Geotechnical Investigation of Foundation of Dyaneshwary Gatha Mandir at Alandi , Pune , Maharashtra, India.

Pramila Sadashiv Kale[1], Prof. Sachin Jaiveersingh Yadav[2], Dr. P. D. Sable[3]
[1]Research Scholar (B.E.), ABMSP'S APCOER, Parvati, Pune, India. pramilasadashivkale999@gmail.com , [2]Professor, ABMSP'S APCOER, Parvati, Pune, India, [3]Head of the Dept, AIHC & Archaeology & Professor in Environmental Archaeology, Deccan College Deemed University , Pune, India.

ABSTRACT— An approach to the estimation of safety of on rock foundations is discussed from the viewpoint of strength and total structural load. Design of foundations for the large buildings is complex and time-consuming, above all due to great number of the load combinations and the coexistent influences of numerous equipment and installations. Reliable foundation of the huge buildings is significantly important, due to strategic role of this type of engineering objects in the respective economy. Due to importance of the investment and its great costs, all buildings are classified to the third geotechnical category regardless of the soil conditions. Adequate foundations of this building shall fulfill safety requirements for the structure as well as shall provide the proper cooperation between neighboring objects and the equipment. The important criterion which ensures adequate work of the equipment is to fulfill rigorous values of total, vertical displacements of the foundation, as well as to fulfill strict requirements towards differential settlements between various foundation points. In this paper, foundational strength analysis is investigated by rock properties like compressive strength calculated in laboratory and by total structural load calculation.

Literature survey is sufficient to understand standard method for design of project. On basis of literature, we design the methodology of our work. The work we have been designed in 3 steps: 1) Pre-survey, 2) Literature review, 3) Actual survey etc. then field investigation which include detailed field survey, subsurface survey to understand the nature of actual ground truth condition which are required for concrete rock mechanical solution of site area. So, in this way a detailed investigation of foundation of Dnyaneshwary Mandir on site analysis of different types of rock with respect to compressive strength of different rock were carried out by actual application of standard method. Finally based on field investigation of rock the remaining studies such as hardness and unconfined compressive strength of rock material, weathering terminology,construction quality of rock and rock mass stability were planned for lab analysis. On the basis of field and lab analysis is inferences/result. Based on inferences final conclusion is made.

Keywords : Compressive Strength, Hardness, Foundation, Inferences, Investigation, Rock Mass Stability, weathering terminology.

—————————— ◆ ——————————

1.INTRODUCTION

INITIALLY, the International Society for Rock Mechanics organized its first Conference on Rock Mechanics in 1966 at Lisbon. Definition of rock mechanics was described by the Committee on Rock Mechanics of Geological Society of America in 1964 and this was followed by the Committee on Rock Mechanics of National Academy of Sciences in 1966. Rock Mechanics is the theoretical and applied science of behavior of rock. It is that branch of mechanics, which is concerned, with the response of rock to the field of its environment. These techniques apply to surface excavation as well as underground. It has important role in mine planning and design viz. selection of mining methods, optimum slope angle, and design of support system, drilling and blasting parameters.

The two Rock mechanics engineering is the branch of engineering concerned with mechanical properties of rock and application of this knowledge in dealing with engineering problems of rock materials. Underground structures in rock, i.e., any excavated or natural subsurface opening or system of openings that is virtually supported by wall pillar only and not by any support placed within the openings need geotechnical study. For designing and stability evaluation— a) the stresses and/or deformation in the structure resulting from external or body load; b) the ability of structure to withstand the stress or deformation, need to be determined.

2,LITERATURE REVIEW

The foundation is very important part of any structure. Therefore to know the sub surface condition, behavior of soil under foundation, to determine the fault, fracture and permeability of soil below the sub surface of ground, we will be studying all different parameters of rock in following literature paper.

So-ngo Clifford Teme, Patrick Omorodion Youdeowei in 2004: Steel sheet piles were recommended and used as foundation systems for the shore protection works with the length of sheet piles equal to H + Df + h, where H = depth to the bottom of the river bed at low-low water, Df = depth of embedment of pile into the bearing medium and h = height of sheet pile above the river bank cliff (free-board) at the time of investigations (18th – 28th November, 2002). [1]

S. C. Handa , Swami Saran , G. Ramasamy ,A S. R. Rao , B. Prakash in 1984: . At foothill of Himalaya, it is not possible to provide raft foundationto the buildings and hence the alternatively of pile foundation was suggested. [2]

Abhishek Arya1, Dr. N.K. Ameta in 2017: Foundation is the most important part of any structure. Bearing capacity of the soil underneath and the settlement of footing are the two major concerns in the design. A lot of work from a long time is going on for finding the bearing capacity of soil and the settlement of the footing. This paper reviews the work done so far on these. [3]

Aria Mardalizad1,a, Andrea Manes1,a and Marco Giglio in 2017: The mechanical response of a middle strength rock, namely Pietra sandstone, is assessed both numerically and experimentally under unconfined compressive loading condition. Two experimental approaches, based on different specimens' arrangements, have been conducted on Pietra Serena sandstone to determine its unconfined compressive strength (UCS).[4]

N. Sivakugan*1, B. M. Das2, J. Lovisa1 and C. R. Patra in 2014: Cohesion (c) and friction (w) angle are the two key parameters required in numerical simulations and designs of underground openings, excavations, and foundations in rocks. The paper discusses a simple method, based on a theoretical framework, to determine the two parameters from uniaxial compression test and indirect tensile strength test. [5]

Ravi Sundaram in 2017: The paper presents four case studies of difficult ground conditions in different parts of India. It explains the geotechnical investigations done to study the problem and work out an engineering solution. The case studies pertain to soft clays, gravel-boulder deposits, liquefaction of loose sands and artesian conditions. [6]

G.Tsiambaos in 2009: The paper presents the results of laboratory tests performed on a large number of intact sedimentary rock specimens (limestone, sandstone, siltstone) and metamorphic rocks from Greece. The physical properties (porosity, dry density), mechanical properties (uniaxial compressive strength), Young's modulus, point load index, Schmidt hardness) and dynamic properties (wave velocity) were determined. [7]

Abiodun Ismail Lawal, Sangki Kwon in 2020: The literature review shows that AI methods have successfully been used to solve various problems in the rock mechanics field and they performed better than the traditional empirical, mathematical or statistical methods. [8]

M. Fener1, S. Kahraman2, A. Bilgil3, and O. Gunaydin in 2005: The uniaxial compressive strength (UCS) of rock is widely used in designing surface and underground rock structures. But comparing to uniaxial compression test, indirect tests are simpler, faster and more economical. [9]

Bo Wu and Wei Huang in 2020: In the upper soft and lower hard composite strata, it is very difficult to sample the rock and test the mechanical properties of the samples. The study of the mechanical properties of similar material samples by artificial manufacture may enable an alternative method to solve this problem. The research results can provide reference for the test and analysis of mechanical properties in similar complex strata with difficult sampling. [10]

J. Li and E. Villaescusa in 2005: New relationships have been established between critical strain and modulus and between critical strain and compressive strength for intact rock and rock masses. [11]

Gandhi S. R., Elango J. et.al 2004: This paper discusses the Geotechnical and Geophysical investigations carried out at power plant site located in India.[12]

From the above literature review, we have studied different type of rocks, different methods of soil investigation, different parameters of rock which is been observed in core. The behavior of soil under pressure of foundation and how to determine the strength of rock is studied in the literature. By studying this, we have discussed and adopted methodology for our project.

3.MATERIALS AND METHODS

Rocks of 'Indrayani' river bank at Alandi, Pune, India, UTM machine, Bucket, Water, Weighing Balance, Plan of

ISSN 2229-5518

Building, Rock Cutting Machine- Power Saw/Hacksaw, Hightgauge Vernier Caliper, scale, V-Block, Surface plate, Hand Grinder-10cm Blade, Screw Tighting Spanner-19 No were required for laboratory testing.
With the help of UTM machine in my college laboratory we conduct compressive strength & bending strength of rock samples. One rock cutting was done in Mechanical Department laboratory. Water Absorption test also conducted in my Civil Engineering laboratory.

Fig. 1: Rock samples from Indrayani river.

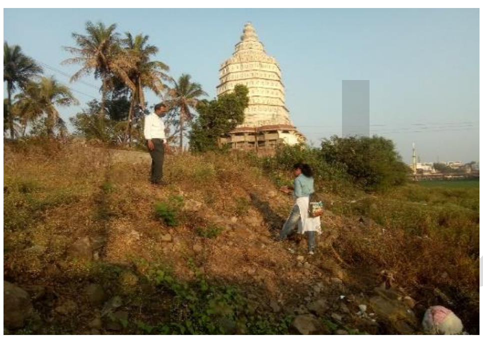

Fig.2: Field Investigation for rock collection.

Fig.3: Rock strength testing on UTM .

Fig.4: Dnyaneshwary Gatha Temple

Rock mass classification systems place different emphases on the various parameters, and it is recommended that at least two methods be used at any site during the project. Methods are:-

- Compressive strength caculation
- Hardness Rating
- Weathering terminology rating
- Construction quality of mass Rating
- Rock mass stability Rating
- Cementation of rock Rating.

3.1 Compressive strength caculation

The laboratory uniaxial (unconfined) compressive strength is the standard strength parameter of intact rock material. If strength is to be determined by correlating with hardness, use table 1 as a guide.

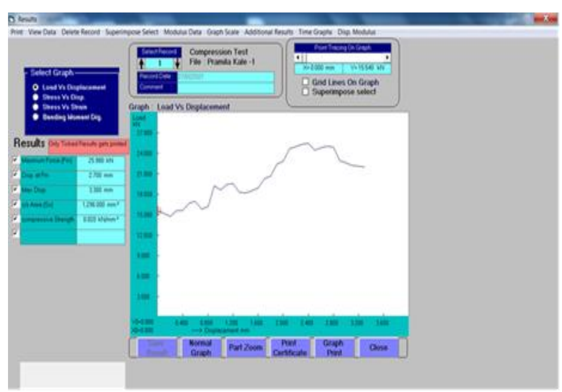

Fig.5 Graph of maximum compressive force of Core

Fig. 6 Graph of maximum compressive force of Tackletic Basal

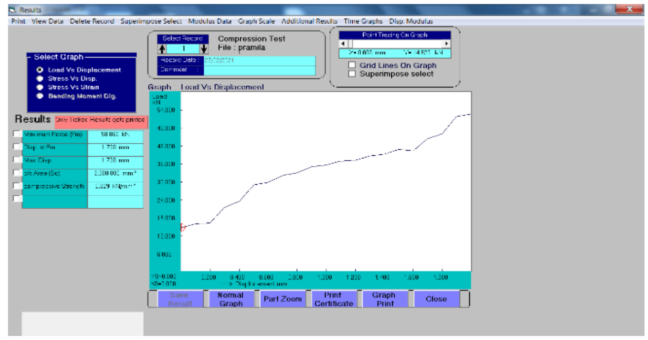

Fig.7 Graph of maximum compressive force of Amecdol Basalt

Table3.1 Hardness and unconfined compressive strength of rock

Hardness category	**Typical range in unconfined compressive strength (MPa)**	**Strength value selected (MPa)**	**Field test on sample**	**Field test on outcrop**
Soil*	< 0.60		Use USCS classification s	
Very soft rock or hard, soillike material	0.60–1.25		Scratched with fingernail. Slight indentation by light blow of point of geologic pick. Requires power tools for excavation. Peels with pocket knife.	
Soft rock	1.25–5.0		Permits denting by moderate pressure of the fingers. Handheld specimen crumbles under firm blows with point of geologic pick.	Easily deformable with finger pressure.
Moderately soft rock	5.0–12.5		Shallow indentations (1–3 mm) by firm blows with point of geologic pick. Peels with difficulty with pocket knife. Resists denting by the fingers, but can be abraded and pierced to a shallow depth by a pencil point. Crumbles by rubbing with fingers.	Crumbles by rubbing with fingers.
Moderately hard rock	12.5–50		Cannot be scraped or peeled with pocket knife. Intact handheld specimen breaks with single blow of geologic hammer. Can be distinctly scratched with 20d common steel nail. Resists a pencil point, but can be scratched and cut with a knife blade.	Unfractured outcrop crumbles under light hammer blows.
Hard rock	50–100		Handheld specimen requires more than one hammer blow to break it. Can be faintly scratched with 20d common steel nail. Resistant to abrasion or cutting by a knife blade, but can be easily dented or broken by light blows of a hammer.	Outcrop withstands a few firm blows before breaking.
Very hard rock	100–250		Specimen breaks only by repeated, heavy blows with geologic hammer. Cannot be scratched with 20d common steel nail.	Outcrop withstands a few heavy ringing hammer blows but will yield large fragments.
Extremely hard rock	> 250		Specimen can only be chipped, not broken by repeated, heavy blows of geologic hammer.	Outcrop resists heavy ringing hammer blows and yields, with difficulty, only dust and small fragments.

materials

3.2

ISSN 2229-5518

HARDNESS OF ROCK RATING

Hardness is the subjective description of the resistance of an earth material to permanent deformation, particularly by indentation (impact) or abrasion (scratching).

3.3 WETHERING TERMINOLOGY RATING &

3.4 CEMENTATION OF ROCK RATING

A summary of description of weathering terminology is shown in table3.2, and terminology to describe cementation conditions of rock in table 3.3.

Term	Weathering description	Grade
Fresh	No visible sign of weathering: perhaps slight discoloration on major discontinuity surfaces.	I
Slightly weathered	Discoloration indicates weathering and discontinuity surfaces. May be discolored and somewhat weakened by weathering.	II
Moderately weathered	Less than half is decomposed or disintegrated to a soil material. Fresh or discolored rock is present either as a continuous framework or as corestones.	III
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.	IV
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact	V
Residual soil	All rock material is converted to soil material. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported	VI

Table 3.2 Weathering terminology

	Cementation
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

Table 3.3 Cementation chart

3.5 CONSTRUCTION QUALITY OF ROCK

For construction quality, use table 4, which shows rock quality classification for riprap, aggregate, embankment fill, and road armor for construction application.

Classification elements	Class I	Class II	Class III
	High grade	**Medium grade**	**Low grade**
	Rock material is suitable for high-stress aggregate, filter and drain material, riprap, and other construction applications requiring high durability. **Must fulfill all conditions below:**	Rock material is potentially suitable for construction applications. **May require additional evaluation if at least one condition below is fulfilled:**	Rock material is unsuitable for aggregate, filter and drain material, or riprap. Reacts essentially as a soil material in embankments. **Must fulfill at least one condition below:**
Strength (table 4–3)	> 50 MPa (> 7,250 lb/in²)	12.5–50 MPa (1,800–7,250 lb/in²)	< 12.5 MPa (< 1,800 lb/in²)
Hardness (table 4–3)	Hard to extremely hard rock	Moderately hard rock	Moderately soft to very soft rock

Table 3.4 **Construction quality of rock**

3.6 ROCK MASS STABILITY

Table 3.5 shows rock mass stability of natural or constructed slopes for gravity or seismic activity. For the purpose of design and to evaluate the stability of underground structure, mechanical properties of the rock must be known. It provides the knowledge of material deform or fail, under the action of applied force.

Classification elements	Class I	Class II	Class III
	Stable	**Potentially unstable**	**Unstable**
	Rock material has very low potential for instability. **Must fulfill all conditions below:**	Rock material has potential for instability. **May require additional evaluation if at least one condition below is fulfilled:**	Rock material has significant potential for instability. **Must fulfill at least one condition below:**
Strength (table 3.1)	> 50 MPa (> 7,250 lb/in^2)	12.5–50 MPa (1,800–7,250 lb/in^2)	< 12.5 MPa (< 1,800 lb/in^2)
Hardness (table 3.1)	Hard to extremely hard rock	Moderately hard rock	Moderately soft to very soft rock

TABLE 3.5 ROCK MASS STABILITY

4. RESULT AND DISCUSSION

By the overall Rock Mass classification , following result is obtained by laboratory testing.

5. CONCLUSION

Based on this, field and lab data, following conclusions were made :-

I. Presence of the joints in especially basalt makes the avenues for circulation of surface water and resulting into decomposition of the rock. e.g.Tackelatic Basalt.

II. But, at the deeper level, due to the presence of unjointed, fresh and undecomposed rock fragments, resulting the RQD value is increased. Such rock shows suitability for the foundation, eg. Core

III. On the basis of compressive strengh calculations, it is found that its average percentage in case of rock foundation is varies from 10 to 48. The average result of compressive strengh shows, the present condition of rock is weathered to moderately weathered .

ROCK	STRENGTH	[AS PER HARDNESS AND UNCONFINED COMPRESSIVE STRENGTH]	[AS PER WEATHRING TERMINOLOGY]	[AS PER CONSTRUCTION QUALITY OF ROCK]	[AS PER ROCK MASS STABILITY]	[AS PER CEMENTATION]
CORE	48.61	Moderately hard rock,	Slightly weathered-gradeII	Medium grade-ClassII	Potentially Unstable-ClassII	Strong
TACKELETIC BASALT	10	Moderately soft rock,	Moderately weathered-gradeIII	Low grade-ClassIII	Unstable-ClassIII	Moderate
AMEGDOL BASALT	29.43	Moderately hard rock,	Moderately weathered-gradeIII	Medium grade-ClassII	Potentially Unstable-ClassII	Strong
AMEGDOL BASALT	30.65	Moderately hard rock,	Moderately weathered-gradeIII	Medium grade-ClassII	Potentially Unstable-ClassII	Strong
COMPACT BASALT	15.31	Moderately hard rock,	Slightly weathered-gradeII	Medium grade-ClassII	Potentially Unstable-ClassII	Strong

TABLE 4.1 RESULT AS PER ROCK CLASSIFICATION (RATING)

IV. Therefore, the foundation should be treated carefully and in future there are chances of requirement of maintenance. Otherwise the remaining character of Basalt at this location is highly suitable for this foundation purpose.

V. As per the cementation ratings Tacklatic Basalt as Moderately strong, and all others rating as strong.

ACKNOWLEDGEMENET

This study is a part of analysis of strength of foundation of Dnyaneshwary Gatha Temple. So for further investigation of maintainance work or foundational study of that area ,it gives guideline to reserchers. The author is grateful to God for his providence.The authoris most grateful to HOD Dr. P.D. Sable : Department of Archaeology, Deccan College Post Graduate and research Institute, (Deemed University), Pune-411 006 (Maharashtra) & Prof. Sachin J.Yadav of ABMSP'S "Anant Rao Pawar College of Engineering And Research" Pune, for their supports and valuable guidance in my paper. The author is also grateful to Principal Dr. S.B. Thakare of ABMSP"S "Anant Rao Pawar College of Engineering And Research" Pune, for their supports . The author is grateful to HOD Prof. A.B. Shelar of Civil Engineering Department for his valuable support. Last but not the least author is grateful to management staff, College Staff members, Peons, etc for their supports in our project as well as paper.

REFERENCES

JOURNALS

[1] So-ngo Clifford Teme, Patrick Omorodion Youdeowei (2004), "Geotechnical investigations for design of foundations for erosion and flood control structures at Unwana beach, Afikpo, Ebonyi state, South-Eastern Nigeria".

[2] Gandhi S. R., Elango J. et.al. (2004), "Evaluation of rock characteristics for power plant site in India."

[3] S. C. Handa, Swami Saran, G. Ramasamy, B. Prakash, A. S. R. Rao (1984), " Geotechnical Investigations for Foundation Design for Multistoreyed Building ."

[4] Nagaratnam Sivakugan, C. R. Patra, Julie Lovisa (2014), "Determination of c and Φ of rocks from indirect tensile strength and uniaxial compression tests."

[5] Abhishek Arya, Dr. N.K. Ameta (2017), "Bearing Capacity Of Foundation- Review Paper."

[6] Jianping Li, Ernesto Villaescusa(2005), "Determination of rock mass compressive strength using critical strain theory."

[7] Georgios P. Tziallas, George Tsiambaos(2009), "Determination of Rock Strength and Deformability of Intact Rocks."

[8] Abiodun Ismail Lawal , Sangki Kwon(2020), "Application of artificial intelligence to rock mechanics: An overview."

[9] Mingqing You(2015), "Strength crieterion for rocks under compressive-tensile stresses and its application."

[10] Mustafa Fener, Sair Kahraman, Ahmet Bilgli, O.Gunaydin(2005), "A comparative evaluation of indirect methods to estimate compressive strength of rocks".

[11] Bo Wu, Wei H uang(2020), "Uniaxial Compression Mechanical Properties of Rock Samples in Soft and Hard Composite Strata."

[12] Ravi Sundaram(2017), "Geotechnical investigation in difficult Ground conditions- Indian Experiences."

[13] https://scientific.net/AMR.778.1072

[14] National Engineering Hanbook (Part 631 Geology) Chapter -4 Engineering classification of Rock Materia

Dr. Pandurang Digamber Sabale obtained PG in M. Sc. Applied Geology (1997) First Class with Distinction first rank from Shivaji University, Kolhapur & Ph .D. Geology

(Morphotectonics) (2008) from Shivaji University, Kolhapur, Maharashra. Special Lectures delivered: India: 47 , Abroad: 11 Seminars/Conferences attended and papers presented National: 35 , International: 32 . Publications: -Research Papers: National: 37 , International: 31. Books: 02 (In Press) . Edited Volumes: -01 . Popular articles: 06. Editorial work: 07 Journals .

Sachin Jaiveersingh Yadav obtained PG in Business Administration and ME Civil Environmental in Akhil Bhartiya Maratha Shikshan Parishad's, "Anant Rao Pawar College of Engineering and Research, Pune". And Professor of Akhil Bhartiya Maratha Shikshan Parishad's, "Anant Rao Pawar College of Engineering and Research, Pune". He has published 6 research papers in National Conference.

Pramila Sadashiv Kale obtained Deploma in Civil Engineering and currently pursuing BE Civil Engineering in Akhil Bhartiya

Maratha Shikshan Parishad's, "Anant Rao Pawar College of Engineering and Research, Pune".