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RESEARCH ARTICLE

COMPARATIVE STUDY OF REINFORCEMENT REQUIREMENTS FOR RC BUILDING SUBJECTED TO STATIC AND DYNAMIC LOADING

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ABSTRACT

It is the responsibility of structural engineers to ensure the built environment that can withstand extreme dynamic actions, such as wind, traffic or earthquake. Structural engineers must understand how the built environment will respond to such dynamic actions. In essence an earthquake resistant structure has to resist the lateral inertial forces in a safe and reliable manner. A structure has to be designed to resist the lateral actions applied to it by the earthquake ground motion. The main objective of this study is to understand the requirement of reinforcements for static and dynamic loading on the structure. Here the analysis is carried out for two models with uniform column size for whole building height i.e 450X450mm and two models with varying column size from bottom to top storey i.e from 400X400mm to 300X300mm varying 50 mm per two stories. The analysis and design is carried out using the standard & convenient software package ETABS 2015 and manual designs are carried out to validate the reinforcement obtained from the software. It is observed that the reinforcement required for beam reinforcement required for dynamic behaviour is 5.3% more than that required for static loading of structure. It is also observed that the reinforcement required for columns for dynamic loading is 27.3% more than that required for static loading. In case of footings the reinforcements are 3% more for dynamic loading than static loading if structure is provided with varying column size from bottom to top storey and 5% more if structure is providing with uniform column size for entire structure.

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INTRODUCTION

When an earthquake occurs, a structure moves laterally and vertically caused by surface ground motion induced by seismic waves. The lateral motion is typically much greater than the vertical motion, with the ground moving at acceleration (a_g). Inertial forces (F) are generated in the building as a result of this lateral motion (Fig.1.1), defined as the product of the mass of the structure (m) multiplied by the acceleration of the structure (a) according to Newton's Second Law (F = m x a). At a fundamental level, the mass, size and configuration of a building structure dictate how the structure will respond to an earthquake event. A structure has to be designed to resist the lateral actions applied to it by the earthquake ground motion. In order to achieve this, a lateral load resisting system is needed to resist these lateral forces. Typical methods of achieving moderate increased lateral stiffness are moment resisting frames, shear walls, infilled frame as shown in Fig.1.2. The moment resisting frame resists the lateral actions through framing action of rigid connections at the joints. Shear wall systems can be masonry but are typically constructed in reinforced concrete and resist lateral actions through in-plane resistance of the shear wall. To perform well in an earthquake, a building should possess four main attributes, namely, simple and regular configuration, adequate lateral strength, stiffness and ductility. Buildings having simple regular geometry and uniform distribution of mass and stiffness in plan as well as in elevation, suffer much less damage than buildings with irregular configurations.

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Seismic methods of analysis

There are different methods of analysis, which provide different degree of accuracy. Based on the type of externally applied load and behaviour of structure the seismic methods of analysis can be classified as

1) Linear Static Analysis,
2) Linear Dynamic Analysis,
3) Non-Linear Static Analysis and
4) Non-Linear Dynamic Analysis

1) Linear Static Analysis

Linear static analysis can be performed by equivalent static lateral force method. This method can be applied for regular structure with limited height i.e. for low and medium height buildings.

2) Linear Dynamic Analysis

Linear dynamic analysis can be performed in two ways either by Mode Superposition Method (Response Spectrum Method) or Elastic Time History Method. This analysis will produce the effect of higher modes of vibration and the actual distribution of forces in the elastic range in a better way. This analysis represents an improvement over Linear Static Analysis. The significant difference between linear static and linear dynamic analysis is the level of force and their distribution along the height of the structure.

Methodology and Modeling

Introduction

Earthquake produces lateral forces on structures. The resultant loads are called earthquake loads denoted by EQ or EL. When planning a building against natural hazards like earthquakes or cyclones, it can be designed to behave in one of the following three limit states:

1. Serviceability limit state
2. Damage controlled (damageability) limit state
3. Survival limit state

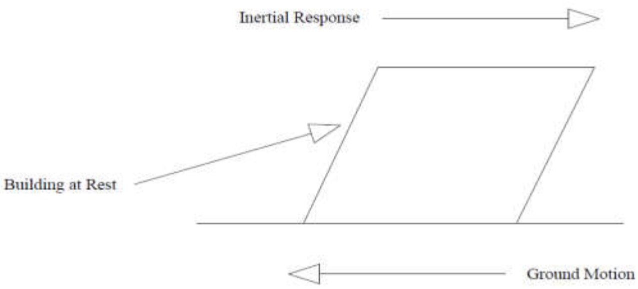

Fig.1. Lateral deformation of building

Fig.2. Moment resisting frame of shear wall and infilled frame structure

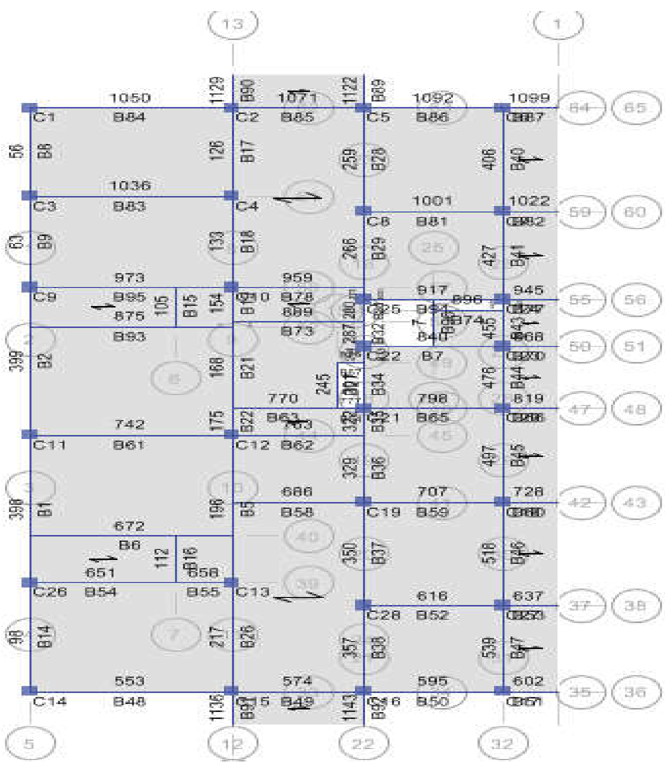

Fig.3. Typical beam column layout

The general finite element package ETABS (version-2015) has been used for modeling and analysis. It is a versatile and user-friendly program that offers a wide scope of features like static and dynamic analysis, nonlinear dynamic analysis and nonlinear static pushover analysis, etc. These features and many more, make ETABS the state-of-the-art in structural analysis programs. Linear dynamic response spectrum analysis is a very powerful feature offered in the linear version of ETABS. Response Spectrum analysis can be performed on both two and three dimensional structural models. ETABS can also perform response spectrum analysis for various zones and different soil types.

Model description

In this study, a 7 storey RC building, 7 storey bare RC building with infills is considered. These models are analysed by linear static and linear dynamic (response spectrum) method. Medium type of soil is considered for response spectrum analysis in this study. A brief summary of the building is presented.

Type of structure: Special moment resisting RC frame

Grade of concrete: M 25 for slabs & beams and M30 for columns

Grade of reinforcing steel: Fe 500

Number of storeys: (G+6)

Building height: 21 m

Column size: Square columns:
450mmX450mm For uniform columns
400mm X 400mm First to Third Floor
350mm X 350mm Fourth and Fifth Floor
300mm X 300mm Sixth to Seventh floor

Beam size

Rectangular beam at all floor levels: 230mmx450mm.

Slab thickness

RC Building frame slab thickness is 150mm.

Support condition

The support is fixed at the ends.

Modeling cases

Case 1: Static analysis using varying column size
Case 2: Dynamic analysis using varying column size
Case 3: Static analysis by providing uniform column size
Case 4: Dynamic analysis by providing uniform column size

Analysis type

Linear static and Linear dynamic response spectrum analysis

Structural system and members

Structural system

The building is an RC framed structure. The floor plan is same for all floors. The concrete slab is 150 mm thick at each floor level.

Foundation

The structure is resting on isolated footing.

Loading

The various loads to which a building is subjected to are given below:

- Dead loads
- Live loads
- Seismic loads

Dead Load = Wd= 2.75kN/m^2 (Excluding self weight of slab)
Live Load

For residential building live load = 3kN/m^2

Seismic Load Parameters as per IS: 1893-2002

Seismic loads (EQ) (IS: 1893(part 1) -2002)
Location of proposed site lies in Zone IV, (Z) : 0.24
Importance factor (I) : 1
Response reduction factor, (R) : 5 (SMRF)
Height of the Structure, : 21m
Type of soil at founding depth : Type II Medium

Fundamental time period (T_a) :

$$T_a = \frac{0.09h}{\sqrt{d}}$$

(IS 1893 (part 1):2002, clause 7.6.2), T_X=0.53 sec
T_Y=0.4 sec

Sa/g = 2.5*(As per clause 6.4.5 page 16)*

Design spectrum, $A_h = \frac{Z\,I\,Sa}{2\,R\,g}$ = 0.06 (As per clause 6.4.2)

Design base shear, =A_hW (As per clause 7.5.3)

W= Seismic weight of building as per 7.4.2 of (IS 1893 (part 1):2002

Percentage of imposed load to be considered in seismic weight calculations (clause 7.3.1 table 8) is 25%.

Uniformly distributed wall load

Masonry wall Loads

Density of wall with 20 mm plaster: 0.02 x 20.4 x 2 + 19x0.2 = 4.62 kN/m^2

a. For 3.0m height wall, 150 mm thick with 20 mm plaster on both Sides, considering 0.45 avg. depth of beam: (3.0-0.45) X 4.62=11.77, say 12 kN/m
b. Parapet wall load, considering 1m high = 1.0 x 4.62= 4.62kN/m, say 5.0 kN/m

Note: Software **Etabs 15** would be made use of for the application of above said loads on the said structure.

Load cases considered for analysis

1. DL
2. LL
3. EQ(X)
4. EQ(-X)
5. EQ(Y)
6. EQ(-Y)
7. Response spectrum –X
8. Response spectrum-Y

Geometric modeling

ETABS 2015 offers an option to choose between two and three dimensional geometric models depending upon the user's convenience and problem definition. A three dimensional model of the RC frame building was developed in ETABS 2015 3D model was chosen to in-corporate the slab modelling and to accurately predict the response of the structure. Beams and columns were modelled by frame element formulation. Member stiffness is defined by the dimensions of the section, assigned through section properties and modulus of elasticity of the concrete.

Material properties

The material properties considered for the analysis are given. Material Characteristic strength (MPa) of Concrete (M25) & (30) ,fck = 25N/mm^2 , 30N/mm^2 & Ec = 316227 Modulus of Elasticity (MPa) of Reinforcing steel fy = 500 N/mm^2

Structural modeling

The analytical model was created in such a way that the different structural components represent as accurately as possible the characteristics like mass, strength, stiffness and deformability of the structure. Non structural components were not modelled. The various primary structural components that were modelled are as follows:

(a)Beams and columns: Beams and columns were modelled as 3D frame elements. The members were represented through the assignment of properties like cross sectional area, reinforcement details and the type of material used.

(b)Beam-column joints: The beam-column joints were assumed to be rigid and were modelled by giving end-offsets to the frame elements. This was intended to get the bending moments at the face of the beams and columns.

(c)Foundation modelling: The foundation was modelled based on the degree of fixity which is provided. The effect of soil structure interaction was ignored in the analysis. In the model, fixed support was assumed at the column ends at the end of the footing.

(d)Slab Modelling (Modelling of joints): Slab is modelled as a rigid diaphragm. In rigid diaphragm case all the joints in the slab moves together as a single unit. ETABS offers features such that slab can be modelled as rigid diaphragm as well as shell element but in present case slab is modelled as rigid diaphragm. Being a rectangular slab meshing was done by dividing the area into smaller rectangular segments. Meshing improves the results but increases the computational time by a large extent.

Table 1. Reinforcement details of beams

S.No.		Static analysis				Dynamic analysis			
		M_ukNm	V_ukN	Reinforcement		M_ukNm	V_u kN	Reinforcement	
				Top	Bottom			Top	Bottom
01	Building with varying column size	161.3	145.3	1069	535	161.68	145.5	1129	564
02	Building with uniform column size	153.81	143	1025	513	154.55	143.5	1082	514

Table 2. Column results (varying column size)

Column No.	Column type	Static analysis					Dynamic analysis					Difference
		P_uKn	M_{ux} kNm	M_{uy} kNm	A_{st} mm^2	P_t%	P_ukN	M_{ux}kNm	M_{uy}kNm	A_{st} mm^2	P_t %	
C_{19}	Axial	1888	37.75	250.74	6139	3.84	1746	211.17	233.3	8393	5.25	1.41
C_4	Uniaxial bending	1846	36.93	253.19	6142	3.84	1710	207.15	218	7841	4.9	1.06
C_1	Biaxial bending	1357	27.13	245.5	5024	3.14	1462	181	207	6688	4.18	1.04

Table 3. Column results (Uniform column size)

Column No.	Column type	Static analysis					Dynamic analysis					Difference in reinforcement
		P_u kN	M_{ux} kNm	M_{uy} kNm	A_{st} mm^2	P_t%	P_ukN	M_{ux} kN-m	M_{uy} kN-m	A_{st} mm^2	P_t %	
C_{19}	Axial	2012	40.43	295.71	5135	2.54	1860	282.42	289.03	8188	4.04	1.51
C_4	Uniaxial bending	1970	39.6	270.57	4409	2.18	1834	285.4	250.2	7408	3.66	1.48
C_1	Biaxial bending	1630	210	50	3155	1.56	1589	200	226	5193	2.56	1.00

Table 4. Reinforcement details of footing

S.No.	Column size	Linear static analysis					Linear dynamic analysis				
		M_u kN -m	P_u kN	Footing size	Footing thickness mm	Footing reinforcement both directions	M_u kN m	P_u kN	Footing size	Footing thickness	Footing reinforcement both directions
01	400x400	253.2	1846	2.9X2.9	845	20#-@ 145mm c/c	218	1710	2.7X2.7	1240	20#-@110m c/c
02	450x450	270.57	1970	2.9X2.9	1165	20#-@ 100mm c/c	250.2	1834	2.8X2.8	1200	20#-@ 95mm c/c

Fig. shows the beam column layout of the building at typical floor level (Obtained from ETABS)

Analysis

Static analysis

The method of analysis of a structure for linear static analysis is same as that of analysis of regular buildings.

Dynamic analysis

Dynamic analysis is carried out using Response Spectrum method

A 3D model of the building is as shown in fig 4

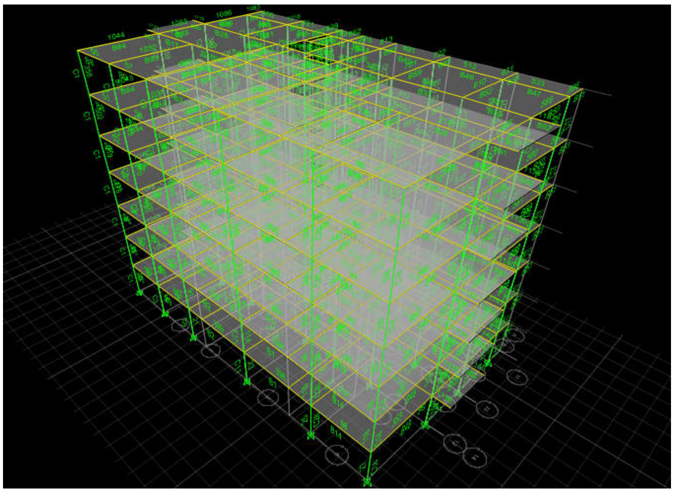

Fig.4. D model of building

The designs are cross checked manually by considering the output obtained from the analysis and results are tabulated.

RESULTS

Beams

It is observed that the reinforcement required for beam reinforcement required for dynamic behaviour and static behaviour of structure are tabulated in the Table 1.

Columns

Hence the reinforcement requirement for both static and dynamic is compared by using various column size and also with uniform column size and tabulated in the Table 2 & 3 .the details of column numbering is shown in Fig. 3.

Footings

The values of reinforcements required for the column (C_4) for both linear static and linear dynamic analysis are presented in the form of table as shown below Table 4.

Conclusion

In the present investigation an attempt is been made to study the requirement of reinforcements for both static and dynamic behaviour. The analysis is carried out by providing both varying column size from bottom to top and uniform column size throughout the building. The linear static analysis is carried out using Response spectrum method using ETABS software for Zone IV. The conclusions drawn from the present investigation are

Based on the limited study carried out, the following conclusions are drawn.

1. In case of beams the reinforcement requirement for dynamic behaviour is 5.3% more than that required for static behaviour of building.
2. The requirement of reinforcements for columns in case of dynamic analysis is 27.3% more than that required for static analysis.
3. In case of footings the reinforcements are 3% more for dynamic behaviour than static behaviour if structure is provided with varying column size from bottom to top storey and 5% more if structure is providing with uniform column size for entire structure.

REFERENCES

Haroon Rasheed Tamboli and Umesh.N.Karadi, 2012. "Seismic Analysis of RC Frame Structure with and without Masonry Infill Walls". *Indian Journal of Natural Sciences, International Bimonthly*, ISSN: 0976–0997, Vol.3, PP. 1137-1148.

Rucha S. Banginwar, Vyawahare M. R., Modani P. O. 2012. "Effect of Plans Configurations on the Seismic Behavior of the Structure By Response Spectrum Method", *International Journal of Engineering Research and Applications (IJERA)*, Vol.2, Issue 3, may-June 2012.

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