Effect of Vertical Irregularity In Multistoried Building Under Seismic Loading

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Abstract- *Major structural collapses occur when a building is under the action of Dynamic Loads which includes both Earthquake and Wind loads. In these modern days, most of the structures are involved with architectural importance and it is highly impossible to plan with regular shapes. These irregularities are responsible for structural collapse of buildings under the action of dynamic loads. Hence, extensive research is required for achieving ultimate performance even with a poor configuration. In the present work, "Effect Of Vertical Irregularity In Multi-Storied Buildings Under seismic loading. ", considering three types of15, 20,25 Storied 3-D frames (i.e., a symmetrical elevation configuration throughout its height and three other frames with unsymmetrical vertical configuration starting from tenth floor, placed at corner, at the center and at edge of the plan respectively) it is focused to study their response using non linear time history Analysis. From the studied results of the analysis of three frames, it is observed that storey drift of G+25 is more than G+15,G+20 Story frame and base shear of G+25 is more than G+15,G+20 Story frame.*

Keywords- Vertical irregular building , time history analysis, STAAD PRO V8i.

I. INTRODUCTION

1.1 Introduction:-

During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. For example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the regular building

A building is said to be a regular when the building configurations are almost symmetrical about the axis and it is said to be the irregular when it lacks symmetry and discontinuity in geometry, mass or load resisting elements. Asymmetrical arrangements cause a large torsion force. IS 1893: 2016 (part1) has explained building configuration system for better performance of RC buildings during earthquakes. The building configuration has been described as regular or irregular in terms of the size and shape of the building, arrangement of structural the elements and mass. There are two types of irregularities 1) Horizontal irregularities refers to asymmetrical plan shapes (L, T, U and F) or discontinuities in horizontal resisting elements such as re-entrant corners, large openings, cut outs and other changes like torsion, deformations and other stress concentrations, 2) Vertical irregularities referring to sudden change of strength, stiffness, geometry and mass of a structure in vertical direction. The main objective of the present work is to study the response of the irregular structures under dynamic loads. In this present study it is proposed to consider the building frames that are irregular in elevation and analyze the response and behaviour of the structures under earthquake and wind loads. For this purpose, Three RC building frames are selected and it is proposed to analyze all the frames that are considered and are modeled. STAAD PRO analysis package is proposed for the analysis of all structures, to get the all nodal displacements. Frames considered in this study are 15,20,25-Storied 3-D frames with symmetrical elevation configuration throughout its height and three other frames with unsymmetrical vertical configuration starting from tenth floor, placed at corner of the plan respectively. It is proposed that the responses of all the above frames are to be determined for all the load combinations. Lateral loads and Storey shears of all the three frames due to earthquake loads is proposed to determine using Time history analysis method, the IS 1893(Part 1) : 2016 has recommended dynamic analysis.

1. Plan Irregularities
2. Vertical Irregularities.

b) Stiffness Irregularity
ii) Mass Irregularity
iii) Vertical Geometric Irregularity

iv) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force
v) Discontinuity in Capacity

1.2 Objectives of the study

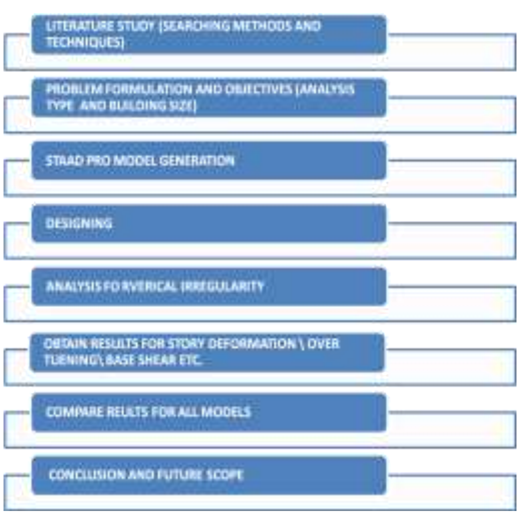
The main objectives of the present work is to study the effect of vertical irregularity in Multi-Storied building.

1) To calculate the design lateral forces on regular buildings using Equivalent static method and compare results with staad pro results.
2) To study the structural response of the building models with respect to following aspects Fundamental time period of the building, Base shear, Storey drift.

1.3 Need for Research

Irregular buildings constitute a large portion of the modern urban infrastructure. Structures are never perfectly regular and hence the designers routinely need to evaluate the likely degree of irregularity and the effect of this irregularity on a structure during an earthquake. Need for research is required to get economical & efficient lateral stiffness system for high seismic prone areas. For optimization & design of high rise building with different structural. framing systems subjected to seismic loads. To improve the understanding of the seismic behavior of building structures with vertical irregularities.

II. METHODOLOGY OF WORK



3.1 Description of Method

In engineering problems there are some basic unknowns. If they are found, the behaviour of the entire structure can be predicted In a continuum, these unknowns are infinite. The finite element procedure reduces such unknowns to a finite number by dividing the solution region into small parts called elements and by expressing the unknown field variables in terms of assumed approximating functions (Interpolating functions/Shape functions) within each element. The approximating functions are defined in terms of field variables of specified points called nodes or nodal points. Thus in the finite element analysis the unknowns are the field variables of the nodal points. After selecting elements and nodal unknowns next step in finite element analysis is to assemble element properties for each element. For example, in solid mechanics, we have to find the force-displacement i.e. stiffness characteristics of each individual element. Mathematically this relationship is of the form.

2.1 Finite Element Analysis

$$[k]e \ \{\delta\} \ e = \{F\} \ e$$

Where $[k]e$ is element stiffness matrix, $\{\delta\}$ eis nodal displacement vector of the element and $\{F\}$ *e*is nodal force vector. The element of stiffness matrix *kij* represent the force in coordinate direction '*i*' due to a unit displacement in coordinate direction '*j*'. Four methods are available for formulating these element properties viz. direct approach, Element properties are used to assemble global properties/structure properties to get system equations $[k]\ \{\delta\} = \{F\}$. Then the boundary conditions are imposed. The solution of these simultaneous equations give the nodal unknowns. Using these nodal values additional calculations are made to get the required values e.g. stresses, strains, moments, etc. in solid mechanics problems.

Thus the various steps involved in the finite element analysis are:

(i) Select suitable field variables and the elements.
(ii) Discretize the continua.
(iii) Select interpolation functions.
(iv) Find the element properties.
(v) Assemble element properties to get global properties.
(vi) Impose the boundary conditions.
(vii) Solve the system equations to get the nodal unknowns.
(viii) Make the additional calculations to get the required values

2.2 Methods of Seismic Analysis of Building

Earthquakes are nature's greatest hazards to life on this planet. The hazards imposed by earthquakes are unique in many respects, and consequently planning to mitigate earthquake hazards requires a unique engineering approach. An important distinction of the earthquake problem is that the hazard to life is associated almost entirely with manmade structure expect for earthquake triggered landslides, the only earthquake effect that causes extensive loss of life are collapse of bridges, buildings, dams, and other works of man. This aspect of earthquake hazard can be countered only by designs and construction of earthquake resistant structure. The optimum engineering approach is to design the structure so as to avoid collapse in most possible earthquake, thus ensuring against loss of life but accepting the possibility of damage.

Various methods for determining seismic forces in structures fall into two distinct categories:

(I)Equivalent static force analysis
(II) Dynamic Analysis

2.3 Equivalent static force analysis:

These are approximate methods which have been evolved because of the difficulties involved in carrying out realistic dynamic analysis. Codes of practice inevitable rely mainly on the simpler on the simpler static force approach, and incorporate varying degree of refinement in an attempt to simulate the real behaviour of structure. Basically they give total horizontal force (Base Shear) V, on a structure:

$$V = ma$$

Where,
m is mass of structure

V is applied to the structure by a simple rule describing its vertical distribution. In a building this generally consist of horizontal point loads at each concentration of mass, most typically at floor level. The seismic forces and moments in the structure are then determined by any suitable analysis and the results added to those for the normal gravity load cases. An important feature of equivalent static load requirement in most codes of practice is that calculated seismic forces are considerably less than those which would actually occur in the larger earthquakes likely in the area concerned.

V=F1+F2+F3

2.4 Time History Analysis

In this method of dynamic analysis, instead of going through a process of determining a response spectrum for a given ground motion and then applying the results to given structure, it is possible by using computers to apply the earthquake motion directly to the base of a given structure. Instantaneous stresses throughout the structure are calculated at small interval of time for full duration of the earthquake or significant portion of it. The maximum stress in any member that occur the earthquake can then be found by scanning the output records and the design reviewed. The procedure usually includes the following steps: The earthquake record is selected which represent the expected earthquake. The record is digitized as a series of small time interval of about 1/4 to 1/25 of a second with given levels of acceleration occurring for each interval. The digitized record is applied to the model as acceleration at the base of structure. The acceleration and relative displacement of the lumped masses are translated into member stresses. The maximum values can then be found by scanning of each output record. This process automatically included various modes of vibration and combines their effects as they occur, thus eliminating the uncertainties of combining the modes which are inherent to the spectrum analysis Response spectrum technique is a simplified case of modal analysis. The modes of vibration are determined in period and shape in the usual way and the maximum response magnitude corresponding to each mode is found by reference to a response spectrum. An arbitrary rule is then used for superposition of the maximum response in various modes. The resultant moments and forces in the structure correspond to envelop of maximum values rather than as set of simultaneously existing values. The response spectrum method has the great virtues of speed and cheapness. This technique is strictly limited to a linear analysis because of the use of superposition. Simulations of nonlinear behaviour have been made using pairs of response spectra, one for deflection and one for acceleraon.

Modal combination rules

I) Square- Root of sum of squares (SRSS)

This rule for modal combination developed in E. Rosenblueth’s Ph.D. thesis (1951) is

$$r_o = \left({}^{N}\sum_{n-1} r^2{}_{no} \right)$$
(3.16)

The peak response in each mode is squared. The squared modal peaks are summed, and the square root of the sum provides an estimate of the peak total response. This modal combination rule provides excellent response estimates for structures with well-separated natural frequencies. This limitation has not been recognized in applying this rule to practical problems, and at times it has been misapplied to systems with closely spaced natural frequencies, such as piping systems in nuclear power plants and multistoried buildings with unsymmetrical plan.

II) The Complete Quadratic combination (CQC)

This rule for modal combination is applicable to a wider class of structures as it overcomes the limitations of the SRSS rule.

$$r_o = \left({}^{N}\sum_{n=1} {}^{N}\sum i = 1 P_{in} r_{io} r_{no} \right) \tag{3.17}$$

Where
ro = Peak value of r(t)
r(t) = any response quantity
Pin = Cross correlation spectrum ordinate

The modal combination rules will becomes less accurate for short duration impulsive ground motions and are not recommended for ground motions that contain many cycle of essentially harmonic excitation. Thus, modal combination rules are intended for use when excitation is characterized by smooth response spectrum, based on response spectra for many earthquake excitations.

Buildings are subjected to ground motions. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behavior of RC buildings under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion amplitude, frequency and duration. Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories:

1) High-frequency content PGA/PGV > 1.2
2) Intermediate-frequency content 0.8< PGA/PGV< 1.2
3)Low-frequency content PGA/PGV < 0.8

Material Properties

shows the concrete and steel bar properties, which are used for modelling of the reinforced concrete buildings in STAAD PRO . Concrete and steel bar properties as per IS 456

Concrete Properties		Steel Bar Properties	
Unit weight (γcc)	25 (kN/m3)	Unit weight (γss)	76.9729 (kN/m3)
Modulus of elasticity ($EEcc$)	22360.68 (MPa)	Modulus of elasticity ($EEss$)	2x105 (MPa)
Poisson ratio (vcc)	0.2	Poisson ratio (vss)	0.3
Thermal coefficient ($\alpha\alpha cc$)	5.5x10-6	Thermal coefficient ($\alpha\alpha ss$)	1.170x10-6
Shear modulus ($GGcc$)	9316.95 (MPa)	Shear modulus ($GGss$)	76923.08 (MPa)
Damping ratio (ςcc)	5 (%)	Yield strength ($FFyy$)	500 (MPa)
Compressive strength ($FFcc$)	30 (MPa)	Tensile strength ($FFuu$)	485 (MPa)

III. PROBLEM STATEMENT

Present research involves the study effect of vertical irregularity in multistoried building under seismic loading. For this study, a G+15, G+20, G+25 story building with 3.1 meters height for each story, regular in plan is considered. This building is considered to be situated in seismic zone III and designed in compliance to the Indian Code of Practice for Earthquake Resistant Design of Structures IS 1893(part–I):2016.The building is considered to be fixed at the base. The building is modeled using relevant software. Model is studied for comparing base shear, storey drift.

Table 5.1: Description for All Frames

Type of structure	Special Moment Resisting frame (SMRF)
Number of stories	G+15, G+20, G+25
Seismic zone	III
Floor height	3.1m
Type of soil	Medium
Size of Column	300*600, 300*450
Size of Beam	300*600
Depth of Slab	150mm
Live Load	3.5 kN/m²
Material	M30 & Fe 500 reinforcement,
Unit weight	Concrete -25 kN/m³ Masonry – 20 kN/m³
Damping in structure	5%
Importance factor	1.5

IV. RESULTS

Problem Statement

Thickness of slab: 130mm
Beam size: 250mm X 350 mm
Column size at G.L.:250mm X 400 mm
Thickness of outer wall including plaster: 250 mm
Thickness of partition wall including plaster: 175 mm
Load due to roof finish: 2kN/m2
Load due to floor finish: 1kN/m2
Imposed load: 4kN/m2
Type of foundation: Isolated footing
Soil Condition: Hard Murum available at depth of 1.5m below G.L.
Zone-III

Results

1) Comparison of base shear by equivalent static method and staad pro

Story level	$Q_i = V_B \cdot \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$	Q_i STAAD-Pro
4	212.5	221.06
3	211.9	220.40
2	125.4	130.42
1	61.4	63.9
Plinth	15.7	16.3

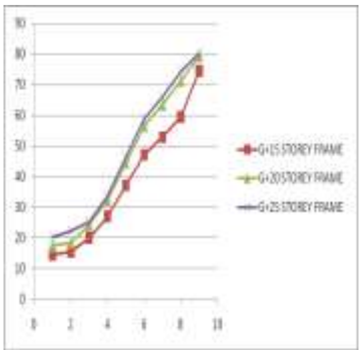
2) calculation of base shear and storey drift:

Storey Drift

STOREY NO.	G+15 RCC BARE FRAME	G +20 RCC BARE FRAME	G+25RCC BARE FRAME
1	0.10647	0.127764	0.1638
2	0.14976	0.179712	0.2304
3	0.249795	0.299754	0.3843
4	0.38025	0.4563	0.585
5	0.459225	0.55107	0.7065
6	0.5616	0.67392	0.864
7	0.659295	0.791154	1.0143
8	0.82017	0.984204	1.2618
9	0.87867	1.054404	1.3518

Base Shear

STOREY NO.	G+15 STOREY FRAME	G+20 STOREY FRAME	G+25 STOREY FRAME
1	14.490432	17.3885184	20.11304
2	15.490432	18.3885184	22.1974
3	20.0448	24.05376	25.056
4	26.964	32.3568	33.705
5	37.152	44.5824	46.44
6	47.088	56.5056	58.86
7	52.848	63.4176	66.06
8	59.4504	71.34048	74.313
9	74.448	79.3376	80.313



V. CONCLUSION

1. The storey shear force is Minimum for the first storey and it increases to maximum in the top storey.

2. It is concluded that storey drift of G+25 is more than G+15,G+20 Story frame.

3. It is concluded that base shear of G+25 is more than G+15,G+20 Story frame.

4. Vertical irregular structures can be designed accurately and economically for earthquake resistance building using STAAD.pro v8i.

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