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Seismic Qualification and Retrofitting Of Existing Structures

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Abstract: **In the project, an existing building shall be analyzed for seismic condition for zonal classification as per IS 1893-2002(part-1) and IS 1893-1984(part-1). Based on the analysis the structure shall be classified for seismic qualification. Based on the seismic qualification, Retrofitting shall be done accordingly.**

Keywords: **Seismic Qualification, Column Jacketing, Rehabilitation, Retrofitting, Strengthening, Structural repair.**

1. INTRODUCTION

Buildings on hill slopes differ in a way from other buildings. The various floors of such buildings steps back towards the hill slopes and at same time building may have setbacks also. A setback is sudden change in plane dimension or a sudden change in stiffness along the height of a building. The stepping back of buildings towards hill slopes may results into unequal column heights at the same floor. Some columns of the buildings may be resting in the cutting may be resting in fillings. Most of hill regions of India are highly seismic, normally buildings are not designed for earthquake forces except for a very few government buildings. Taking the general slope into account, some of these considerations lead to the disorder in building height which appears as the destructive phenomenon of short column at the lowest floor. The majority of reinforced concrete columns are subjected to primary stresses caused by flexure, axial force, and shear. Secondary stresses associated with deformations are usually very small in most columns used in practice. These columns are referred to as "short columns". The capacity of a short column is the same as the capacity of its section under primary stresses, irrespective of its length. The chief role of this column is to transfer the inertia force originated from earthquake to columns. The main part of these forces is exerted on the short column since the stiffness varies from column to column. Thus, the short column shows an enormous potential for serious damage by earthquake in the case of an inappropriate design.

1. Aim

The aim of this project is to evaluate a seismic qualification and retrofitting of existing structures. Analysis of structures by using linear static analysis method and modeling were carried out using staad Pro Software. To retrofit the structural components of the existing building at Coimbatore in Zone III.

2. Objectives

The construction of multistory RC framed buildings on hill slopes has a popular and pressing demand, due to its economic growth and rapid urbanization. This growth in construction activity is adding increase in population density. While construction, it must be noted that Hill buildings are different from those in plains i.e., they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled.

The objective of the present study is to perform linear static analysis of medium height RC buildings and investigate the changes in structural behavior due to consideration of sloping ground.

3. Scope

The scope of the present study is to bring the awareness and methods of construction consideration of sloping ground, through which the stability of the structure can be ensured. In addition, the weaker columns are identified and suggested for jacketing in case of existing structures.

2. METHODOLOGY

This present work deals with study of behavior of sloping ground building (reinforced concrete moment resisting frame (MRF)) frames considering different inclination (7.5o, 15o) under earthquake forces. The comparison of sloping ground and plane ground building under seismic forces is done. Here G + 3 storey is taken and same live load is applied in three the buildings for its behavior and comparison.

The framed buildings are subjected to vibrations because of earthquake and therefore seismic analysis is essential for these building frames. The fixed base System is analyzed by employing in three building frames in seismic zone III by means of Staad Pro Software. The modeling carried out using Staad Pro software. The response of three the building frames is studied for useful interpretation of results. In this project has been analyzed by Approximate Structural Analysis method.

1. Flow chart

The flow chart clearly shows the process which have been carried out in this work. The step by step process of this project is explained in the flow chart.

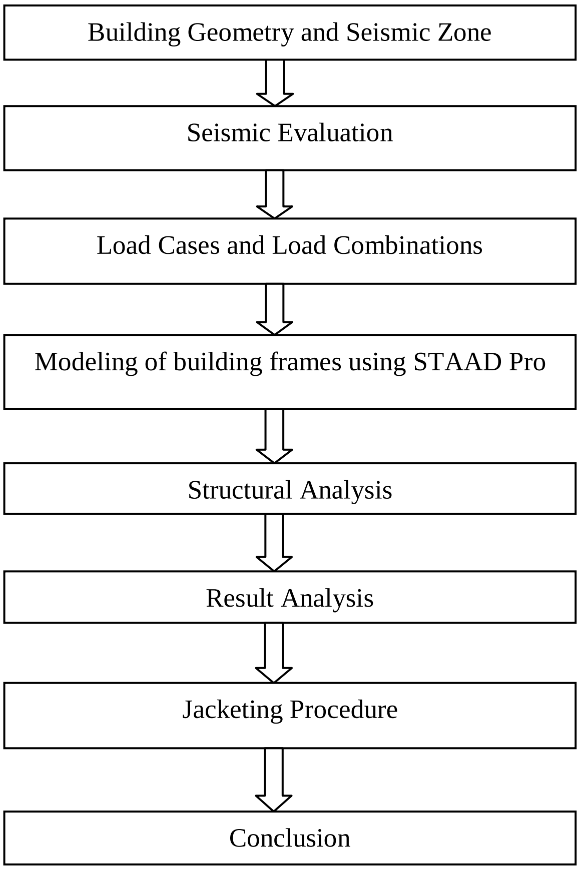

Fig. 1: Working Methodology

3. MATERIAL PROPERTIES

1. Building geometry and Seismic zone

Description of the Building considered for the project work as below

Size of the building in plan: 13.5m X 12.0m.

Bay sizes in the X-direction: 3m, 4.5m, 3.0m & 3m - 4 bays

Bay sizes in the Z-direction: 3m, 3m, 3.0m &3m-4bays

Depth of foundation considered at 1.5m below the ground level

Floor height has taken for analysis is 3.5m

Initial, member sizes are considered for analysis

Column 300 x 400 mm (for all columns)

Beam 300 x 300 mm (for all beams)

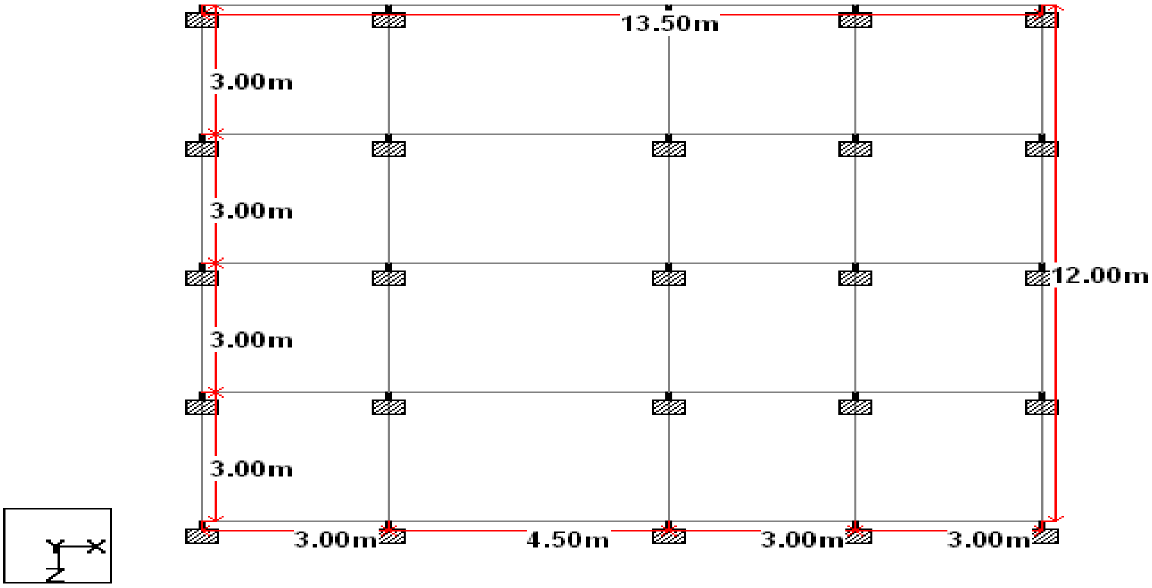

Fig. 2: Plan view

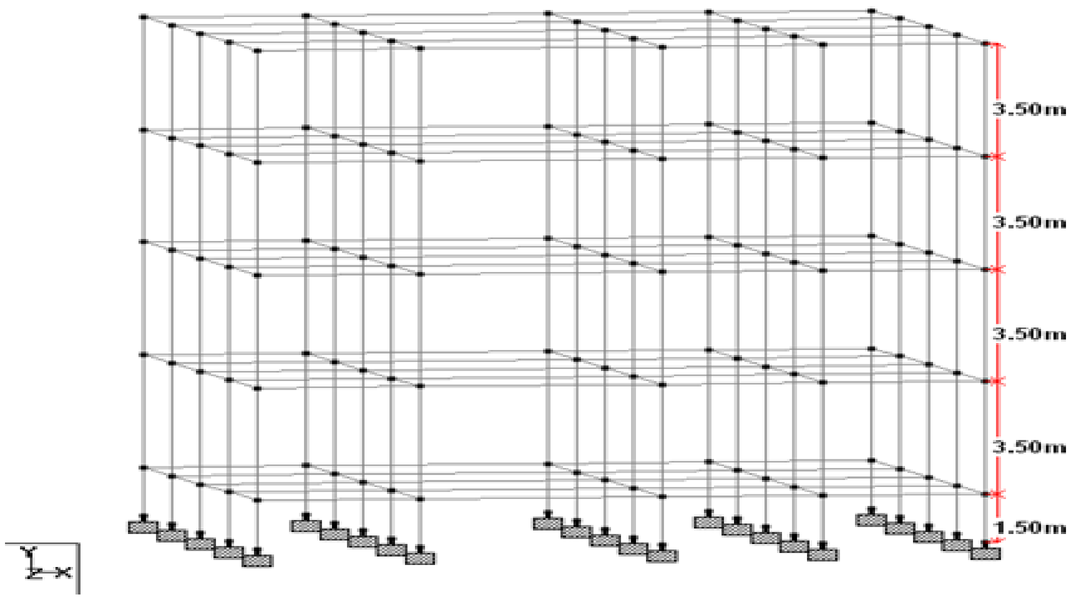

Fig. 3: Isometric view

2. Applying load

a. Dead Loads

Loads of walls, slabs have been calculated and applied in Staadpro as an input for the analysis.

Floor load (Self weight of slab + floor finish) =3.75 kN/m2

Wall load (230 mm thick _external walls) =14.72 kN/m

Wall load (115 mm thick _ external walls) = 7.36 kN/m

Parapet wall load (230mm thick, 1m ht) = 4.60 kN/m

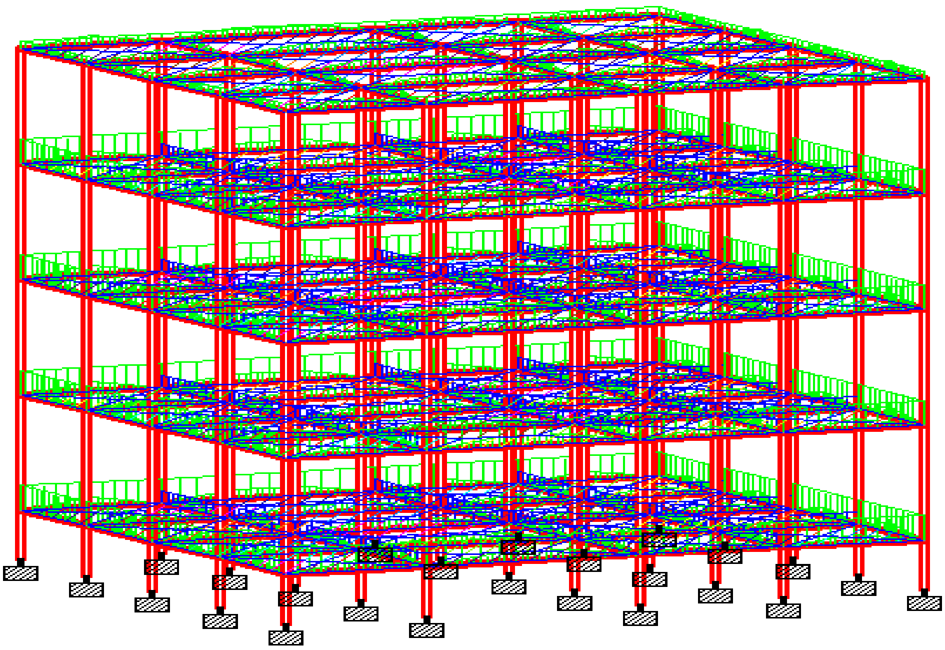

Fig. 4: Self weight and Floor dead load

b. Live Loads

Live load (AS per IS 875-1987(part2)) = 3.00 kN/m2

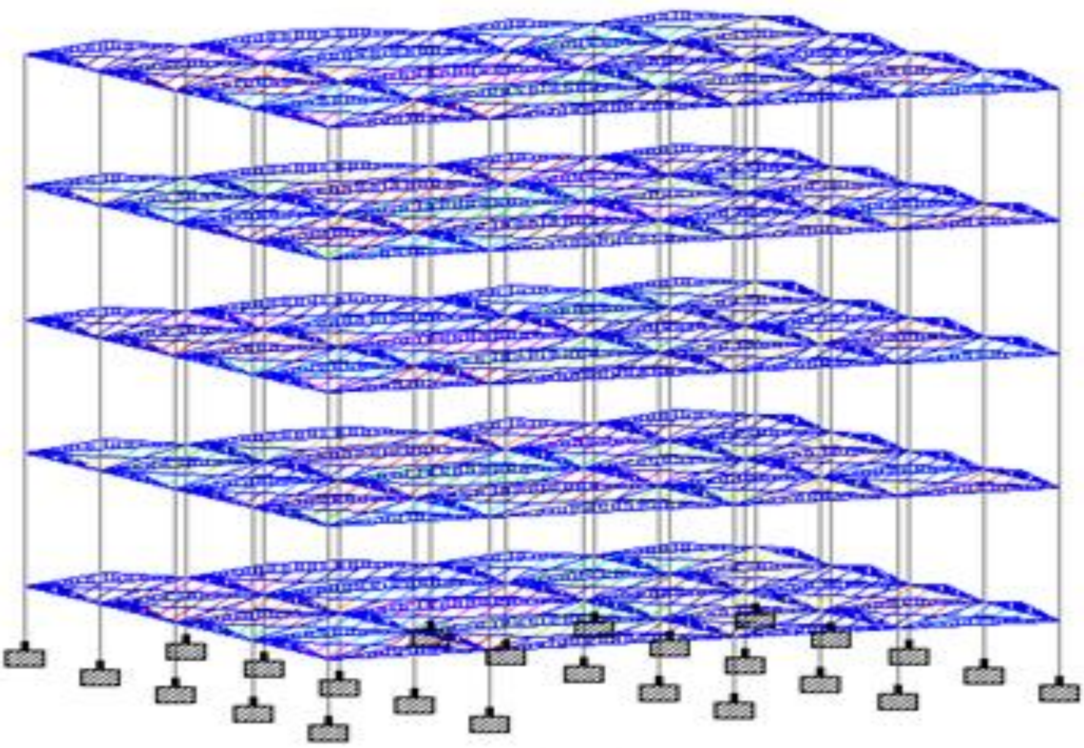

Fig 5: Floor Live Load

c. Earthquake Loads

All the buildings are analysed for seismic loads. Loads are calculated as per IS 1893:2002 (Part 1)

Seismic parameters considered for analysis are:-

Seismic Zone	III	(Table 2, IS 1893-2002)
Zone factor (Z)	0.16	
Response Reduction Factor (R)	3	(Table 7, IS 1893-2002)
Importance factor (I)	1	(Table 6, IS 1893-2002)
Soil type	Medium soil	
Damping	5 %	

The design horizontal seismic coefficient A_h for the structure shall be calculated by the following expression, (IS:1893-2002, Cl.6.4.2)

$$Ah = \frac{Z\ I\ Sa}{2\ R\ g}$$

Building height above the ground level is 14 m.

As per IS 1893-2002(P1), Cl.7.6.2, Fundamental natural time period, T

EL in X-Direction:

$$T = \frac{0.09h}{\sqrt{d}}$$

$$T = (0.09*14) / (\sqrt{13.5})$$

$$T = 0.35 \text{ sec}$$

EL in Y-Direction:

$$T = \frac{0.09h}{\sqrt{d}}$$

$$T = (0.09*14) / (\sqrt{12})$$

$$T = 0.37 \text{ sec}$$

From the Fig.2 of IS 1893:2002(part1), for T< 0.5, Sa/g = 2.5

Therefore,

$A_h = (0.16*1.0*2.5)/(2*3)$

$A_h = 0.06 < (Z/2) = 0.08$

$A_h = 0.1$ (Adopted)

In Staad pro, all dead load are multiplied by A_h value for seismic load in each direction.

It means that A_h times the dead load act as seismic load in lateral direction.

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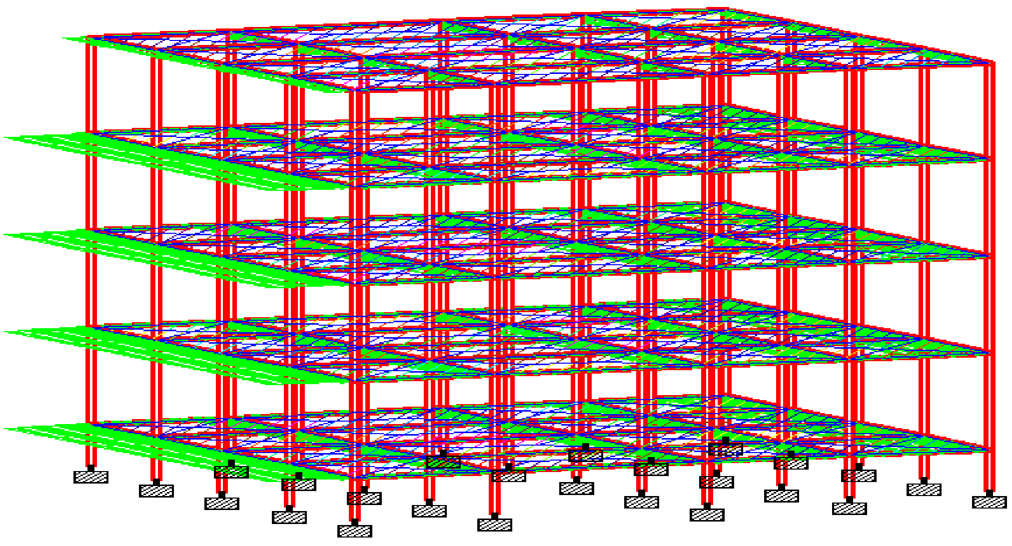


Fig. 6: Seismic load X-Direction

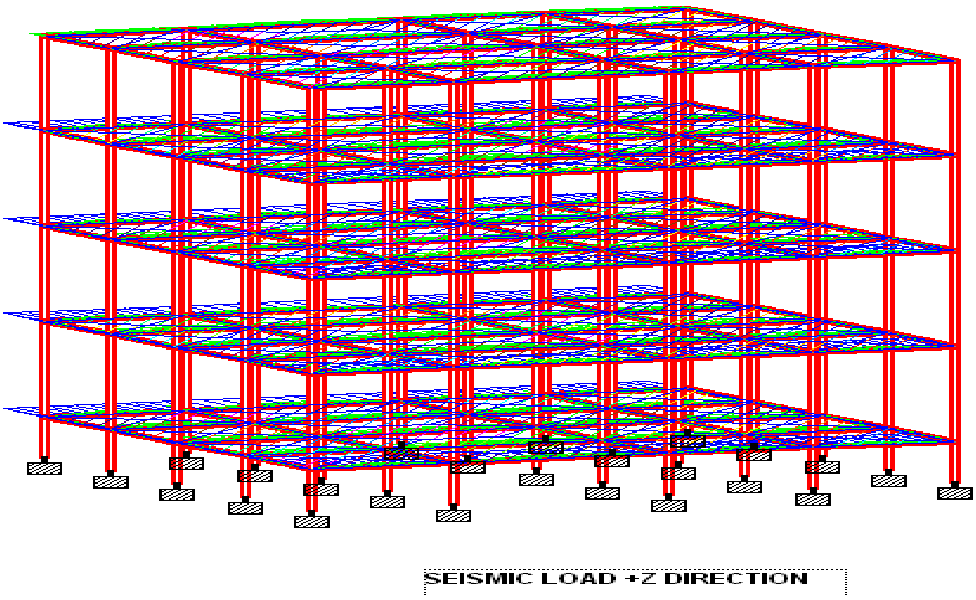


Fig. 7: Seismic load Z-Direction

4. RESULT ANALYSIS

Table 1: Beams along X-direction, are experience increased forces due to increase in slope. The below table and the graphs are explains.

	Force			%	%
Ground Slope	Slope 0 deg	Slope 7.5 deg	Slope 15 deg	slope 7.5 & 0	slope 15 & 0
Axial force (kN)	14.0	88.1	118.9	84.1	88.2
Shear Force (kN)	69.1	79.1	85.5	12.6	19.2
Bending moment (Mz) (kNm)	76.8	94.5	107.8	18.7	28.8

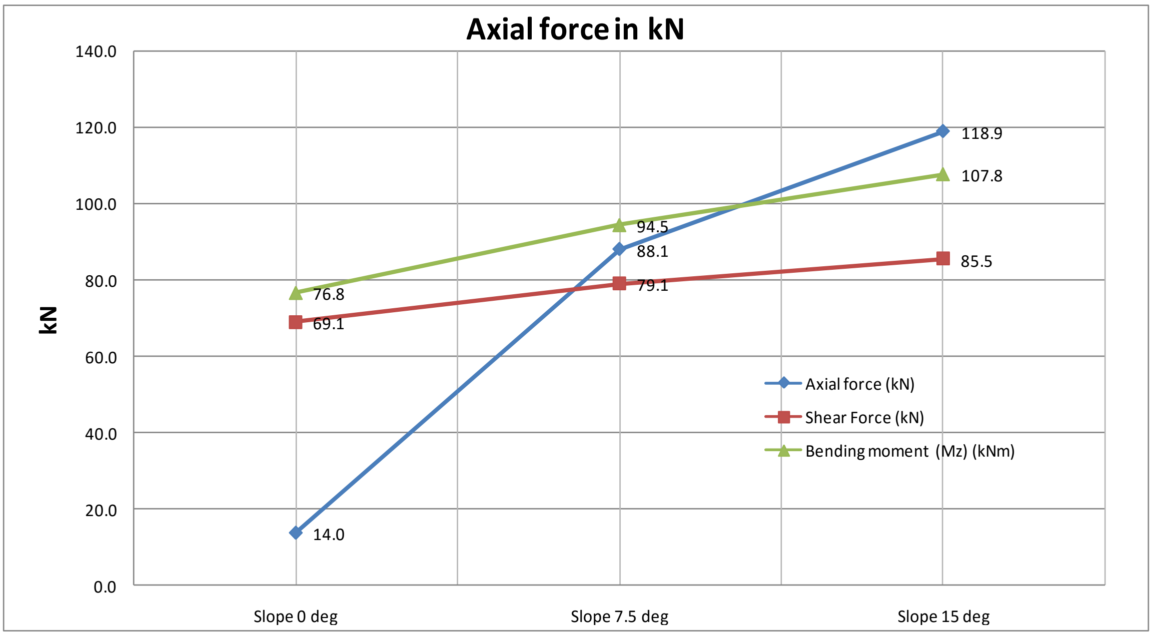


Fig. 8: Axial Force in X- Direction

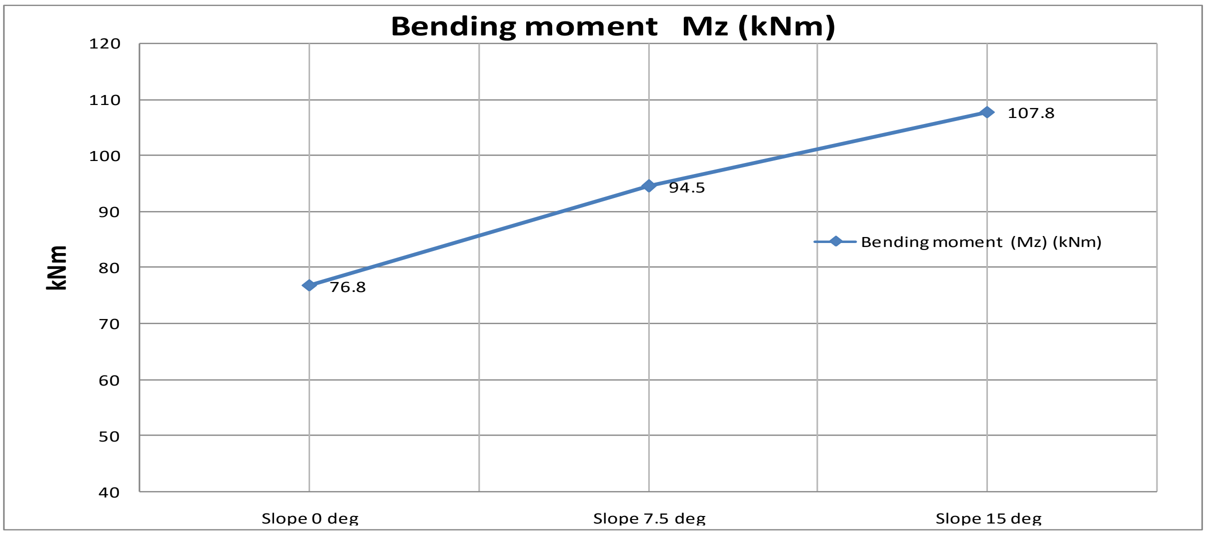


Fig. 9: Bending Moment in X- Direction

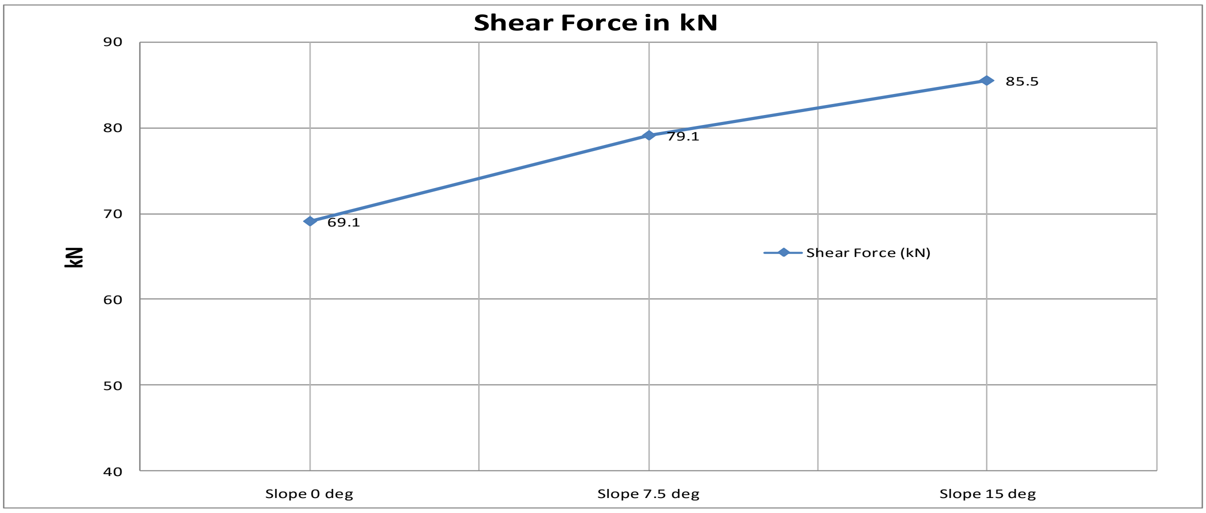


Fig. 10: Shear Force in X- Direction

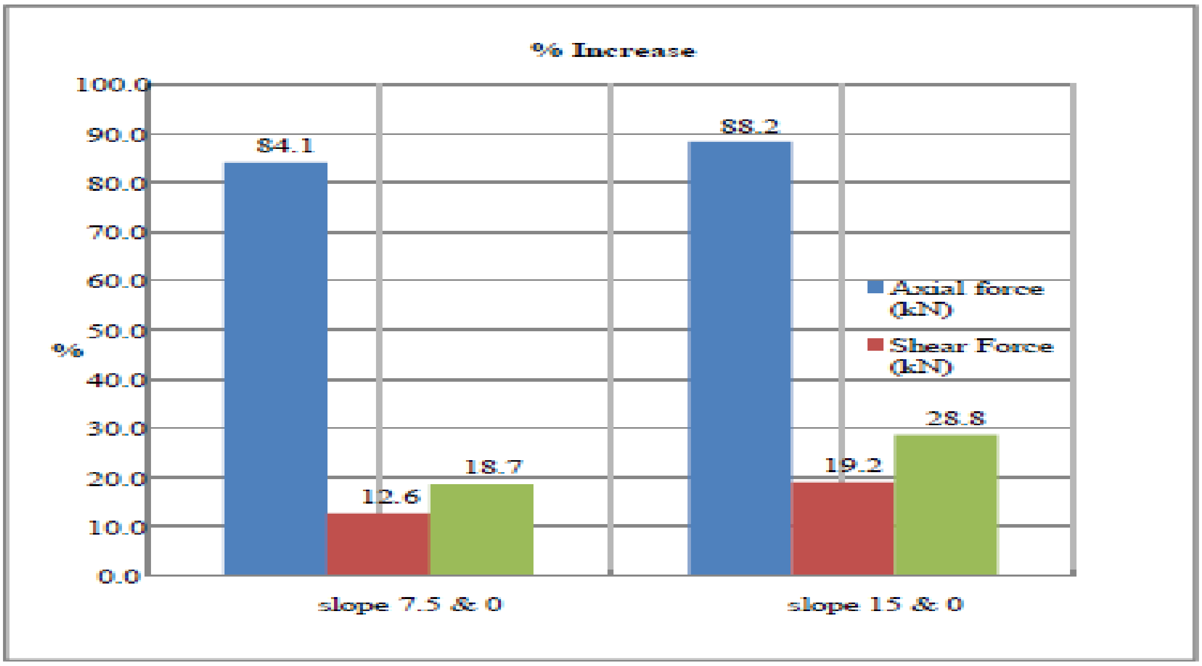


Fig. 11: % of Force Increase in X- Direction

Table 2:- Beams along Z-direction, are experience increased forces due to increase in slope. The below table and the graphs are explains.

	Force			%	%
Ground Slope	Slope 0 deg	Slope 7.5 deg	Slope 15 deg	slope 7.5 & 0	slope 15 & 0
Axial force (kN)	10.9	9.9	9.2	-10.1	-18.5
Shear Force (kN)	68.3	79.5	87.7	14.1	22.1
Bending moment (Mz) (kNm)	68.9	88.1	104.9	21.8	34.3

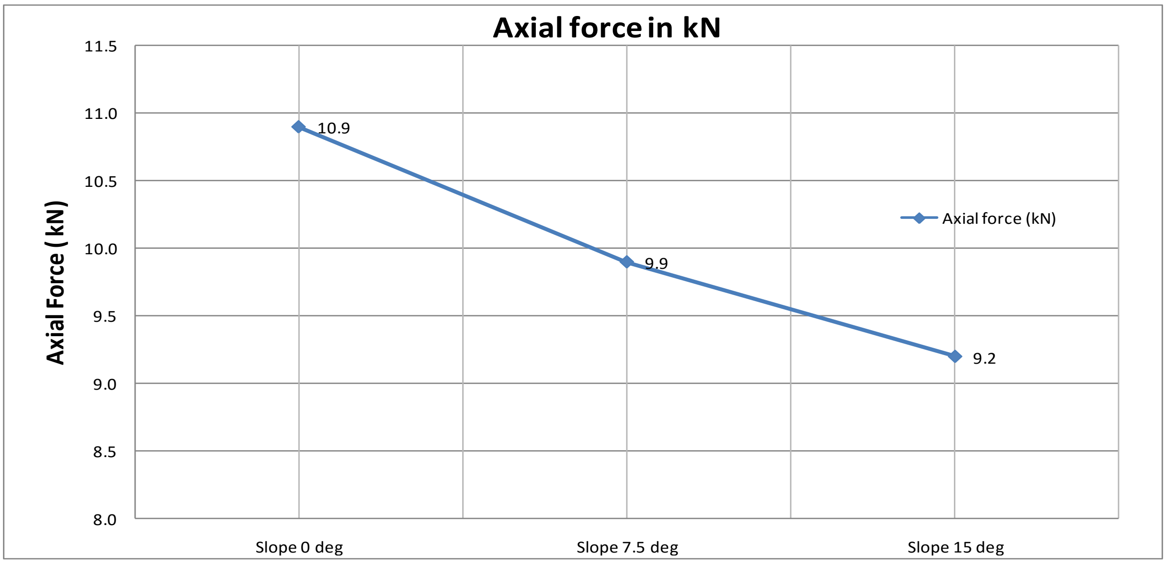


Fig. 12: Axial Force in Z- Direction

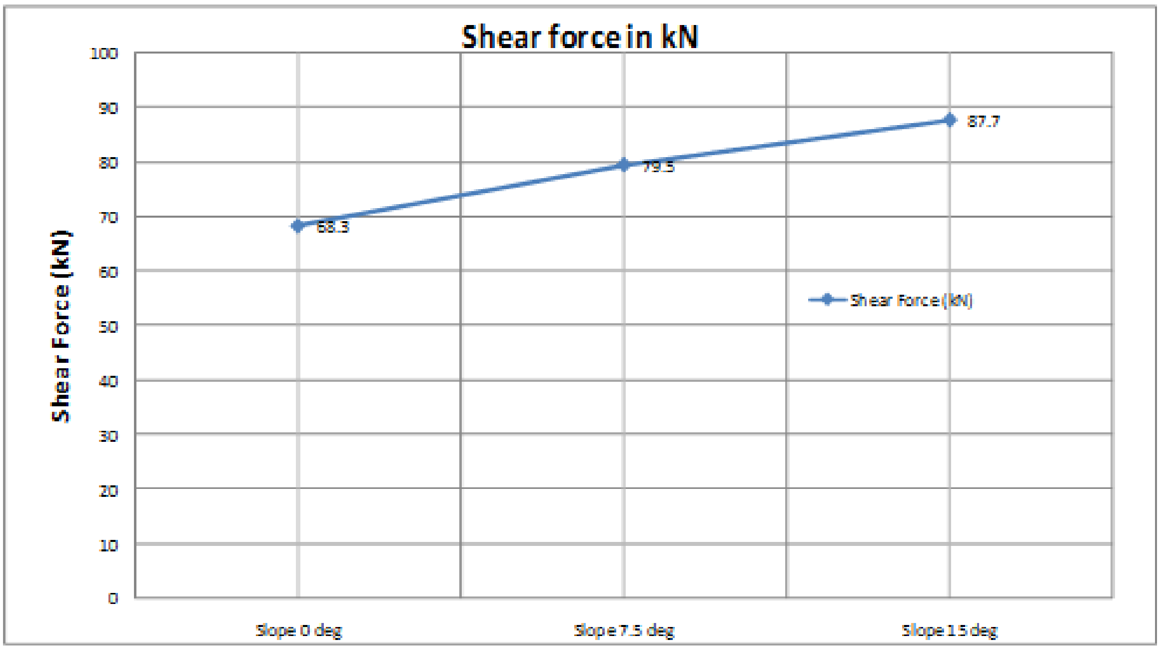


Fig. 13: Shear Force in Z- Direction

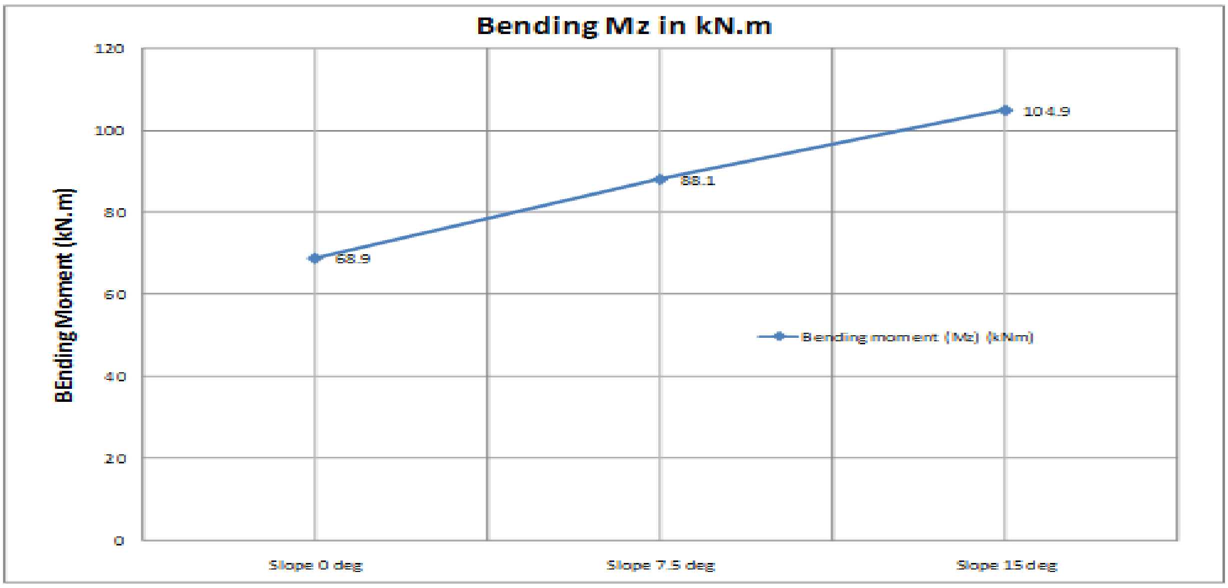


Fig. 14: Bending Moment in Z- Direction

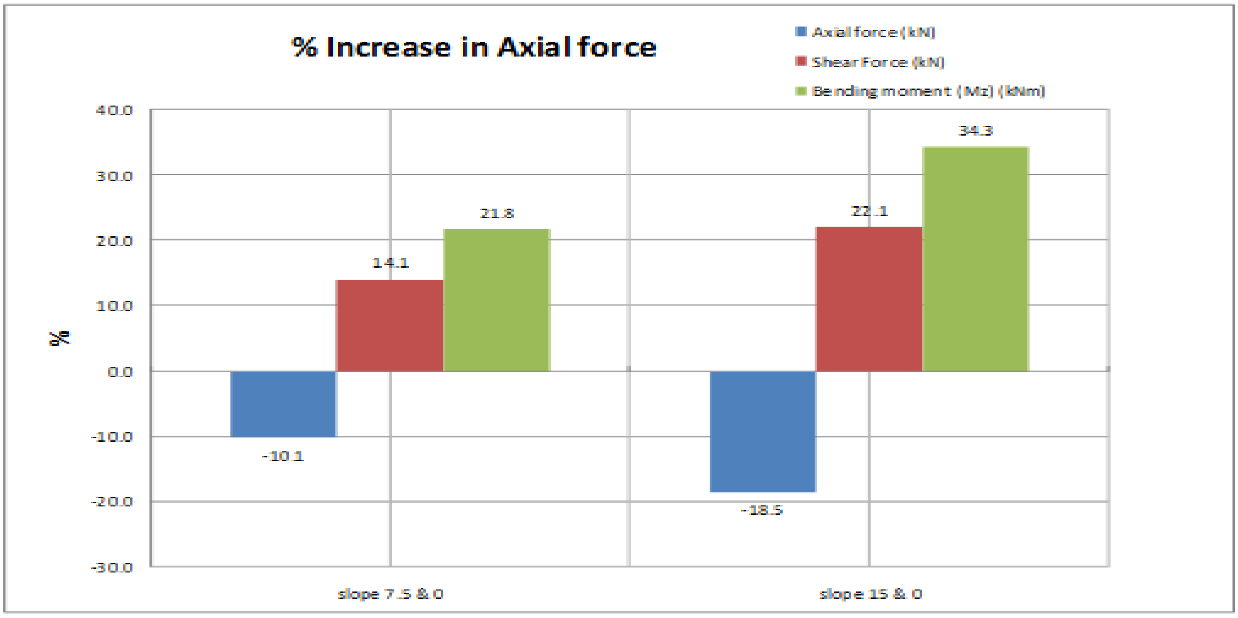


Fig. 15: % 0f Force Increase in Z- Direction

5. DISCUSSION

1. Retrofitting

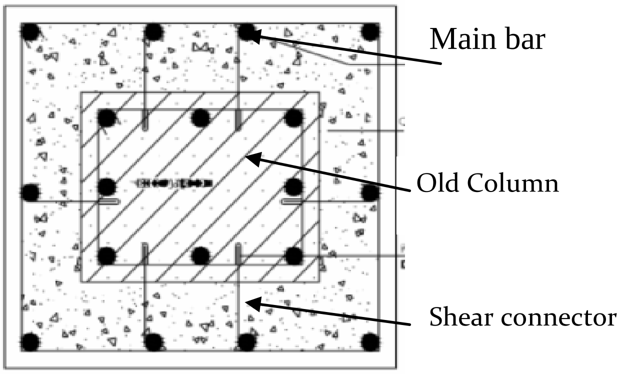
In this project study on the three buildings located in the slope ground levels, the level 1 columns and beams experiences high degree forces. The analysis results convey that there is increase in member's forces. Hence those members to be designed approximately. Since the common practice pertaining in general, designing a building without considering the ground slope and constructing in a sloped ground.

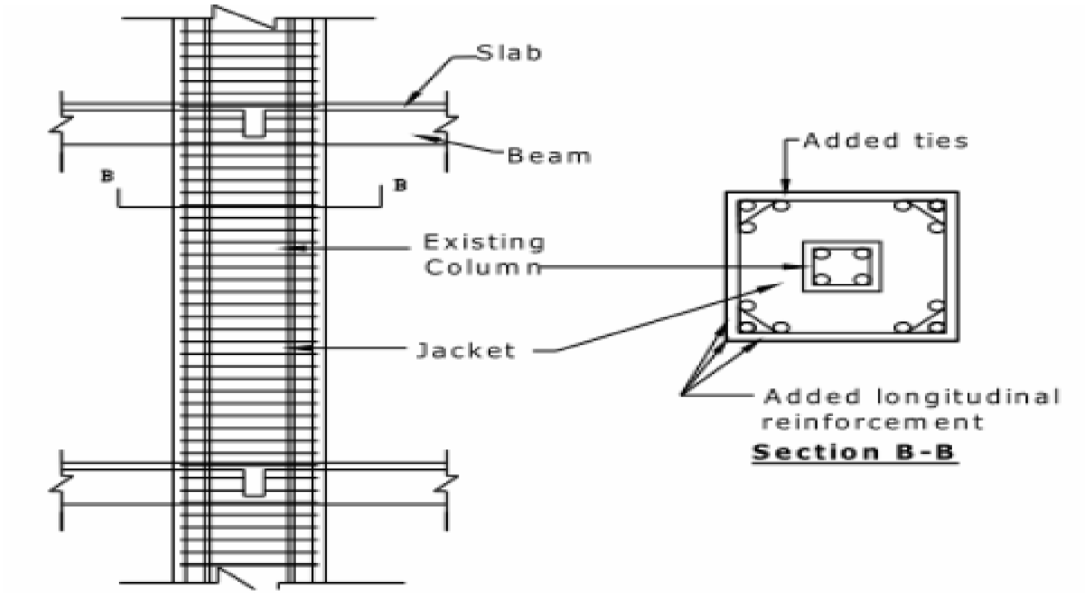
In case of a new building, constructed in a sloped ground those members are designed properly and sizing shall be done accordingly. So there will not be any issues after the construction. But in case of already constructed building in the sloped ground, the strength auditing shall be conducted for the benefit of life the building and safety to the habitants. If there is a need for the strengthening of building elements then the only available option is jacketing process.

Due to the lack of Jacketing knowledge, the people are used to provide external supports without proper connectivity which are unfair towards the safety. So it is necessary to educate them about the Jacketing and implementation.

The following figures are giving the need for jacketing to the failure columns and resizing of members using Staad Pro software.

2. Jacketing





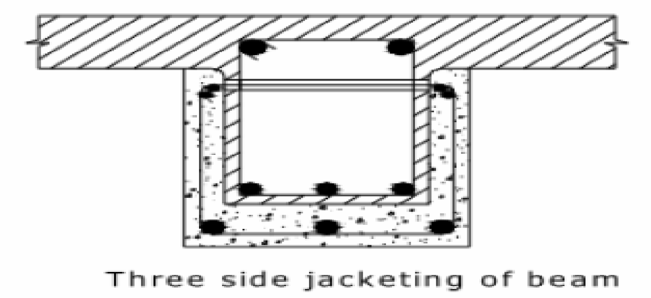


Fig. 16: Construction Techniques in Jacketing

Design of RCC Column Jacketing As Per IS 15988:2013

Height of Column= 3 m,

Width (b) = 250 mm,

Depth (D) = 250 mm,

Ultimate Axial Load (P) = 804.9 kN,

Ultimate Moment (M) = 25kN.m,

Concrete grade by NDT=12 N/mm^2,

d'= effective cover = 40 mm.,

Reinf. Provided: 4-16Ø = 804.2 mm^2

But minimum steel for jacketing section = 0.8% of cross section Area of Jacketed section = 645 mm^2

Hence provide 6-12 Ø for jacketing section.

Thickness of the jacket section to be provided wills 100mm.

Revised jacketed section of the column will be 450mm wide x 450mm deep.

Design of literal Ties

Dia of bar = ¼ of Ø of largest longitudinal bar

= ¼ x 16 = 4mm ….take 8mm

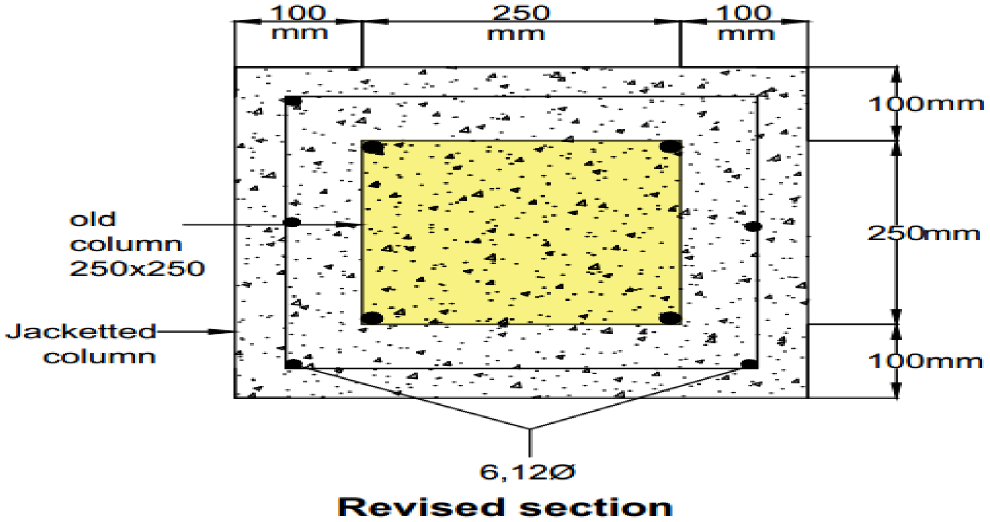


Fig. 17: Column Jacketing

Spacing of bar :

1. Least lateral dimension = 250mm
2. 200mm
3. 16 x Ø of smallest longitudinal reinforcement = 16x16 =256mm
4. Provide 8mm Ø @200mm C/C

Design of RCC Beam Jacketing As Per Is 15988:2013

Mu = 47 kN.m,

Ast provided = 2, 16 ϕ = 402.12 mm^2,

f_{ck} by NDT = 12 N/mm^2,fy =415 N/mm2,

b = 300mm,d=275mm, D = 300mm,

RCC jacketed section

Extra A_{st} = 2-16 ϕ, b = 500mm, d = 475mm,

D = 500mm

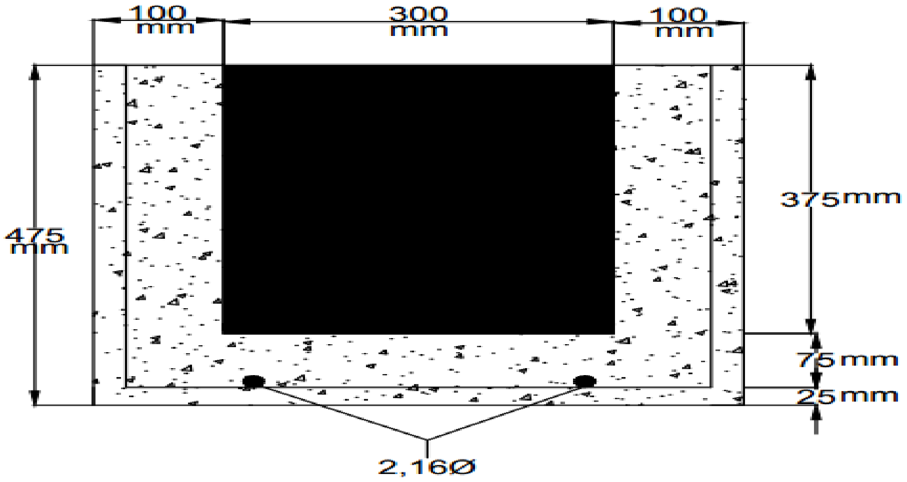


Fig. 18: Beam Jacketing

Spacing Required

1. $Sv = \frac{0.87xfyxASVxd}{vd}$

   = 733.649mm

2. 0.75xd = 0.75x475 = 356 mm

3. 300mm

4. $Sv = \frac{0.87xfyxASV}{0.4xb}$

   =181.48mm

Take minimum of above value Provide 2 legged 8mm ϕ stirrups @180mm C/C.

Results of R.C.C. retrofitting technique are significant improvement in Moment resisting capacity, shear strength capacity in Beam and Axial load carrying capacity in column.

6. CONCLUSION

Analysis results were tabulated and compared for the three cases. It has been observed that the level1 columns were experiences heavy forces than the all other levels. Hence it has been decided to compare the member forces for the level 1 columns and beams only in this project work. From the compared results it has been concluded the following points.

- From the figures the Column axial forces were found that there were about 1.5 % and 3.5 % only increased for 7.5^0 and 15^0 ground slopes respectively comparing with the flat (0 deg) ground.
- Column moments (Mz) were found to be about 45% and 64% increased for 7.5^0 and 15^0 ground slopes respectively comparing with the flat (0 deg) ground, about the slopes direction.
- Column moments (My) were found to be about 28% and 52% increased for 7.5^0 and 15^0 ground slopes respectively comparing with the flat (0 deg) ground, about the non-sloped direction.
- At level 1, Beams along the sloping direction were found to be increased in the member forces. Axial forces were found to be increased about 80% compared with flat ground surface. But there were not significant increase in moments of the beams. Hence these beams shall be design for axial forces as well.
- At level 1, Beams along the non-sloping direction were not significant increase in axial force and moments of the beams. Hence these beams shall be design for axial forces as well.

With the above observations, it has been recommended that the members experience heavy forces with respect to the ground slope must be checked with respect to the strength of the member. It has been concluded that the level 1 column members must be carried out Jacketing in case of already constructed buildings. The illustration of design for Jacketing principles would be helpful for understanding the steps involved in the Jacketing.

Due to disturbance of eco-friendly environment, there will be likely possibility of natural hazards such earthquake in future. Finally, it is our duty to educate each and every common man towards ensuring the safety of the building and save life of human.

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