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# The Effect of Structure -Soil Interaction on Eccentrically Loaded Frame

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**Abstract:-** The interaction among structures, their foundations and the soil medium below the foundations alter the actual behaviour of the structure considerably than what is obtained from the consideration of the structure alone. Thus, a reasonably accurate model for the soil–foundation–structure interaction system with computational validity, efficiency and accuracy is needed in improved design of important structures. The framed structures are normally analyzed with their bases considered to be either completely rigid or hinged. However, the foundation resting on deformable soils also undergoes deformation depending on the relative rigidities of the foundation, superstructure and soil. Interactive analysis is, therefore, necessary for the accurate assessment of the response of the superstructure.

In this thesis ABAQUS 6.8, a FEA (Finite Element Analysis) package is used for the analysis of a building frame founded on piles of 2 x 2 groups for a particular spacing of piles and for a particular L/d ratio of the pile. Type of foundation adopted is a free standing pile group. Soil condition is considered as infill dry sand in its loosest state. It is modeled as Winkler's foundation. The analysis is carried out to study the behaviour of the frame. A load transfer approach using linear springs (Lateral, Axial and Tip) is used for the analysis. Displacements, Rotations, Shear force and Bending moments are obtained by applying an eccentric load at 0.2(L/2) and 0.4(L/2) distance from the centre of the beam in the model frame. Applicability of ABAQUS6.8 a FEA package is verified by taking a worked out problem from J.Won et al (2006).

**Keywords:-** *Piles of 2 x 2 groups,ABAQUS6.8,Displacements, Rotations, Shear force, Bendingmoments, axial forces.*

## I. INTRODUCTION

Due to the increasing need for infrastructures and the decreasing availability of space, both structural and geotechnical engineers are challenged to design, analyze, and evaluate more expensive and strategic structural systems (e.g. high-rise buildings, offshore platforms, multi-story highways, etc.) for extreme lateral loadings (e.g. earthquakes, gusty winds, terrorist attacks, etc.). In weaker soils, foundation piles, both single pile and pile groups, may be used to transfer large superstructure.
loads through deeper soils. In these cases, the influence of the foundation piles should be included

The three-dimensional frame in superstructure, its foundation and the soil, on which it rests, together constitute a complete system. With the differential settlement among various parts of the structure, both the axial forces and the moments in the structural members may change. The amount of redistribution of loads depends upon the rigidity of the structure and the load-settlement characteristics of soil.

The framed structures are normally analyzed with their bases considered to be either completely rigid or hinged. However, the foundation resting on deformable soils also undergoes deformation depending on the relative rigidities of the foundation, superstructure and soil. Interactive analysis is, therefore, necessary for the accurate assessment of the response of the superstructure.

## II. OBJECTIVES OF WORK

The main objective of the thesis used to see the effect of soil-structure interaction (SSI) on a building frame founded on piles (Free stand pile foundation).

1. To verify the design parameters like Shear force, Bending moment, Axial force, Displacements and rotations in a building frame.
2. To carryout the conventional method of analysis of the building frame for finding the design parameters using conventional design software used by most of the practicing engineers.

3. To carryout the Analytical method of analysis for finding the above said design parameters in the building frame using load transfer method of analysis with the help of analysis software ABAQUS.
4. To conduct the experiments for the observation of actual behaviour of the frame and also to find the design parameters.
5. To compare the behaviour of the building frame in conventional method of analysis, load transfer technique and from the experiments. And also to quantify the variation of the design parameters in the three methods of analysis used.

## III. ANALYSIS

In analysys doing two types of analysis

1. Analytical method using ABAQUS.
2. Experimental analysis.

In this analysis, a pile group type foundation was taken to analyse the frame. Here the pile-soil-pile interaction plays a major role in producing forces at pile head and in frame.However, the basic problem of the building frame is three dimensional in nature. Although a complex three-dimensional finite element approach, when adopted for the analysis, is quite expensive in terms of time and memory, it facilitates realistic modeling of all the parameters involved.

### 3.1.1 PROBLEM DESCRIPTION:

A schematic diagram of a single bay frame of 2 x 2 pile group structure is shown in Fig. 6.1. This structure aluminum, consists of a frame, pile caps and identical vertical piles, which are spaced by 128mm (=8D, where D is the pile outer diameter). In each pile group, four piles have an embedded length of 160mm (i.e., a free standing length of 160mm), a diameter of 16mm, and a flexural rigidity (EI) of 147,264 KN $m^2$. The thickness of the pile cap is 13mm, and the pile head and beam-column joint conditions are fixed. The column is 320mm in length and 16mm in diameter, and has a flexural rigidity of 1,963,600 KN $m^2$. The beam is 500mm in length and 16mm in diameter, and has a flexural rigidity of 1,963,600 KN $m^2$. Table 3.1 shows the material properties used in this study.

| Elements | Properties | Values |
|---|---|---|
| **Columns, Beams** | Elastic modulus (E) (MPa)<br>Moment of inertia (Ix, Iy)(m4)<br>Area (A) (m2) | 40,000<br>0.04909<br>0.7864 |
| **Pile cap** | Elastic modulus (E) (MPa)<br>Poisson's ratio (m)<br>Thickness (t) (m) | 40,000<br>0.18<br>0.75 |
| **Pile** | Elastic modulus (E) (MPa)<br>Moment of inertia (Ix, Iy)(m4)<br>Area (A) (m2) | 48,000<br>0.003068<br>0.19635 |

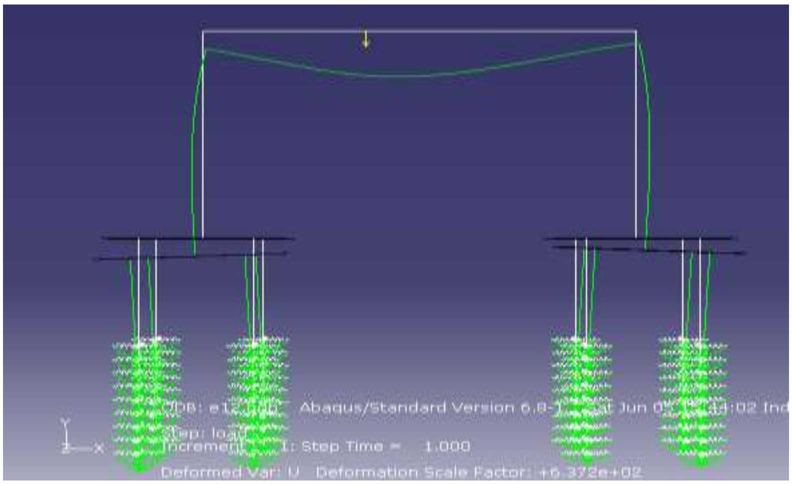
**Table 3.1 Material Properties for Pile groups**

### 3.2 CASES OF ANALYSIS

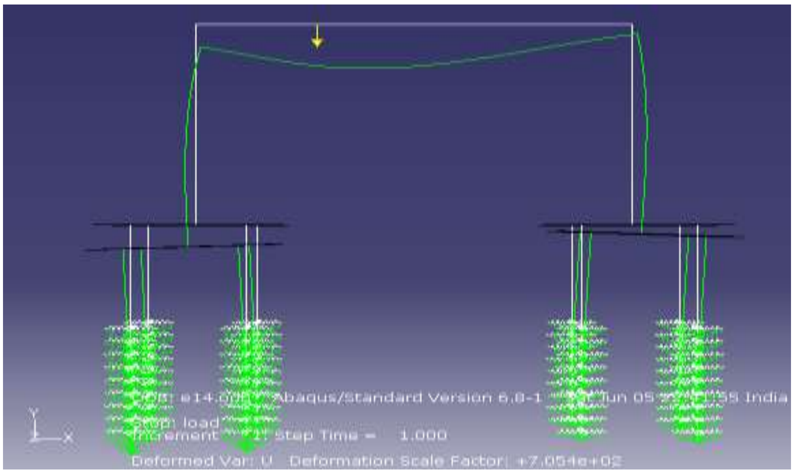
The present analysis was mainly focused on Eccentric loading on the frame. The eccentric loading was applied at two different locations on beam. Following are the two different locations on beam chosen for the application of eccentric load.

1. Eccentric loading at 0.2(L/2) from centre of Beam
2. Eccentric loading at 0.4(L/2) from centre of Beam

Where L is the length of the beam



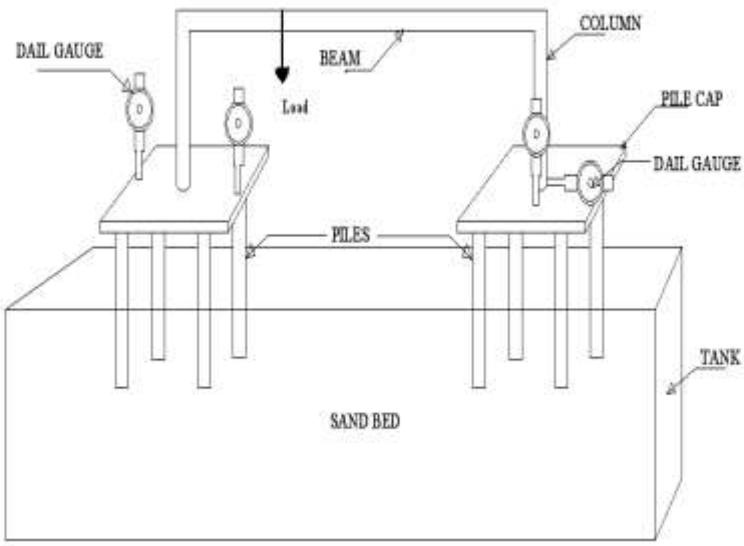

**Shows Behaviour of frame with eccentric loading at 0.2(L/2) from centre of Beam**




**Shows Behaviour of frame with eccentric loading at 0.4(L/2) from centre of Beam**

**3.2.1 PROBLEM DESCRIPTION:**

Beam: A beam of length 5 m and the cross sectional dimensions are 230 x 330 mm.
Column: Length of the column was taken as 3.2 m and its cross sectional dimensions are 230 x 330 mm.
Pile cap: Pile cap of size 2 x 2 x 0.13 m.
Pile: The pile of length 3.2 m and its diameter was 345 mm.

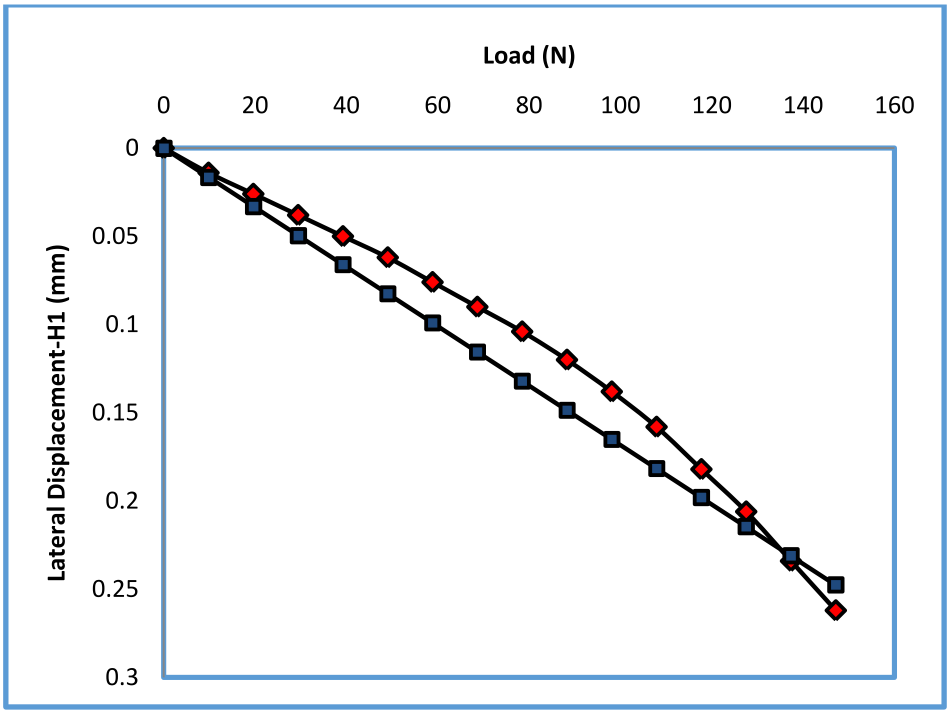



**Schematic diagram of the test setup**

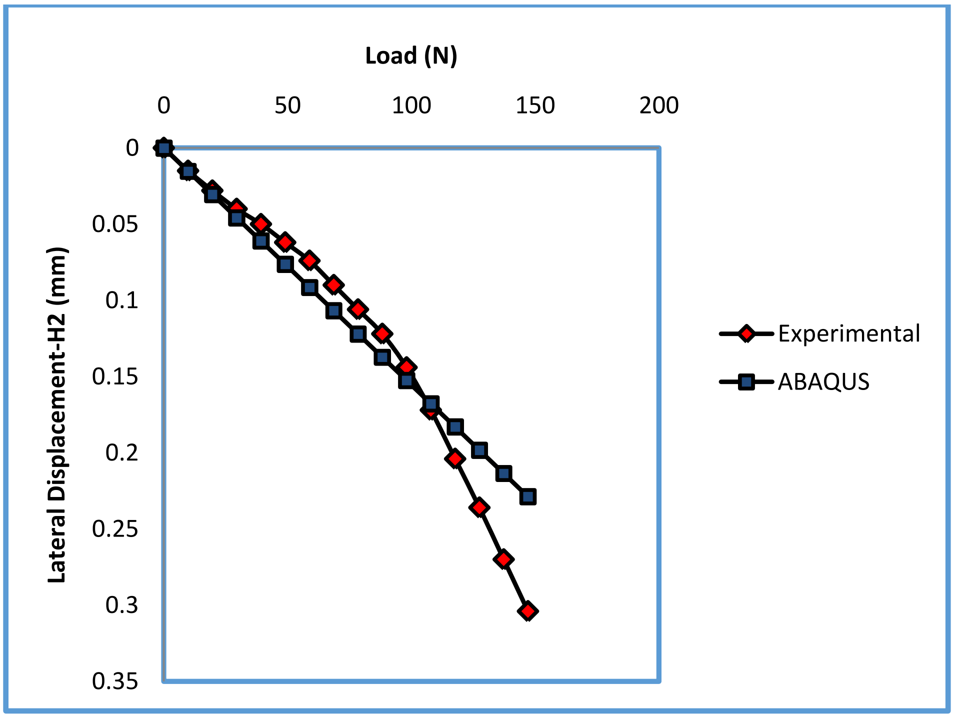
# IV. RESULTS

## 4.1 Eccentric Load At 0.2(L/2) Distance From The Centre Of The Beam

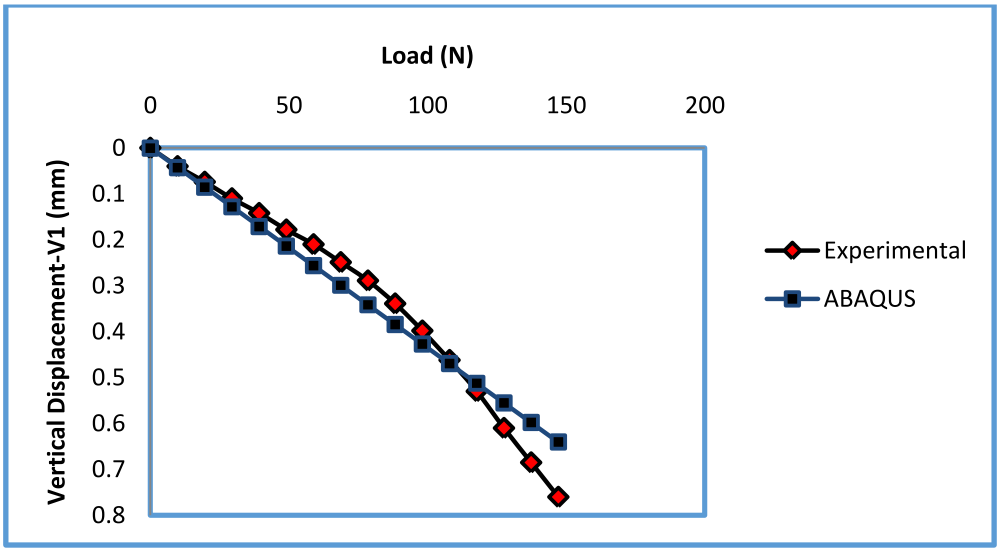
Concentrated eccentric loads were applied at 0.2(L/2) distance from the centre of the beam in the model frame. Loads were applied gradually like 1, 2, 3Kg…..etc. The deflections were measured at column base and top of the pile cap. The forces developed in the frame were calculated and are shown in Table 4.1., 4.2., and 4.3. Graphs were drawn; like load verses lateral displacement at the base of the column; vertical settlements and rotations and also forces (Shear force and Bending Moment) developed in the frame.



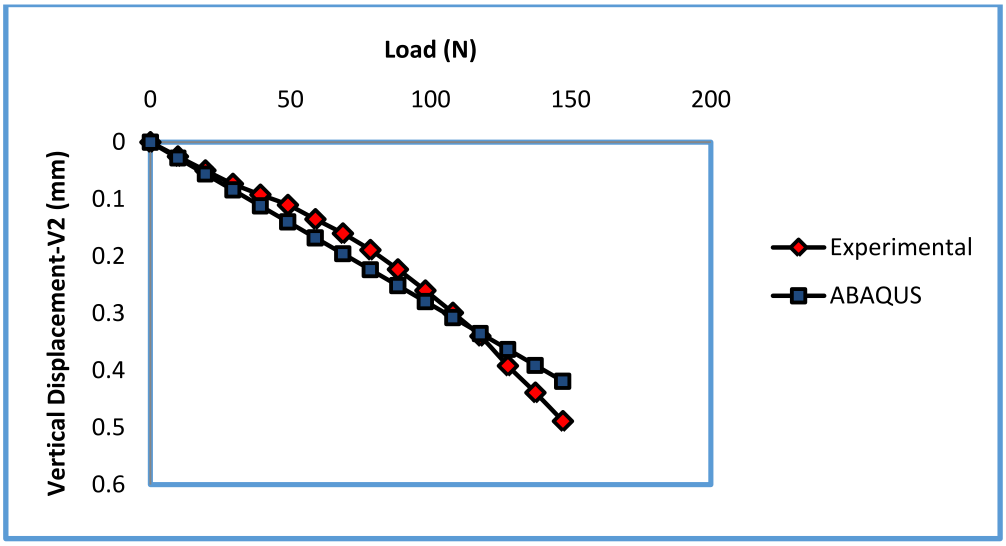

**4.1.1Load Vs Lateral displacement at base of the column**



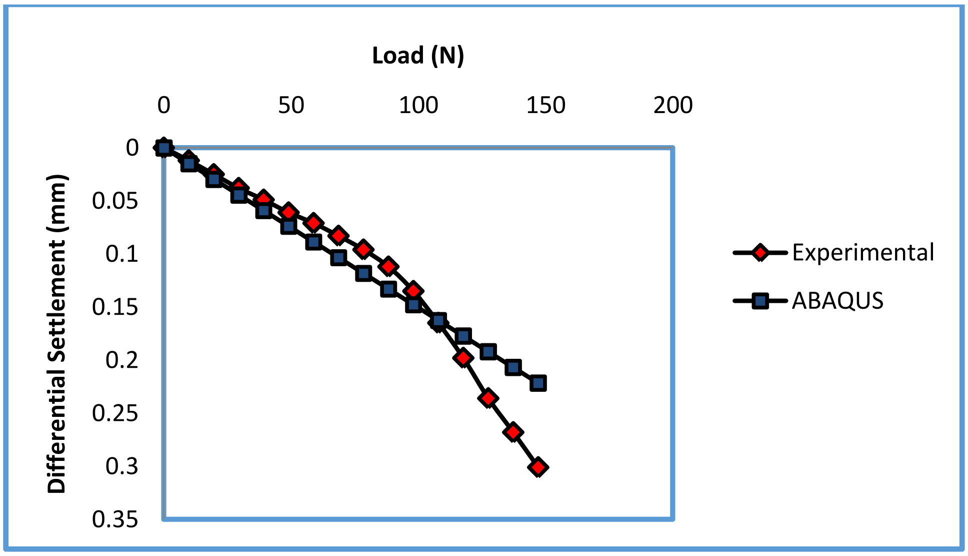

**4.1.2 Load Vs Lateral displacement at base of the column**




**4.1.3 Load Vs Settlement at base of the column**

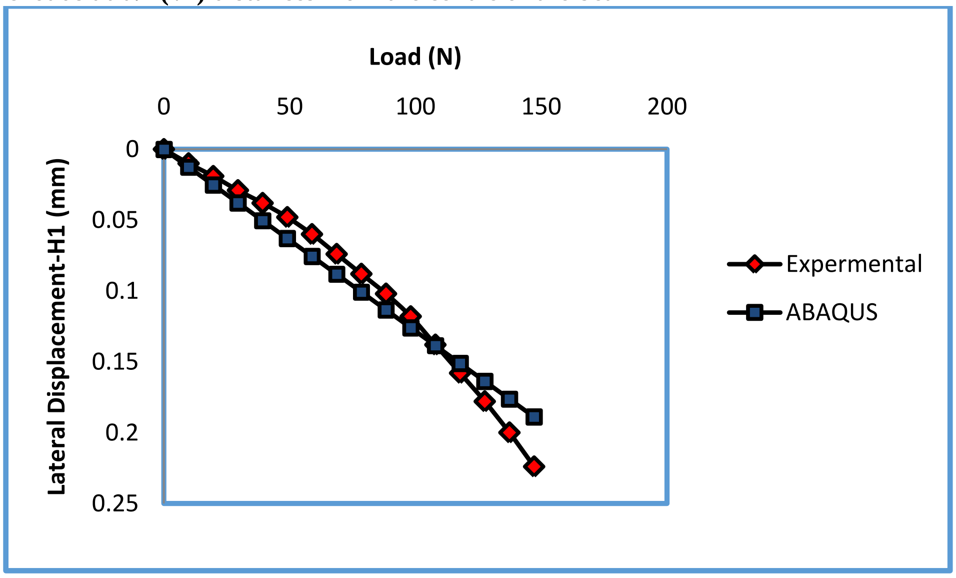



**4.1.4 Load Vs Settlement at base of the column**

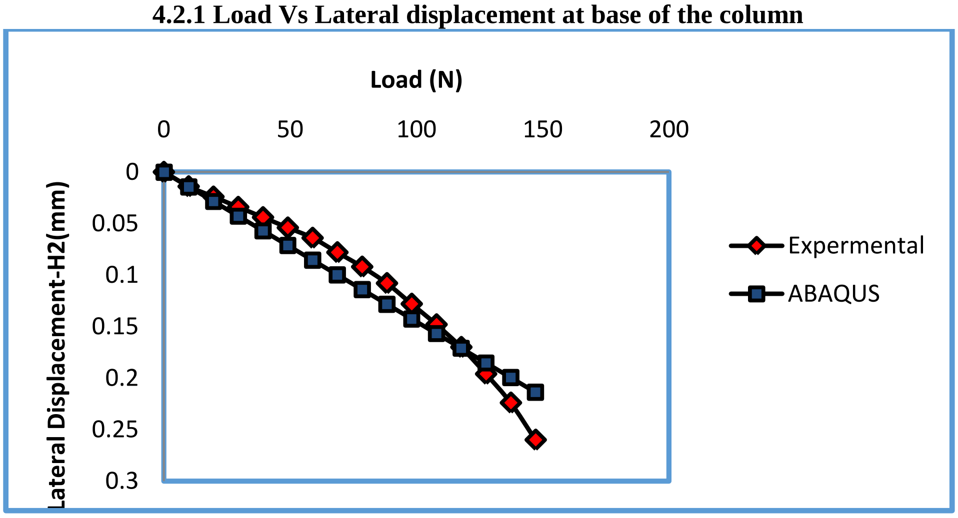



**4.1.5 Load Vs Differential Settlement at base of the columns**

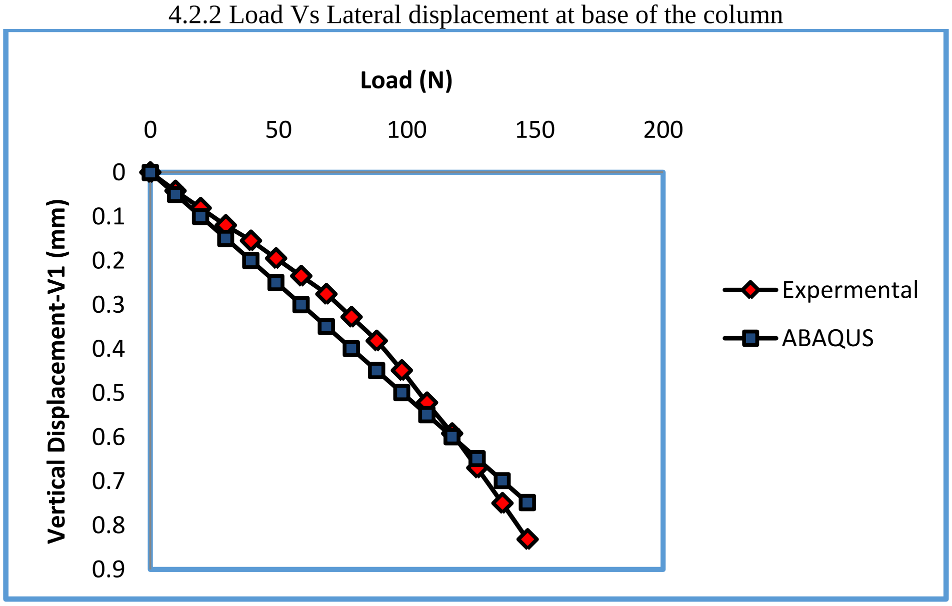
**4.2 eccentric loads at 0.4 (l/2) distances from the centre of the beam**



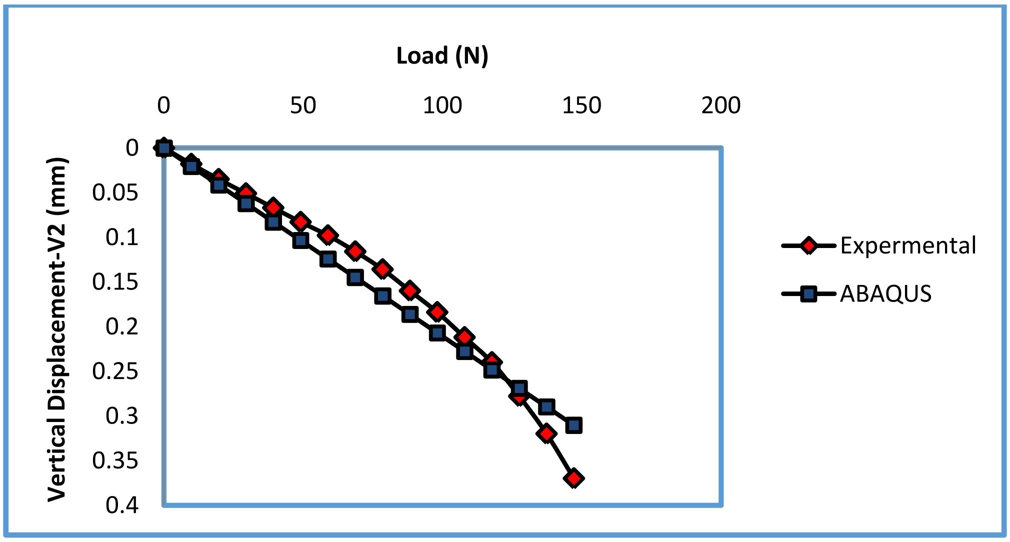

**4.2.1 Load Vs Lateral displacement at base of the column**



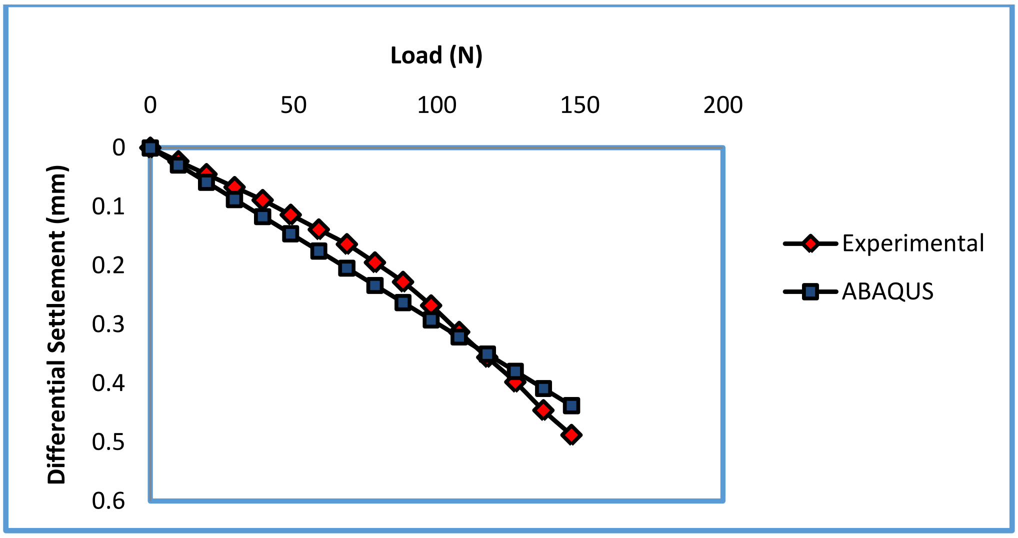

4.2.2 Load Vs Lateral displacement at base of the column



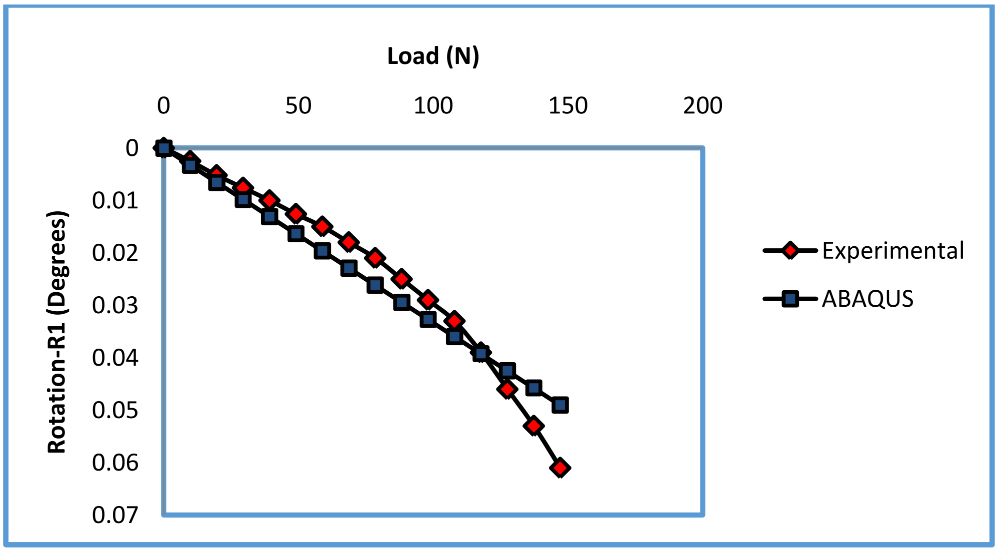

**4.2.3Load Vs Settlement at base of the column**




**4.2.4 Load Vs Settlement at base of the column**




**4.2.5 Load Vs Differential Settlement at base of the columns**




**4.2.6Load Vs Rotation of pile cap**

## VI. CONCLUSIONS

Based on the results of the present Analytical and Experimental investigations on model frame with pile groups in loose sand, the following conclusions are drawn.

1. Strong Soil-Structure Interaction exists.
2. With the increase in load on the frame load-settlement variation becomes non-linear. This is because at relatively higher loads sand shows non-linear variation.
3. The percentage of variation in bending moments and shear forces at the column base when compared with the experimental results and conventional method were 60-100% and 25-50% respectively.
4. The percentage of variation in bending moments and shear forces at the column base when compared with the experimental results and ABAQUS (Finite Element Analysis) were 20% and 40% respectively.
5. The percentage of variation in Lateral displacements and Rotations over the pile cap when compared with the experimental results and ABAQUS (FEA) were 22% and 20% respectively. And also differential settlement is 54%.
6. Frame elements when designed based on soil-structure interaction were more economical as design forces are less compared to conventional analysis.

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