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Effect of Rigidity of Plinth Beam on Soil Interaction of Modeled Building Frame Supported on Pile Groups

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***Abstract* - This paper presents the results of static load tests carried out on a model plane frame with plinth beam founded on pile groups embedded in the cohesionless soil (sand). The response of the superstructure considered include the displacements, rotations, shear forces and moments in the frame. Comparison of the interactive behaviour from the experimental results has been made with the behavior from conventional method. Results revealed that the shear force and bending moment in the considerably because of soil interaction. It is also found that, as the rigidity of the plinth beam reduces the shear force and bending moment values from the experimental results have shown considerable reduction. The response of the system from the conventional method of analysis is always on higher side irrespective of level of loading which emphasizes the need for consideration of building frame-pile foundation-soil interaction and reduction of rigidity of plinth beam.**

***Keywords* - Plinth Beam, Rigidity, Cohesionless Soil.**

I. Introduction

The foundation resting on deformable soils undergoes deformation depending on the rigidities of the foundation, superstructure and soil. However, the conventional method of analysis of framed structures considers bases to be either completely rigid or hinged. Hence interactive analysis is necessary for the accurate assessment of the response of the superstructure. Numerous interactive analyses have been reported in studies. (Chameski (1956), Morris (1966), Lee and Brown (1972), King and Chandrasekaran (1974), Shriniwasraghavan and Sankaran (1983), Subbarao et al. (1985) and Deshmukh and Karmarkar (1991), P. Srinivasa Rao (1995), J. Noorzaei (1995), Ramakanth Agrawal (2009), H. S. Chore (2010)). Much numerical work and comparative studies are available on pile foundation, but comparatively little experimental work (C. Ravi Kumar Reddy and T. D. Gunneswara Rao (2011)), was reported on the analysis of framed structures resting on pile foundations to account for the soil-structure interaction. In this study, an extensive experimental investigation was carried out on the model pile groups supported plane frame with plinth beam on pile groups embedded in sand subjected to static loads (central concentrated load and uniformly distributed load). The need for consideration of soil interaction is emphasized by comparing the behavior of the frame obtained from the experimental analysis with that of conventional method of analysis.

II. Experimental Program

A. Testing Chamber, Frame and Pile Groups

The testing chamber is a rectangular concrete tank with base resting on a firm finished floor. The infill cohesionless soil bed is used for the present study. The size of the bed is selected in such a way that there should be no boundary effect on the behaviour of the frame founded on pile groups when loaded statically. The depth of sand bed is provided such that the depth available below the tip of the pile is more than the length of the pile. Using the scaling law Eq. (1) (Wood et al., 2002) the material and dimensions of model is selected. An aluminum tube with outer diameter 16mm and inner diameter 12mm was selected as the model pile with a length scaling factor of 1/10. This is used to simulate the prototype pile of 350mm diameter solid section made of reinforced concrete with a compressive strength of 20MPa. Aluminum plates of 13mm thickness were used as pile caps. Rigidity of the plinth beam is varied by using aluminum round solid bars of 3mm and 5mm diameter and square bars of 8x8mm and 10x10mm. The freestanding length was maintained from the bottom of the pile cap to top of the soil bed for both the pile groups. Columns and beam of the plane frame were scaled in the same manner. Beam column junctions are made by welding for the fixidity condition. Screwing of piles and columns in the threads provided in the pile cap leads to partial fixity condition. The scaling factors used in the study are presented in Table 1.

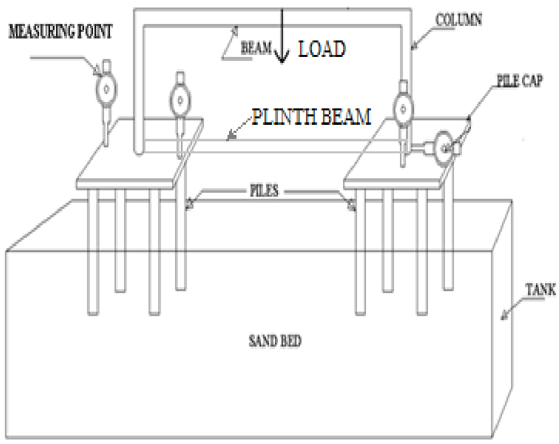

Fig.1. Experimental setup

B. Experimental setup and Instrumentation

The schematic diagram of the test setup is shown in Fig. 1. Tests were conducted on model pile groups with frame embedded in sand bed in a testing chamber which is well instrumented to study the lateral, vertical displacements and rotations. Iron hooks were used to hang the loads on the frame. In the pile group setup pile spacing of eight diameter was maintained throughout the test. Bottom tip of the hallow piles were closed with the rubber cork.

Table 1: Scaling Factors Used in the Study

Variable	Length	Density	Stiffness	Stress	Strain	Force
Scaling Factors	1/10	1	1/10	1/10	1	$1/10^3$

$$\frac{E_m I_m}{E_p I_p} = \frac{1}{n^5}$$

Where E_m is modulus of elasticity of model, E_p is modulus of elasticity of prototype, I_m is moment of inertia of model, I_p is moment of inertia of prototype, $1/n$ is scale factor for length.

C. Testing Phases

Static vertical load tests were conducted on model frame with 2 x 2 pile groups embedded in sand bed as shown in the Fig. 1. Tests were conducted in the following sequence:

1. Concentrated loads were applied in increments (1, 2, 3Kg etc.) at the centre of the beam.
2. The beam is loaded at third points with equal loads in increments (3, 6, 9Kg etc.) to simulate uniformly distributed loading condition.

III. Analytical Programme Using ANSYS

The numerical analysis of the model plane frame is carried out for the following cases

1. Frame with bases fixed to evaluate shear force and bending moment in the column which is the usual practice done as the conventional method
2. Frame with bases released by giving the lateral displacements, vertical displacements and rotations obtained from the experimental results for the corresponding loading on the frame to get the back figured shear forces and bending moments in the column.

The frame is loaded with a central concentrated load and uniformly distributed load in increments as applied in the experimental program and the response in terms of deformations, rotations, shear forces and bending moments is obtained for each load increment and is plotted as given below.

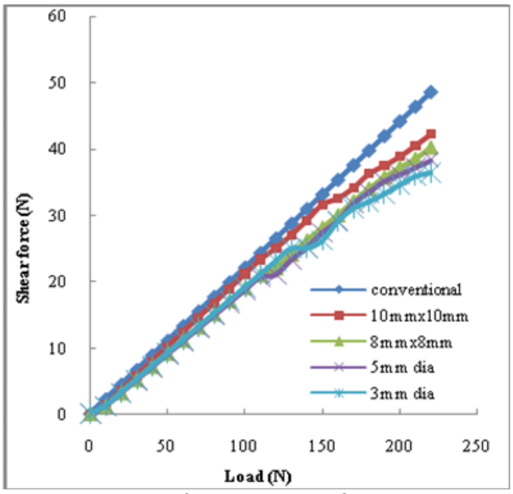

Fig.2. Load Vs Shear force in column for central concentrated load on the frame

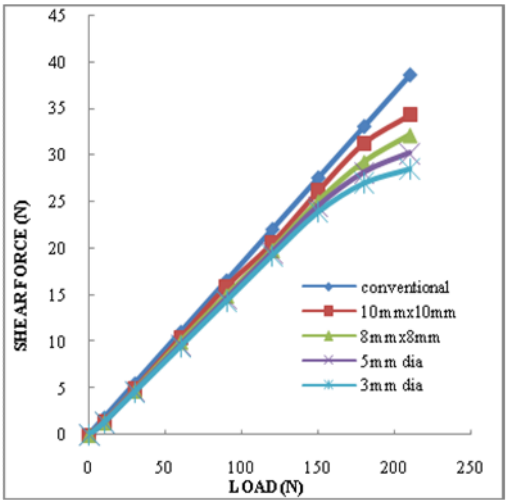

Fig. 3. Load Vs Shear force in column for total uniformly distributed load on the frame

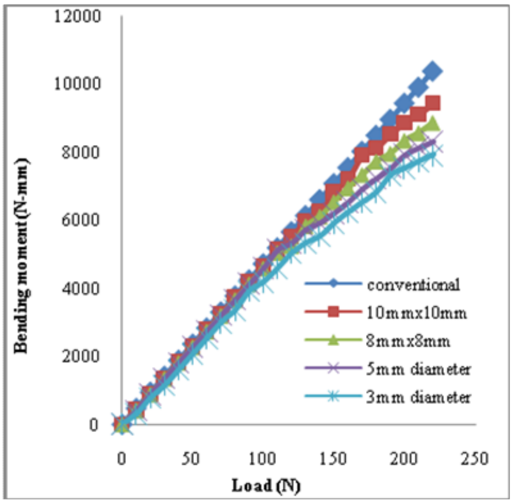

Fig.4. Load Vs bending moment at beam column joint for central concentrated load on the frame

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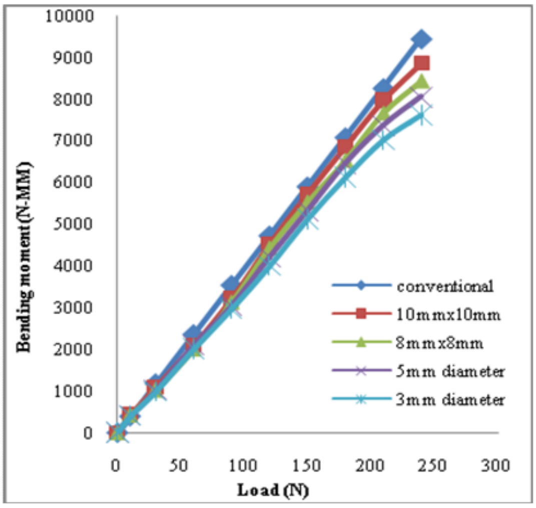

Fig.5. Load Vs bending moment at beam column joint for total uniformly distributed load on the frame

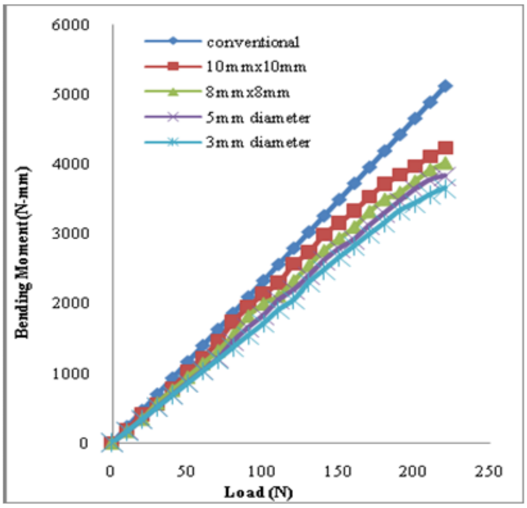

Fig.6. Load Vs bending moment at the base of the column for central

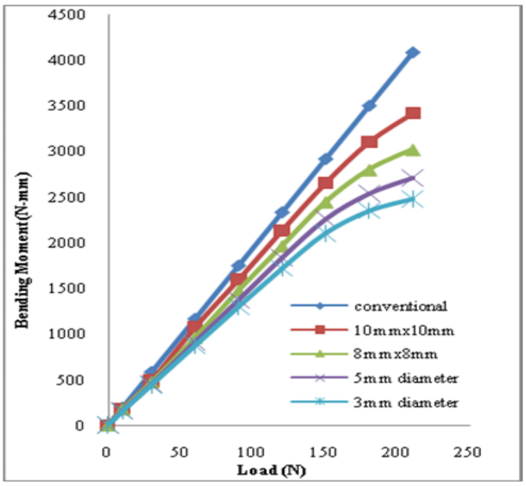

Fig.7. Load Vs bending moment at the base of the column for total uniformly distributed

Fig. 2 and Fig. 3 represent the variation of shear force in the frame for various values of central concentrated loads and uniformly distributed loads applied on the frame in the case of conventional method of analysis and experimental method of analysis. The plots show that, as the load increases shear force in the frame increase in the linear manner for smaller loads and it shows nonlinearity for higher loads. The conventional method of analysis gives a shear force of about 35% more value than that is given by the experimental results for frame with plinth beam of 3mm diameter. As the load increases on the frame load-settlement variation becomes non-linear. This is because at relatively higher loads sand shows non-linear variation. As the rigidity of the plinth beam reduces by 93%, the shear force also reduces by 15%. As the load on the frame increases the percentage of variation of shear force given by the conventional method with that of experimental results also increases.

Fig. 4 and Fig. 5 represents the variation of bending moment at the top of the column for various values of central concentrated loads and uniformly distributed loads applied on the frame in the case of conventional method of analysis and experimental method of analysis. The plots show that, as the load increases the bending moment increase in the linear manner for smaller loads and it shows nonlinearity for higher loads. The conventional method of analysis gives a bending moment 25% more value than that is given by the experimental results for frame with plinth beam of 3mm diameter. As the rigidity of the plinth beam reduces by 93%, the bending moment also reduces by 19%. As the load increases on the frame load-settlement variation becomes non-linear. This is because at relatively higher loads sand shows non-linear variation. As the load on the frame increases the percentage of variation of bending moment given by the conventional method with that of experimental results also increases.

Fig. 6 and Fig. 7 represents the variation of bending moment at the base of the column for various values of central concentrated loads and uniformly distributed loads applied on the frame in the case of conventional method of analysis and experimental method of analysis. The plots show that, as the load increases the bending moment increase in the linear manner for smaller loads and it shows nonlinearity for higher loads. The conventional method gives a bending moment at the base of the column which is 58% more than that is given by the experimental results for frame with plinth beam of 3mm diameter. As the rigidity of the plinth beam reduces by 93%, the bending moment also reduces by 28%. As the load on the frame increases the percentage of variation of bending moment given by the conventional method with that of experimental results also increases.

V. Conclusions

Based on the results of the present experimental and Numerical investigations on the model pile groups supported frame, the following conclusions are drawn:

1. The conventional method of analysis gives a shear force 35% more than that is given by the experimental results for frame with plinth beam of 3mm diameter. As the rigidity of the plinth beam reduces by 93%, the shear force also reduces by 15%.
2. Conventional method gives a bending moment at the top of the column which is 25% more than that is given by the experimental results for frame with plinth beam of 3mm diameter. As the rigidity of the plinth beam reduces by 93%, the bending moment also reduces by 19%.
3. The conventional method gives a bending moment at the base of the column which is 58% more than that is given by the experimental results for frame with plinth beam of 3mm diameter. As the rigidity of the plinth beam reduces by 93%, the bending moment also reduces by 28%.
4. As the load on the frame increases the percentage of variation of shear force and bending moment given by the conventional method with that of experimental results also increases. The response of the system from the conventional method of analysis is always on higher side irrespective of level of loading which emphasizes the need for consideration of building frame-pile foundation-soil interaction and also the reduction of rigidity of plinth beam.

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