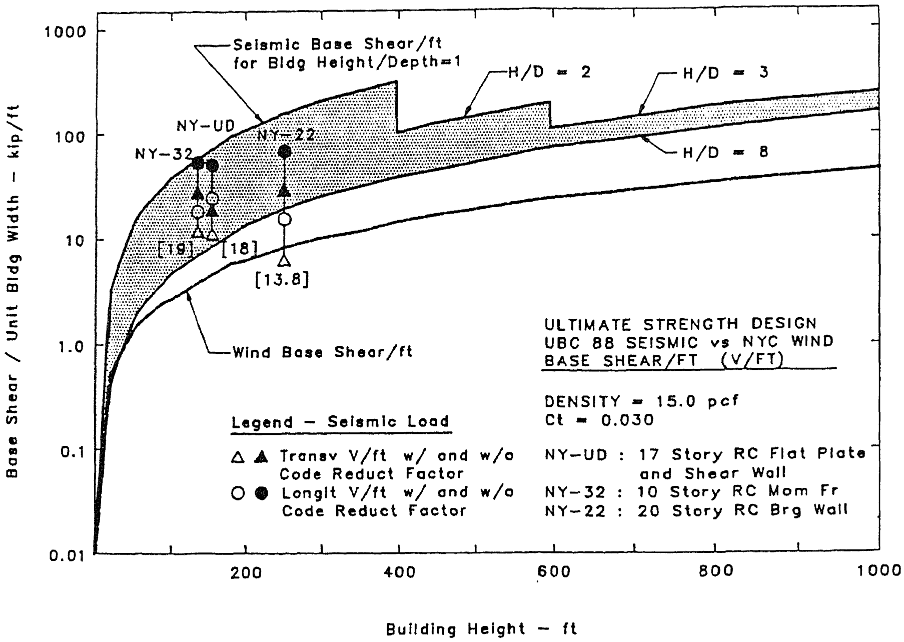


Figure 5

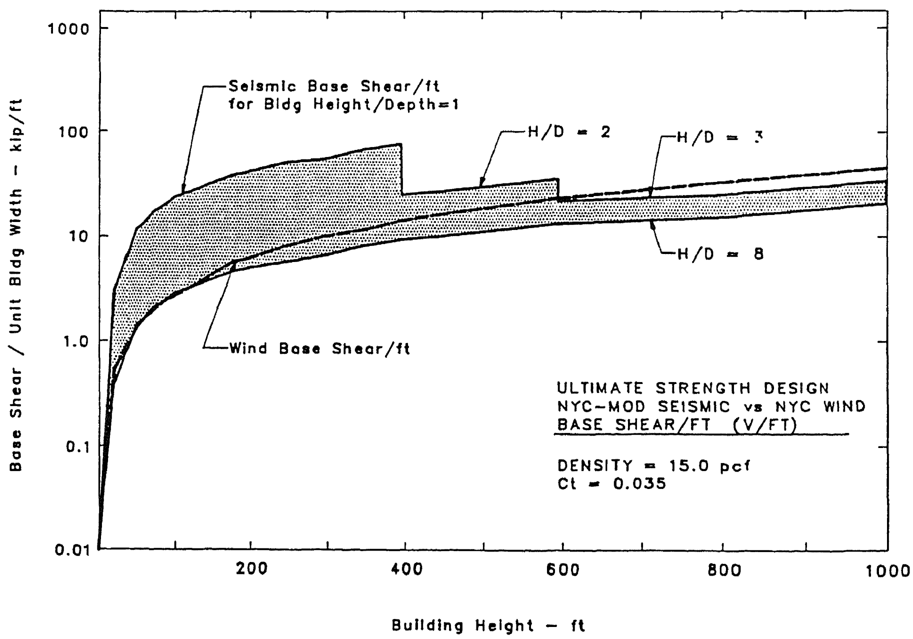


Figure 6