INELASTIC AND RESERVE ENERGY ANALYSIS OF MULTISTOREYED BUILDINGS

by

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SYNOPSIS

The ductility demand in multistoreyed building frames, treated as shear-buildings, is worked out by rational dynamic analysis and reserve energy technique for several storey-stiffness combinations under El Centro 1940 and Port Hueneme 1957 earthquakes which are quite different in their nature of motion. Conclusions are drawn regarding design shear distribution, effect of flexible ground storey and comparison of ductility ratios obtained by dynamic analysis and reserve energy technique. A modified reserve energy procedure is suggested which gives better correlation of the ductility demand with the rational dynamic analysis.

INTRODUCTION

Much work has been done on the inelastic dynamic analysis of multistoreyed buildings subjected to earthquake type motions. The aim of this study is to investigate the effect of certain design parameters on maximum ductility demand in the various storeys. The variables studied are the following:

a) In a fourteen storeyed building the stiffnesses and yield levels of the storeys are varied frome one problem to another as follows:

i) Yield levels, corresponding to the seismic forces proportional to maximum probable elastic response based on first three modes.

ii) Yield levels corresponding to the seismic forces proportional to 'mass x square of height' of floors, as in Indian Standard 1893, the base shears in i) and ii) being kept the same.

iii) Flexible first storey, the upper storeys made three times as stiff and strong as in other cases due to consideration of infill panels.

b) Two earthquakes of very different characteristics are considered as the base motion. One is El Centro earthquake of May 18, 1940, N-S component with acceleration ordinates reduced to 84%. The other is Port Hueneme earthquake of 1957 with equivalent spectral intensity.

c) Elasto-plastic as well as bilinear hysteresis diagrams are considered in the analysis, For bilinear case, the ratio of stiffness slopes was 0.3.

The parameter combinations of the building are shown in Table 1.

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RESULTS OF DYNAMIC ANALYSIS

The maximum ductility ratios computed in various storeys are drawn in Fig. 1. From these diagrams, the following observations can be made:

a) The ductility ratios have a different pattern along the height for the two earthquakes, the lower storeys needing larger ductility for El Centro and the upper storeys for Port Hueneme earthquake. Therefore the optimisation a structure from ductility consideration for one earthquake motion would not necessarily meet the requirements of another different type of shock.

b) The distribution of shear proportional to (mass x height^2) generally leads to more uniform distribution of ductility ratios than the one obtained by elastic modal analysis. This result corroborates with the recommendation of uniform shear distribution along height (1)

c) For the flexible first storey case, the ductility requirement is concentrated in the first storey, the upper storeys remaining more or less elastic for both the types of ground motion. Of course the requirements of ductile deformations is so large that it will need special devices to permit the same without leading to failure of columns (2).

d) The ductility requirements are less in the bilinear case than the elasto-plastic case.

In the above studies of timewise calculations of ductile deformations it was remarkable to note that the maximum deformation in each storey occurred at a different instant of time. That is, for purposes of estimating an upper bound on ductility ratio it could be assumed that when one storey undergoes plastic deformations, the others remain elastic. This assumption is used subsequently in deriving a simple reserve energy analysis.

RESERVE ENERGY TECHNIQUE

The same multistoreyed buildings were analysed by the Reserve Energy Technique (RET) (3). The resulting values of ductility ratios obtained by RET are compared with those obtained by dynamic analysis in Fig. 2 (a to d). It is seen that the ductility demand indicated by RET particularly in the upper storeys is much higher than that given by dynamic analysis. The main reason for this seems to be the factor which tends decrease the energy output of the frame.

NEW RESERVE ENERGY ANALYSIS

It is based on two considerations as follows:

a) One storey becomes plastic at a time. It can be considered as a single mass system having a time period T_z given by

$$T_z = 2\pi\sqrt{W_z/(gK_z)}$$

where W_z = weight of all storeys above and including the storey under consideration, g = acceleration due to gravity and K_z = stiffness of storey. Depending upon the elastic shear V_e, the ductility ratio of the storey, μ' can be found as usual. For instance, for elasts-plastic systems,

$$\mu' = 0.5\left[1 + (V_e/V_y)^2\right]$$

where V_y = the yielding shear of the storey.

b) The above ductility ratio is increased in the ratio of the square-root of kinetic energy input corresponding to the fundamental time period of the building T_o. Assuming that S_v is proportional to $T^{1/4}$ and since kinetic energy is proportional to S_v^2, the modified ductility ratio would become

$$\mu = \mu' (T_o/T_z)^{\frac{1}{4}}$$

The ductility ratios so determined are also shown in Fig. 2 (a to d) and show a closer correlation with those obtained by dynamic analysis than RET.

CONCLUSION

The mass x height^2 distribution of floor level forces is suitable for proportioning the multistoreyed frames from plasticity point of view. Very good upper bound on ductility ratios in various storey can be estimated by a simple reserve energy analysis.

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TABLE 1 - PARAMETER COMBINATIONS OF 14 - STOREYED BUILDING

Storey No.	Mass $t\text{-}sec^2/cm$	Stiffness t/cm	Yield deformation case(i) cm	Yield deformation case(ii) cm	Stiffness on (iii) t/cm	Yield deformation case(iii) cm
1	0.266	665	0.635	0.635	665	0.635
2	0.455	590	0.710	0.717	1770	Elastic
3	0.514	562	0.720	0.750	1686	"
4.	0.514	562	0.685	0.743	1686	"
5	0.514	514	0.720	0.800	1542	"
6	0.514	514	0.685	0.780	1542	"
7	0.514	462	0.715	0.835	1386	"
8	0.514	462	0.660	0.792	1386	"
9	0.514	368	0.745	0.924	1104	"
10	0.514	368	0.655	0.833	1104	"
11	0.514	368	0.558	0.720	1104	"
12	0.514	352	0.480	0.610	1056	"
13	0.514	352	0.350	0.442	1056	"
14	0.595	352	0.182	0.244	1056	"

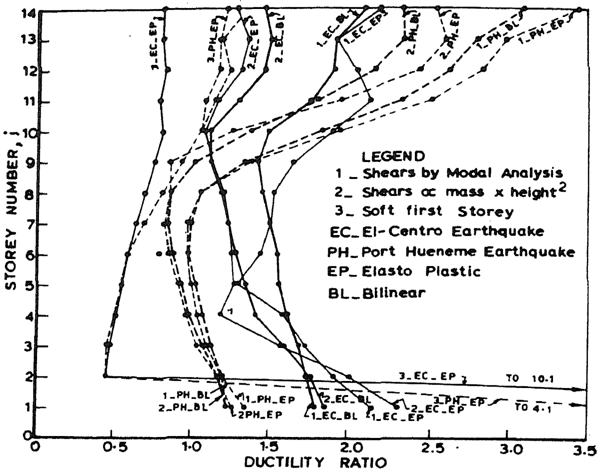
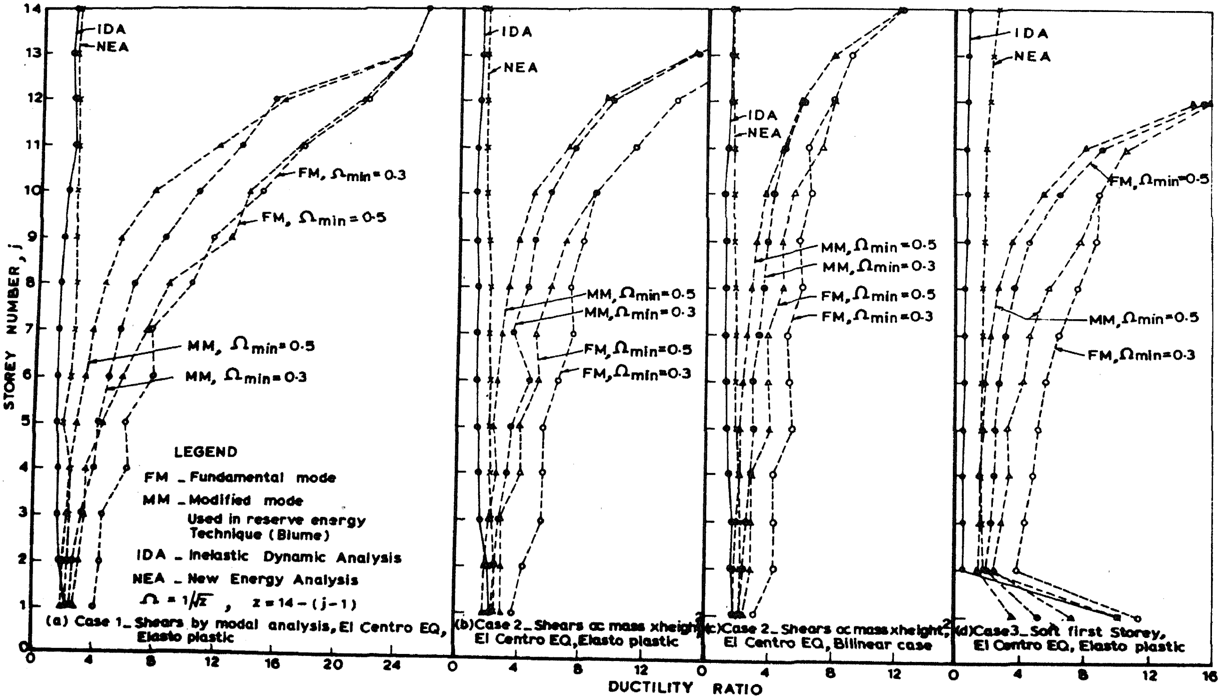


FIG. 1 _MAXIMUM DUCTILITY RATIO IN STOREYS



(a) Case 1_Shears by modal analysis, El Centro EQ, Elasto plastic

(b)Case 2_Shears ∝ mass xheight², El Centro EQ,Elasto plastic

(c)Case 2_Shears ∝ mass xheight², El Centro EQ, Bilinear case

(d)Case3_Soft first Storey, El Centro EQ, Elasto plastic

FIG. 2 _DUCTILITY RATIO (RESERVE ENERGY TECHNIQUE, INELASTIC DYNAMIC ANALYSIS AND NEW ENERGY ANALYSIS)