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Analysis And Design of Multistoried Building (C+G+10) by Considering Raft And Pile Foundation

KHAZI MOHAMMED NADEEMULLAH[1], MUSTAFA[2], MOHD ABDUL MUQEET[3], ABDUL ASIM KHAN[4], MD. SAIFUDDIN[5], AFTAB TANVEER[6]

Dept of Civil Engineering, SVITS, Mahbubnagar, Telangana, India.

Abstract: Civil engineering structures such as building must have sufficient safety margin under dynamic loading like earthquake. The dynamic performance of a RCC building can be determined accurately that requires appropriate modelling considering foundation-soil, building-foundation and soil interactions. Building-foundation-soil interactions are complex phenomena requiring advanced mathematical and numerical modelling. The soil-structure interaction plays an important role particularly when subjected to seismic excitation, due to the potentially disastrous consequences of a seismic event. In the present work effectiveness of modelling in software for determination of seismic behaviour of the medium rise building over raft considering soil flexibility interaction is studied. Modal analysis of building system is carried out in software. For the analysis, three dimensional multiple bays regular RC building model for eight storeys is considered and the soil beneath the structure is modelled as equivalent soil springs connected to the raft foundation. The response spectrum analysis of the soil-structure model was carried out using the general software E-tabs. In both the cases (fixed base and flexible base) of modelling the structure, the earthquake records have been scaled according to the Indian Standard 1893-2002 for each type of soil (i.e. I, II & III) and applied to the ordinary moment resisting frame with seismic zone III, zone IV and zone V.

Keywords: Dynamic Soil-Structure Interaction, Seismic Response, STAAD.Pro, Spring Stiffness, Displacement, Mat Foundation, Natural Period.

I. INTRODUCTION

Earlier structures and foundations were dealt in complete isolation, where the structural and geo-technical/foundation engineers hardly interacted. While the structural engineer was only bothered about the structural configuration of the system in hand he hardly cared to know anything more about soil other than the allowable bearing capacity and its generic nature, provided of course the foundation design is within his scope of work. On the other hand the geotechnical engineer only remained focused on the inherent soil characteristics like (c, φ, Nc, Nq, Nγ, eo, Cc, G etc.) and recommending the type of foundation (like isolated footing, raft, pile etc.) or at best sizing and designing the same. The crux of this scenario was that nobody got the overall picture, while in reality under static or dynamic loading the foundation and the structure do behave in tandem. The common design practice for dynamic loading assumes the building frames to be fixed at their bases. In reality, supporting soil medium allows movement to some extent due to its natural ability to deform. This may decrease the overall stiffness of the structural system and hence, may increase the natural periods of the system. Such influence of partial fixity of structures at the foundation level due to soil-flexibility in turn alters the response. On the other hand, the extent of fixity offered by soil at the base of the structure depends on the load transferred from the structure to the soil as the same decides the type and size of foundation to be provided. Such an interdependent behaviour between soil and structure regulating the overall response is referred to as soil structure interaction.

II. LITERATURE REVIEW

Bhojegowda V T and K G Subramanya (2015): Present study provides systematic guidelines for determining the natural periods of framed buildings due to the effect of soil-flexibility and identification of spring stiffness for different regular and irregular story buildings and various influential parameters are identified. The study were carried out for building with isolated, mat and pile foundations for soft, medium and hard soil conditions. It is observed that framed structure with pile foundation resting on hard, medium and soft soil can be treated as fixed since no much variation in the response of the structure. Famed structure with mat foundation possesses high foundation stiffness than isolated foundation hence base shear for mat foundation has increased and other parameters like displacement, bending moment and time period were reduced.

III. METHODOLOGY

A. Idealization of building and raft foundations

To analyze the dynamic behaviour while considering the effect of soil flexibility, building frames have been idealized as 3-D space frames using two nodded frame elements and have being analyzed using STAAD.Pro software. In conventional design technique, the building is analyzed as fixed base frame with the help of computer software. In present study considers frames to see how correctly the influence of soil-structure Interaction on dynamic behavior can be predicated. This may give an idea about the error, which one should liable to commit if this popular but grossly inaccurate approach is invoked.

B. Idealization of soil

The function of the foundation media is to resist the forces applied to it by the base of the buildings. During earthquake, a rigid base may be subjected to displacement in six degrees of freedom, and the resistance of soil may be expressed by the six corresponding resultant force component. Hence the structural behavior of the elastic half space is represented completely by a set of force displacement relationships defined for these degrees of freedom. To simulate the static behavior of soil-structure system, it is evident that the foundation medium could be modeled by six linear springs acting in rigid base degrees of freedom. Appropriate static spring constants can be evaluated for the elastic half space by the method of continuum mechanics.

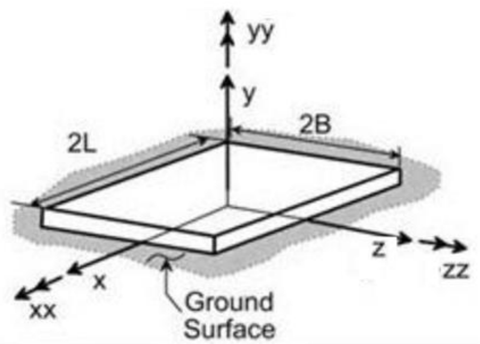

Fig1. Equivalent soil spring stiffness.

Table1. Stiffness's of equivalent soil springs along various degrees of freedom

Degrees of freedom	Stiffness of equivalent soil spring
Translation along x – axis (Kx)	KZ -{[(0.2GL)/(0.75-μ)][1-(B/L)}
Translation along y – axis (Ky)	{[(2GL)/(1-μ)][0.73+1.54(B/L)0.75]}
Translation along z – axis (Kz)	{[(2GL)/(2-μ)][2+2.5(B/L)0.85]}
Rocking about x – axis (Krx)	{[(GIX0.75)/(1-μ)](L/B)0.25[2.4+0.5(B/L)]}
Torsion along y – axis (Kry)	GJt0.75{4+11[1-(B/L)]10}
Rocking about z – axis (Krz)	{[(GIZ0.75)/(1-μ)][3(L/B)0.15]}

To analyze the entire structural system consisting of soil-foundation and structure under dynamic loading, the impendence function associated with a rigid mass less foundation may be used to make the analysis most general, translations of foundations in two mutually perpendicular principal horizontal directions and vertical direction as well as rotations of the same about these 3 directions are considered in the present study. The mat foundations system is idealized has a combination of a series of parallel foundations strips oriented in two principal directions resting in the same horizontal plane. Springs are attached in the above mentioned six degrees of freedom. The effect of soil-flexibility on building resting on different types of soils (hard, medium, soft) is also attempted to be studied in the present work. Gross spring values is obtained on the full raft dimension as mentioned in table 1 and then are broken up into discrete values.

$$K' = K\ (AP/AG)$$

Where:

K' - Value of discrete spring for the finite element

IV. MODELING AND ANALYSIS

A. Details of soil parameters considered

The structure is assumed to be resting on three different soils (soft, medium and hard). The details of soils considered for present study is shown in table 2.

Table2. Characteristic properties of soils

Type of soil	Shear wave velocity Vs (m/s)	Elastic modulus E (kg/cm²)	Shear Modulus G (kg/cm²)	Density of soil ρ (kN/m³)	Poisson's ratio of soil μ
Hard	600	16400	6480	17.322	0.28
Medium	320	4945	1808	16.841	0.39
Soft	150	935	335	14.435	0.40

B. ETABS

In the last 30 years TABS and ETABS have set the international standards in structural analysis and design. They first took into consideration the characteristic properties of a building's mathematical model, thereby allowing the graphical creation of a building's model in the same sequence that will actually be constructed (slab by slab, floor by floor). Worldwide, ETABS is considered the most popular analysis and design software. The "Top Seismic Product of the 20th Century" (2006) and "Honour Award in Engineering Software" (2002) awards, establish it as the innovator in structural analysis and design and the reference point for the entire market. The latest version of ETABS continues in that tradition, incorporating structural element terminology that is used on a daily basis (Columns, Beams, Bracings, Shear Walls etc.), contrary to the common civil engineering programs that use terms such as nodes, members etc. Additionally, it offers many automatic functions for the formation, analysis and design of the structural system in an efficient, fast and easy way. The user can easily create a model, apply any kind of load to it and then take advantage of the superior capabilities of ETABS to perform a start or art analysis and design. ETABS is the solution, whether you are designing a simple 2D frame or performing a dynamic analysis of a complex high-rise that utilizes non-linear dampers for inter-story drift control.

C. Areas of Application

- Analysis and design of building structures with a structural system consisting of beams, slabs, columns, shear walls and bracings. Different materials can be assigned to the structural elements within the same model such as steel, RC, composite or any other user-defined material

- Easy and automatic generation of gravity and lateral loads (seismic and wind loads) when compared with other FE general analysis programs

D. Advantages:

- Graphic input and editing for easy and fast model generation
- 3D generation of the model through plan views and elevations
  Fast model generation using the concept of Similar stories
- Easy editing through the Move, Merge, Mirror and Copy commands
- Accuracy in dimensionsby using Snaps(end, perpendicular, middle etc.)
- Fast object creation with one click of the mouse
- Multiple viewing windows.
- 3D view with zoom and pan capability
- 3D axonometric view of the model, plan view, elevation view, elevation development view, custom view defined by the user
- Graphic input of cross sections of any geometry and material (Section Designer)
- Copy and Paste of the geometry of a model to and from spreadsheets
- Export of the model geometry to .dxf files
- Integration with EC – Praxis 3J for the analysis and design of steel connections
- Integration with STEREOSTATIKA for easy import of model geometry and design of RC structures according to Greek Code
- Integration with e-Tools for the design of RC structures according to Greek Code, masonry structures according to Euro code 6, RC jackets according to Greek Code and automatic creation of plastic hinges for pushover analysis
- Integration with SAP2000 for 3D analysis and design of structural elements including bridges, dams, tanks and buildings

V. MODELING OF THE STRUCTURE

A. General

R.C moment resisting frame structure having G+10 storey is analysed for garvity and latral load (earth quake and wind loads). The effect of axial force, out of plane moments, lateral loads, shear force, storey drift, storey shear and tensile force are observed for different stories. The analysis is carried out using ETABS and data base is prepared for different storey levels as follows.

B. Modelling of R.C Moment Resisting Frame Structure

In this present study G+5 conventional building is considered. The constriction Technology is R.C.C frame structure and slabs. The modelling is done in ETABS as follows.

- The structure is divided into beam and column elements.
- The nodes are created as plan architect plan and node are connected through beam command, columns also connected.
- Boundary conditions are assigned to the nodes wherever it is required. Boundary conditions are assigned at the bottom of the structure i.e., at ground level where restraints should be against all movements to imitate the behavior of structure.
- The material properties are defined such as mass, weight, modulus of elasticity, Poisson's ratio, strength characteristics etc. The material properties used in the models.
- The geometric properties of the elements are dimensions for the section.
- Elements are assigned to structure.
- Loads are assigned to the joints as they will be applied in the real structure.

The model should be ready to be analysed forces, stresses and displacements

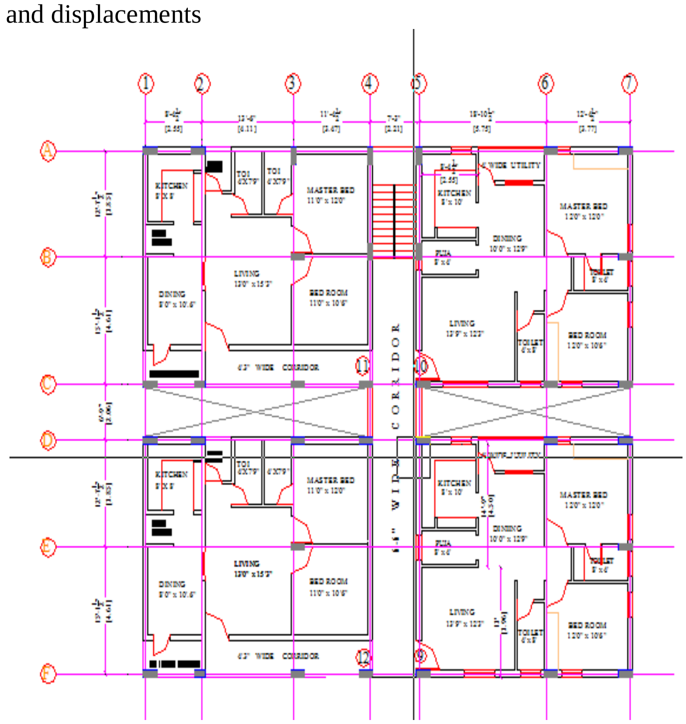

Fig2. Plan of the structure.

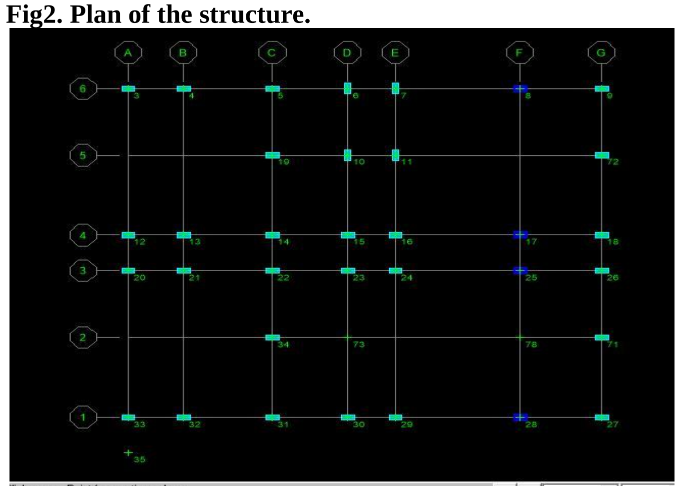

Fig3. Plan of the structure from ETABS.

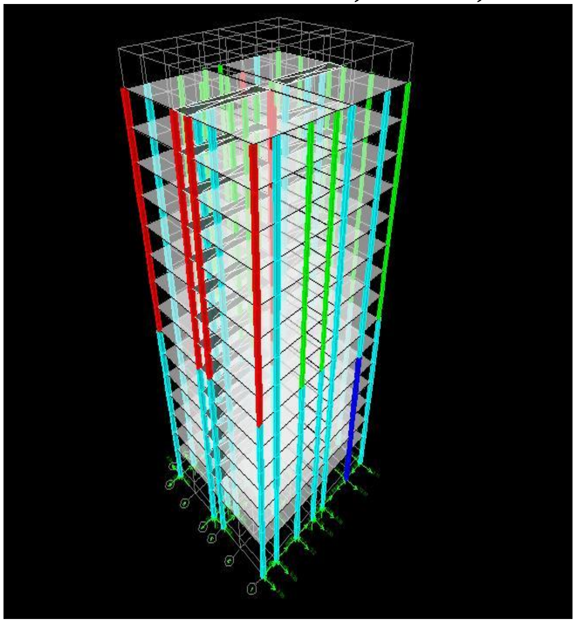

Fig4. 3-D view of the structure.

VI. ANALYSIS AND RESULT

A. General

Structure having 3UG+G+10 storey is analysed for garvity and latral loads (sesimic). The effect of axial force, out of plane moments, lateral loads, shear force, storey drift, storey shear and tensile force are observed for different stories. The analysis is carried out using ETABS and data base is prepared for different storey levels as follows. The raft and pile foundation is Designed by using SAFE software.

B. Load Cases And Load Combinations

In this present work consider both gravity and lateral load case (SESIMIC). The load combinations as per the Indian standards are considered. The primary load cases and the load combinations are shown following tables respectively.

Table2. Primary load cases

Load Case Number	Load Type
1	Dead load
2	Live load
3	EQ in X
4	EQ in Y

Table3. Load combinations

Combination Number	Load Combination
COMB1	D.L+L.L
COMB2	1.5(D.L+L.L)
COMB3	1.5(D.L+EQX)
COMB4	1.5(D.L+EQY)
COMB5	1.5(D.L+EQNX)
COMB6	1.5(D.L+EQNY)
COMB7	1.2(D.L.+L.L+EQX)
COMB8	1.2(D.L.+L.L+EQY)
COMB9	1.2(D.L.+L.L+EQNX)
COMB10	1.2(D.L.+L.L+EQNY)
COMB11	0.9D.L+1.5EQX
COMB12	0.9D.L+1.5EQY
COMB13	0.9D.L+1.EQNX
COMB14	0.9D.L+1.5EQNY
COMB15	D.L+L.L+EQX
COMB16	D.L+L.L+EQY
COMB17	D.L+L.L+EQNX
COMB18	D.L+L.L+EQNY
COMB19	D.L+L.L+WX
COMB20	D.L+L.L+WY
COMB21	D.L+L.L+WNX

C. Analysis And Results

The present structure is modelled and analysed and analysis using ETABS. For the analysis of gravity load and seismic loads. The live load of the structure is considered 3 kN/m^2. For the lateral load analysis (earthquake) parameter are considered as per Indian code basis.

D. Support Reactions

If a support prevents translation of a body in a given direction, a force is developed on the body in that direction. Fixed support the support prevents translation in vertical and horizontal directions and also rotation, Hence a couple moments is developed on the body in that direction as well.

Table4.

Story	Point	Load	FX	FY	FZ	MX	MY	MZ
BASE	3	COMB1	3.3	2.02	3419.29	0.392	5.463	-0.013
BASE	4	COMB1	4.54	9.72	3880.48	-4.773	6.117	0.097
BASE	5	COMB1	3.59	2.75	3059.44	-2.068	6.069	0.037
BASE	6	COMB1	-2.59	-1.54	3202.56	1.719	-0.434	-0.116
BASE	7	COMB1	2.1	-3.55	3488.19	4.022	2.169	-0.101
BASE	8	COMB1	-0.78	14.28	6000.05	-5.262	-2.197	-0.016
BASE	9	COMB1	-4.58	-0.85	2795.86	1.506	-4.673	-0.193
BASE	10	COMB1	1.38	1.17	4185.56	-0.696	1.616	-0.125
BASE	11	COMB1	1.62	2.47	4571.36	0.121	1.732	-0.047
BASE	12	COMB1	4.23	-3.55	3606.22	1.792	6.15	0.209
BASE	13	COMB1	3.82	-9.81	4336.27	4.181	5.817	0.171
BASE	14	COMB1	4.1	-3.07	3697.2	0.266	5.517	-0.136
BASE	15	COMB1	7.78	-3.41	3457.59	1.58	8.474	-0.043
BASE	16	COMB1	-0.88	-5.48	3772.56	3.032	5.178	0.061
BASE	17	COMB1	-9.02	-12.23	6122.86	1.682	-13.662	-0.362
BASE	18	COMB1	-10.75	-2.35	2952.7	1.662	-12.371	-0.099
BASE	19	COMB1	2.03	1.87	4221.71	-2.021	4.467	-0.081
BASE	20	COMB1	4.81	4.85	3622.02	-3.656	6.704	-0.229
BASE	21	COMB1	4.26	10.38	4216.97	-5.515	6.452	-0.17
BASE	22	COMB1	6.11	3.09	3521.18	-2.303	7.441	0.232
BASE	23	COMB1	10.81	4.84	4301.53	-3.77	11.408	0.145
BASE	24	COMB1	0.56	10.17	4978.62	-7.156	7.401	0
BASE	25	COMB1	-9.43	13.88	5841.11	-4.898	-14.431	-0.107
BASE	26	COMB1	-11.14	0.64	2843.01	-0.254	-12.916	-0.036
BASE	27	COMB1	-9.9	-2.11	2955.59	0.623	-11.332	-0.067
BASE	28	COMB1	-7.89	-12.07	6116.51	1.543	-12.413	-0.054
BASE	29	COMB1	1.13	-8.29	5025.98	0.701	5.527	0.222
BASE	30	COMB1	8.05	-2.33	4329.63	-1.813	8.272	0.144
BASE	31	COMB1	3.92	-3.2	3941.71	0.215	5.199	-0.068
BASE	32	COMB1	4.36	-9.25	4346.35	3.494	5.494	-0.081
BASE	33	COMB1	4.2	-3.05	3581.81	-0.784	5.428	-0.052
BASE	34	COMB1	14.75	2.11	4875.13	-2.244	22.048	0.066
BASE	71	COMB1	-18.3	1.92	4000.98	-1.314	-25.86	-0.057
BASE	72	COMB1	-16.18	-0.04	3998.43	0.725	-25.114	-0.132

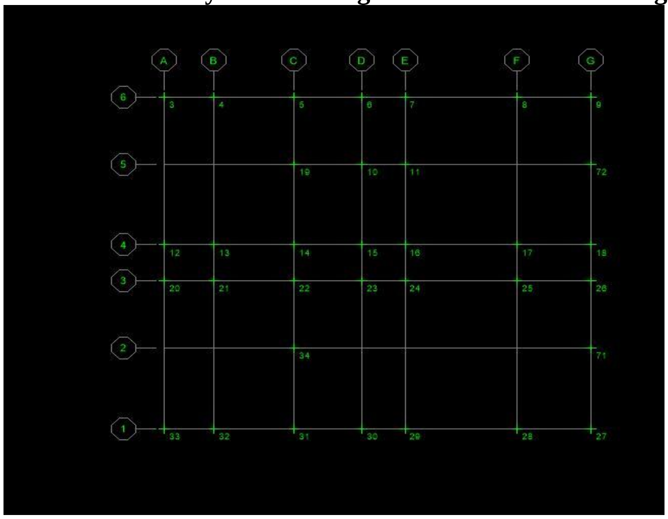

Fig5. Supports Numbers.

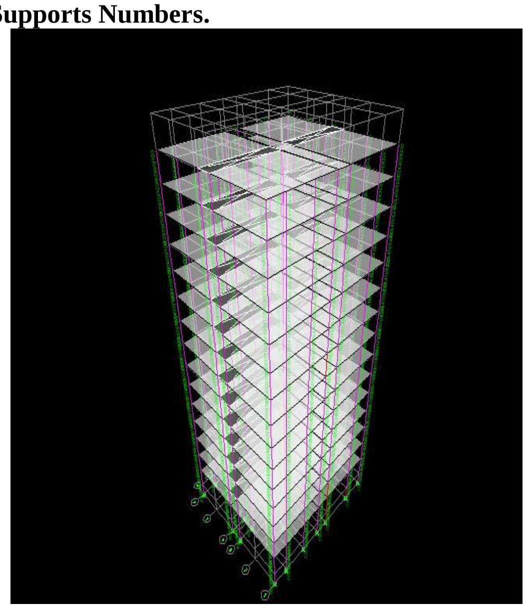

Fig6. ETABS Model.

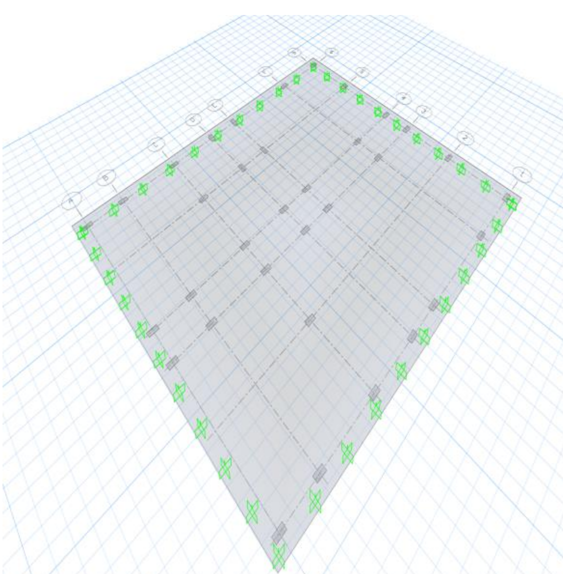

Fig7. Safe Model.

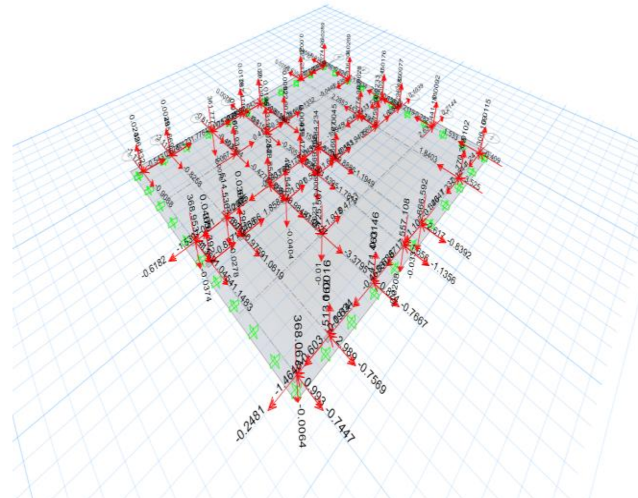

Fig8. Load Details In Safe.

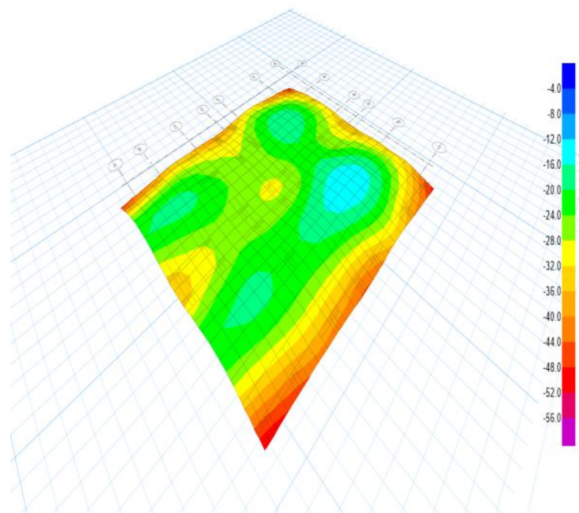

Fig9. Deformed Shape.

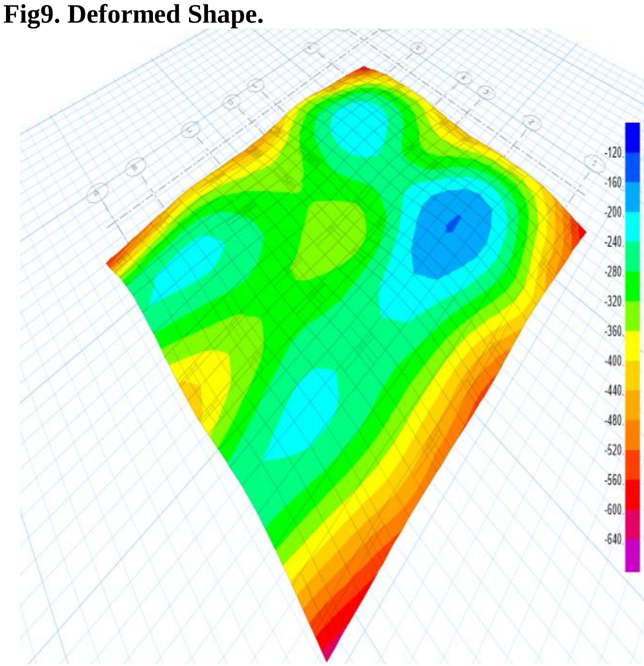

Fig10. Soil Pressure Diagram.

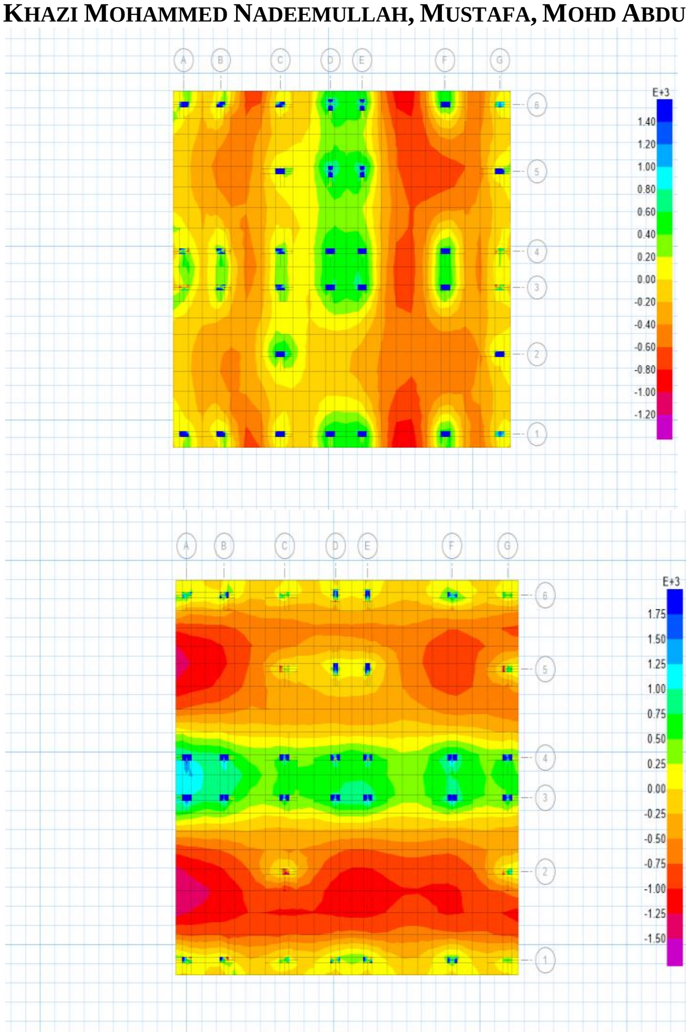

Fig11. Slab Stress Diagrams in Both the Axis.

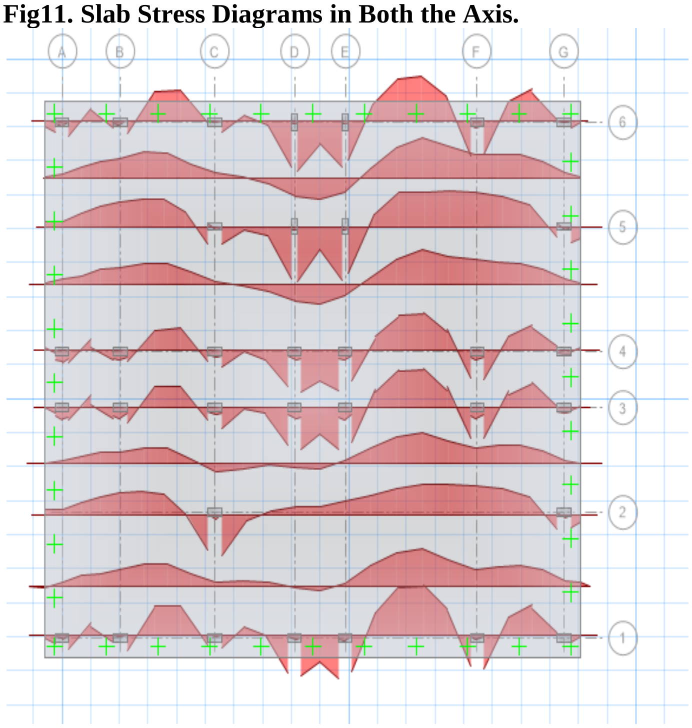

Fig12. Strip Moments in X-Axis.

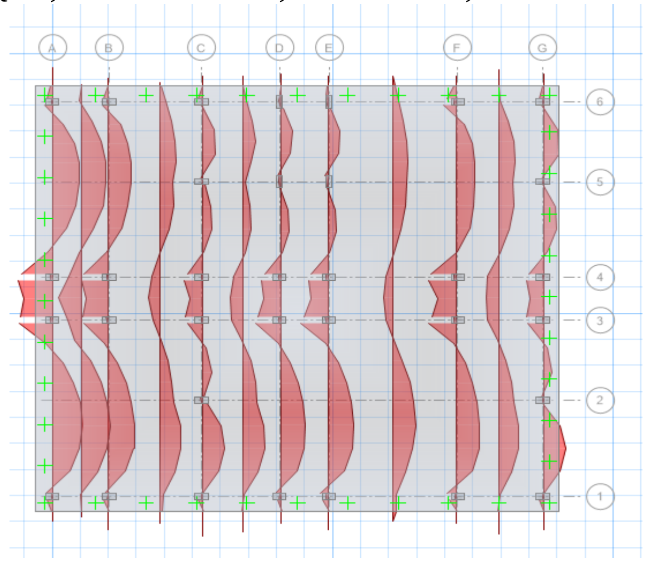

Fig13. Strip Moments in Y-Axis

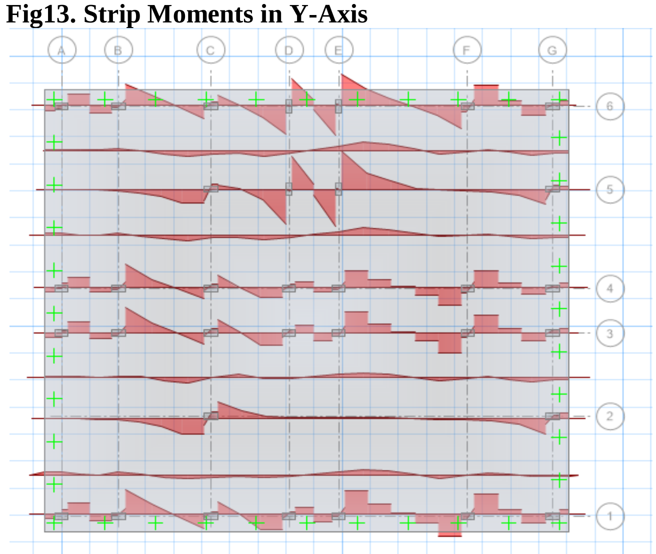

Fig14. Strip Forces in X Axis.

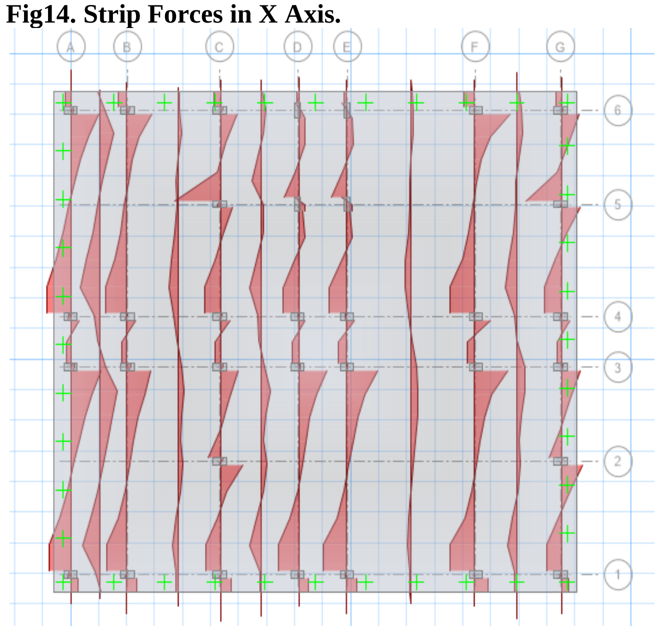

Fig15. Strip Forces in Y-Axis.

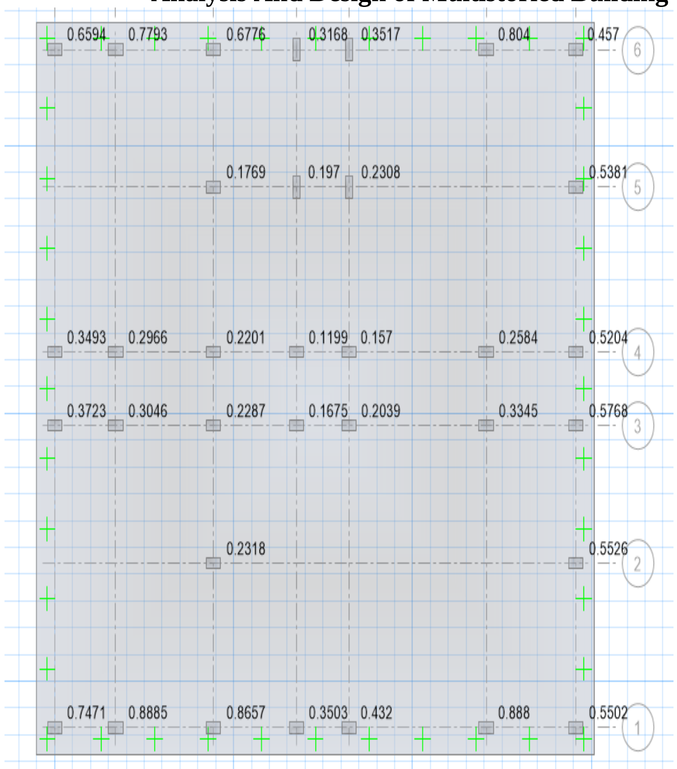

Fig16. Punching Shear Check.

VI. CONCLUSION

From the above detailed study following conclusions have been listed as fallows

- From above detailed study it can be concluded that, modelling of 3D mathematical building models in software like ETABS are more user-friendly in which Earthquake loading can easily be applied according to country's codal provisions.
- Detailed seismic analysis reveals that, analysis and design of multi-storeyed buildings are important in which ignoring the seismic loads will invite sever disaster in earthquake prone zone.
- Modal studies shows that, considered building model is performing excellently according to IS-1893-2002.
- Drifts and Displacements are within the specified limits prescribed by IS codes.
- Shear wall will increases the lateral stability of the building in turn reduce the Lateral displacement and increases base shears.
- Detail piles and piles cap have been modelled in SAFEv12.0. Depth, Punching shear, steel and vertical displacements for all the pile caps are well within the prescribed limits.
- Software like SAFEv12.0 is most suitable for deep foundation analysis and designs.

VII. BIBLIOGRAPHY

We have used a number of books and code as a reference for carrying out this project work. Some of the books (s) that we refer are mentioned below.

INDIAN STANDARD CODE

- IS CODE 456-2000
- IS CODE 875-1987 PART I
- IS CODE 875-1987 PART II
- IS CODE 875-1987 PART III
- DESIGN AIDS TO IS -456-2000 (SP 16)
- Arrangement of Reinforcement Using SP 34

Author's Profile:

Khazi Mohammed Nadeemullah B.Tech student in the Civil Engineering from Sri Visvesvaraya Institute of Technology and Science, MBNR.

Mustafa B.Tech student in the Civil Engineering from Sri Visvesvaraya Institute of Technology and Science, MBNR

Mohd Abdul Muqeet, B.Tech student in the Civil Engineering from Sri Visvesvaraya Institute of Technology and Science, MBNR.

Abdul Asim Khan, B.Tech student in the Civil Engineering from Sri Visvesvaraya Institute of Technology and Science, MBNR.

Md. Saifuddin B.Tech student in the Civil Engineering from Sri Visvesvaraya Institute of Technology and Science, MBNR.

Aftab Tanveer, HOD Civil Engineering from Sri Visvesvaraya Institute of Technology and Science, MBNR.