# Experimental Analysis of Pile Group Supported Columns

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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 cohesion less 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 frame reduced 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***

***Index Terms- Model Piles, Suitable L/D Value, Dial Gauges, Super Structure, Soil-Structure Interaction Phenomenon***

## I. INTRODUCTION

Foundation is that part of structure which transmits the load of the structure to the ground. It is the supporting part of the structure. It acts a connecting link between the structure and ground. The pile foundation is a type of deep foundation. A complete pile design project involves determination of pile capacity for given soil conditions to fix the diameter, length and judicious grouping of piles to transfer the upcoming load to soil below for safe functioning of the foundation system throughout its operating life and finally covering the pile with the properly design pile cap.[3] Apart from their ability to transmit foundation loads to underlying strata, piles are also widely used as a means of controlling settlement and differential settlement. For the design of the pile, the designer has to come up with best possible option for the given conditions of the soil by considering the aspects such as bearing capacity, group action and design.

History And Development of Piles in Britain, a Roman bridge spanned the Tyne at Core bridge, about 20 miles west of Newcastle on Tyne, using piles to support the construction. The piles used in this were block oak and were 3mts in length. Amsterdam was founded about 1000 years ago, was build almost entirely on pile foundations of 15-20 meters of length. The Romans capped their piles with a mixture of stone rubble and concrete. Creasy (An Encyclopedia of Civil Engineering 1861) says that in Holland piling and capping by planking was still in use, with rough stones rammed between the planks. Necessity of Pile Foundation The pile foundation is necessary to resist the uplift forces created due to water table rise or any other cause.

*When the structure is need pile foundation*

1. When the strata just below the ground surface is highly compressible and very weak to support the load.
2. When the plan of structure is irregular to its outline and load distribution. It would cause non-uniform settlement.
3. When horizontal forces in addition to vertical loads are to be resisted.
4. When soil layer immediately below the structure are when structure is subjected to uplift, overturning moments subjected to scour.
5. Where expansive soils, such as black cotton soil exist, which swells or shrink due to change in water content.
6. In areas where settlement issues are common due to soil liquefaction or water table issues, pile foundation is a better choice.
7. Pile foundation is necessary for areas where the structure surrounding has chances for soil erosion. This might not be resisted by the shallow foundations.
8. Pile foundation is needed near deep drainage and canal lines.

*Uses of Pile Foundation*

1. If a high groundwater table exists beneath the structure.
2. If the superstructure load is high and non-uniform.
3. Pile foundation is economic than other proposed foundation types.
4. If highly compressible soil is present at shallow depth.
5. If the structure is located near the river bed or sea shore etc, pile foundation is suggested to secure the structure form the possible scouring.
6. If a canal or deep drainage systems pass near the structure, pile foundation is suggested.
7. If soil condition is very poor and it is not possible to excavate the soil up to the desired depth.
8. If it becomes impossible to keep the foundation trenches dry by any measure due to heavy inflow of seepage

## II. REVIEW OF LITERATURE

In the studies by Chore and Ingle (2008a, b), an uncoupled analysis (sub-structure approach) of the system of building frame and pile foundation was presented. By this methodology, a building frame was analyzed separately with the assumption of fixed column bases. Later, equivalent stiffness was derived for the foundation head and used in the interaction analysis of the frame to include the SSI effect. More recently, Chore et al. (2009) presented an interaction analysis for the building frame resting on the pile group using a coupled approach, i.e., by considering the system of building frame - pile foundation - soil as a single combined unit. Although such an analysis is computationally uneconomical, fair agreement was observed between the results obtained using coupled and uncoupled approaches.

More recently, much work was done on the quantification of the effect of soil-structure interaction on the behaviour of framed structures (Dasgupta et al. 1998, Mandal et al. 1999). Viladkar et al. (1991) used coupled finite-infinite element in the interactive studies of framed structures and demonstrated the viability of application of such a technique in analysis. Similarly, an interactive analysis was conducted by Noorzaei et al. (1991) for space frames resting on raft. Recently, Stavirdis (2002) presented a simplified interaction analysis of layered soil-structure interaction, and Hora (2006) the non-linear soil-structure interaction analysis of infilled building frames. While most of the aforementioned studies dealt with the interaction of frames with isolated footings or combined footings or raft foundation, only the study by Buragohain et al. (1977) is found to deal with the interaction analysis of frames resting on piles.

## III. METHODOLOGY

*Scope of study*

The experimental analysis for static vertical loads on a model building frame without plinth beam, with conventional plinth beam supported by pile groups embedded in cohesion less soil (sand) is presented in this thesis. The effect of soil interaction, conventional plinth beam on displacements and rotation at the column base and also the shears and bending moments in the columns of the building frame were investigated. The experimental results have been compared with those obtained from the conventional method of analysis.

Properties of sand

Specific gravity – 2.62

Bulk density – 1.65 g/cc

Relative density –31%

Zone – 3

Angel of internal reflection – 28deg

*Experimental setup*

Initially the soil is placed in the form of layers. Prior to this work it is required to obtain properties of soil such as Zone, Relative density, angle of internal friction. Model pile group along with building frame is placed such that it should have a cover of 5cm. It refers to free standing pile group which is most commonly used in coastal areas. Dial gauges were placed at proper locations by suitable means to determine deformations in vertical and lateral directions as shown in below figure

*Introduction to FEM and ANSYS*

The Finite Element tool has the ability to solve the complex problems FEA has a history of being used to solve complex and cost critical problems. Classical methods alone usually cannot provide adequate construction or an automobile or an aircraft.

In the recent years, FEA has been universally used to solve structural engineering problems. The departments, which are heavily relied on this technology, are the automotive and aerospace industry. Due to the need to meet the extreme demands for faster, stronger, efficient and high rise structures and aircraft, manufacturers have to rely on this technique to stay competitive.

The friction stir welding process incorporates a challenging set of physical phenomena. These phenomena include: very large non linear material deformations, highly dependent material properties, and thermal heating from coupled frictional and shear deformation. There are three approaches to numerical modeling. The finite element, Difference, and Finite volume approaches .Finite Element approach is widely popular its generic formulation, a technique that lends itself to commercial code product nodal points and elemental volumes are generally formulated to accommodate of problems. Finite Element method approach can be used for irrotational material advection, thermal diffusion large displacement of solid materials. Therefore finite element method is used for analysis.

*The Basic Steps Involved in FEA*

The major steps are given below

1. Discretization of the domain
2. Application of Boundary conditions
3. Assembling the system equations
4. Solution for system equations
5. Post processing the results

*Ansys Software:*

The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis.

ANSYS finite element analysis software enables engineers to perform the following tasks:

a. Build computer models or transfer CAD models of structures, products, components, or systems.
b. Apply operating loads or other design performance conditions.
c. Study physical responses, such as stress levels, temperature distributions, or electromagnetic fields.
d. Optimize a design early in the development process to reduce production costs.
e. Do prototype testing in environments where it otherwise would be undesirable or impossible (for example, biomedical applications).

*Applying Loads*

The word loads as used in ANSYS includes boundary conditions (constraints, supports, or boundary field specifications) as well as other externally and internally applied loads. Loads in the ANSYS program are divided into six categories: Most of these loads can be applied either on the solid model (key points, lines, and areas) or the finite element model (nodes and elements).Two important load-related terms are load step and sub step. A load step is simply a configuration of loads for which a solution is obtained. In a structural analysis, for example, wind loads may be applied in one load step and gravity in a second load step. Load steps are also useful in dividing a transient load history curve into several segments.

Sub steps are incremental steps taken within a load step. They are mainly used for accuracy and convergence purposes in transient and nonlinear analyses. Sub steps are also known as time steps - steps taken over a period of time. The ANSYS program uses the concept of time in transient analyses as well as static (or steady-state) analyses. In a transient analysis, time represents actual time, in seconds, minutes, or hours. In a static or steady-state analysis, time simply acts as a counter to identify load steps and sub steps.

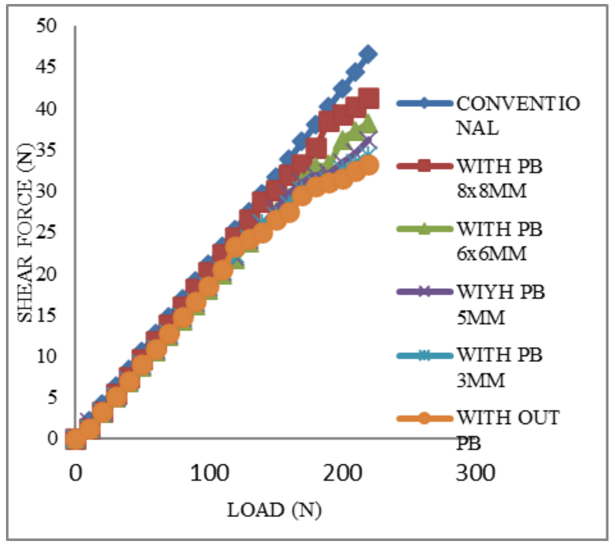
## IV. OBJECTIVE

The aim of this thesis is to present the Experimental investigation of model plane frame without plinth beam and frame with plinth beam supported by pile groups embedded in cohesion less soil (sand) under the static loads (central concentrated load, uniformly distributed load (UDL) and eccentric concentrated load). The need for consideration of soil interaction in the analysis of building frames and the use of plinth beam instead of conventional one is emphasized by comparing the behavior of the frame obtained by the experimental results the conventional method of analysis. An attempt is made to quantify the soil interaction effect and the use of plinth beam on the response of the building frame in terms of displacements, rotations, shears and bending moments through the experimental investigation.

## V. RESULTS

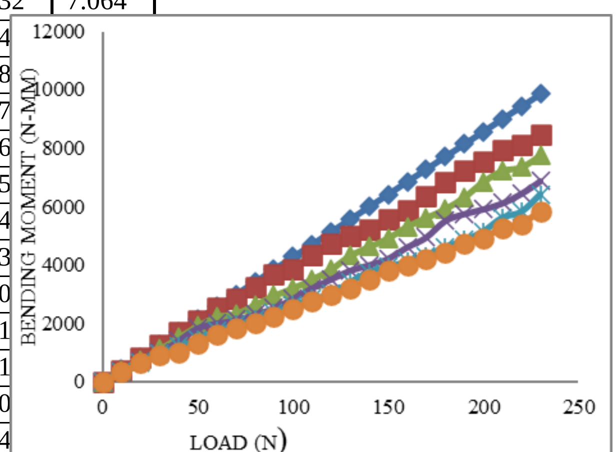
The experimental results of shear force for the eccentric load far end load vs shear force

| LOAD IN N | CONVENTIONAL | WITH PB 8x8MM | WITH PB 6x6MM | WIYH PB 5MM | WITH PB 3MM | WITH OUT PB |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 2.1151 | 1.1651 | 1.2289 | 1.189 | 1.228 | 1.303 |
| 20 | 4.2302 | 3.2802 | 3.1085 | 3.098 | 3.204 | 3.225 |
| 30 | 6.3453 | 5.3953 | 4.983 | 5.001 | 5.118 | 5.145 |
| 40 | 8.4604 | 7.5104 | 6.8626 | 6.91 | 7.032 | 7.064 |
| 50 | 10.575 | 9.625 | 8.7343 | 8.811 | 8.94 | [illegible] |
| 60 | 12.691 | 11.714 | 10.6118 | 10.71 | 10.8 | [illegible] |
| 70 | 14.806 | 13.856 | 12.479 | 12.614 | 12.7 | [illegible] |
| 80 | 16.921 | 15.971 | 14.35 | 14.514 | 14.6 | [illegible] |
| 90 | 19.036 | 18.086 | 16.214 | 16.408 | 16.5 | [illegible] |
| 100 | 21.151 | 20.201 | 18.087 | 18.31 | 18.4 | [illegible] |
| 110 | 23.266 | 22.316 | 19.948 | 20.201 | 20.3 | [illegible] |
| 120 | 25.381 | 24.431 | 21.807 | 22.09 | 21.0 | [illegible] |
| 130 | 27.496 | 26.546 | 23.677 | 23.989 | 22.1 | [illegible] |
| 140 | 29.611 | 28.45 | 25.524 | 24.54 | 23.1 | [illegible] |
| 150 | 31.726 | 30.12 | 27.405 | 26.54 | 25.0 | [illegible] |
| 160 | 33.841 | 31.245 | 28.15 | 27.12 | 26.4 | [illegible] |
| 170 | 35.957 | 34.254 | 30.12 | 28.54 | 27.12 | 26.14 |
| 180 | 38.072 | 36.25 | 32.41 | 29.54 | 28.32 | 27.41 |
| 190 | 40.187 | 37.15 | 34.21 | 30.75 | 29.42 | 28.34 |
| 200 | 42.302 | 38.86 | 35.53 | 31.65 | 30.74 | 29.65 |
| 210 | 44.417 | 39.76 | 36.54 | 32.54 | 31.71 | 30.41 |
| 220 | 46.532 | 40.12 | 37.52 | 33.67 | 32.41 | 31.01 |




Variation of Load Vs Near end Shear Force for eccentricity Load

- Shows the variation of near end shear force at column bases with eccentricity load.
- The above graph is drawn between load vs near end shear force.
- The plot shows that for the lower load on the frame load vs near end shear force is follows liner relation for higher loads on the frame it is non liner relation.
- It is found as the axil rigidity various from 0 to 4480 KN, the near end shear force increases by 11.39%.




Variation of Load Vs far end bending moment top for eccentricity Load

- Shows the variation of far end bending moment top at column bases with eccentricity load.
- The above graph is drawn between load vs fear end bending moment top.
- The plot shows that for the lower load on the frame load vs fear end bending moment top follows liner relation for higher loads on the frame it is non liner relation.
- It is found as the axil rigidity various from 0 to 4480 KN, the fear end bending moment top increases by 14.19%.

## CONCLUSION

- The experimental results shows the variation of load vs. displacement is nearly linear of loading for higher load on the frame it is showing nonlinear variation.
- As the axial rigidity of plinth beam increases from 0 to 4480 KN, the lateral displacement decreases by 55.88%.
- As the axial rigidity of plinth beam increases from 0 to 4480 KN, the rotation decreases by 64.12%.
- As the axial rigidity of plinth beam increases from 0 to 4480 KN, the settlement decreases by 54.45%.
- The results show that the lateral displacement, rotation and settlement as the base of the column of a building frame deepens as the axial rigidity of the plinth beam increases.
- As the axial rigidity of plinth beam increases from 0 to 4480 KN ,the shear force increases by13.7%
- As the axial rigidity of plinth beam increases from 0 to 4480 KN, the bending moment top increases by 14.19%
- As the axial rigidity of plinth beam increases from 0 to 4480 KN, the bending moment bottom increases by 19.77%
- Hence the shear force and bending moment in the frame increases.
- So to reduce the effect of rigidity of plinth beam on design parameters.
- it is suggested that any element which will have less axial rigidity such as geo textiles can be used as plinth beam.

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