A CALIBRATION OF THE LATERAL FORCE REQUIREMENTS OF THE UBC

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SUMMARY

This paper quantifies some of the more significant underlying assumptions and experiences introduced into the seismic provisions of the Uniform Building Code over many decades. The effective peak ground acceleration associated with the Zone coefficients, the ductility ratios associated with the K factors, the direct interpretation of the S factor and the implications of the importance factors, in terms of non-exceedence probabilities, have all been studied and reported.

INTRODUCTION

The seismic provisions of the UBC (Uniform Building Code) are fashioned after the Recommended Lateral Force Requirements of the Structural Engineers Association of California. Embodied in these recommendations are the collective experience of California engineers since the great San Francisco earthquake of 1906, even though it was not until the 1925 Santa Barbara earthquake that legislative actions were taken towards the development of seismic building codes. Since then, many West Coast earthquakes, in addition to other earthquakes worldwide, have come to impact on the provisions of the Code. Over the years, the behavior of structures during earthquakes has been studied in an attempt to identify both weaknesses and successful performance and to improve the Code provisions accordingly. Thus, the present Code (1982) has been arrived at by a process of successive changes over many decades. Before the Code is modified or completely replaced by more recent developments, it would be extremely useful to calibrate its lateral force requirements. The present paper is such an attempt. Due to space limitations, many of the details of the study are not included.

UNIFORM BUILDING CODE SEISMIC PROVISIONS

The UBC requirement for total base shear is given by

$$V = ZIKCSW \tag{1}$$

where Z = Zone Coefficient, with the following values

Zone	4	3	2	1	0
Coefficient	1	3/4	3/8	3/16	-

I = Importance Factor, used for different types of occupancy

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Factor	Std. Deviation			Non-Exceedence Probability		
	D	V	A	D	V	A
1.25	0.56σ	0.71σ	1.47σ	71%	76%	93%
1.50	1.11σ	1.43σ	2.94σ	87%	92%	99.8%

The following observations may be made from the above data. The Importance Factor as presently recommended by the Code provides different safety margins for the same type of occupancy depending on the structural frequencies. For structures in the 3-8 Hz range, a 1.5 factor provides an inordinately high relative safety margin.

CONCLUSIONS

The basic objective of this study was to explore the implicit assumptions and decisions embodied in the seismic provisions of the UBC and in the process to salvage the experience gained through many decades of successive improvements. The quantification of this experience should prove useful in future changes of the Code.

REFERENCES

International Conference of Building Officials, Uniform Building Code, 1982, Whittier, California

Riddle, R. and Newmark, N. M., Statistical Analysis of the Responses of Nonlinear Systems Subjected to Earthquakes, UILU 79-2016, Dept. of Civil Engineering, University of Illinois, August 1979

Table 1. Building Coefficient, K

Structural System	K
Building with box system: No complete vertical load-carrying space frame; lateral forces resisted by shear walls.	1.33
Building with dual bracing system consisting of ductile moment-resisting space frame and shear walls, designed so that: (1) Frames and shear walls resist total lateral force in accordance with their relative rigidities, considering the interaction of shear walls and frames. (2) Shear walls acting independently of space frame resist total required lateral force. (3) Ductile moment-resisting space frame has capacity to resist at least 25% of required lateral force.	0.80
Building with ductile moment-resisting space frame designed to resist total required lateral force.	0.67
Other building framing systems.	1.00
Elevated tanks, plus full contents, on four or more cross-braced legs and not supported by a building.	2.50
Structures other than buildings.	2.00

Table 2. Possible Sets of Ductilities Associated with K Values (Ductilities are computed from Eq. 4b as an example)

	Trial 1		Trial 2		Trial 3		Trial 4	
K	R	μ	R	μ	R	μ	R	μ
0.67	0.134	11.3	0.167	8.1	0.223	5.3	0.267	4.1
0.80	0.160	8.6	0.200	6.2	0.267	4.1	0.320	3.2
1.00	0.200	6.2	0.250	4.5	0.333	3.0	0.400	2.4
1.33	0.266	4.1	0.333	3.0	0.444	2.1	0.533	1.7
2.00	0.400	2.4	0.500	1.9	0.667	1.4	0.800	1.2
2.50	0.500	1.9	0.625	1.5	0.833	1.1	1.000	1.0
3.0	0.600	1.5	0.750	1.2	1.000	1.0	-	-
4.0	0.800	1.2	1.000	1.0	-	-	-	-
5.0	1.000	1.0	-	-	-	-	-	-

Table 3. Ductility Factors Associated with Coefficient K

K	Displacement	Lower Freq. (Hz)	Velocity	Upper Freq. (Hz)	Acceleration
0.67	3.3	(0.28)	4.1	(2.7)	8.7
0.80	2.8	(0.26)	3.2	(2.6)	5.9
1.00	2.2	(0.24)	2.4	(2.4)	3.7
1.33	1.7	(0.23)	1.7	(2.2)	2.2
2.00	1.2	(0.23)	1.2	(2.0)	1.2
2.50	1.0	(0.23)	1.0	(1.9)	1.0

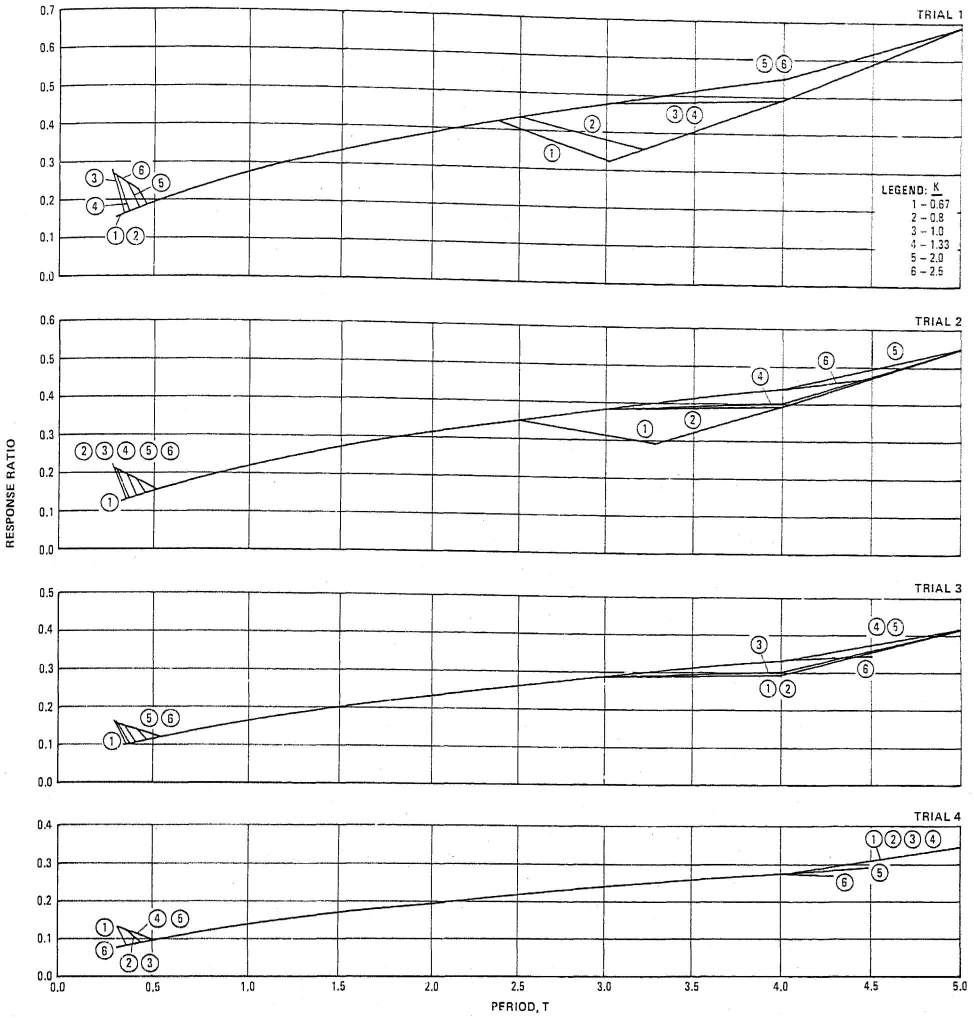

FIG. 1. PLOTS OF THE RATIO OF THE UBC RESPONSE TO THAT FROM THE INELASTIC RESPONSE SPECTRA

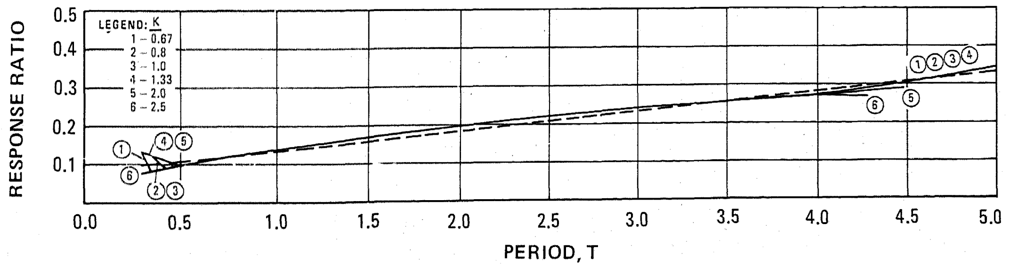

FIG. 2. LINEARIZATION OF THE RESPONSE RATIO FOR TRIAL 4

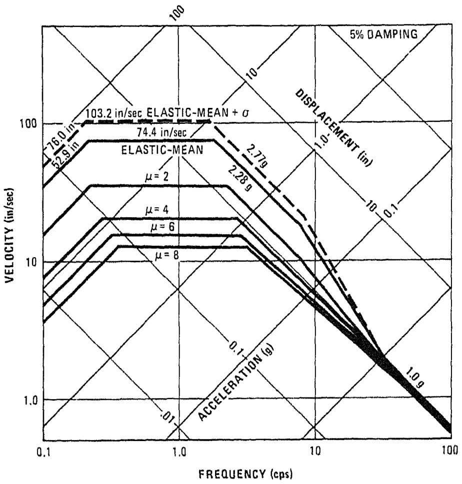

FIG. 3. MEAN DESIGN SPECTRA SCALED TO 1g GROUND ACCELERATION (RIDDLE AND NEWMARK, 1979)

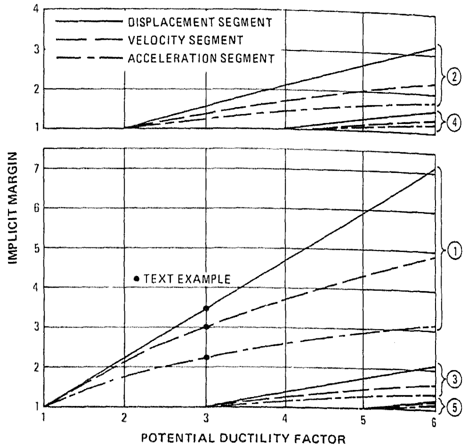

FIG. 4. IMPLICIT MARGINS FOR ELASTO-PLASTIC SYSTEMS WITH 5% DAMPING AS A FUNCTION OF POTENTIAL DUCTILE CAPABILITIES

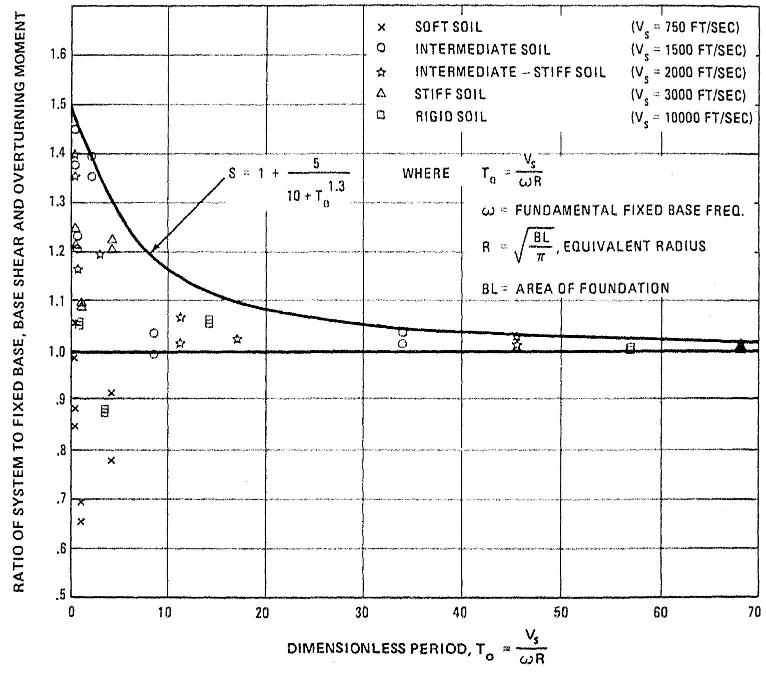

FIG. 5. IMPACT OF SOIL-STRUCTURE INTERACTION ON BASE SHEAR AND OVERTURNING MOMENT