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An Integrated Approach to Classify Earth's Strata for Open Excavation

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Abstract: Classification of soil and rocks based on a classification index which is related to physical characteristic is very empirical and rippability guidelines based on the Caterpillar Performance Handbook (1979-1990) were found to be over optimistic and are not suitable to be applied at the excavation sites. An attempt is done in this research project to overcome the problems arise from conflicting claims as where the transition zone between soil and rock really exists in excavation work and develop a new method of soil and rock classification for geological engineering study to determine the stiffness properties of earth material using integrated approach. Normally materials from weathering of bedrock can have considerable variation in physical and mechanical properties (Bell, F.G). These properties are influenced by nature (type) of bedrock, geology, topography and geomorphology, groundwater circulation and mechanical performance of excavation machines. As such a classification system is to define the boundary between soft and hard rock that are to be excavated. The tool used to define boundary is the seismic refractive survey and the profile in correlating with the core obtained from core drilling or free face obtained after excavation and UCS of tested samples.

Keywords: *Strata, Rockmass, soil, ordinary rock, hard rock, rock quality designation, seismic refraction, excavability and rippability*

1. Introduction

Strata classification is one of the main input parameter for any excavation on the Earth's crust. The Earth's crust is too undulating and varies with respect to geological and geotechnical features [1]. At present there is no standard classification technique available for the open excavations. This has misguided the operator to adopt a non-particular method for strata classification. In most of the cases strata classification is done by empirical methods or by trial pits and the results is often misleading. The second alternative is by core drilling which is both costly, time-consuming and point oriented information. The existing system of classification is useful for support design in underground mines and tunnels [2]. It is observed that weathering of bedrock leads to considerable variation in physical and mechanical properties of the rock. These properties are influenced by nature (type) of bedrock, topography, nature of effects on the bedrock and geological features (Goodman R.E). Even though laboratory testing of rock samples leads to higher strength, it is physically possible to excavate the rock under heavily jointed conditions [3]. In certain cases the rock sample tested will provide less value but the strata cannot be excavated by normal excavating equipment. Thus scale effect comes into play in the overall behaviour of the Rockmass.

Today open excavation is not limited to shallow depths, the excavation is been done up to a depth of 15 to 20m from the surface in both urban area as well as in rural areas to fulfil the needs of civilisation [8]. In most of the areas ordinary rock/hard rock is encountered at this depth. The use of crust layer varies from rural to urban areas. The crust layer is used for agricultural purpose, Construction of dams, channels, tunnels, buildings, underground metro stations, LPG and weapons storage cravens, mining, etc (Ronald E Smith). To excavate the ordinary rock/hard rock different methods are adopted like mechanical breaker, feather and wedge method, chemical compound, drilling and blasting etc. [4]. Out of many excavation methods drilling and blasting is one of the cost effective method when the blasting is executed in controlled manner. To avoid the situations it is proposed to utilize the surface exploration technique to classify the soil and rock before operating the open excavation.

2. Methodology

The main objectives of strata classification using integrated method is to provide safe, cost effective and to achieve maximum efficiency from the adopted techniques for excavation. An extensive field survey was involved to collect surface wave data, UCS and geological and geotechnical data. Studies were carried out to assess the strata under the categories specified as soil, ordinary rock and hard rock for the excavations undertaken of earth strata to facilitate foundation of various structures, utility tunnel, etc. Normally the strata classification, quantification and excavation activity starts on the basis of the data available from the point source [6]. The open excavation depends on the terrain of the area and design of infrastructure to be constructed in that area. As the excavation progress the unexpected ordinary rock/hard rock this was in the alignment of point sampling present at certain depth halts the progress. This is because the machineries that are adopted for the excavating the soil of lower strength are not capable to excavate hard rock of higher strength. At this stage, to make necessary arrangements to excavate the hard rock is time consuming and there exists huge financial losses which results in increase of project cost and which have a direct influence of economic growth of the country.

To overcome this problem an integrated method of strata classification was adopted at two sites, one at Bangalore and another at Chennai to classify the strata into soil, ordinary rock and hard rock. These two areas have varying rock mass, different geological features, fluctuating ground conditions, erratic design parameters, dissimilar ground water table, etc.. Based on different classification systems for various natures of excavation and the experience of the authors in similar projects, the integrated approach for strata classification system in the form of a flow chart involving various field and lab tests was evolved as shown in Figure 1.

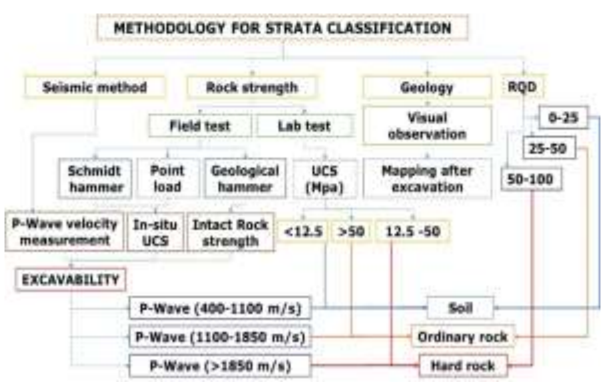

Figure 1 *Methodology adopted for strata classification*

The technique involves an integrated approach wherein seismic refraction survey, geological and geotechnical studies, borehole rock quality designation (RQD) and uniaxial compressive strength values are used for strata classification. In order to overcome the averaging effect of P-wave velocity of subsurface horizons, Point load and Schmidt hammer tests were conducted on selected samples of different rock types so as to estimate the uniaxial compressive strength indirectly at site.

Geological mapping of different rock types, facies and dip/ joints were done for a realistic estimate of subsurface condition after the excavation is done. Using these three parameters (geophysical, geological and geotechnical), an integrated index was developed for arriving at the most appropriate classification by giving due weightage to each factor. In order to test the proposed approach, an extensive field survey was involved to collect surface wave data at selected sites and to conduct spectral analysis of the wave in order to obtain the shear modulus profile of the subsurface material.

First the subsurface was scanned upto a depth of 20m by seismic refraction method, then samples were tested for uniaxial compressive strength at site and at laboratory[10]. Based on the seismic refraction studies (p-wave velocity), RQD, point load test values, Schmidt hammer values and laboratory determined UCS, the strata was classified into three strata units such as soil, weathered rock and massive rock. Thickness of subsurface horizons was determined from seismic sections, borehole data (RQD) and geological survey of exposed faces at every 5m interval. Large variation in the strata was observed with the predominant rock being charnokite at Chennai site and plutonic igneous rock at Bangalore site. Large variation in the strata thickness was observed with the predominant rock being charnokite at Chennai site. Various degrees of weathering were observed in each site which has yielded five strata units such as soil, residual rock, fragmented rock, unfragmented rock and massive rock (figure 5). The method involving seismic refraction (P-wave velocity), geological cum geotechnical studies and uniaxial compressive strength were used for strata classification and excavability assessment. Seismic refraction survey was carried out in all the accessible areas. Point load and Schmidt hammer tests (Güney, R. Altındağ, H. Yavuz & S. Saraç) were conducted for estimation of indirect uniaxial compressive strength. Representative samples were taken for laboratory studies to determine their uniaxial compressive strength. The study gave the clear overview of cost minimization and improvement in functionality of excavating the strata. The P-wave varied from 400 to 3000m/s for soil and hard rock respectively and uniaxial compressive strength exceeding varied from 3 to 268MPa. Based on the geological sections, seismic refraction studies (p-wave velocity), point load test values, schmidt hammer values, estimated UCS and laboratory determined UCS, the strata was classified into three strata units such as soil+residual rock, ordinary rock and massive rock.

3. Discussion of Experimental Results

Based on the seismic refraction studies (p-wave velocity), geological sections, point load test values, Schmidt hammer values, estimated UCS and laboratory determined UCS, the strata was classified into soil+residual rock, ordinary rock and hard rock.

3.1. Strata Classification using Seismic Refraction Survey

The seismic refraction survey was carried out for a stretch of 1000m in the proposed excavation site. The seismic section gives information about the subsurface stratigraphy in terms of their seismic velocities [4]. The output of seismic refraction survey is a plot of seismic velocity contour vs. depth. Seismic velocity of a medium (layer) is reflective of its rippability and excavability character. One of the seismic processed section of Chennai site is given in figure 2. As per these criteria any medium with a velocity above 1100m/s and uniaxial compressive strength of over 12.5 MPa is non-rippable and is classified as ordinary rock. Based on this criterion the P-wave velocity of the subsurface layers is classified into three segments i.e. 400-1100m/s , 1100-1850m/s and >1850m/s corresponding to top soil, the ordinary rock and hard rock respectively.

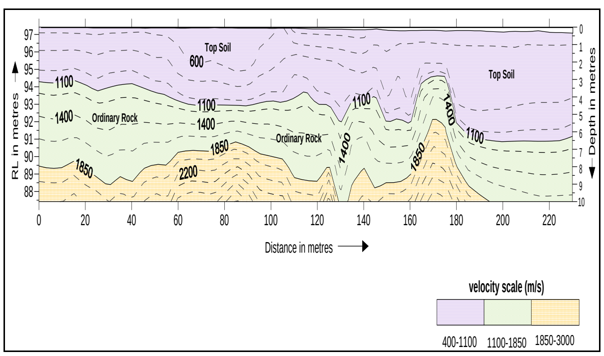

Figure 2 *Seismic section demarcating soil, ordinary rock and hard rock*

3.2. Strata Classification using Strength Properties

Standard test procedures prescribed by International Society for Rock Mechanics (ISRM) was used to determine uniaxial compressive strength (UCS) of the rock samples collected from site. UCS was determined by point load testing, schmidt hammer testing and by lab testing. The indirect method of determining UCS by Point load strength and Schmidt hammer test was conducted for the samples picked at every 5 m interval along the geological section lines. Core samples were drilled from 1*1*1m3 size samples picked from site and the compressive strength was determined at laboratory by using 300 tonne Compression Testing Machine (Figures 3) as per the Standards. The summary of estimated UCS values is given in table 1.

Figure 3 *Testing of samples for UCS using 300 tonne compression testing machine*

Table 1 *Average estimated UCS values for the excavated area*

Estimated UCS (MPa) from Point load test			
	Maximum	**Minimum**	**Average**
North face	169.58	2.79	47.53
West face	160.76	11.98	47.4
South face	189.52	3.5	45.39
East face	123.61	7.3	69.68
Estimated UCS (MPa) from Schmidt hammer			
	Maximum	**Minimum**	**Average**
North face	43.29	4.09	15.84
West face	78.1	4.09	29.46
South face	43.29	4.09	14.57
East face	78.1	4.09	26.83

The laboratory determined UCS ranged from 83 to 221 MPa. The estimated UCS from point load test ranged from 45 to 70 MPa and it varied from 15 to 30 MPa for Schmidt hammer. Based on UCS values, the strata in the above studies are distinctly falling in "Moderately hard rock (12.5 to 50 MPa) to Hard rock (50 – 100 MPa)" categories with respect to excavability. The UCS values exceeding 12.5 MPa can be categorised as "ordinary rock". The UCS values below 12.5MPa can be categorised as soil stratum and the UCS more than 50 MPa are considered as hard rock. The large variation noted in the UCS indicates that, the performance in terms of energy consumption, output etc. of the excavation technique may also vary accordingly.

3.3. Strata Classification based on Geological cum Geotechnical Studies

Detailed geological and geotechnical studies were conducted on the exposed faces after the excavation is completed. Strata variation was demarcated by drawing the geological Sections vertically at every 5m interval to full height of the walls. The geological section mapped for one of the faces is given in figure 4. The lines demarcating soil, ordinary rock and hard rock are clearly indicated in the sections. The contour lines for ordinary rock and hard rock were drawn by correlating with uniaxial compressive strength and the seismic P – wave velocity data which was matching around 95%.

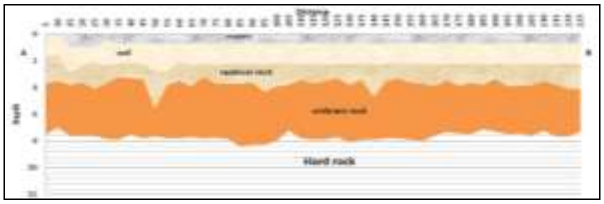

Figure 4 *Cumulative Geological Section along one of the face*

3.4. Estimation of Volume

Based on the geological sections, seismic refraction studies (p-wave velocity), point load test values, Schmidt hammer values, estimated UCS and laboratory determined UCS, the strata was classified into soil+residual rock, ordinary rock and hard rock (figure 5).

Figure 5 *Classification of strata into soil, residual rock, weathered rock and hard rock*

The average thickness of all the faces was considered for volume calculations. The strike and dip of formations were carefully studied for isolating the strata. Accordingly the volumes caluclated at chennai site for soil+residual rock, ordinary rock and hard rock are given in Table 2.

Table 2. *Estimated volume of soil, ordinary rock and hard rock*

Estimated Volume	Soil + residual rock	1,03,815 m^3
	Ordinary rock	1,28,520 m^3
	Hard rock	86,759 m^3

4. Conclusions

More importance has to be given for strata classification during exploitation stage. Non-availability of qualified, trained and motivated manpower in adopting perfect means of classification and excavation has lead the industry into great problems. Sufficient funds needs to be allotted for pre investigation of the site to be excavated thus avoiding the unexpected issues with respect to strata. Also in future the excavation to greater depths increases and rural/city/town continues to expand, to avoid the unexpected outcome adoption of perfect acceptable strata classification method is very important. But most of the existing construction projects are facing difficulty in excavation stage when they encounter unexpected hard rock during excavation. In such cases it is not possible to change the design of the project or stop the project, the only way is to excavate the required area by drilling and blasting or with application of mechanical means. When the strata are classified to whole area by adoption integrated method, the industry and engineers will greatly be benefited. The strata to be excavated are identified during the investigation stage itself so that extra care shall be taken during excavation process and design. This study relates to classification of strata by adopting integrated methods that are available and relating the end data to excavabality and rippability characterises. Apart from classifying the strata by adopting integrated method, the other parameters that are directly involved in excavation process are also identified. The parameters that can be directly determined are area and volume of the excavation site which is very important during preparation of method statement. Methods to be adopted to excavate the area is distinguished before the commencement of operation, the cost figure that has to be involved in excavation process is identified, the time schedule for excavation process is pre-determined, the market value of strata (granite or marble that can be processed as flooring slabs, aggregate for manufacturing sand, pebbles, etc.) that has to be excavated can be determined by testing physic-mechanical properties of the strata.

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References

[1] Auto Park Way September 5, 2008, Escondido, California Project No. 108235.

[2] Bell, F.G. Open excavations in rock masses, In 'Engineering in Rock Masses', Butterworth Heinmann, pp 400-442, 1992.

[3] Broch E. (1988): Site investigations. Norwegian Tunnelling Today, Tapir publ. Trondheim, Norway, pp. 49 - 52.

[4] Cecil O.S. (1971): Correlation of seismic refraction velocities and rock support requirements in Swedish tunnels. Statens Geotekniska Institut, Publ. no. 40, 58 pp.
[5] Chapman and Hall, London, 270 pp.
[6] Goodman R.E. (1989): Introduction to rock mechanics. John Wiley & Sons, New York, 561 pp.
[7] Güney, R. Altındağ, H. Yavuz & S. Saraç "Evaluation of the Relationships between Schmidt Hardness Rebound Number and Other (Engineering) Properties of Rocks", the 19th International Mining Congress and Fair of Turkey, I.
[8] I.W Johnston and E.A.Novello, "Soft rocks in the geotechnical spectrum", Geotechnical Engineering of Hard Soils - Soft Rocks, Anagnostopoulos et.al (eds), 1993, Balkema, Rotterdam, ISBN 90 5410 3442, Vol-1, PP 177-183.
[9] MCET2005, İzmir, Turkey, June 09-12, 2005, pp 83-89.
[10] NIRM Report on (domestic and international terminal excavations) "Assessment and Expert Advice on Rock Strata Classification for the excavations related to the construction of New Terminals and Ancillary Buildings at Chennai Airport, August 2009.
[11] Nord G., Olsson P. and By T.L. (1992): Probing ahead of TBMs by geophysical means.
[12] Palmström A. (1995): RMi - a rock mass characterization system for rock engineering purposes Ph.D thesis, University of Oslo, Norway, 409 pp.
[13] Part 628 Dams and 631 Geology, of National Engineering Handbook, June 2002, United States Department of Agriculture, National Resources Conservation services, Chapter 12 & 52.
[14] Reprint from COAL AGE, August 1979, copyright 1979 by McGraw-Hill, Inc.,
[15] Robert Hack and Marco Huisman, Section Engineering Geology, Centre for Technical Geosciences, International Institute for Aerospace Survey and Earth Sciences (ITC), Kanaalweg 3, 2628 EB Delft, The Netherlands.
[16] Ronald E Smith, PhD, PE "Excavations in the Atlantic Piedmont", Owner, Smith Geo Consultants, 1605 Benchley Court, Henderson, NV 89052, 702-228-2698. Resmithl131E2aol corn.
[17] Sjögren B. (1984): Shallow refraction seismics.
[18] Sjögren B. (1994): Private communications.
[19] Sjögren B., Øvsthus A. and Sandberg J. (1979): Seismic classification of rock mass qualities. Geophysical Prospecting, Vol. 27, No. 2, pp. 409 - 442.
[20] Tunnelling and Underground Space Technology, Vol. 7, No. 3, pp. 237-242.
[21] Yoshida, M., Rajesh, H.M. and Santosh, M., 1999. Juxtaposition of India and Madagascar: A perspective. Gondwana Research Vol. 2. P 449-462.