10.48047/jocaaa.2026.35.07.02

"SEISMIC ANALYSIS OF RESIDENTIAL BUILDING WITH SHORT COLUMN EFFECT USING STAAD PRO"

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Abstract

Short-column effect is a significant structural concern that can lead to severe damage or even collapse of buildings during earthquakes. This study investigates the influence of short columns on the overall seismic behaviour of reinforced concrete (RCC) buildings. A G+4 storey RCC building is analysed under two conditions—constructed on level ground and on inclined ground—to understand how ground slope contributes to the formation and severity of short columns. Using STAAD Pro, both static and dynamic analyses are performed to evaluate key structural responses, including shear forces, bending moments, displacements, deflections, and ground-storey lateral movements.

The study highlights the adverse impact of short columns on displacement capacity and load-carrying behaviour. To mitigate these effects, shear walls are introduced at various strategic positions, and their efficiency is assessed by examining changes in, displacement, shear forces, vibration frequencies, The results demonstrate that the proper placement of shear walls significantly enhances the seismic performance of buildings affected by short-column behaviour.

Keywords: Short Column, RCC building, Earthquake, Response spectrum analysis, Shear wall

Literature Review

1. **Harumi Yashiro et al. (1990)** studied "Shear failure mechanisms of reinforced concrete short columns", experimental and analytical study on the shear failure mechanisms of reinforced concrete short columns of shear span ratio of 1.5 was carried out. They used 31 specimens for the experimental study and finite element analysis was applied for the analytical study by considering bond-splitting cracks of concrete surrounding tensile steels, the failure processes, until the maximum shear load, were followed. As a result, of the study they carried was the failure processes and stress condition of reinforced concrete short columns of shear span ratio of 1.5 are as follows: first, bending cracks and bending shear cracks occur in the end positions; next, shear cracks in the end positions occur due to bending yielding. Therefore, the solution for a seismic design of reinforced concrete structures such as beams, columns are necessary to be ductile enough to make sure the structures should not fail in brittle state under earthquake shear loading. For all column specimens, the cross section is 25x25 cm, the length is 75 cm, the ratio of shear span to depth is 1.5 and tensile steel ratio (pt) is 0.96 %. To cut bond between tensile steel bars and concrete, tensile steels are coated with wax at first, coated with grease next and finally covered with soft paper.

2. **K. Galal et al. (2005)** studied "Retrofit of RC square short columns", they analysed the performance of seven reinforced concrete short columns under lateral cyclic loading and constant axial load. Carbon or glass fiber reinforced polymers were used to strengthen the short columns. It is demonstrated experimentally that it is possible to strengthen the shear resistance of short columns such that a flexural ductile failure occurs by developing plastic hinges at both ends of the column. Anchoring of the fiber wraps to the columns was found to be effective in increasing the shear resistance and energy dissipation capacities of the columns. Low shear span/depth ratio makes a brittle column failure. Three layers of CFRP are applied. The unstrenghtened columns failed in shear were rehabilitated and later exhibited ductile behavior and enhanced shear resistance. The seven specimens had the same column overall dimensions. The specimens were divided into two groups: Group 1 includes SC 1 which is unstrengthened, SC2, SC1R, SC2R and SC1U and are strengthened with high content of transverse reinforcement. In Group 2 includes SC3 and SC3R has low content of transverse reinforcement. The column SC2 was strengthened using 3 layers of CFRP. SC1R included 4 layers of unidirectional glass FRP. SC1U was strengthened by 3 layers of CFRP similar to specimen SC2 but without anchors. In Group 2 (SC 3 and SC3R) had low transverse reinforcement ratio according to 1968 ACI design practice. SC3 was strengthened using 3 layers of CFRP. SC3R was retrofitted using 6 and 3 layers that provided by the 3 CFRP layers of SC3. Using anchored carbon fiber sheets rather than anchored glass fiber sheets for strengthening RC short columns increases both the shear force and the energy dissipating capacity. It also decreases the strains in the steel ties and the FRP along the column height.

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3. **Ercan Isik (2023)** studied structural models for three situations: the hill slope effect, band-type window and mezzanine floor, which may cause short column formation. The structural analyses by SAP2000 were compared with the reference building model with no short columns. Structural analyses were performed separately according to strength-based and deformation-based design approaches in the updated Türkiye Building Earthquake Code (TBEC-2018). Short column formation; the effects on soft-storey irregularity, the relative storey drifts, column shear force, plastic rotation in columns, roof displacement, base shear force and column damage levels were investigated. As a result of the analysis, it was determined that the relative drifts from the first floor of the building decreased significantly due to the band-type window and slope effect, which caused the second storey to fall into the soft-storey status. In addition, short-column formation caused a significant increase in both plastic rotation demand and shear force in short columns.

4. **Laila Taoufiq (2025)** performed a case study on the earthquake in Morocco he results indicated that the main causes of the observed damage were attributable to the nature of the soil, the short columns, soft story, the lack of sufficient reinforcement, and the construction materials used. An evaluation was conducted to assess compliance with Moroccan seismic regulations (RPS 2011) and identify deficiencies requiring revisions to the standard. This assessment also involved a comparison with other international seismic regulations, such as those in China and Eurocode 8, to examine best practices and learn valuable lessons. This comparative approach aims to enhance local standards by incorporating proven approaches to improving the seismic resistance of structures.

5. **Yilin Yue (2026)** investigated into the seismic performance of UHTCC short columns reinforced with NPR steel rebars, yielding significant insights into their structural behavior. The innovative combination of NPR rebars and UHTCC materials offers a novel approach for achieving ductile seismic design in short column applications.

Objectives

❖ Study the behavior of buildings constructed on plane ground and sloping ground for static load and dynamic load by use of appropriate software (STAAD Pro, ETABS).

❖ Strengthening solutions for a short column

Scope of this Study

To investigate the effect of short columns on the behaviour of buildings and to rectify effective measures to increase the strength of the building. The study focuses on both under construction building and existing structures where localized repairs may be required. By utilising the software, we can evaluate the behaviour of the builidng, with special emphasis on short and long columns, particularly at the base level. The findings help in understanding the vulnerability of short columns and enable the implementation of appropriate design and construction practices to mitigate potential failures.

Various Steps involved in the comparison of horizontal forces

1. Selection of building geometry and seismic zone Chamba, Kullu, Kangra, Una, Hamirpur, Mandi, and Bilaspur Districts lie in Zone V. The remaining districts of Lahual and Spiti, Kinnaur, Shimla, Solan and Sirmaur lie in Zone IV. So, let us take seismic zone IV as per IS code 1893 (Part-1):2002 for which zone factor Z is .24.

2. Load combinations are formed Types of Primary Loads and Load Combinations: The structural systems are subjected to Primary Load Cases as per IS 875:1987 and IS 1893: 2002. Six Primary load case and thirteen load combinations are used for analysis.

3. Modelling of building frames using STAAD Pro Software.

4. Study of structural behavior in terms of bending moments and horizontal footings, axial force and bending moments in columns. They compared two four-storey reinforced concrete moment resisting frame (MRF) buildings with medium deformability, one of which is located on a flat lot and the other one is on a lot sloped by 20 degrees. Flexural frame for building on slope and plane ground is shown in Figures shown below.

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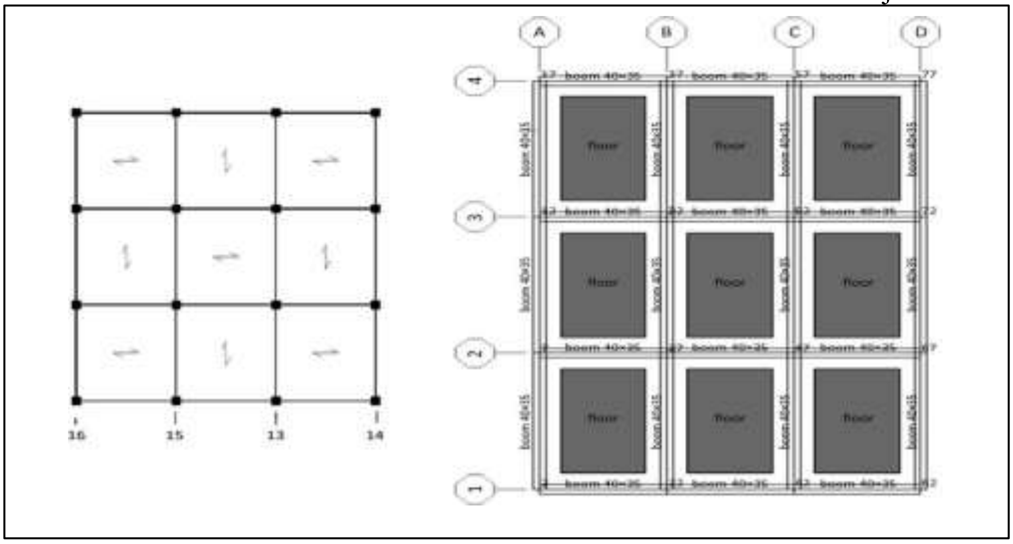

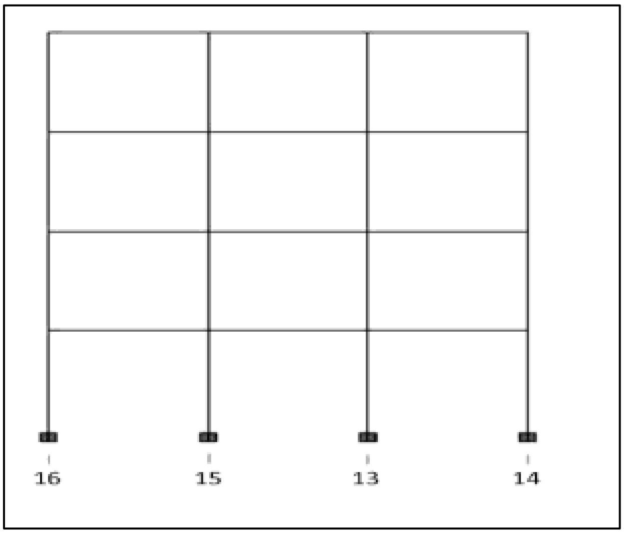

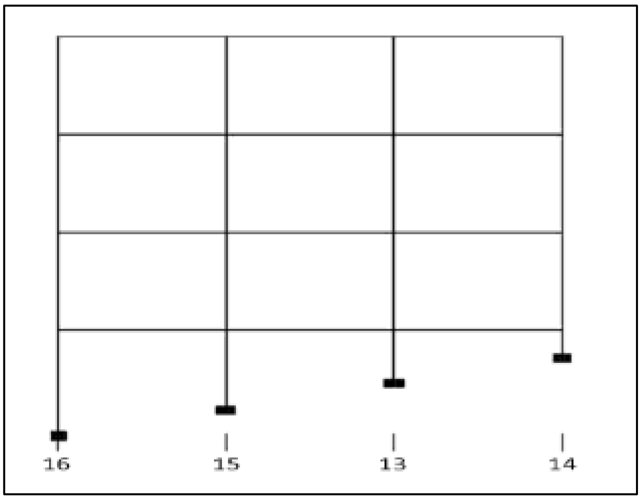

(a) The flexural frame for the structure on flat lot

(b) The flexural frame for the structure on sloping lot

Research Gap

Short columns have great influence on structural behaviour and safety of buildings, often leading to great failures during seismic events. Over the previous year's researchers has focused behaviour and proposed several methods to control and reduce their adverse effects. This study focuses analysing and comparing different mitigation methods to identify the most cost-effective solutions real world applications. By examining parameters such as load-carrying capacity and structural response, the study aims to assist engineers in behavior of short columns and assist in improving design practices. Although methods such as Fiber Reinforced Polymer (FRP), alternative retrofitting techniques—including ferrocement jacketing are easier, economical, and showed effectiveness in restoring the capacity of deteriorated columns. Additionally, considering the preventive measures during design are important Overall, the scope of this study is to investigate the impact of short columns on building performance and to improve the safety and performance of structures.

Shear wall

Shear walls are constructed structural components which has a mandatory role in bearing lateral seismic loads and wind loads. These elements act as dynamic part of the building's lateral load-resisting system and help in carrying horizontal forces safely to the foundation. In this study, shear walls are modeled and designed using STAAD Pro V8i for a **G+4** residential structure, with the objective of improving seismic performance and minimizing the impact of lateral forces, particularly on short columns located at the base in sloping ground conditions.

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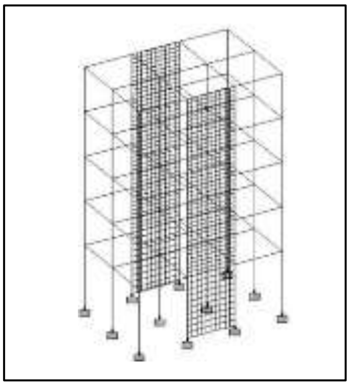
A shear wall is essentially a reinforced concrete vertical member, functioning alongside beams, slabs, and columns. These walls typically originate at the foundation level and continue uninterrupted up to the top of the structure, ensuring a continuous load path. Depending on the building height and design requirements, the thickness of shear walls generally ranges from about 150 mm to 400 mm.

For better structural stability, shear walls placement matters the most, usually placed along both principal directions of the building plan. So Proper and symmetrical placement is important to reduce torsional effects and prevent uneven structural response during seismic events. In this work, different configurations of shear wall locations are considered, and their impact on parameters such as lateral displacement, torsional response, natural time period, and frequency is calculated and graphs are made for comparision.



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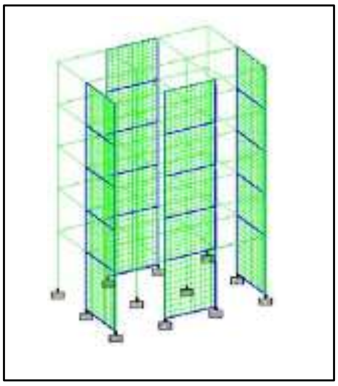

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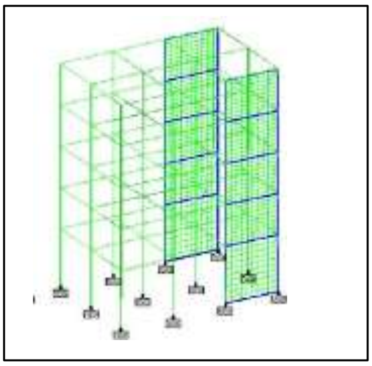

(c)

ASSUMPTIONS in MODELING, ANALYSIS and DESIGN

Material & Geometrical Properties	
Density of RCC	25 kN/m³
Young's Modulus of Concrete	5000 √fck
Foundation Depth	1.5 m below ground
Beam Cross Section	300 × 400 mm
Column Cross Section	300×450 mm, 300×300 mm, 450×300 mm
Height of Short Column	0.6 m, 2.3 m
Height of Long Column	4 m
Ground Level + Floor Height	4 m
Thickness of Shear Wall	230 mm
Dead Loads (IS 875 Part 1:1987)	
Self Weight of Slab	3.75 kN/m²
Floor Finish Load	1.47 kN/m²
Total Slab Load	4.75 kN/m²
Live Loads (IS 875 Part 2:1987)	
Live Load	2 kN/m²
Seismic Consideration	25% of Live Load
Seismic Parameters (IS 1893:2002)	
Seismic Base Shear	Vb = Ah × W
Design Seismic Coefficient	Ah = (ZISa) / (2Rg)
Zone Factor (Z)	0.24
Importance Factor (I)	1
Response Reduction Factor (R)	3
Soil Type	Soft soil (N ≈ 13.8)
Spectral Acceleration (Sa/g)	As per IS 1893

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Foundation Depth Consideration	1.5 m
Wind Load (IS 875 Part 3:1987)	
Wind Load	As per code

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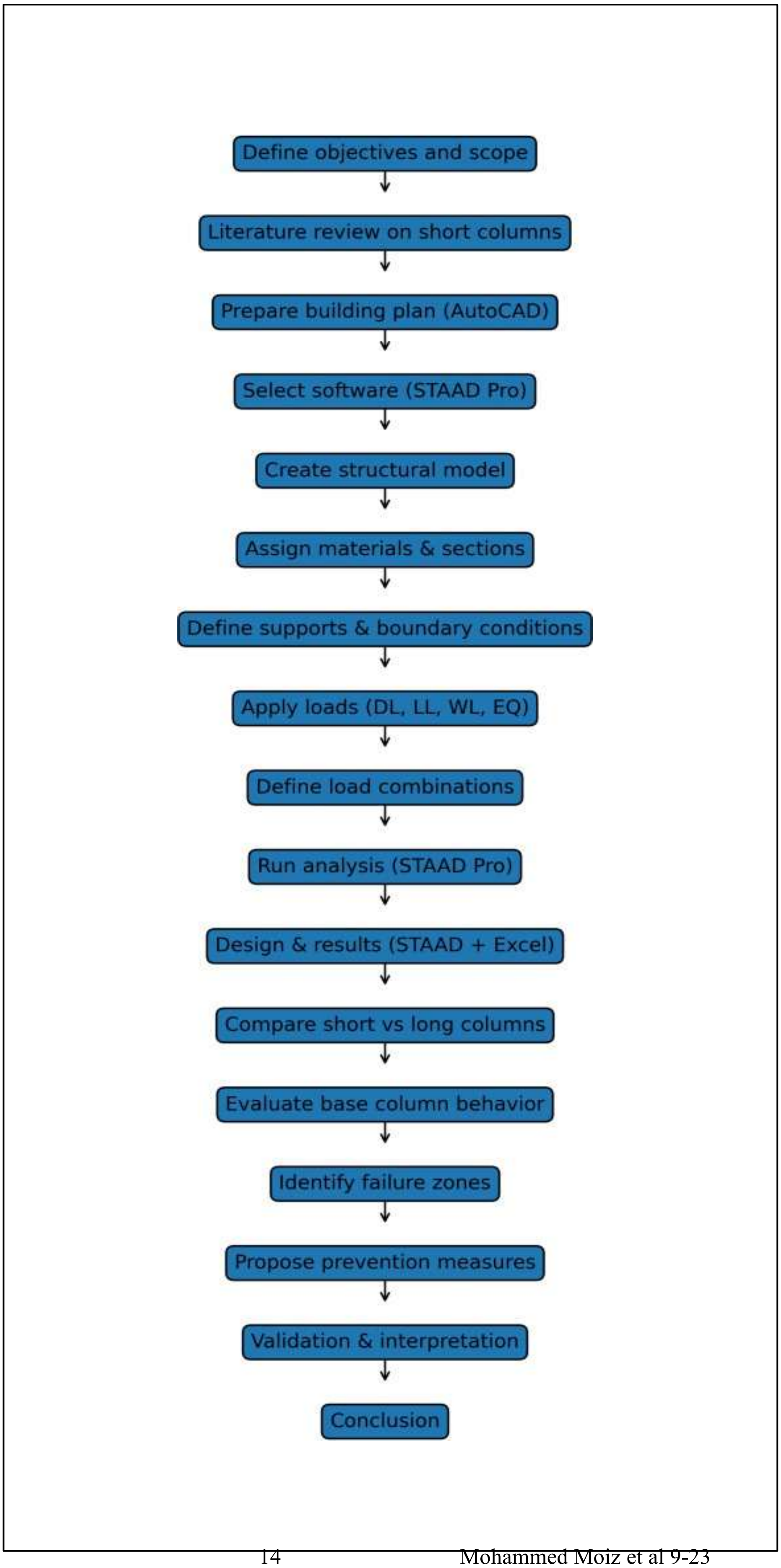
Methodology-



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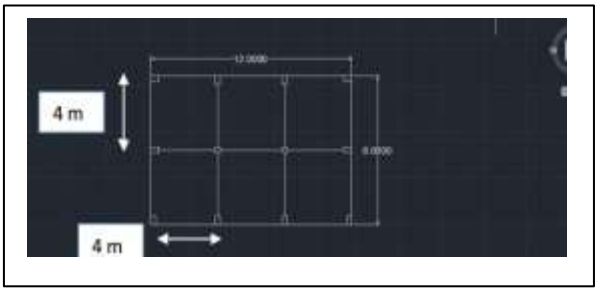
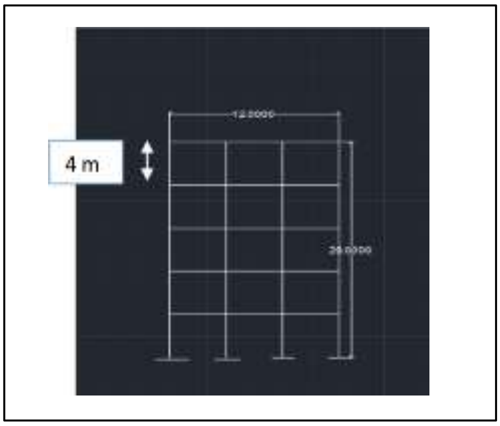
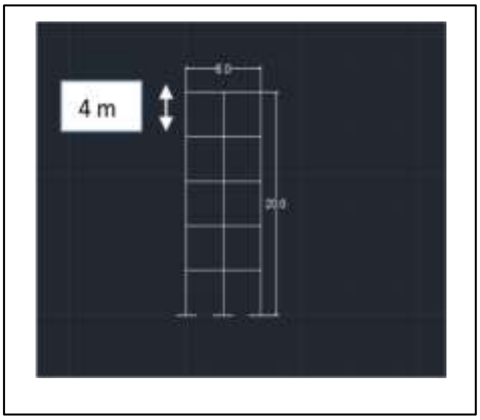
Plan Of Buildings



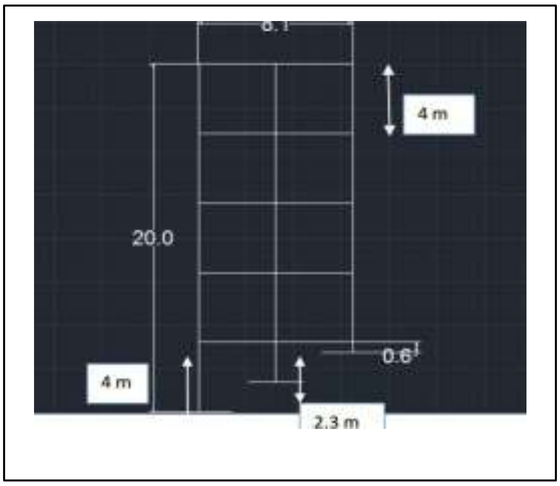
Plan considered same for both the structures



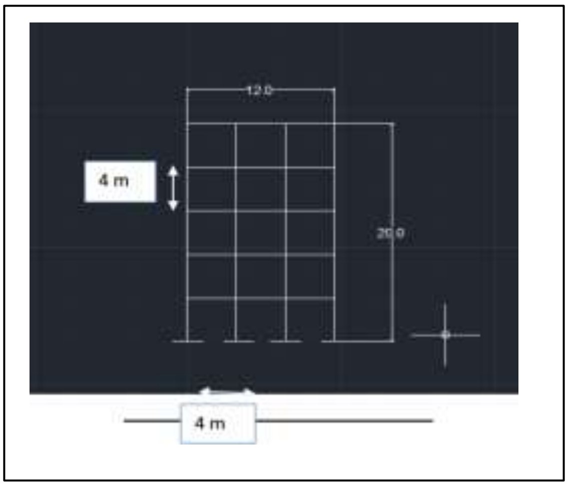
(a) Front view plan of building resting on Plain



(b) Side view plan of building resting on Plain



(a) Front view of building resting on sloping ground



(b) Front view of building resting on sloping ground

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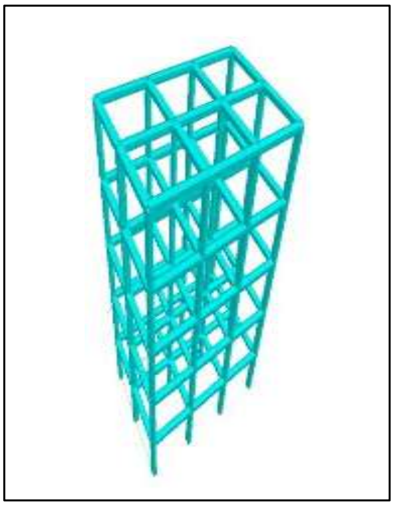
Modelling

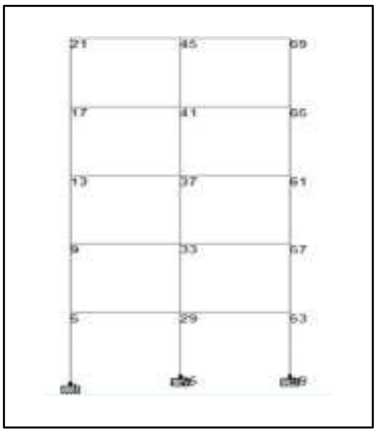
STAAD Pro. V8i Reports

Model of RC frame on sloping ground



Model of RC frame on plain ground

Position of nodes on sloping ground



Position of nodes building on plain ground

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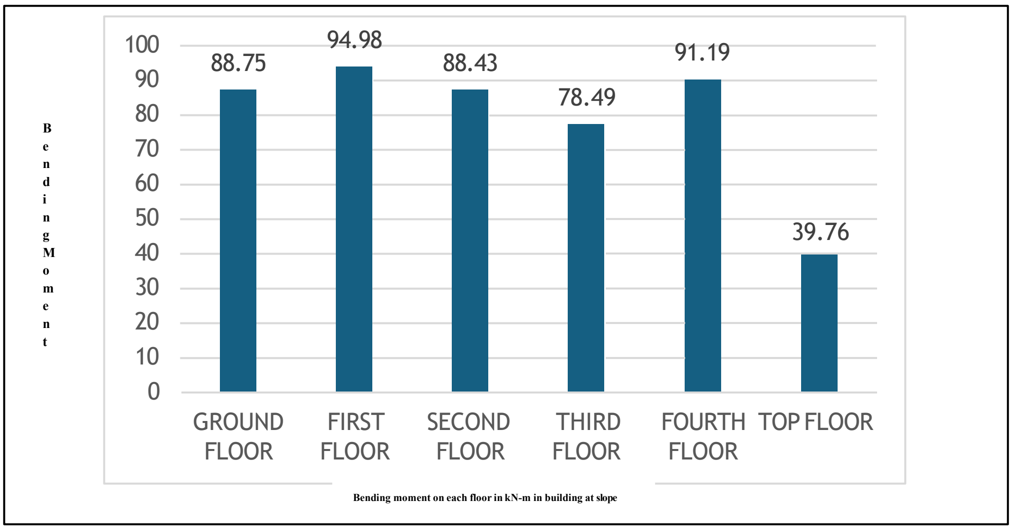
Data Analysis

Results and Discussions

The following results were recorded after the analysis done on **STAAD PRO** Software for static analysis.

Maximum bending moments and shear forces in each floor in building on sloping ground

Floor	BENDING MOMENT (Mz) Kn-M
Ground Floor	87.347
First Floor	93.973
Second Floor	87.347
Third Floor	77.357
Fourth Floor	90.374
Top Floor	38.757



Maximum Bending moments on each floor in building on Sloping ground

FLOOR	SHEAR FORCE (kN)
Ground Floor	78.69
First Floor	80.26
Second Floor	104.25
Third Floor	101.36
Fourth Floor	98.98
Top Floor	95.69

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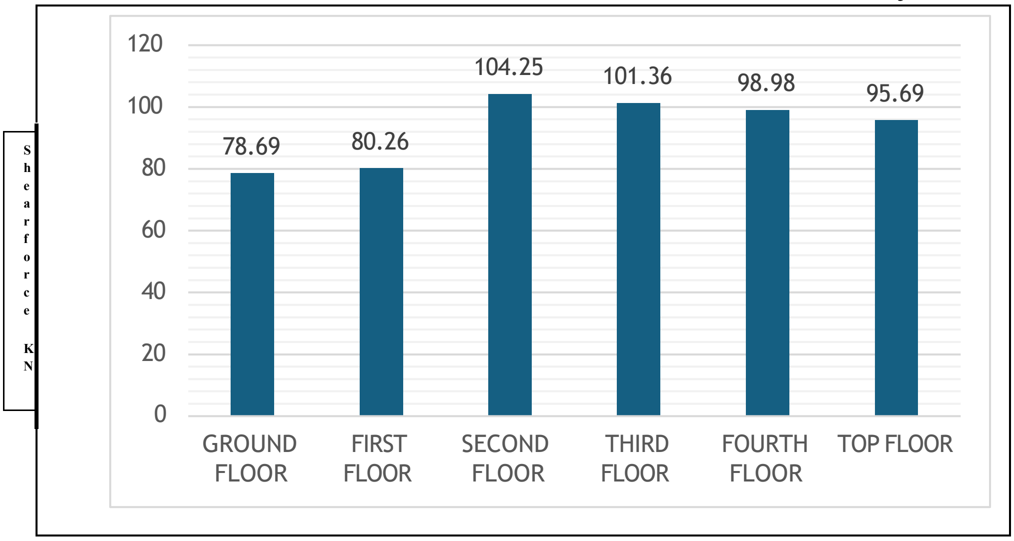
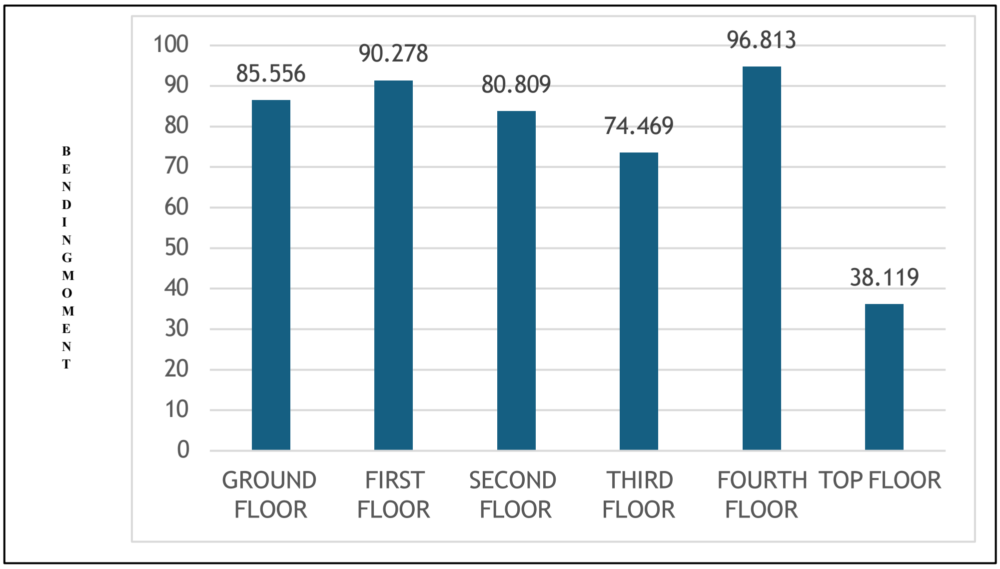


Shear force in kN on each floor in building at sloping ground

- **Maximum bending moments and shear forces in each floor in building on Plain ground**

Maximum Bending Moment on each floor in building on Plain ground

FLOOR	BENDING MOMENT (Mz) kN-m
GROUND FLOOR	85.556
FIRST FLOOR	90.278
SECOND FLOOR	80.809
THIRD FLOOR	74.469
FOURTH FLOOR	96.813
TOP FLOOR	38.119



Maximum Bending moments on each floor in building on Plain ground

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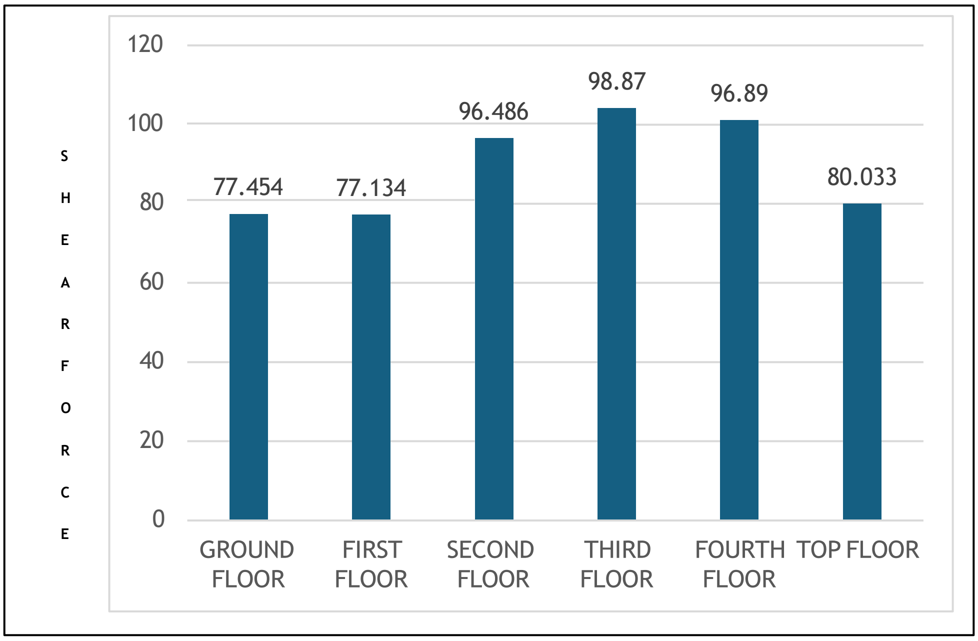
- **Maximum Shear force on each floor in building on Plain ground**

FLOOR	SHEAR FORCE (kN)
GROUND FLOOR	77.454
FIRST FLOOR	77.134
SECOND FLOOR	96.486
THIRD FLOOR	98.87
FOURTH FLOOR	96.89
TOP FLOOR	80.033



Maximum Shear force at various floors in building at plain ground

- **Maximum axial forces in columns from top to bottom**

COLUMN AT SLOPING GROUND	AXIAL FORCE (kN)	COLUMN AT PLANE GROUND	AXIAL FORCE(kN)	MANUALLY CALCULATED AXIAL FORCES (kN)
TOP	61.2	TOP	60.4	58.8
FIRST	175.6	FIRST	173.9	159.38
SECOND	288.69	SECOND	286.79	260.68
BASE (SHORT COLUMN)	461.69	BASE (LONG COLUMN)	460.97	463.29

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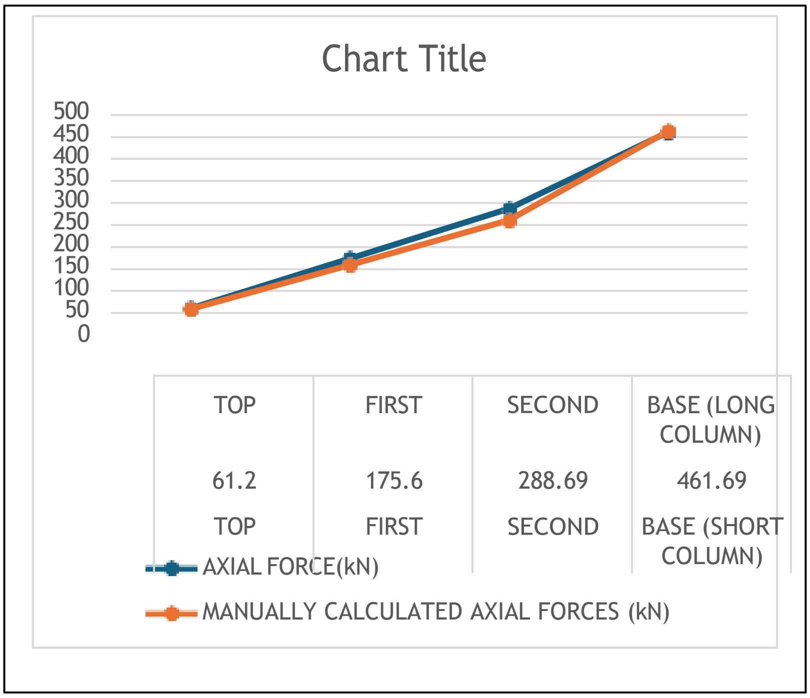

- **Comparison of results**

Comparing the results for two models, it depicts that base shear for the building at slope is slightly greater than the building at plain for about 5.5% more at building at slope. Also, as mentioned in the objective of the study, the behavior of multi-storey building frame under dynamic response in terms of displacement, moment, shear. Response spectrum analysis has increased the effect of, shears force bending moment and deflection in lower elements of buildings and thus are compared. The displacement of the lower elements in a building at slope is lesser as compared to the displacement of nodes 53, 54, 55, 56. The results obtained for the critical elements are represented in the tables below.

Table 1 Maximum moments floor wise in kN-m

Floor	Sloping ground	Plain ground	Percentage increase %
Ground floor	87.347	85.556	2.05
First floor	93.973	90.278	3.93
Second floor	87.347	80.809	7.49
Third floor	77.357	74.469	3.73
Fourth floor	90.374	86.813	3.94
Top floor	38.757	38.119	1.65

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Table 2 Maximum shear force floor wise in kN

Floor	Sloping ground	Plain ground	Percentage increase %
Ground floor	78.69	77.454	1.57
First floor	80.26	77.134	3.89
Second floor	104.25	96.486	7.45
Third floor	101.36	98.87	2.46
Fourth floor	98.98	96.89	2.11
Top floor	95.69	80.033	16.36

Table 3 Axial force in columns in kN

Column position	Sloping ground	Plain ground	Percentage increase %
Top	60.141	58.08	3.426
First	174.705	159.38	8.77
Second	287.839	260.685	9.43
Base	490.9	468.7	4.522

Table 4 Displacement of top nodes in mm

Sloping ground	Sloping ground (Shear wall position at middle)	Plain ground	Plain ground (Shear wall position at middle)
77.256	21.319	118.44	26.944
77.256	12.318	118.443	26.944
77.25	12.818	118.443	27.095
77.25	21.319	118.444	27.095

Table 5 Displacement of bottom nodes in mm

Node	Sloping ground	Sloping ground (Shear wall position at middle)	Plain ground	Plain ground (Shear wall position at middle)
53	5.953	1.758	44.853	4.017
54	5.55	0.972	44.903	4.397
55	5.55	0.972	44.903	4.397
56	5.954	1.758	44.903	4.017

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Conclusion

This study presents a comparative evaluation of residential building frames constructed on plain ground and sloping ground, with particular focus on the **short column effect**, under both static and dynamic loading conditions. Based on the analytical results, the following conclusions are drawn:

- **Structural Behavior under Static Loads**

  The analysis under dead load (DL) and live load (LL) combinations indicates that short columns perform adequately and remain structurally safe under normal loading conditions. No critical distress is observed in static behavior due to geometric irregularities caused by slope.

- **Beam Force Response**

  Maximum bending moments and shear forces in beams are predominantly observed at the ground floor level. This is attributed to the direct transfer of loads to the foundation system, making the ground storey structurally more efficient in resisting forces.

- **Comparison of Static and Dynamic Analysis**

  While static analysis shows negligible variation in bending moments and shear forces between sloping and plain ground structu res, response spectrum analysis highlights significant differences. Short columns in sloping ground buildings and long columns in plain ground buildings experience relatively higher bending moments under seismic excitation.

- **Column Axial Force Distribution**

  The maximum axial force is concentrated in base columns, as they support the entire structural load. A gradual reduction in axial force is observed towards the top storeys, where values decrease to nearly one-third of those at the base. The structure remains stable under static loading conditions.

- **Dynamic Characteristics**

  Buildings on sloping ground exhibit higher natural frequencies and lower time periods compared to those on flat ground. This indicates increased stiffness in sloping ground structures.

- **Torsional and Displacement Effects**

  Dynamic analysis reveals that torsion, shear force, bending moment, and displacement effects are more pronounced in lower structural elements. Short columns are particularly vulnerable to torsional effects. However, overall displacement in sloping ground structures is comparatively lower than in flat ground structures.

- **Ductility and Stiffness**

  Flat ground structures demonstrate relatively higher ductility, whereas sloping ground structures exhibit greater initial stiffness due to geometric constraints and uneven column heights

- **Effect of Wind Loads**

Wind loads contribute to noticeable variations in bending moments of both beams and columns, thereby influencing the overall structural response.

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