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Study the Behavior of Multistory Building with Consideration of Non-Structural Element

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***Abstract* - Non-structural elements are not a part of the main load-resisting system. Non-structural elements are those elements within a building that are not considered to be part of either the primary or secondary structural systems. Because of that these non-structural elements are often neglected from the structural design point of view. Performance of past earthquake is clearly defined the absence of non-structural elements it has resulted in poor performance in life of buildings. In absence of design provisions for non-structural elements and their attachments which result in huge loss of human lives and structural damage. Non-structural elements such as sign board, ceiling, Architectural elements such as, parapets, cladding systems, sign boards, etc. and Mechanical equipment such as, for example, boilers, piping systems, fire protection systems and Electrical equipment such as electric motors, light fixtures, etc. Indian seismic code IS 1893 (Part 1, part 2, part 3 and part 4): 2002 does not have specific provisions on design of non-structural elements and their connections or attachments.**

This paper shows the application of a displacement sensitive element like sign board through solved example. And shows different parameters such as base shear, displacement, Mass Participation, time period, Node Displacement, Beam Displacement and Effect of nonstructural Element (Sign board) of the building by using Staad software.

Keywords* - *Non-structural element, Seismic analysis.

I. INTRODUCTION

1.1 General

The behavior of a building during earthquake depends on its overall shape, size and geometry. The seismic performance of both regular and irregular shape buildings, depends on the height of building along with other important structural parameters The design of every structure subject to seismic movement should consider that the non-structural elements in building such as ceilings, panels, windows and doors as well as equipment, mechanical and sanitary installations. Non-structural elements should be designed to resist the seismic forces or seismic relative displacement depending on their nature. During an earthquake, the non-structural elements are subjected to large relative displacements depending on their nature. These are three types of risk associated with the earthquake damage of non-structural elements: loss of life or injury to building occupants, loss of property especially in commercial buildings, loss of function of an important building or lifeline structure. for example, fire resisting system, communication facilities, telecom Centre.

1.2 Non-structural element: -

The design of every structure subject to seismic movement should consider that the non-structural elements in building such as ceilings, panels, windows and doors as well as equipment, mechanical and sanitary installations. Non-structural elements should be designed to resist the seismic forces or seismic relative displacement depending on their nature. Serval parameters have been considered, for example, dynamic amplification of the component relative to the fundamental period of structure; ductility, redundancy, and energy dissipation capacity of the element and its attachment to the structure; vertical location of the element in the building importance and weight of the non-structural elements itself.

Classification of Non-structural element [1]: -

1. Acceleration sensitive
2. Deformation sensitive
3. Both deformation and acceleration sensitive.

1.2.1 Acceleration sensitive: -

Acceleration sensitive non-structural elements should be designed according to the force provisions. Acceleration sensitive nonstructural components are vulnerable to sliding, overturning, or tilting. Mechanical and electrical components are generally acceleration sensitive.

Design Seismic Force: -

Design seismic force, F_p on the non-structural element should be calculated using the following expression [1]

$$F_p = \frac{Z}{2}\left(1+\frac{x}{h}\right)\frac{a_p}{R_p} I_p . W_p \geq 0.10 W_p \qquad \text{......... (1)}$$

where,

Z = zone factor given in IS 1893 (part 1): 2016

x = height of point of attachment of the non-structural element above the foundation

h = height of the structure

a_p = component amplification factor

R_p = component response modification factor

I_p = importance factor of the non-structural element

W_p = weight of the non-structural element.

For vertical non-structural elements, F_p, will be the horizontal force, and for horizontal non-structural elements, F_p , will be the vertical force.

Connection: -
Connection and attachment shall be bolted, welded, or otherwise positively fastened without consideration of frictional resistance produced by the effect of gravity.

1.2.2. Deformation sensitive: -
Non-structural components are regarded as deformation sensitive when they are affected by supporting structure's deformation, especially the inter-storey drift. Good performance of deformation sensitive non-structural elements can be ensured in two ways:

i) by limiting inter-storey drift of the supporting structure in case of important non-structural elements
ii) by designing the element to accommodate the expected lateral displacement without damage.

Seismic relative displacement: -
Seismic relative displacement equations are provided to support the selection and design of cladding, stairwells, piping systems, sprinkler systems, and other components that are connected to the building at multiple levels.

1.For two connection points on the same structure A, one at a height hx, and other at a height hy, seismic relative displacement shall be determined as:

$D_p = \delta xA - \delta yA$ ……… (2)

D_p is not required to be taken as greater than R (hx- hy) $\frac{\Delta aA}{hsx}$

δxA = deflection at building level x of structure A due to design seismic load determined by elastic analysis, and multiplied by response reduction factor (R) of the building as per IS 1893 (part 1): 2016
δyA = deflection at building level y of structure A due to design seismic load determined by elastic analysis, and multiplied by response reduction factor (R) of the building as per IS 1893 (part 1): 2016
Hx = height of level x to which upper connection point is attached
hy = height of level y to which lower connection point is attached
ΔaA = allowable storey drift for structure A calculated as per 7.11.1 of IS 1893 (part 1): 2016
hsx = storey height below level x.

2. For two connection points on separate structures A and B, or separate structural systems, one at height, hx , and the other at a height, hy , D_p shall be determined as:

$D_p = |\delta xA| + |\delta yB|$ ……… (3)

D_p is not required to be taken as greater than

R(hx $\frac{\Delta aA}{hsx} + hy\frac{\Delta aB}{2hsx}$)

where,
δyB = deflection at building level y of structure B due to design seismic load determined by elastic analysis, and multiplied by response reduction factor, R, of the building as per IS 1893 (part 1): 2002,
ΔaB = allowable storey drift for structure B calculated as per IS 1893 (part 1): 2016.

1.3.3. Both acceleration and deformation sensitive: -
Some components may be both acceleration and deformation sensitive. They must be analyzed for both forms of response, that is, design seismic force and seismic relative displacement.

2. HISTORICAL BACKGROUND

2.1 Design philosophy and design provisions in various seismic codes

Goutam Mondal and Sudhir K Jain [1], In this study is concerned with the contains proposed provisions for inclusion in IS 1893, detailed commentary of the proposed clauses as well as some solved examples of the seismic design of non-structural elements. This paper also shows the application of these provisions for equipment, equipment supported on vibration isolator, and for a displacement sensitive element like sign board through. solved examples

Goutam Mondal and Sudhir K Jain [2] In this paper, Design of non-structural elements for buildings: A review of codal provisions .This paper reviews the design philosophy and design provisions of several international seismic codes and compares design lateral forces recommended in these codes. (Eurocode 8, UBC 1997, IBC 2003, NZS 4203:1992 and IS 1893)

Eurocode 8[3] This code requires very important and dangerous non-structural elements to be analysed by making a realistic model of the relevant structures and using floor response spectra. The design provisions in Eurocode 8 take into account ground motion, structural amplification, soil factor, and self-weight, flexibility and importance of the non-structural element.

Uniform Building Code (UBC) [4] This code describe The Uniform Building Code (UBC) recommends design seismic forces, Fp, for "elements of structures and their attachment, permanent non-structural components and their attachment, and the attachments for permanent equipment supported by a structure." Attachments of furniture and floor or roof mounted equipments weighing less that 181 kg are exempted from this requirement. Attachments include anchorages and bracing system.

International Building Code (IBC) [5] International Building Code 2003 recommends that the non-structural element should be designed to satisfy both seismic force and seismic relative displacement requirements. IBC 2003 also recommends minimum design seismic relative displacement D_p, between two connections of a component having multiple connections same structure and two connection points on separate structures. The effect of seismic relative displacements shall be considered in combination with displacements caused by other loads as appropriate.

New Zealand Code (NZS) [6] The New Zealand code specifies seismic forces on all parts of structures, including permanent non-structural components and their connections, and the connections for permanent services equipment supported by the structures. This code also recommends that the connection for regular structure should be designed by capacity design concept.

Indian Standard IS 1893 (Part 1): [7] Different codes assume that floor acceleration varies from the ground to the roof linearly; the acceleration at the roof is generally assumed as two to four times that at the ground level. In most of the seismic codes, a response modification factor is also included to account for the over strength and inelasticity of the non-structural element and/or its connections. In general, the design seismic force specified in the above codes should be applied for the non-structural element if its mass and/or stiffness does not affect those of the main structure significantly. When the mass and/or stiffness of the non-structural element affect significantly those of the supporting structure, structure and non-structural element should be analysed together considering the flexibility of the elements and its support

Goutam Mondal and Sudhir K Jain [8], In this study is concerned with the contains proposed provisions for inclusion in IS 1893, detailed commentary of the proposed clauses as well as some solved examples of the seismic design of non-structural elements. This paper also shows the application of these provisions for equipment , equipment supported on vibration isolator, and for a displacement sensitive element like sign board through solved examples.

Suresh L. Dhanani, Sumant B. Patel, Snehal V. Mevada [9], this research paper a numerical study has been carried out to investigate the seismic response of non-structural elements. The time history analysis has been performed to obtain the displacement and acceleration of non-structural elements which is placed on various floor of three-story asymmetric building. It is found that the displacement of non-structural elements is minimum at center of first floor.
It is observed from literature survey that the reviewed the design philosophy and design provisions on non-structural elements contained in several international seismic codes. One paper reviews and compares the design provisions of non-structural elements in different seismic codes and provides a basis of making a draft code for Indian scenario. The paper contains proposed provisions for inclusion in IS 1893, detailed commentary of the proposed clauses as well as some solved examples of the seismic design of non-structural elements. In Eurocode 8 code requires very important and dangerous non-structural elements to be analyzed by making a realistic model of the relevant structures and using floor response spectra. In Uniform Building Code (UBC) This code described The Uniform Building Code (UBC) recommends design seismic forces, f_p , for elements of structures and their attachment. New Zealand Code (NZS) code also recommends that the connection for regular structure should be designed by capacity design concept. In Indian Standard IS 1893 Different codes assume that floor acceleration varies from the ground to the roof linearly; the acceleration at the roof is generally assumed as two to four times that at the ground level. In most of the seismic codes, a response modification factor is also included to account for the over strength and inelasticity of the non-structural element and its connections. In general, the design seismic force specified in these codes (Eurocode 8, UBC , IBC , NZS) should be applied for the non-structural element if its mass and stiffness does not affect those of the main structure significantly. When the mass or stiffness of the non-structural element affect significantly those of the supporting structure, structure and non-structural element should be analyzed together considering the flexibility of the elements and its support.

The Provisions of seismic relative displacement should be included for displacement sensitive elements that are attached to the structure at multiple points, for example, piping system, stairwells, cladding, etc. And It is necessary to define clearly the displacement sensitive and force sensitive elements. Amplification of lateral force that increases with the increase of vertical location of the non-structural elements should be included for the design of the non-structural elements and their attachments. The Importance factor for various types of non-structural elements should be defined clearly. A parameter should be included to take care of flexibility of the non-structural elements. And a modification factor should be considered that represents ductility, redundancy, and energy dissipation capacity. Codes generally recommend that the non-structural elements should be designed for much higher seismic coefficient values than the supporting building itself. Most of these codes provide simplified method to obtain design seismic force which depends on the response of its supporting building, size and weight of the element, relative location of the element in the building, flexibility of the component, etc.

3. OBJECTIVES

To study the different parameters of the buildings such as base shear, displacement, time period with respect to Non-structural element such as sign board.

4. PRELIMINARY DATA CONSIDERED FOR THE ANALYSIS:

a) Material Properties:
Assuming, G+18 number of storey are considered. The Plan is having Dimension is 30.36X17.15 m. M30 grade of concrete and Site location is Delhi which is in zone IV And the Height of Each Story is 3.0m. Having Inner and outer Wall thickness is 0.15 m. Slab Thickness is 0.125 m. Frame Type is Ordinary Moment Resisting Frame (OMRF) and Soil Type is medium or stiff soils. Also, considering Grade of steel is Fy500.

Columns Details for G+18 building (column dimension)

1. Foundation to 6th floor- 300x750mm
2. 7th floor to 14th floor- 300x600mm
3. 15th floor to 18th floor- 300x530mm

Beams Details for G+18 building (Beam dimension)

1. Foundation to 6th floor- 300x750mm
2. 7th floor to 14th floor- 300x600mm
3. 15th floor to 18th floor- 300x530mm

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b) The basic parameters considered for the Analysis and design

- Live load in floor area is 3kN/m^2
- Dead load is 10.5 kN/m^2
- Floor finish load is 1.5 kN/m^2
- Stair case loading is 3 kN/m^2

c) Earthquake parameters considered

- Zone is IV (DELHI)
- Soil type is Medium soil
- Zone factor is 0.36
- Static Time period is Based on IS 1893
- Importance factor is 1.5

Following fig shows the nonstructural element resting on the roof of the building as
[sign board] by using point load in the Staad pro model .

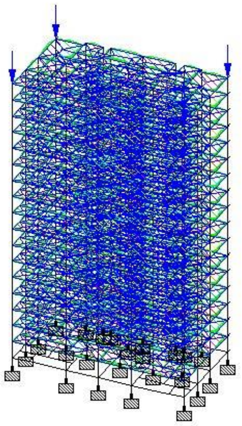
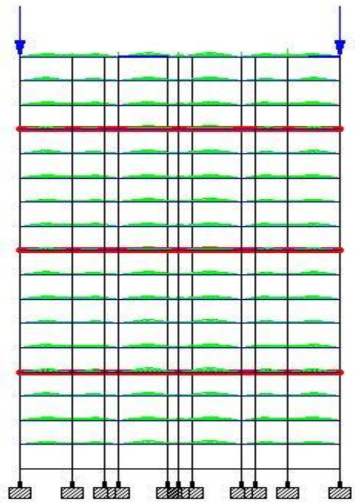


Fig.01 G+18 storey structure



Following fig shows the plan shows the Loading plan view of nonstructural element resting on the different floor of the building as [Sign Board] by using area load in the Staad pro model.

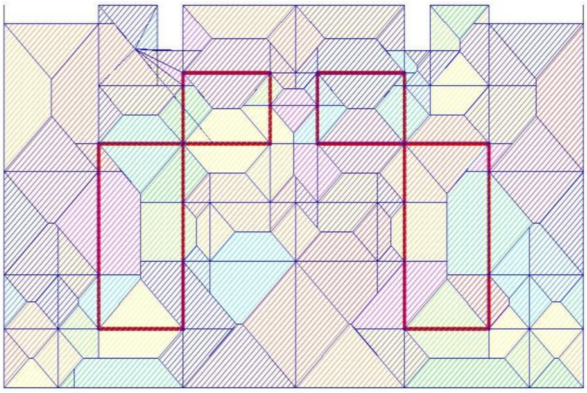


Fig.02 Floor plan of nonstructural element resting

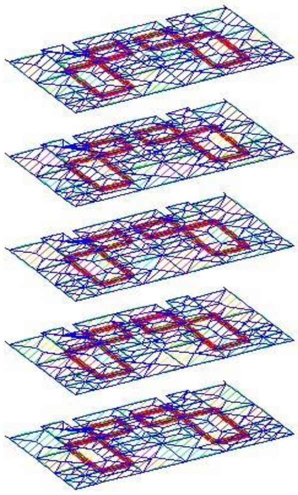


Fig.03 Nonstructural element resting on different floors

5. PROBLEM FORMULATION

a) **Details of the pole**

Hoarding board
Size of board is 3mx6m

- Section is used 0.05m x0.05m pipe (for bracing)
- Signage is hanged on 0.038m x 0.05m pipe covered with ACP panels.
- Steel Column of diameter 0.35m is provided to support the frame of hoarding.
- Type of Structure: Steel Structure.

b) Wind calculation

Preliminary data:
Wind Load As per IS 875 Part 3 (2015)
Risk Coefficient (K_1) is 1
Terrain or Height Factor (K_2) is 0.91
Topography Factor (K_3) is 1

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Basic wind Speed (V_b): 39m/s (Delhi)
Design Wind Speed (V_z): V_b x K_1 x K_2 x K_3 = 39x1x0.91x1 = 35.49 m/s (IS: 875 PT-3, Sec5.3) .... (4)
Design Wind Pressure (p_z): $0.6(V_z)^2$ =0.6 x $(35.49)^2$ = 755.72 /1000= 0.755kN/m² .... (5)
After considering the above wind load data the structure is analyzed using staad pro software.
Area of Hoarding is 3x6m
(Design wind pressure) X (Area of hoarding) = 0.755 x (3x6) =13.59kN
Dividing this load and applying on node points = 13.59/32= 0.424 kN
Applying UDL at the plate (Width of plate=0.1m)
= 0.755x0.1=0.0755 kN/m
Applying this load in Staad-pro Software.

Parameters-
V_z = design wind speed at height z, in m/s;
K_1 = probability factor (risk coefficient) (Cl. 6.3.1)-In the design of structure a regional basic wind speed for terrain is consider.
K_2 = terrain roughness and height factor (Cl. 6.3.2)- Selection of terrain categories is mainly depending on the effect of obstructions which constitute the ground surface roughness.
K_3 = topography factor (Cl. 6.3.3)- The effect of topography is to accelerate wind near the summits of hills or crests of cliffs, escarpments or ridges and decelerate the wind in valleys or near the foot of cliffs, steep escarpments, or ridges.

C. Design of a large sign board attached to a building

Problem statement:

A neon sign board is attached to a 18-storey building in Delhi (Seismic zone IV). It is attached by two anchors at height 10.0m and 6.0m. from the elastic analysis under design seismic load, it is found that the deflections of upper and lower attachments of the sign board are 45.0mm and 35.0mm, respectively. Find the design relative displacement.

Solution:
Since sign board is a displacement sensitive non-structural element, it should be designed for seismic relative displacement.
hx = height of level x to which upper connection point is attached, 10.0m
hy = height of level y to which lower connection point is attached, 6.0m
Deflection at building level x of the structure A due to design seismic load determined by elastic analysis = 45mm
Deflection at building level y of the structure A due to design seismic load determined by elastic analysis = 35mm
Response reduction factor of the building R= 5 (special RC moment resisting frame, table-7 of IS 1893 (part 1): 2002

$\delta xA = 5\ x\ 45 = 225mm$
$\delta yA = 5\ x\ 35 = 175mm$
1) $Dp = \delta xA - \delta yA$ .... (6)
= (225-175) mm = 50mm

Design the connections of neon board to a accommodate a relative motion of 50mm

2) Alternatively, assuming that the analysis of building is not possible to assess deflections under seismic loads, one may use the drift limits
Maximum inter-storey drift allowance as per Clause 7.11.1 of IS 1893 (part 1) :2002 is 0.004 times the storey height, that is:

$$\frac{\Delta aA}{\text{hsx}} = 0.004$$

1) $Dp = R(hx - hy)\,\dfrac{\Delta aA}{\text{hsx}}$ .... (7)
= 5 (10,000-6,000) (0.004) mm
= 80mm

The neon board will be designed to accommodate a relative motion of 80mm.

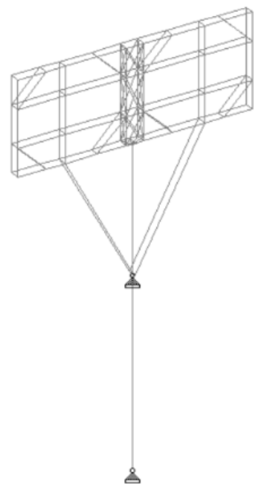

Fig.04 Sign board

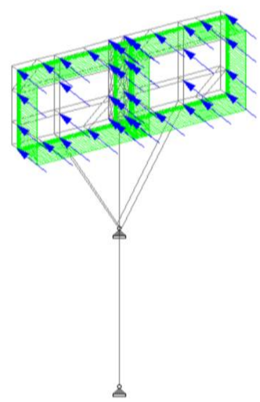

Fig: 05 Staad Pro Model of sign board after applying point load of 0.424kN

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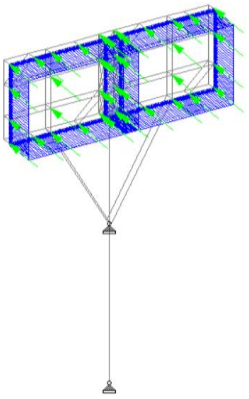

Fig:06 Staad Pro Model of sign board after applying point load of 0.0755 kN/m

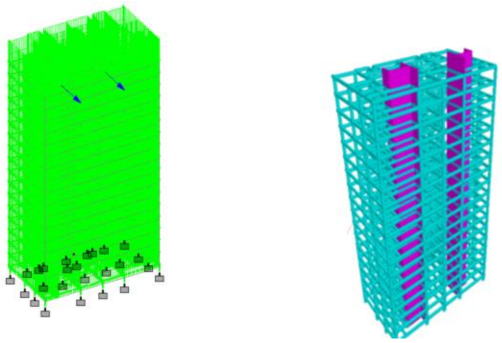

Fig. 07 building after applying two sign boards at columns with shear wall

6. RESULTS AND DISCUSSION

6.1 Result

This paper shows the application of a displacement sensitive element like sign board through solved example. And shows different parameters such as base shear, displacement, Mass Participation, time period, Node Displacement, Beam Displacement and Effect of nonstructural Element (Sign board) of the building by using Staad software.

1. Modal Time period
   It is the modal time period of vibration. Time of 4seconds.
   In G+18 building with consideration two sign boards (Non-structural element) then the maximum model time period is 6.3216 secs. obtained.

Table 1. Modal time period

Modes (1)	Modal Time Period (Secs) (2)
1	1.4311
2	3.8248
3	1.9102
4	6.3216
5	1.2759
6	1.1010

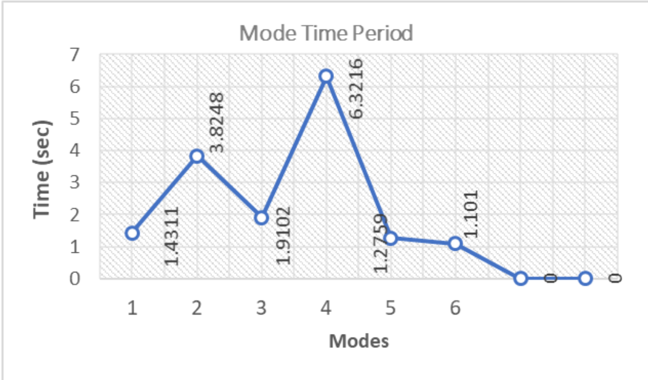

Fig 08. Modal time period

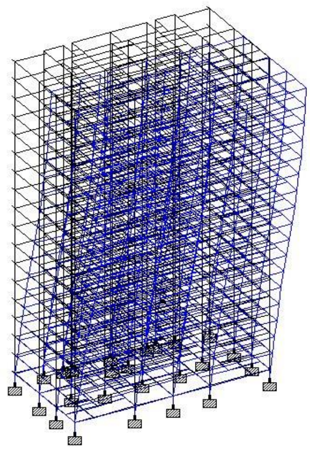

Fig.09 Modal Time Period in 3-D view

2. Mass Participation in Z
   "The effective mass participation factor represents the percentage of the system mass that participates in a particular mode."
   In G+18 building with consideration two sign boards then the maximum Mass Participation in Z direction is 84.540% obtained.

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Table 2. Mass participation in Z

Modes (1)	Mass participation factor in z (%) (2)
1	18.496
2	67.929
3	67.954
4	68.035
5	84.526
6	84.540

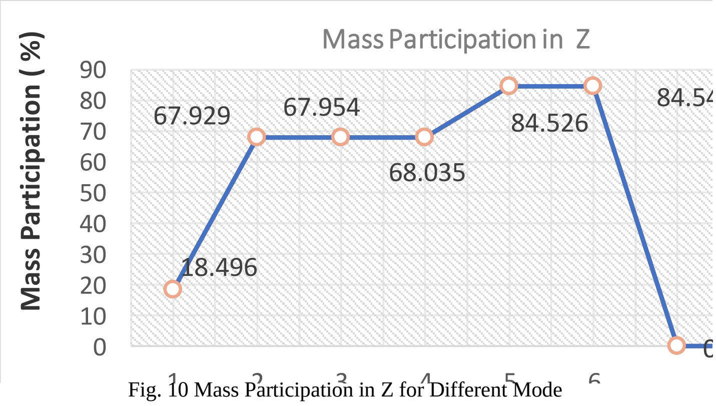

Fig. 10 Mass Participation in Z for Different Mode

3. Base shear
   Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. It is calculated using the seismic zone and soil material.
   In G+18 building with non-structural element the base shear values for X, Z are more. In x-direction 24413.39KN and in z-direction 24301.25KN.

Direction (1)	Base Shear (kN) (2)
Base shear X	24413.39 KN
Base shear Z	24301.25 KN

Table 3. Base shear

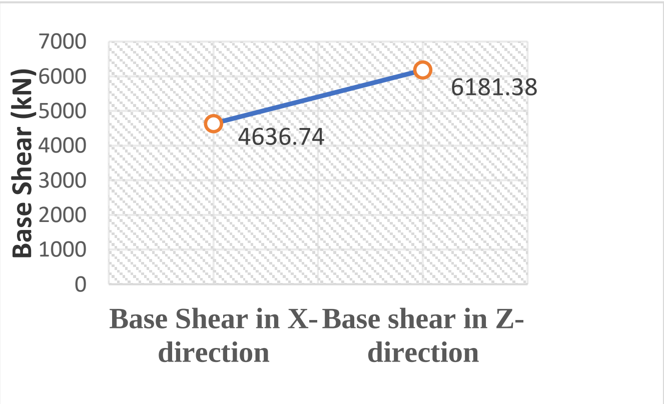

Fig. 11 Base shear in X and Z

4. Node Displacement
   Node displacement is the overall motion of the object or the minimum distance between the starting point of the object and the final position of the object at node. In G+18 building with consideration of Non-structural element building Node Displacement values for X, Y and Z direction are obtained. And maximum nodal displacement is 106.169mm

Directions (1)	Node Displacement (mm) (2)
X	76.088
Y	106.169
Z	48.722

Table 4. Node displacement

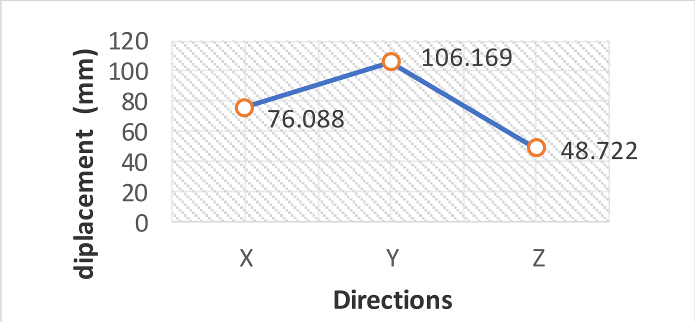

Fig. 12 Node Displacement details in X, Y and Z direction

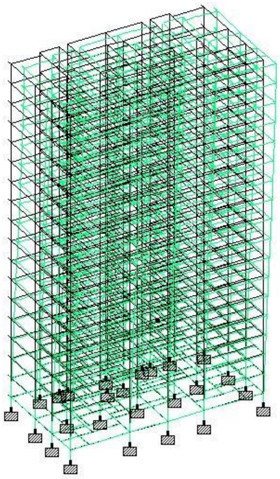

Fig. 13 Node Displacement details in 3-D view

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5. Beam Displacement
Beam displacement is the overall motion of the object or the minimum distance between the starting point of the object and the final position of the object at beam.In G+18 building with consideration two sign boards Beam Displacement values for X, Y and Z direction are obtained. And maximum Beam displacement is 851.78mm

Types of load (1)	Displacement (mm) (2)
DL	718.203
LL	43.209
EX	714.313
EY	851.78

Table 5. Beam Displacement

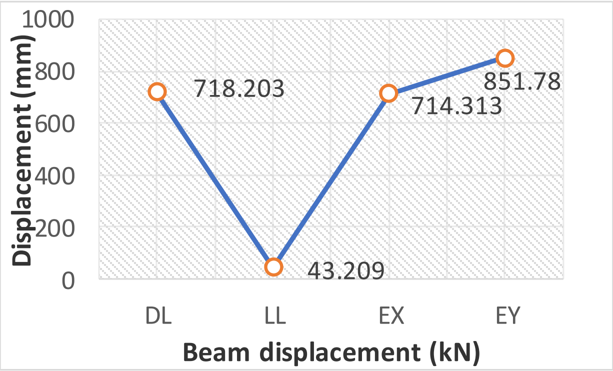

Fig. 14 Beams Displacement details

7.CONCLUSION

The main aim of this research was to study the behavior of multi storey building with consideration of Non-structural element such as sign board.in this paper two sign board are considered on two columns. Then the behavior of building parameters such as base shear, displacement, Mass Participation, time period, Node Displacement, Beam Displacement and Effect of nonstructural Element (Sign board) of the building by using Staad software.
Following conclusions are drawn based on the result discussed in the previous chapter:

1. In G+18 building with consideration two sign boards (Non-structural element) then the maximum model time period is 6.3216 secs. obtained.
2. Maximum Mass Participation in Z direction is 85.255% obtained
3. Base shear is calculated using the seismic zone and soil material. In G+18 building with non-structural element the base shear values for X, Z are more. In x-direction 24413.39KN and in z-direction 24301.25KN
4. Node displacement is the overall motion of the object or the minimum distance between the starting point of the object and the final position of the object at node. In G+18 building with consideration of Non-structural element building Node Displacement values for X, Y and Z direction are obtained. And maximum nodal displacement is 2612.87mm
5. Beam displacement is the overall motion of the object or the minimum distance between the starting point of the object and the final position of the object at beam. In G+18 building with consideration two sign boards Beam Displacement values for X, Y and Z direction are obtained. And maximum Beam displacement is 14.836mm.
6. It also necessary to analyses the structure with consideration of nonstructural Elements due to that the additional load is acting on structure and we get better behavior of the building.

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