Interactive Analysis of Plane Frames on Non-Homogeneous Soils

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ABSTRACT

Any civil engineering structure is made up of three components i.e. superstructure, foundation and supporting soil. The performance of the structure mainly depends on performance of its foundation, which in turn depends on the behavior of the soil lying underneath. In conventional design procedure structure is designed assuming unyielding supports and interaction between superstructure, substructure and soil is not considered. Existence of non-homogenous soil layer below the foundation present one of the most common and major problem with respect to settlement.

1. INTRODUCTION

The superstructure, foundation and supporting soil medium are integral units of load carrying system. For proper evaluation of various forces acting in the superstructure and to determine the settlements it is necessary to consider the interaction between the superstructure-foundation-soil system. In the present study both interaction and conventional analysis without taking interaction into account are considered taking different forms of superstructure plane frames. A typical four storied structure having 1, 2 and 3 bays has been considered. Perfect homogeneous soils are rare in nature. Generally non homogenous soils are mostly encountered. It is very difficult to predict the behavior of soil accurately because of its variability. Hence, a two layered soil system is considered. Since the depth of weak layer is large, a rubble layer was used as a replacement material over the layer of mixed sand with gravel. The depth of rubble is varied from 0.5 to 3.0m and its effect on the settlement has been studied. Placing of hard rubble layer on weak layer is an effective technique usually adopted. Also the effect of replacing the rubble only below the footing of the structure has been studied.

Advantages of Interactive analysis

1) It takes into account the loads and deformations in various parts of the system all at a time.

2) In interactive analysis it is found that the critical bending moment, shear force etc are disturbed in the entire system and therefore it leads to economical design.

3) The effect of stress in any part is taken into account in this system analysis. For e.g. By interactive analysis the settlement of a footing will be exactly known whereas in conventional methods we assume certain settlements which is not reliable and likely to be far from reality.

4) Interactive analysis is highly useful in parametric study i.e. effect on the entire design due to a change in a single parameter.

2. INTERACTION ANALYSIS

Typical plane frames of G+3 building having 1, 2 and 3 bays were considered for study. A typical frame with the soil profile is shown in Fig 1.

The loading condition is taken as per code The total load taken was equal to 25 KN/m². The E value is taken equal to 25000 KN/m².

![Fig. 1: Showing Two Bay Frame Resting on Original Soil System](image-url)
The rubble layer laid over the top of the existing layer is shown in Fig 2. The depth of the rubble layer is varied from 0.5 – 3.0 m and its effect on the settlement were studied.

Fig. 2: Showing Two Bay Frame Resting on Strong Layer

Soil structure interaction analysis is carried out. A typical grid is shown in the Fig 3. The result obtained by interactive analysis was compared with the conventional analysis which does not consider interaction.

Fig. 3: Showing Discretisation of Superstructure Foundation and Soil for a Typical Two Bay Frame in Finite Element Method

The interactive analysis is carried out using a FEM software and some typical outputs showing Shear force, Bending moment and deformation diagrams are shown in Figures 4a, 4b and 4c.

Fig. 4a: Showing Shear Force in Beams and Columns
Fig. 4b: Showing Bending Moment in Beams and Columns
Fig. 4c: Showing Deformation of Underlying Soil
3. RESULTS AND DISCUSSION

From the Bending moment, Shear force and settlement obtained from the analysis of different frames by increasing the depth of rubble layer the moment ratio, Shear ratio and settlement ratio is calculated respectively. The three ratios are calculated by finding the value of each parameter at a particular rubble layer depth and then finding the ratios between that for the next subsequent rubble depth.

The variation of moment ratio with depth is shown in fig 5a below.

![Fig. 5a: Graph of Moment Ratio v/s Depth of Strong Layer](image)

It was clearly observed from the graph that, as the depth increases the moment ratio increases in the single bay frame but in 2 bay and 3 bay frames it decreases gradually and there is not much difference in the pattern of decrease of moment ratio of 2 and 3 bay frames.

The variation of settlement ratio with depth is shown in fig 5b below.

![Fig. 5b: Graph of Settlement Ratio v/s Depth of Strong Layer](image)

In the graph shown above it was noticed that there was a decrease in settlement ratio for all three i.e. 1, 2 and 3 bay frames. But it was also noticed that there was a drastic change in settlement ratio of 1 bay frame between 0.5m to1.5 where it deeps down to a very low value of the settlement ratio. After 1.5m depth all the three frames settlement ratios were almost equal.

The variation of shear force ratio with depth is shown in fig 5c below.

![Fig. 5c: Graph of Shear Force Ratio v/s Depth of Strong Layer](image)

By this graph it was found that the shear ratio also decreases smoothly in case of 2 and 3 bay frames. But in 1 bay frame there was a large fluctuation. It was linear till 0.5m but at 1m it again increased which goes down at 1.5m and then increased again at 2m depth and than a constant value.

The variation of maximum bending moment in beams and number of bays with depth was shown in fig 5d below.

![Fig. 5d: Graph of Maximum Bending Moment v/s No. of Bays](image)

This graph is a comparative graph between the maximum bending moment observed in both interaction and non interaction type analysis. It was observed that in interaction analysis the maximum bending moment increases linearly as the number of bays increases. But in the non interaction analysis it was observed that the maximum bending moment increases from 1 bay to 2 bay but remains almost constant for 3 bay.

The variation of maximum bending moment in columns and number of bays with depth is shown in fig 5e below.
It was observed that in interactive analysis the maximum bending moment increases for two bay frames in comparison with single bay. But it increases even more in case of three bays. When observed in non interaction analysis the difference in maximum bending moment in columns increases in two bay but not by a large value, again the value is increased for three bays with a slightly greater difference.

4. CONCLUSIONS

It can be concluded that by taking into account interaction effect, the design will be on safer side. As it was observed that the conventional type analysis underestimates maximum bending moments in beams and columns in comparison to interaction analysis. It was also observed that introduction of strong layer and with increase in number of bays the maximum bending moment, shear force in beams and columns tend to decrease. The strong layer also proves to be most economical method to minimise settlement.

REFERENCES

References in the text: Figure 1-3, Figures 4a, b, c, Figures 5a, b, c d.
References between parentheses: Figure 1-3, Figures 4a, b, c, Figures 5a, b, c d.