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# Seismic Response of G+20 Storey Geometric Irregular Reinforced Concrete Structure

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**Abstract:** Several seismic learning of structure have been developed. This paper discusses actions that have been applied for the dynamic study of irregular structures. In present study, a G+20 storey reinforced concrete composite and geometrically irregular structure has been analyzed using a finite element based software namely"ANSYS" for El-Centro time history data. The modelling of the building is carried out by using a software namely "SOLIDWORKS". The method of approach is based on Indian codes of standard IS:1893(Part-1) 2002 and the adopted method is response spectra time history analysis. This study comprises of different irregularity responses due to plan and vertical irregularity. The comparative parameter studied, includes; base shear, modal displacement storey drifts for the structure at different level.

**Keywords:** Base Shear; Finite Element; Fundamental Frequencies; Geometric Irregularities; Modal Displacement; Response Spectra Time History Analysis; Storey Drift.

## 1. Introduction

Structural design of buildings for seismic loadings is predominantly concerned with structural safety during major ground motions. Seismic loading needs an understanding of the structural performance under huge in-elastic deformations. Many of the structures are evaluated for earthquake forces and then designed accordingly. Several research have been carried out to analyze the response of irregular structures. Work that has been already done relating to the seismic response of vertically irregular building frames, structures with plan irregularities and those with elevation irregularities are common in the affected zone. Major failures happened because of irregularities like soft storey failure, mass irregularity failure, plan irregularity failure, shear failure.

The objective of the project is to carry out response spectra time history analysis of geometrically vertical and horizontal irregular composite building frames. Horizontal structural irregularities exist in lateral load resisting system. Vertically irregular building is analyzed for their stability. Structures with vertical offsets will fall under this category. Also, a building may have no apparent offset, but its lateral load carrying elements may have irregularity (for instance, shear wall length may suddenly reduce).

Vertical geometric irregularity: shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey. Buildings with vertical offsets will fall under this category. Also, a building may have no apparent offset, but its lateral load carrying elements may have irregularity. When building is such that larger dimension is above the smaller dimension, it acts as an inverted pyramid and is undesirable.

Horizontal geometric irregularity: in the layout of vertical lateral-force-resisting elements, thus producing a differential between the centre of mass and centre of rigidity, that typically results in significant torsional demands on the structure.Horizontal Structural Irregularities Exist in Lateral Load Resisting System.Horizontally Irregular Building are analyzed for their Stability.

## 2. Literature Survey

**Mahajan and Kalurkar (2016)** considered two different structures for the comparison under seismic analysis. "pushover analysis" are done for G+20 storey structure. The building is analyzed and design for seismic loading by using ETABS software. Results are compared for the base shear, modal time-period, storey displacement and storey drift for both structures. As the composite is having more lateral stiffness, the results of time-period and storey displacement shows the significant variation. While analyzing for "non-linear static analysis the performance point for the FEC (Fully Encased Composite) is significantly much more as compared to the RCC model.

**Deshmukh et al. (2016)** have analyzed and design a multi-storied building G+19 (3-dimensional frame) using STAAD Pro software. The design methods used in STAAD-Pro analysis are limit state design conforming to

Indian standard code of practice. G+19 storied building is considered and applied various loads like wind load, static load, earthquake load and results are studied and compared by manual calculations.

**Kangda et al. (2015)** have studied effect of height of building on base shear, lateral forces and storey drift by using STAAD software by considering seismic coefficient method and the results are compared with IS:1893 (Part1:2002). The study includes the modeling of two buildings having plan areas 15m x 9m and 25mx15m and the height is varied from 3m, 6m, 9m and 12m. The buildings are in zone II. The conclusion part is that as the height and area of building increases the base shear and storey drift increases.

## 3. Critical Appraisal on Literature Survey

The analysis done is based on the equivalent static method. The equivalent static analysis work is appropriate for low to medium-rise buildings without significant coupled lateral torsional modes, in which only the first mode in each direction is considered. Whereas the most preferable method to calculate the dynamic response of a structure is by adopting response spectrum method (RSM) o/r time history analysis (THA).

The dynamic analysis would be more accurate if the finite element based software were preferred. A multi-storey irregular building with G+20 stories using software packages ETABS and SAP 2000 v.15. The results of two different software's were compared, but the software ETABS and SAP 2000, both have the same analysis engine at core. The only difference is that the sap 2000 is lot easier while dealing with geometry of the structure, whereas ETABS have all the necessary tools for building systems, as well as help in geometry formation of building systems. Henceforth the analyzed parameters should have compared with a finite element based software such as ANSYS to obtain a better result.

Earthquake produces significant deflection which is also serious factor leading to major damage or complete breakdown of structures. It is, therefore, necessary that irregular buildings should be carefully analyzed for deflection.

Irregular structures are commonly preferred by engineers from architectural point of view and hence such structure should be thoroughly analyzed for the seismic stability.

## 4. Problem Defination

Response spectra-time history analysis of a RCC building frames carried out with vertical geometric irregularities and horizontal geometric irregularities. The Fig-1(a), Fig-1(b) shows the design modeler of a G+20 storey structure such as plan and elevation of the structure. The modelling is carried out by using a software namely "SOLIDWORKS" and analysis is done by using a finite element based software namely "ANSYS".

Model comprises of RCC-column, slab and the beams for whole structure. The following Table-1, Table-2 and Table-3 shows the input data such as geometric properties, material properties, loading details require to get the seismic response of the structure.

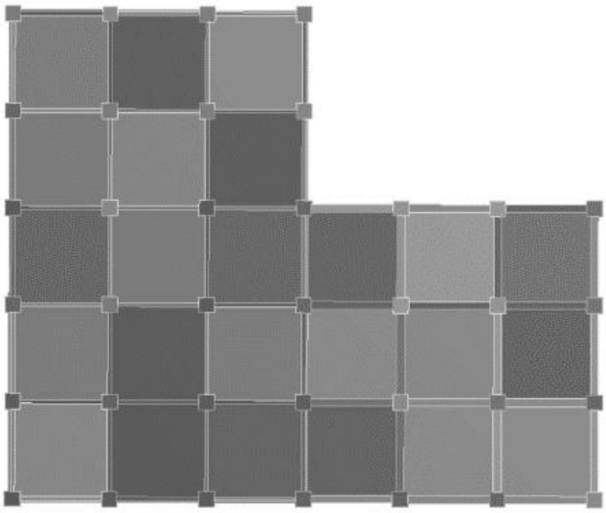

**Figure 1(a):** Plan view of G+20 storey structure

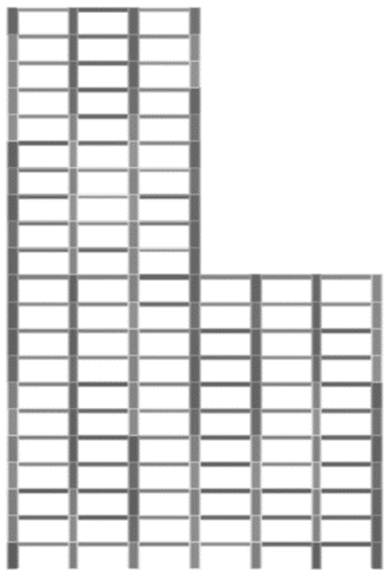

**Figure 1(b):** Elevated view of G+20 storey structure

**Table1:** Geometric properties

| Description | Salient Features |
|---|---|
| | **Model** |
| **Floor** | G+20 |
| **Floor to floor height (m)** | 3.5 |
| **Height of Structure** | 73.5 |
| **Grade of Concrete** | $M_{30}$ |
| **Grade of Steel** | Fe 415 |
| **Column Size in mm** | 800 × 800 |
| **Beam Size in mm** | 400 × 600 |
| **Size of Slab (m × m)** | 5 × 5 |
| **Thickness of Slab (mm)** | 150 |

**Table2:** Concreteproperties

| Description | Salient Features |
|---|---|
| | **Concrete** |
| **Density (kN/m$^3$)** | 25 |
| **Coefficient of Thermal Expansion** | $1.4 \times 10^{-6}$ |
| **Poisson’s Ratio** | 0.18 |
| **Young’s Modulus (MPa)** | 30000 |
| **Ultimate Tensile Strength (MPa)** | 5 |
| **Ultimate Compressive Strength (MPa)** | 30 |

**Table 3:** Loading details

| Description | | Salient Features |
|---|---|---|
| | | **Model-1b** |
| **Dead Load** | Gravity Pressure (m/s$^2$) | 9.8066 |
| **Live Load** | Floor Finish (kN/m$^2$) | 1.5 |
| | Floor Loading (kN/m$^2$) | 2.5 |
| **Seismic Load Data** | | El-Centro Time History Data |
| **Zone** | | V |
| **Zone Factor** | | 0.36 |
| **Importance Factor** | | 1.0 |
| **Type of Frame** | | SMRF |
| **Type of Soil** | | Medium Soil (Type-II) |
| **Response Reduction Factor** | | 5 |

Fig-2 shows the graphical representation of time versus acceleration for the El-Centro time historyseismic data.

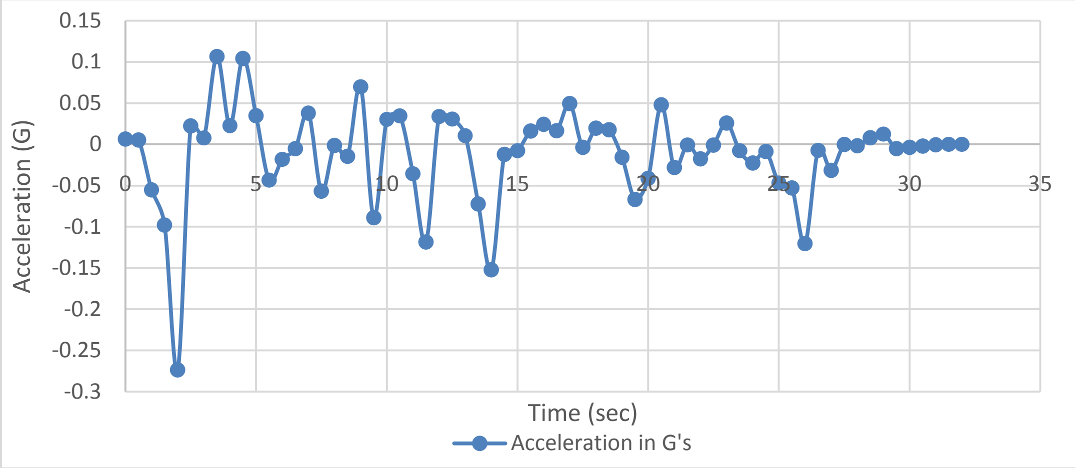


**Figure 2:** El-Centro time-acceleration graph

## 5. Analysis

The analysis describes the seismic coefficient procedure to obtain the base shear of a G+20 storey office building. The analysis is carried out as per standards of IS:1893(2002).

### 5.1 Design Seismic Horizontal Coefficient ($A_h$):

Following calculation shows the seismic coefficient value obtain as per IS:1893(2002) code provisions.

$A_h = \frac{ZIS_a}{2Rg}$ where,

- Z = Zone factor; I = Importance facto; R = Response reduction factor
- $\left(\frac{S_a}{g}\right)$ = Average response acceleration coefficient, depends upon fundamental natural period.
- $T_a = \frac{0.09 \times h}{\sqrt{d}}$ = Moment resisting frame with brick infill panel
- $T_a = 0.075 \times h^{0.75}$ = Moment resisting frame without brick infill panel.

$$T_a = 0.075 \times 73.5^{0.75} = 1.8826 \text{ sec} \qquad \left(\frac{S_a}{g}\right) = \frac{1.36}{1.8826} = 0.7224$$

$$T_{a(x)} = \frac{0.09 \times 73.5}{\sqrt{30}} = 1.2077 \text{ sec} \qquad \left(\frac{S_a}{g}\right)_{(x)} = \frac{1.36}{1.2077} = 1.1261$$

$$T_{a(z)} = \frac{0.09 \times 73.5}{\sqrt{25}} = 1.323 \text{ sec} \qquad \left(\frac{S_a}{g}\right)_{(z)} = \frac{1.36}{1.323} = 1.0279$$

$$\therefore A_h = \frac{ZI}{2R}\left(\frac{S_a}{g}\right) = \frac{0.36 \times 1.0}{2 \times 5} \times 0.7224 = 0.026$$

$$\therefore A_{h(x)} = \frac{ZI}{2R}\left(\frac{S_a}{g}\right) = \frac{0.36 \times 1.0}{2 \times 5} \times 1.1261 = 0.0405$$

$$\therefore A_{h(z)} = \frac{ZI}{2R}\left(\frac{S_a}{g}\right) = \frac{0.36 \times 1.0}{2 \times 5} \times 1.0279 = 0.037$$

## 6. Results and Discussion

The following tables and figures shows the output generated for the Reinforced concrete composite structure. The findings were, fundamental natural frequency, shear stress, total lateral displacement in lateral direction (i.e. about X-axis and Z-axis), Mode Shapes, Modal Displacement. The model of the building is analyzed for the static structural analysis, modal analysis and response spectra-time history analysis using the finite element based software namely ANSYS. The result so obtain are describe and demonstrated below.

**Table 4:** Results for static and dynamic response

| **Description** | **Building Model** | | |
|---|---|---|---|
| **Mass of Structure** | 9414900 **Kg** | | |
| **Max Total Deflection** | 10.111 **mm** | | |
| **Max Equivalent Stress** | 8.5785 **MPa** | | |
| **Total Force Reaction** | 127100 **kN** | | |
| **Direction** | **X** | **Y** | **Z** |
| **Total Max Lateral Displacement** | 55.717 **mm** | 0.18993 **mm** | 69.613 **mm** |
| **Total Maximum Shear Stress** | 2.2339 **MPa** | 0.0088 **MPa** | 3.1303 **MPa** |
| **Design Base Shear $V_B$** | 4443.015 **kN** | - | 4059.051 **kN** |

**Table 5:** Results for natural frequency and modal displacement

| **No. of Modes** | **Natural Frequency (Hz)** | **Time-Period in (Sec)** | **Modal Displacement X Axis (mm)** | **Modal Displacement Z Axis (mm)** |
|---|---|---|---|---|
| **Mode-1** | 0.72586 | 1.377676136 | 0.019178 | 0.025223 |
| **Mode-2** | 0.78675 | 1.271051795 | 0.019157 | 0.019157 |
| **Mode-3** | 1.0281 | 0.972668028 | 0.029974 | 0.025305 |
| **Mode-4** | 1.9602 | 0.510152025 | 0.02586 | 0.024637 |
| **Mode-5** | 1.9939 | 0.501529665 | 0.023532 | 0.02225 |
| **Mode-6** | 2.2286 | 0.448712196 | 0.02755 | 0.029292 |
| **Mode-7** | 3.8354 | 0.260728998 | 0.015001 | 0.019691 |
| **Mode-8** | 3.8999 | 0.256416831 | 0.019527 | 0.019527 |
| **Mode-9** | 4.235 | 0.236127509 | 0.029068 | 0.025077 |
| **Mode-10** | 5.3208 | 0.187941663 | 0.033123 | 0.023561 |

**Table 6:** Results for Storey Displacement and Storey Drift(X-Axis)

| **Max Storey Displacement in (mm)** | **Response Spectrum analysis in X-Direction** | | | |
|---|---|---|---|---|
| | **About Horizontal X-Direction** | **Storey Drift About X-Direction** | **About Horizontal Z-Direction** | **Storey Drift About Z-Direction** |
| **Roof** | 42.338 | - | 35.841 | - |
| **20th Floor** | 41.284 | 1.054 | 35.262 | 0.579 |
| **19th Floor** | 40.037 | 1.247 | 34.534 | 0.728 |
| **18th Floor** | 38.563 | 1.474 | 33.627 | 0.907 |
| **17th Floor** | 36.868 | 1.695 | 32.543 | 1.084 |
| **16th Floor** | 34.965 | 1.903 | 31.287 | 1.256 |
| **15th Floor** | 32.869 | 2.096 | 29.865 | 1.422 |
| **14th Floor** | 30.599 | 2.27 | 28.289 | 1.576 |
| **13th Floor** | 28.182 | 2.417 | 26.568 | 1.721 |
| **12th Floor** | 25.679 | 2.503 | 24.73 | 1.838 |
| **11th Floor** | 23.247 | 2.432 | 22.82 | 1.91 |
| **10th Floor** | 21.036 | 2.211 | 20.86 | 1.96 |
| **9th Floor** | 18.914 | 2.122 | 18.836 | 2.024 |
| **8th Floor** | 16.756 | 2.158 | 16.732 | 2.104 |

| | | | | |
|---|---|---|---|---|
| **7th Floor** | 14.537 | 2.219 | 14.556 | 2.176 |
| **6th Floor** | 12.268 | 2.269 | 12.324 | 2.232 |
| **5th Floor** | 9.9687 | 2.2993 | 10.05 | 2.274 |
| **4th Floor** | 7.6575 | 2.3112 | 7.7534 | 2.2966 |
| **3rd Floor** | 5.3587 | 2.2988 | 5.455 | 2.2984 |
| **2nd Floor** | 3.1195 | 2.2392 | 3.1996 | 2.2554 |
| **1st Floor** | 1.1006 | 2.0189 | 1.1424 | 2.0572 |

**Table 7:** Results for Storey Displacement and Storey Drift (Z-Axis)

| **Max Storey Displacement in (mm)** | **Response Spectrum analysis in Z-Direction** | | | |
|---|---|---|---|---|
| | **About Horizontal X-Direction** | **Storey Drift About X-Direction** | **About Horizontal Z-Direction** | **Storey Drift About Z-Direction** |
| **Roof** | 47.334 | - | 50.488 | - |
| **20th Floor** | 46.377 | 0.957 | 49.649 | 0.839 |
| **19th Floor** | 45.228 | 1.149 | 48.643 | 1.006 |
| **18th Floor** | 43.842 | 1.386 | 47.397 | 1.246 |
| **17th Floor** | 42.224 | 1.618 | 45.912 | 1.485 |
| **16th Floor** | 40.384 | 1.84 | 44.194 | 1.718 |
| **15th Floor** | 38.334 | 2.05 | 42.253 | 1.941 |
| **14th Floor** | 36.09 | 2.244 | 40.1 | 2.153 |
| **13th Floor** | 33.673 | 2.417 | 37.748 | 2.352 |
| **12th Floor** | 31.121 | 2.552 | 35.219 | 2.529 |
| **11th Floor** | 28.516 | 2.605 | 32.54 | 2.679 |
| **10th Floor** | 25.95 | 2.566 | 29.731 | 2.809 |
| **9th Floor** | 23.365 | 2.585 | 26.807 | 2.924 |
| **8th Floor** | 20.711 | 2.654 | 23.779 | 3.028 |
| **7th Floor** | 17.982 | 2.729 | 20.659 | 3.12 |
| **6th Floor** | 15.194 | 2.788 | 17.467 | 3.192 |
| **5th Floor** | 12.364 | 2.83 | 14.227 | 3.24 |
| **4th Floor** | 9.5157 | 2.8483 | 10.96 | 3.267 |
| **3rd Floor** | 6.6751 | 2.8406 | 7.7002 | 3.2598 |
| **2nd Floor** | 3.8977 | 2.7774 | 4.5088 | 3.1914 |
| **1st Floor** | 1.3804 | 2.5173 | 1.6066 | 2.9022 |

## 7. Results Discussion

1. With respect to the obtain value of results; from Table-6 and Table-7, it'sunderstood that, the storey displacement is more about X direction compare to Z direction for the acceleration applied in X direction while the value is vice versa for the model when acceleration applied in Z direction.
2. The maximum storey drift is 3.267 mm4$^{th}$ floor forresponse spectrum in Z direction.
3. The base shear is (4443.015 kN) greater in X Direction as compared to that in Z direction (Table-4).
4. The maximum static deflection is about 10.111 mm. and the maximum stress in concrete is8.5785 MPa.
5. The natural frequency is gradually increasing and is maximum at 10$^{th}$mode (5.3208Hz) while the time-period is maximum for 1$^{st}$ mode (1.377676136sec) and is gradually decreasing.

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