# EFFECT OF SOIL STRUCTURE INTERACTION ON SEISMIC BEHAVIOR OF MULTI-STOREY [G+5] BUILDING WITH DIFFERENT TYPES OF SLABS

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**Abstract -** *The aim of this study is to know the seismic behavior of multi-storey [G+5] structure with different types of slab systems and how soil structure effects that behavior. This paper deals with four types of slab systems, they are Flat plate system, Flat slab with drop system, Grid slab system and Dia-Grid slab system. The seismic behavior of these slab systems are studied by modeling a G+5 building. This analytical study can be done by ETABS software. This study comprises of comparison of story displacement, base shear, bending moments and axial forces of columns of the building and how much amount of concrete and steel required for each floor in different slab systems.*

***Key Words***: Equivalent linear static analysis or seismic coefficient method, soil structure interaction, storey displacement, base shear, axial force, bending moment, ETABS.

## 1. INTRODUCTION

Natural disasters involves in the development of civil engineering structures. Earthquake is one of the natural disaster which creates huge destruction of structures. There are few methods which are used for earth quake analysis. Earthquake creates huge amount of lateral loads which destructs the structures in higher degree. Due to rapid population growth there is necessary arises for construction of multi storey structures. Buildings which are designed for static loads are not capable to withstand against earthquake loads because they acts laterally. So we have to consider seismic loads while designing of structures. Earthquake loads creates huge amount of base shear so columns faces much amount of bending moments. Structures fail suddenly or number of cracks appears on structural components this leads to loss of life of people and/or economy.

### 1.1 Soil structure interaction

A study of recent earthquakes has indicated that understanding the relationship between the period of vibration of structures and period of the supporting soil is profoundly important for determining the seismic response of the structure. The pattern of structural damage is directly related to the period of vibration of soil alluvium overlying the bedrock, which in turn is directly related to the period of the soil.

## 2. OBJECTIVES

1) storey structure with four types of slab systems and how soil profile effects the seismic behaviour. Here these four models first analysed with fixed supports and later these are compared with spring supports.

2) To study the seismic performance of flat slab, flat slab with drop panel, grid slab and dia-grid slab on medium soil and in seismic zone V.

3) To study the Seismic performance by comparing base shear, storey displacement and column axial forces and bending moments of the building.

4) To perform seismic analysis using "seismic coefficient method" to find base shear of the building and is compare with manual calculation.

5) To develop models and to analyze these models using ETABS 2015 software.

6) To compare how much quantity of steel and concrete required per slab.

7) To find size of footings using " TERZAGHI'S BEARING CAPACITY " formula for shallow square footing.

## 3. METHODOLOGY

### 3.1 Modeling

A regular G+5 multi-storey structures with four different types of slabs are modeled through ETABS software.

### 3.2 Description of models

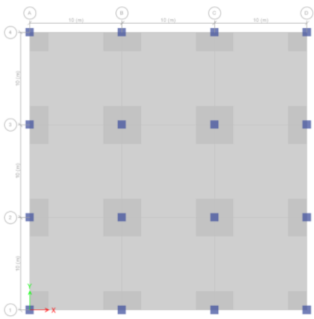


**Fig-1**: Flat slab system.

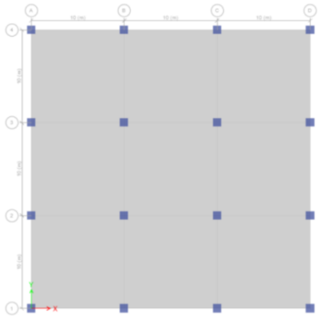


**Fig-2** : Flat slab with drop System.

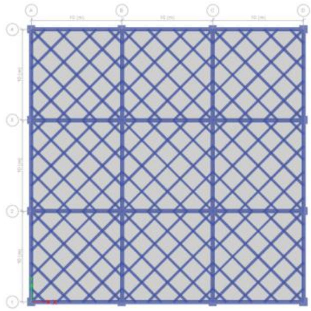
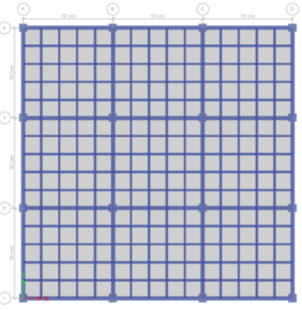
 

**Fig-3 :** Grid slab system. **Fig-4 :** Dia-Grid slab system.

### 3.3 Idealization of structure

To study the dynamic behavior of building structure with soil structure interaction. Here 3 bay x 3 bay five storey building frame with each 10 m x 10 m panel size. This frame is located on isolated footings. The height of each storey is taken as 3.5 m and plinth level is at 1 m above from ground level and 2.5 m above from footing bottom. For all buildings columns of size 900 m x 900 m are considered. Type II soil and seismic zone V is considered. For model (a), thickness of slab is considered as 380 mm. For model (b), 320 mm thick slab and 420 mm thick drop of 4mx4m size is considered. For model (c), 100 mm thick slab, 400x600 mm primary beams and 200x400 mm secondary beams with spacing 2 m are considered. For model (d), 100 mm thick slab, 400x700 mm primary beams and 200x400 mm secondary beams with spacing 2 m are considered. These section sizes are found through design as per IS 456-2000. Importance factor is 1. Live load is taken as 3 KN/m$^2$, floor finish load as 1 KN/m$^2$, wall load as 1.5 KN/m$^2$. Isolated sloped square footings of base sizes 2.6m x 2.6m, 3.2m x 3.2m and 4.2m x 4.2m with edge thickness 200 mm are considered. M30 grade of concrete and Fe415 steel is considered.

### 3.4 Idealization of soil

Medium soil with standard penetration number N = 10 is considered. Cohesion of soil C = 15 KN/m$^2$, unit weight of soil Γ = 20 KN/m$^2$, depth of footing $D_f$ = 1.5 m.

Flexibility of soil medium below foundation may appreciably alter the natural periods of any building. It usually causes to elongate time period of structure. Generally effect of soil profile reduces while considering soft soils to hard. The flexibility of soil is usually modeled by inserting springs between the foundation member and soil medium. While modeling, the number of degree of freedom should be selected carefully considering the objective of the analysis. During earthquake a rigid base may be subjected to a displacement in six degrees of freedom, and therefore resistance of soil can be expressed by the six corresponding resultant force components. Hence to make the analysis most general, translations of foundation in two mutually perpendicular principle horizontal directions and vertical direction as well as rotation of the same about these three directions are considered in this study. In this project, for isolated footing below each column, three translation springs along two horizontal and one vertical axis, together with three rotational springs about those mutually perpendicular axes, have been attached to simulate the effect of soil flexibility.

Idealization arrangement at a typical column square foundation strip and equivalent soil spring junction as shown below

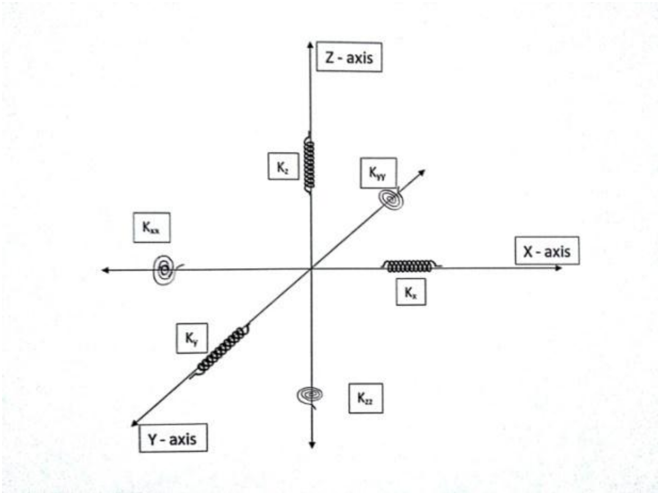



**Fig 5:** Idealization arrangement at a typical column square foundation strip and equivalent soil spring junction.

GAZETAS (1991); MYLONAKIS et al (2006) gave some formulas as given below

**Table 1:** Stiffness of rigid footings in respective degrees of freedom.

| | |
|---|---|
| Translation along Z-axis | $K_z = \frac{2GL}{1-\upsilon}[\,0.73 + 1.54(B/L)^{0.75}\,]$ |
| Translation along Y-axis | $K_y = \frac{2GL}{2-\upsilon}[\,2 + 2.5(B/L)^{0.85}\,]$ |
| Translation along X-axis | $K_x = K_y - \frac{0.2}{0.75-\upsilon}GL(\,1 - B/L\,)$ |
| Torsion about Z-axis | $K_{zz} = GJ_t^{0.75}[\,4 + 11(\,1-B/L\,)^{10}\,]$ |
| Rocking about Y-axis | $K_{yy} = \frac{G}{1-\upsilon}(\,I_x\,)^{0.75}[\,3(L/B)^{0.15}\,]$ |
| Rocking about X-axis | $K_{xx} = \frac{G}{1-\upsilon}(\,I_x\,)^{0.75}(L/B)^{0.25}[\,2.4 + 0.5(B/L)\,]$ |

Where $I_i$ is area moment of inertia of soil foundation contact, i denotes which axis to take the surface around, $J_t = I_x + I_y$ is polar moment of inertia of soil foundation contact surface, G is reduced shear modulus for large strain effects, L is half the length of the footing, B is half the width of the footing, υ is poison's ratio of the soil.

**Table 2 :** Embedment correction factor for stiffness of rigid footings.

| | |
|---|---|
| Translation along Z-axis | $\eta_z = [1 + \frac{D}{21B}(1 + 1.3B/L)][1 + 0.2(\frac{A}{4BL})^{2/3}]$ |
| Translation along Y-axis | $\eta_y = [1 + 0.15\sqrt{\frac{D}{B}}][1 + 0.52(\frac{ZA}{BLL})^{0.4}]$ |
| Translation along X-axis | $\eta_x$ = Same equation as for $\eta_y$, but A term changes for B ≠ L |
| Torsion about Z- axis | $\eta_{zz} = 1 + 1.4(1 + B/L)(d/B)^{0.9}$ |
| Rocking about Y-axis | $\eta_{yy} = 1 + 0.92(d/B)^{0.6}[1.5 + (d/D)^{1.9}(B/L)^{-0.6}]$ |
| Rocking about X-axis | $\eta_{xx} = 1 + 1.26(d/B)[1 + (d/B)(d/D)^{-0.2}\sqrt{\frac{B}{L}}]$ |

Where "d" is height of effective side wall contact, "Z" is depth to centroid of effective side wall contact, "A" is side wall solid contact area for constant effective contact height "d" along perimeter.
For each degree of freedom calculate $K_{emb} = \eta K$

Correlated formula for Shear wave velocity

$$V_s = 50N^{0.41} \text{ m/sec}$$

Where "N" is standard penetration number and for medium soils, it's value = 10

Shear modulus $G_{max} = V_s^2 x \rho_s$ due to ground acceleration there are is some reduction occurs for maximum shear modulus and the considered reduction factor for medium soils is = 0.75

Where $\rho_s$ = density of soil = 2000 kg/m$^3$

## 4. RESULTS AND DISCUSSIONS

### 4.1 Base shear

It is the design lateral force at all the levels above storey under consideration. A bar graph is plotted for base shear as shown below. Here all models are regular, so base shear and storey displacements in X and Y directions are same.

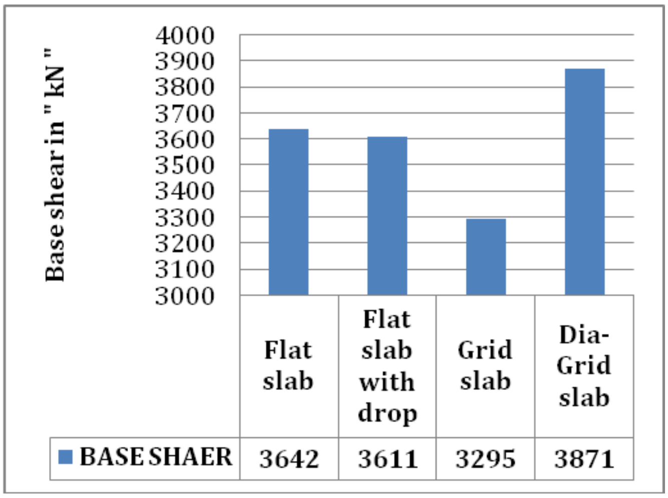



**Chart 1 :** Base shear values for fixed models.

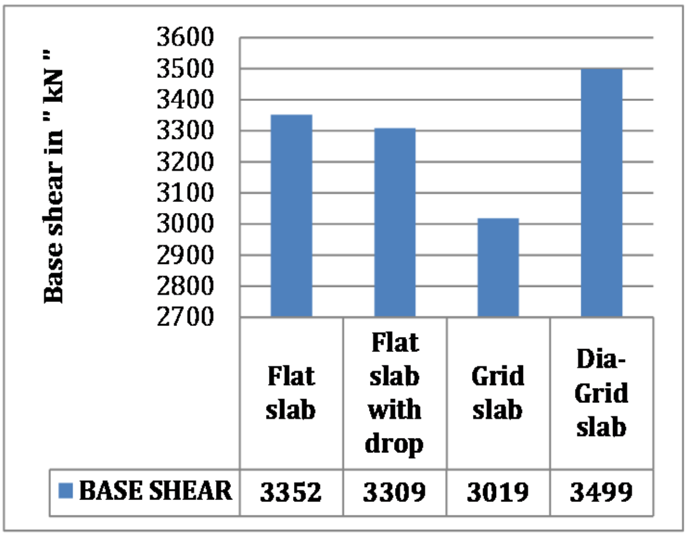



**Chart 2 :** Base shear values for spring models.

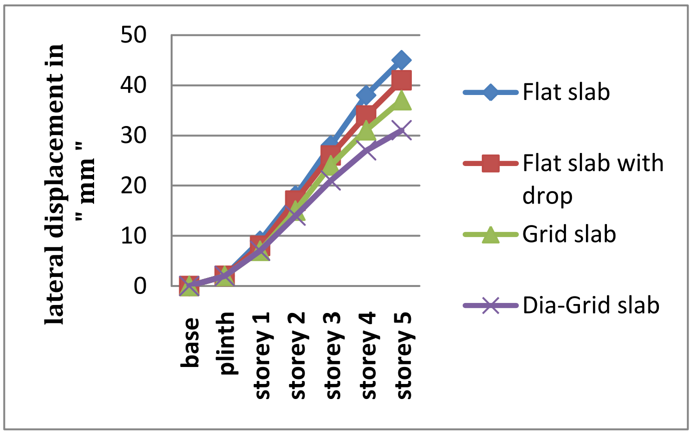
**Table 3 :** Base shear values for all models.

| Model | Base shear in" kN " | | Percentage reduction in base shear ( % ) |
|---|---|---|---|
| | Fixed model | Spring model | |
| Flat slab | 3642 | 3352 | 7.96 |
| Flat slab with drop | 3611 | 3309 | 8.36 |
| Grid slab | 3295 | 3019 | 8.38 |
| Dia-Grid slab | 3871 | 3499 | 9.61 |

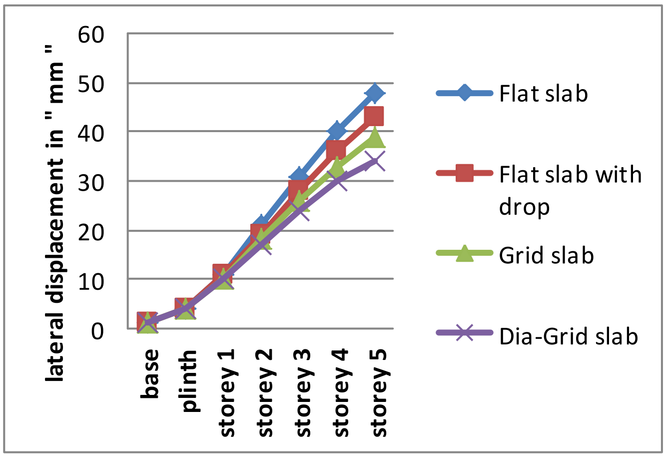
### 4.2 Storey displacements

Storey displacements in X and Y directions also same and storey displacements are plotted as shown below.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 05 | May-2018 www.irjet.net p-ISSN: 2395-0072




**Graph 1 :** storey displacements for fixed models.




**Graph 2 :** storey displacements for spring models.

**Table 4 :** Storey displacements values for all models.

| | Flat slab in "mm" | | Flat slab with drop in "mm" | | Grid slab in "mm" | | Dia-Grid slab in "mm" | |
|---|---|---|---|---|---|---|---|---|
| | Fixed | Spring | Fixed | Spring | Fixed | Spring | Fixed | Spring |
| Storey 5 | 45 | 48 | 41 | 43 | 37 | 39 | 31 | 34 |
| Storey 4 | 38 | 40 | 34 | 36 | 31 | 33 | 27 | 30 |
| Storey 3 | 28 | 31 | 26 | 28 | 24 | 26 | 21 | 24 |
| Storey 2 | 18 | 21 | 17 | 19 | 15 | 18 | 14 | 17 |
| Storey 1 | 9 | 11 | 8 | 11 | 7 | 10 | 7 | 10 |
| Plinth | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 |
| Base | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |

**Table 5 :** Percentage change in storey displacements.

| Model | Flat slab | Flat slab with drop | Grid slab | Dia-Grid slab |
|---|---|---|---|---|
| Percentage increase in max storey displacement ( % ) | 6.67 | 4.88 | 5.41 | 9.68 |

### 4.3 Axial force and bending moment for columns

**Table 6 :** Axial force and Bending moment for corner columns.

| Model | Axial force in " kN " | | Bending moment in " kN-m " | |
|---|---|---|---|---|
| | Fixed model | Spring model | Fixed model | Spring model |
| Flat slab | 3019 | 3282 | 937 | 432 |
| Flat slab with drop | 2676 | 2910 | 897 | 409 |
| Grid slab | 2937 | 3121 | 856 | 379 |
| Dia-Grid slab | 3075 | 3320 | 912 | 395 |

**Table 7 :** percentage change in Axial force and Bending moment for corner columns.

| Model | Percentage increase in axial force ( % ) | Percentage decrease in bending moment ( % ) |
|---|---|---|
| Flat slab | 8.71 | 53.9 |
| Flat slab with drop panel | 8.74 | 54.4 |
| Grid slab | 6.26 | 55.72 |
| Dia-Grid slab | 7.97 | 56.67 |

**Table 8 :** Axial force and Bending moment for edge columns.

| Model | Axial force in " kN " | | Bending moment in " kN-m " | |
|---|---|---|---|---|
| | Fixed model | Spring model | Fixed model | Spring model |
| Flat slab | 6171 | 6433 | 1018 | 617 |
| Flat slab with drop | 5440 | 5670 | 984 | 591 |
| Grid slab | 5050 | 5089 | 888 | 538 |
| Dia-Grid slab | 5292 | 5381 | 947 | 564 |

**Table 9 :** percentage change in Axial force and Bending moment for edge columns.

| Model | Percentage increase in axial force ( % ) | Percentage decrease in bending moment ( % ) |
|---|---|---|
| Flat slab | 4.25 | 39.39 |
| Flat slab with drop panel | 4.23 | 39.94 |
| Grid slab | 0.77 | 39.41 |
| Dia-Grid slab | 1.68 | 40.44 |

**Table 10 :** Axial force and Bending moment for inner columns.

| Model | Axial force in " kN " | | Bending moment in " kN-m " | |
|---|---|---|---|---|
| | Fixed model | Spring model | Fixed model | Spring model |
| Flat slab | 13382 | 12595 | 1039 | 914 |
| Flat slab with drop | 11847 | 11152 | 1001 | 873 |
| Grid slab | 9052 | 8789 | 893 | 787 |
| Dia-Grid slab | 9417 | 9151 | 952 | 828 |

**Table 11 :** percentage change in Axial force and Bending moment for inner columns.

| Model | Percentage decrease in axial force ( % ) | Percentage decrease in bending moment ( % ) |
|---|---|---|
| Flat slab | 5.88 | 12.03 |
| Flat slab with drop panel | 5.87 | 12.79 |
| Grid slab | 2.91 | 11.87 |
| Dia-Grid slab | 3.64 | 13.03 |

### 4.4 Material requirement for various slabs

**Table 12 :** Quantity of materials required for each floor.

| Type of slab | Volume of concrete in " $m^3$ " | Quantity of steel in " kg " |
|---|---|---|
| Flat slab | 340 | 18884 |
| Flat slab with drop panel | 300 | 23136 |
| Grid slab | 201 | 31527 |
| Dia-Grid slab | 225 | 34725 |

## 5. CONCLUSIONS

The seismic behaviour of G+5 building considering various types of slab systems i.e, flat slab, flat slab with drop panel, grid slab and dia-grid slab including soil structure interaction is studied. The following are the major conclusions:

1. Base shear is maximum in Dia-Grid slab system and least in Grid slab system.
2. Storey displacement for Dia-Grid slab system is least and Flat slab system has higher value.
3. Columns faces lower axial forces and bending moments in Grid slab system when compared it with remaining models.
4. percentage change in base shear and storey displacement is higher in Dia-Grid slab system which has lower Time period when compared with remaining models so it is stiffer than others.
5. By observing soil structure interaction effect, we have to conclude that stiffer structures are more sensitive to soil profile effect.
6. Here, Flat slab system required higher amount of concrete and lower amount of steel, Grid slab system required lower amount of concrete and Dia-Grid slab system required higher amount of steel.

## SCOPE OF FUTURE WORK

Here only low rise building are considered with isolated footings. So it is better to compare these models on raft foundations and consider tall buildings like sky-scrapers on different types of foundations. And study seismic behaviour of all these models with infill stiffness, shear walls in different seismic zones and in three types of soils.

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