Engineering Geological Mapping and Rock Mass Characterization

Dr. Gopal Dhawan*

Introduction and Definition

Engineering Geological Mapping & Rock Mass Characterization together contribute the bulk of Engineering Geological Studies. For geological assessment of any civil structure, it is necessary to know the existing geological set-up together with physical & engineering properties of rock mass. As such, beginning with engineering geological mapping and continuing with sub-surface explorations, the assessment for a foundation of dam, underground excavation or for a high cut slope, is based on rock mass characterization.

In case the history of mapping is traced, it is really amazing to know that earliest geological map dates back to 1150 B.C. in Egypt which was made for Gold mineralization. However, since then a long journey has brought us from the use of geological maps mainly for mineral exploration, mining purpose to utilization of geological information for assessment of large civil engineering structures in the late 19th century.

The modern definition of Engineering Geological Mapping is the examination of natural or man made exposures of rock (which means outcrops & exposures) or unconsolidated materials, systematic recording of geological data from these exposures and their analysis & interpolation in two or three dimensional format (maps, cross-section & block diagram).

It may be understood that the geological maps and cross sections

1. Serve as record of the location of factual data.
2. Present an overall picture of the conceptual model generated by the Geologist.
3. Serve as a tool for solving three-dimensional problems related to design, construction &/or maintenance of engineering structures or site characterization.

It may be noted that gathering of engineering geological information & site characterization is a dynamic process of collecting, evaluating & revision of geological data. It is extremely important that the significance of original & subsequent revisions in geological data are realized and its implication on civil structures as well as further explorations are continuously evaluated.

The initial exploratory programme for a particular structure is always based on incomplete or scanty data and must be modified continuously as the site features becomes more and more understood.

The procedure

Before embarking upon the Engineering Geological Mapping for a particular site or structure, it important to remember steps given below:

- Review of literature and casting geological reports/maps.
- Base maps which may be toposheets on contour plans alongwith control points.
- Setting out a plan of work, arrangement for necessary equipment, survey instruments, GPS etc.
- Picking up outcrops and exposures, overburden.

*Executive Director (Geotech.), NHPC Ltd. Sector-33, Faridabad -121003 (Haryana)

- Collection of data in discontinuities, ground water and related information.
- Plotting of data and digitization.

In the light of the above scope of works the salient points that are to be given due cognizance in Geological Mapping / Rock Class Characterization include the following:

i. Purpose and scope of mapping depending upon Stage of Project, Geological Setting & Type of Civil Structure.

ii. Study limits based on Engineering and Geological needs.

iii. Survey & accuracy : control points

iv. Work schedule and priorities.

v. Previous studies, collection of information

vi. Photography : Terrestrial & Aerial

vii. Determination of critical geologic features.

viii. Required physical and engineering properties. Discuss difficulties in getting representative samples.

ix. Identification of locations for insitu tests also.

x. Collection of data on discontinuities (format to be used)

xi. GPS information : use precision required

a. Needs of project

b. Capability of GPS equipment

c. Collect data in appropriate form to be used later on.

xii. Comparison of cost of traditional surveying with GPS. It may be noted that cost of GPS equipment increases exponentially with increase in accuracy.

xiii. Divisions of overburden & bedrock & sub-divisions to be decided based on engineering and geological requirements.

xiv. Accurate probing of geological contacts, major structural elements is necessary for good engineering geological maps. Use of dashed line & dotted lines with caution.

xv. Study of landforms, weathering, water bodies, occurrences, vegetation, indirect indications of ground water & mineralization are required.

xvi. Man made features, roads, walls, explorations are to be marked.

xvii. Preliminary mapping, detailed surface mapping & construction stage mapping.

Prior knowledge of accessibility, important land-marks is a must for successful mapping cam-paign

As seen from the above the procedure for geological mapping involves certain steps for which base maps, scales, methods of plotting and collection of data are important.

i. Base Maps

The toposheets & contour plans serve as base maps. There availability is to be ascertained in advance otherwise topographic survey would be necessary to develop large scale contour plans. Of late there have been attempts to produce topographic maps from satellite imageries. In case aerial photographs are available, they may be used for development of base maps.

ii. Scales

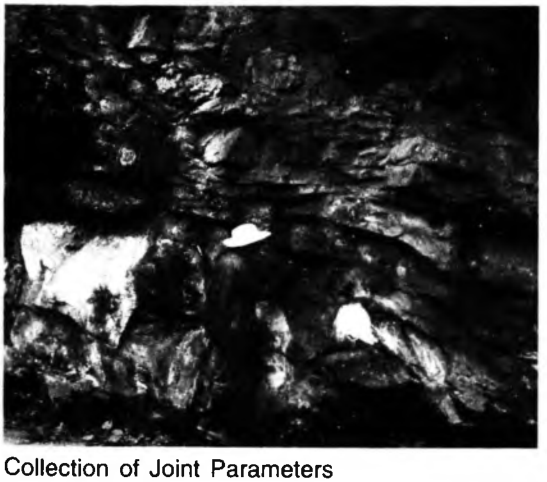
The scales of geological mapping are mentioned in IS 6065. It may be seen that in case of 1:50000 or 1:25000 mapping, the procedure is quite different when compared to large scale map say on 1:2000 or 1:1000 scale. It is very important to recognise the mappable units for a particular scale. For instance a 10m x 10m outcrop cannot be indicated on 1:50000 scale map whereas it can be shown on a 1:1000 scale map for a dam site or a power house. In case of foundation maps of dam site the scale may be 1:100. Engineering geological map for a dam site is given as figure 1.

iii. Methods

It is extremely useful to carryout preparatory work in office before leaving for the field. The plotting of control points or known places like rivers, hill streams, landmarks such as roads, bridge, paths, village need to be marked on base map before proceeding to actual geological mapping.

In case of mapping for dam sites it is necessary to work on overburden details also giving sub-division like terrace deposits, slope wash and tallus, as every material has engineering significance. For concrete dam it is particularly useful to make the assessment of thickness of overburden so that feasibility of removing the same can be established.

For assessment of slopes, it is useful to divide the ground with respect to concave & convex breaks in the slope. The materials along with slope angle are to be mentioned. Even though slope angles can be obtained from the contours. It may be necessary to carryout a few checks by actual survey so that reliable sections can be developed. Old landslides in concave slopes constitute vital information for engineering geologist. It is also incumbent during field survey to identify the parameters that are useful for rockmass characterization. Emphasis on collection of information about the discontinuities is also crucial for geotechnical evaluation of engineering structures. The format as given in figure 2 for collection of discontinuity data greatly facilitates systematic and complete data collection during surface geological mapping.



Collection of Joint Parameters

Hydro-geological information in the form of springs, seepage is to be noted alongwith any other indicators. All the data thus generated is to be plotted on base maps & notes made. Digitization of geological maps is a necessity these days so as that geotechnical software & tools can be conveniently used.

For tunnels also it is very important to emphasize on relevant information. For instance a shallow overburden 2-5m for a tunnel having 100-200 of cover shall not be significant. Plotting and collecting detailed information on rock masses which by virtue of their dip and strike are expected at tunnel grade is more useful. Collection of data on contacts and fault zones, ground water is also necessary for tunnel mapping. A planning regarding judicious use of exploratory holes for tunnel alignments has to be made by engineering geologist during making stage only.

In case of underground caverns, it is necessary to fully ascertain the availability of safe cover on all sides together with expected litho units. Surface data on discontinuities is required for orientation of cavern in preliminary stages.

High quality engineering geological maps form the basis of geotechnical assessment. However, there are a number of hindrances like weather conditions, paucity of time available for field work, law & order problems, accessibility wherein practical compromises have to be made. It is also a good idea to use remote sensing & GPS to the extent possible particularly in early stages of investigation.

For underground geological mapping of the drifts or test galleries, the collection of geological data is to be done with care and precision. The collecting the data pertaining to rock mass parameters is to be done in the format as given as figure 3. Appropriate classification can be used once the data is gathered and proper characterization has been done.

Rock mass characterization

The aspect of rock mass characterization before construction requires through understanding of rock mass by means of several investigative techniques & rock mechanic tests. The preliminary characterization comes from surface geological mapping followed by development of geological sections. The next stage in geological explorations is geophysical surveys, exploratory drill holes & galleries (drifts).

The methods of geological data collection have not changed much during last two decades. However, the processing of data & presentation has got changed with the use of new software's & presentations. As Dr. Hoek has stated, still there is no acceptable substitute for field mapping and core logging carried out by experienced engineering geologist. The site of an underground excavation or a high structure is seldom investigated fully as would have been liked by the geologists & designers due to time, cost & accessibility constraints. In that scenario, recourse has to be taken to engineering geological map for sub-surface interpretations.

In general, all types of geological models are developed with some degree of extrapolation. How well this is performed has practical implications both on further sub-surface explorations & constructions.

As already mentioned, for rock mass characterization collection of certain parameters is required. In order to systematize the observations in a format which can be later used for engineering calculations or for application of rock mass classifications, ISRM suggested methods are available. In India, the Bureau of Indian Standards which is a Government Organization responsible for application of codes & standards, has formulated Indian Standard Codes for various methods of data collection. Most of the codes required to be used for rock mass characterization are listed below:

i. IS:7422 (1974) Pt-I : (Reaffirmed 1995) & Symbols & Abbreviation for use in Geological Mapping, Sections & Subsurface Exploratory Geological Logs.

ii. IS:7974 (1976) Pt-I : (Reaffirmed 1989) Graphical symbols for use on Detailed Map, plans & Geological Cross Sections.

iii. IS:12608 (1989) Pt-I : (Reaffirmed 1995): Method for determination of hardness of rock.

iv. IS:4464 (1985) Pt-I : (Reaffirmed 1995) Code of practice for presentation of drilling information & core description in foundation investigation.

v. IS: 5313 (1980): (Reaffirmed 1989) (Ed. 2.1 1999-02) Guide for core drilling observation

vi. IS:8764 (1998): Methods for determination Point Load Index of rocks.

vii. IS:11315 1987: Methods for Quantitative descriptions of discontinuities in rock masses

a. Pt 1 : Orientations

b. Pt 2 : Spacing

c. Pt 3 : Persistence

d. Pt.4 : Roughness

e. Pt 5 : Wall strength

f. Pt 6 : Aperture

g. Pt 7 : Filling

h. Pt 8 : Seepage

i. Pt 9 : Number of Sets
j. Pt 10 : Block Size
k. Pt 11 : Core Recovery & RQD
l. Pt 12 : Drill Core Study

The above mentioned process of rock mass characterization has some essential ingredients. Looking at the steps involved in the process, rock parameters which are an input in Rock Mass Characterization are as follows:

i. Strength of Intact Rock

Beginning from manual index in which geological hammer is used (ISRM, 1978) IS codes 8764 (1998), for Point Load Index and 12608(1989) for direct uniaxial compressive strength can also be done for detailed characterization. However, in mapping stage estimation of strength by geological hammers or Schmidt hammer is sufficient. In bore hole logging, point test index can be easily used.

ii. No. of joints per cubic meter (Jv) and RQD

RQD may be calculated by using Palmstrong relationship. This is very popular amongst field geologists and can be readily used.

RQD=115-3.3Jv.

iii. The other parameters required for Rock Mass Characterization are data on discontinuities, ground water and properties of intact rock, in fillings or rock mass as a unit. For the discontinuities it is necessary to follow the IS code IS:11315(1987) which is titled "Methods for Quantitative description of discontinuities in rock".

iv) Ground water observations are to be clearly made by supplementary surface data with geophysical tests, permeability tests in bore holes and recording of water level in drill holes. Recently, preservation of drill holes for long term observations of fluctuation in water table has been started. Seepage and groundwater observations are also required from test galleries or drifts.

v) Detailed characterization is to include rock mechanic tests also. As such, IS Codes for laboratory & in-situ tests which are available shall have to be followed. It may be noted that physical & engineering properties of intact samples as well as rock mass are required for calculation of stresses, deformation & loads etc. for which supports have to be designed. The important aspect which is to be kept in mind during laboratory or in-situ testing is that sampling or testing location should be completely representing the rock mass expected in foundation or underground excavations or in slope cutting.

The testing program is divided into two parts (1) Laboratory Testing (2) Insitu Field Testing.

In case of laboratory testing properties like density, water absorption, porosity, bulk specific gravity, shear strengths, elastic properties and UCS are measured. Separated IS codes are available for each testing. In-situ testing is performed to collect elastic properties, shear strength, in-situ stresses around the excavation etc.

In the construction stage, the detailed mapping of excavated surfaces is carried out. It may be on surface or underground the scale is generally 1:100 as indicated in IS 6065. It may be possible to develop comprehensive foundation plans overlapping the structures for overall appraisal as presented in figure 4.

Mapping of excavated surfaces before shotcrete is important in construction phase

Therefore, after Engineering Geological Mapping and Rock Mass Characterization, we have the following type of information.

1. Areas of rock outcrops/exposure and overburden. Types of overburden, types of rock and estimates of strength.
2. Locations of major weak zones, faults that are described individually.
3. Description of joints, spacing and frictional properties.
4. Data on occurrences and availability of surface water bodies as well as ground water
5. Rockmass which is characterized for use in any of classification systems.
6. Geotechnical attributes of rock mass with physical & engineering properties.

According to Bieniawski the simple observations made on surface provide the most reliable data of rock mass parameters. If an outcrop fails to yield sufficient information other methods like bore holes, test galleries may be used to collect information about rock mass quality. It may be understood that investigation for rockmass characterization are to be carefully planned keeping in view the time constraints, cost and geologic setting. It may not be wise to go for drill holes when some information is readily available from the rock exposures. Accordingly, judicious use of subsurface methods is highly recommended.

The Rock Mass Characterization presents the data in such terms that the same can be readily applied in Rock Mass Classification Systems. It may be recalled that several classifications have been in vogue since several years being with Terzaghi's classification. When the geological data is collected and characterized with parameters of intact rock strength, RQD, discontinuity orientations, details of spacing, continuity, infilling, shear strength, ground water occurrence, insitu stress measurements it is very easy to apply modern classification like RMR, Q-system, DMR & Slope Mass Ratings.

The classification rock mass further implies that geological information can now be presented in number of engineering calculations. Estimation of rock mass properties, which are highly representative by rock mass classifications, is another advantage for geotechnical assessment and engineering applications. Calculation of rock load for design of tunnel supports etc or selection of supports based on rock classes is also a facility available after rock mass characterization and classification.

Conclusions

Engineering geological mapping and rock mass characterization are basic requirement for understanding the rock media so that the same can be utilized for engineering applications. To evaluate a site for the dam the engineering geological map cannot be dispensed with. Similar is the case with tunnel alignment or underground power stations. A number instances and experiences of big failures are known to happen when initial site selection and planning are done without due respect to geology. Even then it is rather strange to note that the practice of sidelining local geological conditions or even major faults continues. It should be understood and appreciated that geological information is required for building safe and economic structures. For detailed study of slope stability or deep excavations, detailed study of every geological parameter is required. The groundwater occurrences and pressures are also critical in many engineering constructions. By taking geological advice optimum utilization of site conditions can be done.

Last but not the least, for engineering geological mapping and rock mass characterization, it is reemphasized that accepted procedures of ISRM or relevant IS Codes should be utilized. Rock mass classification serve as an important tool of communication between geologists, engineers and designers. They should be extensively utilized for Geotechnical assessment and engineering applications.

Bibliography

Fell, Robin, Patrick, Mac Greger; Stagledan, David. Geotechnical Engineering & Dams, AA Balkema Publishers, India.

Hoek, Dr. Evert, Manual, Engineering & Design, Rock Foundation, U.S. Army Corps. Of Engineers.

Choubey, Vishnu, D; Dhawan, Gopal (1990) Co-relation of Rock joints at surface and sub surface for support assessment in a Himalayan Tunnel. Proed. Int. Symp. Rock Joints Balkema, Rotherdan (Ed. Barton & Stephansson).

Romana, Manual (2003). DMR (Dam Mass Rating). An adaptation of RMR geo-mechanics classification for use in dams foundations. ISRM-2003-Technology road map for rock mechanics. South Affrican Institute of Mining and Metallurgy 2003.

Dhawan, Gopal; Sayeed, Imran; Mathur, N.K.(1998) Application of Geo-mechanical classification for a low cover tunnel in Bhutan Himalaya. Proced. Int. Conf. on Hydropower Development in Himalayas, Shimla, India.

U.S. Department of the Interior Bureau of Reclamation-Engineering Geology Field Manual. Second Edition Vol.-I 1998.