ULTIMATE STATE PARAMETER AND SEISMORESISTANCE RESERVE STUDIES ON THE BASIS R.C.COLUMN AND FRAME TESTS UNDER DYNAMIC AND STATIC CYCLICAL LOADING

By
V.A.Stepanian[I]

Many tall R.C. frame buildings have been constructed in areas of seismic activity during last several years. A real character of intensive seismic effects and also real reserves of seismic resistance have to be taken into account in the design methods of these structures. Natural dimension R.C. columns and frame fragments have been tested under cyclic horizontal and impulsive loadings ($S=P\cdot\tau$ at $\tau=T/2$) on the special test-stand designed by author. The experimental studies have allowed to conclude that after repeated loading with values of $P\leq 1{,}5\ P_{design}$ and subsequent anloading the crack width has not exceeded the normal values envisaged by Building Codes. Furthermore, the repeated loading with values of $P=(2{,}2\div2{,}8)P_{design}$ have resulted in substantial growth of elasto-plastic deformations (exceeding the elastic design values up to 10 times) and in subsequent rise of energy reserve. The extensive residual deformations and cracking have made the further normal use of tested structure really inpossible. But even in such deteriorated conditions owing to large energy reserves the R.C. frames guarantee the safety of people and protect the building structure from total collapse. This has been stated experimentally. A following is recommended for frame structuress designed to withstand a given ground acceleration: the factor accounting for short-term load appication to be $M_{sh.}=1{,}4$, the decrement of oscillation $\delta=1{,}0$ and the ultimate deflection to be limited $y\leq 1/100H$, where H--is the hight of structure. The design deflection is to be calculated on the basis of mean values of beam and column rigidities considiring the Cracking and plastic moment of resistance.

[I] Candidate of Technical Sciences, head of the Laboratory Structural Seismic Resistance, Research Institute of Construction and Architecture of Gosstroy of Armenian SSR, Yerevan-44, D.Sasoonsky str. 3.

DISCUSSION

B.R. Seth (India)

The importance of ultimate analysis under seismic loads has been nicely stressed by the author, for R.C.C. frames. The following limit analysis is suggested.

PLASTIC HINGE V/S MOMENT RELATION:

Yield point curvature and moment can be expressed as[I]

$$\phi_e.d = \frac{f_y}{E_s(1-k)} = \frac{f_y}{E_s\left\{1 + pm-(2pm + p^2m^2)^{1/2}\right\}}$$

$$M_e = f_y p.bd^2 (1 - k/3)$$

The ultimate curvature and moment can be written as

$$\phi_u.d = \frac{e_u(0.85\ k_1\ f'_c)}{p.f_y} = \frac{0.00255\ k_1 f'_c}{p.f_y}$$

taking $e_u = 0.003$

$$M_u = f_y\ p.b.d^2 (1 - p.f_y/ 1.70\ f'_c)$$

and

$$M_e/M_u = \frac{1 + (pm - (2\ pm + p^2m^2)^{1/2}/3}{1 - p.f_y/ 1.70\ f'_c}$$

From the plots of M_e/M_u v/s p for particular usual values of f_y and f'_c it can be seen that M_e/M_u does not vary much and considering the effect of shear, M_e/M_u equal to 0.9 can be accepted. The general moment curvature curve can be approximated as bilinear curve. If M/M_u v/s $\phi_e.d$ is plotted, M_e/M_u has constant ordinate and abscissa is also almost constant as for good ductility, section is underreinforced and variation in percentage of steel is not much.

I Notations are explained at the end.

A.C.I. Committee recommends the length of effective plastic zone as equal to the effective depth. Therefore, plastic hinge rotation is $\theta = (\phi_u - \phi_e)\ d$

Plots of hinge rotation v/s moment for different p are given at the end. From it the hinge rotation is expressed as

$\theta = 0.1\ (M/M_u - 0.9\ )\ /\ e^{438p}$ for $M > M_e$

The maximum hinge rotation the section can provide is $\theta_{max} = 0.01/e^{438p}$ where p is fraction of area of steel.

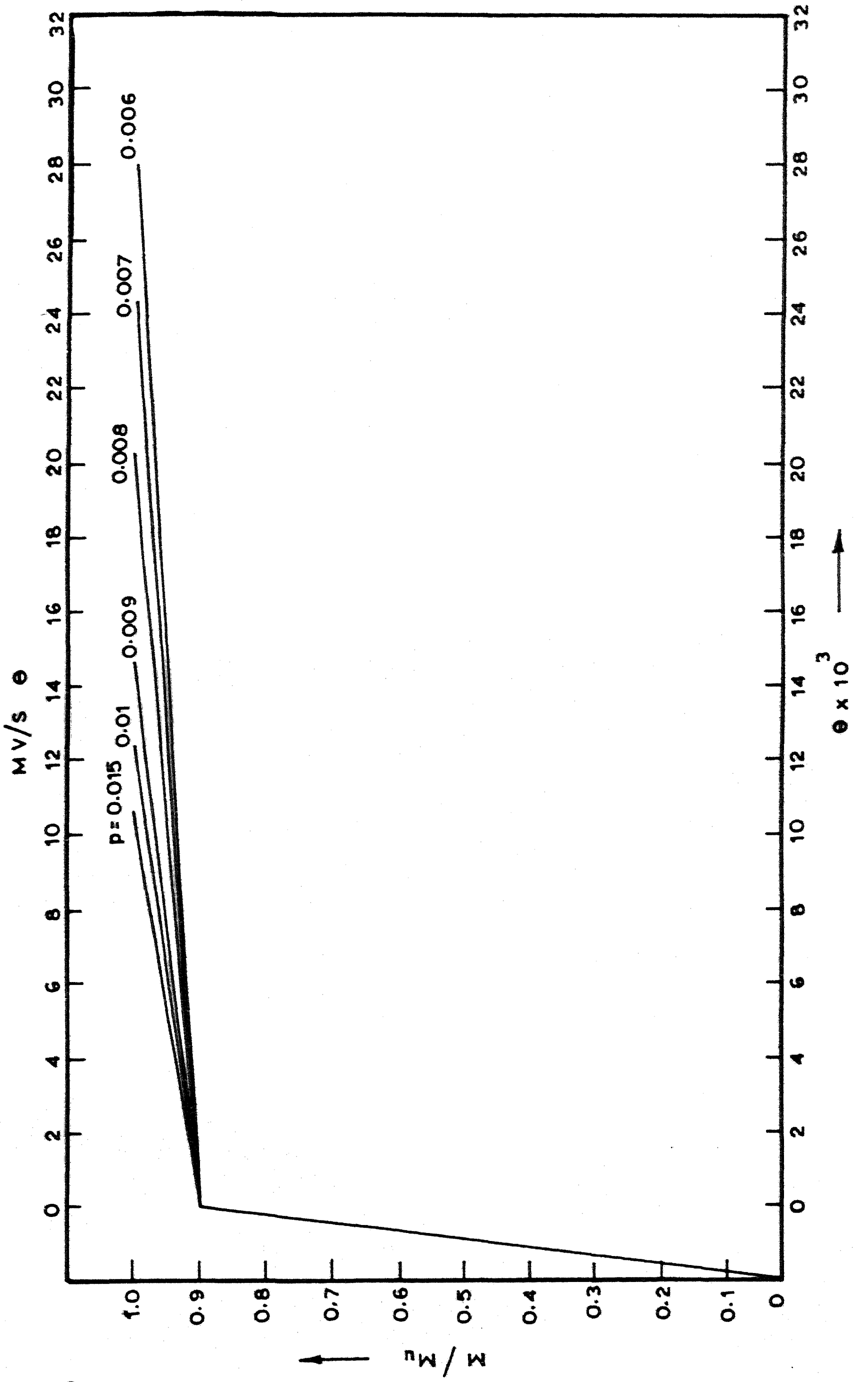
LIMIT ANALYSIS:

For multistoreyed frames, the method of angle distribution is very suitable. Under the repeated cyclic loading of earthquake, due to fatigue the ductility is reduced so much so that plastic hinge rotation capacity after one reversal at yield load is only 2/3 of its initial value. So 30% of this maximum hinge rotation is utilised, and angle distribution is done. As the columns are more susceptible to damage by earthquakes and failure of column leads to collapse of building, plastic hinges have not been allowed in the columns by finally designing the column section well stronger than required. For this purpose a computer program for IBM 7044/1401 has been prepared.

The analysis showed that 10% redistribution of moments can be utilized.

NOTATIONS:

b, d	are width and effective depth of section.
e_u, f_y, f'_c	are the ultimate strain of concrete, yield stress of steel and cylinder strength of concrete.
k, k_1	are fraction for depth of neutral axis in elastic stage and factor for uniform ultimate stress block.
m, p	are modulus ratio and fraction of area of steel.
M_e, M_u	are the moment resistance capacity of the section at yield of steel and ultimate stage.
ϕ_e, ϕ_u, θ	are the curvature at yield and ultimate stage, and plastic hinge rotation.



Author's Closure

Not received.