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Seismic Evaluation of RC Buildings Designed with Past Codes

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Abstract: Recent earthquakes have caused past reinforced concrete buildings severe damage compared to newer buildings because they have many structural deficiencies. To prevent future losses during earthquakes, the seismic capacity of these older buildings needs to be assessed with recent codes so that appropriate measures may be implemented to mitigate their vulnerability.

This report compares the seismic evaluation method of two different codes on an existing building. The guidelines of two such documents by Bureau of Indian Standards (BIS) and New Zealand Society for Earthquake Engineering (NZSEE) are presented in this report. These guidelines intend to provide a systematic procedure for the seismic evaluation of buildings which may be applied reliably to a wide range of buildings.

The objective of this article is to go through the documents of the Indian Standards and the New ZealandStandards on the seismic evaluation of existing buildings and compare the results of the two. Indian code IS 15988 including IS 1893:2016 Part1 provides some analytical solution for the seismic evaluation. However, these solutions may be or may not be sufficient for all types of failure, which may be overcome by using New Zealand Draft Code (NZDC). Upon comparing the results obtained from the analysis done using the two codes, one can understand the behaviour of a structure from all perspective. In the present study, analytical and manual work has been carried out and shown in a well-explained manner and easy to understand

METHODLOGY

1. ***Visual Survey***
2. ***Test Plan***
3. ***Sample and Data Collection***
4. ***Structure Stability Analysis***

I. INTRODUCTION

Recent earthquakes in India and the World have caused insurmountable losses, especially human lives. They have highlighted the structural inadequacy of existing buildings to carry earthquake loads. At a particular site, all structures (either proposed or existing) are exposed to the same seismic hazard level, but the response of every building is different from the other. The number of existing buildings not designed based on the current seismic codes are enormous compared to the number of newer buildings designed based on current seismic codes. The seismic evaluation of these existing buildings is of utmost importance. Because of this, various organizations of countries located in the seismic risk zone have come up with documents, which provide guidelines for the assessment of the strength, expected performance, safety of existing buildings and rehabilitation, if required.

Two such documents of the Indian Standards and the New Zealand Standards are used here for the seismic evaluation of existing buildings. These guidelines act as a standard protocol for instructing design professionals on how to determine the adequacy of existing buildings, subjected to seismic forces. The seismic evaluation process, according to Indian Standards, IS 15988 guidelines is composed of two levels of evaluation. The first level is the preliminary evaluation, and the second level is a detailed evaluation. The transition from preliminary seismic evaluation to detailed seismic evaluation includes anincrease of detailing of structures and decreasing conservatism. Once the building complies with preliminary seismic evaluation (i.e. shear and axial strengths), its detailed seismic evaluation is not required and therefore can be considered suitable for current seismic demand. The building which fails in shear and axial strength requirements are considered for detail seismic evaluation. The seismic assessment, according to New Zealand Standards as suggested by the New Zealand Society for Earthquake Engineering (NZSEE) comprises of two methods. The first is the force-based method, and the second is the displacement-based method, wherein the seismic demand is determined from response spectra. In the force-based method, the building performs satisfactorily during a seismic event corresponding to the given response spectra if its ductile capacity is higher than the ductile demand. According to the displacement-based method, a building performs satisfactorily during a seismic event corresponding to response spectra, if the lateral displacement capacity is higher than the lateral displacement demand

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II. CONFIGURATION RELATED CHECK

1) *Load Path:* There shall be at least one complete load path to transfer all the inertial forces in the building to the foundations.
2) *Redundancy:* The no. of lines of vertical, lateral load resisting components in each principal direction shall be greater than or equal to 2. In the case of the moment/braced frames, the number of bays in each line shall be greater than or equal to 2.
3) *Geometry:* There shall be no change in the horizontal dimension of the lateral force resisting system of more than 1.5 times of one storey relative to adjacent stories.
4) *Soft Storey:* The stiffness in any storey of the vertical lateral load resisting system shall not be less than 70% of the average stiffness of the three storeys above or less than 60% of the stiffness in another storey.
5) *Weak Storey:* The strength in any storey of the vertical lateral load resisting system shall not be less than 70% of the strength in another storey.
6) *Vertical Discontinuities:* All elements in the vertical lateral load resisting system shall be continuous from the mass to the foundation.
7) *Mass:* The change in the effective mass of one storey shall not be more than 100% of the mass of the other storey.
8) *Torsion:* The distance between the storey center of mass and center of stiffness shall not be more than 30% of the building dimension, which is at right angle to the direction of loading considered.
9) *Adjacent Buildings:* The horizontal distance between the building considered and any other adjacent building shall be greater than 4% of the shorter building height, except for the buildings that are of same height with floors located at the same levels.
10) *Short Columns:* The reduced height of the columns of lateral load resisting system, due to infill wall, surrounding parapet, etc. shall not be less than 50% of the nominal height of the typical columns in that storey

III. FORCE BASED PROCEDURE

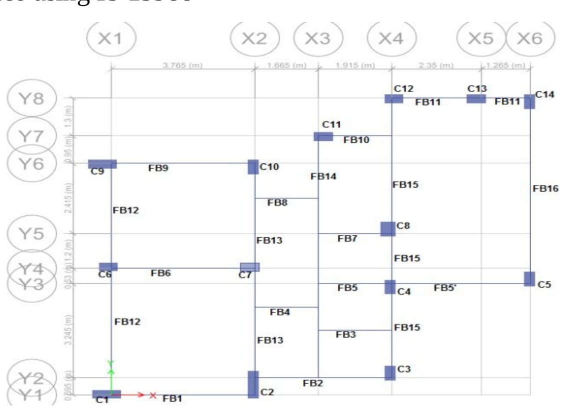
Determine the inelastic sub-system mechanisms within the building that are likely to occur during seismic loading and from these calculate the probable horizontal seismic base shear capacity of the structure, Vprob, (Δprob)top, and (Δy)top, using the SLaMA technique. Estimate the global structural ductility factor, µsys as the ratio (Dprob)top/(Dy)top.

A. Analysis Over 2D Frame Of RC Moment Resisting Frame Building

An existing five-storey RC moment resisting frame building, symmetric in plan and regular in elevation is located in the seismic zone V and on hard soil. At all elevations, storey height is about 4 m. In plan, the building measures 68 m each way at all floor levels. Slab thickness is 75 mm. The floor slabs are rigid in plane, and as the exterior frames are much stiffer laterally than the interior frames, most of the lateral forces will be resisted by the exterior frames. The beam sizes in the building are of 0.8m x 1.5m, and column sizes are of 0.8m x 0.8m. The material properties are M20 for concrete Fe 415 for steel. We assess the building for seismic resistance by doing analysis over a 2D frame of the building using both the codes, IS 15988 and NZDC

B. Seismic Evolution of Existing RC Frame Building (ACC. TO IS 15988)

An existing five-storey reinforced concrete moment bare frame building, asymmetric in plan but regular in elevation is located in the seismic zone III (Kochi) and on medium soil. Storey heights are about 3.2m at all elevations except plinth level which is at 0.45m elevation. Slab thickness is 150mm. The floor slabs are rigid in plane. The beams in the building are of 0.3m x 0.45m, and columns in the building are of different sizes. The material properties are M30 for concrete and Fe 500 for main steel and Fe 415 forsecondary steel. We evaluate the building for seismic resistance using IS 15988



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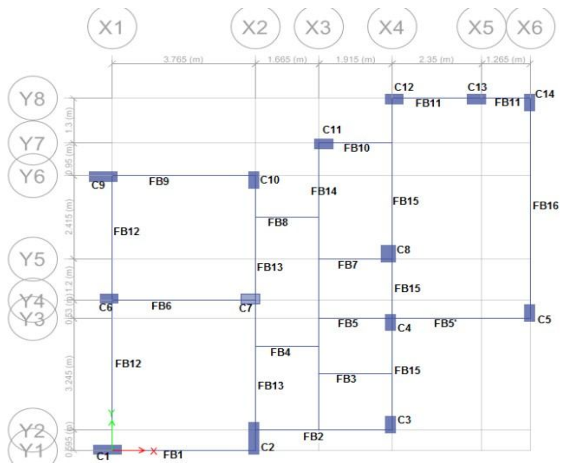
C. Seismic Evalution of Existing RC Frame Building (ACC. TO NZDC)

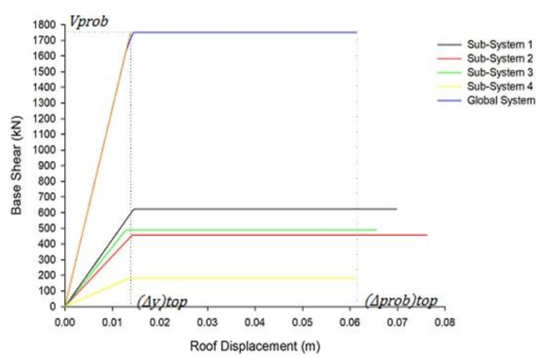
An existing five-storey reinforced concrete moment bare frame building, asymmetric in plan but regular in elevation is located in the seismic zone III (Kochi) and on medium soil. Storey heights are about 3.2m at all elevations except plinth level which is at 0.45m elevation. Slab thickness is 150mm. The floor slabs are rigid in plane. The beams in the building are of 0.3m x 0.45m, and columns in the building are of different sizes. The material properties are M30 for concrete and Fe 500 for main steel and Fe 415 for secondary steel. We evaluate the building for seismic resistance using NZDC



IV. DISPLACEMENT BASED PROCEDURE

A. Step D1

It is same as Step F1 for the force-based procedure as explained above.The capacity of the global system taken from Figure 7.6 as:
$V_{prob} = 1749.46$ kNm



B. Step D2

For a frame structure, the deflection profile of the lumped mass model at level i, as shown in Figure 4.1,is calculated using eqn. (4.3):
Here, n = 6h_1 = 0.45 m, h_2 = 3.65 m, h_3 = 6.85 m, h_4 = 10.05 m, h_5 = 13.25 m, h_6 = 16.45 m;
$\therefore\ \delta_1 = 0.0362, \delta_2 = 0.2794, \delta_3 = 0.4974, \delta_4 = 0.6902, \delta_5 = 0.8577, \delta_6 = 1$

C. Step D3

As per NZS 1170.5, the inter storey drift is calculated by multiplying a scale factor equal to the structural ductility factor, μ_{sys}, to the elastic deflection envelope and the allowable ultimate limit state inter storey drift shall be limited to 2.5% of the corresponding storey height

D. Step D4

The %NBS earthquake rating for the building is the lowest score among all.
∴ %NBS = 24.38%

V. RESULTS ANS CONCLUSIONS

The Codes used in this study are the Indian Code (IS 15988: 2016) and the New Zealand Draft Code (NZDC).

New Zealand Code has described a detailed procedure for ductility evaluation while theIndian Code only recommends ductile detailing

Both codes follow similar assessment steps which can be broadly grouped into two categories: (a) Primary/Initial Assessment and (b) Detailed assessment. The first tier involves a quick assessment of the earthquake resistance of the building and its potential deficiencies, with the objective to screen out the significantly vulnerable structures for the second tier detailed evaluation. The next level of evaluation consists of proper force and displacement analysis to assess structural performance at both the global and local level. Both codes suggest some reduction in the force level for analysis of existing building compared to new buildings.

Building I that has been analyzed using IS 15988 and NZDC is unacceptable according to both the codes as all the members of lateral force resisting system have lesser strengths than computed member actions Drift checks are also not satisfied. %NBS for this building is 21.85% which is less than 33%, shows that it is a high risk building and does not satisfy the ductility demand. Therefore, retrofitting is recommended to this building by both the codes. Building II, when analyzed using IS 15988, is satisfying both preliminary and detailed evaluation criteria. Hence this building is acceptable according to IS 15988 as all the elements of the lateral force resisting system have greater strengths than computed actions and drift checks are also satisfied. But when analyzed using displacement based method of New Zealand Draft Code, this building is found to be highly risky for occupation and unacceptable as ductility demand is not satisfied. Thus, this building requires retrofitting, according to NZDC.

On comparing the results of the two codes, it can be concluded that the building which is found to be safe according to the Indian Code, is unacceptable and requires improvement according to New Zealand Code. Thus, the Indian code is not comprehensive for the seismic assessment of the existing buildings asit doesn't provide any criteria for ductility evaluation of the building and provides few ductile detailing requirements. However, ductility evaluation criteria are properly explained in the New Zealand code using force based and displacement based assessment.

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BIOGRAPY

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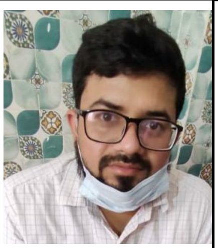

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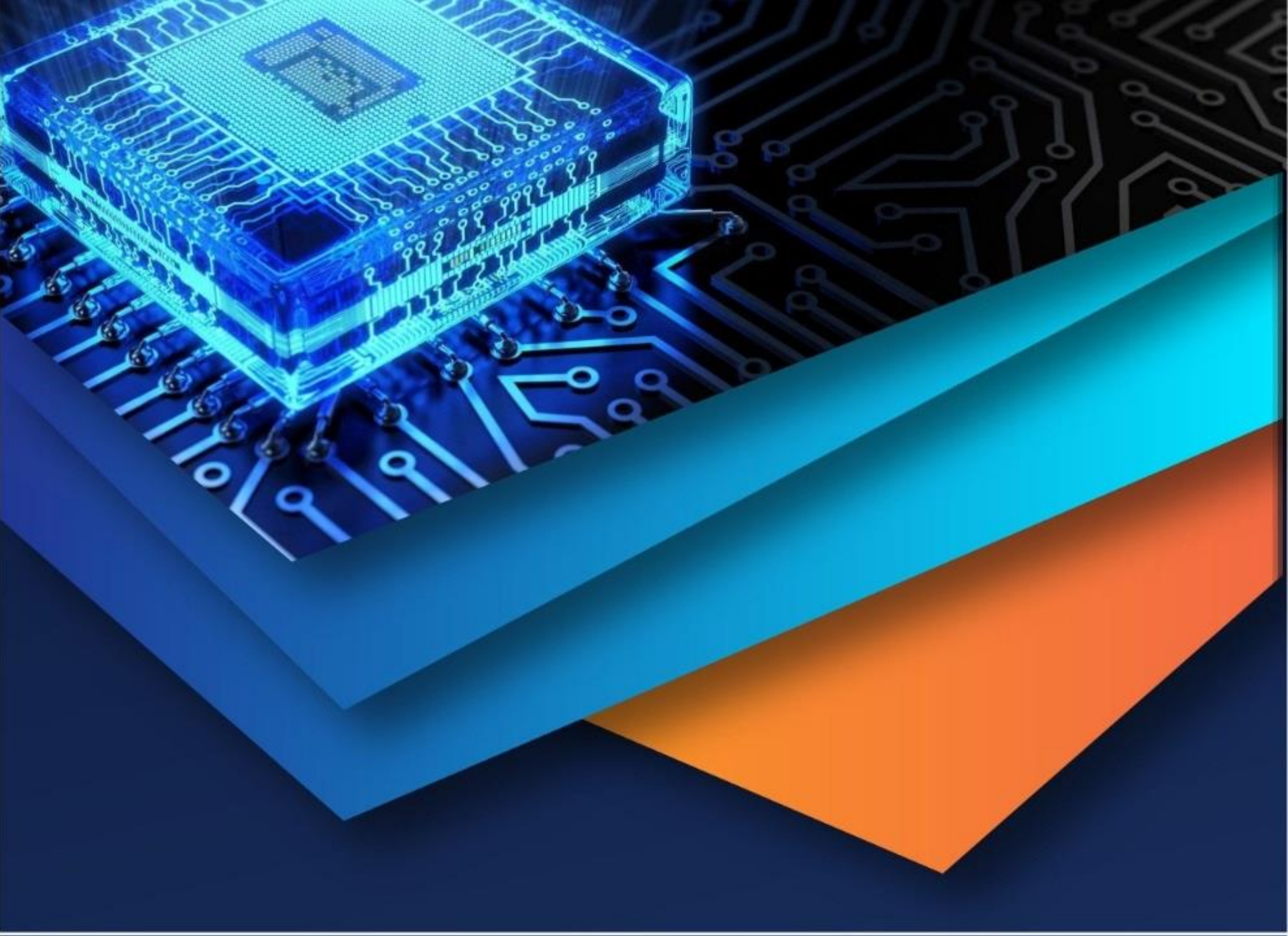

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