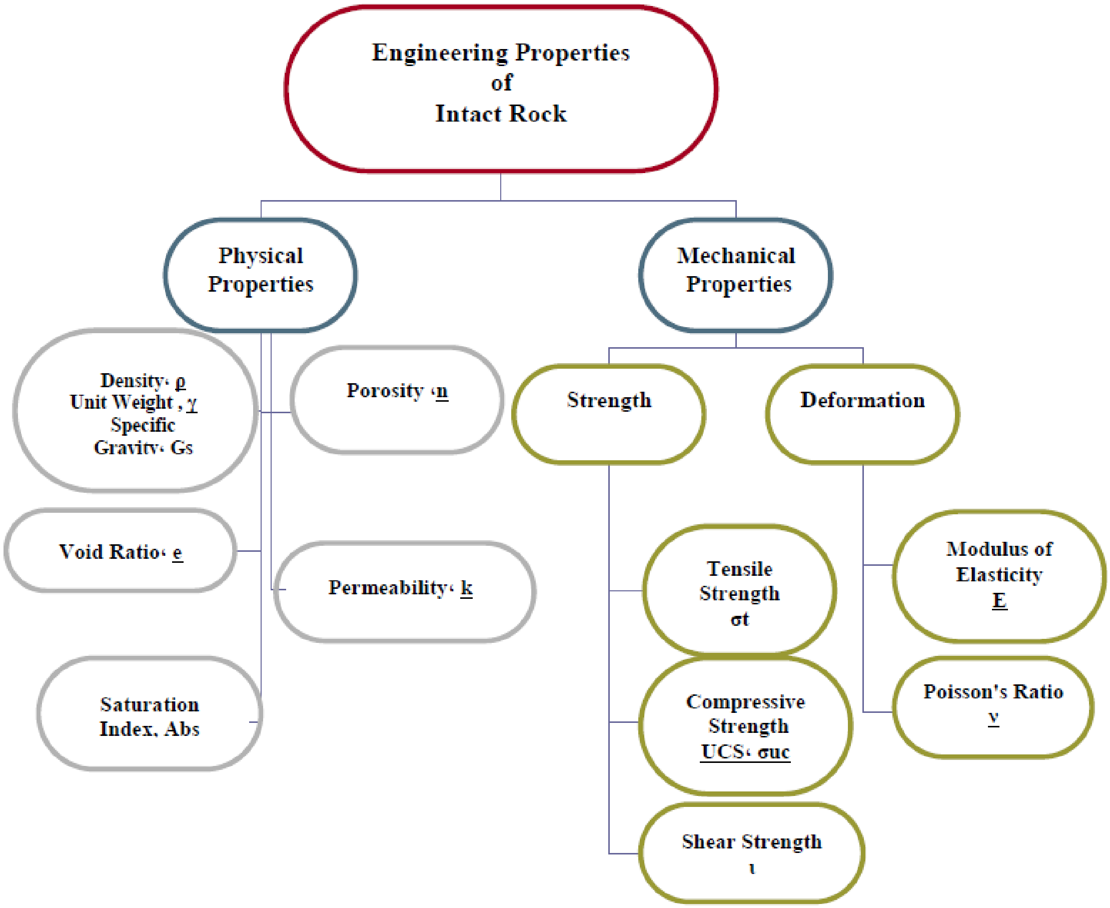
Rock Mechanics Properties



Introduction:-

Strength and deformation properties play a very important role while designing structures in rocks. Determining the appropriate strength parameters are important as the design should be in accordance with the type of structures, loading characteristics and characteristics of rocks in the bearing strata. The important design aspects and the shearing failure possibilities are to be checked before any superstructure or heavy temporary load allowed on the bearing strata.

Appropriate tests to determine various strength properties for rock need to be planned before any final design.

In geotechnical engineering prediction of performance involves determination of properties of soil/rock and rock mass through laboratory or field tests. Laboratory tests have the limitations like variability and sample disturbance. Also, testing is done on small specimens and extrapolation of the measured properties for the entire site is often challenging. In contrast, insitu test provide the response of a larger mass under natural insitu condition. They provide more economical and rapid estimates of properties. The limitation includes poorly defined boundary condition, non-uniform and high strain rates imposed during testing and inability to control drainage condition etc. Despite various limitations both laboratory as well as insitu tests are essential part of any geotechnical design. The Figure (1) depicts the typical disturbed rock mass found at site. A typical rock mass found in the site which mostly comes with joints & discontinuities, fractures, fissures and many other weak planes and explains the complexity with the rock characteristics.

Figure 1. Typical rock mass in the field.

Rock Coring and Logging:-

Obtaining rock core is an expensive affair and should be done carefully. Proper logging methodology need to adopted and should maximise amount of data recorded. It should be presented in a readily understable form and involves the careful systematic logging of rock cores by a qualified engineering geologist. Details about the rock core drilling and sampling may be found out in ASTM standards (D2113-08) "Standard practice for rock core drilling and sampling of rock for site investigation”. The corresponding Indian code IS 9179-1979 Indian Standard method for preparation of rock specimen for laboratory testing. The all sampling and logging operation should be as per the guidelines. Final log should include the general information, borehole number, location and orientation of borehole, drilling technique, contract details, drilling progress, drillers daily record, flush returns and standing water levels.

State of recovery of core need to properly recorded. Systematic rock sample description and rock grade classification is important. Expensive information may be lost if cores are not properly labelled in core boxes. Core boxes must be sound and robust (Figure 2). Usually rock cores are heavy, so must be an appropriate size to be handled by two people. The boxes are made 1.5m long and should be made of hard board for durability. Core box reads as a book i.e. shallow core start at top left and boxes must have site name, borehole

number, contractors name and contract. Labels should appear on the box lid plus on the side. State of recovery of the core is dependent on the drilling methods used and needs to be taken into account when analysing core recovery.

Figure 2. Picture showing core box with cylindrical cores as recovered

DREAM

One of the biggest rock core in the world at AECL URL in Canada (2002). ~ 1m

Rock cutting from Pohang EGS site. ~few mm

REALITY

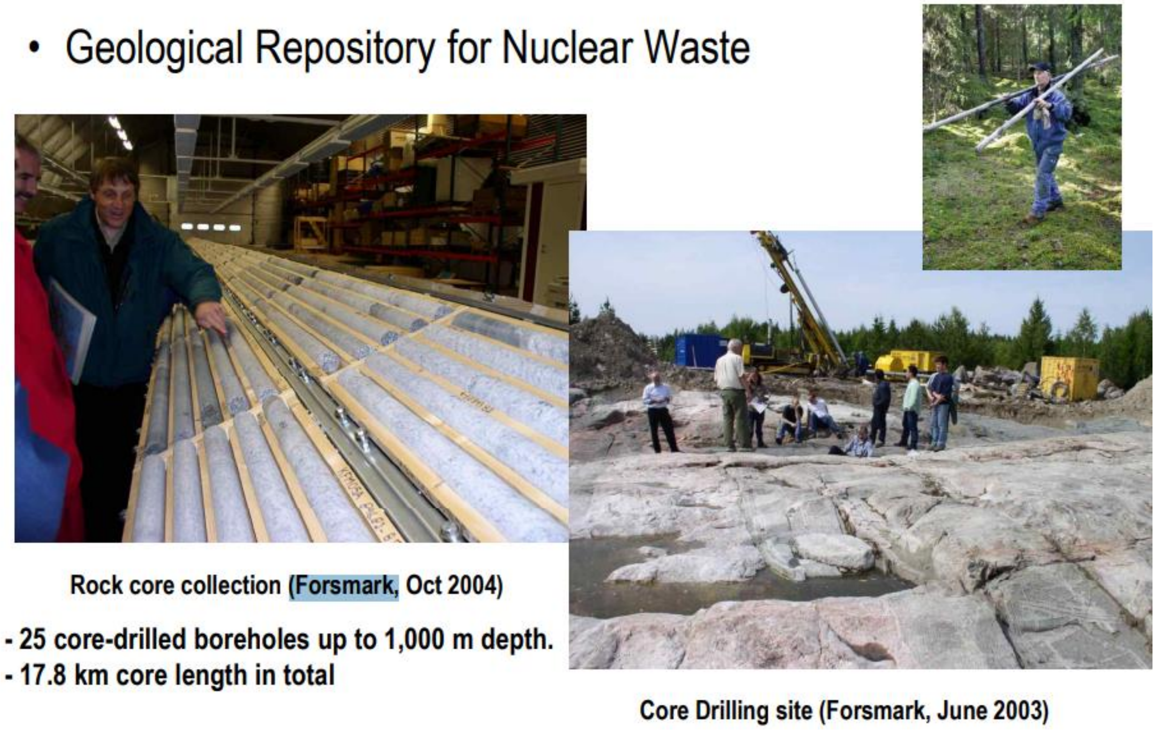


Figure 3. Rock core collection and Core Drilling site (Forsmark, Sweden)

The state of the rock recovered is a valuable indicator of the in situ conditions and mass behaviour. Logger decides on how to split the core into zones associated with different fracture spacing. The term total core recovery- it is the percentage of the rock recovered during a single core run and gives indication of material that has been washed into suspension of the presence of natural voids. Solid core recovery- percentage of full diameter core recovered during a single core run and gives indication of fracture state. Identification of man-made fractures (Figure 4) can be made with proper visual inspections. Natural discontinuities will normally be planar, discoloured and weathered. They usually form in sets and sometimes found to be in filled. Man made fractures will normally be looks irregular, fresh usually random.

Figure 4. Drilling induced fractures

Once the rock samples are recovered and the specimens are prepared, laboratory studies can be conducted. Basic rock parameters which are commonly derived from laboratory investigations for design application are mostly deformation modulus, compressive strength (intact and rock mass), shear strength characteristics (cohesion and friction), tensile strength and time dependent properties. The deformation modulus in the field helps in calculating the settlement and can be determined commonly using plate load test or pressure meter test. The compressive strength for intact rock as well as for the rock mass is helpful in calculating the bearing capacity of footing and may be estimated with the compressive strength test. Shear strength properties helps in finding out the shearing resistance of the interface of the structure and the foundation rock and also to check the stability of sliding block to avoid any shear failure. Tensile strength would help if there is stiffer layer underlying a weaker layer in the foundation strata, which may lead to flexural or punching failure. Many a time, settlement occurs with time as a result of rock creep or degradation due to weathering and hence need to be assessed the time dependent behavior of rock mass. A complete rock mass classification is also needed for the overall understanding the rock mass characteristics. The site characterization should include details on the structural discontinuities, joints and weakness plane, water table and other geological abnormities and need to be assessed carefully. Strength degradation on saturation and pore pressure effect need to be checked to know the stability during rains when the water table heights are relatively high. For such structures, stability against uplift force also needs to be checked.

2- Mechanical Properties of Rock:-

Rock mechanical properties, such as strength (compressive, tensile and shear), Young’s modulus, and Poisson’s ratio, play an important role in wellbore stability, fracture prediction, and other engineering techniques.

Mechanical properties of rocks are usually measured using static and dynamic methods. Static methods are generally conducted in the laboratory with specific test equipment that contain core specimens. The specimens are continuously compressed until failure occurs. Stress-strain curves are simultaneously recorded using a computer and mechanical parameters can be obtained from the curves.

Dynamic methods are usually calculations of compressional wave velocities (VP) and shear wave velocities (VS), which can be obtained from logs or in the laboratory. Abundant studies regarding the differences between static and dynamic methods have demonstrated that static methods are more direct and realistic, while dynamic methods are easier and more continuous.

In most cases, the rock mechanics information is obtained from tests on borehole core, so it is essential that the drilling report and borehole core logs are correctly completed and available. In natural materials such as rock, it is important to know and understand its properties and behavior at the loading processes.

Analysis of mechanical properties are done using the stress-strain curve (figure 5). Stress is defined as the applied force per unit of area. Usually all failures can be qualified as certain stress quantities. Materials can be stressed at the same time by different types of stress. Stress is a tensor quantity, which means that it has magnitude, direction and “the plane under consideration”.

Under the influence of the forces, materials tend to deform. At compression, the axial length reduces while the diameter expands. When materials tend to elongate at tension, the diameter contracts. This phenomenon is called Poisson effect and termed, Poisson’s ratio. Mathematically expressed as:

$$v = \frac{\varepsilon l}{\varepsilon a}$$

Where v is the Poisson's ratio, εl is *lateral strain*, εa is *axial strain*

The axial strain is a ratio of change in length to initial length and it is expressed as:

$$\varepsilon a = \frac{\Delta l}{l}$$

Where εa is the axial strain, Δl is *change in mea ured axial length* and l is the original measured length

The lateral strain is the ratio of the change in diameter to the original undeformed diameter. It can be expressed as:

$$\varepsilon l = \frac{\Delta d}{d_0}$$

Where εl is the lateral strain, Δd is change in diameter and d_0 is the original diameter.

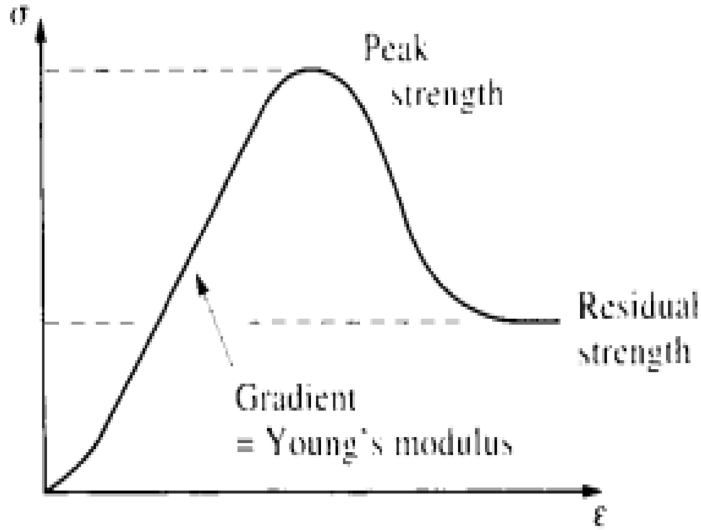


Figure 5. The complete stress-strain curve illustrating various mechanical parameters (Harrison and Hudson, 1997).

Researchers have investigated the effects of factors on the complete stress-strain curve and hence, mechanical properties of rocks. The elastic modulus increased with the ratio of specimen height to diameter and strain rate, whereas the Poisson's ratio was independent of these two factors. With regards loading conditions, stated that the compressive strength exhibited a positive correlation with strain rate, while the stress damage index hardly depended on strain rate. The physical and mechanical properties of limestone and granite under different temperatures. They pointed out that the tensile strength of rocks decreased with increasing temperature, and the strength became much low for a temperature above 600oC. Understanding these variables, enhances the prediction of mechanical behaviour of rock under conditions which may differ from those under which a specimen of the same rock was tested in the laboratory.

The process of rock failure is extremely complex and not subject to convenient characterization through simplified models. It may be either in terms of the precise details of each microcrack initiation and propagation, or in terms of the total structural breakdown as many microcracks propagate and coalesce. It is established that stress has been traditionally regarded as the ‘cause’ and strain as the 'effect' in materials testing. As consequence, early testing and standards utilized a constant stress rate application. Failure criteria have been developed to assist engineers in understanding failure properties and be able to predict when a rock is likely to fail.

Will explain the compressive strength, Brazilian tensile strength, Young’s modulus and Poisson’s ratio for cylindrical and discs specimens.