Analysis of Structure Supported on Elastic Foundation

Vinod Kumar Rajpurohit, N.G. Gore, V. G. Sayagavi

Abstract: - This study presents an analysis of beams, columns and raft, in a multistoried building structure, supported by elastic foundation. The structure is analyzed using E-Tab and Safe software for three different values of modulus of subgrade reaction 'K' pertaining to different soil types, and it has been compared with the structure having fixed supports representing rigid base. The analysis highlights the fact that significant alteration of displacements, design forces and moments occur in the beams, columns and raft. The analysis also brings out the fact that settlement in a raft foundation depends on the stiffness of the soil. The settlement of raft at different values of modulus of subgrade reactions were analysed and compare with rigid support raft. The objective of this research is to develop a workable approach for the analysis of plates on elastic foundations that will provide the designer with realistic stress values for use in The design of the plate or, more specifically, reinforced concrete raft slabs.

Keywords: - Soil - structure interaction, modulus of subgrade, Winkler model , raft slab.

I. INTRODUCTION

1.1 Soil – Structure Interaction

Successful application of the principles of structural engineering are directly linked to the ability of the engineer to model the structure and its support conditions in order to perform an accurate analysis and thereby a correct design. Soil is a very complex material for the modeling. It is very difficult to model the soil-structure interaction problem and hence arriving at a realistic model is complicated in foundation analysis.In particular, concrete building slabs, supported directly by the soil medium, is a very common construction system. It is used in residential, commercial, industrial, and institutional structures. In some of these structures, very heavy slab loads occur, such as in libraries, grain storage buildings, warehouses, etc… A mat foundation, which is commonly used in the support of multi-story building columns, is another example of a heavily loaded concrete plates supported directly by the soil medium. In all these structures, it is very important to be able to compute plate displacements and consequent stresses with an acceptable degree of accuracy in order to ensure a safe and economical design.

1.2 Winkler Model

Winkler first studied the beam on elastic springs. The model he developed is known as Winkler foundation model.

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This model is the oldest and simplest elastic foundation model. The beam in Winkler foundation model is based on the pure bending beam theory commonly used in structural analysis. In this model it is assumed that the displacement at any point on the surface of the foundation is directly, proportional to the foundation surface pressure, acting at that point and is independent of pressure applied at other locations. The Winkler foundation model is advantageous in obtaining fast solutions to more complicated structure/soil interaction problem. The Winkler foundation model has found the application in the analysis of soil/structure interaction problems, e.g., footings on soil, lateral loaded piles in soil. Winkler has proposed a very popular method of modeling the soil-structure interaction. In this method, the vertical translations of the soil 'w', at a point is assumed to depend only upon the contact pressure 'p', acting at the point in the idealized elastic foundation and a proportionality constant, K.

p = Kw………..…………………………… (3.1)

The proportionality constant, K, is commonly called the modulus of subgrade reaction. The model was first used to analyze the deflections and resultant stresses in railroad tracks. In the intervening years, it has been applied to many different soil-structure interaction problems.

1.3 Modulus of subgrade reaction

The modulus of subgrade reaction is a relationship between soil pressure and deflection that is widely used in structural analysis of foundation members. It is used for continuous footings, mats and various types of piling. The modulus of subgrade reaction is calculated from plate load test using following equation

$$k = \frac{q}{\delta} \ldots\ldots\ldots\ldots$$

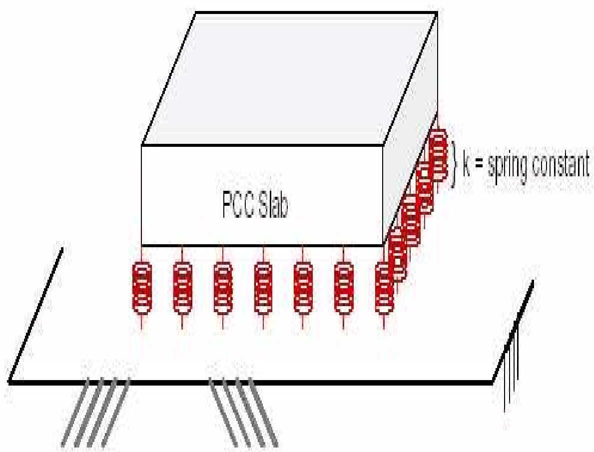

Fig. 1.1 Modulus of Subgrade Reaction

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1.4 Structural Model

The plan dimensions of the building are 24.5 m x 22.5 m.. The structure has 11 stories with height of 3m each. The raft is modeled with the structure. The soil under the raft slab is represented by a set of springs for which the spring constants k, adjusted to reflect the corresponding soil type. Member sizes used for the structures are as follows:

a) Beam – 230 × 600 mm, Column Exterior Column : 350 × 700 mm , Interior Column : 450 × 450 mm , Raft Slab.

b) The columns of the structure are founded on raft slab. The raft slab is divided into finite number of plates with plan dimension of 1.0 × 1.0 m approximately and having thickness of 800 mm for analysis purpose.

c) The raft slab is projected 1.0 m from the face of exterior columns on allfour sides of the structure.

d) The supporting soil with modulus of subgrade reaction is 10000,45000 ,95000 for soft , medium soft and stiff soil respectively.

e) For analysis purpose E-tab and safe software is used and various load comination effect of subgrade on structure and soil is studied.

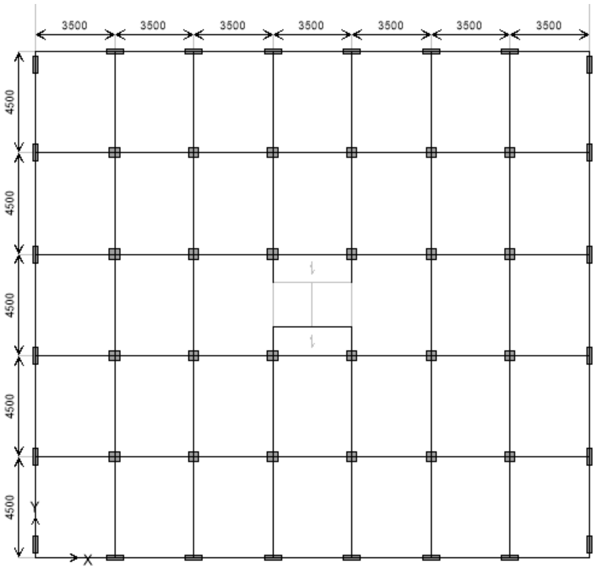


Fig. 1.2 Plan of Structure

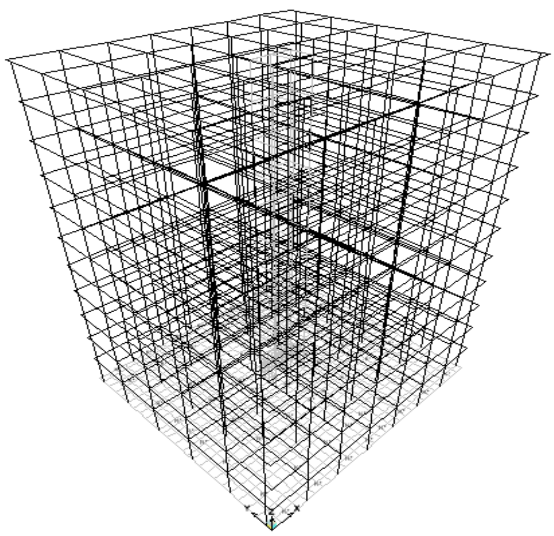
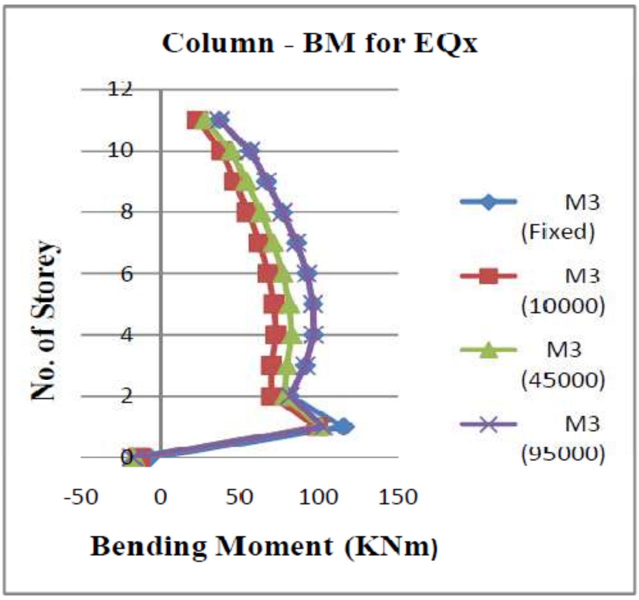


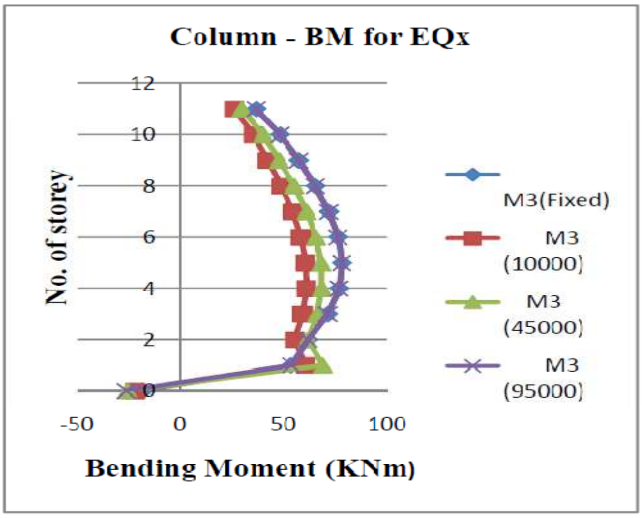
Fig. 1.3 3D View of Structure

II. RESULT AND DISCUSSIONS

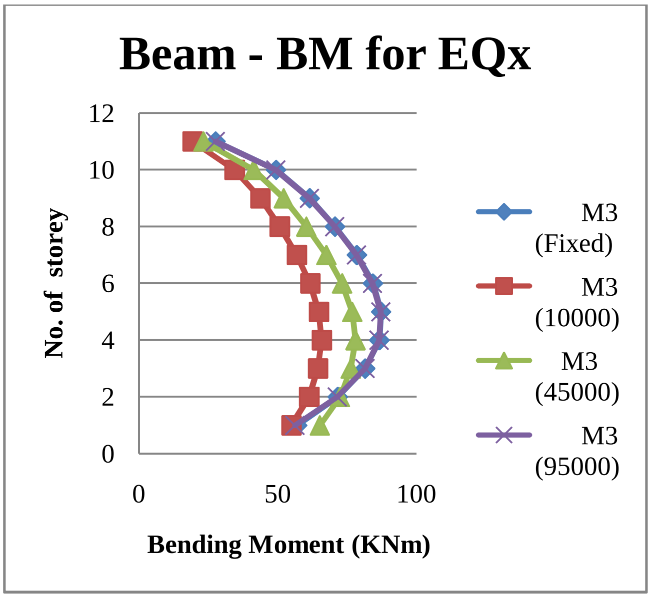
2.1Bending Moments for for Exterior column



2.2Bending Moments for for Interior column



2.3Bending Moments at Support of Beam connected with Exterior Column



2.4Bending Moments at Support of Beam connected with Exterior Column

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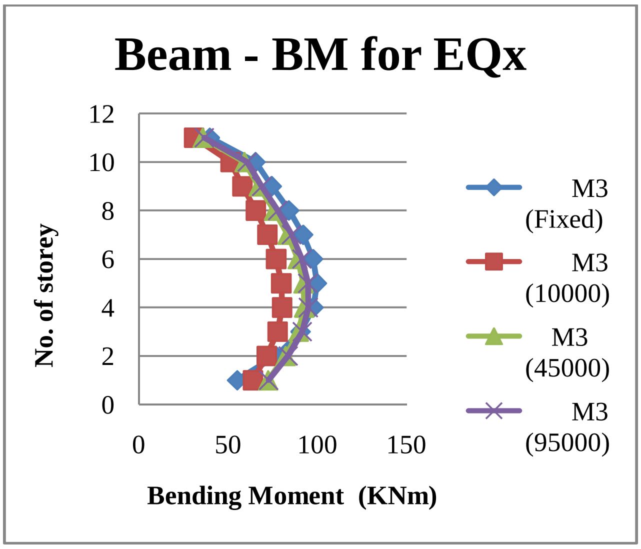
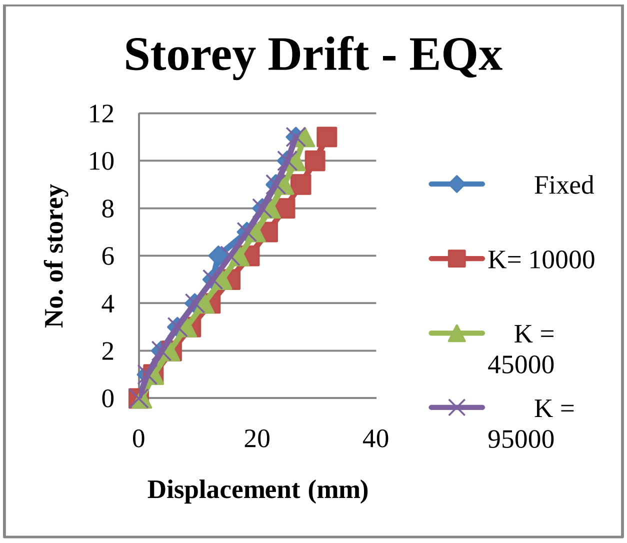
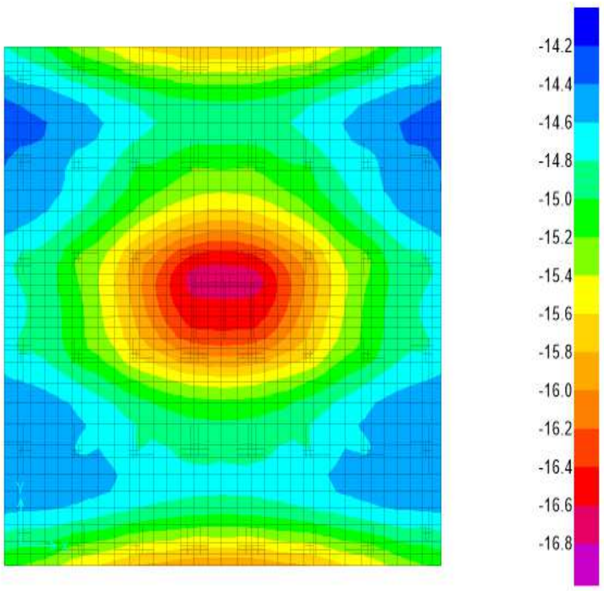


2.5 Storey Drift noted along height of Exterior Column and interior column

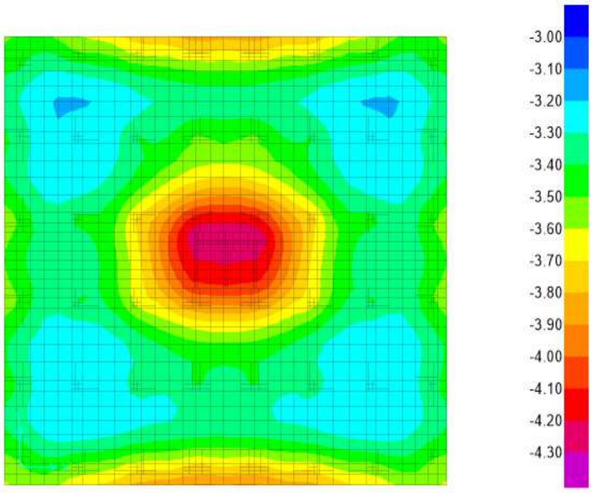


III. ANALYSIS RESULTS OF SETTLMENT OF SLAB

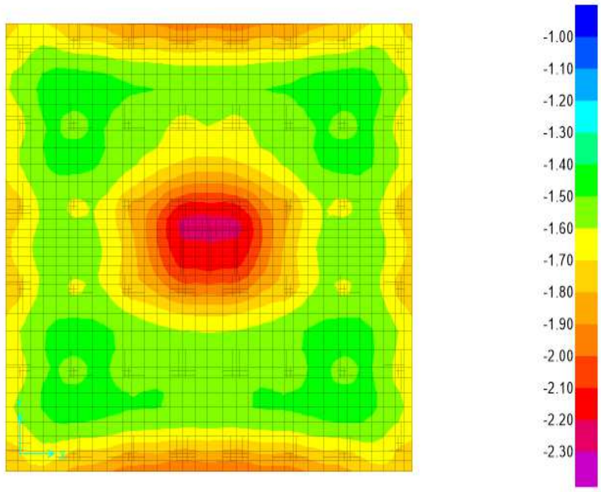
3.1 Settlement of raft with spring support K=10000, for load case of 1.0(DL+LL) in mm



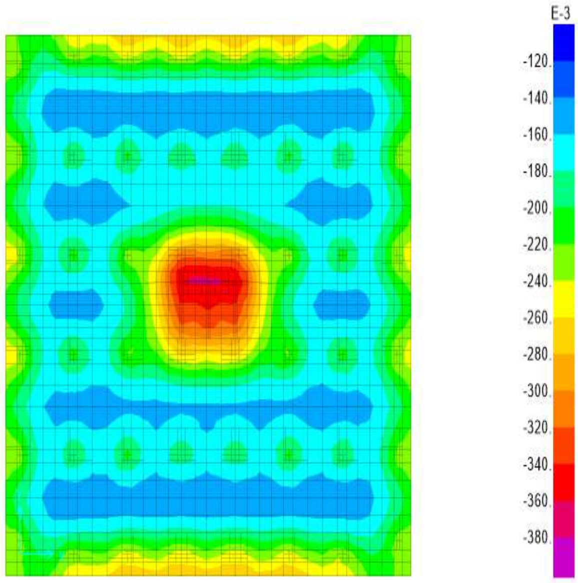
3.2Settlement of raft with spring support K=45000, for load case of 1.0(DL+LL)



3.3 Settlement of raft with spring support K=95000, for load case of 1.0(DL+LL)



3.4 Settlement of raft slab with fixed support for load case of 1.0 (DL+LL)



3.5 Bending Moments in the Raft Slab along X-Direction (MX)

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The study of moment distribution in raft slab has been carried out for structure subjected to EQX and 1.2(DL+LL+EQX) loading conditions. A glance at these values reveals that the moments have been affected by the change in the values of the modulus of subgrade reaction K. For loading condition of 1.2(DL+LL+EQX), negative bending moments shows hogging bending moments which produces tension at the top can cause the foundation to loose contact with soil and positive bending moments indicate sagging bending moments producing tension at bottom face of raft slab.

Case I – EQX

K = 10000 kN/m^3

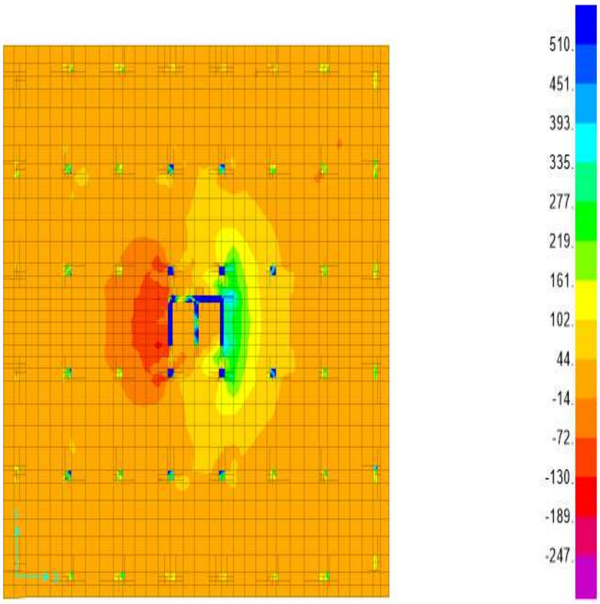

Fig. 3.5.1 BM variations in raft slab for K = 10000 kN/m3 in EQX loading case

K = 45000 kN/m^3

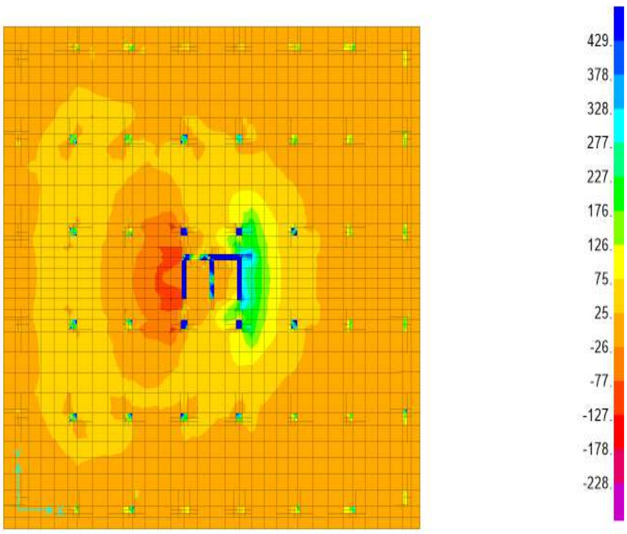

Fig. 3.5.2 BM variations in raft slab for K = 45000 kN/m3 in EQX loading case

K = 95000 kN/m^3

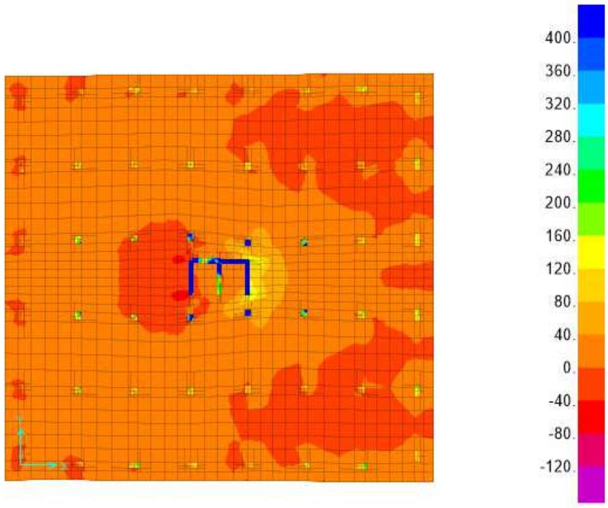

Fig. 3.5.3 BM variations in raft slab for K = 95000 kN/m3 in EQX loading case

Fixed Support

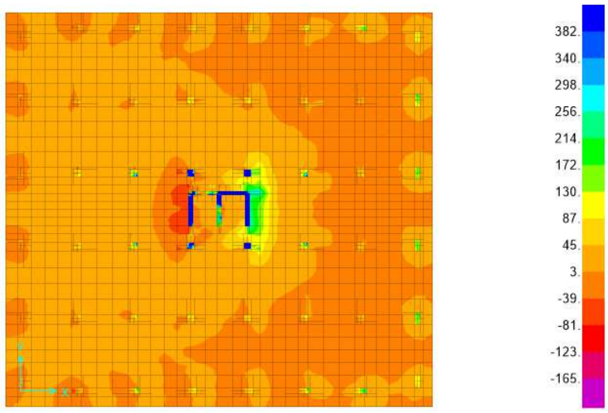

Fig. 3.5.3 BM variations in raft slab for fixed supports in EQX loading case

Case II –1.2(DL+LL+EQX)

K = 10000 kN/m^3

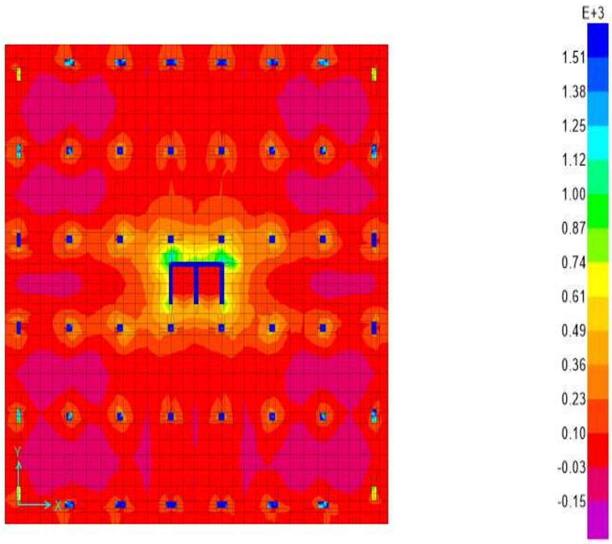

Fig. 3.5.4 BM variations in raft slab for K = 10000 kN/m3 in 1.2(DL+LL+EQX)

K = 45000 kN/m^3

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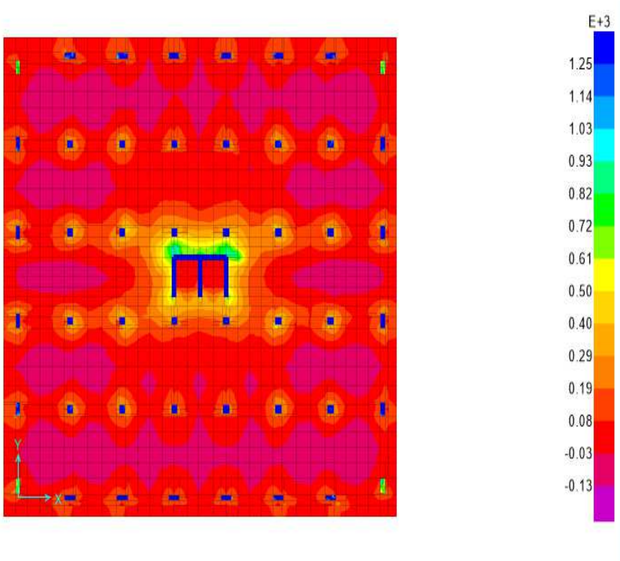

Fig. 3.5.5 BM variations in raft slab for K = 45000 kN/m3 in 1.2(DL+LL+EQX)

K = 95000 kN/m^3

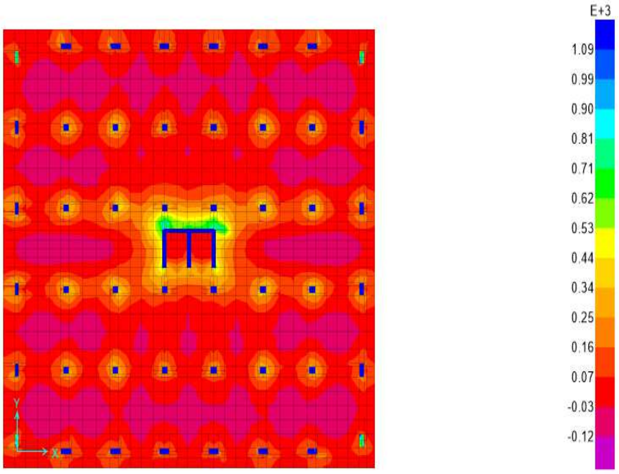

Fig. 3.5.6 BM variations in raft slab for K = 95000 kN/m3 in 1.2(DL+LL+EQX)

Fixed Support

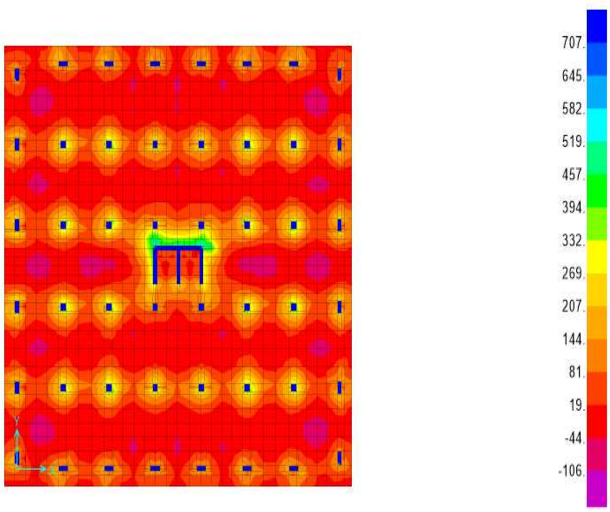

Fig. 3.5.7 BM variations in raft slab for fixed supports in 1.2(DL+LL+EQX)

IV. CONCLUSIONS

The effects of soil-structure interaction on the analysis of a three-dimensional multistoried structure have been demonstrated. The analysis was performed utilizing the E-tab and Safe software. The soil reactions were represented by the use of elastic springs under the raft slab. Based on the findings and the discussion of the different loading and modulus of subgrade reaction K, the following conclusions can be made.

1. A redistribution of forces and moments has been found to occur in the entire structure. As shown in 2.1 to 2.4, due to consideration of the interactive behavior between soil and structure, redistribution of forces and moments takes place in columns and beams. It has been also noted from Fig. 3.5.1 to Fig. 3.5.6, redistribution of moments can occur in raft slab.
2. As per the discussion in section 2.1 to 2.4 of , for seismic forces, magnitude of bending moments in the columns and beams of the structure provided with elastic supports are 10% to 20% less than that of the structure with fixed supports. The reason behind that in case of soft soils, the structure deflects as a whole body. The relative displacements between successive floors are less than that observed for the structure with rigid base. Hence due to the flexibility offered by soil, moments are lesser for structure resting on soft soils.
3. Since softer soil allows more vertical displacements under the gravity loadings The bending moments in beams and columns increases significantly for structure with elastic foundation. Hence the additional bending moments due to the differential settlement of raft slab resulted into the increase in bending moments.
4. Very significant increase can occur in displacements of the structure for the soft soils subjected to lateral forces due to earth-quake. Fig.2.5, show that for EQX forces deflection increased by 15% to 20% from the 1st to 11th floor of the structure supported on soft soil.
5. The raft slab behaves as a flexible foundation and experiences an uneven settlements depending upon load transferred by column. As we have discussed in section 3.1, the differential settlement of the raft slab under gravity loadings is directly proportional to the soil stiffness. The softer the soil, the more the differential settlement and which is responsible for the changes in forces and bending moments as shown in Figs.3.5.1 to , we can say that As the value of modulus of subgrade reaction (K) decreases the differential settlements increase leading to an increase in both the hogging and sagging bending moments and shear force goes on increasing.

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INDIAN STANDARD CODES
IS875-1997: Indian Standard Code of Practice for Structural Safety of Buildings Loading Standard.
IS1893-2002: Indian Standard Code of Practice for Criteria for Earthquake Resistance Design of Structures.

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