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Assessment of Safe Load Carrying Capacity of End Bearing Piles at erection- A layman's approach

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Abstract:

Piles are elements of deep foundation and carry loads of the problematic strata and structure to the beneath stable surface in a distributed way. The frictional part of the pile and skin effect carries the contact of the pile to the surrounding surface making it a good choice of geotechnical engineers. In the present work a simplified method of assessing the safe load-carrying capacity of flyover piles as well as valuable information about the variables that are interdependent on each other is carried over. The primary focus is on determining the safe load carrying capacity of a pile in the intermediate geo-materials and rock mentioned in sub-cluse 9.1, IRC: 78-2014 includes multiple ways to evaluate the safe load carrying capacity of piles in various types of strata. It is discovered that the formula therein has several variables and restrictions during the safe bearing capacity assessment of a pile in a flyover project. With the help of these restrictions, the formula can be constrained into a more straightforward approach that only requires a few variables to evaluate the safe load-carrying capacity of an end-bearing pile. It is also found that by doing the reverse calculation, the value of (CR+RQD) (rock core + rock quality designation) can be verified at the site. Efforts are also done to find alternate methods for deciding the pile termination point at the site by combining the various aspects between the Unconfined Compressive Strength of rock, rock core recovery (CR), RQD (rock quality designation), shear strength of rock, and Pile Penetration Ratio (PPR).

The design ideology of flyovers, initial load tests on piles, the characteristics of piling rig equipment, and other terms needed to evaluate the safe load carrying capacity of piles are briefly inferred and covered.

Keywords — **Pile, End Bearing, Rock, CR, RQD, UCS, Carrying Capacity, Load Test, PPR, Piling Rig Machine**

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I. INTRODUCTION

Estimating the safe load carrying capacity of piles is a complex task that typically involves conducting detailed geotechnical investigations on the ground, performing laboratory tests, analyzing the results in accordance with the guidelines provided by relevant codes, such as the IRC and BIS, etc., and verifying the analysis on the ground through axial, lateral, and uplift load tests.

To verify and simplify the equations used in calculation of the safe load carrying capacity of end bearing piles (of 1 meter-diameter), with a focus on alternative methods for calculating rock's UCS and establishing the relationship between CR+RQD, UCS of rock and PPR. The ultimate goal is to assist site engineers in quickly and efficiently estimating the safe load-carrying capacity of end-bearing piles with the limited information available at the site.

The methods used in this study are those covered by subclauses 9.1 and 10 of Appendix 5 of IRC: 78-2014, which deal with the capacity of piles in intermediate geo-materials and rock (method 1) and pile termination criteria as a quality control tool in rocks, respectively. Estimating the safe load-carrying capacity of end-bearing piles in flyover projects is made simpler by the reduction of the current approach provided in IRC: 78-2014 to a simplified equation with fewer variables. Additionally, methods for determining the UCS of rock from the PPR data of a particular piling rig machine have been explored. Verifying the safe load-carrying capacity of a pile and finding the interdependency of various variables during assessing the safe load-carrying capacity of a pile.

Geotechnical Investigations:

Conducting a geotechnical study to examine the soil and rock qualities at the site is the first stage of this procedure. Collecting soil and rock samples, doing laboratory experiments to identify engineering qualities, and conducting in-situ tests to analyse the soil's behaviour under load are all part of this inquiry. These tests yield useful information for later computations and analyses.

In a descriptive way, A geotechnical investigation seeks to ascertain the strength, compressibility, permeability, and groundwater conditions of the soil and rock at a given location as well as other physical and engineering characteristics. Engineers can use this information to determine whether the site is suitable for a particular project, such as the construction of a road, underground infrastructure, earthworks, or building foundations. A geotechnical investigation typically involves several steps:

1. Desk study: This entails looking over the site's geological, topographic, and geotechnical information that is currently available, including maps, reports, and earlier studies.
2. Field research: This entails utilising drilling or excavation methods to obtain soil and rock samples from various depths. The samples are then put through a series of tests in a lab to ascertain its structural and engineering features, including grain size distribution, moisture content, density, shear strength, and consolidation traits.
3. Geophysical survey: This is the process of studying the subsurface and identifying potential risks of differences in soil or rock qualities using non-invasive techniques including seismic, electrical, or ground-penetrating radar surveys.
4. Interpretation and analysis: To ascertain the geotechnical characteristics of the site, the gathered data and test results are examined. This entails assessing the state of the soil and rocks, the water table, and any possible dangers or concerns.
5. Reporting: A geotechnical report is created that provides design guidelines for engineers and architects to employ in their project designs, describes the investigation's results, and makes geotechnical suggestions.

For structures and infrastructure to be safe and stable, geotechnical investigations are necessary. Engineers can reduce hazards and guarantee the project's long-term performance by designing the necessary foundations, slope stability measures, and drainage systems by knowing the geotechnical characteristics of a site.

In general, geotechnical analyses are crucial to the conception, design, and execution of civil engineering projects. Engineers can use this information to make educated judgements and put the right technical measures in place to maintain the security, stability, and long-term performance of buildings and infrastructure. They also provide essential information about the soil, rock, and groundwater conditions. A technique called geotechnical investigation is performed to learn more about the physical features and traits of soil, rock, and groundwater at a place. It is carried out by geologists or geotechnical engineers and is essential for guaranteeing the stability and safety of any construction project.

A geotechnical investigation's primary goals are:

1. Site characterization: This includes locating and mapping different soil and rock layers on the property. The study identifies the type, makeup, and characteristics of the soil as well as any groundwater, rock cracks, or other geological phenomena that may be present.
2. Geotechnical parameter determination: samples of soil and rock are tested as part of the study to ascertain their physical and mechanical characteristics. These features include the kind of soil, the distribution of grain sizes, the shear strength, compressibility, permeability, and consolidation traits. Engineers can evaluate the stability, bearing capacity, and deformation potential of the soil using these factors.
3. Risks identification: Geotechnical investigations evaluate any possible geotechnical risks that might have an impact on the site, such as slope stability, liquefaction potential, or seismic

activity. The assessment assesses the potential risks associated with the planned flyover and suggests suitable mitigation strategies to ensure public safety.

4. Recommendations for foundation design: The geotechnical engineer offers recommendations for the foundation design, including the type of foundation, depth, and reinforcement needs, based on the data gathered. These suggestions guarantee that the foundation can support the weight of the structure and continue to be stable even under unfavourable soil conditions.
5. Recommendations during construction: Geotechnical investigation can also make recommendations for specific construction procedures, such as excavation, dewatering, or ground enhancement approaches. In order to ensure cost effectiveness and reduced risks, these recommendations optimise construction practises based on the geotechnical conditions of the site.

Overall, a geotechnical investigation is an important stage in the building process. It offers crucial knowledge that engineers, architects, and builders need to make wise choices and create long-lasting, secure structures. Construction projects run the danger of failing or suffering expensive damage without a comprehensive geotechnical examination.

In the case of the pile foundations, the results of the laboratory test must be examined in accordance with IS and IRC regulations after the geotechnical study is finished. To guarantee the accuracy and dependability of the estimated safe load carrying capacity, these suggestions specify a number of restrictions and processes that must be taken into account during the study.

The findings of on-ground tests, such as initial and routine load tests and the PPR values obtained during the test pile bore activity, must be verified and maintained in addition to thorough geotechnical investigations and intensive laboratory testing.

Background Motivation:

A critical part of pile foundation design is the determination of a safe load-carrying capacity. End-bearing piles, which transfer the imposed loads via the pile tip into the underlying rock or stronger soil layer, play an important role in ensuring the structural stability and integrity of flyover constructions. Traditionally, evaluating the safe load-carrying capacity of end-bearing piles entails a number of processes that take a significant amount of time, effort, and resources.

Rock Core Recovery (RCR): The recovery of undamaged rock samples for analysis and study from the subsurface is referred to as rock sample recovery, or rock core recovery. Depending on the depth and geological characteristics of the location, many approaches can be used to accomplish this.

One popular technique is drilling. Boreholes can be made by drilling rigs, providing access to subterranean rock formations. Different drilling methods, such as rotary drilling, core drilling, or percussion drilling, may be utilised, depending on the goal of the investigation.

Rock quality designation (RQD) is a metric used in civil engineering to characterise the quality of rock material. It is a measurement of a rock mass's general intactness or fracture.

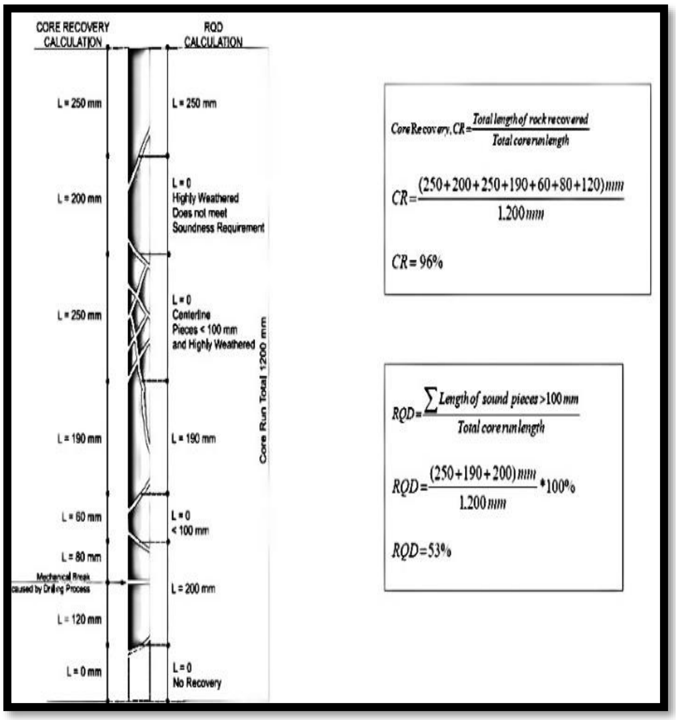


Fig. 1: Formulation of CR and RQD

RQD is calculated by analysing drill core samples taken from boreholes. To determine the RQD value, the percentage of intact or sound rock bits over a given length of the sample is determined. A greater value denotes a higher rock quality, and the RQD value ranges from 0 to 100. A rock mass that has an RQD value below 25 is typically severely fractured or extremely weathered. On the other hand, a rock mass with a high quality has an RQD value more than 75. Several civil engineering applications, such as the analysis of rock slope stability, foundation design, tunnelling, and underground mining, utilise RQD. Engineers can use this information to make educated judgements about construction techniques, support systems, and safety precautions by using it to learn more about the strength, stability, and behaviour of the rock mass.

Table 1 – classification of rock of IRC 78:2014, when, UCS of rock is;

>200 MPa	Extremely Strong Rock
100 to 200 MPa	- Very Strong Rock
50 to 100 MPa	- Strong Rock
12.5 to 50 MPa	- Moderately Strong Rock
5 to 12.5 MPa	- Moderately Weak Rock
1.25 to 5 MPa	- Weak Rock
<1.25 MPa	- Very Weak Rock

A quantitative measure called **Rock Mass Rating (RMR)** is used to rate the stability and appropriateness of rock masses for various engineering uses, particularly in underground construction. Z. T. Bieniawski created it in 1976, and afterwards it underwent modifications to add elements like groundwater conditions and discontinuity orientation.

UCS of rock: The ability of a rock to bear compressive stress without the aid of external support or confinement is known as its unconfined compressive strength (UCS). It is a crucial rock engineering characteristic that is frequently applied in geotechnical and civil engineering.

Ultimate load carrying capacity of a end bearing pile: In general, the ultimate carrying capacity of an end-bearing pile is determined by the load-carrying capacity of the pile shaft and the load-carrying capacity of the pile base or tip. The frictional resistance between the pile and the surrounding soil is the main factor that affects the pile shaft's ability to support loads. The diameter, length, type of soil, and characteristics of the soil all have an impact on this frictional resistance. The bearing capacity of the soil at the pile tip determines the load-carrying capacity of the pile base or tip

To ensure that the desired rock layer is reached, the **pile penetration ratio (PPR)** is used throughout the construction process. The energy needs of the rotary piling rig for a particular PPR dictate the precise pile termination point.

Mathematically, PPR stands for the energy in ton-meters required to move a pile bore with 1 m^2 cross-sectional area by 1 cm, as defined by IRC: 78-2014.

Prior to the construction of a flyover, a pile is subjected to an initial load test to ascertain its load-bearing capacity and evaluate its structural integrity. It entails putting a predefined load on the pile typically in increments—and watching to see how it reacts. Generally, three types of tests are performed to assess the safe bearing capacity of a pile: axial, lateral, and pullout tests. There are two on-ground testing methods that are currently in use to assess the load-carrying capacity of piles:

Maintained load method

A common approach for conducting pile load testing is the maintained load method. An instruction manual for performing a pile load test using the maintained load method is provided below:

1. Select a suitable test pile: Choose a test pile that is typical of the piles that will be utilised in the project. The pile should be built using methods and proportions similar to those used for production piles.
2. Make the pile ready: Clear the pile surface of any soil or loose debris. Make sure the pile head is straight and unobstructed.

3. Install instrumentation and load cells: To measure the applied load, install load cells on the pile head. To measure the pile's deflection during the test, insert displacement transducers at various points along the pile.
4. Applying the initial load: This will help to ensure that the pile is sturdy and firmly in place. Usually, 10% to 20% of the estimated ultimate load makes up this load.
5. Application of the load: Start by applying the load gradually in phases. To allow for the dissipation of any extra pore water pressure and pile settlement, each load increment should be sustained for a particular amount of time, often between 15 and 30 minutes.
6. Load Monitoring: Utilising the load cells, continuously monitor the load being applied to the pile. At each load step, note the applied load and the related pile deflection. Depending on the anticipated pace of load settlement, take readings at regular intervals.
7. Load increment and time: Until the desired test load is reached, gradually increase the load. Generally speaking, it is advised to use at least two and a half times the anticipated operating load, or the pile's maximum load capacity.
8. Maintain the load: Maintaining load for a predetermined amount of time, usually 24 to 48 hours after the required test load has been obtained. This enables estimate of any potential pile settlement or deformation as well as assessment of pile behaviour under sustained load circumstances.
9. Monitoring during the Maintenance Phase: During the Maintenance Phase, keep a close check on the weight on the pile and its deflection. This makes it easier to find any load or deflection changes that might occur over time.
10. Unloading: After the maintenance phase, unload the pile gently by progressively lowering the burden. Observe the behaviour of the pile during the unloading process by taking readings of the load and pile deflection at each stage.

11. Interpretation: To ascertain the pile's behaviour and load-bearing capacity, analyse the data gathered, particularly the load-settlement curve. Compare the actual and expected pile deflections in light of the anticipated pile behaviour. The effectiveness of the pile and its suitability for the proposed project will be assessed with the aid of this study.

12.Reporting and record-keeping: Create a thorough report outlining the test's methodology, findings, and outcomes. To support the results and conclusions of the pile load test, include graphs, figures, and computations. It's vital to remember that this is just a general review of the pile load testing-maintained load method. Depending on elements like the project requirements, the soil conditions, and the availability of equipment, specific techniques and specifics may change. To ensure a complete and accurate test is completed, it is advised to speak with a geotechnical engineer or pile load test specialist.

Cyclic load method

A type of test known as the cyclic load method is used to ascertain a pile's maximum bearing capacity as well as its load-displacement behaviour under cyclic loading conditions.

In this test, the pile is subjected to a load that is applied progressively over time, alternating between increasing and decreasing loads. Typically, a hydraulic jack or other comparable equipment is used to apply the load.

The pile load test using the cyclic load method is used to mimic how a pile would behave in real-world situations where the load may change over time as a result of variables like wind, waves, or structural movements.

At regular intervals throughout the test, the load and the accompanying pile displacement are measured. The outcomes are used to calculate the pile's load-settlement curve, which offers details on the pile's load-bearing capacity and behaviour under cyclic loading conditions.

Usually, the test is run up to the pile's maximum permissible displacement or until failure occurs. Failure is characterised as a severe reduction in load-bearing capacity or an excessive amount of pile settlement.

In the design and construction of foundations for structures like bridges, buildings, and offshore platforms, the pile load test by cyclic load method is frequently employed. It offers useful data for confirming the design presumptions and evaluating the performance and safety of the pile over the course of its service life. The following steps are commonly included in the test procedure for a pile load test using the cyclic load method:

1. Preparation: The pile is first prepared by being cleaned and checked for obstacles or debris on the top surface. Before the test, the pile is free of any loads or stresses that may have been present.
2. Instrumentation: For the purpose of measuring the applied load and the consequent displacement during the test, load cells and displacement sensors are mounted on the pile. These devices go through calibration and accuracy checks.
3. Pre-loading: The pile receives a pre-load before the cyclic loading process begins. To prevent any initial settlement or to compact the earth surrounding the pile, the pre-load, which is normally a small portion of the anticipated design load, is applied.
4. Cyclical loading: The cyclic loading begins at a modest initial load and steadily increases in steps to the desired maximum load. The application of each load step lasts for a certain number of cycles.
5. Data collection: The applied load and the related pile displacement are noted at regular intervals during each load step. The load-displacement curve of the pile is plotted using this data.
6. Post-loading: The pile is normally unloaded to a reference load level after achieving its maximum load before being completely discharged. This is done to evaluate the pile's recovery from the cyclic loads and any residual settlement.
7. Data analysis: To ascertain the behaviour of the pile under cyclic loading conditions, the gathered data is analysed. To evaluate the pile's load-bearing capacity, stiffness, and settlement characteristics, the load-settlement curve is plotted.
8. Analysis: The test data are analysed to determine the pile's effectiveness and safety. To ascertain whether the pile satisfies the design specifications, factors such ultimate bearing capacity, maximum displacement, residual settlement, and structural integrity are taken into account.\
9. Reporting: A thorough report summarising the test technique, outcomes, and interpretations is generated. The study also offers suggestions for any required alterations or enhancements to the pile's construction or design.

An essential test for assessing the performance and behaviour of a pile under cyclic loading conditions is a pile load test using the cyclic load method. This knowledge is essential for guaranteeing the stability and safety of structures supported by piles, particularly in regions vulnerable to dynamic stress from events like earthquakes or strong winds.

IRC: 78-2014 outlines a method for figuring out how much load end-bearing piles can safely support. Several interdependent variables and coefficients in the equation defined by the code must be carefully considered during the estimation process.

The ultimate capacity of a pile socketed into rock, denoted as Q_u, is calculated using the formula below:

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$ …eq (1)

The permissible/ allowable capacity of pile, represented by Q_{allow}, may be determined using the following equation:

Q_{allow}=(Re/3) + (Raf/6) …eq (2)

To calculate the value of K_{sp}, an empirical coefficient, the equation provides precise values based on CR and RQD. K_{sp} equals 0.3 when $\frac{CR+RQD}{2}$ is 30% and 1.2 when $\frac{CR+RQD}{2}$ is 100%. For middle values, K_{sp} can be linearly interpolated. The average UCS of the rock core beneath the pile base "q_c" is calculated by laboratory testing. It is measured in megapascals (MPa) and represents the compressive strength of the rock material.

The formula for calculating the depth factor, d_f, is: **d_f = 1 + (0.4 x (Socket Length/Socket Diameter)).** Calculating the pile depth factor takes the socket's length and diameter into account.

The area of the pile in contact with the underlying rock, or the area of rock under the pile, is represented by the cross-sectional area of the pile base, A_b.

C_{us}, ultimate shear strength of the rock along socket length, is calculated using the formula:

C_{us} = 0.225 x $\sqrt{qc}$. The ultimate shear strength, however, is limited to the shear capacity of the concrete in the pile. The shear capacity of M35 concrete under constrained conditions is assumed to be 3.0 MPa. For various concrete strengths, this number can be adjusted by a factor of $\sqrt{fck/35}$.

R_e computes the vertical capacity of the pile embedded or socketed in the rock, and R_{af} computes the frictional capacity of the pile socket.

Divide R_e and R_{af} by the code-required safety factors of 3 and 6, respectively, to determine the pile's permitted capacity, or safe capacity.

Use of this formula is subject to the restrictions and guidelines set forth in IRC: 78-2014. These restrictions ensure that the estimation process is accurate and reliable while taking into account the unique characteristics and circumstances of the pile as well as the underlying rock layer.

The Pile Penetration Ratio (PPR) is an important factor in determining pile termination depth. PPR is a measurement used during the piling process to determine the extent of pile penetration into the underlying strata. It aids in the finalization of the pile's termination depth, ensuring that it achieves an acceptable level of penetration to accomplish the specified load-carrying capacity. When piles are built using the Dynamic Compaction Method (DMC) and Piling Rig Machines, IRC: 78-2014 gives a method for calculating PPR. However, given the popularity and widespread usage of piling rig machines in current building practices, the following formula is used to calculate PPR (for piling rig machines):

The formula to calculate PPR is expressed as:

PPR = (2 x π x n x T x t) / (A xP) … eq (3)

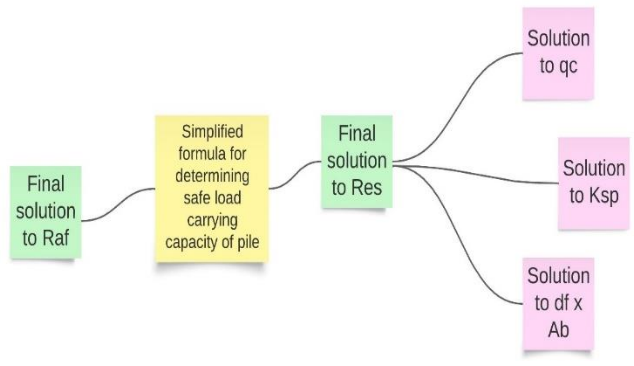


Fig. 2 path followed for optimal solution

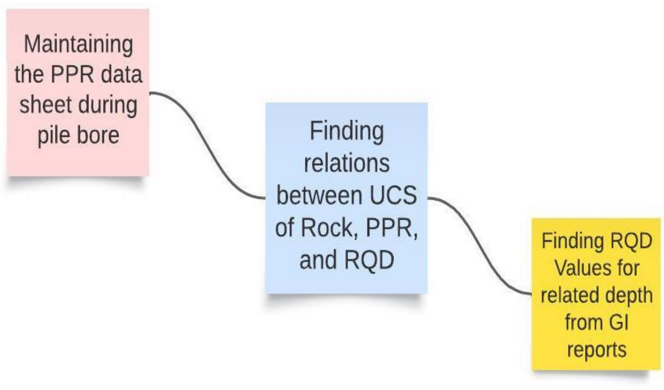


Fig. 3 experimental flow of work

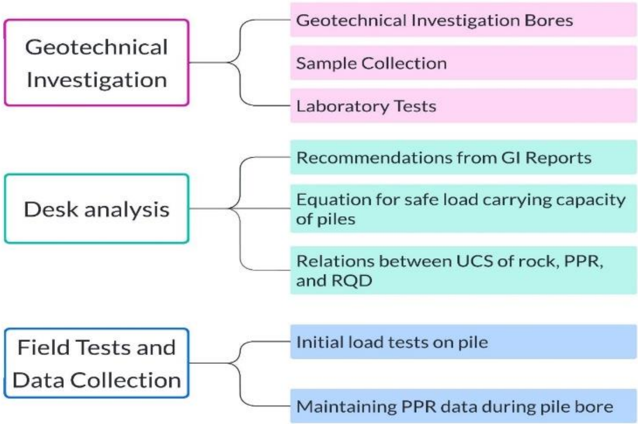


Fig 4 : lab investigation cycle

fig. 5 final arrangement of test crown and datum bar with LVDT

fig. 6 initiation of axial load test on test pile near RP3 pier

fig. 7 cage insertion in test pile and 6 mm thick MS liner

fig. 8 pile concreting

Fig. 9 alternate arrangement of initial load test on pile context of the equations, as well as the final solution to Res, and Raf

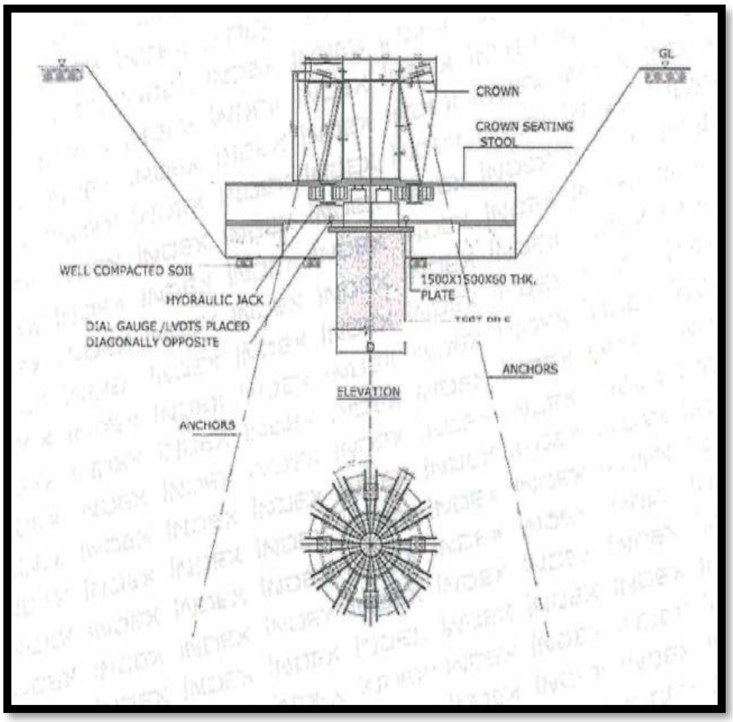


Fig.10 crown arrangement over test pile

II. LABORATORY INVESTIGATION

TABLE 2 SAFE LOAD CARRYING CAPACITY AND OTHER PROPERTIES

Sno	Bore Hole No (Pier No)	Depth of pile tip level from GL	UCS of rock/ f_{ck} of concrete in t/sqm	CR	RQD	Safe Vertical Capacity in tonne
A	B	C	D	E	F	G
1	BH01A(RP2 Rebore)	12.0	2171/3500	80%	51.33 %	558.43
2	BH02 (RA1)	12.0	4652/3500	56%	20%	493.39
3	BH03 (LA1)	13.5	4228/3500	46%	37.33 %	546.48
4	BH04 (LP1)	12.0	4480/3500	58%	27%	557.54
5	BH05 (LP4)	13.5	14405/3500	72%	66%	933.58
6	BH06 (RP4)	12.0	8730/3500	46%	40.67 %	568.60
7	BH07 (RP7)	12.0	5830/3500	45.33 %	44%	590.72
8	BH08 (RP1)	13.5	5967/3500	64.67 %	34%	657.08
9	BH09 (RP6)	11.0	10329/3500	59.33 %	50.67 %	734.50

10	BH10 (RP3)	11.0	6988/3500	65.33%	60%	834.04
11	BH11 (RP8)	11.0	3430/3500	74.67%	66.33%	937.09
12	BH12 (LP2)	11.0	3030/3500	66.67%	61.67%	753.95
13	BH13 (RP9)	11.0	4189/3500	65.33%	60.33%	845.10
14	BH14 (LP3)	11.0	4592/3500	41.33%	38%	517.72
15	BH15 (LP6)	11.0	3844/3500	61.33%	50.13%	745.56
16	BH16 (RP10)	11.0	4255/3500	60%	52.67%	756.62
17	BH17 (LP7)	11.0	4021/3500	65.67%	59.33%	841.78
18	BH18 (RA2)	12.0	2943/3500	65.33%	47%	636.22
19	BH19 (LP8)	11.0	3229/3500	62%	49%	689.71
20	BH20 (LP9)	13.5	6200/3500	64.67%	50.67%	900.40
21	BH21 (LP13)	11.0	2915/3500	58.66%	50%	608.27
22	BH22 (LA2)	11.0	3915/3500	57.33%	33.33%	601.78
A	B	C	D	E	F	G
23	BH23 (LP14)	11.0	3314/3500	54.67%	50.33%	665.51
24	BH24 (LP11)	11.0	5738/3500	65.33%	58%	830.72
25	BH25 (RP5)	12.0	4260/3500	53.33%	28.67%	535.42
26	BH26 (LP5)	12.0	2873/3500	72%	54.8%	706.94
27	BH27 (LP10)	12.0	4248/3500	60%	46%	712.38
28	BH28 (LP12)	11.0	3888/3500	64.67%	49%	762.15

III. RESULTS

The first objective, simplification of the formula given in IRC 78: 2014, Appendix 5, subclause 9.1, is achieved as specified below:

Solution to Ksp: Adding (CR+RQD) into the calculation right away and treating it as a variable that just relies on the information provided in the geotechnical investigation report and doesn't call for any interpolation is the solution to Ksp. As a result, the equation becomes more streamlined and efficient in computing the end-bearing pile's safe load-carrying capacity. However, several constants need to be entertained to consider interpolation for ((CR+RQD)/2). The number (CR+RQD) shows the combined percentage of core recovery (CR) and rock quality designation (RQD), both of which are indications of the strength and integrity of the rock. Now, the equation becomes simpler, and the value may be easily replaced into the formula without further computations. This method simplifies determining the pile's safe load bearing capacity.

Solution to df.Ab including F.O.S OF 3

The solution offered is designed particularly for a 1-meter-diameter pile with a 1-meter-long socket. It takes into account the depth factor (df) and the cross-sectional area of the pile's base (Ab). The depth factor takes into account the length and diameter of the socket, providing an adjustment factor for the computation.

Additional formulae are required to derive the constant values for df.Ab for other pile diameters and socketing lengths. These constants will allow for precise estimations of the safe load bearing capacity of various pile layouts.

It is necessary to highlight that this approach has a factor of safety (FOS) of 3. The safety factor is an important aspect in geotechnical engineering because it ensures that the pile's predicted safe load bearing capacity is much more than the projected applied loads. By including a safety factor, the design becomes more trustworthy and robust, taking into account uncertainties and anticipated variances in actual field circumstances.

Final Solution to Res including F.O.S of 3

The final solution to Res entails combining the equations relating to Ksp, df. Ab, and other pertinent quantities. By combining these equations, a comprehensive formula for calculating the end bearing pile's safe load carrying capacity is developed.

The solution considers several variables, including (CR+RQD), qc and constants like df and Ab. The value of (CR+RQD) may be calculated on-site using core recovery and rock quality designation analyses. The value of qc, which indicates the average unconfined compressive strength of the rock core beneath the pile's base, can be taken from relating values of PPR and confirmed from Table 3 of IS: 11315 (Part 5) or measured in a laboratory.

The safe load carrying capacity of the end bearing pile (Res) may be calculated by integrating these variables and using the established formula. It is critical to consider the factor of safety of 3 to guarantee that the predicted capacity is much more than the applied loads, hence maintaining the pile foundation's structural integrity and stability.

Final solution to Raf including F.O.S of 6

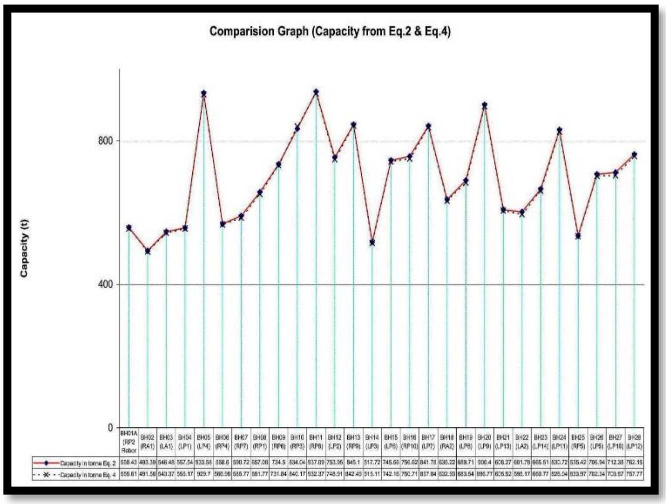
The top 0.3 m length is neglected during the calculation of the surface area of socketing (the base area should not be calculated); now the value of qc should be the value of either the characteristic strength of concrete or the UCS of rock, whichever is less. However, as per IRC 78:2014, the value of Cus taken as 3 MPa or 300 t/sqm, but in the project, the friction resistance of the socket is taken the least due to safety reasons.

The safe load-carrying capacity of end-bearing piles can be calculated using one of these approaches, which takes into account a number of factors, including the characteristics of the rock, the design of the pile, and the factor of safety. The calculations and solutions proposed make an effort to accelerate the design procedure and boost the dependability of the pile foundation

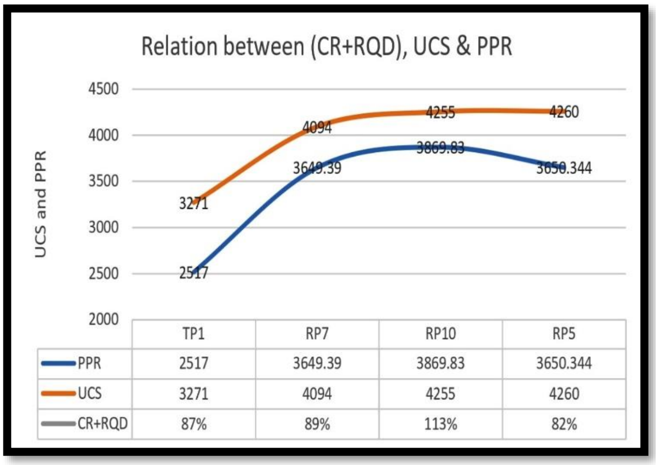
Final solution is

Qallow = [{0.3 + (0.643 x ((CR+RQD) – 0.6))} x 0.314 x q_c] + [0.825 x $\sqrt{q_C}$] …eq (4)

1. Diameter of pile is 1 m
2. RQD should not be nil
3. CR+RQD ≥ 60% (it should always be in percentage)
4. The value of q_c given in the above formula should always be the smaller value of the characteristic strength of concrete or the UCS of rock.
5. The formula is with factor of safety as per IRC 78:2014



Graph 1 : difference in capacity, calculated from Eq. 1 and Eq. 4



Graph 2 UCS and PPR vs (CR+RQD)

The final equation

q_c=(0.76x(PPR)) +1366.99 …eq (5)

IV CONCLUSIONS

The evaluation of safe load carrying capacity for end bearing piles using the presented formula is a preliminary approach that site engineers can employ. However, it is crucial to remember that there may be some difference in the evaluation compared to the pile's actual safe load carrying capacity of end bearing pile.

The paper's formula provides a simpler technique to evaluating the safe load carrying capacity of end bearing piles. It includes variables like (CR+RQD) and q_c, which indicate the rock's strength and integrity. And the formula is included with all factor of safety and there is no need to solve the equation for factor of safety.

However, it is critical to understand that this method has limits and should be used with caution. The little amount of difference detected in the evaluation when compared to the actual safe load bearing capacity suggests that more refining may be required. This fluctuation might be caused by errors in rock qualities, the correctness of assumptions made, and changes in field circumstances.

To overcome these constraints, it is critical to adhere to the rules and principles outlined in the article. These constraints may include taking into account the precise conditions under which the formula was established, such as a 1-meter-diameter pile with a 1D- long socket. Deviations from these parameters may necessitate further calculations and formula tweaks to assure accurate projections.

Furthermore, site engineers should use professional judgement and consider the project site's particular geotechnical characteristics. Comprehensive site investigations, including geotechnical testing and analysis, can give more accurate data for determining geotechnical safe load carrying capacity. Furthermore, geotechnical engineers' experience and collaboration with other specialists may assist improve the design and assure its durability.

Finally, while the formula described in the study provides a basic way for evaluating the safe load carrying capacity of end bearing piles, it is not without limits and constraints. Because of the minor fluctuation observed and the omission of socket resistance, site engineers should utilize this calculation with caution. To ensure the accuracy and dependability of the safe load bearing capacity evaluation, a complete design strategy that includes detailed site inspections, professional judgement, and coordination with geotechnical specialists is required.

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REFERENCES

[1] IRC:78-2014, Standard Specifications and Code of Practice for Road Bridges, Section: VII, Foundations and Substructure (Revised Edition)

[2] IS 11315-5 (1987): Method for the quantitative description of discontinuities in rock masses, Part 5: Wall strength (CED 48: Rock Mechanics)

[3] Ministry of Road Transport & Highways, Specifications for Road and Bridge Works, (Fifth Revision)

[4] Soil Mechanics and Foundation Engineering, Dr. K.R. Arora

[5] Design of Piles in Cohesive Soil, Nguyen Truong Tien, Swedish Geotechnical Institute, Sweden

[6] Bridge Engineering, Third Revision, S. Ponnuswamy, McGrawhill Publication

[7] Essentials of Bridge Engineering, Sixth Edition, D. Jhonson Victor

[8] IDA Agreement for Design and Construction of Flyover including allied works at Bhawrasla (Lavkush) Square along MR-10 Road and Super corridor, Indore

[9] Concrete Bridge Practice, V.K. Raina, Shroff Publishers, 2nd Edition

[10] "Design and Construction of Rock Socketed Pile Foundation for Bridges – Case Study on Road Project in Madhya Pradesh, India" by Avik Kumar Mandal and Et al.

[11] "Socketing of Bored Piles in Rock" by B.R. Srinivasamurthy and K.L. Pujar

[12] "Pile termination criteria for rock socketed piles in Chennai Metro Project" by Rajaraman R.

[13] "Challenges to Quality Control in Bored Cast-in-Situ Piling in Growing Urban Environment" by D. V. Karandikar

[14] "Study of theoretical and observed capacities of bored cast-in-situ piles in tuff, braccia and weathered basalt" by V.T. Gunpule and S.M. Gupte

[15] Preliminary estimation of rock mass strength using diamond bit drilling operational parameters, H. Basarir & C. Karpuz

[16] Simple Correlations between Rock Abrasion and Other Significant Rock Properties for Rock Mass and Intact Quartzite, Scott Ureel, Moe Momayez

[17] IS 2911-4 (1985): Code of practice for design and construction of pile foundations, Part 4: Load test on piles (CED 43: Soil and Foundation Engineering)

[18] IS 14593 (1998): Design and construction of bored cast-in-situ piles founded on rocks - Guidelines [CED 48: Rock Mechanics]

[19] IS : 2911 (Part 4) – 1985, (Reaffirmed 2000), Code of Practice for Design and Construction of Pile Foundations, part 4 – Load Test on Piles (First Revision)

[20] Indian Railway Standard, Manual on the Design and Construction of Well and Pile Foundations (1985), (Well and Pile Foundation Code)