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A COMPARATIVE STUDY ON THE SENSITIVITY OF MAT FOUNDATION TO SOIL STRUCTURE INTERACTION

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Abstract - *Influence of stiffness characteristics of the foundation system on the overall structural behavior of structures has always been an area of interest in the domain of structural engineering. In the present study an attempt is made to assess the sensitivity of the structural behavior of a 100 mT capacity silo resting on a mat foundation to the variation in soil sub grade modulus. For this purpose, Winkler model of linear springs has been used to model the soil structure interaction and the analysis is carried out for different modulus of sub-grade reaction keeping the SBC of soil as 150kN/m² and considering the allowable settlement as 1mm. 12.5mm, 25mm and 50m. STAAD Pro V8i and STAAD foundation software tools have been used for modeling and analysis of the structure. Internal forces and deflections in the structural members are monitored and compared considering different modulus of sub-grade reaction. The results show a significant influence of sub-grade soil characteristics on the internal forces and displacements in the structural elements.*

Key Words: **Soil structure interaction, Sub structure method, Winkler model, Sub-grade of modulus.**

1. INTRODUCTION

All problems in Civil Engineering involve interaction of structural elements with ground. When forces are applied externally to the structural element, the physics of the problem dictates the structural Element and ground to deform in a compatible manner. This is because of inherent intendancy of structural-element displacements and ground displacements by the virtue of their intimate physical contact. Therefore, these types of problems are broadly referred to as Soil-structure interaction (SSI) problems. In conventional structural design, SSI effects are not considered. Neglecting SSI effect for a relatively flexible structure founded on hard soil is reasonable. But, for a relatively stiff structure founded on either soft or medium soil neglecting SSI has a great impact on structural response and design.

1.1 SOIL – STRUCTURE INTERACTION

If the structure is supported on soft soil deposit, the inability of the foundation to conform to the deformations of the free field motion would cause the motion of the base of the structure to deviate from the free field motion. Also the dynamic response of the structure itself would induce deformation of the supporting soil. This process, in which the response of the soil influences the motion of the structure and the response of the structure influences the motion of the soil, is referred as SSI. The first significant structure where the dynamic effect of soil was considered in the analysis in industry in India was the 500MW turbine foundation for Singrauli (Chowdhary, 2009).

1.2 Winkler model

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

$$p = K\,w \quad \text{.................} \quad (1)$$

The proportionality constant, K, is commonly called the modulus of sub grade 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.

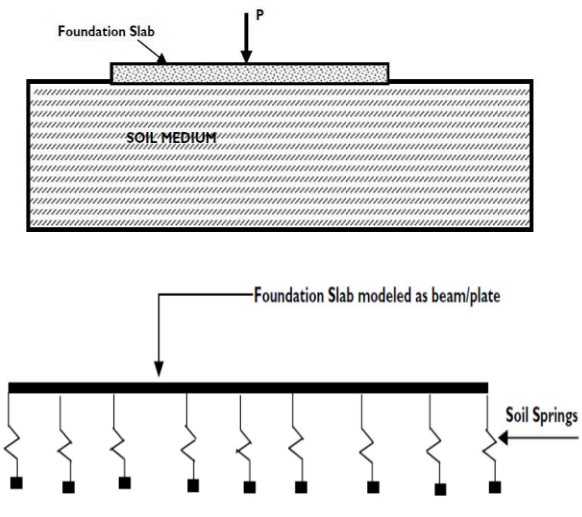


Fig - 1: Mechanical model by Winkler (1867)

a. Winkler's idealization represents the soil medium as a system of identical but mutually independent, closely spaced, discrete, linearly elastic springs

b. According to this idealization, deformation of foundation due to applied load is confined to loaded regions only.

c. Figure shows the physical representation of the Winkler foundation.

d. The pressure–deflection relation at any point is given by p= K w, where K = modulus of sub grade reaction.

1.3 MODULUS OF SUB GRADE REACTION

The modulus of sub-grade 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 sub-grade reaction is calculated from plate load test using following equation

$$K = q/\delta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Here, K = modulus of sub-grade reaction (kN/m^3), soil spring

q = mean bearing pressure

δ = mean settlement

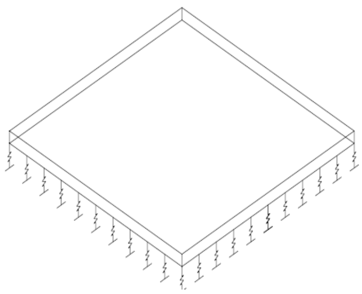


Fig - 2: Mat foundation rest on soil spring support

1.4 MODELING OF MAT FOUNDATION BY WINKLER APPROACH

Modeling of RC MAT foundation describes the structural behavior of different soil modulus of sub grade and change in foundation depth. Mat selected for analysis is symmetrical in plan of 4.5 x 4.5m with centre to centre column spacing is 2.26 m. Different modulus of sub grade is introduced keeping same SBC with varying settlement criteria and also varying in depth for that soil stiffness in order to know internal force of mat foundation the displacement and moment. 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.

1.5 Mat size used for the foundation structures are as follows

- The columns of the frame are founded on raft slab. The raft slab is divided into finite number of plates with plan dimension of 100mm×100mm and having thickness of 300 mm for analysis purpose.
- The raft slab is projected 1.12 m from the centre of columns on all four sides of the structure.
- The supporting soil with modulus of sub grade reaction is 150000, 12000, 6000, 3000 for SBC 150 kN/m^3, for the deflection of 1 mm, 12.5 mm, 25 mm, 50 mm respectively.
- For the same settlement and sub grade modulus the foundation depth is 300mm, 400mm, 500 mm varied for study.
- For analysis purpose STAAD Pro and STAAD foundation is used and vertical and lateral load combination effect of sub grade on structure and varying depth of foundation on soil interaction is studied. In this study we have taken forces in vertical and lateral along x direction for the same we have carried out analysis.

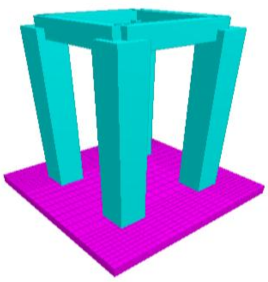


Fig - 2: Typical 3D modeling of mat foundation

1.6 METHOD OF ANALYSIS

Generally we have two type of soil condition namely elastic and inelastic type. In the elastic condition we have again two type of methodology namely direct method and sub structure method. In the present study we have adopted sub structure method to analyses the foundation resting on elastic soil media. In which soil material properties are used for incorporation of springs to represent the stiffness at the soil foundation interface. Sub-structure method is computationally more efficient than the direct method as most of the disadvantages of the direct method can be removed, if the substructure method is employed. The load considered for the analysis of mat foundation as below, these load are derived at the base of cement silo where cement silo placed on concrete stub. Cement silo having capacity of 100 T and diameter of 3.2 m. This cement soil is located at a Karimnagar district, Telangana state having basic wind speed of 44 Kmph. The force is derived and provides at silo bottom by batching plant by vendor for the same mentioned below.

Table 1: Loading details

LOAD DETAILS : ACTION FORCE (kN)						
CEMENT SILO 100T Ø 3.2m	C1	C2		C3	C4	
	Vz	Vz	Hx	Vz	Vz	Hx
Dead load	30	30		30	30	
Use full load	338	338		338	338	
Wind in X-Direction	+59.5	-59.5	+15.4	59.5	-59.5	+15.4

2. RESULT

In the present study mat foundation maximum and minimum displacement, moment in both direction are considered to evaluate the Performance of under different soil modulus of sub grade and variation in thickness of mat parameters under the vertical and lateral loading condition. This analysis was carried out under sub structure method consider soil as in elastic condition.

a) Table 2 shows that the maximum displacement below the mat footing increases as the modulus of sub grade decreases.

b) Table 3 shows that the minimum displacement below the mat footing increases as the modulus of sub grade decreases.

c) From the graph 1 and 2 it is observed that initial settlement causes major changes in the moment in both ‘x’ and ‘y’ directions.

d) From the graph 3 and 4, it is observed that the displacement below mat footing is directly proportion to the stiffness of the soil. Hence, when the stiffness of the soil is higher; the displacement below footing is lower and vice- versa.

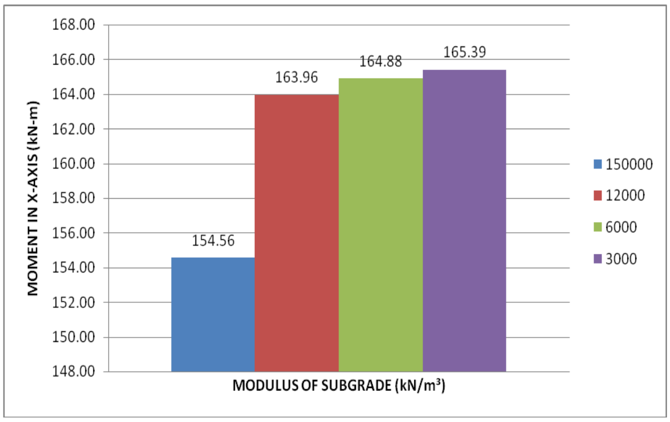
e) Form the graph 5 to 8 and tables 4 & 5; it is observed that as the depth of foundation mat increases, there is a variation in the bending moment. As seen from the table 4, for 300mm depth of mat; moment in X-axis is 6.08%, 0.56% and 0.31%. Accordingly, it is also observed that the bending moment decreases as the depth of the mat increases; with respect to the modulus of sub-grade in both ‘x’ axis and ‘y’ axis.

Table 2: Maximum displacement corresponding soil stiffness

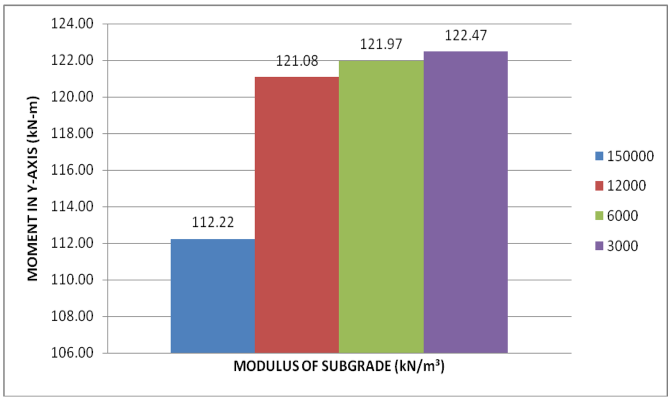
SBC 150 (kN/m²)		
Allowable settlement (mm)	Modulus of sub grade (kN/m^3)	Max displacement (mm)
12.5	12000	8.849
25	6000	18.027
50	3000	36.402

Table 3: Minimum displacement corresponding soil stiffness

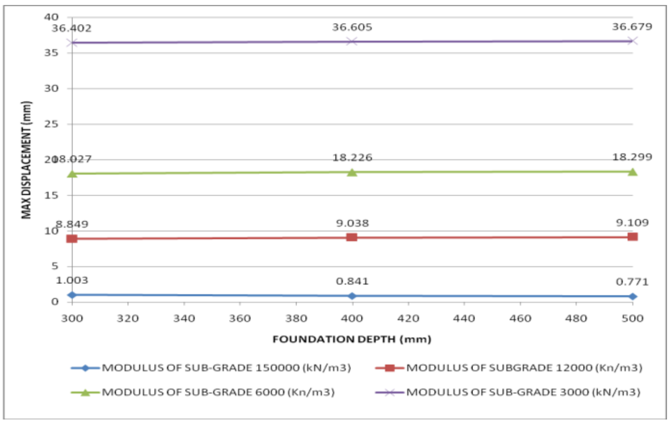
SBC 150 (kN/m²)		
Allowable settlement (mm)	Modulus of sub grade (kN/m^3)	Min displacement (mm)
12.5	12000	3.78
25	6000	8.291
50	3000	17.399



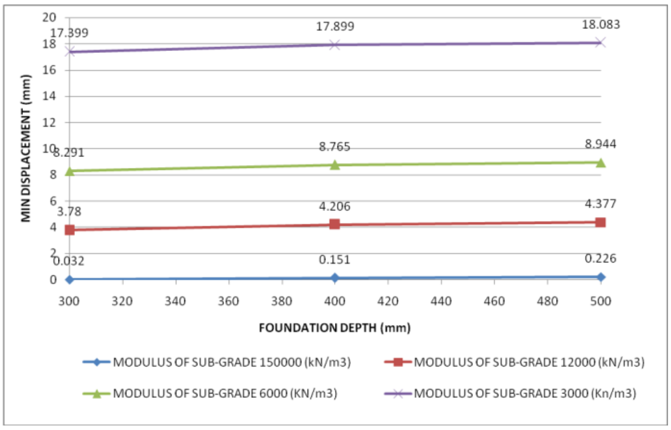
Graph 1: Bending moment variation with respect to modulus of sub-grade in X-axis with constant mat thickness



Graph 2: Bending moment variation with respect to modulus of sub-grade in Y-axis with constant mat thickness



Graph 3: Maximum displacement for varying mat depth to soil stiffness



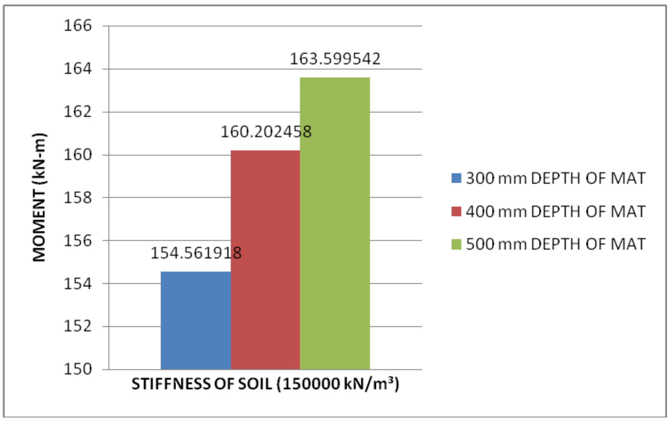
Graph 4: Minimum displacement for varying mat depth to soil stiffness

Table 4: Percentage of bending moment variation along X axis SBC 150 (kN/m^2)

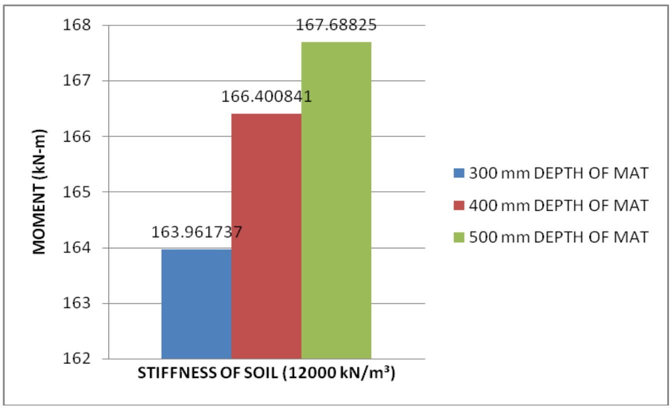
Allowable settlement (mm)	Moment in X-axis 300 (mm)	Moment in X-axis 400 (mm)	Moment in X-axis 500 (mm)
12.5 to 25	0.56	0.27	0.14
25 to 50	0.31	0.14	0.07

Table 5: Percentage of bending moment variation along X axis SBC 150 (kN/m^2)

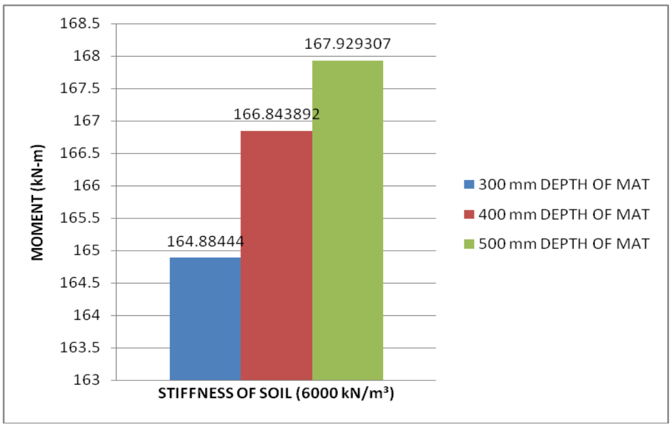
Allowable settlement (mm)	Moment in Y-axis 300 (mm)	Moment in Y-axis 400 (mm)	Moment in Y-axis 500 (mm)
1mm to 12.5mm	7.89	5.16	3.38
12.5mm to 25mm	0.74	0.36	0.19
25mm to 50mm	0.41	0.19	0.10



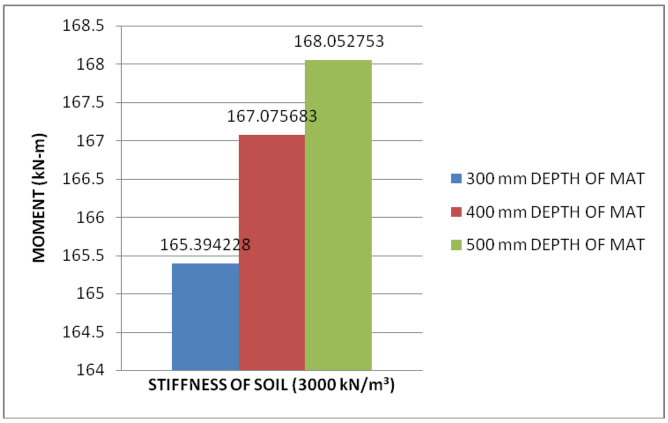
Graph 5: Maximum bending moment for varying mat depth having soil stiffness as 150000 KN/m^3



Graph 6: Maximum bending moment for varying mat depth having soil stiffness as 12000 KN/m^3



Graph 7: Maximum bending moment for varying mat depth having soil stiffness as 6000 KN/m^3



Graph 8: Maximum bending moment for varying mat depth having soil stiffness as 3000 KN/m^3

3. CONCLUSION

It appears from this study that the linearity of the elastic modulus of sub-grade leads to greater displacement than when this modulus is assumed to be constant in the soil. This study shows that the concrete alone does not solve all problems related to disorders in a foundation and mastery of soil parameters is important to minimize disorders.

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