Analysis of Multistoried Building with Masonry infills under Earthquake Loading

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Abstract: Earthquakes in different parts of the world demonstrated the disastrous consequences and vulnerability of inadequate structures. Many reinforced concrete (RC) framed structures located in zones of high seismicity in India are constructed without considering the seismic codal provisions. The vulnerability of inadequately designed structures represents seismic risk to occupants. The seismic inertia forces generated at its floor levels are transferred through the various beams and columns to the ground. The failure of a column can affect the stability of the whole building, but the failure of a beam causes localized effect. Therefore, it is better to make beams to be the ductile weak links than columns. This method of designing RC buildings is called the strong-column weak-beam design method. The Reinforced concrete buildings are constructed with masonry infills. Masonry infills are often used to fill the void between the horizontal and vertical resisting elements of the building frames. The aim of this project work is to present a detailed worked out of Analysis of Multistoried Building with Masonry Infills under Earthquake Loading.

Keywords: Earthquake resistant structure, Masonry infills, seismicity, framed structures

I. INTRODUCTION

Structural design of buildings for seismic loads is primarily concerned with structural safety during major ground motions, but serviceability and the potential for economic loss are also of concern. Seismic loading requires an understanding of the structural performance under large inelastic deformations. Conventional Civil Engineering structures are designed on the basis of strength and stiffness criteria. The strength is related to ultimate limit state, which assures that the forces developed in the structure remain in elastic range. The stiffness is related to serviceability limit state which assures that the structural displacements remains within the permissible limits. In case of earthquake forces the demand is for ductility. The seismic inertia forces generated at its floor levels are transferred through the various beams and columns to the ground. The correct building components need to be made ductile. The failure of a column can affect the stability of the whole building, but the failure of a beam causes localized effect. Therefore, it is better to make beams to be the ductile weak links than columns. This method of designing RC buildings is called the strong-column weak-beam design method. The response of a structure to earthquake-induced forces is a dynamic phenomenon. Consequently, a realistic assessment of the design forces can be obtained only through a dynamic analysis of the building models. Although this has long been recognized, dynamic analysis is used only infrequently in routine design, because such an analysis is both complicated and time-consuming. A major complication arises from the fact that most structures are designed with the expectation that they would be strained into the inelastic range when subjected to the design earthquake. Although the ability to carry out a nonlinear analysis has seen significant improvement over recent years, considerable uncertainty persists in modeling the nonlinear behavior of structural materials and components. In addition, nonlinear response to two different ground motions may differ significantly, even when such ground motions produce similar elastic responses.

II. METHODOLOGY OF THIS STUDY

2.1 METHODS OF SEISMIC DESIGN

Based on the three criteria strength, stiffness and ductility the methods for seismic design are described below:

2.1.1 LATERAL STRENGTH BASED DESIGN:

This is most common seismic design approach adopted nowadays. It is based on providing the structure with the minimum lateral strength to resist seismic loads, assuming that the structure will behave adequately in the non-linear range. For this reason only some simple construction detail rules are needed to be satisfied.

2.1.2 DISPLACEMENT BASED DESIGN:

In this method the structure is designed to possess adequate ductility so that it can dissipate energy by yielding and survive the shock. This method operates directly with deformation quantities hence gives better insight on the expected performance of the structures. The displacement based design approach has been adopted by the seismic codes of many countries.

2.1.3CAPACITY BASED DESIGN:

In this design approach the structures are designed in such a way so that plastic hinges can form only in predetermined positions and in predetermined sequences. The concept of this method is to avoid brittle mode of failure. This is achieved by designing the brittle modes of failure to have higher strength than ductile modes.

2.1.4 ENERGY BASED DESIGN:

This is the most promising and futuristic approach of earthquake resistant design. In this approach it is assume that the total energy input is collectively resisted by kinetic energy, the elastic strain energy and energy dissipated through plastic deformations and damping.

2.2 SEISMIC ANALYSIS PROCEDURE

Main features of seismic method of analysis based on Indian Standard 1893 :(part 1): 2002 are described as follows

2.2.1EQUIVALENT LATERAL FORCE METHOD:

The Equivalent lateral force method is the simplest method of analysis and requires less computational effort because the forces depend on the code based fundamental period of structures with some empirical modifier. The design base shear shall first be computed as a whole, and then be distributed along the height of buildings based on simple formulae appropriate for buildings with regular distribution of mass and stiffness. The design lateral force obtained at each floor level shall be distributed to individual lateral load resisting elements depending upon floor diaphragm action. The design lateral force or design base shear and the distribution are given by some empirical formulae given in the I.S 1893.

2.2.1.1 DETERMINATION OF BASE SHEAR

The total design lateral force or design base shear along any principal direction shall be determined by the following expression.

$$V_b = A_h W$$

Where,

A_h = Design horizontal seismic coefficient for a structure

W = Seismic Weight of building

$A_h = (Z/2)(I/R)(S_a/g)$

Z = Zone Factor (Table 2 of IS 1893 2002)

I = Importance Factor (Table 6 of IS 1893 2002)

R = Response Reduction Factor (Table 7 of IS 1893 2002)

The fundamental natural period for buildings

$T_a = 0.075h^{0.75}$ moment resisting RC frame building without brick infill walls.

2.2.1.2 LATERAL DISTRIBUTION OF BASE SHEAR:

The computed base shear is distributed along the height of the building. The Shear force, at any level, depends on the mass at that level and deforms shape of the structure. Earthquake forces deflect a structure into number of shapes, known as the natural mode shapes.

2.2.2 RESPONSE SPECTRUM ANALYSIS:

This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. In this method the response of Multi degree of freedom system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of Single–degree of freedom system, which is then combined to compute the total response.

2.2.3 ELASTIC TIME HISTORY ANALYSIS:

A linear analysis, time history analysis over comes all disadvantages of modal response spectrum provided non linear behavior is not involved. The method requires greater computational efforts for calculating the response at discrete times. One interesting advantage of this is that the relative signs of response quantities are preserved in the response histories.

III. DESIGN CONSIDERATIONS

3.1 GENERAL

In structural design, account shall be taken of the dead, imposed and wind loads and forces such as those caused by earthquake, and effects due to shrinkage, creep, temperature, etc.

3.1.1 DEAD LOAD

Dead load shall be calculated on the basis of unit weights which shall be established taking into consideration the materials specified for construction.

3.1.2 IMPOSED LOADS, WIND LOADS AND SNOW LOADS

Imposed loads, wind loads and snow loads shall be assumed in accordance with IS 875 (Part2), IS 875 (part3), and IS 875 (part4) respectively.

3.1.3 LOAD COMBINATIONS USED FOR DESIGN

1 1.5 (DL + IL)
2 1.2 (DL + IL + EXTP)
3 1.2 (DL + IL + EXTN)
4 1.2 (DL + IL – EXTP)
5 1.2 (DL + IL – EXTN)
6 1.2 (DL + IL + EZTP)
7 1.2 (DL + IL + EZTN)
8 1.2 (DL + IL – EZTP)
9 1.2 (DL + IL – EZTN)
10 1.5 (DL + EXTP)
11 1.5 (DL + EXTN)
12 1.5 (DL – EXTP)
13 1.5 (DL – EXTN)
14 1.5 (DL + EZTP)
15 1.5 (DL + EZTN)
16 1.5 (DL – EZTP)
17 1.5 (DL – EZTN)

3.1.4 DESIGN LOADS

Design load is the load to be taken for use in the appropriate method of design; it is the characteristic load in case of working stress method and characteristic load with appropriate partial safety factors for limit state design.

3.1.5 EARTHQUAKE FORCES

The earthquake forces shall be calculated in accordance with IS 1893.

3.1.5.1Seismic Weight (W)

It is the total dead load plus appropriate amounts of specified imposed load.

3.2 ANALYSIS OF INFILLED FRAMES

The distribution of lateral forces in the frames of building basically depends upon the center of rigidity of the building and the resultant of the applied lateral loads. If both nearly coincide, distribution of lateral load remains straightforward i.e. in the ratio of their relative stiffness. If it is not the case, large torsional forces are introduced in the building. These type of structures can be better analysed on the 3D analysis of building after considering the increased stiffness of the infilled frames.

3.2.1. EQUIVALENT DIAGONAL STRUT

The geometric and material properties of the equivalent diagonal strut are required for conventional braced frame analysis to determine the increased stiffness of the infilled frame.

IV. RESULTS AND DISCUSSIONS

4.1 PROPOSED BUILDING DETAILS

The name of the proposed project is "Multistoried Residential Building". The proposed project is located in srinagar. Area of the building is 175 sq m. The zone is to be considered V.

4.2 PLAN

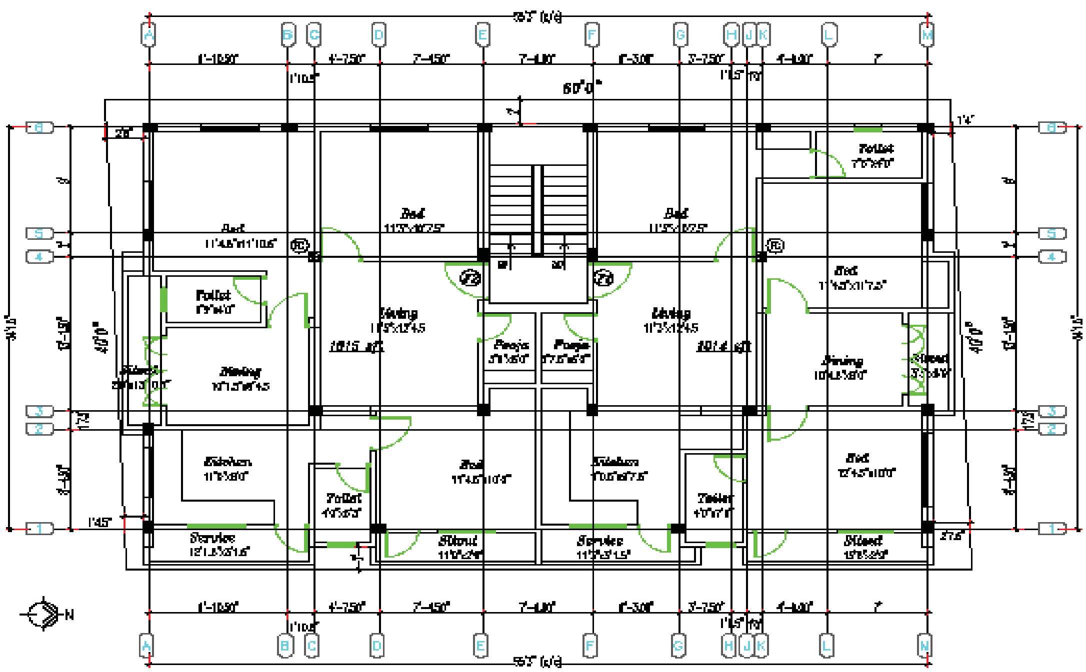

Fig 4.2 Layout Diagram

4.3 COMPUTER AIDED ANALYSIS AND DESIGN

4.3.1GENERAL

Staad is the abbreviation for structural analysis and design. Staad is the first software developed in the world for the purpose of structural analysis for structural engineers.

4.3.2 FREE VIBRATION ANALYSIS

Un damped free vibration analysis of the entire building shall be performed as per established methods of mechanics using the appropriate masses and elastic stiffness of the structural system, to obtain natural periods (T) and mode shapes {$} of those of its modes of vibration that need to be considered.

4.3.3 COMMANDS USED IN STAAD Pro

- JOINT COORDINATES
- MEMBER INCIDENCES
- MEMBER PROPERTY
- MEMBER LOAD
- LOAD COMBINATION

- FREE VIBRATION ANALYSIS
- PRINT ANALYSIS RESULTS
- PERFORM ANALYSIS
- MODAL CALCULATION REQUESTED

4.4 VIEW DIAGRAMS AND MODE SHAPES

ISOMETRIC VIEW

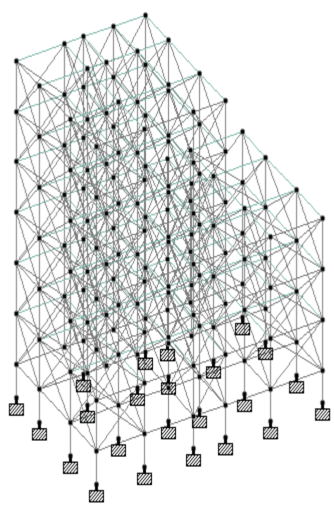

Fig 4.4 (a) Isometric View Diagram

3D RENDERING

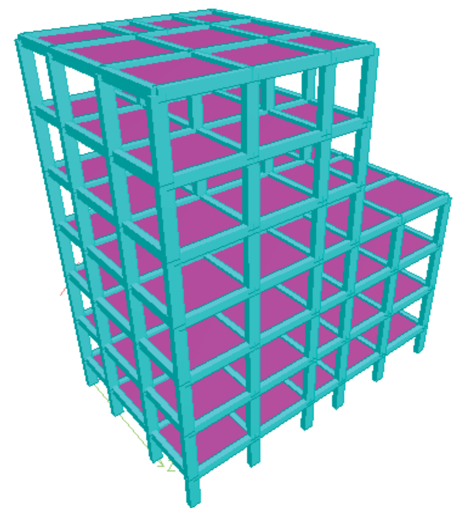

Fig 4.4 (b) 3D Rendering view

MODE SHAPE-1

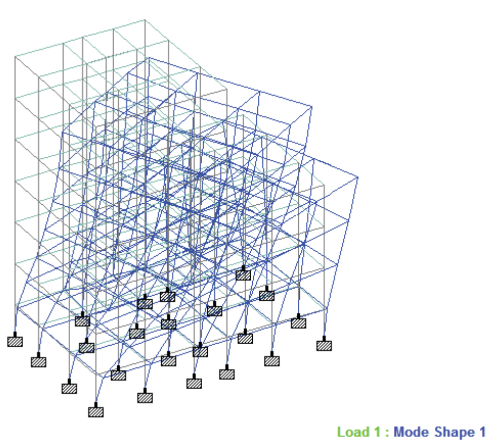

Fig 4.4 (c) Mode shape 1

MODE SHAPE -2

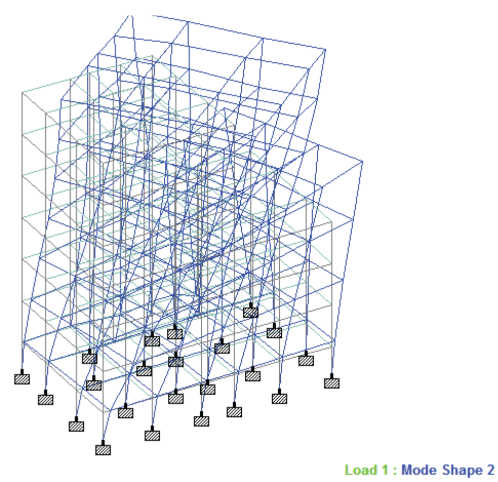

Fig 4.4 (d) Mode shape 2

MODE SHAPE – 3

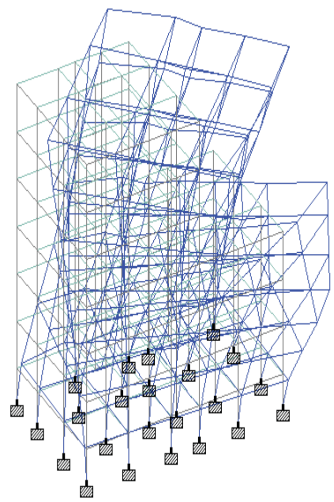

Fig 4.4

(e) Mode shape 3

ELX AND ELZ

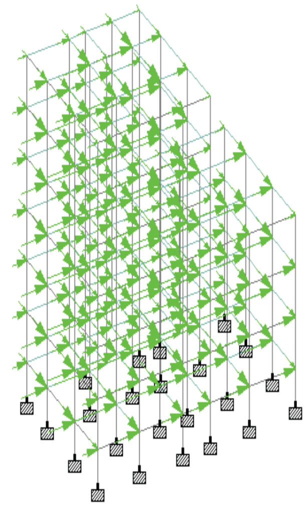

Fig 4.4 (f) ELX and ELZ diagram

4.5 DESIGN DETAILS OF MEMBERS:

4.5.1 DESIGN OF SLABS

- Span of slab: 4.1m
- Thickness of slab: 190mm
- Reinforcement details:
  - 10mm dia bars @147mm c/c

4.5.2 DESIGN OF BEAMS

- Doubly reinforced beam
- Span: 3050mm
- Beam size: 300mm × 450mm
- Reinforcement details:
  - Provide 6 nos of 25mm dia bars @ top
  - Provide 4 nos of 25mm dia bars @ bottom

4.5.3 DESIGN OF COLUMN

- Size of column : 300×530mm
- Reinforcement details:
  - Provide 8 nos of 25mm dia bars in main reinforcement
  - Provide 8mm dia two legged stirrups

4.5.4 DESIGN OF FOOTING:

- Size of foundation : 1.5m ×1.22m
- Thickness of slab: 400mm
- Reinforcement details:
  - Provide 10mm dia bars in 125mm c/c spacing @ longer direction
  - Provide 10mm dia bars in 185mm c/c spacing @shorter direction
  -

V. CONCLUSION

The seismic analysis is carried out by equivalent static and response spectrum method. Design forces have been worked out by considering all the load combinations and analysed with considering the infill wall panels. Results of STAAD Pro and Analysis of reinforced concrete frames such as both static loads (dead, live and combinations) and dynamic load (Earthquake load) are considered.

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