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Analytical study of seismically vulnerable RC buildings and their strengthening

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ABSTRACT: There are many buildings existing in different parts of India which were either designed before introduction of seismic code or where upgradation of seismic zone has been effected subsequent to their construction. Such buildings need to be strengthened for seismic forces. The present paper examines two types of buildings designed for vertical loads only and evaluates their seismic resistance. One category of buildings includes those with uniform stiffness distribution over the height and the other with varying stiffness over the height. Subsequently buildings which indicate distress are strengthened by increasing the column and beam sections and reanalysed. The analysis is done on the basis of assumption that perfect bond exists between the old and new concrete. However, in view of possible increase in friction at joints and increased stiffness, damping characteristics of the building may change. Therefore effect of variation in damping is also examined.

BUILDING STUDIED

The study was carried out on single bay three and five storey buildings having plan dimensions as shown in Fig. 1. In tapered buildings the stiffness varies from 1 to 1/3 from ground to top floor in three storey building and from 1 to 1/5 in five storey building.

SEISMIC LOAD

The buildings are designed as per Indian standards for gravity loads 1.5(DL+LL) and checked for earthquake loads corresponding to Indian Standards for seismic zone V, IV and III using pseudo static method. Members are checked for (DL + Reduced LL + EQL).

BEHAVIOUR OF BUILDINGS

Figures 2 to 5 indicate the pattern of distress in various members of the buildings in zone III, IV and V. The distress is expressed as ratio of checking moment (i.e. with consideration of seismic loads) to design moment. It is seen that this ratio is relatively less downward in tapered building as compared to uniform building. This is due to the fact that in tapered building design moments are greater downward in comparison to uniform building. It is clear from figures that uniform buildings are more prone to earthquake distress in lower portions while tapered buildings are more vulnerable in upper portions.

STRENGTHENING MEASURES

As stage I of strengthening process the sections of members which indicate failure are increased arbitrarily. The column size was increased by 50mm on all four sides to accomodate new steel as per the requirements of Indian Standard. Due to earthquake, beams indicate failure at ends due to hogging and therefore these are strengthened by 'build up' method, by increasing the depth (by 100mm) at top only in the 20% of the span at the ends without increasing the width of beam.

In stage II, the seismic forces are worked out for the modified sections as per Indian Code IS:1893-1984 using modal analysis and for three different values of damping namely 5,7 and 10% of critical. Further, gravity load analysis was repeated and combined moments as per code were worked out. The amount of reinforcement required for strengthening was worked out for these design forces as per IS Code (during this stage II).

Reinforcement requirement

Strengthening reinforcement as a ratio of design reinforcement for column and beams for various buildings in three zones is shown in Fig.6 to Fig. 15.

COST ANALYSIS

Fig. 16 indicates the cost involved in the strengthening of buildings under study, wherein ratio of cost of strengthening to original cost of construction is given for different buildings in different zones. The required cost is seen to be about four times in zone V as compared to that in zones III for a 5 storied building.

CONCLUSIONS

For the buildings studied following conclusions are drawn :

1. A building with tapered stiffness distribution along its height has relatively higher lateral load capacity compared to uniform structure for the same seismic zone. Further, uniform buildings are more prone to earthquake damage in lower portions while tapered buildings are more vulnerable in upper portions.
2. Strengthening of beams by build up method at top is advantageous to resist increased hogging moment near support as it avoids strengthening at mid span.
3. Columns must be strengthened by casing in view of biaxial bending effects. However sometimes minimum reinforcement requirement of four bars at four corners may lead to reinforcement more than needed.

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Nath, B.C. Strengthening of RC Buildings for Earthquake Forces. M.E. Thesis 1991, Earthquake Engg. Department, University of Roorkee, Roorkee, India.

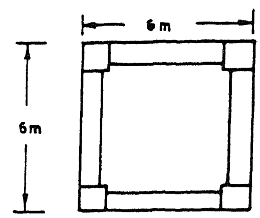

Figure 1. Building Plan.

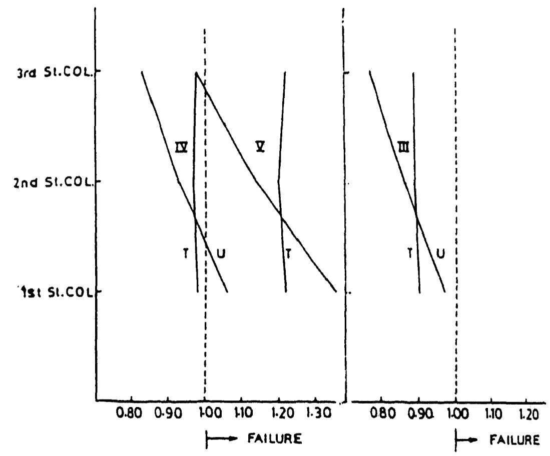

Figure 2. Ratio of checking moment to design moment for columns of three storey buildings.

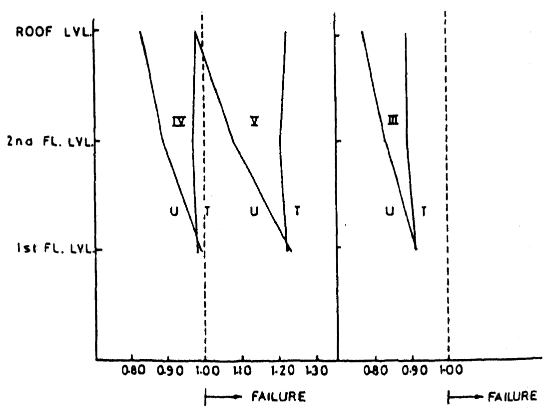

Figure 3. Ratio of checking moment to design moment for beams of three storey buildings.

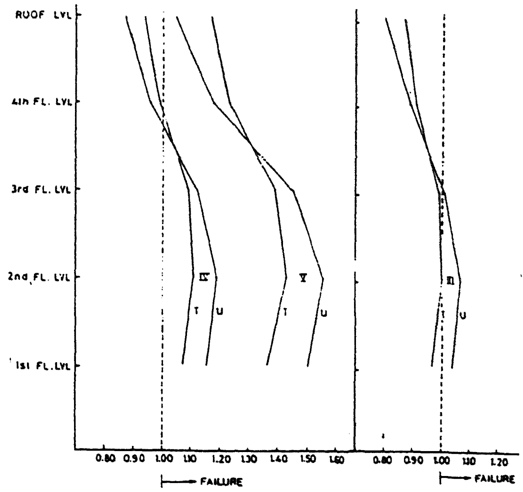

Figure 4. Ratio of checking moment to design moment for columns of five storey buildings.

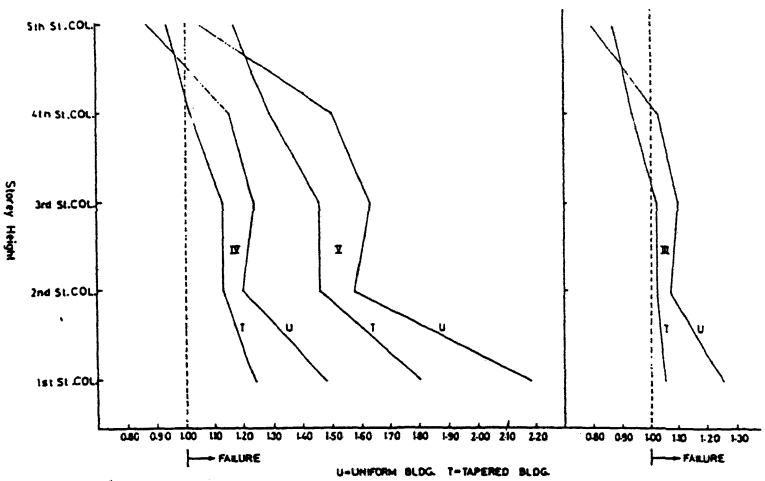

Figure 5. Ratio of checking moment to design moment for beams of five storey buildings.

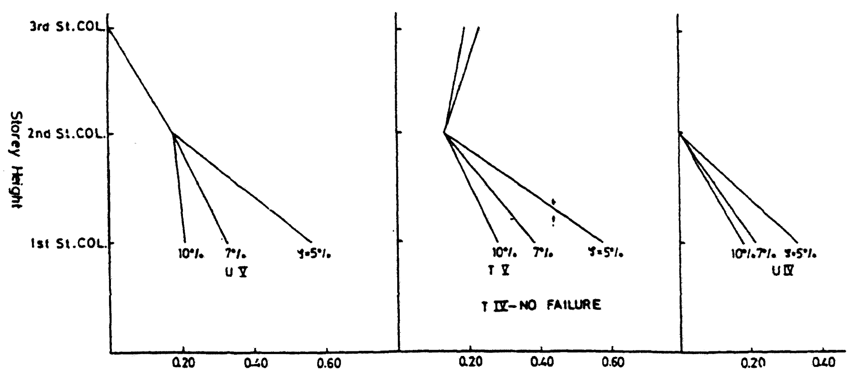

Figure 6. Column strengthening reinforcement/design reinforcement in three storey buildings.

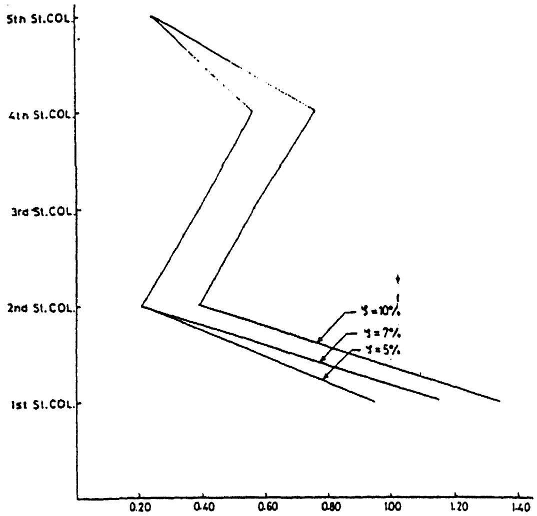

Figure 7. Zone V column strengthening reinforcement/designs reinforcement for five storey uniform building.

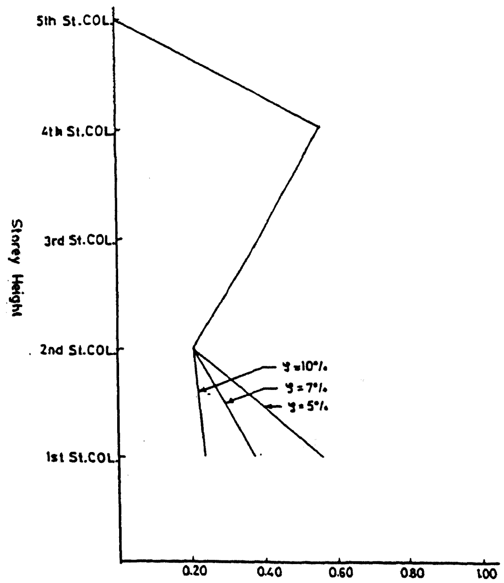

Figure 8. Zone IV column strengthening reinforcement/design reinforcement for five storey uniform building.

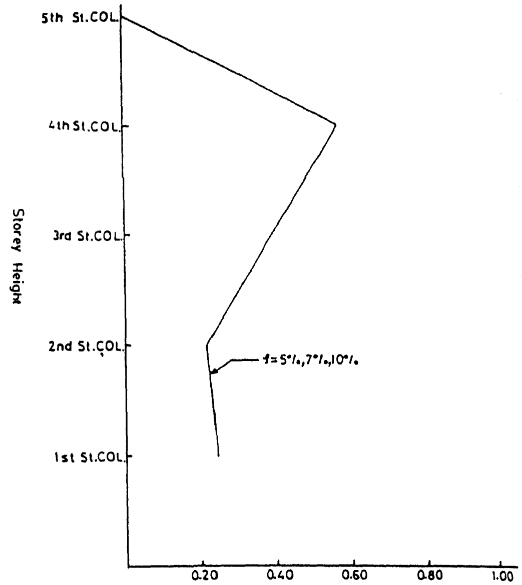

Figure 9. Zone III column strengthening reinforcement/design reinforcement for five storey uniform building.

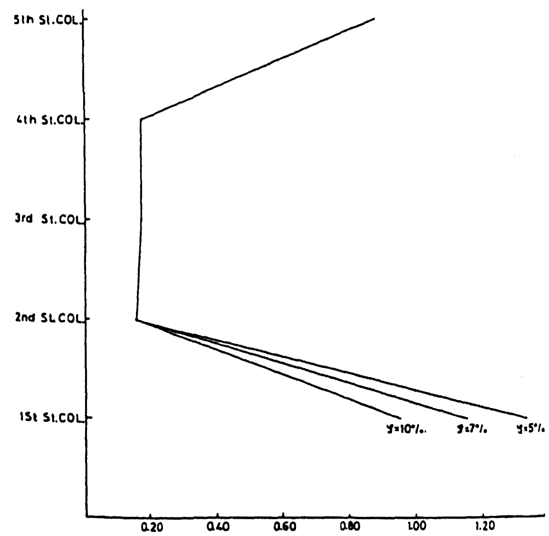

Figure 10. Zone V column strengthening reinforcement/design reinforcement for five storey tapered building.

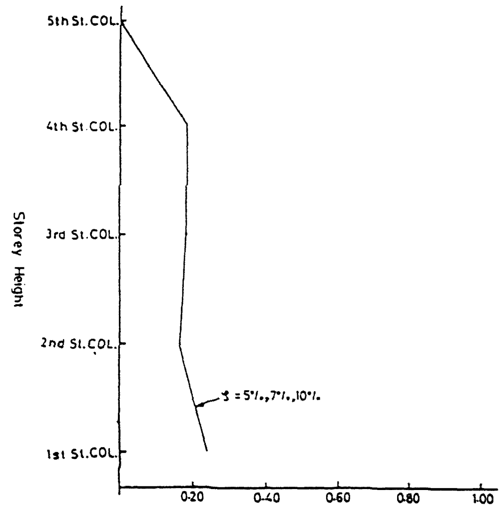

Figure 11. Zone IV column strengthening reinforcement/design reinforcement for five storey tapered building.

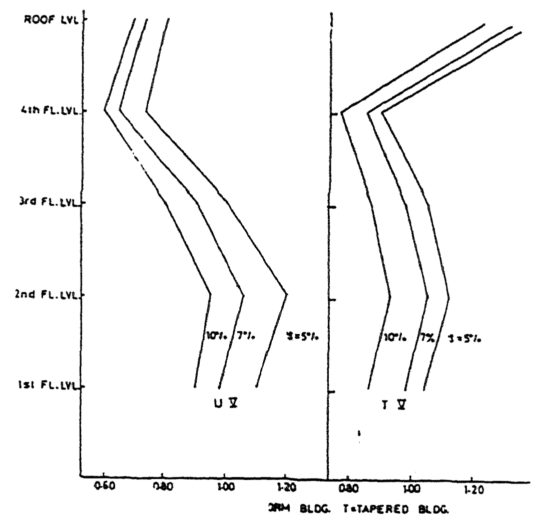

Figure 14. Zone V beam strengthening reinforcement/design reinforcement for five storey buildings.

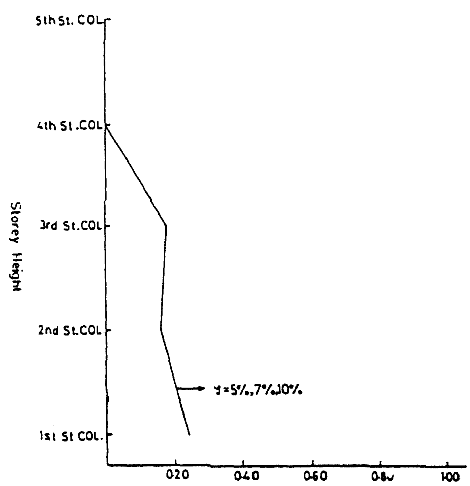

Figure 12. Zone III column strengthening reinforcement/design reinforcement for five storey tapered building.

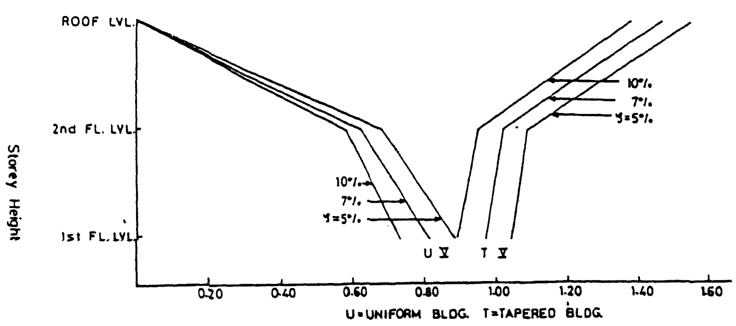

Figure 13. Zone V beam strengthening reinforcement/design reinforcement for three storey buildings.

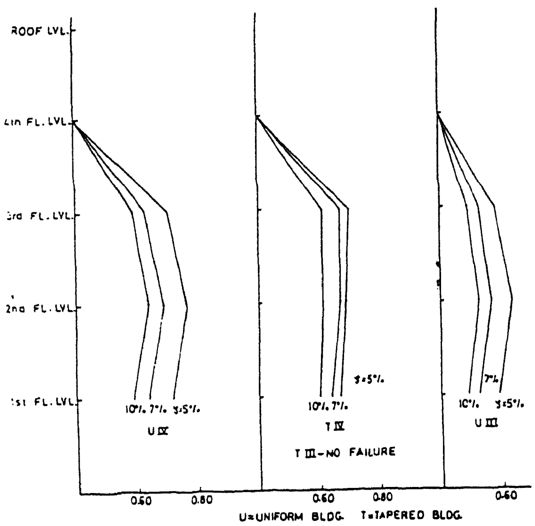

Figure 15. Zone IV & III beam strengthening reinforcement/design reinforcement for three storey buildings.

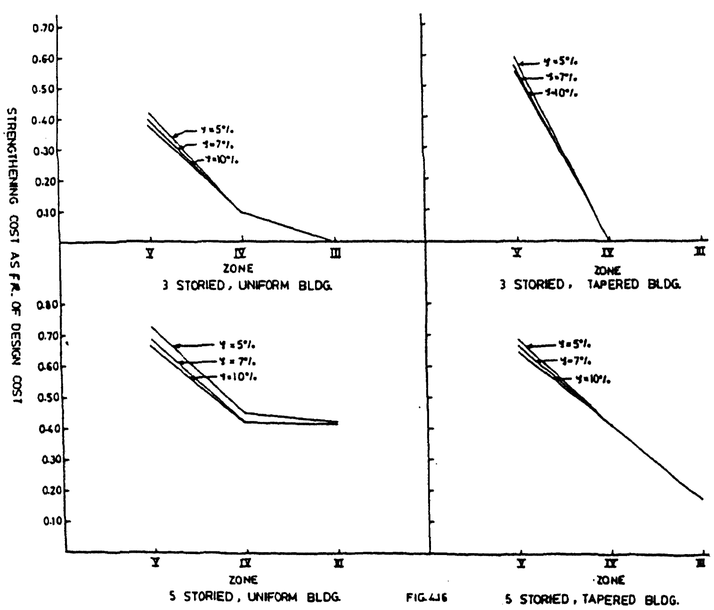

Figure 16. Strengthening cost/design cost for various buildings.