# Numerical study of rock socketed pile

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**Abstract.** Rock socketed pile means the end portion pile get inserted into the bed rock. Such pile contributes high bearing capacity and high lateral stability. Different studies said that this type of pile posses both friction resistance along the socketed length and end resistance at bottom against the coming load. In many cases of end bearing pile with frictional resistance contribute high capacity as same as a large diameter pile gives. So beyond the total capacity of pile it is better to determine the skin friction and end bearing separately for a good design of a pile. The separation of skin friction and end bearing can only perform by conducting cyclic pile load test. But the problem is the analytical and graphical IS code analysis of separation of friction and end bearing exist only for pile resting in sand. Till now we have been using the same method for pile in rock with the assumption that rock is in dense sand condition. This assumption leads to this project and then it is aiming to determine how the rock and pile will react when load comes, how much part of the coming load takes up by friction and end bearing. These are analyzed through finite element analysis. The software abaqus is used here to find the performance of rock socketed pile. The study on behavior of load versus settlement curve of rock socketed pile, the load distribution along the pile and socket of rock and early development of skin friction are discussed.

Keywords: Rock socketed pile; Numerical analysis; Stress

## 1 Introduction

We all know that there exist mainly two types of pile friction pile and end bearing pile .In friction pile the load is carried by friction developed there and in end bearing pile the hard strata at bottom bears the load. Here the discussion is on the topic of rock socketed pile whose bottom portion is get inserted in to the bed rock in which it rests. In case of rock socketed pile both friction and end resistance act together against load. But the people have many questions that how the load transfer happens, how much portion of the coming load is taken by the friction and how the failure occur. In this paper the rock socketed pile is analyzed numerically in software Abaqus. In finite element method the entire structure to be analyzed is descritized into small individual parts that we can analyze and summed up to get the behavior of entire structure while loading. The site condition properties were assigned and the loading also done. The people are thinking that all the time the major part of load is resisted by the end even there the friction develops but some studies are discussed about the extent of frictional resistance developed along the socket and found greater resistance at initial time. This paper discusses the development of friction and its mobilization. Yang and Robert (2013) shows 3D finite element model to study the response of drilled shaft in rock mass using abaqus. The vertical side shear forces on shaft are determined and this study gives a basic idea about how to input the properties of rock socketed pile into software.

Numerical analysis is always a support to the experimental studies. The accuracy of experimental work can be proved with this numerical analysis. In numerical analysis the entire structure which is to be analyzed is descritized into small elements and the behavior of each element is considered to analyze the entire structure. Initially rock and pile wanted to be modeled geometrically and property vice. It should have a proper idea about how to apply loading too. In software, every site conditions are needed to be assigned correctly to get exact behavior of rock socketed pile in site. The detail modeling, assigning properties and application of load are discussed here in this study.

## 2 Methodology

### 2.1 Geometric modelling

The rock socketed pile consist of mainly three parts 1st one the socketed rock mass then a concrete pile and reinforcement. These are modeled as per the size of materials used in the experimental study. The rock mass, pile and steel were modeled separately and after all these would be assembled as rock socketed pile. The parts were created as 3D deformable solid part which means they are of homogeneous solid material and allow deformations.

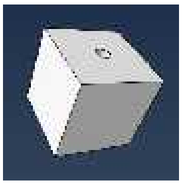
**Fig. 1.** Rock mass, pile and steel bar in numerical analysis

Here the rock mass was made in 350*350*350 mm size cube, a cylindrical shaped socket of 60mm diameter and 120mm depth was also made in it. The pile is simulated by 60mm diameter and 900mm length cylinder and 6mm diameter cylinder simulates steel bars.

## 2.2 Material modelling

Every part has to be assigned with the corresponding properties of the materials in the site. Here these parts are assigned with the properties of materials used for the experimental study for validating the results. The values of properties for each part are shown below. The elastic behavior of concrete is taken for the pile. The elastic behavior of rock is given as per its property and the plastic behavior is analyzed through drucker prager option. In drucker prager, the angle of friction and dialation angle are given and the drucker prager hardening option has put on. The elastic propertie of steel is given to the reinforcement bar. The other essential data are taken from the study by Ke Yeng et al( 2013).

**Table 1.**Properties assigned for each parts

| Parts | Properties assigned |
|---|---|
|  Rock mass | Density - $2920kg/cm^3$<br>Modulus of elasticity - 10000Mpa<br>Angle of friction - 35˚<br>Dilation angle - 5˚<br>Poisson’s ration - 0.25 |
|  Pile | Density - $2400kg/cm^3$<br>Modulus of elasticity - 26362.85Mpa<br>Poisson’s ration - 0.15 |
|  Steel bar | Density - $7850kg/cm^3$<br>Modulus of elasticity - 200000Mpa<br>Poisson’s ration - 0.2 |

## 2.3 Assembling

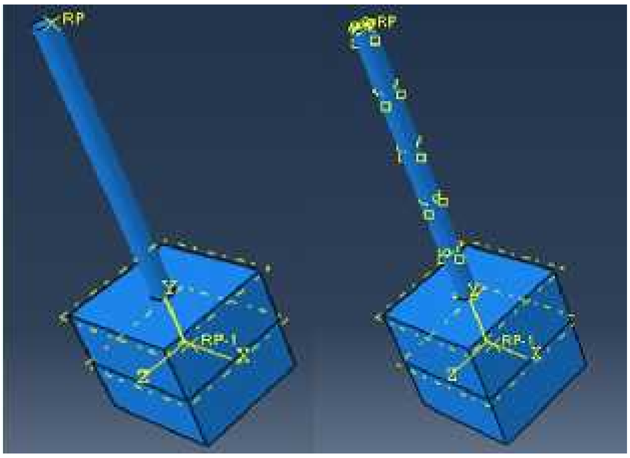


Fig.2. Assembly of rock socketed pile

The parts are assembled as per the site condition or as per the experimental arrangement. The contact areas were assigned with the interaction properties. The interaction properties were assigned after the assignment of properties to the parts. There are two interactions exist 1st one is between bottom of the pile and rock and the 2nd is between the cylindrical area of pile with the surrounding rock along the socket depth. The coefficient of friction is the main interaction property and it is about 0.8 along the side of pile with rock and at the bottom. These common interaction and other properties are taken from Yang(2013). Now the all properties were assigned as per the experimental data.

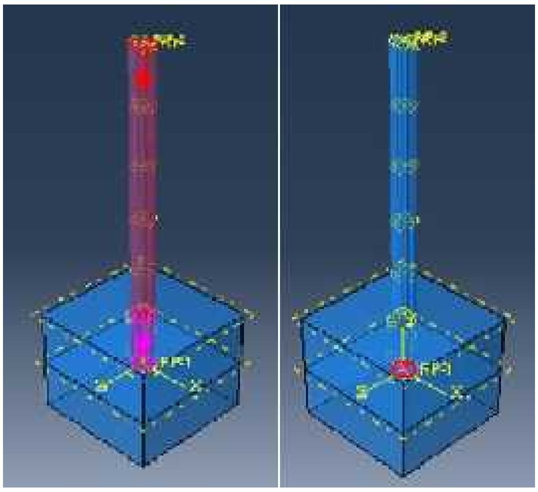


Fig.3. Parts of interaction

## 2.4 Loading

The loading can be done in two ways they are displacement controlled and load controlled. In displacement controlled type the required displacement at any point is initially assigned, so after the run of program it would show the load correspond to the predetermined deformation. In load controlled type the estimated load was applied and the corresponding deformations will be noted.

Here this analysis is done by controlling displacement of 6mm in the subgrade and the load wanted to be acted compressively at the top of pile in static manner as shown in fig.3. The loading period was taken as 10s which means the 6mm displacement in subgrade by loading at pile head would be completed in 10s. The rotation was restrained at bottom, sides and pile head while loading. The displacement is restrained all direction except the direction of loading. These are the boundary conditions applied to the assembly.

## 2.5 Meshing

In finite element analysis the entire assembly of structure needs to be discretised into small element. This process in abaqus is called meshing. There exist different basic elements for example 3 noded bar element, 6 noded triangular element and 8 noded cubical element. Here the 8 noded brick element was used to discretize the structure. As abaqus it is known as C3D8R, means 8 noded brick element with reduced integration.

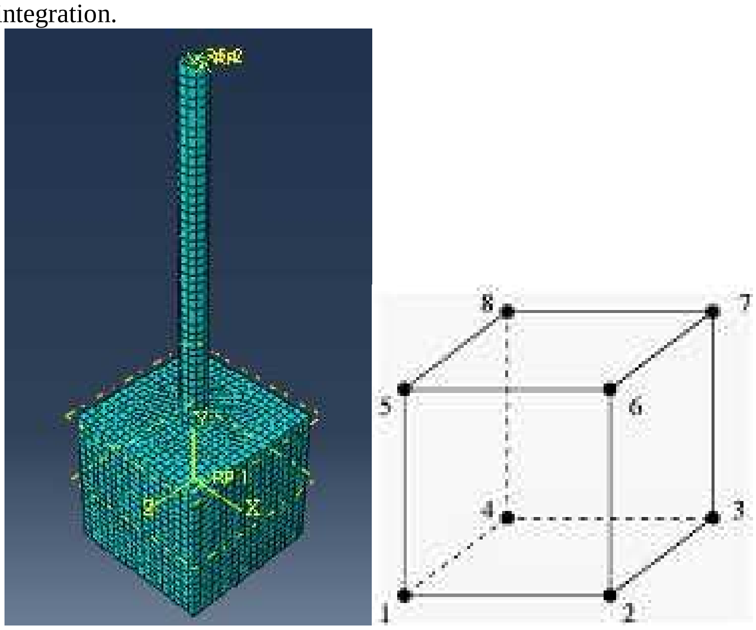



Fig.4. Meshing of assembly

After meshing the program was allowed for running and the skin friction v/s settlement curve was drawn and it was validated with the experimental results.

## 3 Results and Discussion

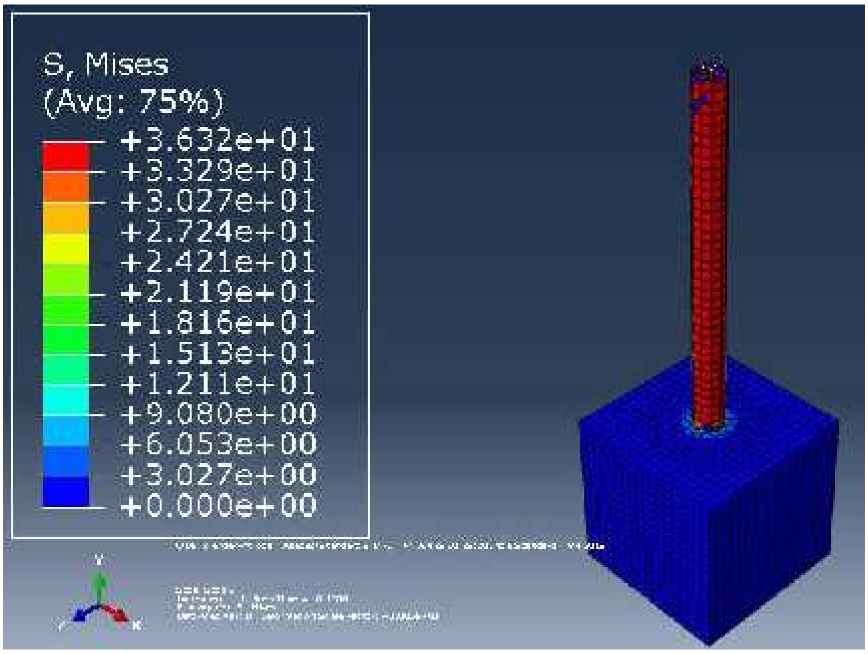



Fig.5. stress distribution of entire structure

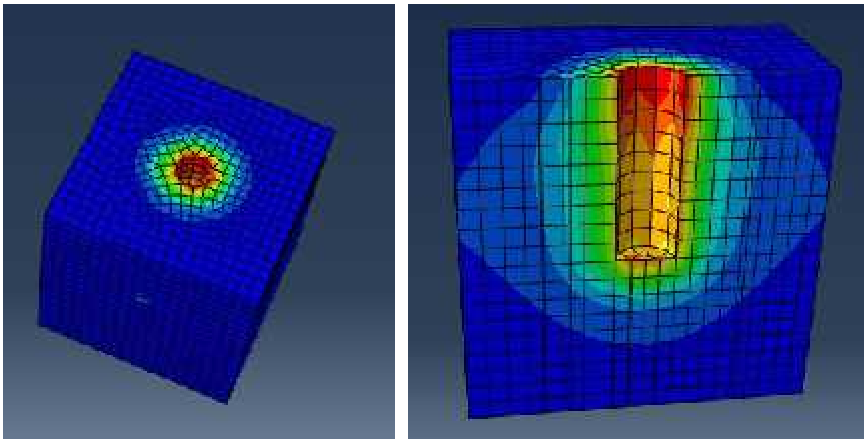


Fig.6. Friction developed in the socket

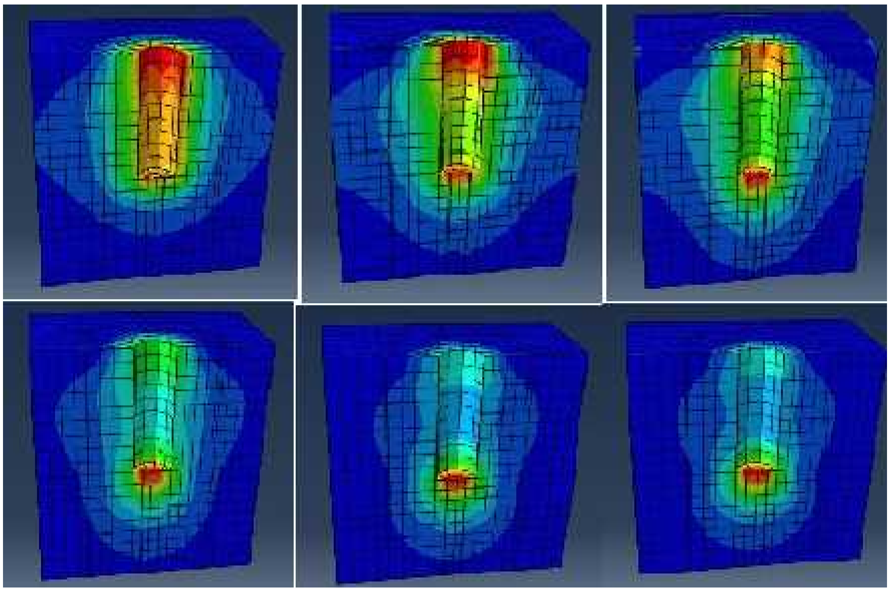


Fig.7. Skin Friction to End bearing

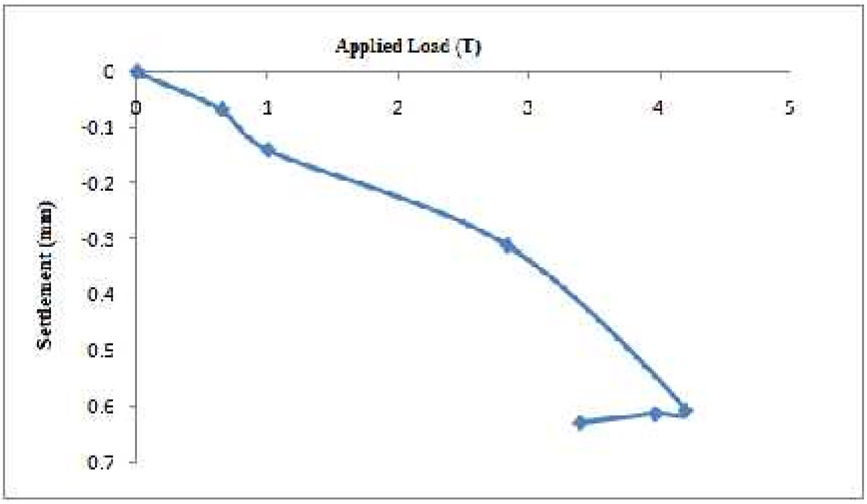



Fig.8. Skin friction v/s settlement

The applied load is initially resisted by skin friction developed in the socket. So the variation of applied load in the above curve shows the development of friction there. The friction increases linearly with the settlement and after a particular point the load value decreases and defletion increases which shows the complete mobilization of friction. the highest frictional value is about 4.2T by the numerical analysis which is almost similar to the maximum frictional value determined as per the new method and the same as the friction which is directly measured. When the frictional value decreases the load will be taken by the end and that variation has shown in Fig.6.

## 4 Conclusion

- The initial development of friction while loading is easily visible in numerical results since the stress concentration is greater at socket length and gradually decreases and concentration of stress at bottom increases.
- The greater coefficient of friction between rock and pile gives larger skin friction than end bearing at earlier stages of loading
- The hard strata at bottom of pile will start to take load when the developed skin friction mobilizes completely.

## 5 Reference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