SOCKETING OF BORED PILES IN ROCK

B.R. Srinivasamurthy  
Professor (Retd), Indian Institute of Science, Bangalore–560012, India.  
E-mail: murthybrs@gmail.com.  

K.L. Pujar  
Director, United Foundations Pvt Ltd., Chennai–600041, India.  
E-mail: ufcfoundation@yahoo.com.

ABSTRACT: Socketing of bored piles in rock is always seen as matter of debate at construction site between consultants & contractors. Normal assumption is that rock socketed piles are end bearing piles and friction component developed in the length of socket is neglected. To achieve the proper socketing of pile on rock surface, the rock layer is subjected to heavy chiseling may cause cracks in rock mass and heavy grinding may cause reduction in friction component due to smooth surface of drill holes in rock. Both the above effects may become detrimental to safe load carrying capacity of piles. Hence it is necessary to take proper care to decide the socketing of pile in rock and to determine the length of socketing so that effects of friction (in rock strata surface) and bearing on rocks can be utilized judiciously to their optimum values. The socketing depth normally depends on type of rock, depth at which the rock is available below the pile cap and load carrying capacity of pile. In this paper the review of existing methods to determine the socketing length is made and an attempt has been made to formulate a practical approach & determine length of socketing of bored piles in rock. Also a realistic method of estimating the friction capacities of the socketed length of the pile has been proposed.

1. INTRODUCTION

In the present construction activities, large diameter bored piles are being used to carry heavy loads from super structures. Almost in all infrastructure projects, the diameters of bored piles being used are 1000 mm, 1200 mm and 1500 mm. Since these piles are designed for heavy loads (from 450T to 650T per pile), they are essentially to be taken to bed rock level and are to be socketed into rock. 

In the piling specifications, socketing in solid/hard rock is usually specified for termination criteria. For all practical considerations the socketing in solid rock is very much essential where the piles are resting on rock situated at shallow depths (with lesser depth of over burden) and/or on the sloping solid rock. Where the hard rock is situated at greater depths i.e. having larger over burden to resist lateral displacement, the socketing of piles as being currently specified in most of piling specifications may not be necessary and heavy chiseling for specified socket length will be a wasteful exercise and sometimes the heavy chiseling may spoil the quality of hard rock.

Boring up to rock surface will practically have no difficulty, except for intermittent service lines and boulders. Socketing in rock will pose many practical problems which generally range from classification of rock to socketing length and final termination criteria. In this paper, some of the practical problems faced during socketing of piles into hard rock are discussed and probable solutions are recommended.

2. BRIEF HISTORY

Piles carry load by friction and end-bearing. In case of major structures like bridges, flyovers, high rise buildings, etc the load carried by end-bearing component only will be considered as safe load carrying capacity of pile. This is to avoid any settlement in the friction-end bearing combination.

In doing so, the strength contribution by skin friction of the pile length drilled through weathered/soft rock will be neglected completely. If the thickness of weathered/soft rock is less, then neglecting the strength contribution from this layer may be justified. If the thickness of weathered/soft rock is more, say to the extent of 5 m and above (for large diameter of piles, say 1.2 m dia.), neglecting the strength contribution from this layer may become uneconomical and time consuming in boring through rock layers resulting into over-run of project time.

3. SOCKETING OF PILES

Present practice of socketing the piles in rock is being done, or rather being insisted upon, by cutting the sound rock for a minimum of 1D (for large diameter piles). If the pile diameter is 1.2 m, the socketing is to be done for a depth of 1.2 m by chiseling the sound hard rock. Chiseling the hard rock whose crushing strength is of the order of 1000 kg/cm² requires heavy chisel energy and chiseling for more time. Both of these aspects may cause damage to structure of rock.
Piles on rocks carry the load by point bearing. To ensure the proper contact between base of pile and rock surface, it is needed to socket the pile into hard rock by cutting through weathered and soft rock and by cutting the hard rock for a reasonable depth mainly to get the level surface of rock and to remove the top weathered surface of rock. This reasonable depth may vary from 150 mm to 300 mm. Further if soft and medium rocks are preceding the hard rock the socketing length may be counted from the level at which soft rock with N more than 50 has been met.

Most of the times there are differences in recognizing the type of rock—weathered/soft/hard. First, the classification of rock layer is to be done properly. For this purpose we can refer to field test reports like RQD, CRR and SPT results and crushing strength of rock core samples.

For major projects like bridges and flyovers, the soil investigation is to be done under every pier location. Hence the above-mentioned tests are essential to be carried out for every pier location.

Rock Quality Designation (RQD) is expressed as,

\[ \text{RQD} = \frac{L_o}{L_t} \]  

where

- \( L_o \) = total length of intact hard rock of core length 100 mm or more arranged in its proper position
- \( L_t \) = total length of drilling

The behavior of rock mass is affected by factors like presence of fractures in the rock, size and spacing of the fractures, degree of weathering of fractures and presence of soil within the fractures.

4. METHODS TO DETERMINE SOCKETED LENGTH OF PILE IN ROCK

4.1 Based on Uniaxial Compression Strength of Rock

Rock socketing of piles is mainly done to utilize the full structural capacity of piles. Since rock socketed piles can be designed to carry compressive loads by skin friction and end bearing, it is necessary to collect all details mentioned above. In addition, chemical properties of rock at founding level also should be obtained to find out chemical constituents affecting the strength of pile (concrete and rock).

With all the above details, safe load carrying capacity of the piles socketed in rock can be calculated by combining the skin friction and end bearing components of the load.

Normally, sound rock free from fractures and fissures (compressive strength greater than 500 kg/cm², i.e. more than the compressive strength of concrete) will have the required strength to carry the designed load on piles. Based on uniaxial compression strength of rock, the safe load carrying capacity of pile, \( Q_s \), is given by

\[ Q_s = q_c N_j A_p + q_c \pi D l_s \alpha \beta \]  

where

- \( q_c \) = uniaxial compression strength of rock, T/m²
- \( N_j \) = Depth factor = 0.8 + 0.2l_s/D, limited to 2
- \( A_p \) = Area of pile toe, sq m
- \( D \) = Dia of pile, m
- \( l_s \) = socket length into rock, m
- \( \alpha \) = rock socket side resistance reduction factor
  (Figure 1)
- \( \beta \) = rock socket correction factor (Figure 2)
- \( N_j \) = values as per Figure 2 of IS 12070

\( N_j \) value also depends on spacing of discontinuities. For sound rock having negligible discontinuities, \( q_c \) can be taken as equal to safe strength of concrete in T/m²

\[ N_j = 0.3 \]
\[ \alpha = 0.05 \]
\[ \beta = 1 \text{ and} \]
\[ N_d = 1 \]

For safe load of 500 mT for 1200 mm dia pile with M40 grade concrete, the socketed length of pile will be

\[ 500 = 1330 \times 0.3 \times 1.13 + 1330 \times 3.14 \times 1.2 \times l_s \times 0.05 \times 1 \]
\[ = 450.87 + 79.8 l_s \]
\[ l_s = (500 - 450.87)/79.8 \]
\[ = 0.61 \text{ m} \]

From the above, it can be seen that for a socketed length of 61 cm i.e. about 0.5D in sound hard rock, we can get the safe load of 500T for 1.2 m dia pile.
4.2 Based on Shear Strength of Parameters of Rock

Shear stress of rock ($\tau$) is a fraction of its unconfined compression strength ($\tau_c$). $\tau$ may be taken either as a linear fraction of $\tau_c$ with coefficients ranging from 0.1 to 0.4 or as a fraction of square root of $\tau_c$ with coefficients ranging from 0.2 to 0.6. Shear strength of rock can also be determined by testing the samples in laboratory or by some in situ tests in the bore hole.

Ultimate capacity of pile $Q_u$ in rock for socketed length $l_s$ is given by

$$ Q_u = C_u N_c \times \pi D^2/4 + \alpha C_s \pi D l_s $$

(3)

where
- $C_u = \text{Shear strength of rock below pile tip, T/m}^2$
- $N_c = \text{BC Factor} = 9$
- $C_s = \text{Arc. shear strength of rock in socketed area, T/m}^2$
- $\alpha = \text{shaft adhesion factor, varies from 0.3 to 0.9}$ and $l_s = \text{socket length in m}$

Rock socket length can be calculated by knowing the shear values of rock.

4.3 Based on Energy Criteria

Designing of rock socketing length of pile in weathered/soft rock can also be calculated based on energy criteria. Rock socketing criteria gains much importance in weathered/soft rock. Core recovery ratio/Rock Quality Designation is the ideal test for determining the type of rock.

It is difficult to get cores in weathered/soft rock. To determine the length of socketing of piles in weathered rock to get the pile capacity and its structural strength, the method suggested by Cole and Stroud is being used widely. Cole and Stroud method uses $N$ values to identify the type of rock and its shear strength. Table 1 gives the relationship between SPT values and strength of rocks as suggested by Cole and Stroud.

<table>
<thead>
<tr>
<th>Value of N</th>
<th>Shear Strength (kg/cm²)</th>
<th>Strength</th>
<th>Grade</th>
<th>Breakability</th>
<th>Penetration</th>
<th>Scratch</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>400</td>
<td>Strong</td>
<td>A</td>
<td>Difficult to break against solid object with hammer</td>
<td>Cannot be scratched with knife</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>200</td>
<td>Moderate</td>
<td>B</td>
<td>Broken against solid object by hammer</td>
<td>Can just be scratched with knife</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>100</td>
<td>Moderately Strong</td>
<td>C</td>
<td>Broken in hand by hitting with hammer</td>
<td>Can be just scratched by thumb nail</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>80</td>
<td>Moderately Weak</td>
<td>D</td>
<td>Broken by leaning on sample with hammer</td>
<td>Can be scratched by thumb nail</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>60</td>
<td>Weak</td>
<td>E</td>
<td>Broken by hand</td>
<td>2 mm with knife</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>40</td>
<td>Hard or very weak</td>
<td>F</td>
<td>Easily broken by hand</td>
<td>5 mm with knife</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(N less than 60 are considered as soil)
Equation 3 can be used to arrive at socketing length of pile to get the capacity of pile equal to its structural strength.

Another method by using chisel is also in practice to determine the type of rock and socket length. In the chisel energy method, the main points to be considered are: weight of chisel, weight of fall, number of blows and penetration in rock for pre-determined number of blows. Though this approach seems to be more practical and rational, there are so many limitations to use this approach, like sharpness of chisel, chisel falling through water/bentonite solution, weight of chisel for particular diameter of pile, type of chisel, etc. Chisel energy can be calculated by the formula

\[ \eta = \frac{W \times n \times \alpha \times N}{A_p \times s} \text{Tm/sqm/cm} \]  

where  
- \( W \) = weight of chisel, Tones
- \( n \) = weight of fall, meters
- \( \alpha \) = reduction factor, usually varies between 0.6 to 0.8
- \( N \) = Number of blows
- \( A_p \) = Base area of bore hole, sq m
- \( s \) = penetration, cm

Value of \( \eta \) varies with respect to the diameter of bore hole and can be fixed based on local conditions and experience of consultant under similar conditions or based on results of load tests conducted in such areas. Based on energy value, the socket length can be divided.

In general for piles resting on sound rock with sufficient overburden and with level surface, rock socketing should not be more than 0.5D, where D is the diameter of pile.

5. PRECAUTIONS TO BE TAKEN IN ROCK SOCKETING

Apart from drilling/chiseling the rock up to required depth of rock socketing, there are some more very important practical aspects to be observed:

(i) During rock socketing process, heavy chiseling of high torque drilling may produce vibrations. These vibrations may cause destabilization of soft rock/soil strata over laying the rock layer. Thus the pile will lose friction component from these layers. Hence greater care should be taken to reduce the vibrations.

(ii) Rock socketing takes more time and also imparts disturbance to the layers over laying the rock strata. This disturbance will cause spalling of fine particles which will settle at the bottom. To remove these fine particles and other cuttings, the bore hole should be thoroughly washed with fresh bentonite slurry just before pouring concrete.

6. CONCLUSION

Length of socketing of piles into rock should be such that the pile can carry its structural strength as safe load.

To determine optimum length of socket in rock, various methods are described. It is a waste of time, energy and money to go for more length of socketing than required. For rock socketing in weathered/soft rock, both end bearing and frictional component from side friction in socketed length should be taken into account.

For rock socketing to be most effective, the precautions mentioned in paragraph V are to be considered carefully. Heavy chiseling of rock should be avoided to maintain the in situ quality of rock.

REFERENCES


