International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Effect of Height and Position of Shear Wall on G+5 Multi-Storey Building for Zone III

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Abstract: ***Shear wall is a structural member that provides stability to structure against lateral loads. These walls play important role in multi-storey building situated in seismically active zones. They can resist large horizontal loads and simultaneously support gravity loads owing to its higher stiffness and strength. In this study, we have focused on the comparison between the effects of earthquake and wind loading on G+5 storey building with different positions of shear wall in Zone III. Twelve models were prepared and then analyzed for earthquake and wind loading in +X direction with the help of STAAD.Pro v8i software. These models include different position of full height shear wall and also include partial shear wall at different floor levels. Results were prepared in terms of maximum lateral displacements in the whole structure, nodal displacements at particular node and bending moments at corner column. The results were accurate and displayed acceptable performance in terms of lateral displacement and bending moment.***

From the analysis, it was found that lateral nodal displacements and bending moments are reduced in building with shear wall as compared to building without shear wall. Also, building with shear wall has more earthquake and wind resistance as compared to building without shear wall.

Keywords: ***STAAD.PRO, Shear wall, Seismic load, Wind load, Nodal displacements, Bending moment, Multi-Storey***

I. INTRODUCTION

Shear wall is a vertical member that transfers the lateral forces of the structure to the ground due to its cantilever action [1]-[3]. Shear walls always starts from foundation level and mostly goes up to full height of the building. Shear walls do not have fixed positions in building, but are generally preferred near staircase and lift area to control the vibrations produced due to movement of visitors and mechanical parts of elevators.

The thickness of shear wall varies from 150-400 mm depending on structural loading [4]. The reinforcing bars provided in shear wall have thickness in between 1/10 of wall thickness. They are of many types such as concrete shear wall, steel plate shear wall, plywood shear wall, etc.

Manuscript published on 30 September 2019
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II. METHODOLOGY

A. Load Calculations

Loads are given as per Indian Standard Code IS 1893:2002 and IS 800:2007 [5].

i. Gravity Loading

Dead loads and live loads are calculated as per IS 875 Part-I [6].

Live load = -4 kN/m^2

ii. Wind Loading

The static wind load is calculated as per IS 875 (Part-III) [7], [8]. According to IS 875 (Part-III),

$$V_Z = V_B \times K_1 \times K_2 \times K_3 \times K_4$$

Where

V_Z is the design wind speed at a height z meter in m/s.

V_B is the basic design wind speed at 10 m height.

P_Z is the design wind pressure at height z in meter.

$$P_Z = 0.6V_Z^2$$

The following assumptions are taken for the wind load calculation:

- Location: Lucknow
- Basic wind speed: 47 m/s
- Terrain category: 3
- K_1: 1.08 (life : 50 years)
- K_2: depending upon the variation of height
- K_3: 1 (for flat topography)
- K_4: 1 (for all other structure)

iii. Seismic Loading

The following expression is used for distribution of design base shear (V_B) along the height of the multi-storey building [9]:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Where

Q_i is the design lateral force at floor i

W_i is the seismic weight of floor i

h_i is the height of floor i measured from the base of building

n is the number of storeys in the building

B. Modeling of Structure

i. Description of building

The structure selected for this study is G+5 multi-storey building having a plan area of 25×20 m. The overall height of the building is 18 m and the building is assumed to be situated in Zone III (Lucknow). The foundation is assumed to be fixed and medium type of soil is considered for study. The analysis of the building was done using STAAD Pro and Indian Standard Code of Practice for Seismic Resistant Design of Buildings was used for design.

ii. Materials

In this study, high yield strength deformed bars are provided as per IS Code having yield strength 415 N/mm^2. Grade of concrete is M-25 with density 25 kN/m^3 is adopted. The density of masonry infill used for main and partition wall is 20 kN/m^3.

iii. Member dimensions

The size of beam and column provided are 400×250 mm and 400×400 mm respectively and both are modeled as frame element. The slab is provided horizontally over the floor area at each floor levels supported by beams having thickness 150 mm whereas, shear wall is provided vertically on the outer bay of the structure having thickness 150 mm. The infill walls are the partition wall that separates the different area of building. These walls are provided with brick masonry having thickness 230 mm for main wall or external walls and 115 mm walls for partition walls of building.

iv. *Models prepared for study*

In this study, total of 12 models are prepared with the help of STAAD.Pro v8i software for analysis of structure. It includes both model with shear wall and without shear wall with plan area 25×20 m and other properties and specifications of building have been stated above. These models are analyzed with seismic and wind loading in +X direction at zone III [10].

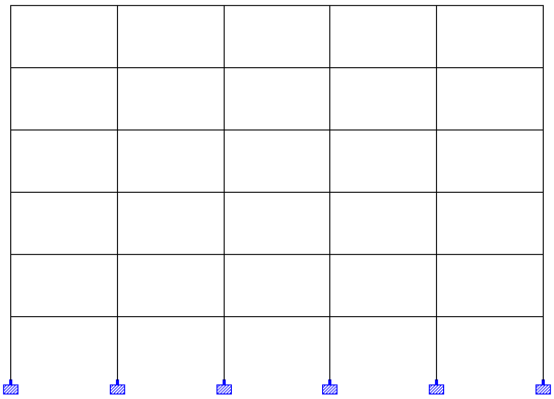

Fig. 1: Model 1 – without Shear Wall

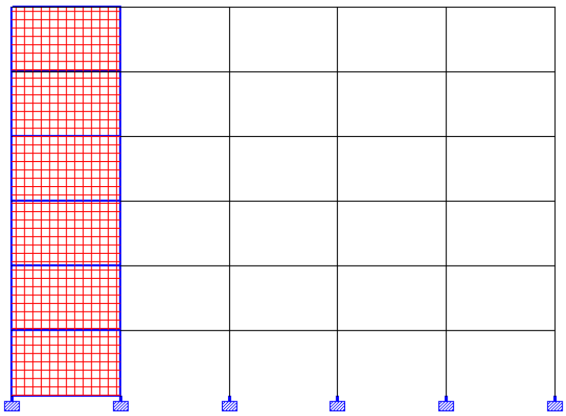

Fig. 2: Model 2 – Shear Wall at Bay 1

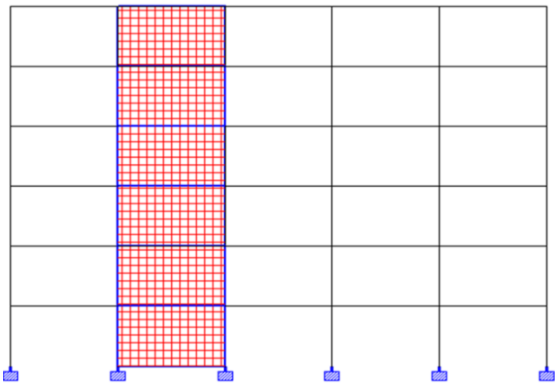

Fig. 3: Model 3 – Shear Wall at Bay 2

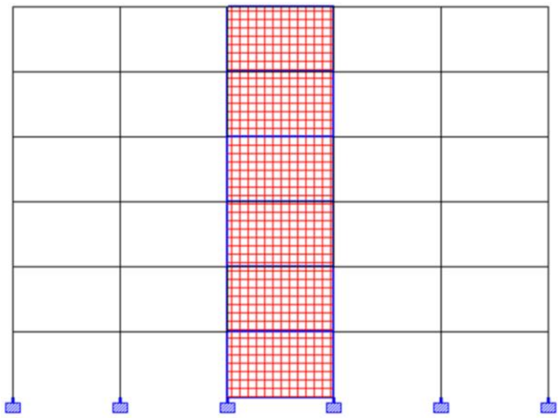

Fig. 4: Model 4 – Shear Wall at Bay 3

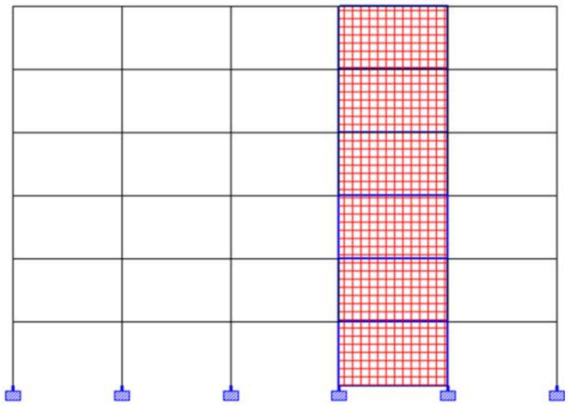

Fig. 5: Model 5 – Shear Wall at Bay 4

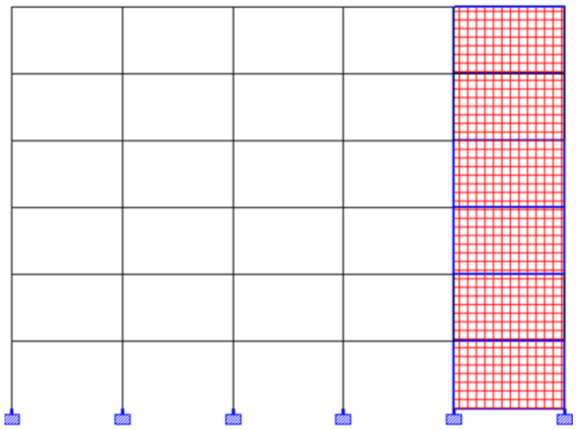

Fig. 6: Model 6 – Shear Wall at Bay 5

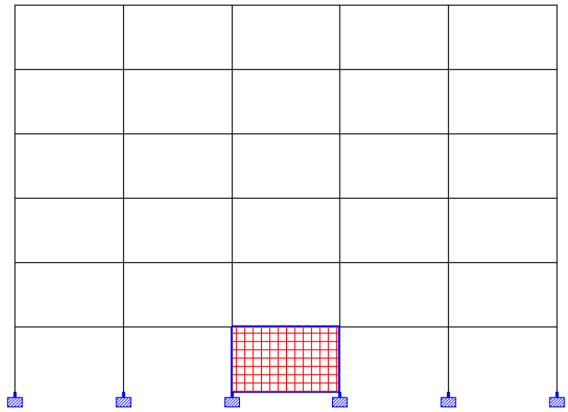

Fig. 7: Model 7 – Shear Wall up to 1st Floor

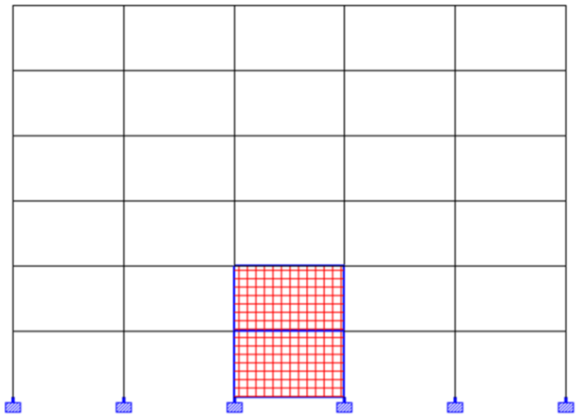

Fig. 8: Model 8 – Shear Wall up to 2nd Floor

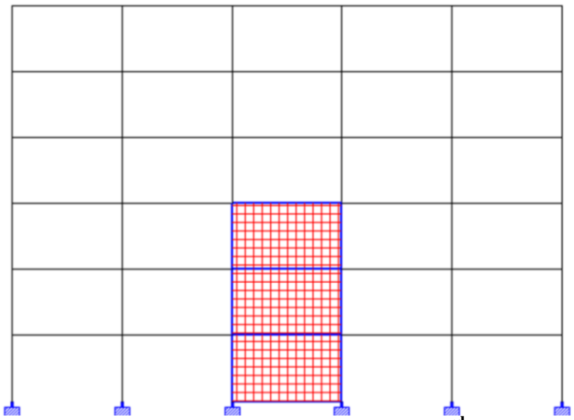

Fig. 9: Model 9 – Shear Wall up to 3rd Floor

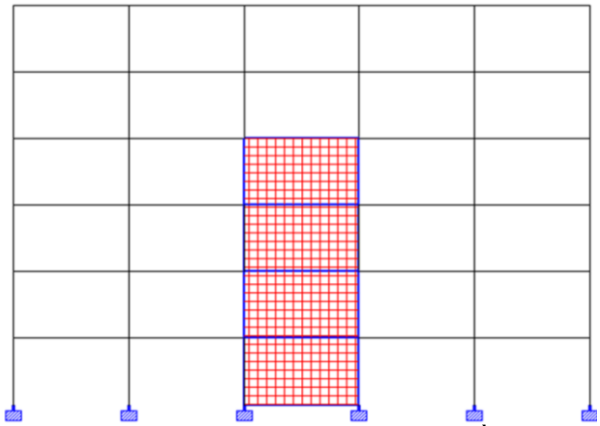

Fig. 10: Model 10 – Shear Wall up to 4th Floor

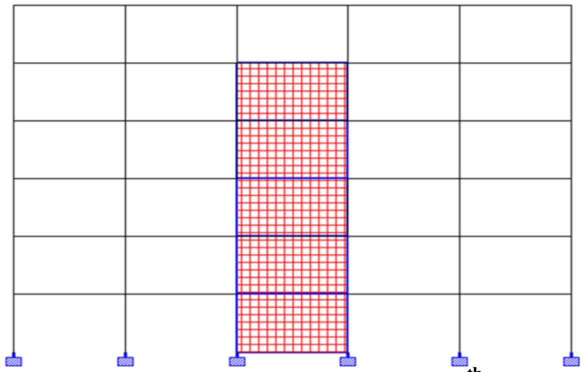

Fig. 11: Model 11 – Shear Wall up to 5th Floor

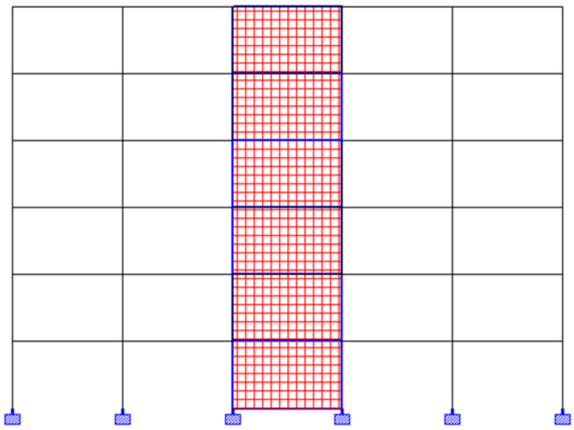

Fig. 12: Model 12 - Shear Wall up to full height

III. RESULTS AND DISCUSSIONS

A. Analysis Results for Maximum Nodal Displacement

In this section, we have discussed the maximum nodal displacement that occurred in overall structure for different models with and without shear wall due to dynamic loading in +X direction such as seismic or wind loading.

i. Shear wall at different bay positions

In this section, the results are given for various models with shear wall that changes its bay position. The comparative graph for maximum nodal displacement for various models due to seismic and wind loading in +X direction are shown below in Fig. 13.

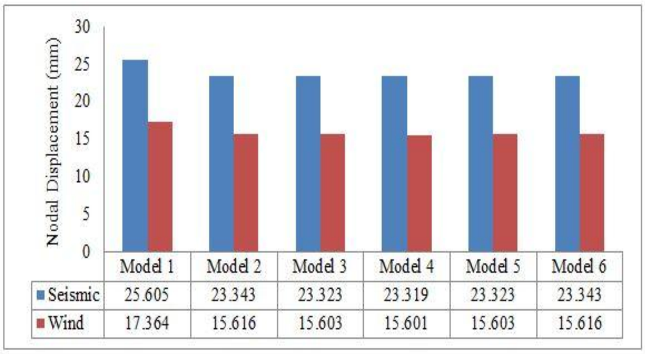

Fig. 13: Maximum Nodal Displacement due to Wind and Seismic loading in +X direction

ii. Shear wall at different floor levels

In this section, the results are given below for models with shear wall at different floor levels. The comparative graph for maximum nodal displacement for various models of shear wall at different floor levels due to seismic and wind loading in +X direction are shown below in Fig.14.

Retrieval Number: C4609098319/2019©BEIESP
DOI:10.35940/ijrte.C4609.098319
Journal Website: www.ijrte.org

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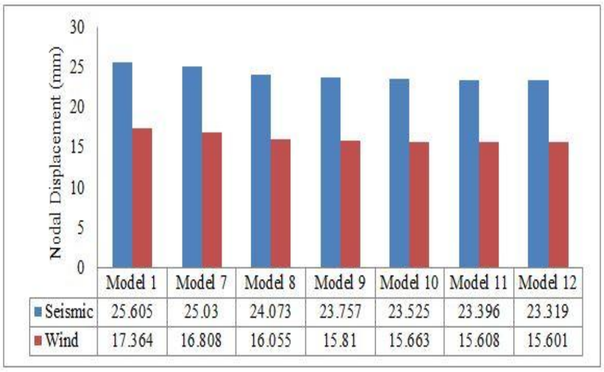

Fig. 14: Maximum Nodal Displacement due to Wind and Seismic loading in +X direction

B. Nodal Displacement at Corner Column Node

In this section, we have discussed the nodal displacements in structure due to dynamic loading in +X direction at corner column top node number 205 as shown below in STAAD.PRO model in Fig.15. The analysis of displacement are done at corner column on top node because the structure are assumed to be fixed at supports therefore, the maximum displacements will take place at top node rather than bottom supports.

Fig. 15: STAAD.PRO Model Showing Node Number 205

i. *Shear wall at different bay positions*

In this section, the results are given for models with shear wall that changes its bay position with different models. The comparative graph for nodal displacement for various models of shear wall due to seismic and wind loading in +X direction are shown below in Fig.16.

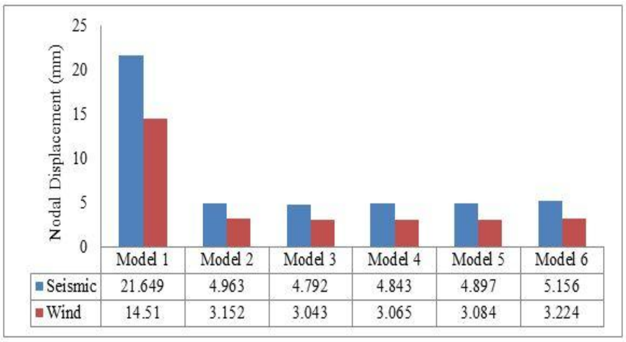

Fig. 16: Nodal Displacement at Node Number 205 due to Wind and Seismic loading in +X direction

ii. *Shear wall at different floor levels*

In this section, the results are given below for models with shear wall at different floor levels. The comparative graph for nodal displacement for various models of shear wall at different floor levels due to seismic and wind loading in +X direction are shown below in Fig.17.

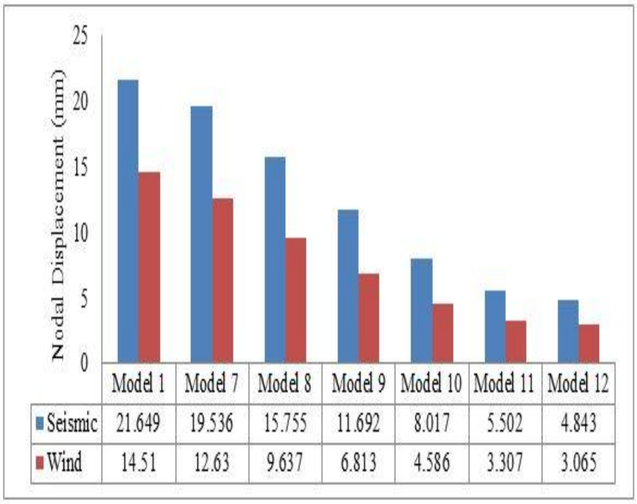

Fig. 17: Nodal Displacement at Node Number 205 due to Wind and Seismic loading in +X direction

C. Analysis Results for Bending Moment

In this section, we have discussed the results for bending moment for different models with and without shear wall at corner column number 295 due to dynamic loading such as seismic or wind loading. The selection of bottom column was done because the bottom corner columns of structure are more prone to higher bending moment compared to upper columns in structure. The beam number 295 is shown below in STAAD.PRO model in Fig. 18.

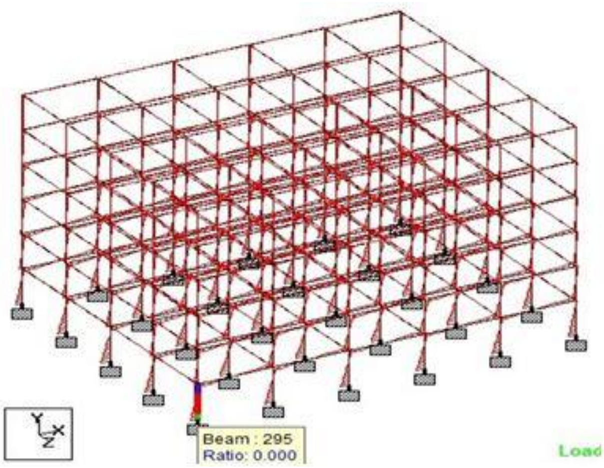

Fig. 18: STAAD.PRO Model Showing Beam Number 295

i. *Shear wall at different bay positions*

In this section, the results are given for models with shear wall that changes its bay position with different models. The comparative graph for bending moment for various models due to seismic and wind loading in +X direction are shown below in Fig.19.

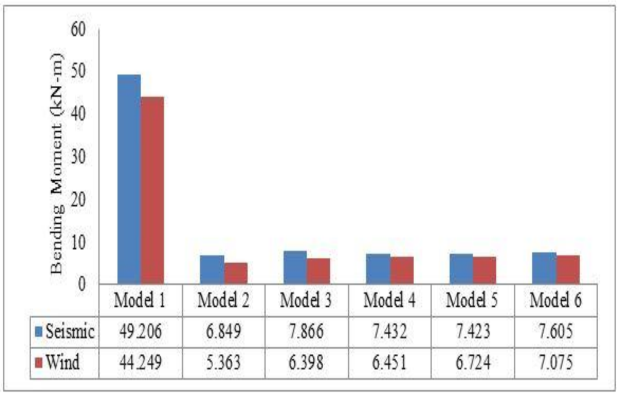

Fig. 19: Bending Moment due to Wind and Seismic loading in +X direction at Beam number 295

ii. Shear wall at different floor levels

In this section, the results are given below for models with shear wall at different floor levels. The comparative graph for bending moment for various models of shear wall at different floor levels due to seismic and wind loading in +X direction are shown below in Fig.20.

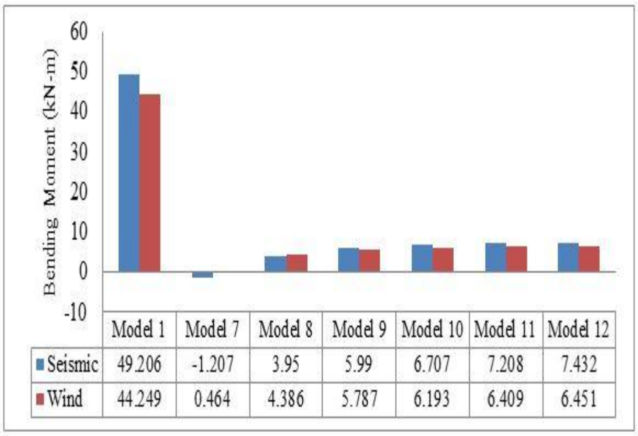

Fig. 20: Bending Moment due to Wind and Seismic loading in +X direction at Beam number 295

IV. CONCLUSIONS

During analysis, it was observed that the lateral nodal displacements are reduced in building with shear wall as compared to building without shear wall and building with shear wall has more earthquake and wind resistance as compared to building without shear wall. Also, Bending moments are reduced drastically in building with shear wall compared to building without shear wall.

Some of the main conclusions drawn from our present study are as follows:

1) The nodal displacement is higher for seismic load in comparison to wind load for Zone III.
2) With increase in height of Shear wall at different floor levels from foundation to top height of building, there is significant decrease in lateral displacement of the building.
3) There is no major difference in nodal displacement with different models of bay positions.
4) Bending moment is more for bottom node as compared to top node for all models due to fixidity of the bottom supports.
5) Bending moment does not make major difference for different bay positions of shear wall models.
6) Bending moment in column increases with increase in height of shear wall.

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Mr. Pankaj Yadav is currently working as a Site Engineer in Ace Consulting Engineer, Delhi. He has completed his Bachelor of Technology in Civil Engineering from Uttar Pradesh Technical University, Lucknow. He worked as Site Engineer for 3 years after his graduation in Civil Engineering. Afterwards, he completed his Master of Technology from Shri Ramswaroop Memorial University, Barabanki with honors degree. He has also published a Review Paper in International Conference organized at SRMU by Faculty of Civil Engineering under able guidance of Mr. Rishabh Joshi. His research interests include structural behavior due to random external loads on multi-storey building, recyclable building materials, self-healing concrete, etc.

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