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Structural Analysis and Design of Tall Buildings with Basements: Evaluating Performance Under Seismic Loads

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Abstract

The paper discusses the structural behavior of tall buildings with and without basements under seismic loading. It highlights the critical parameters such as base shear, lateral deflections, and storey drifts while analyzing structures with different configurations using STAAD Pro and ETABS software. The study concludes that basement walls contribute to reducing roof displacements and soft story effects, ensuring structural stability during seismic events.

Keywords: seismic analysis, tall buildings, basement walls, STAAD Pro, lateral deflections, structural stability.

1. Introduction

1.1 **Background**

- Overview of structural analysis for tall buildings and challenges posed by seismic and wind loads.
- Importance of integrating basements in high-rise buildings for stability and utility.

1.2 **Objectives**

- To evaluate seismic performance metrics: base shear, lateral deflections, and storey drifts.
- Comparative analysis using STAAD Pro between structures with and without basements.

2. Literature Review

2.1 **Key Findings from Previous Studies**

- Techniques for seismic analysis, including response spectrum and time history methods.
- Influence of basement walls on seismic response and structural ductility.
- Key research works reviewed:
    - E. Pavan Kumar et al. (2014): Analysis of B+G+15 buildings under seismic forces.
    - D.G. Lee and H.S. Kim (2001): Impact of basements on vibration periods.

2.2 **Gaps Identified**

- Limited focus on comparative seismic performance in high seismic zones (III and V).

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3. Methodology

3.1 **Structural Configurations**

- Two models considered:
  - G+9 without basement.
  - 2B+G+9 with and without basement walls.

- The dimensions and properties of the analyzed structures are as follows:

  Table :1 The dimensions and properties of the analyzed structures

Structural Part	Dimensions/Values
Building Type	General Tall Buildings
Length (X and Y directions)	30 m
Total Height	32 m (above ground level)
Column Size	230 mm x 450 mm
Beam Size	230 mm x 450 mm
Floor-to-Floor Height	3.2 m
Seismic Zone	III, V
Importance Factor (I)	1
Response Reduction Factor (R)	5
Soil Type	Medium
Damping	5%
Live Load	2 kN/m²

3.2 **Dynamic Analysis**

- Use of STAAD Pro for structural modeling.
- Analysis methods: Response spectrum and equivalent static.

3.3 **Seismic Zones**

- Evaluation for zones III and V as per IS 1893:2002.

3.4 **Key Design Parameters**

- Base shear calculations.
- Distribution of lateral forces.
- Storey-wise performance metrics.

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4. Results and Discussion

4.1 **Comparison in Zone III**

- Natural periods for structures with and without basements.

Table 2 : Natural Period (TN_NN)

Model	Maximum Natural Period (sec)
Without Basement	1.92
With Basement	2.21

- Variation in storey shear, lateral deflection, and storey drifts.

Table :3 Variation in storey shear

Storey	Without Basement	With Basement	Increment (%)
Basement 2	-	1150.25	-
Basement 1	-	1138.72	-
Ground	875.67	935.35	6.81%
9	378.96	435.37	14.88%

Table :4 Lateral Deflection (mm)

Storey	Without Basement	With Basement	Increment (%)
Basement 2	-	0.9	-
Ground	3.4	4.2	23.52%
9	11.1	15.5	39.63%

Table 5 Storey Drift (mm)

Storey	Without Basement	With Basement	Increment (%)
Basement 2	-	1.7	-
Ground	0.92	2.1	128.26%
9	0.35	0.85	142.85%

- Effect of basement walls in reducing displacement and drift values.

4.2 **Performance in Zone V**

- Enhanced seismic forces and their impact on structural performance.

Table 6 Lateral Deflections in X-Direction (mm)

Storey	Without Basement Wall	With Basement Wall	Decrement (%)
Basement 2	1.2	0.8	33.33%
Ground	5.6	2.1	62.50%
9	19.4	12.5	35.56%

Table 7 Storey Drifts in Z-Direction (mm)

Storey	Without Basement Wall	With Basement Wall	Decrement (%)
Basement 2	2.15	0.4	81.39%
Ground	2.45	0.75	69.38%
9	0.95	0.35	63.15%

- Differences in lateral deflections and base shear with increased seismic intensity.

4.3 **Role of Basement Walls**

- Contribution to structural stiffness and reduction in ductility demands.
- Observations on reduced soft story effects.

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5. Conclusions

- Basements introduce flexibility but significantly improve seismic performance when walls are included.
- Effective design with basement walls ensures structural integrity and minimizes lateral deflections and drifts during seismic events.
- Recommendations for incorporating basement walls in high-rise building designs in seismic zones.

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