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Analysis of Building Constructed on an Inclined Surface Considering Different Parameters of Soil Types

Abhishek Kumar Paroha[1], Deepak Kumar Bandewar[2]
[1, 2]*SIRTS*

Abstract: This study draws attention on proper planning and construction practices for multi-storied buildings on sloping ground. However, in usual design practice the designers generally ignorethe behavior of the building due to the effect of sloping ground. The evaluation of a G+4 storey RCC structure on varying sloping angles (0^0, 15^0, 20^0, 25^0, 30^0 and 40^0) were studied and also compared with the flat surface. The evaluations of the structure were carried by the software STAAD Pro v8i to study the effect of slopes on building performance. The evaluation was done to figure out the effect of sloping ground on the forces applied on the structure. Soil interaction must be suitably believed from design point of view. The Research work triesto find the truth about the earthquake-related behavior of multi storey structures on sloping angles thinking about soil-structure interaction. The horizontal reactions, bending moment in footings and axial force, bending moment in columns were critically studied to put the effectsof different sloping ground. It has been followed that the footing columns of lower height attract more forces, because ofa big increase in their stiffness, which in turn increases the horizontal forces and bending moment. So, the section of these columns should be designed for changed forces due to the effect of sloping ground.

It draws attention to the need for proper analysis and designing of the structure resting on sloping surface. Overall movement of the structure with respect to different sloping ground setups is also carefully studied.

Keywords: Structural Behavior, Horizontal Force, Bending Moment, Axial force, Sloping Ground

I. INTRODUCTION

A. General

Now days, expressive constructions were taking place in hilly areas due to lack of plain ground. As a result, the mountain areas have marked effect on the buildings in terms of style, material and method of construction leading to lot of structures in hilly areas. Due to sloping profile, the different levels of such structures step back towards the hill slope andmay also have setback also at the same time. These structures become highly uneven and unsymmetrical, due to different version in mass and stiffness distributions on different upwards and downwards axis at each floor. Such construction in seismic prone areas attracts greater shear forces and torsion compared to usual construction.

A lack of plain ground in hilly area forces the construction activity on sloping ground. Slope construction of buildings built in masonry with mud mortar/cement mortar without going along with earthquake codal provisions and analysis of wind have proved unsafe and, resulted in loss of life and property when subjected to earthquake ground movements and neglecting the winds which flows at upper part of the hills. Hilly areas are more prone in earthquake and wind activity for e.g. Northern area of India.

In some parts of world, mountain area were more likely to get earthquakes; e.g. northeast area of India. In this hilly areas, usually material like, the clay, brick, stone masonryand dressed stone masonry, timber reinforced concrete, bamboo, etc., which is locally available, is used for the construction of houses. The money based growth and rapid growth of the cities with more people in hilly areas has speed up the Real Estate Development. Because of which the population density in the hilly areas has increased hugely. Therefore, there is huge demand for the construction of buildings on hill slope in and around the cities.

Vibrations which causes disturbance in the earth's surface caused by waves created inside the earth are termed as Seismic vibrations. When an earthquake of certain magnitude forces a structure they cause movements in the structure which depends upon the structures vibrational and the location of structure. If a lightweight flexible building wasbuilt on a foundation which was very stiff, idea is that the input movement at the bottom of the structure is similarto free-field movement.

Structures on hills vary from those on regular plains because they are irregularly horizontal as well as vertical. In north and north-eastern parts of India have large scale of hilly terrain which falls in the category of earthquake zone IV and V.

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Figure 1 Building Regulations for Hill Towns

B. Seismic Behaviour Of Buildings On Slopes In India

In the region where seismic zone were categorized under zone IV and V the construction of multi-storey buildings has a more demand, due to its rapid growth economically. While construction, it must be noted that slope buildings are different from those in regular plain construction i.e., they are exceptionally rare and unsymmetrical in flat and up/down planes, and torsional coupled.

Shillong Plateau seismic tremor (M8.2) of 1897 and the Kangra quake (M7.8) of 1905was the major of a few pulverizing tremors to happen in northern India. An estimated of morethan 375,000 population were killed in epicentral region, and over 100,000 buildings were destroyed by the earthquake. Similarly in recent earthquakes like Bihar-Nepal (1980), Uttarkashi (1990), Sikkim (2011), and Doda (2013) affected many buildings on hill slopes.

A seismic plan of tall structures has accepted extensive significance as of late. Incustomary techniques received in light of basic method of the structure and conveyance of tremor compels as static powers at different stories might be satisfactory for structures of little tallness subjected to quake of low Intensity yet as the quantity of stories expands the seismic plan requests more thorough Amid past tremors, fortified cement (RC) outline structures that have segments of various statures inside one story, endured more harm in the shorter sections when contrasted with taller segments in a similar story.

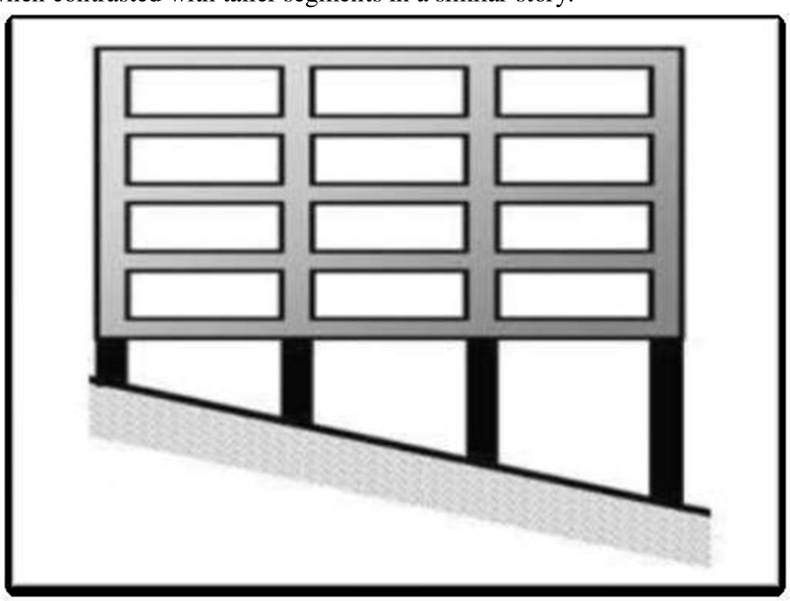
Figure 2 Building frame with short columns

C. Significance Of Study

Slope structures are not quite the same as those in fields, they are exceptionally unpredictable and unsymmetrical in even and vertical planes, and torsionally coupled. Consequently, they are vulnerable to serious harm. At the point when influenced by tremor ground movement. Past seismic tremors [e.g. Kangra (1905), Bihar-Nepal (1934 and 1980), Assam (1950), Tokachi-Oki-Japan (1968), Uttarkashi-India (1991)], have demonstrated that structures situated close to the edge of extend of slopes or slanting ground endured serious harms. Such are horizontal powers under the activity of seismic tremors. Structures have mass and solidness fluctuating along the vertical and level planes, coming about the focal point of mass and focal point of inflexibility don't agree on different floors. This requires torsional investigation. Little data is accessible in the writing about the investigation of structures on inclining ground. The examination exhibits in this paper gone for anticipate on seismic reaction of RC structures with various setups on inclining and plain ground.

II. METHOD OF ANALYSIS

1) The analysis of structures for the vertical and horizontal loads can be done by analysistool STAAD pro.
2) For the static and dynamic analysis of multi-storey buildings have moment resistingframe By STAAD Pro. Software Method.
3) Equivalent static lateral force method – For Static analysis only discussed as per IS1893(part-1):2002 for regular buildings only.
4) Analysis of the soil bearing capacity of different hilly areas.
5) Analysis of Displacement of Column in various slopes configurations.
6) Comparisons of the structure of different configurations on the basis of angle ofsloping with the help of STAAD-Pro.
7) Graphical comparison will be done in accordance to the proposed structure and theirdifferent configurations.

According to Kani's strategy minutes at the close end of a part will be total of:

a) The settled end minutes at the close end because of this stacking on the part.
b) Twice the turn's commitment of the close end.
c) The turn commitment of the far end.

$M_{ab} = M_{ab} + M_{ab} + M_{ba}$ $M_{ba} = M_{ba} + 2\ M_{ba} + M_{ab}$ Where,

M_{ab} = last end minutes at point A.M_{ba} = last end minutes at point B M_{ab}= settled end minutes at A M_{ba}= settled end minutes at B
M_{ab}= revolution commitment of end A
M_{ba}= turn commitment of end B

The parts to which the last end minutes M_{ab} and M_{ba}can be part up as or Minutes are controlled by experiencing the accompanying stages-

- The closes An and B of the part are first viewed as settled and comparing to this conditionthe settled end minutes M_{ab}at A and M_{ba} at B are resolved.
- Now keeping up the fixity of the end B, the end A is turned through a point Q_a toward theend B. the minute M_{ab} is actuated toward the end B. The minute M_{ab} is known as the pivot commitment of the end A.
- In this stage, the end A is considered at settled and the end B is turned through an edge Q_b by the use of a minute $2M_{ba}$at B. The minute M_{ba} is known as the revolution commitmentof end B.

Consequently, the last minutes M_{ab} and M_{ba} can be communicated as conditions-
$M_{ab} = M_{ab} + 2\ M_{ab} + M_{ba}$ $M_{ba} = M\_ba + 2\ M_{ba} + M_{ab}$

III. METHODOLOGY

This thesis deals with relative study of behavior of sloping ground building frames considering different inclination (**0^0, 10^0, 15^0, 20^0, 25^0 and 30^0**) under earthquake forces. The comparison of sloping ground and plane ground building under seismic forces is done. Here G+ 4storey 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 rigid system is determined by applying in five building frames in seismic intensities: V with the help of STAAD Pro.

A. STAAD Pro. Software

The seismic analysis on buildings frame is done by STAAD Pro. (V8i software), It is one of the most popular structural engineering software products for 3D model generation, analysis and multi-material design. It has a sensitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products.

For static or dynamic analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminum or timber buildings, transmission towers, stadiums or any other simple or complex structure, STAAD Pro., has been the choice of design professionals around the world for their specific analysis needs.

B. Steps For Comparison

Comparisons of results in terms of bending moments, displacements, shear force, axial force, drift. Following steps are adopted in this study:

1) Step-1modeling of structures with selection of frame geometry and different Seismic zones: The behavior of all the models is determined for seismic zone
2) (V) of India as per IS code 1893 (Part 1):2002
3) Step-2 defining different load combinations: 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.
4) Step-3 Modeling of building frames using STADD Pro. Software
5) Step-4 Analysis of five structural frames was done under seismic zone V for each load combination.
6) Step-5 Comparative study of results in terms of bending moments in footings, columns and beams, storey displacement, shear force, axial force, and drift.

C. Modelling &Analysis Of Building Frames

Modeling and analysis of building frames are carried out as per followingdetails-

Modelling

STAAD Pro. Software is used in modeling of building frames. STAAD stands for Structural analysis and design Program and it is general purpose software for performing the analysis and design of a wide variety of structures. The basic activities which are to be carried out to achieve this goal:

1) Geometry of the structure
2) Providing material and member properties
3) Applying loads and support conditions

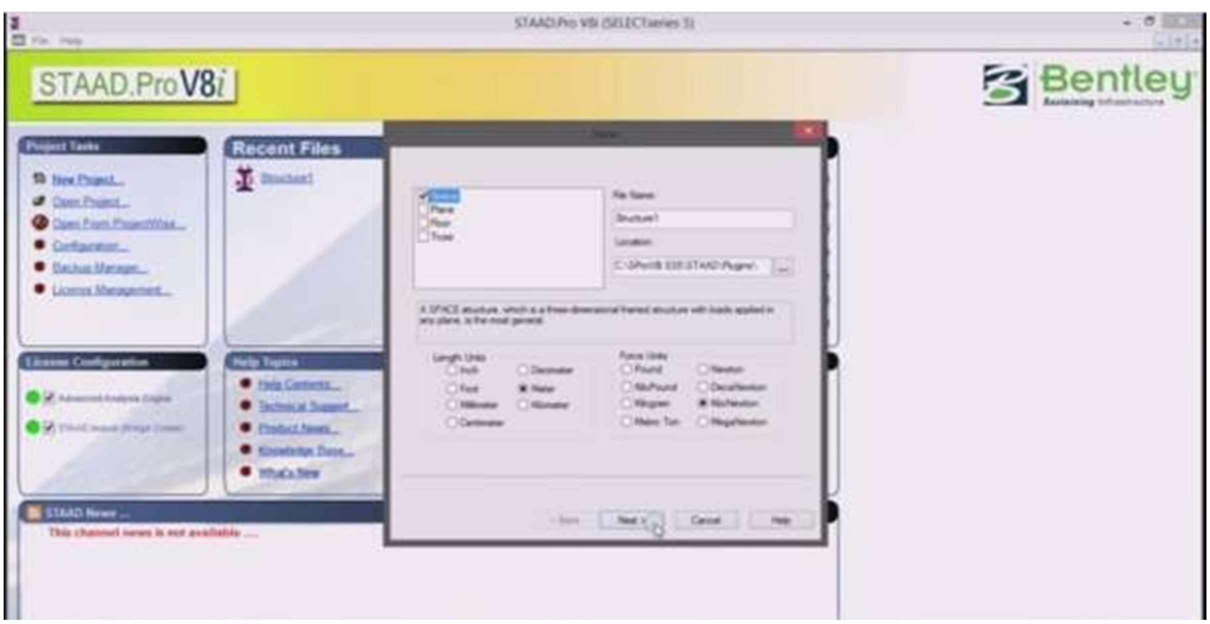

Fig.3 STAAD Pro. Software

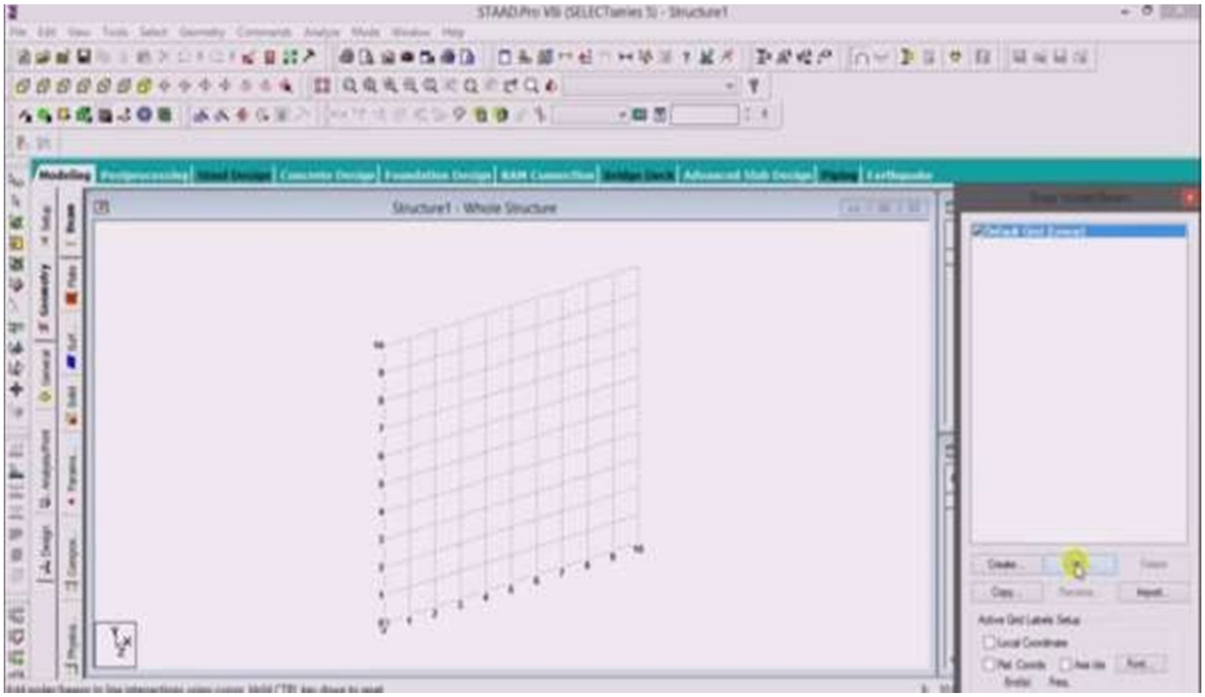

Fig.4 Preparation of structure in STAAD Pro.

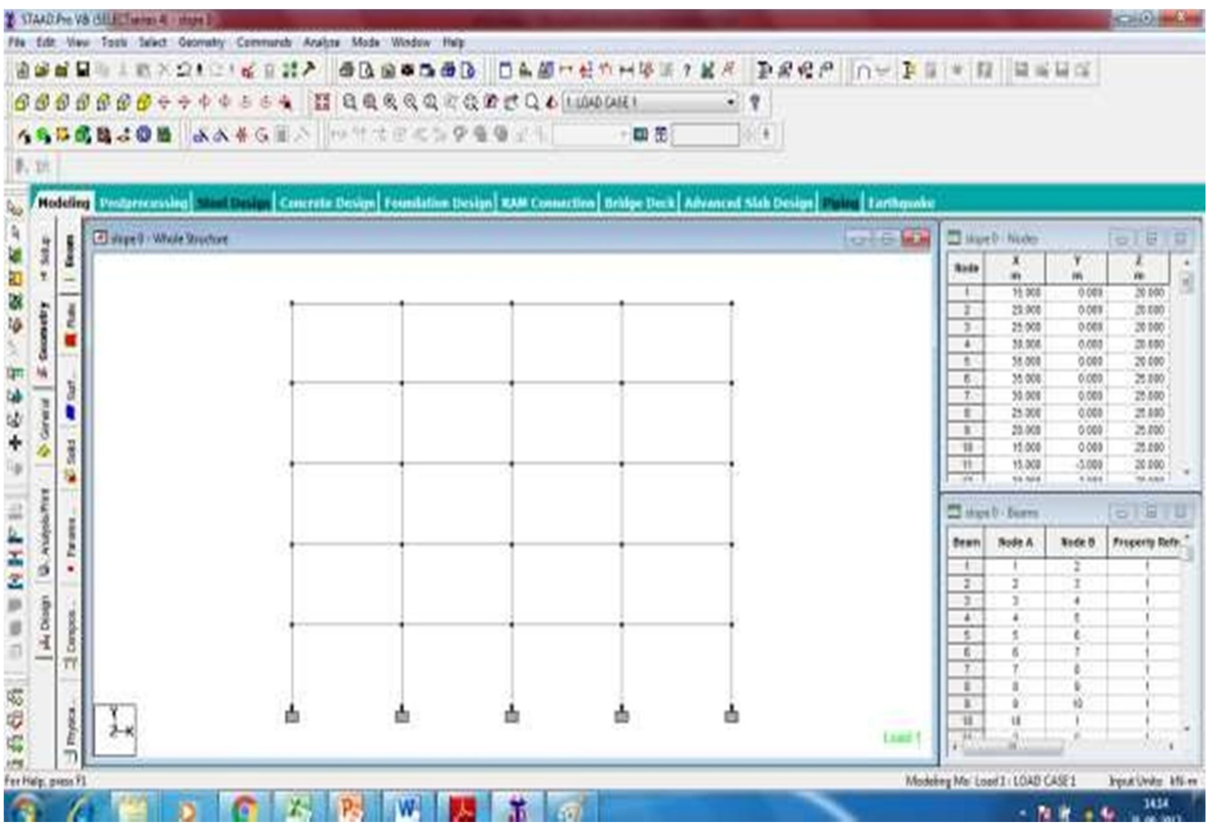

Fig.5 Preparation of Nodes of structure in STAAD Pro.

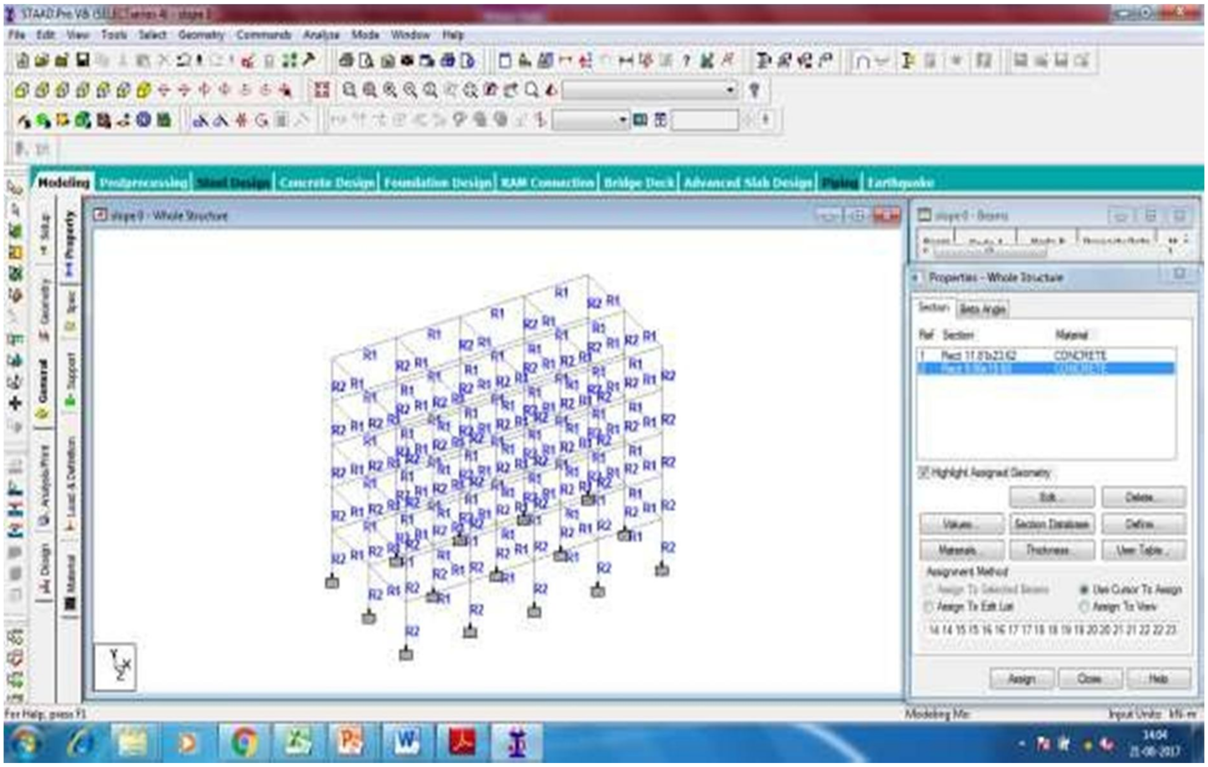

Fig.6 Preparation of Model in STAAD Pro. Assigning Beams and Columns

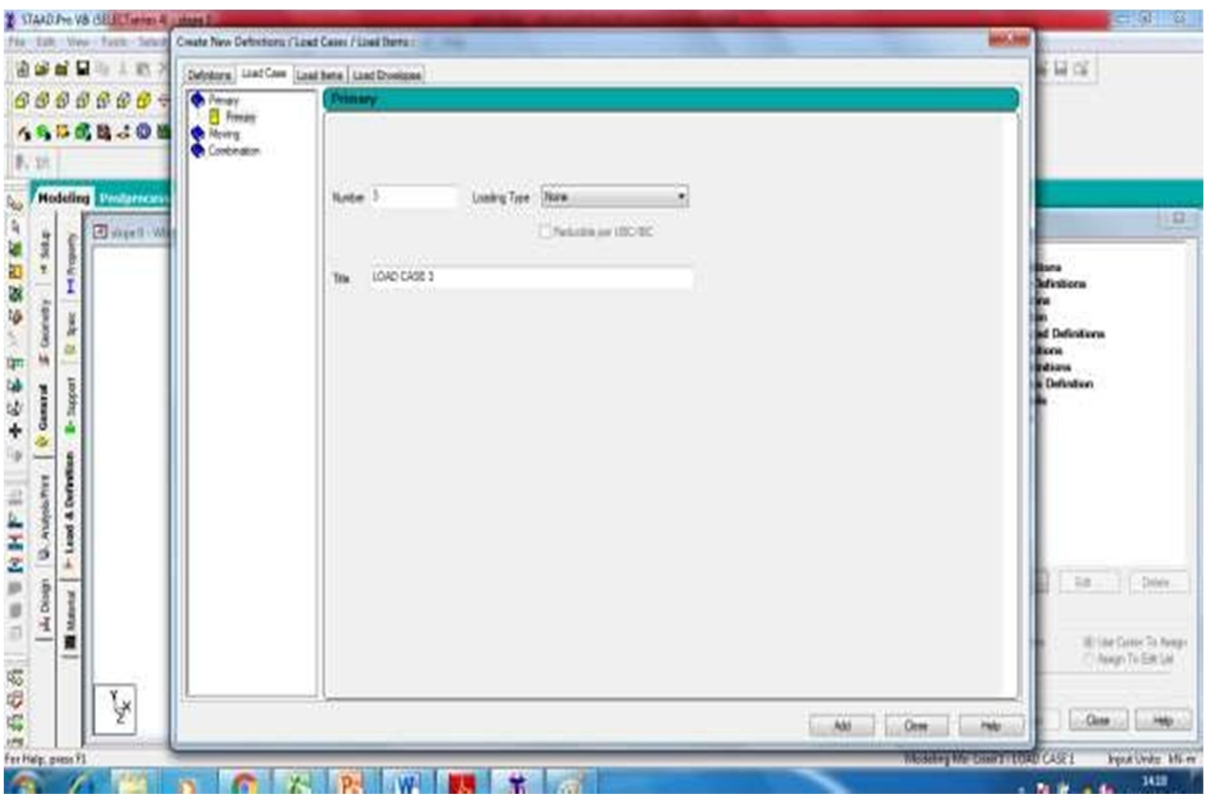

Fig.7 Preparation of Model in STAAD Pro. Assigning Load Distribution

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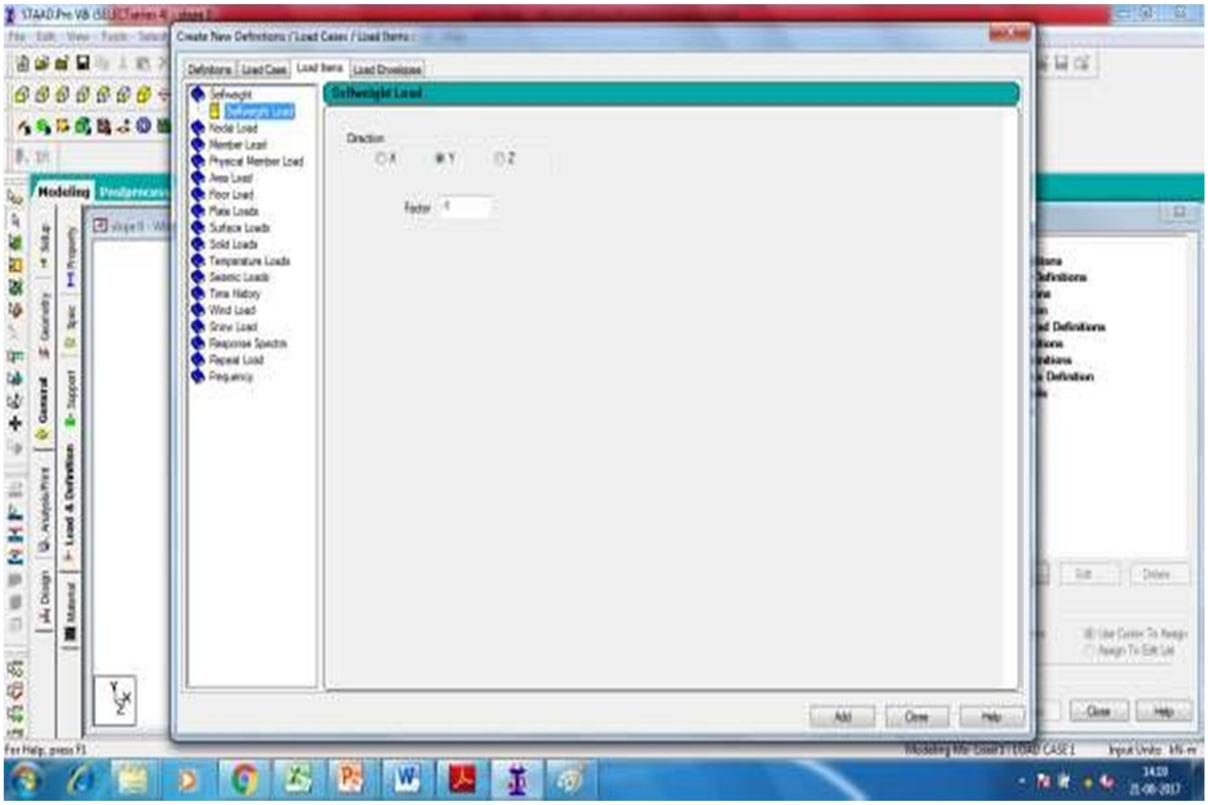

Fig.8 Preparation of Model in STAAD Pro. Load Distribution (Dead Load)

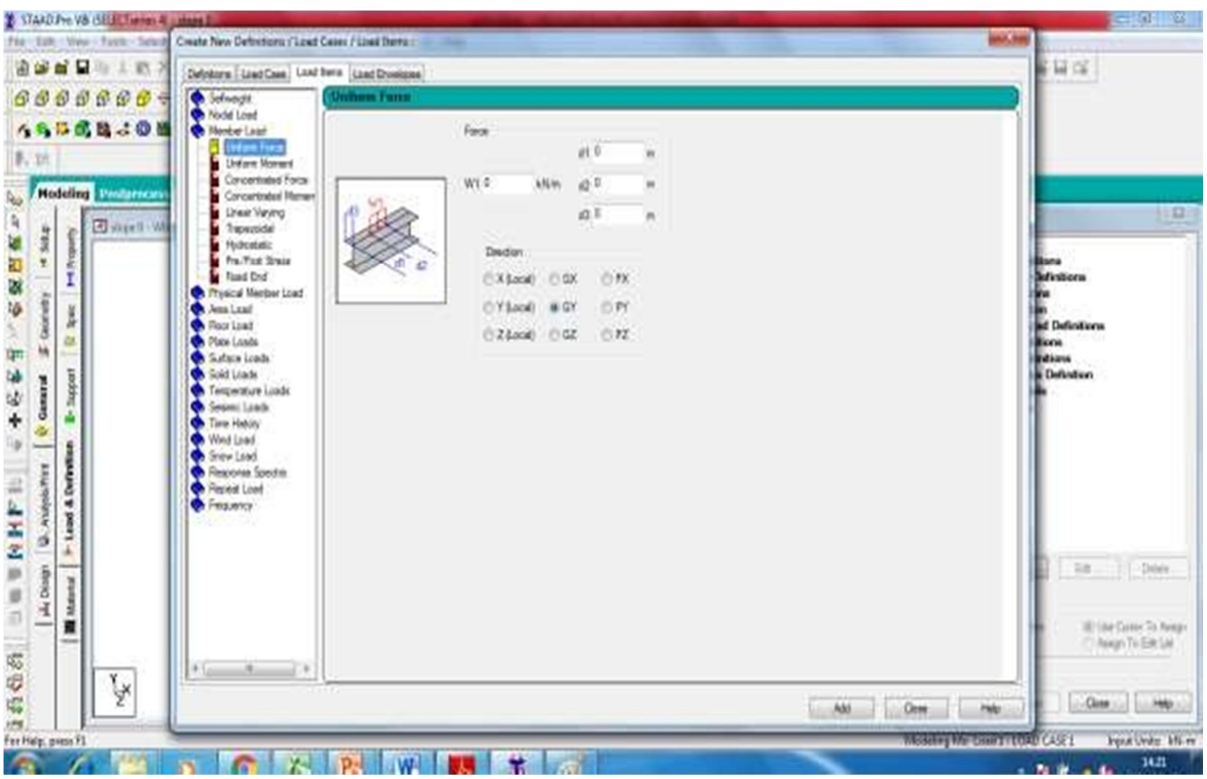

Fig.9 Preparation of Model in STAAD Pro. Load Distribution (Uniform Load)

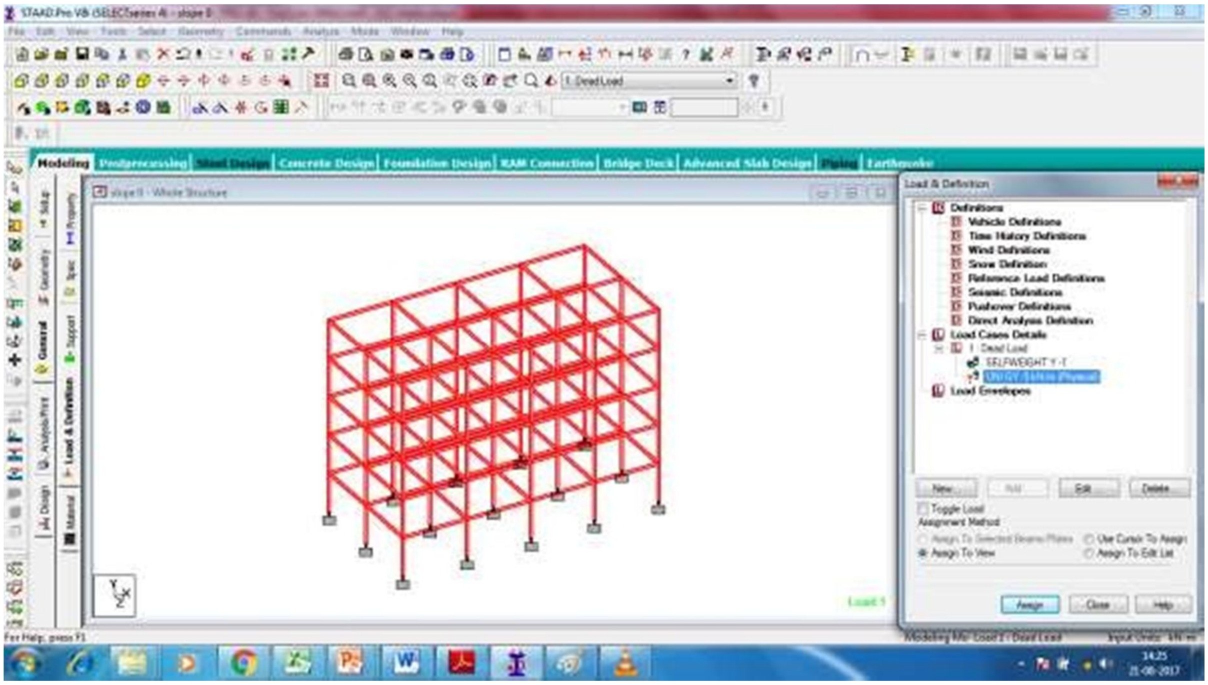

Fig.10 Preparation of Model in STAAD Pro. Assigning Load to structure (Dead Load)

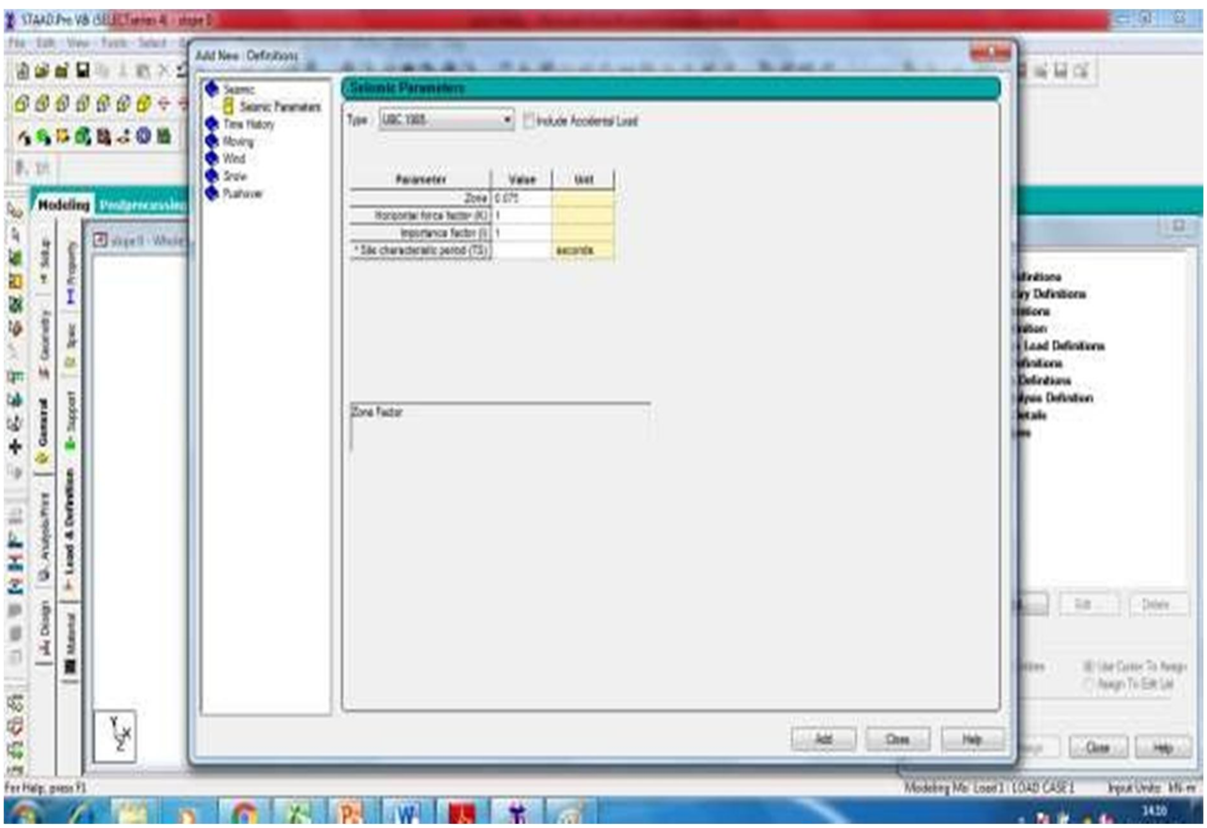

Fig.11 Preparation of Model in STAAD Pro. Assigning Load Distribution (SeismicParameters)

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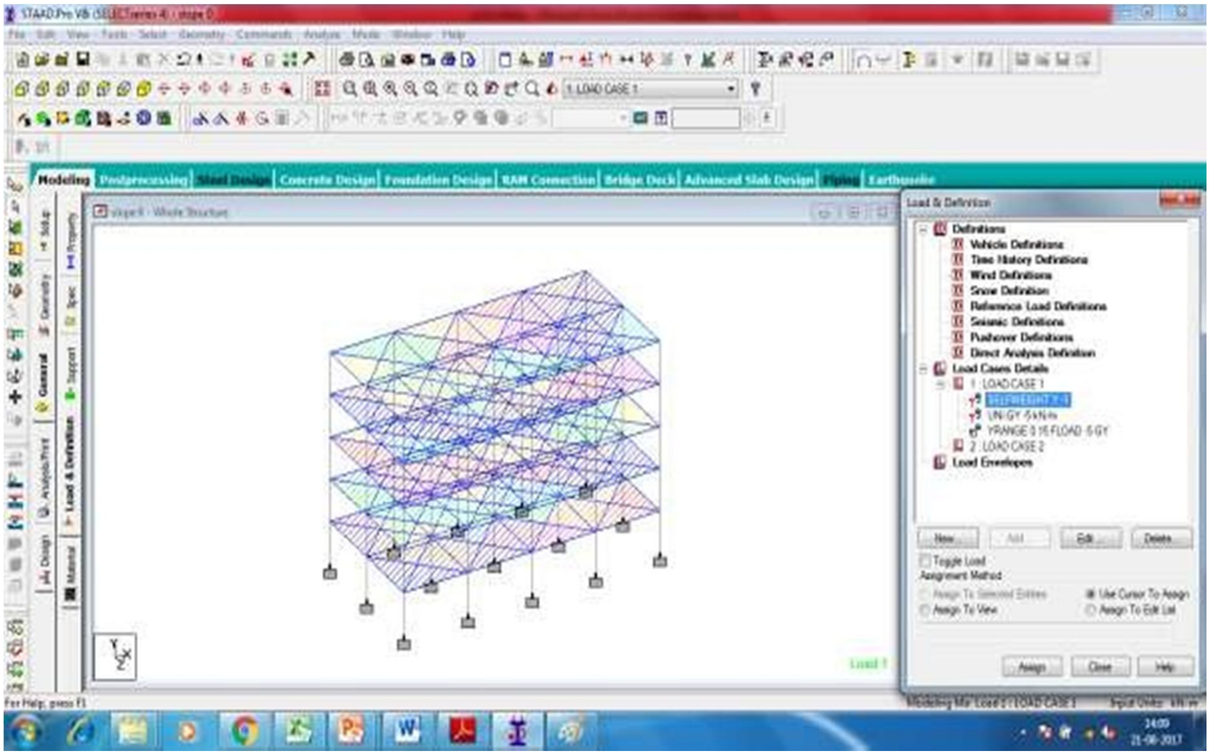


Fig. 12 Preparation of Model in STAAD Pro. Load Distribution

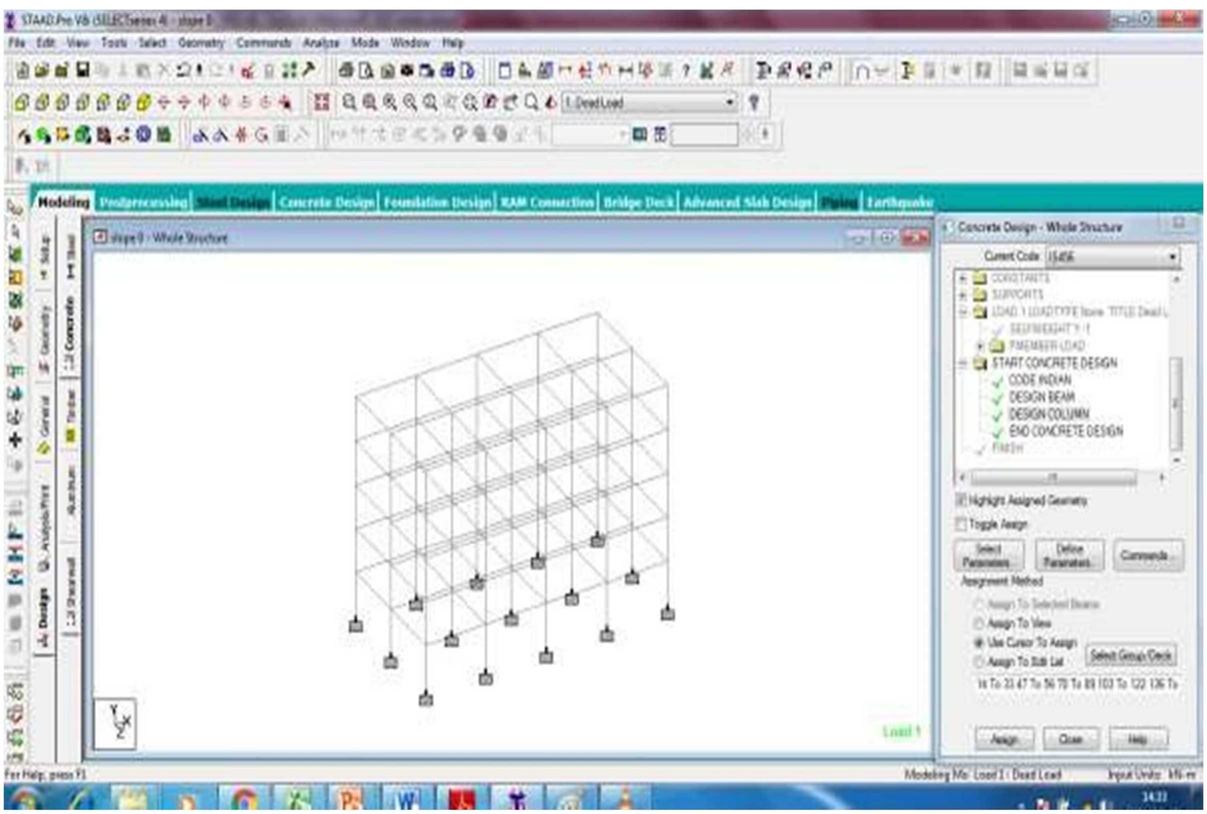


Fig.13 Preparation of Model in STAAD Pro. Assigning Necessary IS Codes

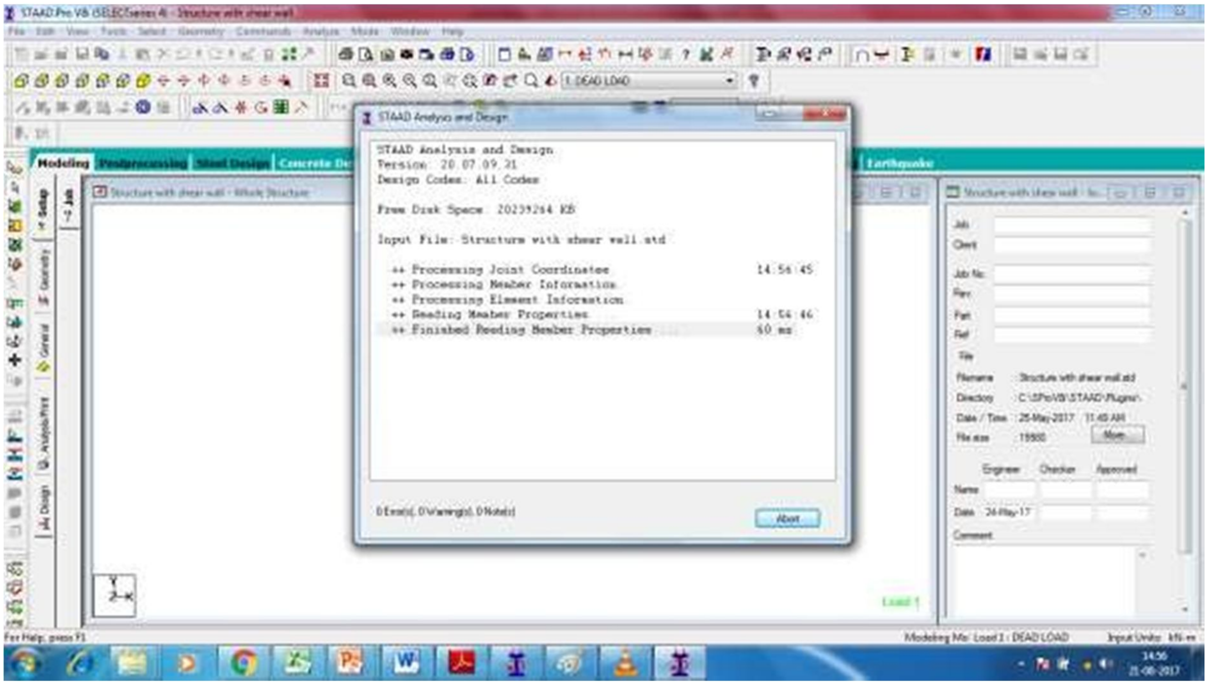


Fig.14 Preparation of Model in STAAD Pro. Result Analysis

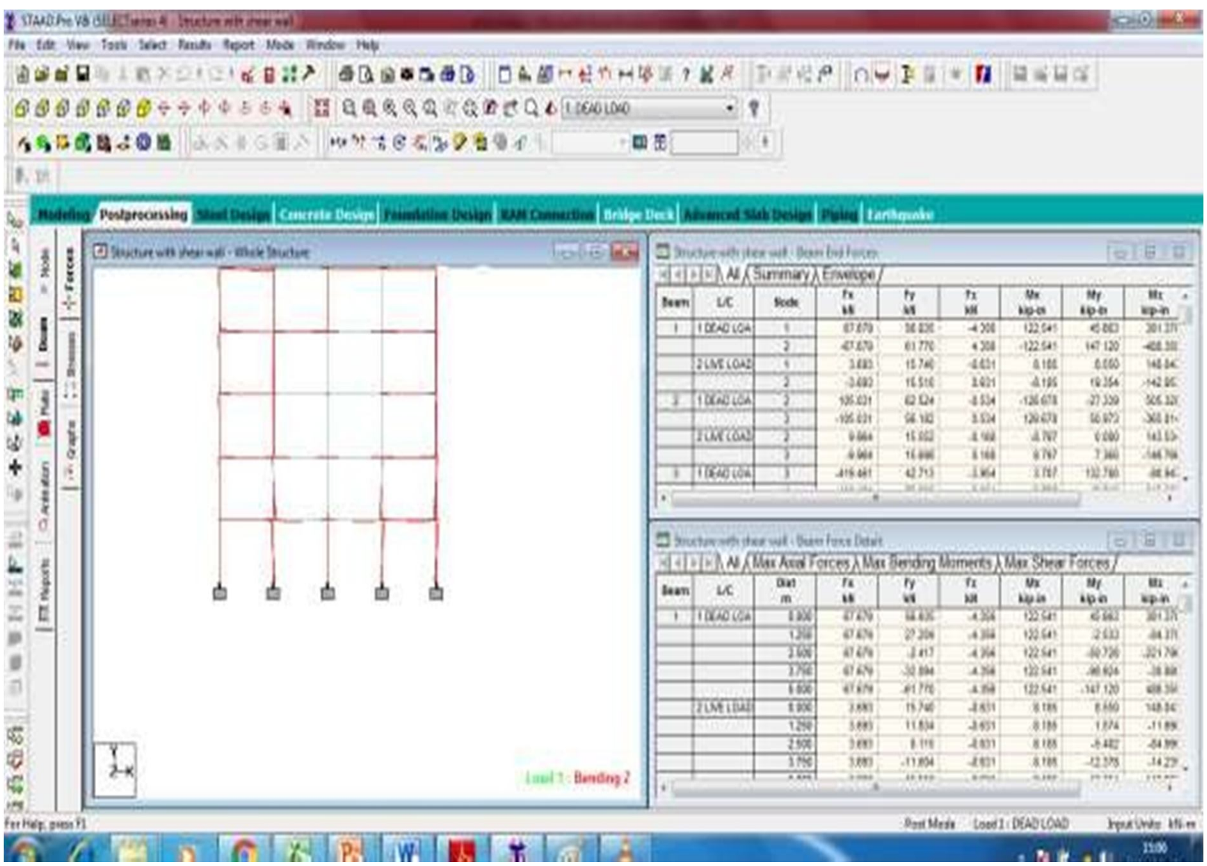


Fig.15 Preparation of Model in STAAD Pro. Result for Beam End Forces

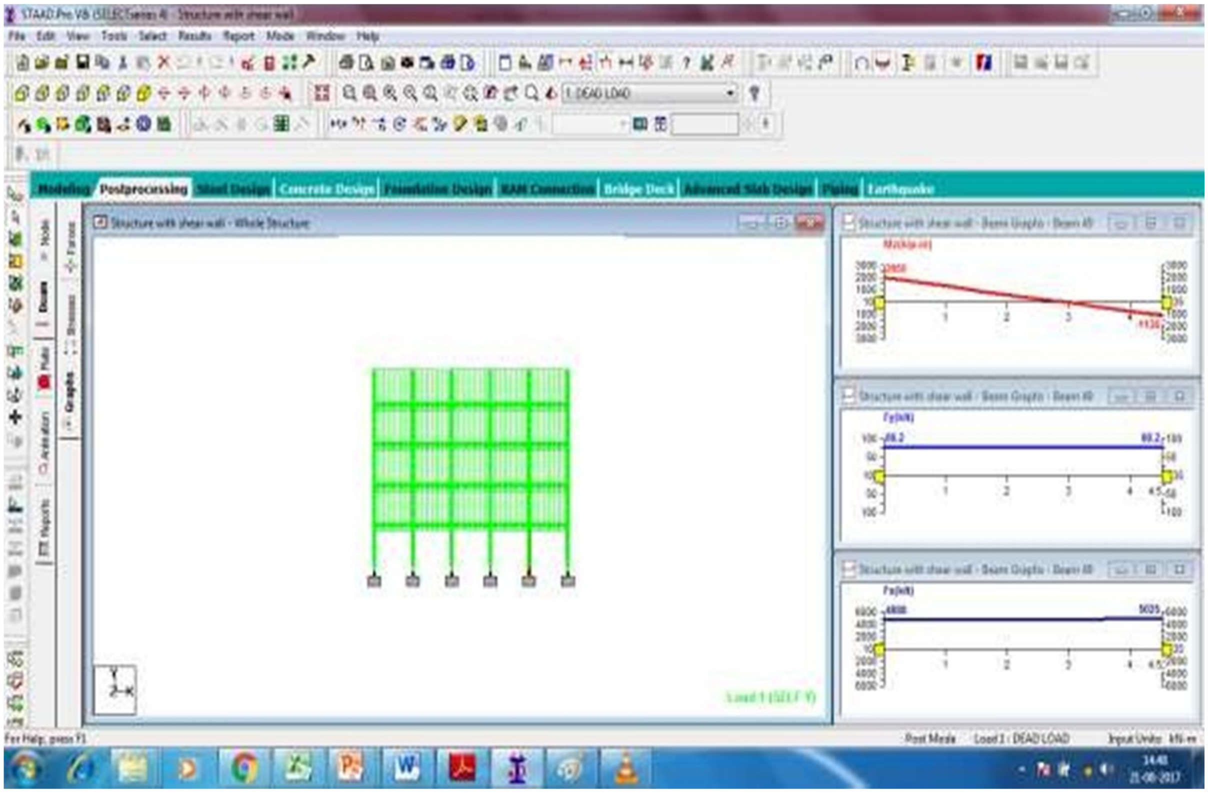


Fig.16 Preparation of Model in STAAD Pro. Result for Shear Force and BendingMoment for Beam

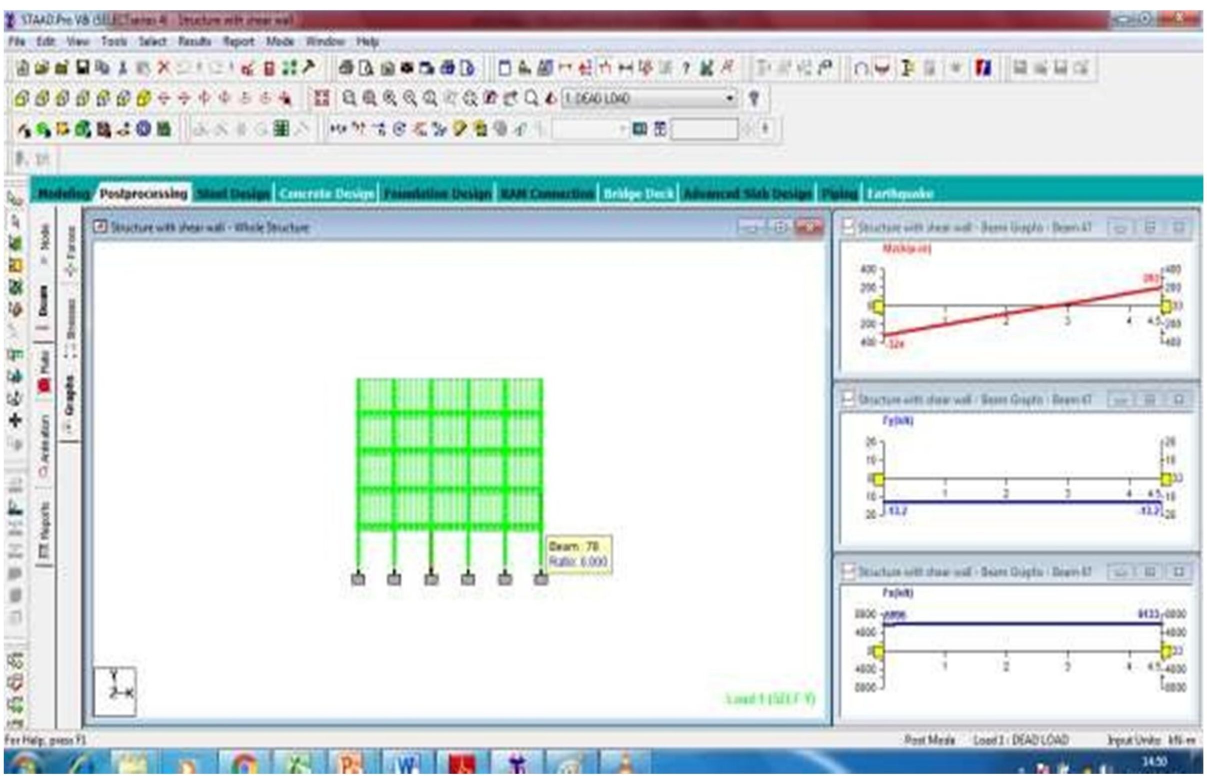


Fig. 17 Preparation of Model in STAAD Pro. Result for Shear Force and BendingMoment for Beam

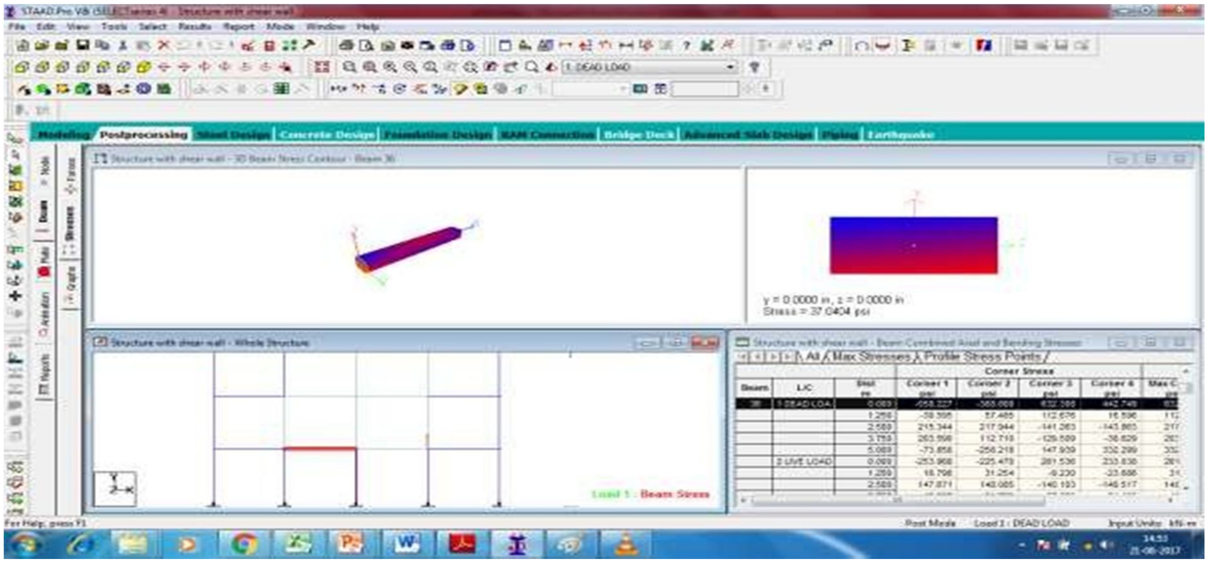
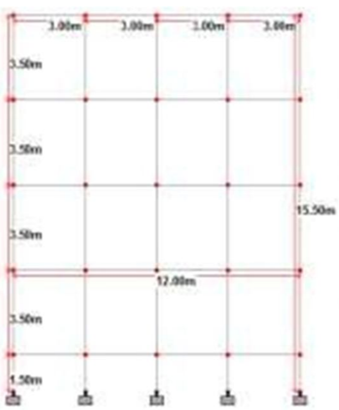


Fig.18 Preparation of Model in STAAD Pro.

D. Structural Models

Structural models for different sloping ground are shown in plan, elevation and 3Dstructural model of plane and sloping ground structures in Fig.



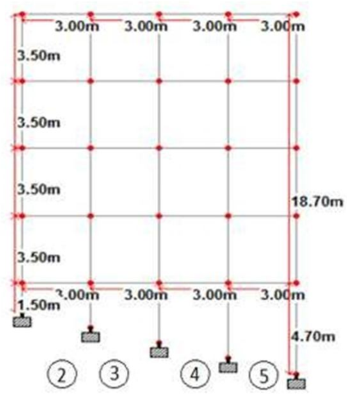
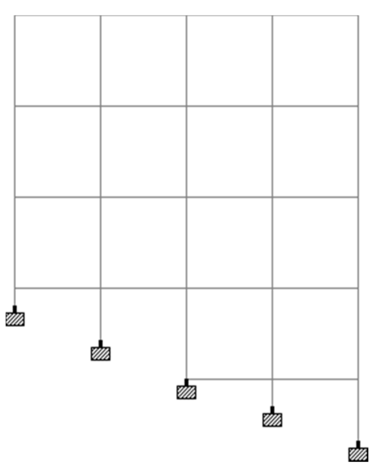


Fig 19 Fig 20

ELEVATION OF A SLOPING GROUND (0^0) ELEVATION OF A SLOPING GROUND (15^0)



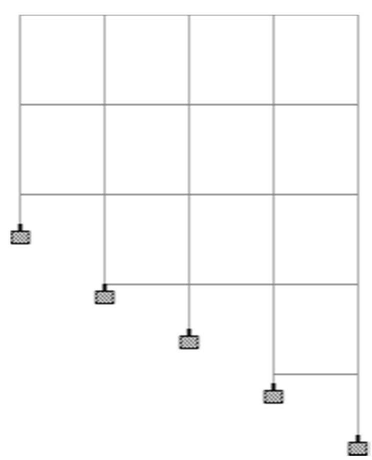


Fig 21 Fig 22

ELEVATION OF A SLOPING GROUND (20^0) ELEVATION OF A SLOPING GROUND (30^0)

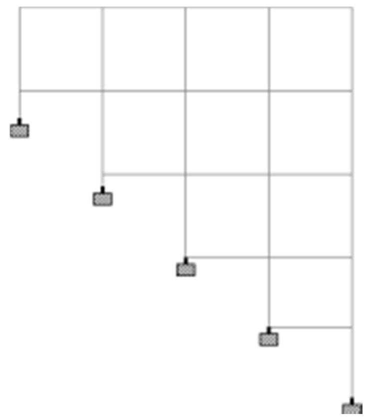


Fig 23 ELEVATION OF A SLOPING GROUND (40^0)

E. *Material And Geometrical Properties*

Following material properties have been considered in the modeling

Table-1 Material properties considered in the modeling

MATERIAL PROPERTIES	VALUES
DENSITY OF R.C.C	25 kN/m^3
DENSITY OF MASONRY	20-25 kN/m^3
YOUNG'S MODULUS (EC)	$2.17X10^4$ N/mm^2
POISSONS RATIO	0.17
COMPRESSIVE STRENGHT	25 N/mm^2
STEEL	Fe415

Table-2 Material properties considered in the modeling

SR.NO	STRUCTURAL MEMBER	SIZE
1	COLUMN ON GROUND	600MMX600MM
2	COLUMNS ON 1ST TO 4TH FLOOR	300MMX600MM
3	BEAMS ON TYPICAL FLOORS	230MMX500MM
4	THICKNESS OF TYPICAL SLAB	150MM
5	EXTERIOR AND INTERNAL WALL THICKNESS	230 MM

Table-3 Seismic Parameter in Building Frame

Seismic Parameter	Data/Value
Earthquake Zone	IV
Response Reduction Factor	3
Importance Factor	1
Damping	5%
Soil Type	Soft Clay, Dense Sand, Hard Clay, Rock

Table-4 Properties **of Soil**

Soil Properties	Type of Soil			
	SC*	DS*	HC*	RCK*
Modulus of Elasticity (E)	25	50	100	14400
Poisson's Ratio (μ)	0.25	0.3	0.1	0.4
Density (kN/m^3)	17	21	20	26.5

SC-Soft Clay	DS- Dense Sand	HC- Hard Clay	RCK- Rock

IV. RESULTS AND DISCUSSION

A. Analysis Result

1) Analysis results in terms of maximum bendingmoment in different cases:

Table-5 Bending Moment for 0^0

COLOUMN	BENDING MOMENT (KN-M)
1	146.4
2	163.7
3	177.8
4	158.3
5	155.5

Table-6 Bending Moment for 15^0

COLOUMN	BENDING MOMENT (KN-M)
1	128.1
2	152.7
3	177.7
4	192.8
5	247.8

Table-7 Bending Moment for 20^0

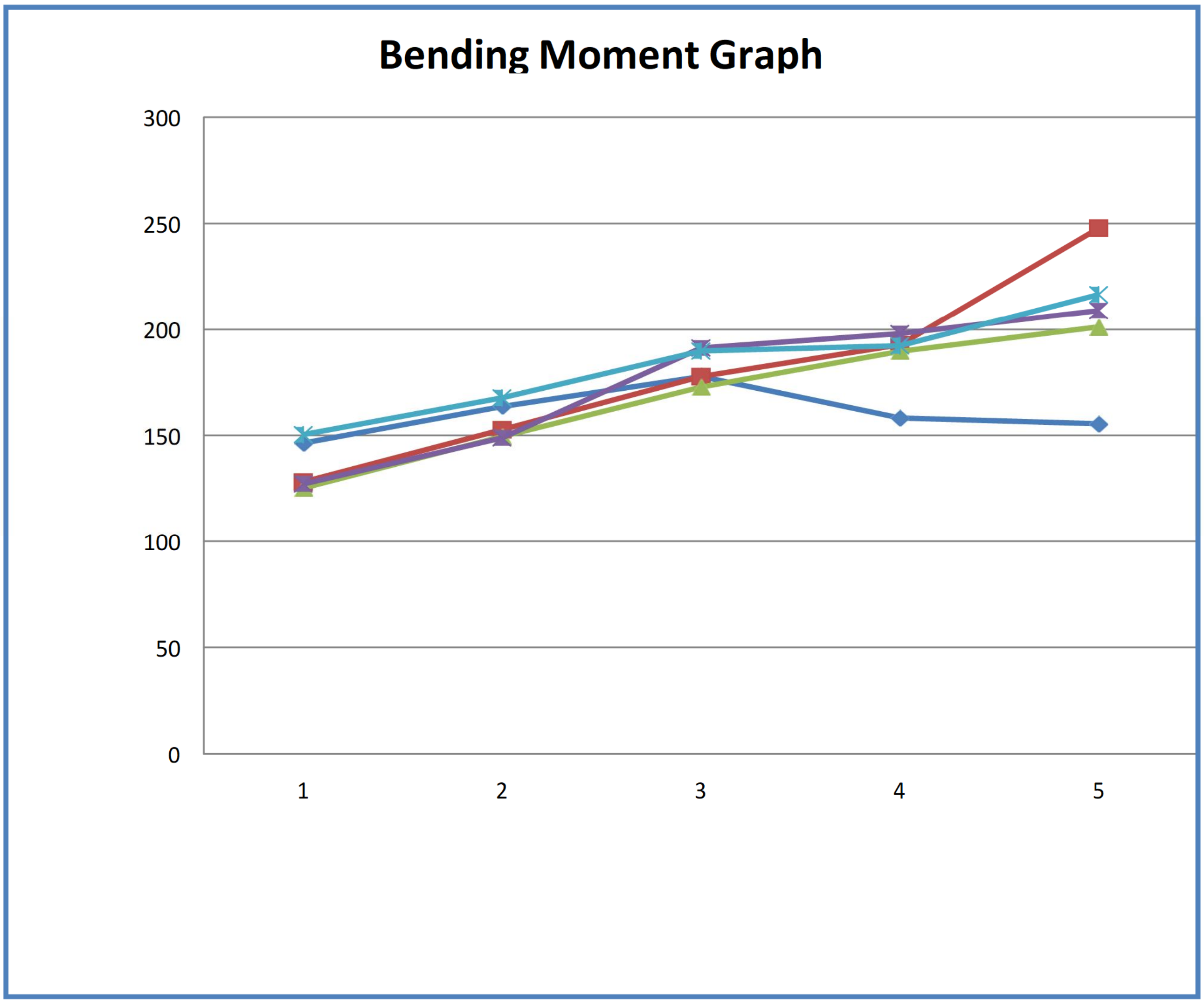
COLOUMN	BENDING MOMENT (KN-M)
1	125.3
2	149.6
3	172.9
4	189.65
5	201.22

Table-8 Bending Moment for 30^0

COLOUMN	BENDING MOMENT (KN-M)
1	127.22
2	148.86
3	191.27
4	198.07
5	208.92

Table-9 Bending Moment for 40^0

COLOUMN	BENDING MOMENT (KN-M)
1	150.4
2	167.7
3	189.8
4	192.3
5	216.5



2) Analysis Results In Terms Of Maximum Deflection In Different Cases

Table-10 Maximum Deflection For Column 1

COLUMN NO.	FLOOR NO.	0	15	20	30	40
1	0	1.992	-	-	-	-
1	1	8.756	0.307	0.207	-	-
1	2	14.34	5.02	4.956	0.461	-
1	3	21.5	9.81	8.3	4.966	0.35
1	4	26.4	13.23	13.19	9.158	3.555

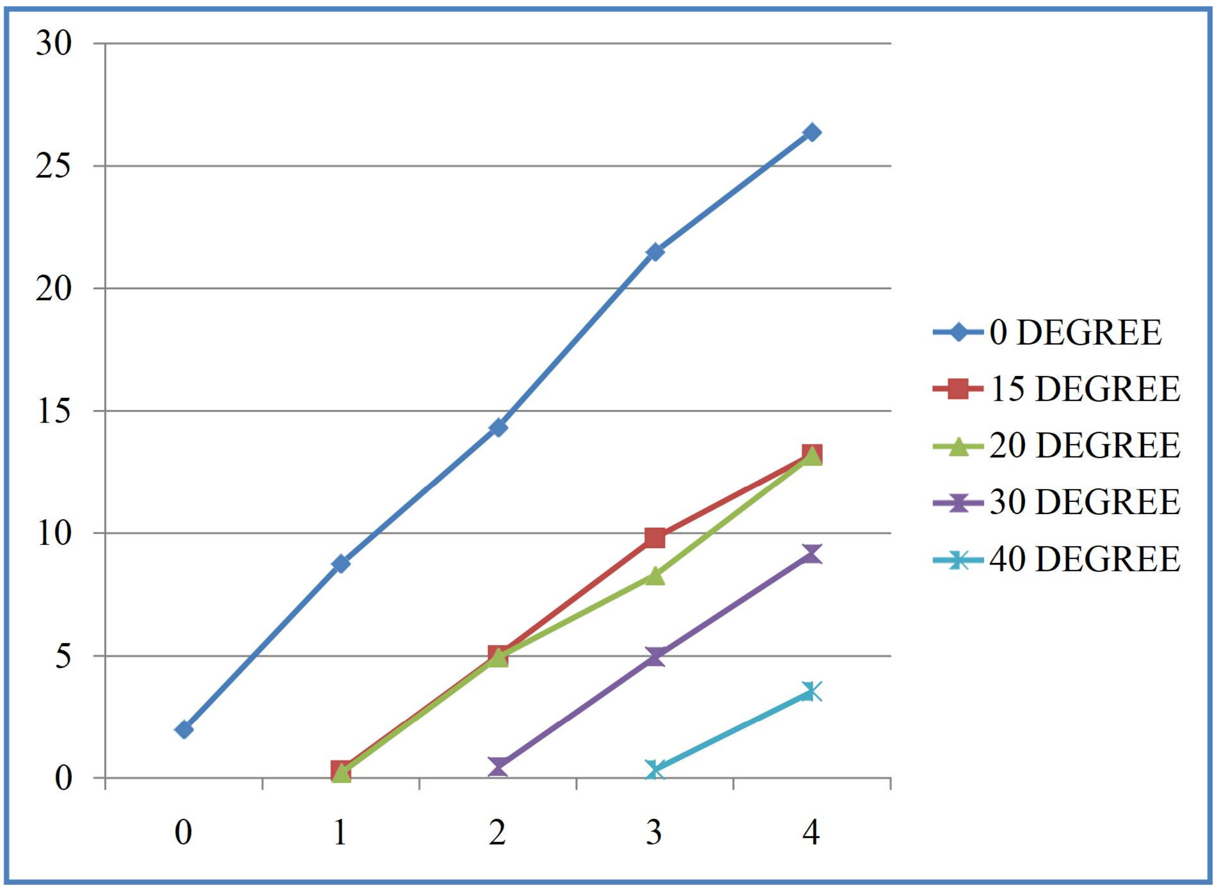


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Table-11 Maximum Deflection For Column

COLUMN NO.	FLOOR NO.	0	15	20	30	40
2	0	1.959	2.3	1.88	2.21	1
2	1	9.70	10.44	8.68	6.34	5.162
2	2	17.05	19.42	16.40	12.74	10.12
2	3	22.12	27.39	23.51	18.91	14.48
2	4	27.6	33.34	28.96	23.76	17.76

Maximum Deflection Graph for Column 1

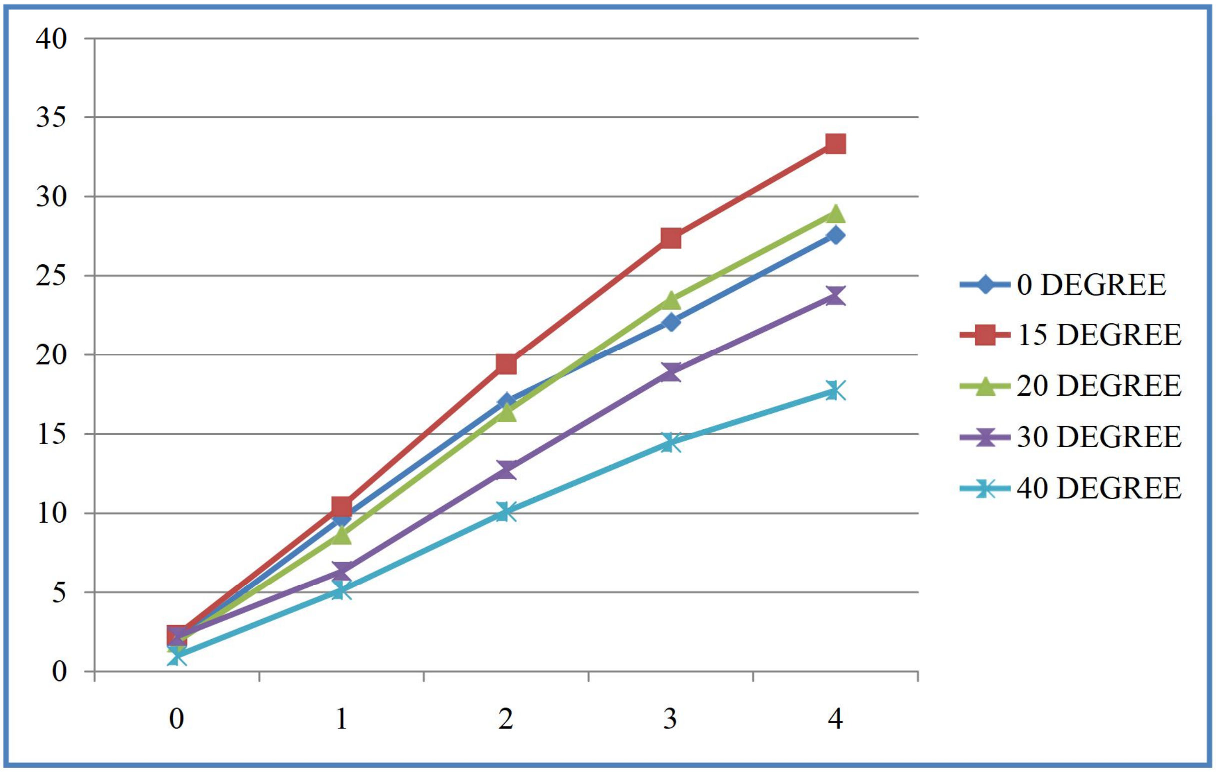

Table-12 Maximum Deflection For Column

COLUMN NO.	FLOOR NO.	0	15	20	30	40
3	0	1.912	-	-	-	-
3	1	7.311	4.14	0.21	-	-
3	2	15.231	11.12	4.96	0.461	-
3	3	21.408	18.31	10.3	4.996	0.35
3	4	26.33	23.23	14.4	9.158	3.56

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Maximum Deflection Graph for Column 1

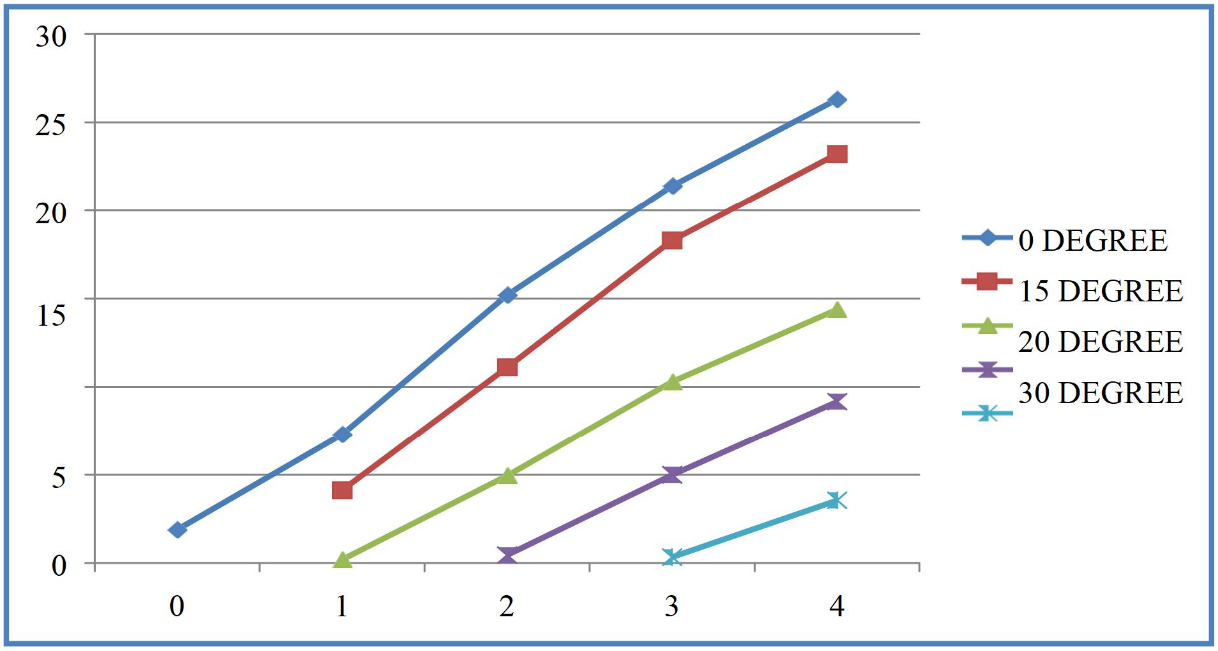


Table-13 Maximum Deflection For Column

COLUMN NO.	FLOOR NO.	0	15	20	30	40
4	0	1.88	2.673	2.3	1.88	2.216
4	1	8.08	11.22	10.44	8.68	6.34
4	2	16.06	22.1	19.42	16.4	12.75
4	3	22.346	29.3	27.4	23.5	18.92
4	4	27.33	36.8	33.34	29	23.77

Maximum Deflection Graph for Column 1

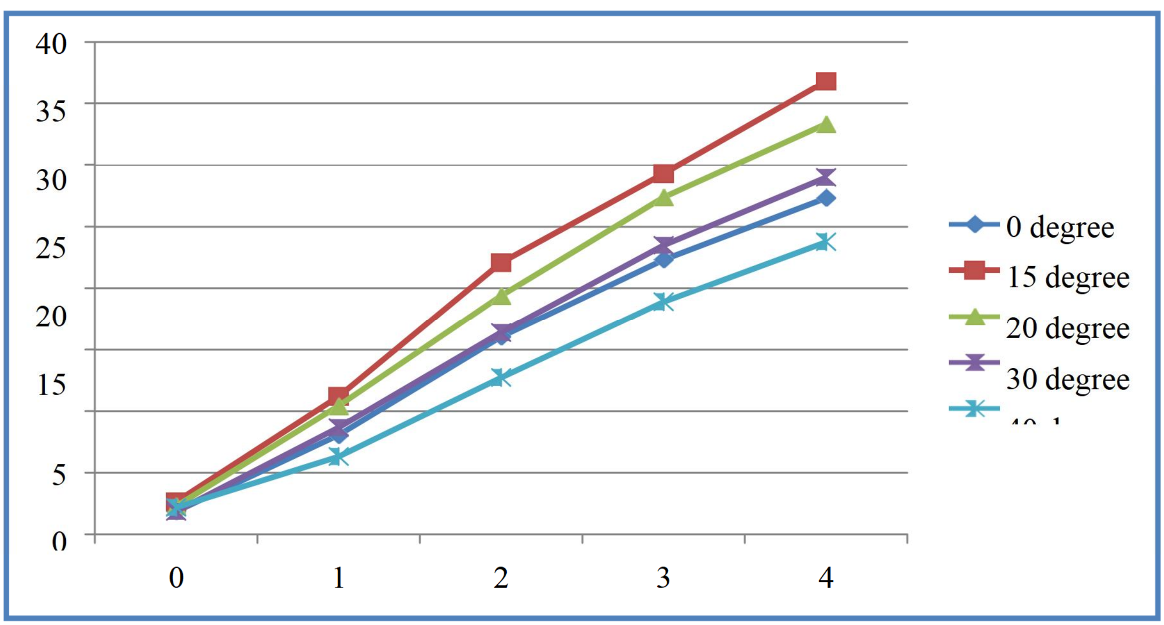
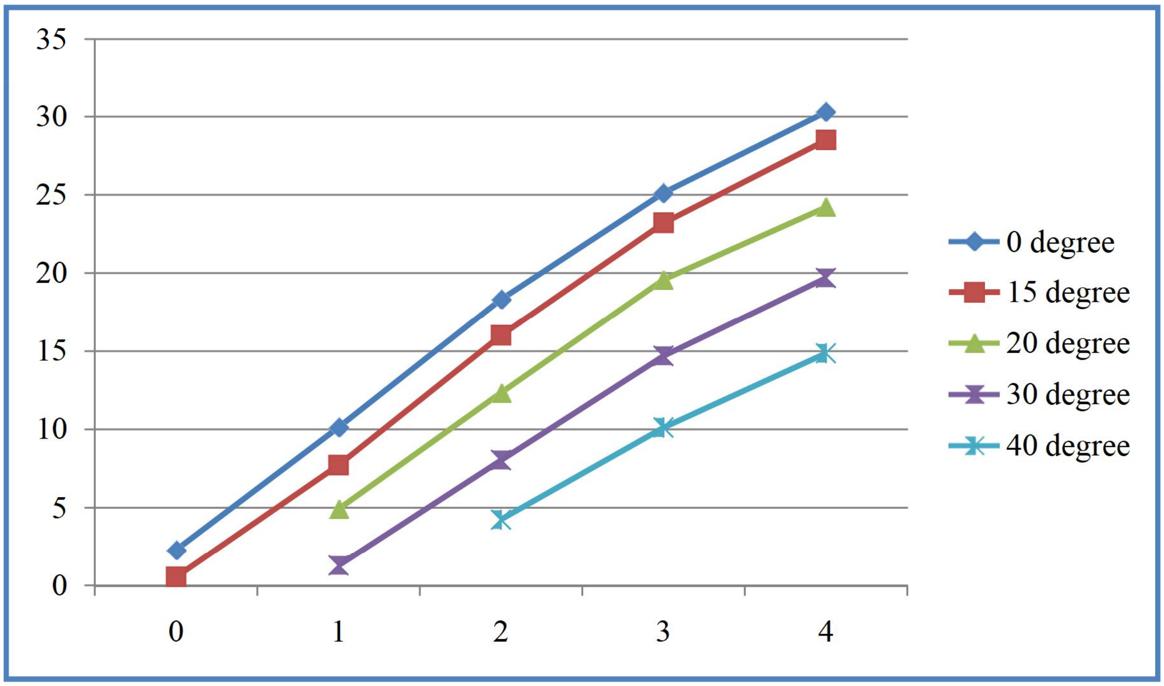


Table-14 Maximum Deflection For Column 5

COLUMN NO.	FLOOR NO.	0	15	20	30	40
5	0	2.289	0.553	-	-	-
5	1	10.14	7.72	4.915	1.299	-
5	2	18.33	16.02	12.35	8.042	4.25
5	3	25.16	23.23	19.61	14.7	10.13
5	4	30.32	28.52	24.24	19.7	14.87

Maximum Deflection Graph for Column 1



3) Analysis Of Shear Force In Different Cases

Table-15 Shear Force For 0 Degree

COLOUMN	SHEAR FORCE (KN)
1	64.7
2	59.3
3	71.5
4	76.6
5	82.2

Table-16 Shear Force For15 Degree

COLOUMN	SHEAR FORCE (KN)
1	52.1
2	44.8
3	47.3
4	49.6
5	50.1

Table-17 Shear Force For20 Degree

COLOUMN	SHEAR FORCE (KN)
1	46.3
2	32.3
3	29.3
4	29.8
5	29.6

Table-18 Shear Force For30 Degree

COLOUMN	**SHEAR FORCE (KN)**
1	21.4
2	18.8
3	16.3
4	17.2
5	13.3

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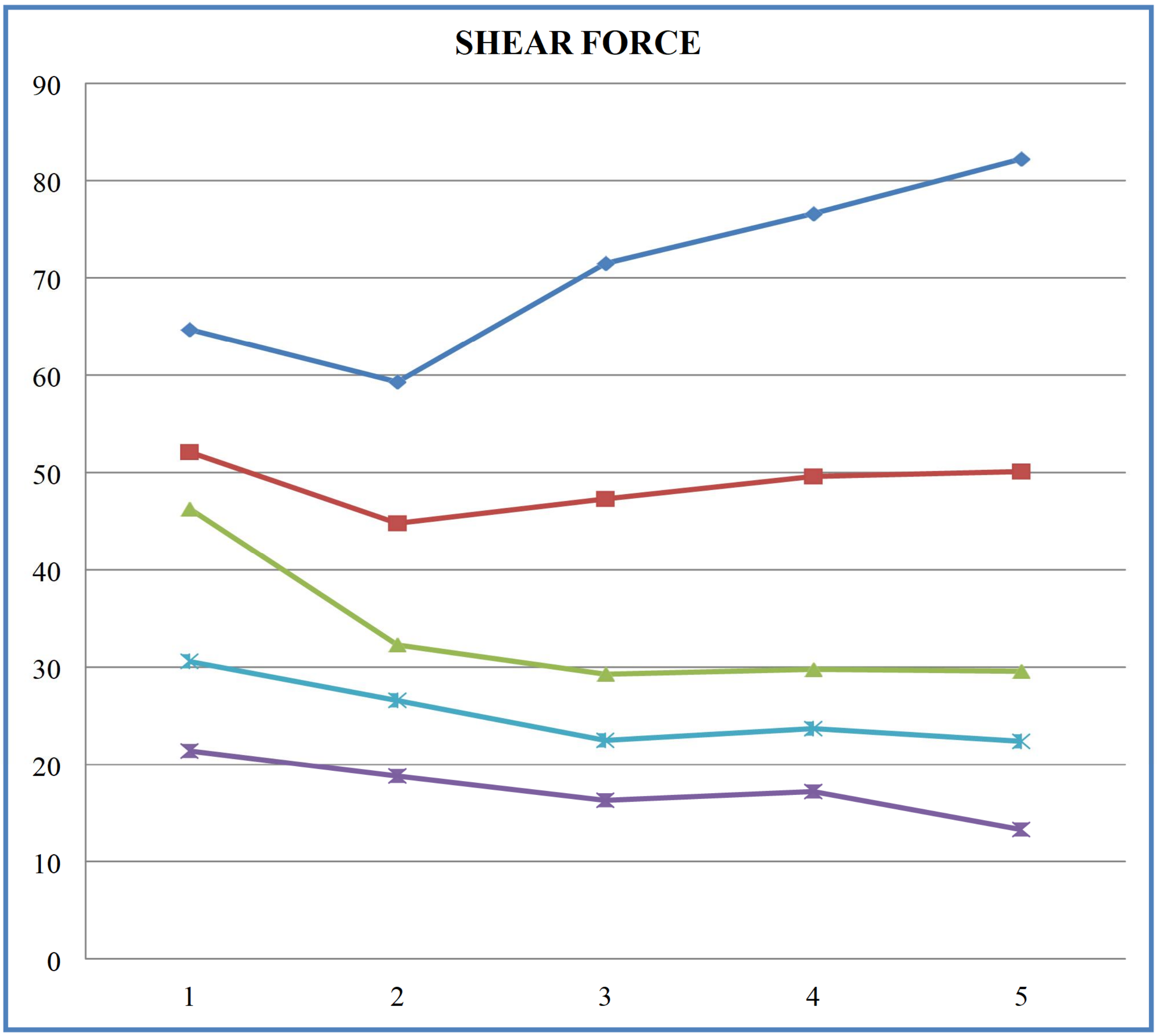
Table-19 Shear Force For40 Degree

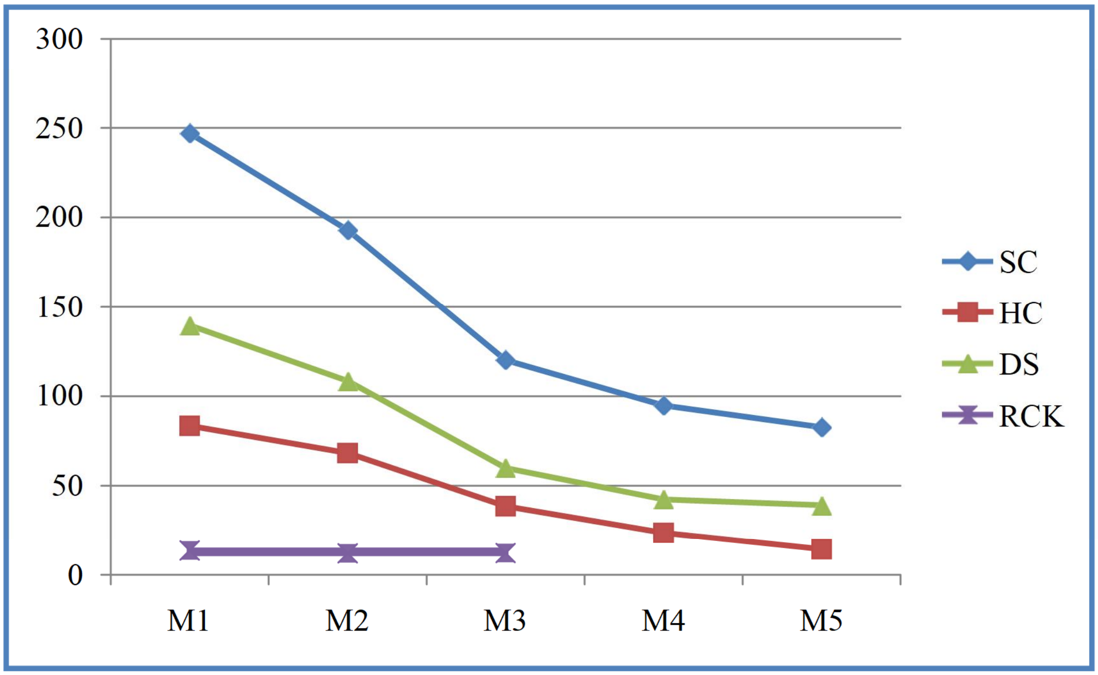
COLOUMN	SHEAR FORCE (KN)
1	30.6
2	26.6
3	22.5
4	23.7
5	22.4



4) Storey Displacement With Respect To DifferentType Of Soil

Table- 20 Story Displacement For Different Types Of Soil

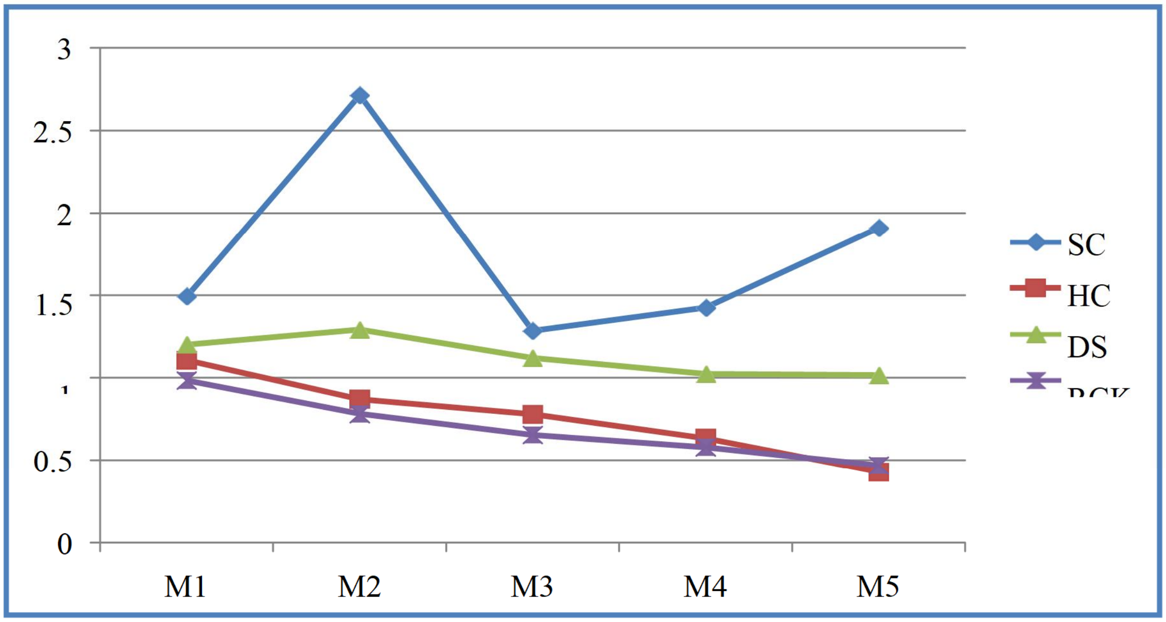
MODEL NUMBER	TYPE OF SOIL			
	SC	HC	DS	RCK
M1	247.10	83.48	139.61	13.66
M2	193.04	68.28	108.47	12.06
M3	120.17	38.54	59.90	12.22
M4	94.87	23.69	42.34	10.32
M5	82.66	14.42	39.06	9.76



5) Time Period For Different Models Under DifferentSoil Conditions

Table-21 Time Period for Different Models

MODEL NUMBER	TYPE OF SOIL			
	SC	HC	DS	RCK
M1	1.493	1.105	1.201	0.982
M2	2.714	0.869	1.292	0.78
M3	1.285	0.777	1.120	0.653
M4	1.425	0.632	1.024	0.578
M5	1.910	0.426	1.017	0.467



V. CONCLUSIONS & FUTURE SCOPE

A. *Conclusions*

Analysis of structural frame for earthquake forces is a common problem formulation now a day's due to presence of several software tools and programs. Reinforced concrete structural frames are common form of constructions resting on plains and sloping ground in India. There structures were subjected to different types of forces during their lifetime, such forces like dead load, live loads and dynamic forces like the wind and earthquake load.

Results from seismic evaluation performed on six RC buildings with six different ground slopes (0^0, 10^0, 15^0, 20^0, 25^0 and 30^0) were carried out by using static method. The displacement of the top storey and the footing reaction, axial force, shear and moment action carried in columns and beams have been followed to analyze the influence of inclined ground on structural performance of building frame.

The static analysis was done with the help of STAAD Pro. Softwareusing the seismic parameters as per the IS: 1893- 2002 for the zone (IV) and thepost processing result were obtained.

1) The development of bending moments in Step back buildings is higher than that in the Step back set back buildings. Hence, Step back Set back buildings are found to be less vulnerable than Step back building against ground sloping.
2) It is observed that extreme left column at ground level, which are short in height, were affected most.
3) Although, the Setback buildings on plain ground attract less action forces as compared to Step back Set back buildings, overall economic cost involved in leveling the sloping ground and other related issues needs to be studied in detail.
4) Bending moment in regular structure will be constant but in irregular structure where length of column changes according to slope then bending moment will vary respectively i.e., as the length increases bending moment will increase.
5) Shear force of Model 1 in all regular columns vary according to load distribution but irregular structure shear force decreases as increase in slope.
6) Deflection is higher on the lower portion of the structure due to higher bending moments on the lower portion (i.e., Longer Column Section).
7) Maximum storey displacement for M-5 obtained from equivalent static analysis decreased for soft clay (SC), dense sand (DS), hard clay (HC) and rock (RCK) with respect to model M1. Thus as increase in thestiffness of soil storey displacement reduces.

B. *Future Scope*

Research work can be carried out in this specific study area and it can help in designing the high rise structures in hilly terrain considering, the variousaspects with different soil spectrum, different seismic zones and varying angleof slope.

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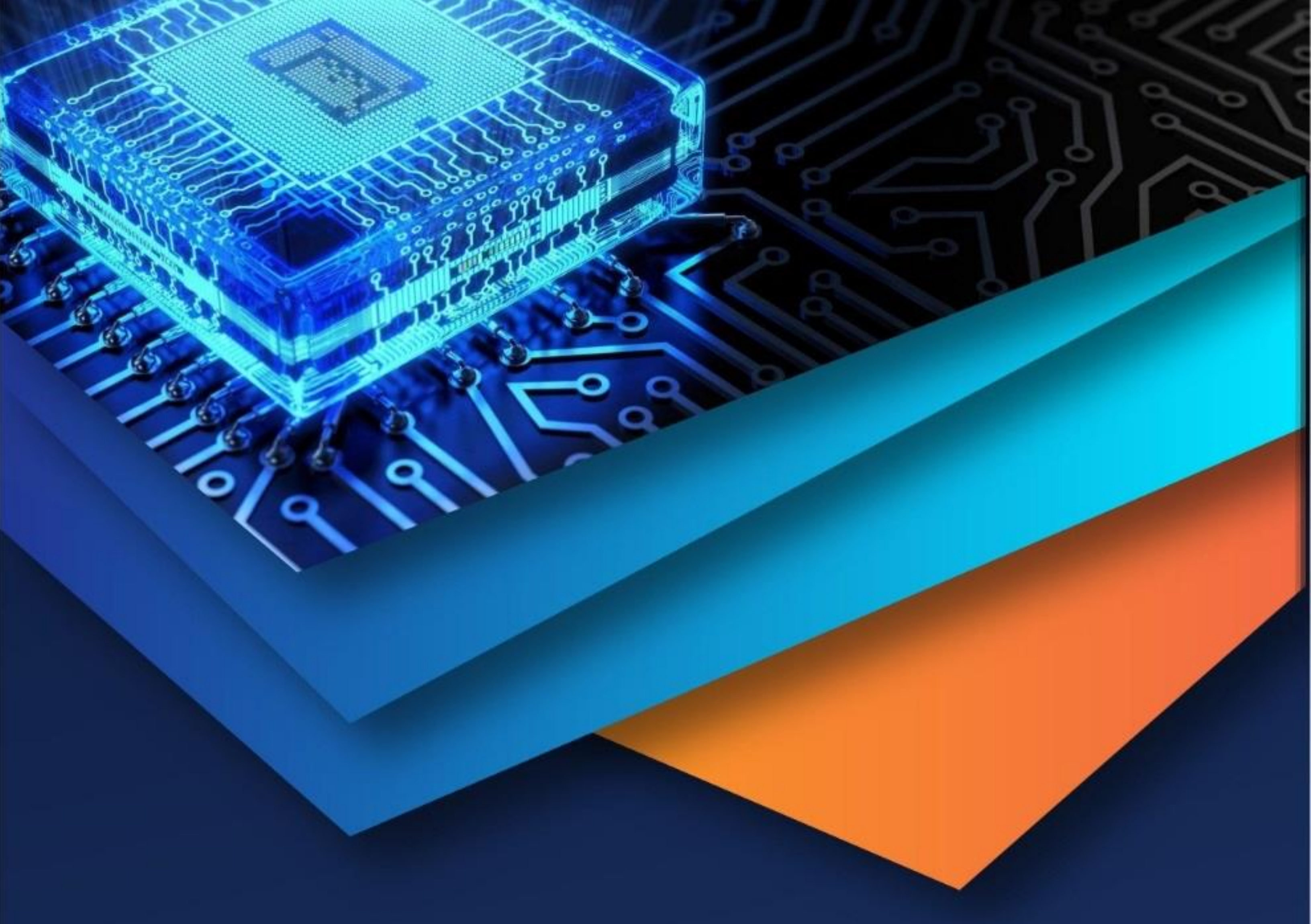

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