



PARAMETRIC STUDY OF R. C. C. CIRCULAR PILE WITH VARIABLE SOIL CONDITIONS AND LOADING PARAMETERS

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ABSTRACT

Firm and strong foundation was always required for the construction of any type of structure. The foundation based on weak soil strength, leads to collapse. If the adequate bearing capacity of soil at expected depth was not available, under such circumstances, instead of open foundation, pile foundation would be selected. Piles were normally classified as end bearing pile, skin friction pile and under reamed pile. To design the piles, minimum parameters required were: diameter of pile, length of pile, load on pile, bearing capacity of soil, frictional resistance of soil. Paper dealt with the design of piles for four different cases. In first case, keeping the length constant with three different bearing capacity of soil, relations between load and diameter were predicted. In this case, end bearing pile condition was considered. In second case, keeping the load constant, varying frictional resistance of soil was the variable, relation between length and diameter of pile was established. All the results thus obtained were shown in a tabular form. In third case keeping the pile diameter as constant parameter relation between loads and length of piles were obtained. In fourth case, for seven different lengths of pile, for the given loads, required diameter of piles were found out. The results thus obtained will not only be useful for field engineers, practicing architects, contractors, academicians, research scholars and budding engineers, but it will also act as a guideline to common person.

Keywords: Angle of Repose, Foundation, Soil Friction, Specific Gravity, Soil Strength, Ultimate Load

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1. INTRODUCTION

It is a well-known fact that the load of structure would transfer to soil through foundation. Design of foundation was decided on various parameters. These parameters include bearing capacity of soil, depth of foundation, size of footing, and percentage of steel. If adequate bearing capacity of soil was not available at expected depth, then instead of open foundation, engineer had no option to switch over to pile foundation. Piles were classified on the basis of, material, size, shape, length, diameter, reinforcements, type of soil, water table etc. Physical conditions at site would decide the pile design system. If the bearing capacity of soil was available to adequate depth, skin friction pile would be the best choice. See **Fig. 1**

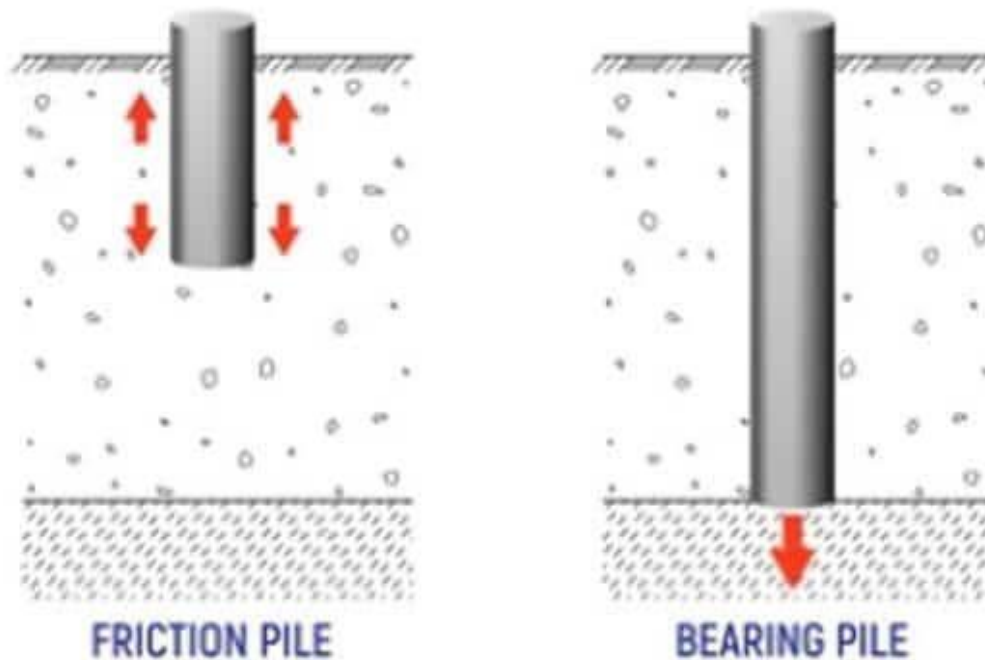


Fig 1: Types of Piles

Paper dealt with four types of cases for the analysis and design of R C C circular piles. In case I, it was considered that the adequate bearing capacity of soil was available at reasonable depth. On this assumption, analysis / design of R C C circular pile was carried out for ultimate bearing capacity of soil as 200 KN/mm^2 , 225 KN/mm^2 and 250 KN/mm^2 . In all the three cases, the length of pile was kept constant equal to 8.m Different diameter of end bearing pile was calculated for axial load taken as 100 KN to 1000 KN at an equal interval of 100 KN (Total 10 loads). In this case, keeping the length constant with variables were loads and diameters. The relations between load and diameter of piles were established. The results thus obtained were shown in tabular form. See table No. 1, 2 and 3.

In second case, cohesive soil factor was considered and thereby skin friction effect was taken in to account. Considering all the five cases for different density of soil as 16 KN/M^3 , 17 KN/M^3 , 18 KN/M^3 , 19 KN/M^3 and 20 KN/M^3 . In this section, magnitude of an axial load of 100 KN was kept constant. Variable parameters were length and diameter of pile. The diameter of pile was calculated for each length of 8 M, 10 M, 12 M, 14 M, 16 M, 18 M, and 20 M. For each density, and for the given length, the diameter of pile was calculated. These relations were shown in tabular form. Refer **table No 4, 5, 6, 7 and 8**. In third case, three relations were established between load and the required length of pile for each diameter of pile as 300 MM, 400 MM, and 500 MM.

To establish these relation, magnitude of axial loads adopted were 100 KN, 200 KN, 300 KN, 400 KN, 500 KN, 600 KN, 700 KN, 800 KN, 900 KN and 1000 KN. The results thus obtained, were shown in **table No 9, 10 and 11**.

In forth case, length of piles was kept constant as 8.0 M, 10 M, 12 M, 14, M, 16 M, 18 M and 20 M. For each length of pile, mentioned above, required diameter of R C C circular pile was calculated. In each case, series of axial loads were applied. Magnitude of these loads were varying from 100 KN to 1000 KN, at an equal interval of 100 KN. The results thus obtained were shown in tabular form from **Table No 12, to 18 (Total Seven)**.

In case II, pile was design as skin friction pile. In skin friction pile design, axial load of 100 KN was kept constant for all five cases Density of soil was considered as 16 KN / M³, 17 KN / M³, 18 KN / M³, 19 KN / M³, and 20 KN / M³. The diameter of s pile was calculated for each density mentioned above. The diameter of pile for the following pile length of 8.0 M, 10.0 M, 12.0 M, 14.0 M, 16.0 M, 18.0 M 19. 0M, and 20.0 M. All these calculations were shown in tabular form. See table No 4,5, 6, 7, and 8, All the results were shown in tabular form.

In case III, the diameter of pile was kept constant, and the loads 100 KN to 1000 KN, total ten loads, the required length of pile was calculated. The length of pile was predicted for three different diameters of pile as 0.3 M, 0.4 M, and 0.5 M. The results thus obtained were shown in tabular form Refer table No **9, 10 and 11**. This case was considered for skin friction pile only.

In case IV, seven different lengths of pile as 8 M, 10 M, 12 M, 14 M, 16 M, 18 M, and 20 M, (Total 7 lengths of pile), for the given loads, required diameter of piles were found out. All the seven results were shown in table No **12 to 18**. The results obtained will not only be useful for field engineers, practicing architects, contractors, academicians, research scholars and budding engineers, but it will also. act as a ready reference for common persons.

2. METHODOLOGY

For analysis and design of R C C pile, considering number of parameters, required to be incorporated. For parametric study, three cases were taken in to considerations. In case I, condition of end bearing pile was considered. In load bearing condition, whole axial load would transfer to soil through pile. In this bearing capacity of pile was taken as 200 KN / M² Calculations were carried out for total ten loads. varying from 100 KN to 1000 KN, at an equal interval of 100 KN. Keeping the pile length of 8.0 M constant for all the 10 loads (mentioned above) diameter of piles were obtained. Similarly, for bearing capacity as 225 KN / M² required diameter of piles was calculated and shown in tabular form. In next step the bearing capacity of soil was raised to 250 KN/M². Keeping all other parameters same and the three results thus obtained were displayed in **table No 1, 2, 3**

In second case, cohesive soil factor was considered and thereby skin friction effect was taken in to account. Considering all the five cases for different density of soil as 16 KN / M³, 17 KN / M³, 18 KN / M³, 19 KN / M³ and 20 KN / M³. In this section, magnitude of an axial load of 100 KN was kept constant. Variable parameters were length and diameter of pile. The diameter of pile was calculated for each length of 8 M, 10 M, 12 M, 14 M, 16 M, 18 M, and 20 M. For each density, and for the given length, the diameter of pile was calculated. These relations were shown in tabular form. Refer **table No 4, 5, 6, 7 and 8**.

In third case, three relations were established between load and the required length of pile for each diameter of pile as 300 MM, 400 MM, and 500 MM. To establish these relation, magnitude of axial loads adopted were 100 KN, 200 KN, 300 KN, 400 KN, 500 KN, 600 KN, 700 KN, 800 KN, 900 KN and 1000 KN. The results thus obtained, were shown in **table No 9, 10 and 11**.

In forth case, length of piles was kept constant as 8.0 M, 10 M, 12 M, 14, M, 16 M, 18 M and 20 M. For each length of pile mentioned above required diameter of R C C circular pile was calculated. In each case, series of axial loads were applied. Magnitude of these loads were varying from 100 KN to 1000 KN, at an equal interval of 100 KN. The results thus obtained were shown in tabular form from **Table No 12, to 18** (Total Seven).

3. OBSERVATIONS

In case I considerations for end bearing piles were opted. In all the three cases, mentioned below, the length of pile was kept 8.0 M constant. With bearing capacity of $200 \text{ KN} / \text{M}^2$ and load vary from 100 KN to 1000 KN (at an equal interval of 100 KN), required diameter of piles were calculated. the results thus obtained were shown in **Table 1**

Table 1: Showing relation between Load vs Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	250	370	470	475	550	600	710	760	800	850

[B C Of soil = $200 \text{ KN} / \text{M}^2$]

In second phase, bearing capacity of soil was taken as $225 \text{ KN} / \text{M}^2$. Other parameters as axial loads on piles were varies from 100 KN to 1000 KN (with an equal interval of 100 KN). With change of bearing capacity of soil, for the given loads, required icted and the was shown in the tabular form. see the results in **Table 2**

Table 2: Showing relation between Load vs Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	250	360	440	500	550	630	670	710	750	800

[B C Of soil = $225 \text{ KN} / \text{M}^2$]

Similarly, the relation between loads and diameter of pile were obtained by changing the bearing capacity of soil as $250 \text{ KN} / \text{M}^2$. Other parameters as length of pile = 8.0 M and load variation from 100 KN to 1000 KN (equal interval of 100 KN), were kept constant. The results thus obtained, were shown in a tabular form. Available results were shown in **Table 3**

Table 3: Showing relation between load Vs Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	240	340	420	475	540	600	630	680	720	760

[B C Of soil = $250 \text{ KN} / \text{M}^2$]

In second case, magnitude of an axial load was kept constant = 100 KN. In this section total five cases were dealt. First of all, the density of soil was adopted was $16 \text{ KN} / \text{M}^3$. The length of pile was taken as 8.0 M, 10.0 M, 12.0 M, 14.0 M, 16.0 M, 18.0 M, and the last value was taken as 20.0 M. (Total number of lengths of piles were 07). For each and every length (mentioned above) diameter of pile required was calculated. Result was displayed in **Table 4**

Table 4: Showing the relation between Length and Diameter

Length in M	08	10	12	14	16	18	20
Diameter in MM	870	690	580	500	450	400	350

[Density = 16 KN / M³]

In next process, density of soil was opted as 17.0 KN / M³. All the seven lengths of pile, mentioned above, were considered again. On the basis of above parameters, diameter of R C C circular pile was calculated. The results thus observed were shown in **Table 5**

Table 5: Showing the relation for Length v/s Diameter

Length in M	8.0	10	12	14	16	18	20	Nil
Diameter in MM	810	660	550	470	410	370	330	Nil

[Density = 17.0 KN / M³]

Proceeding ahead, next relation was again observed for finding the diameter of pile, by changing one parameter as the density of soil. The magnitude of density of soil was now increased to 18.0 KN / M³. Length of all the seven piles, mentioned above, were considered. Using IS Code 29110 (Part 1 and 4), calculation process was carried out to calculate the diameter of piles. The results thus obtained were shown in tabular form in

Table 6: Shows the relation between Length and Diameter

Length in M	8.0	10	12	14	16	18	20
Diameter in MM	610	630	510	440	385	350	300

[Density = 18 KN / M³]

For the constant axial compressive load of 100 KN and specific weight of soil as 19.0 KN / M³, the relation between length of pile and the diameter of pile were established. Length of pile (Total 07 Number) varying from 8.0 m to 20.0 M at an equal interval of 2.0 M were considered. The results were shown in a tabular form for easy view in **Table 7**

Table 7: Shows the relation between Length and Diameter

Length in M	8.0	10	12	14	16	18	20
Diameter in MM	730	590	490	420	370	330	300

[Density = 19 KN / M³]

Keeping the axial load constant =100 KN, and unit weight of soil as 20.0 KN / M³, the diameter of piles was calculated for the pile length from 8.0 M to 20.0 M, at an equal interval of 2.0 M. These results obtained were shown in tabular form. See the following **Table 8**

Table 8: Shows the relation between Length and Diameter

Length in M	8.0	10	12	14	16	18	20
Diameter in MM	690	550	460	400	350	300	280

[Density = 20 KN / M³]

Case three dealt with constant diameter of pile and the variable parameters selected were load on pile and length of pile. In this category in first stage, diameter of pile was considered as 0.3 M. Loads on pile were selected ranging from 100 KN to 1000 KN, with an equal interval of 100 KN (Total 10 loads). Analysis were carried out and for each load, length of pile required were calculated. The results were presented in tabular form. See **Table 9**

Table 9: Shows the relation between Length and Load

Load in KN	100	200	300	400	500	600	700	800	900	1000
Length in M	2.5	5.05	7.6	10	12.5	15	17.5	20	22.5	25

[Diameter of Pile = 300 mm]

In the same category, the diameter of pile was taken as 0.4 M. For each loading as 100 KN, 200 KN, 300 KN, 400 KN, 500 KN, 600 KN, 700 KN, 800 KN, 900 KN, and 1000 KN, length of pile was calculated and the result was displayed in tabular form. See **Table 10**

Table 10: Shows the relation between Length to Load

Load in KN	100	200	300	400	500	600	700	800	900	1000
Length in M	2.5	3.8	5.7	7.56	9.45	11.35	13.25	15.2	17.1	19.0

[Diameter of Pile = 400 mm]

Finally, the diameter of pile was raised to 0.5 M. For the same loading, varying from 100 KN to 1000 KN (Total 10 loads), diameter of pile was calculated and result shown in **Table 11**

Table 11: Shows the relation between Length to Length

Load in KN	100	200	300	400	500	600	700	800	900	1000
Length in M	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0

[Diameter of Pile = 500 mm]

In forth case, total seven problems were considered for the analysis and design of R C C circular pile. In first problem, length of pile was kept constant as 8.0 M. For the magnitude of ten loads, ranging from 100 KN to 1000 KN, at an equal interval of 100 KN, diameter of pile was calculated. The results thus obtained was shown in **Table 12**

Table 12: Shows the relation between Load vs Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	100	200	300	400	500	600	700	800	900	1000

[Length of pile = 8.0 M]

Considering the second length of pile as 10.0 M, with the same loadings, from 100 KN to 1000 KN, the diameter of R C C circular pile was calculated results were shown in the **Table 13**

Table 13: Shows the relation between Load v/s Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	100	150	225	300	400	450	550	600	700	750

[Length of Pile = 10.0 M]

In the next step, the length of pile now increased by 2.0 M Hence for 12.0 M, constant length of pile, for all the 10 loads. mentioned in table No 13, the diameter of pile was calculated in MM. For 12.0 M length of pile, the required diameter obtained were given in **Table 14**.

Table 14: Shows the relation between Load v/s Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	100	150	200	270	325	400	450	500	550	630

[Length of Pile = 12.0 M]

Length of R C C circular pile was taken as 14.0 M. For the constant pile length, it was decided to find out the required diameter of for 10 different loads. Selected 10 loads varies from 100 KN to 1000 KN at an equal interval of 100 KN. the result was shown in **Table 15**

Table 15: Shows the relation between Load v/s Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	100	100	125	220	270	325	380	440	500	550

[Length of Pile = 14.0 M]

Length of R C C circular pile was taken as 16.0 M For the constant pile length, it was decided to find out the required diameter of for 10 different loads. Selected 10 loads varies from 100 KN to 1000 KN at an equal interval of 100 KN. the result was shown in **Table 16**

Table 16: Shows the relation between Load v/s Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	100	125	150	200	250	700	350	400	450	500

[Length of Pile = 16.0 M]

Length of R C C circular pile was taken as 18.0 M. For the constant pile length, it was decided to find out the required diameter for 10 different loads. They were taken as 100 KN, 200 KN, 300 KN, 400 KN, 500 KN, 600 KN, 700 KN, 800 KN, 900 KN, and 1000 KN. For all the ten loads diameters of circular pile was predicted and result was given in Table 17

Table N17: Shows the relation between Load v/s Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	100	100	150	150	225	250	300	350	400	450

[Length of Pile = 18.0 M]

Length of R C C circular pile was taken as 20.0 M. For the constant pile length, it was decided to find out the required diameter for 10 different loads. They were taken as 100 KN, 200 KN, 300 KN, 400 KN, 500 KN, 600 KN, 700 KN, 800 KN, 900 KN, and 1000 KN. For all the ten loads diameters of circular pile was predicted and result was given in **Table 18**

Table 18: Shows the relation between Load v/s Diameter

Load in KN	100	200	300	400	500	600	700	800	900	1000
Diameter in MM	100	100	125	150	200	250	270	300	350	400

[Length of Pile = 20.0 M]

4. CONCLUSION

To establish the relation between axial load on pile, specific weight of soil, length of pile and diameter of pile, number of cases were carried out. Out come to efforts carried out in four different cases. The results, case wise, were shown as under.

First case:

- End bearing pile: Length of pile was kept constant = 8.0 M. B. C. of soil was considered as $200 \text{ KN} / \text{M}^2$, load variation: 100 KN to 1000 KN. From 400 KN to 1000 KN, the diameter of pile decreases by 50 mm at every 100 KN increase of load
- B C of soil = $225 \text{ KN} / \text{M}^2$. The diameter of increases to 50 mm for every 100 KN interval, ranging from 100 KN to 700 KN.
- From 700 KN to 1000 KN, the diameter was found to be increasing @ 60 mm, at an equal interval of 100 KN.

- B C of soil = $250 \text{ KN} / \text{M}^2$: From 100 KN to 800 KN,, the increase of diameter of pile was observed to be 50 mm, up to 800 KN and beyond this value up to 1000 KN, the increase of diameter was 30 mm for every 100 KN load.
- Every $25 \text{ KN} / \text{M}^2$, increase of bearing capacity of soil, the diameter of R C C circular pile decreases by 50 mm

Second case:

- Skin friction pile : Length of pile : 8.0 M to 20.0 M and density of soil as $16 \text{ KN} / \text{M}^3$: Diameter of pile decrease by 100 mm up to 14.0 M. From 14.0 M up to 20.0 M, decrease of pile diameter was observed as 50.0mm
- For all five unit weight of soil from $16.0 \text{ KN} / \text{M}^3$ to $20 \text{ KN} / \text{M}^3$, the diameter of pile decreases by 40 mm at every 2.0 M equal interval.
- Unit weight of soil increases, the diameter of pile reduces.
- As the length of pile increases, diameter of pile decreases

Third case:

- Diameter of pile constant, Variables : Load and length. The length of pile decreases by 30 % with increase of diameter by 100 mm
- Minimum length of piles for every should not be less than 2.5 M
- The length of pile reduces by 0.6 M for every 0.1 M increase of diameter of pile.

Forth case:

- Variable : Load and diameter. Constant : Length. For a fixed diameter of pile = 0.3 M and for every 100 KN increase of load,, length of pile increases by 2.5 M
- Diameter as 0.4 M. For every increase of load by 100 KN, length of increases by 1.9 M
- Diameter of pile =0.5 M, Increase in length =1.5 M for every 100 KN increase. Of load

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