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Analysis and Design of Response Spectrum Analysis of G+12 Building

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Abstract

Many high-rise buildings are designed with basement. In general, we assume the building is fixed at the ground level. Therefore, the basement of the building is not included in the analysis and only gravity loads are considered in designing the basement. However, the basement may introduce flexibility to the structure resulting in larger lateral displacements and longer vibration periods. The seismic loads applied to a building structure will affect the member forces in the basement. Thus, it is recommended to include the basement in the analysis of high-rise building structures. The effect of the basement is investigated based on the seismic response of high-rise buildings and an efficient analysis method to account for the effect of the basement was proposed in this study. Most of the degrees of freedom in the basement are eliminated by the matrix condensation procedure using a rigid diaphragm for each floor in the basement in part or in full. Earthquakes in different parts of the world demonstrated the disastrous consequences and vulnerability of inadequate structures. Many reinforced concrete (RC) G+12 framed structures located in zones of high seismicity in India are constructed without considering the seismic code provisions. The vulnerability of inadequately designed structures represents seismic risk to occupants.

The main cause of failure of multi-storey multi-bay reinforced concrete frames during seismic motion is the soft storey sway mechanism or column sway mechanism. If the frame is designed on the basis of strong column-weak beam *concept the possibilities of collapse due to sway mechanisms can be completely eliminated.*

Reinforced Concrete Frames are the most commonly adopted buildings construction practices in Indian important Indian cities fall under high risk seismic zones; hence strengthening of buildings for lateral forces is a prerequisite. In this study the aim is to analyze the response of a high-rise structure to ground motion using Response Spectrum Analysis. Different models, that is, bare frame, brace frame and shear wall frame are considered in Staad Pro v8i. And change in the time period, stiffness, base shear, storey drifts and top-storey deflection of the building is observed and compared.

Keywords: *Concrete, G+12 Building, Seismic Analysis, Construction, Building code*

Skills Used:

- IS: 1893-2002(Part-1)
- IS: 875(Part-1&2)
- IS: 456-2000
- Staad Pro v8i
- Seismic Analysis etc.

INTRODUCTION

Purpose

Structural and geotechnical engineers and researchers associated with the Earthquake Engineering Research Center developed these Guidelines for Performance- Based Seismic Design of Buildings as a recommended alternative to the prescriptive procedures for seismic design of buildings contained in the IS: 456-2000 Concrete Design and other standards incorporated by reference into the International Building Code (IBC). These Guidelines may be used as:

- Basis for the seismic design of individual tall buildings under the Building Code alternative (non-prescriptive) design provisions; or
- Basis for development and adoption of future Building Code provisions governing the design of tall buildings.

Properly executed, the Guidelines are intended to result in buildings that are capable of achieving the seismic performance objectives for Occupancy Category II buildings intended by IS: 1893 (Part-1). Alternatively, individual users may adapt and modify these guidelines to serve as the basis for designs intended to achieve higher seismic performance objectives.

These Guidelines are intended to serve as a reference source for design engineers, building officials, peer reviewers, and developers of building codes and standards.

Commentary

This document intentionally contains both requirements, which are stated in mandatory language (for example, using “shall”) and recommendations, which use non-mandatory language (for example, using “should”).

An alternative or non-prescriptive seismic design is one that takes exception to one or more of the requirements of the IBC by invoking Section 104.11 of the Building Code, which reads as follows:

Alternate materials, design and methods of construction and equipment

The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed in this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability, and safety.

Design Considerations

In recent years, structural engineers have designed a number of tall buildings in the Western United States using seismic-force-resisting systems that do not strictly comply with the prescriptive requirements of the Building Code in effect at the time of their design. In some cases, these structures generally complied with the applicable Building Code criteria, except that the height limit specified by the Building Code for the selected seismic-force-resisting system was exceeded, while in other cases, seismic force resistance was provided by structural systems that were not covered by the Building Code.

The seismic design of these buildings typically was developed using performance-based capacity design procedures in which the engineer proportioned the building for intended nonlinear response and then used nonlinear structural analysis to verify that the structure's performance would be acceptable when subjected to various levels of ground shaking.

Building permits for these buildings have generally been issued under Section 104.11 of the IBC. Section 104.11 permits the use of alternative means and methods of design and construction, provided that the building official finds that such design and construction results in a building with performance capability equivalent to that anticipated for buildings that strictly comply with the Building Code criteria.

This same approach is adopted by these Guidelines. Seismic design of tall buildings in accordance with these Guidelines can offer a number of advantages including:

- More reliable attainment of intended seismic performance
- Reduced construction cost
- Accommodation of architectural features that may not otherwise be attainable
- Use of innovative structural systems and materials

Design Team Qualifications

Appropriate implementation of the design guidelines presented herein requires sophisticated structural and earthquake engineering expertise including knowledge of:

- Seismic hazard analysis and selection and scaling of ground motions
- Non-linear dynamic behavior of structures and foundation systems and construction of mathematical models capable of reliable prediction of such behavior using appropriate software tools
- Capacity design principles
- Detailing of elements to resist cyclic inelastic demands, and assessment of element strength, deformation, and deterioration characteristics under cyclic inelastic loading
- Engineers who do not have this expertise and knowledge should not undertake projects utilizing these Guidelines, either as the engineer of record or as a third-party reviewer.

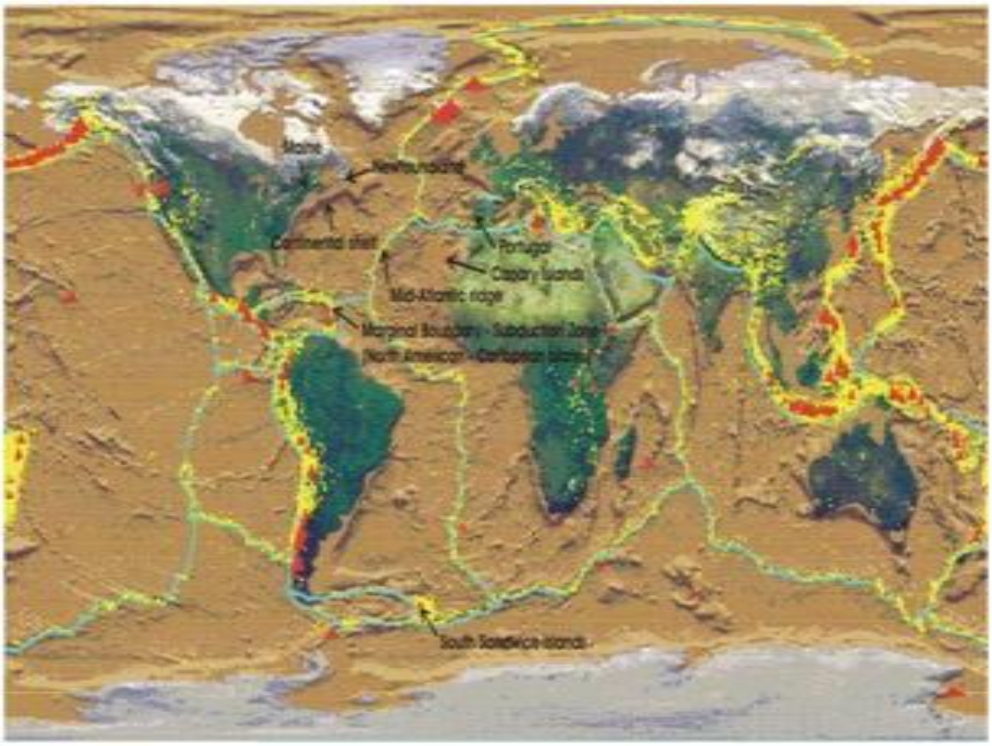
Limitations

These Guidelines are intended to provide a reliable basis for the seismic design of tall buildings based on the present state of knowledge, laboratory and analytical research, and the engineering judgments of persons with substantial knowledge in the design and seismic behavior of tall buildings. When properly implemented, these Guidelines should permit design of tall buildings that are capable of seismic performance equivalent or superior to that attainable by design in accordance with present prescriptive Building Code provisions.

Seismology is the study of vibrations of earth mainly caused by earthquakes. The study of these vibrations by various techniques, understanding the nature and various physical processes that generate them form the major part of the seismology.

Elastic rebound theory is one such theory, which was able to describe the phenomenon of earthquake occurring along the fault lines. Seismology as such is still a much unknown field of study where a lot of things are yet to be discovered.

The above Picture is showing the fault lines and we can see that epicenters are all concentrated all along the fault lines. The reason for seismic activities occurring at places other than the fault lines are still a big question mark Also the forecasting of earthquake has not been done yet and would be a landmark if done so.



LITERATURE REVIEW

Overview

In the literature review, characteristics of ground motion, that play vital rule in the seismic analysis of structures, explained. Then behavior of RC buildings under seismic loads is represented. There are few researches concerning to the seismic behavior of structures under frequency content.

Cakir [3] studied the evaluation of the effect of earthquake frequency content on seismic behavior of cantilever retaining wall involving soil-structure interaction. Also, seismic behavior of partially filled rigid rectangular tank with bottom-mounted submerged block is studied under low, intermediate, and high-frequency content ground motions. Nayak&Biswal [4]. No research work is done on seismic behavior of RC buildings under low, intermediate, and high-frequency content ground motions.

Characteristics of Ground Motion

Ground motion at a specific site because of earthquakes is influenced by source, local site conditions, and travel path. The first relates to the size and source mechanism of the earthquake. The second defines the path effect of the earth as waves travel at some depth from the source to the spot. The third describes the effects of the upper hundreds of meters of rock and soil and the surface topography at the location. Powerful ground motions cause serious damages to made-up amenities and unluckily, From time to time, induce losses of human lives. Factors that affect strong ground shaking are magnitude, distance, site, fault type, depth, repeat time, and directivity and energy pattern

Behavior of RC Buildings under Seismic Load

A seismic design method taking into account performance principles for two discrete limit states is presented by Kappos & Manafpour [18], including analysis of a feasible partial inelastic model of the structure using time-history analysis for properly scaled input motions, and nonlinear static analysis (pushover analysis).

Mwafy & Elnashai [19], studied static pushover vs. dynamic collapse analysis of RC buildings. They studied natural and artificial ground motion data imposed on twelve RC buildings of distinct characteristics. The responses of over one hundred nonlinear dynamic analyses using a detailed 2D modeling approach for each of the 12 RC buildings are used to create the dynamic pushover envelopes and compare them with the pushover results with various load patterns. They established good relationship between the calculated ideal envelopes of the dynamic analyses and static pushover results for a definite class of structure

Data Collection

Various Indian standard codes were collected from the department of civil engineering NIT Rourkela. The earthquake data's were obtained from the site Peer.berkeley.edu. The earthquakes considered in this work are time history of ground motion as per IS 1893:2002 (Part-I), Imperial Valley and San Francisco

METHODOLOGY ADOPTED

As discussed in the scope of the work, the entire work is divided into three parts:

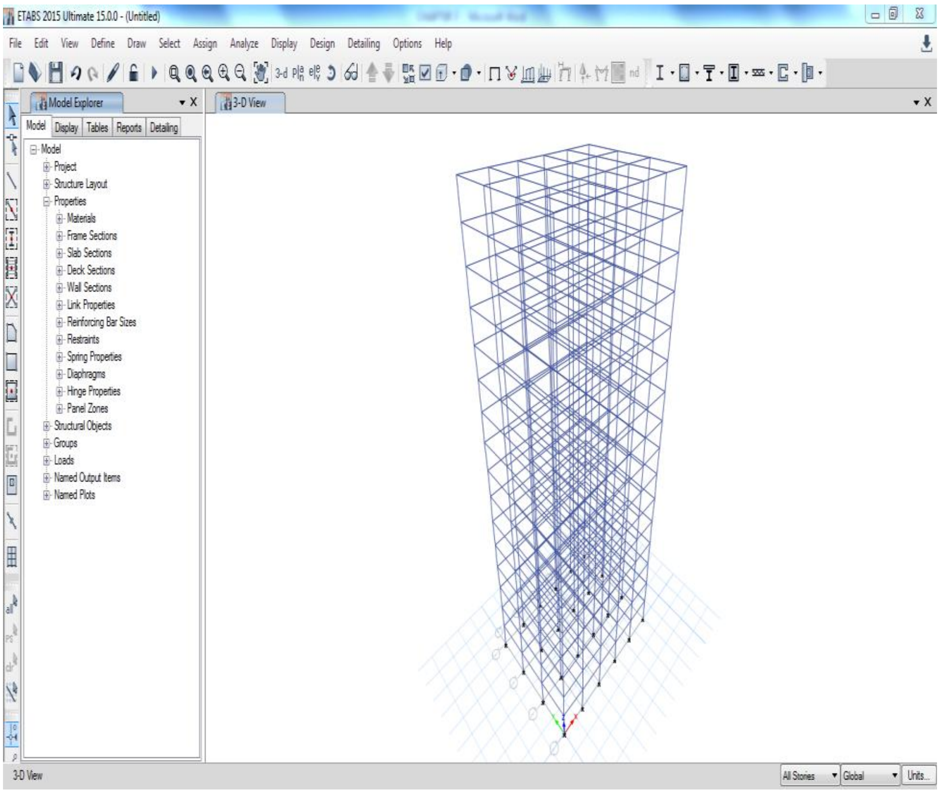
- Analysis of bare frame in all the above three mentioned ground motions
- Analysis of the braced frames.
- Analysis of the frame with shear wall

For analysis a 12 stories high building is modeled in Staad Pro as a space frame. The building is does not represent any real existing building. The building is unsymmetrical with the span more along Z direction than along X direction. The building rises up to 42m along Y direction and spans 15m along X direction and 20 m along Z direction. The building is analyzed by Response Spectrum Analysis, which is a linear dynamic analysis. Dynamic Analysis is adopted since it gives better results than static analysis. The specifications of the frame are given in Table 1

Table 1.Specifications of the building

Specifications of Building	Data
Storey Height	3.5m
No. of bays along X direction	3
Bay Length along X direction	4 m
Bay Length along Z direction	5 m
No of Bay along Z- Direction	5
Concrete grade used	M 30
Columns	0.40m X 0.40m
Beams	0.30m X 0.45m

Slab Thickness	0.15m
External Wall Thick ness	0.23 m
Internal Wall Thick ness	0.120 m
Unit Weight of Concrete	25 kN/m3
Live Load	3.5 kN/m3
Zone	IV
Soil Conditions	Hard Soil
Damping Ratio	5%
No of Floors or Stories	G+15



(G+12) Three Dimensional View of the Structure

SEISMIC DESIGN FORCE

Earthquake shaking is random and time variant. But, most design codes represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. This force is called as the Seismic Design Base Shear VB and remains the primary quantity involved in force-based earthquake-resistant design of buildings.

This force depends on the seismic hazard at the site of the building represented by the Seismic Zone Factor Z. Also, in keeping with the philosophy of increasing design forces to increase the elastic range of the building and thereby reduce the damage in it, codes tend to adopt the Importance Factor I for effecting such decisions (Figure 1.12). Further, the net shaking of a building is a combined effect of the energy carried by the earthquake at different frequencies and the natural periods of the building. Codes reflect this by the introduction of a Structural Flexibility Factor Sa/g. Finally, as discussed in section 1.2 of Chapter 1, to make normal buildings economical, design codes allow some damage for reducing cost of construction. This philosophy is introduced with the help of Response Reduction Factor R, which is larger for ductile buildings and smaller for brittle ones. Each of these factors is discussed in this and subsequent chapters.

In view of the uncertainties involved in parameters, like Z and Sa/g, the upper limit of the imposed deformation demand on the building is not known as a deterministic upper bound value. Thus, design of earthquake effects is not termed as earthquake-proof design. Instead, the earthquake demand is estimated only based on concepts of probability of exceedance, and the design of earthquake effects is termed as earthquake-resistant design against the probable value of the demand.

As per the Indian Seismic Code IS: 1893 (Part 1) - 2007, Design Base Shear VB is given by:

$$V_B = A_h W = \frac{ZI}{2R}\left(\frac{S_a}{g}\right) W, \qquad (2.1)$$

where Z is the *Seismic Zone Factor* (Table 2.1), I the *Importance Factor* (Table 2.2), R the *Response Reduction Factor* (Table 2.3), and S_a/g the *Design Acceleration Spectrum Value* (Figure 2.2) given by:

$$\frac{S_a}{g} = \begin{cases} \begin{cases} 2.5 & 0.00 < T < 0.40 \\ \frac{1.00}{T} & 0.40 < T < 4.00 \end{cases} & \text{for Soil Type I : rocky or hard soil sites} \\ \begin{cases} 2.5 & 0.00 < T < 0.55 \\ \frac{1.36}{T} & 0.55 < T < 4.00 \end{cases} & \text{for Soil Type II : medium soil sites} \\ \begin{cases} 2.5 & 0.00 < T < 0.67 \\ \frac{1.67}{T} & 0.67 < T < 4.00 \end{cases} & \text{for Soil Type III : soft soil sites} \end{cases} \qquad (2.2)$$

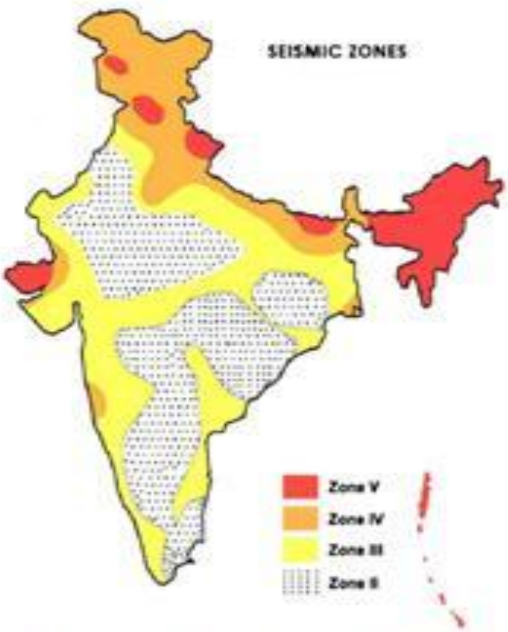
in which T is the fundamental translational natural period of the building in the considered direction of shaking.

Table 2.1: Seismic Zone Factor Z as per IS:1893 (Part 1) - 2007 of the site where the building to be designed is located

Seismic Zone	V	IV	III	II
Z	*0.36*	*0.24*	*0.16*	*0.10*
Note: *The zone in which a building is located can be identified from the Seismic Zone Map of India given in IS:1893-2007, sketched in Figure 2.1.*				

Table 2.2: Importance Factor Z of buildings as per IS:1893 (Part 1) - 2007

Building	*Importance Factor I*
Normal Buildings	1.0
Important Buildings (*e.g.*, Critical buildings required to be functional after an earthquake, Lifeline buildings associated with utilities, like water, power & transportation)	1.5



igure 2.1: *Sketch of Seismic Zone Map of India:* sketch based on the seismic zone of India map given in IS:1893 (Part 1) - 2007

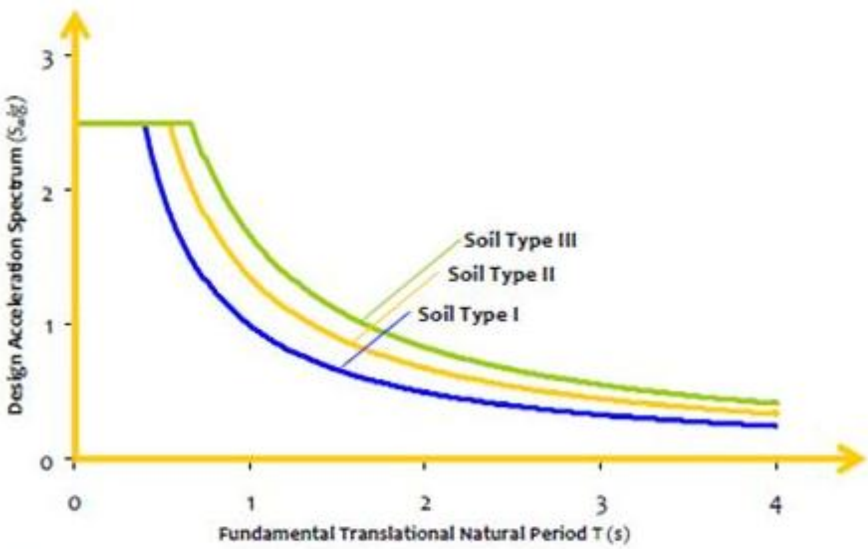


Figure 2.2: *Design Acceleration Spectrum:* This is based on fundamental translational natural period T of the building; this is defined in the following

Table 2.3: Response Reduction Factor R of buildings as per IS:1893 (Part 1) - 2007

Lateral Load Resisting System	*R*
Building Frame Systems	
Ordinary RC moment resisting frame (OMRF)	3.0
Special RC moment-resisting frame (SMRF)	5.0
Steel frame with	
(a) Concentric braces	4.0
(b) Eccentric braces	5.0
Steel moment resisting frame designed as per SP 6 (6)	5.0
Buildings with Shear Walls	
Ordinary reinforced concrete shear walls	3.0
Ductile shear walls	4.0
Buildings with Dual Systems	
Ordinary shear wall with OMRF	3.0
Ordinary shear wall with SMRF	4.0
Ductile shear wall with OMRF	4.5
Ductile shear wall with SMRF	5.0

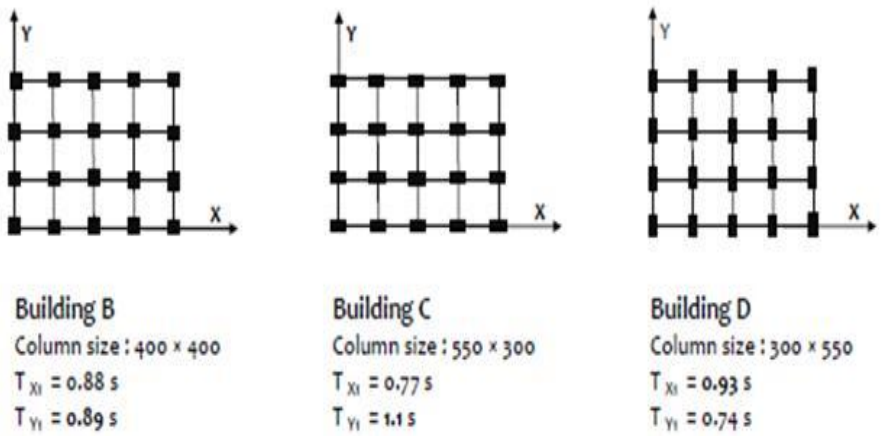


Figure 2.10: *Effect of column orientation*: Buildings with larger column dimension oriented in the direction reduces the translational natural period of oscillation in that direction

a) For Calculation of Dead Load:

Self- weight- 1 kn/Sq.m

Floor load -2 kN/Sq.m

External wall Thickness – 230mm

For Density of Brick Wall

= 20 kN/ m2

= 20 x 0.23 x 3

= -13.8 kN/m3

Internal wall Thickness – 120mm

For Density of Brick Wall = 20kN/ m^2

= 20 x 0.12 x 3

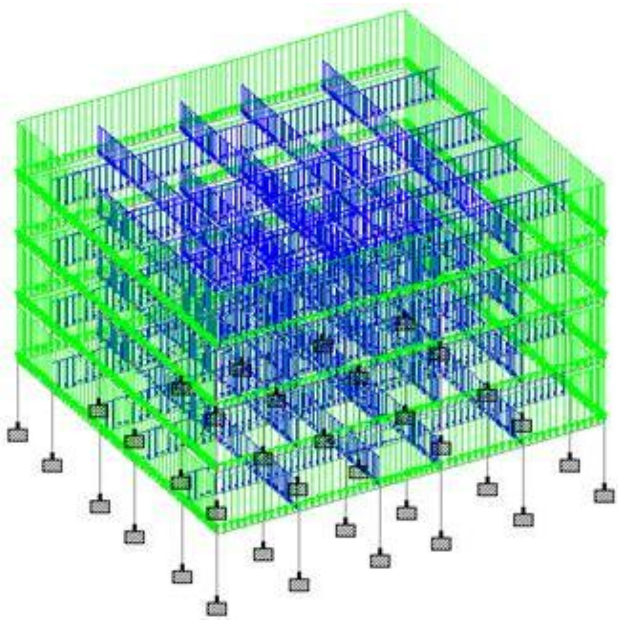
= -7.2 kN/m^3

For Considering of Floor Load -1.8 kN/m^2

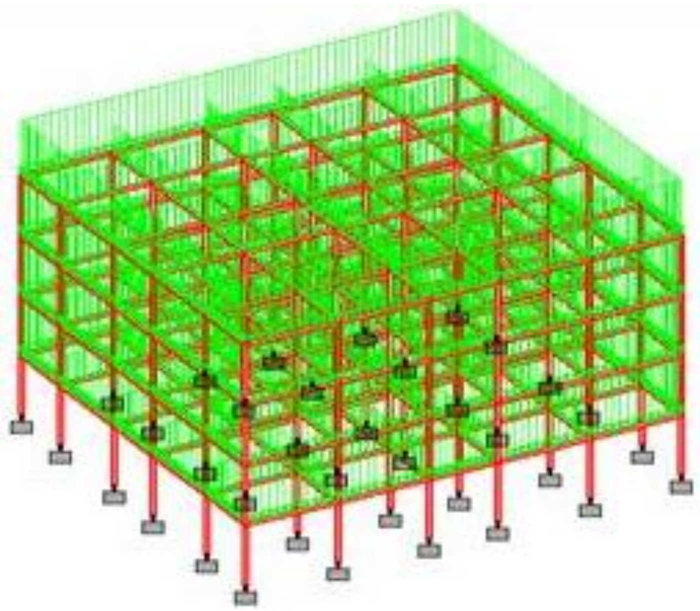
Live Load –3 kN/ m

Keeping this in view and other developments in the field of wind engineering; the Sectional Committee responsible for the preparation of the standard has decided to prepare the second revision in the following five parts:

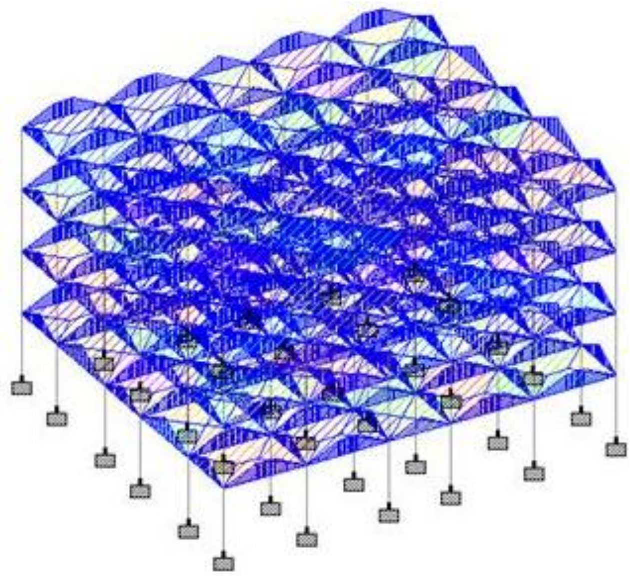
Dead Load (IS875-PART-1):



Dead Load on G+12 Building



Self -Weight of G+12 Building



Live Load on G+12 Building

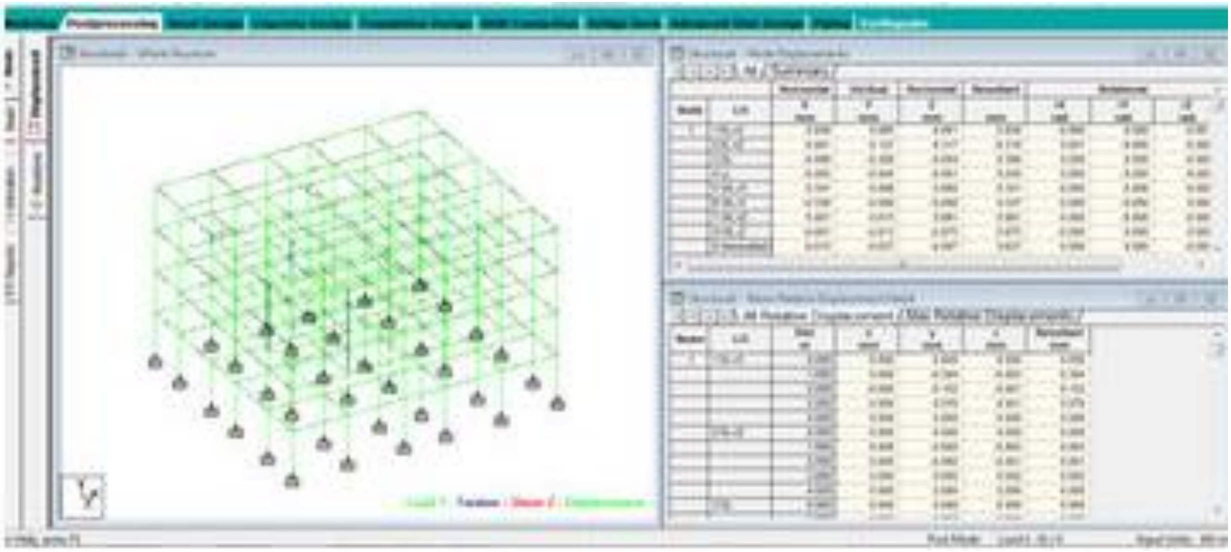
DESIGN OF G+12BUILDING

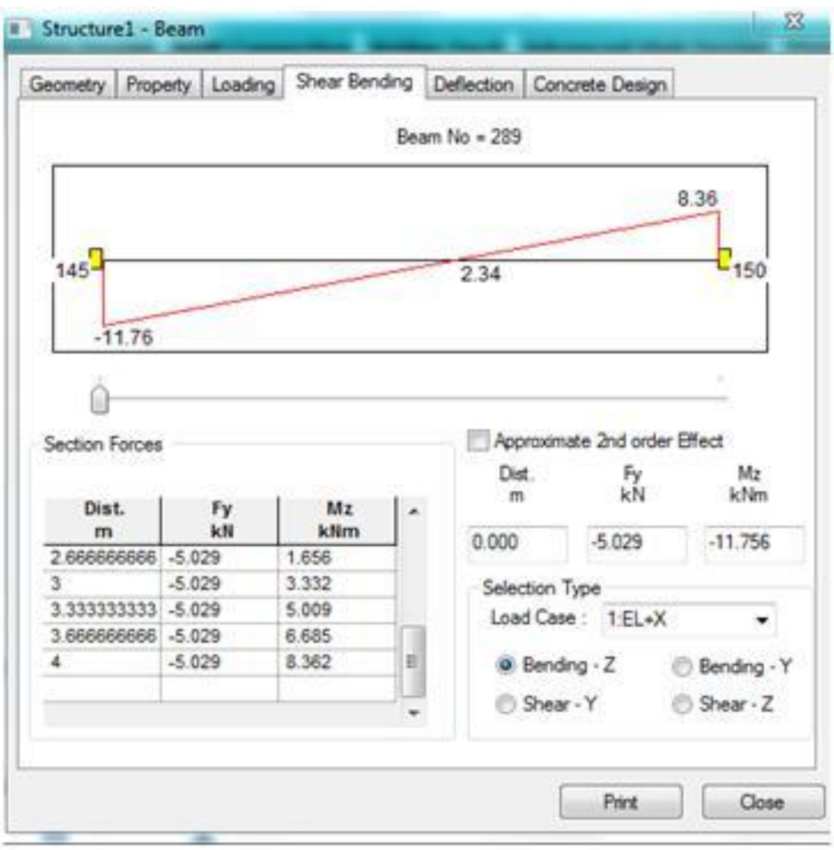
Structural Wall-Frame Systems

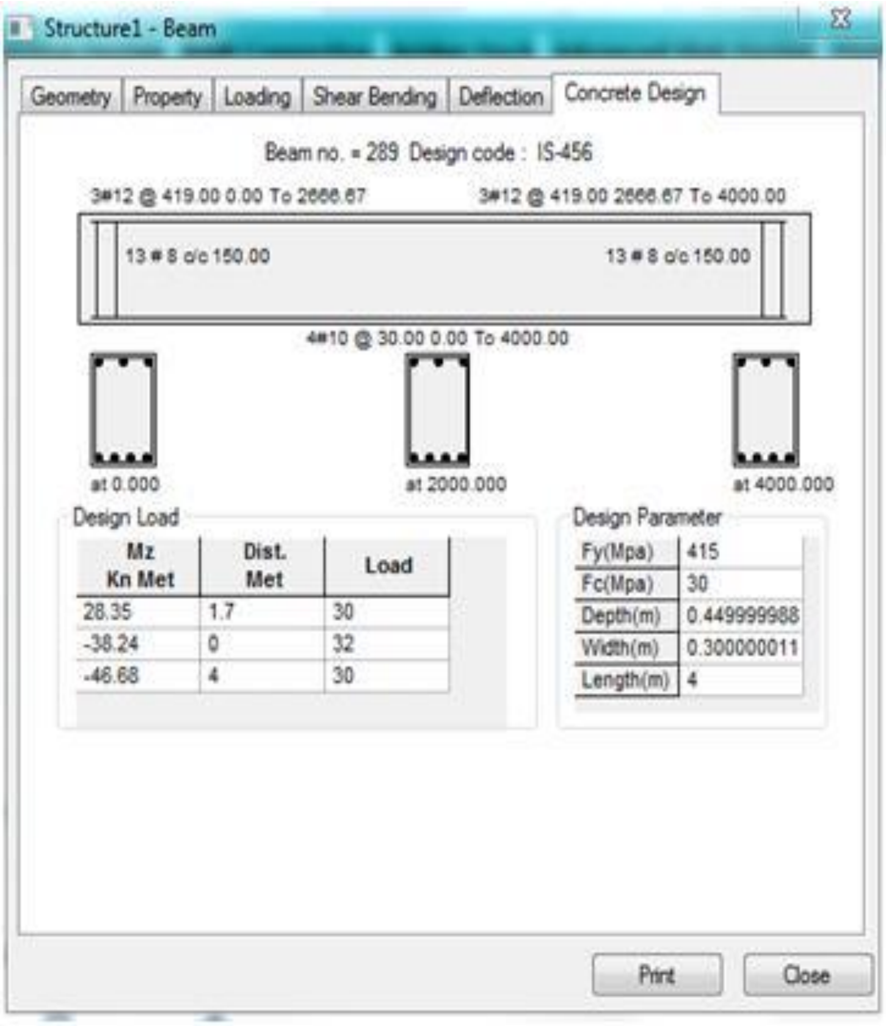
Earthquake resistant buildings should possess, at least a minimum lateral stiffness, so that they do no swing too much during small levels of shaking. Moment frame buildings may not be able to offer this always. When lateral displacement is large in a building with moment frames only, structural walls, often commonly called shear walls, can be introduced to help reduce overall displacement of buildings, because these vertical plate-like structural elements have large in-plane stiffness and strength

Therefore, the structural system of the building consists of moment frames with specific bays in each direction having structural walls (Figure 3.29b). Structural walls resist lateral forces through combined axial-flexure-shear action. Also, structural walls help reduce shear and moment demands on beams and columns in the moment frames of the building, When provided along with moment frames as lateral load resisting system. Structural walls should be provided throughout the height of buildings for best earthquake performance. Also, walls offer best performance when rested on hard soil strata.

Consider the five-storey building, but with structural walls as shown in Figure 3.42. The first case differs from the rest in the position of the structural walls in both direction – the walls are at the building periphery in the first case, while they are placed near the centre in the others. The last two cases represent buildings with twice wall area in the Y-direction; in the last case, two short (one-bay) walls are combined to form one long (two-bay) wall. Structural walls, owing to their large lateral stiffness, draw most of the lateral force and thereby help reduce demands on columns and beams.







INPUT RESULTS:

STAAD SPACE

START JOB INFORMATION

ENGINEER DATE 22-Feb-17

END JOB INFORMATION

INPUT WIDTH 79

UNIT METER KN

JOINT COORDINATES:

4; 72 19 -3 14; 73 0 3 0;
74 19 3 0; 75 19 3 17; 76 0 3 17; 77 4 3 17; 78 4 3 0; 79 8 3 17;
80 8 3 0; 81 11 3 17; 82 11 3 0; 83 15 3 17; 84 15 3 0; 85 0 3 3;
86 4 3 3; 87 8 3 3; 88 11 3 3; 89 15 3 3;
90 19 3 3; 91 0 3 7; 92 4 3 7;
93 8 3 7; 94 11 3 7; 95 15 3 7; 96 19 3 7;
97 0 3 10; 98 4 3 10;
99 8 3 10; 100 11 3 10; 101 15 3 10; 102 19 3 10; 103 0 3 14;
104 4 3 14; 105 8 3 14; 106 11 3 14; 107 15 3 14; 108 19 3 14;
109 0 6 0; 110 19 6 0; 111 19 6 17; 112 0 6 17; 113 4 6 17; 114 4 6 0;

115 8 6 17; 116 8 6 0; 117 11 6 17; 118 11 6 0; 119 15 6 17; 120 15 6 0;

START CONCRETE DESIGN
CODE INDIAN
DESIGN BEAM 1 TO 60 97 TO 156 193 TO 252 289 TO 348
DESIGN COLUMN 61 TO 96 157 TO 192 253 TO 288 349 TO 384

CONCRETE TAKE
END CONCRETE DESIGN
PRINT ANALYSIS RESULTS FINISH
SUMMARY:
0 0 0; 2 19 0 0; 3 19 0 17; 4 0 0 17; 5 4 0 17; 6 4 0 0; 7 8 0 17;
8 8 0 0; 9 11 0 17; 10 11 0 0; 11 15 0 17; 12 15 0 0; 13 0 0 3;
14 4 0 3; 15 8 0 3; 16 11 0 3; 17 15 0 3; 18 19 0 3; 19 0 0 7; 20 4 0 7;
21 8 0 7; 22 11 0 7; 23 15 0 7; 24 19 0 7; 25 0 0 10; 26 4 0 10;
27 8 0 10; 28 11 0 10; 29 15 0 10; 30 19 0 10; 31 0 0 14; 32 4 0 14;
33 8 0 14; 34 11 0 14; 35 15 0 14; 36 19 0 14; 37 0 -3 0; 38 19 -3 0;
39 19 -3 17; 40 0 -3 17; 41 4 -3 17; 42 4 -3 0; 43 8 -3 17; 44 8 -3 0;
45 11 -3 17; 46 11 -3 0; 47 15 -3 17; 48 15 -3 0; 49 0 -3 3; 50 4 -3 3;
51 8 -3 3; 52 11 -3 3; 53 15 -3 3; 54 19 -3 3; 55 0 -3 7; 56 4 -3 7;
57 8 -3 7; 58 11 -3 7; 59 15 -3 7; 60 19 -3 7; 61 0 -3 10; 62 4 -3 10;
63 8 -3 10; 64 11 -3 10; 65 15 -3 10; 66 19 -3 10; 67 0 -3 14;
68 4 -3 14; 69 8 -3 14; 70 11 -3 14; 71 15 -3 1

The obtained results of static and dynamic analysis in OMRF & SMRF are compared for different columns under axial, torsion, bending moment and displacement forces. The results in graph-1 shows that there is equal values obtained of axial forces in static and dynamic analysis of OMRF structure. The results in graph-2 shows that the values are obtained for torsion in static analysis are negative and dynamic analysis values are positive. The results in graph-3 here we can observe that the values for bending moment at dynamic analysis values are high in initially for other columns it decreased gradually as compared to that of static analysis.

The results in graph-4 we can observe that the values for displacement in static analysis of OMRF values are more compared to that of dynamic analysis values of same columns. The results in graph-5 shows that the values obtained of axial forces in dynamic analysis of SMRF structure values are high compare to static analysis

CONCLUSIONS

The effect of the basement on the seismic response of high-rise buildings and the effect of the lateral forces applied to the superstructure on the member forces in the basement were investigated in this study and the following conclusions could be drawn.

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4. IS: 875-1987 (part-1) for Dead Loads, code of practice of Design loads (other than earthquake) for buildings and structures.
5. IS: 875-1987 (part-2) for Live Loads or Imposed Loads, code of practice of Design loads (other than earthquake) for buildings and structures.