Comparing Costs: Multi-Level vs. Conventional RC Structures in Indian Earthquake Zones

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Abstract- *This study endeavours to analyse the cost discrepancies associated with incorporating earthquake-resistant features into the structural framework of buildings. Various commercial and office structures, differing in parameters such as height and seismic zone location, were scrutinized. Design considerations encompassed scenarios ranging from gravity loads alone to seismic force integration. A comparative evaluation was conducted between the expenses incurred for implementing ductile detailing in compliance with IS: 13920-1993 and those adhering to IS: 456-2000 standards. Additionally, a cohort of five pre-existing school buildings was included for comparative analysis against hypothetical structures of equivalent height. The findings elucidate the cost differentials incurred in retrofitting seismic provisions as per Indian building codes, while excluding considerations for wind loads. An importance factor of 1.5 was applied for office building design and cost estimation.*

I. INTRODUCTION

Earthquakes are one of the worst type of natural disasters. Millions of lives are lost and other unbearable economic losses take place due to them each year around the world. In a seismic activity most of the losses and casualties take place due to the failures in civil engineering structures, a majority of them are building structures. In the past building structures have been designed without any consideration of the seismic effects. As the knowledge about the earthquake, their behavior and their effects on structures grew with time; seismic resistant design procedures have been started being followed in the analysis and design of structures.

Even though it is understood by people that seismic resistant features, if provided in the structures, shall provide added safety against seismic fury; they are often reluctant to provide those features in their buildings. It may be due to their ignorance of the actual quantum of increase in the cost of buildings due to the provisions of earthquake resistant design features.

In this paper; an effort has been made to consider a set of building structures to estimate the probable rise, if any, in the cost due to the introduction of earthquake resistant structures. The approach has been to apply the codal guidelines in the design of buildings for imparting earthquake safety. Amounts of concrete and steel reinforcement, calculated in these cases, have been compared with those found out when the buildings are designed for gravity loads only. The findings may provide some information about possible increase in the cost due to the provision of earthquake resistance. Wind load has not been considered in this paper.

II. LITERATURE REVIEW

During a seismic event intense lateral forces are applied on to the building structures. Due to these lateral forces all the elements in a RC building structure are subjected to increased amounts of forces. In a building structure which has been designed for gravity loads only, such increase of forces in building elements may not be sustainable. Consequently, various types of damages occur in such buildings.

To reduce damages in the buildings it is important to provide added capacity in the building elements to take on the possible increase of forces due to seismic effects. Various types of earthquake resistant measures have been devised and reported in research literature and standard codes.

From the seismic resistant design and cost estimation of the representative office buildings in the range of two to ten storeys under various levels of seismic forces in different seismic zones of Indian subcontinent, the following inferences are made:

(i) The requirement of structural concrete and shuttering materials per sq.m of floor area varies from 0.26 cu.m to 0.31 cu.m and 1.66 sq.m to 1.77 sq.m for 2 to 10 storeys respectively. These requirements need not be very sensitive to the seismic zones because structural member sizes are usually kept same except column sizes which could be reduced in the upper storeys of the buildings.

(ii) The effects of increasing levels of seismic forces are taken care in the design by increasing the steel requirements in column and beams. The steel requirements per square meter of floor area vary from 28 kg to 55 kg depending upon the number of storeys and seismic zones as shown in fig.5. For an eight storeyed building located in seismic zone V, a percentage increase of 69% in steel reinforcement is observed compared to non-seismic design.

(iii) The cost premium for incorporating earthquake resistance as a percentage of the structural cost of the building varies from 2 to 30 % depending upon the number of storied and seismic zones as shown in fig.6. For a ten storied building this premium works out to 5%, 10%, 20% and 30% for seismic zones II, III, IV and V respectively. For buildings with normal specification this cost premium in relation to the total cost of the superstructure would be in the range of 3 to 15 % from low to high seismic zones.

To estimate such additional cost it is required that the building blocks are analyzed designed and detailed for the following conditions:-

- o For vertical loads only,
- o For vertical loads and lateral loads without ductile detailing and,
- o For vertical loads and lateral loads with ductile detailing.

III. ASSUMPTION OF THE ANALYSIS

For a complete analysis of the structure, the necessary matrices are generated on the basis of the following assumptions:

1. The structure is idealized into an assembly of beam, plate and solid type elements joined together at their vertices (nodes). The assemblage is loaded and reacted by concentrated loads acting at the nodes. These loads may be both forces and moments which may act in any specified direction.
2. A beam member is a longitudinal structural member having a constant, doubly symmetric or near-doubly symmetric cross section along its length. Beam members always carry axial forces. They may also be subjected to shear and bending in two arbitrary perpendicular planes, and they may also be subjected to torsion.
3. Internal and external loads acting on each node are in equilibrium. If torsional or bending properties are defined for any member, six degrees of freedom are considered at each node (i.e. three translational and three rotational) in the generation of relevant matrices. If the member is defined as truss member (i.e. carrying only axial forces) then only the three degrees (translational) of freedom are considered at each node.
4. Two types of coordinate systems are used in the generation of the required matrices and are referred to as local and global systems.

SEISMIC LOAD INPUT IN STAAD

The seismic load analysis of the structures can be done using STAAD by employing the response spectrum method of dynamic analysis. The following steps are involved in this process.

- User provides the value for Z*I/2R as factors for input spectrum.
- Program calculates time periods for first twelve modes.
- Program calculates Sa/g for each mode utilizing time period and damping for each mode.
- The program then calculates mode participation factor for different modes.
- The peak lateral seismic force at each floor in each mode is calculated.
- All response quantities for each mode are calculated.
- The peak response quantities are then combined as per method(CQC or SRSS or ABS or TEN or CSM) as defined by the user to get the final results.

NUMERICAL STUDY

In this study an attempt has been made to examine the variation in the cost of a selected component of structural frame of the building structures. Various commercial / office buildings with different parameters such as number of stories, place of construction in terms of seismic zone have been considered in the study. These buildings were designed for different loading conditions - for gravity loads only & for the condition when seismic forces also are considered. The cost difference in view of the provision of ductile detailing as per IS: 13920-1993 also has been examined in addition to the application of IS: 456-2000. A set of five school buildings, already constructed, has also been considered. The results as for the variation of cost of these school buildings have been compared with the idealized buildings having the same number of stories in the study. The comparison gives some idea about the relative effect of provision of seismic resistant measures in buildings for different functions.

The building has been analyzed for the following load combinations.

- 1.5*(Dead Load + Imposed Load).

- 1.2*(Dead Load + Imposed Load ± Earthquake Load).
- 1.5*(Dead Load ± Earthquake Load).
- 0.9*Dead Load ± 1.5*Earthquake Load.

In the analysis response spectrum method has been used for seismic analysis of structures. In the response spectrum all buildings has been analysed for each zones. Importance factor has been taken 1.5 for building and soil type chosen is medium soil. For seismic analysis IS 1893:2002 has been used in addition to that help of IS 13920- 1993 has also been taken for ductile detailing. For the calculation of dead load &live load IS 875-1987has been used

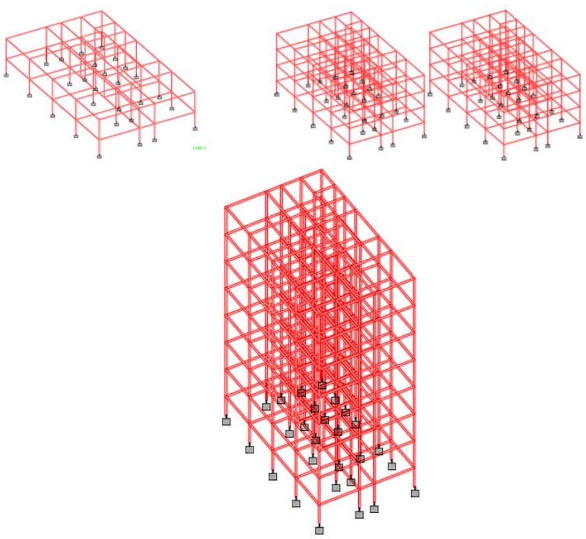

Figure 1: Different stories building frame for comparative analysis

IV. RESULTS &DISCUSSION

it is clear that as the seismic zone increases the value of % increase in cost increases, also shows that as value of seismic zone changes from zone II to zone IV, % increase in cost is gradual from zone II to zone IV while it becomes steep from zone IV to zone V. For one story building the value of percentage increase in cost from zone II to zone V is varies between 7 to 17%. The three story building also shows similar trend as that of one story and variation in percentage increase in cost from zone II to zone V is approximately in between 6 to 30%.Four story is similar one as one and three story and variation in percentage increase in cost from zone II to zone V is in the range of 5 to 20%.Percentage increase in cost for five story building is less in comparison to the building mentioned above and it ranges between 4 to 11% from zone II to zone V respectively.

From three story it can be said that as the number of zone increases the percentage increase in cost increases gradually. Similarly for seven story building percentage increase in cost ranges between 3 to 10% as zone changes from II to V respectively. For nine story the value of percentage increase in cost is further reduced and it ranges between 2 to 7%.Similarly for eleven story and thirteen story the value of percentage increase in cost 1 to 5% and 1 to 4% respectively. Finally it can be said that as the no of story increases the percentage increase in cost is reduced gradually.

The value of maximum % increase in cost for zone II comes for one storey building, and it is approximately 8%. Similarly the value of maximum % increase in cost for zone III falls under three storey building, and it is around 8.4%. It is clear that value of maximum % increase in cost for zone IV comes for three storey building and it comes approximately 15%. Similarly for zone V it also comes for three storey building and it is approximately 30%.

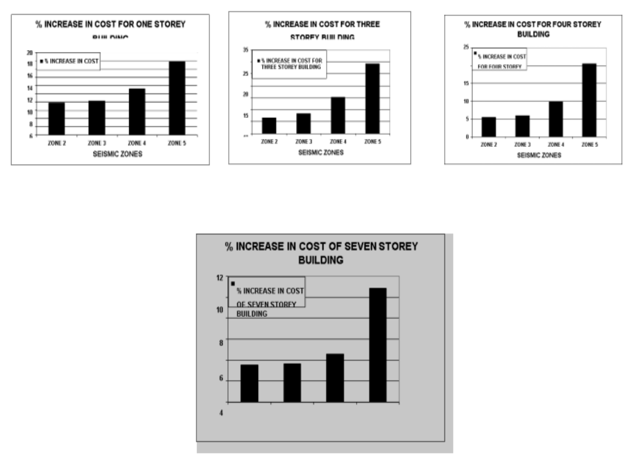

Figure 2 : Showing cost calculation of different stories heights

V. CONCLUSION

1. Percentage increase in cost for one storey building with ductile detailing in zone II, III, IV and zone V are 7.8%, 8.25%, 11.23%, 17.8% respectively.
2. Percentage increase in cost for three storey building with ductile detailing in zone II, III, IV and zone V are 6.57%, 8.37%, 15.16%, 24.26% respectively.
3. Percentage increase in cost for four storey building with ductile detailing in zone II, III, IV and zone V are 5.54%, 5.98%, 9.87%, 20.57% respectively.

4. Percentage increase in cost for five storey building with ductile detailing in zone II, III, IV and zone V are 4.1%, 6.13%, 7.11%, 11.13% respectively.
5. Percentage increase in cost for seven storey building with ductile detailing in zone II, III, IV and zone V are 3.55%, 3.67%, 4.57%, 10.86% respectively.

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