ROCK EVALUATION FOR ENGINEERED FACILITIES

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An engineering classification system was designed for intact rock samples based on simple index tests that could be used to categorize Kentucky surface and near-surface rock types and to assist Kentucky Department of Transportation personnel in planning for transportation facilities. While the literature survey was being conducted, several facts became apparent: (a) A large number of geologic and technical and general and specific rock classification systems already existed; (b) an equally large number of index tests had been devised; and (c) there was a lack of communication among geologists and civil and mining engineers involved in specialized areas of rock-related work and, to some extent, among individuals within each field. It was evident from a careful study of existing classification systems and index testing procedures that developing yet another specialized classification system with associated index tests would not be a significant contribution. It was decided, therefore, to concentrate on development of an overall rock evaluation schema that, although useful for a specific purpose, would avoid the undesirable disparate characteristics of narrowness or overgeneralization prevalent in many classification systems and that would be developed so that accumulated information could be systematically stored for easy access and use. It was apparent that full development and implementation of a program of this nature would require further studies and cooperation of many individuals and organizations. Such a program, properly developed and used, would substantially contribute to an advancement, and a delineation of the schema and guidelines for its implementation would be a worthy goal.

•THE need for comprehensive information on the characteristics and behavior of earth materials has been recognized for many years, perhaps for as long as significant construction has taken place in and on the surface of the earth. Recently, however, the magnitude and complexity of engineered construction have greatly increased and have resulted in a corresponding increase in the need for information on the engineering properties of soil and rock materials. Direct testing of soil and rock can be used to furnish necessary information. However, both field and laboratory testing can be extremely expensive, particularly when testing must include applications of stress to large masses of earth material. For this reason, significant technical and economic advantages can be realized through the development of indirect or shortcut methods for obtaining indications of the properties and characteristics of geologic materials.

Some years ago, the value of topographic maps, aerial photographs, pedologic descriptions, and geologic surveys in characterizing soil materials was realized. To make this information useful for engineering studies, a serious effort was initiated to obtain data on the engineering properties of various soil groups and associations based on geologic and pedologic surveys. The correlation of performance data with information on areal distribution and location based on the surveys has proved extremely valuable in the planning and construction of facilities in and on soil.

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Recently, the size and importance of structures and facilities designed by engineers and architects have greatly increased. This has produced an increased interest in the rock materials underlying surficial soil layers. A clear need has arisen for a program to provide an engineering evaluation of rock materials for the purposes of location, design, construction, and maintenance of engineered facilities. However, a serious gap exists in the association of engineering characteristics with rock units identified from geologic classifications. Therefore, there is a need for the development of a comprehensive evaluation program that permits use of existing data and that helps in the procurement of necessary information on engineering characteristics of rock.

SCOPE OF STUDY

The initial work plan included development of a classification system based on index tests. An investigation of previous works in classification of rock on the basis of index tests showed that a variety of classification systems using many different index tests had been developed. However, this survey showed that no general applicable system had been developed and that little communication had been established between field investigators, facility designers, and those in charge of construction and maintenance of facilities. Therefore, the initial work plan was modified to include the development of a comprehensive methodology for evaluation of rock. The development of such an evaluation schema was to include the establishment of an information bank to provide access to collected data by any interested individual. A survey of the categories of information on geologic materials, particularly rock strata, was undertaken. On the basis of this investigation of existing data, a method was devised to collect, categorize, and present more extensive data on rock materials. The general schema for the evaluation program was then developed. Currently, research is continuing to test and verify the validity of the evaluation program that has been developed. A final step in this effort will be a full implementation of the rock evaluation program for project planning in Kentucky.

GEOLOGIC INFORMATION

Any study of rock materials must rely at least in part on a background of geologic information. For several hundred years, geologists have investigated rocks of the earth surface, attempting to organize and codify rock units so that their origin, genesis, and transformation can be properly understood. This work is of tremendous significance for engineering studies of rock materials. Earth materials of concern to the engineer exist in a geologic environment. These materials possess physical characteristics that are a function of their mode of origin and the subsequent geologic processes that have acted on them. These events in geologic history lead to a particular lithology, to a particular set of geologic structures, and to a particular in situ state of stress. In the planning, design, construction, and maintenance of engineered facilities, geologic structures, distribution of rock types, and variations in existing states of stress in rock materials have significant influence. A familiarity with local geologic conditions and information is valuable because results of past studies and investigations can be incorporated into an information system. This local geologic information can be used to ensure that tests selected for classification purposes are compatible with the rocks encountered in a study area. Geologic structures and materials that have exhibited unfavorable characteristics or that are potential sources of trouble can be quickly located. Moreover, knowledge of in situ stresses can be extremely useful in design, and a knowledge of existing geology in an area under study can provide assistance in the planning and conduct of a testing program for a particular project at a particular site.

In the development of the rock evaluation program for Kentucky, the geology of the state was reviewed, and existing geologic information was organized and codified to provide easy access for engineers and technicians not well versed in the topic. We recommend that such an organization of geologic information be carried out as a primary step in developing any rock evaluation program in other geologic areas.

ROCK CLASSIFICATION

The organization of geologic information as described above illustrates the basic purpose of any rock classification system: the transfer of information on rock properties from laboratory or field investigators to design engineers and contractors. The optimum means for such transfer of information would be the conduct of tests on rock in its native environment to simulate any proposed construction activity. Behavior of the rock under simulated construction conditions could be monitored, and predictions concerning behavior during construction and subsequent operation of the prototype facility could be made. However, the expense of large-scale testing of in situ rock is such that this approach is not economically feasible. For this reason, inexpensive indirect tests are desirable. If such tests can be developed and used to indicate indirectly the behavior of rock materials under actual construction and operating conditions, great economies can be realized not only in exploration and testing but also in design and construction. When index testing of samples of material taken from a particular site has been used and when performance has been predicted on the basis of test results and a knowledge of differences between the laboratory test conditions and actual field conditions associated with the proposed facility, considerable success has been attained in the investigation of soil materials, and, to a lesser extent, in studies of rock materials.

The primary difficulty in using index tests for rock characterization is that large samples would be required to test a representative mass of material. Discontinuities located at significant spacings and changes in characteristics of material over long distances would require testing of large specimens, and this cannot be done economically. Therefore, evaluation of rock properties on the basis of index tests must always be considered as a superficial investigation limited by physical and mathematical continuity. Large-scale rock discontinuities and structural features cannot be preserved in laboratory specimens. These discontinuities and inhomogeneities greatly affect rock deformation and failure in the field. A significant degree of uncertainty will always exist in any prediction of field behavior based on index test results. Nevertheless, index tests can serve as useful indicators of rock behavior, especially in the location and preliminary planning stages. For this reason, we have given considerable attention to selecting index properties and to using such properties in the classification of rock materials. Index tests must be characterized by simplicity, economy, and ease of performance. Additionally, index test results must be reproducible, within reasonable limits, by various practitioners in various locations who use standardized equipment and procedures. Most importantly, the test property must be an index of a material or mechanical property that the design engineer can use effectively.

Many geologic classification systems for rock have been proposed. In general, these systems emphasize properties and characteristics of intact material and neglect discontinuities and possible sources of weakness in rock masses that are of critical importance in engineering activities. The most widespread geologic classification of rock has been based on genesis, and rock materials have been divided into igneous, sedimentary, and metamorphic categories. Within these categories, various subclasses have been developed based on petrographic studies that include characterization of the texture and mineralogy of the rock. In addition to genetic and petrographic classifications, geologists have developed chemical classification systems for rock material that are of limited applicability in engineering studies. Basic genetic classifications have been useful when they could be correlated with the engineering properties of the rock materials; however, genetic classifications are not sufficiently specific and quantitative for engineering applications.

Physiographers and geomorphologists have developed systems for classifications of landforms that have proved to be useful as indicators of properties and structures in underlying bedrock. Physiographic classification systems of surficial terrain have proved useful in the location, planning, design, and construction of transportation facilities. The general qualitative character of most geological classification systems has been modified to yield a quantitative methodology of terrain description in the pattern-unit-component-evaluation (PUCE) system developed in Australia. The PUCE system appears to be a useful transitional step between purely qualitative geologic classifications and quantitative engineering classification systems for rock.

A number of engineering classification systems have been developed for rock materials. Some of these systems are based on inherent rock characteristics, others are based on a particular purpose or use for the rock, and some are based on a combination of inherent characteristics and intended uses. A review of existing classification systems indicated that strength, lithology, anisotropy, and durability can be used to characterize the properties of an intact sample. These characteristics are shown in the form of a classification system in Table 1.

A variety of tests have been proposed as indicators of rock strength. Uniaxial compressive tests have been used in rock classification systems, and hardness tests and various penetration tests have been used as indicators of rock strength. Compressive strength tests require machined specimens and thus are somewhat costly in terms of sample preparation. Hardness tests appear to be subject to variations in testing techniques. The point-load strength index has been selected as a measure of tensile strength; empirical results show excellent correlation between this index and the unconfined compression strength of rock materials.

The lithology of rock materials does not have a direct bearing on mechanical properties, but traditional geologic rock names based on the texture, mineral content, structure, particle size, and cementing matrix yield significant information on the relation between an intact sample and the rock mass from which the sample was taken. Knowledge of rock lithology can provide an intuitive feeling for the character of the rock mass and can suggest mass effects that may be common to certain groups of rocks.

Almost all rock materials show directional differences in their responses to applied stresses and environmental conditions. For this reason, anisotropy of an intact specimen is of significant interest. We have selected point-load test results to define the strength anisotropy index as the ratio between maximum and minimum strength values. In general, this ratio is established by performing the point-load test on specimens oriented so that the load first is applied parallel to the planes of weakness in the specimen and then is applied perpendicularly to those planes.

Behavior of rock materials under long-term changes in environmental conditions can be of significant importance to engineering projects. Durability tests have been used to characterize earth materials as soil or rock and to indicate susceptibility of rock material to alteration in a weathering environment. A large number of durability tests have been suggested by other investigators; swell tests and slake-durability tests have been commonly used. The most successful classification scheme for transitional materials with characteristics intermediate between those of true soils and true rock appears to be that developed by Gamble (14). We have modified this work to yield the system shown in Figure 1. This classification system uses values of plasticity index and two-cycle slaking durability. All samples with a low plasticity index and durability values greater than 95 percent can be considered rock materials.

Intact sample testing and classification may be sufficient for preliminary planning and location studies, but the design of facilities will require more comprehensive and direct testing of rock materials and will necessitate examination of in situ conditions. To satisfy this need, some sort of in situ classification system is required. Many classification systems have been developed by previous investigators, and relatively few are generally applicable in situ classification systems, which for the most part, have been evaluation schemes used at particular sites for specific purposes (e.g., for tunneling or blasting requirements).

It appears that the greatest success has been attained by combining tests on intact samples with an analysis of field conditions that tend to govern the behavior of rock materials. Upper limits for strength and deformation resistance may be established on the basis of laboratory tests on intact samples, and these values may be reduced (adjusted) on the basis of field tests that show the influence of discontinuities and weathered zones. Rock models have been prepared to allow an assessment of rock behavior under conditions associated with construction and operation of a proposed facility. The basis of these modeling studies has been, in most cases, a comprehensive survey of discontinuities present at the proposed site of a facility. Since joints are the most widespread discontinuities in rock, in situ classification systems often

Table 1. Proposed intact sample classification system.

Class Number	Tensile Strength: Description	Tensile Strength: Point-Load Index[a] (MPa)	Anisotropy: Description	Anisotropy: Strength-Anisotropy Index[b]	Durability: Description	Durability: Slake-Durability Index[c] (percent)	Lithology: Description	Lithology: Symbol[d]
1	Very strong	>10	Isotropic	1.0 to 1.2	Very durable	>50	Sandstone	SS
2	Strong	3 to 10	Slightly anisotropic	1.2 to 1.5	Durable	25 to 50	Shale	SH
3	Moderately strong	1 to 3	Moderately anisotropic	1.5 to 5.0	Moderately alterable	10 to 25	Limestone	LS
4	Weak	0.3 to 1	Anisotropic	5 to 20	Alterable	5 to 10		
5	Very weak	<0.3	Very anisotropic	>20	Highly alterable	<5		

Note: 1 in. = 25.4 mm. 1 psi = 6895 Pa.

[a]Force at failure/square of distance between loaded points in test method (10).
[b]Maximum strength/minimum strength.
[c]Percentage retained on 2-mm screen after slaking in a test (13).
[d]1-LS-2-1 indicates a very strong, slightly anisotropic, very durable limestone.

Figure 1. Durability-plasticity classification for shales and other argillaceous rocks.

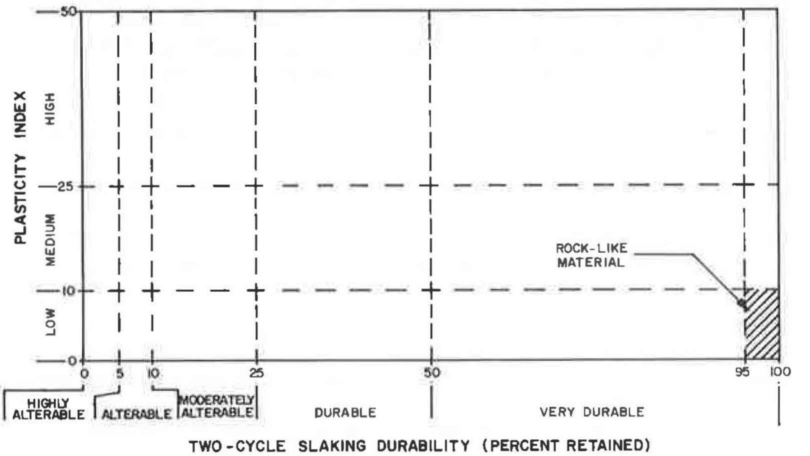

Table 2. Proposed in situ rock classification system.

Class Number	Bedding Thickness: Description	Bedding Thickness: Size (mm)	Joint Spacing: Description	Joint Spacing: Size (mm)	Joint Frequency: Description	Joint Frequency: Joints per Meter	Joint Infiltration Material[a]	Gross Heterogeneity: Description	Gross Heterogeneity: Permeability (nm/s)	Intact-in Situ Reducti Factor[a]: Degree of Correlation	Velo Ratio
1	Very thin	<10	Very close	<10	Very low	<0.3	Air	Very low	<1	Excellent	>0.8
2	Thin	10 to 50	Close	10 to 50	Low	0.3 to 1.0	Water	Low	1 to 10	Good	0.6 t 0.8
3	Medium	50 to 300	Moderately close	50 to 300	Medium	1 to 2	Cohesion-less soil	Medium	10 to 100	Fair	0.4 t 0.6
4	Thick	300 to 1,500	Wide	300 to 1,500	High	2 to 4	Inactive clay	High	100 to 1,000	Poor	0.2 t 0.4
5	Very thick	>1,500	Very wide	>1,500	Very high	>4	Active clay	Very high	>1,000	Very poor	<0.2

Note: For lithology description and symbol see Table 1. 1 ft = 0.3 m. 1 in. = 25.4 mm.

[a]Subject to modification with further testing. [b]In situ sonic velocity/intact specimen sonic velocity.

include a comprehensive joint survey program. On the basis of a review of existing in situ classification systems, we have developed a classification system (Table 2). This system is designed to incorporate the effects of discontinuities and mass anisotropy on the characteristics and behavior of the rock. The presence of faults and shear zones has been taken into account by considering these discontinuities and joints in the same way.

PROPOSED ROCK EVALUATION SYSTEM

After the classification systems for intact samples and for in situ conditions were developed, the next step was to create a method for exchange of information in the evaluation system. Results of classification programs would be essentially useless if there were no means to make such information readily available in understandable form to engineers and other investigators involved in design and construction activities. Therefore, a system has been developed to provide engineers with a means to obtain information for site selection, facility design, and construction and maintenance planning. The proposed system consists of two phases: an acquisition segment for the collection and collation of data and an application segment in which collected data can be used in classification programs and can be analyzed with regard to the use of rock materials in various circumstances.

The first segment of the program consists of data acquisition. The central feature of this segment is the data bank in which information from field and laboratory testing and from case histories will be stored. The attributes of the data bank are shown in Figure 2. Information storage is to be accomplished under three categories. Category 1 contains information pertinent to the location, identification, and natural environment from which the data (sample or case history information) originated. Category 2 is provided for storage of results of visual observations, index tests, and detailed tests of rock mechanical properties. Category 3 is for the storage of information from case histories and performance reports from contemporary construction and also from completed facilities.

Procurement of data for insertion under categories 1 and 2 of the data bank will involve both laboratory and field testing techniques. Samples should be selected on the basis of geologic considerations and current availability. Samples should be tested at the site immediately after removal from a core barrel or similar device if at all possible. Since this is not practical in all situations, samples can be returned at their natural moisture content and in an undisturbed condition to a laboratory for further testing. The testing sequence in the laboratory should begin with a swell test and a slake-durability test to provide immediate differentiation between soil and rock materials. The remainder of the information for storage in category 2 of the data bank can be obtained through index testing and refined laboratory or large-scale in situ tests.

Case history information for inclusion in the data storage system generally cannot be easily quantified. However, a concise version of empirical information can be placed in a coded reference file. The code and identification of site or formation investigated can be entered in the data bank so that when a search is made the existence of this information will be made known to the investigator, who can then conduct further searches for the detailed information on previous experience at a given site or in a particular formation.

The data bank will consist of a system of computer files arranged according to categories 1, 2, and 3. Computer programming will be used to facilitate storage, retrieval, and use of acquired information. A sample showing the methodology for storage and retrieval of category 1 information is shown in Figure 3. The same methodology has been followed for category 2 and category 3 data.[1]

[1] Illustrations of the transfer of information to positions on a computer data card are available in Xerox form at cost of reproduction and handling from the Transportation Research Board. When ordering, refer to XS-58, Transportation Research Record 548.

Figure 2. Data bank attributes.

- CATEGORY 1
  - LOCATION
    - STATE
    - COUNTY
    - PHYSIOGRAPHIC REGION
    - USGS QUADRANGLE NUMBER
    - LONGITUDE
    - LATITUDE
  - SAMPLE IDENTIFICATION NUMBER
  - MAJOR GEOLOGICAL FORMATION
  - ROCK TYPE (GENERIC)
  - GROUND ELEVATION
  - SAMPLE ELEVATION
  - WATER TABLE ELEVATION
  - SAMPLE ORIENTATION w/r GROUND SURFACE
  - SAMPLE ORIENTATION w/r BEDDING PLANE
  - METHOD OF OBTAINING SAMPLE
  - RELEVANT COMMENTS
- CATEGORY 2
  - INTACT
    - VISUAL
      - COLOR
      - TEXTURE
      - STRUCTURE
      - GRAIN SIZE
      - CALCIUM CARBONATE CONTENT
    - INDEXING
      - FREE SWELL
      - SLAKE DURABILITY INDEX
      - POINT-LOAD INDEX
      - STRENGTH ANISOTROPY INDEX
      - LITHOLOGY
      - STRENGTH SOFTENING
      - TIME-STRAIN BEHAVIOR
    - PHYSIO-MECHANICAL RESULTS
      - LABORATORY SONIC VELOCITY
      - SHORE SCLEROSCOPE HARDNESS
      - SCHMIDT "L" HAMMER HARDNESS
      - UNCONFINED COMPRESSIVE STRENGTH
      - TANGENT MODULUS
      - NATURAL WATER CONTENT
      - SATURATION WATER CONTENT
      - APPARENT SPECIFIC GRAVITY
      - BULK SPECIFIC GRAVITY
      - APPARENT POROSITY
      - APPARENT VOID RATIO
      - BULK SPECIFIC GRAVITY (SSD)
      - DEGREE OF SATURATION
      - VOID INDEX
      - DIRECT SHEAR PHI ANGLE
      - DIRECT SHEAR COHESION
      - DIRECT SHEAR TIME TO FAILURE
      - TRIAXIAL COMPRESSION PHI ANGLE
      - TRIAXIAL COMPRESSION COHESION
      - LOS ANGELES ABRASION
      - DEVAL ABRASION
      - TRETON IMPACT
      - FRACTURE ENERGY
      - COST ANALYSIS DATA
      - STRENGTH COEFFICIENT OF VARIATION
      - SCALE EFFECT
      - MINERALOGICAL COMPOSITION
  - IN SITU
    - MASS DESCRIPTION (INDEXING)
      - ROCK QUALITY
        - BEDDING THICKNESS
        - JOINT SPACING
        - JOINT FREQUENCY
        - JOINT INFILTRATION MATERIAL
      - GROSS HETEROGENEITY
      - VELOCITY RATIO
    - JOINT ORIENTATION
    - JOINT SURVEY
    - SECONDARY INDEXING
      - CORE BORINGS
        - CORE RECOVERY
        - RQD
        - FRACTURE FREQUENCY
        - WEIGHTED CORE LENGTH
      - SCHMIDT HAMMER TEST
    - GEOPHYSICAL SURVEYS
    - FIELD TESTS
    - LANDFORM CLASSIFICATION
- CATEGORY
  - PREVIOUS EXPERIENCE
  - CONSTRUCTION PRACTICES
  - PERFORMANCE MONITORING

Figure 3. Portion of coding instructions for category 1 file subsystem.

CATEGORY 1, IDENTIFICATION DATA SUBFILE
(Data Card No. 1)

ATTRIBUTE	ATTRIBUTE CODE	LOCATION (COLUMN)	FORMAT	INSTRUCTIONS AND REMARKS
State	ST	1 - 2	I2	List the names of the states alphabetically and assign numbers sequentially from 01 through 50. Code number for Kentucky would be 17.
County	CO	3 - 5	I3	List the names of the counties within a state and assign numbers sequentially from 001.
Physiographic Region	PR	6 - 7	I2	Physiographic region from which the sample was obtained 01 Purchase 02 Western Coal Field 03 Western Pennyroyal 04 Eastern Pennyroyal 05 Knobs 06 Outer Bluegrass 07 Inner Bluegrass 08 Eastern Coal Field
USGS Map	MN	8 - 11	I4	USGS number of geologic quadrangle map which encompasses the sample site. Examples No. Map Name 0246 Kirsey 0763 Lovelaceville 1025 Addyston 0000 Crofton (map not published)
Longitude	[illegible]	[illegible]	[illegible]	Longitude of the sample site will be described in terms of degrees and minutes. Seconds of longitude will be rounded to the nearest minute. Examples 82° 34' 17" = 8234 86° 06' 47" = 8607 89° 15' 15" = 8915
Latitude	LAT	16 - 19	I4	Latitude of the sample site will be described in the same manner as longitude.
Sample Identification No.	ID	20 - 24	A5	Columns 20-21 – Last two digits of the year in which the sample was obtained. Column 22 -- Month in which sample was obtained: 1 -- January 2 -- February • • • 9 -- September 0 -- October N -- November D -- December Columns 23-24 -- Specimen number.
Geological Formation	GF	25 - 27	I3	Major geological formation from which the sample was obtained
				Ground elevation at sample site to nearest tenth of a meter.
		- 36	F4.1	Elevation from which sample was taken to nearest tenth of a meter.
	WTE	37 - 40	F4.1	Elevation of water table to nearest tenth of a meter.
Elevation				
Sample Orientation	SOG	41 - 42	F2.0	00 to 90 indicates the angle between the sample axis and the ground surface to the nearest degree.
Sample Orientation	SOB	43 - 44	F2.0	00 to 90 indicates the angle between the sample axis and the major bedding plane to the nearest degree.
Method of Obtaining Sample	MOS	45	I1	1 – NX core 2 – block sample 3 – quarry sawn 4 – hand tools 9 – other (may be further delineated at a future time)
Relevant Comments	RC	46	I1	0 – no comments 1 – relevant comments available
	FREE1	47 - 48	I2	Blank (may be designated at a later time)

Use of the information stored in the data bank can be accomplished through the development of specific classification and application programs. However, a generalized classification can be obtained by using the systems given in Tables 1 and 2. For specific purposes, such as the analysis of rock formations for suitability in tunneling operations, a more detailed classification system could be developed. Acquired information can be used in the classification of rock materials and could be further used through the development of a series of use tables. In such a table, a number of uses (e.g., aggregate and rock fill) for rock materials are shown. The four indexes used for classification of rock materials can be quantified in terms of acceptable values for the rock material for use in any one of the ways given in the table. If a rock is to be used as aggregate in a highway construction project, acceptable values of the point-load index, lithology, strength anisotropy index, and slake-durability index can be developed. Then, any rock available for use in a particular project as aggregate can be tested, and the test values obtained for that rock can be compared with the ranges of acceptable values given in the table. In this way, the acceptability of various rock units for use in different ways can be quantitatively evaluated. Use tables can be developed for particular applications. For example, Franklin developed a diagram in the form of a use table that showed the ease of excavation of rock by blasting, ripping, and digging. The diagram was based on ranges of point-load index and fraction frequency. Use tables represent quantitative criteria developed from behavioral models of rock masses.

Use tables and the classification system can be combined in the application segment of the rock evaluation program. A user can request information from the data bank through a selected classification system and use table. The information retrieved from the data bank can be processed in the classification system, and a particular site or a particular rock unit can be evaluated for specific uses. The user must then evaluate the data obtained from the data bank. In general, the user must decide whether or not sufficient data have been obtained for the evaluation of a particular site as the location of a proposed facility. If sufficient data have been obtained, they will allow the user to decide whether or not the particular site under investigation is suitable for the proposed activity. If the site is not suitable, it can be abandoned. If the site is suitable, the user can then indicate that design and construction operations are appropriate at this site. If the user decides that insufficient data are available on the characteristics of the rock units at a particular site or under a particular stress environment, he or she may then specify the performance of additional tests to furnish required information. On the basis of these additional tests, the user may decide that the site is unsuitable for the planned activity or may elect to proceed with design and construction. During construction phases, performance of the rock units at a particular site should be monitored and evaluated. This information can then be returned to the data bank as case history information. After construction is completed, performance of the engineered facility and the rock units adjacent to that facility should be monitored. This performance monitoring also furnishes data that will be valuable in the location, design, and construction of other facilities. For this reason, performance monitoring data should be returned to the data bank as case history information. Ideally, the proposed rock evaluation program will be a self-sustaining, ever-expanding source of valuable information concerning the engineering properties and behavior of rock materials.

SUMMARY

Rock engineering includes a number of significant major operations: engineering analysis and interpretation of geologic information, prediction or determination of engineering properties of rock masses for use in analysis and design, and implementation of completed designs through construction activities in or on rock. Individuals drawn from various professions and disciplines are involved in these facets of rock engineering. To facilitate communication among these individuals and to assist in all facets of rock engineering, a rock evaluation program has been proposed.

This evaluation program is especially useful for the planning, design, and construction of transportation facilities in and on rock. Data on engineering characteristics of

rock units are used in a classification program. The classification program includes characterization of rock units based on tests on intact samples and on evaluation of in situ rock properties. Classifications can be modified for particular types of projects, and use tables can be developed for the evaluation of rock units for use in specific purposes. A computerized system for the storage and retrieval of information has been developed. Data for inclusion in the information bank are derived from laboratory and field testing and from monitoring rock behavior during construction and subsequent operations of completed facilities. Current study efforts are directed toward verifying and improving the methodology set forth in this preliminary development of the rock evaluation program. It is hoped that development of this program will be significantly helpful to individuals engaged in rock engineering and, in particular, to individuals concerned with the planning, design, construction, and maintenance of transportation facilities in and on rock.

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