Paper No. 810

GEOTECHNICAL CHARACTERIZATION OF PRECAMBRIAN LIMESTONE AT A CEMENT PLANT SITE IN ISKANDARABAD

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By

Sohail Kibria[1], Muhammad Ali[2] and M. Umar Aziz Khan[3]

Abstract

The geology and geomorphology of rock formations has a lot of bearing on their geotechnical characteristics. In Pakistan, a variety of rock formations exist ranging from very soft to very hard rock, across the country from north to south.

Recently, extensive geological and geotechnical studies were conducted for the extension of a cement plant by addition of two more lines in Iskandarabad, Pakistan. The sites are characterized by barren mountains with excessive weathering, extremely difficult access, adverse geology and high seismicity. The exhaustive studies included execution of sixty five (65) boreholes up to 55 m depth for Line – III and thirty six (36) boreholes up to 35 m depth for Line – IV. The drilling was mainly carried out in predominantly limestone formation of Precambrian age. In addition, a number of high stiffness pressuremeter tests were also conducted in the boreholes to evaluate the elastic response of limestone beds, for aid in the pile design. The strength and elastic properties of erratic limestone formation were carefully determined on a number of intact specimens in the laboratory.

This paper describes the geological and geotechnical characteristics of limestone formation at site, as a consequence of extensive explorations & establishes very useful first-hand correlations between the elastic modulus, unit weight, rock quality designation (RQD), point load strength index and unconfined compressive strength of rock formation, in extreme geological and seismic environment. These correlations are first of their kind for such limestone and may be used for other projects too, with similar geologic conditions.

Introduction:

Geotechnical evaluation of a cement plant site has to be exhaustive in nature, so as to reveal the engineering characteristic of the site as well as problematic ground conditions. Very detailed geotechnical investigations were planned at a premier cement plant site in Iskandarabad recently, keeping in view the size and loading of plant facility and the geology at site. The huge quantum of drilling was accomplished by using wireline straight rotary drilling rigs, with NX/NQ/HQ size coring bits and using double / triple tube core barrels, under a strictly supervised manner to ensure high quality of data.

The project location map is shown in Figure-1. The main geomorphic regions in the vicinity of project area can be distinguished from Figure-2 are as follows:

- Tredian Hills (a part of western salt range), Khisor and Marwat ranges in the western and southwestern part of project area;
- Central and eastern salt ranges in south and southeastern direction of project area; and

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- Kalabagh Hills in the north and Potwar Plateau in north, east and northeastern side of the project area.

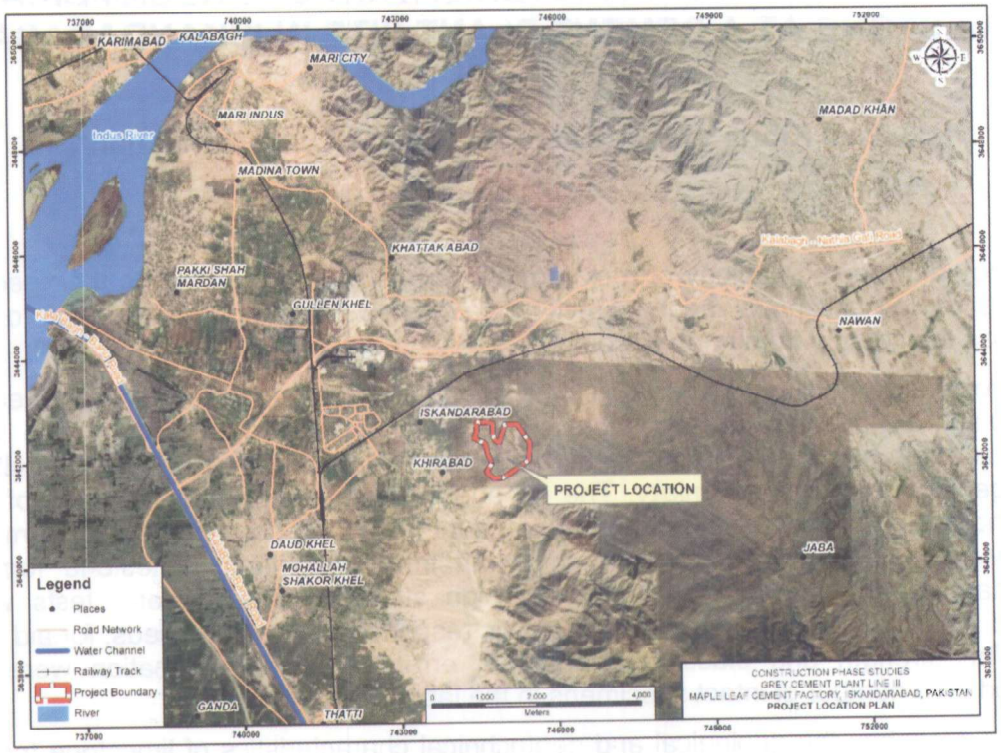


Figure-1: Location of Maple Leaf Cement Factory

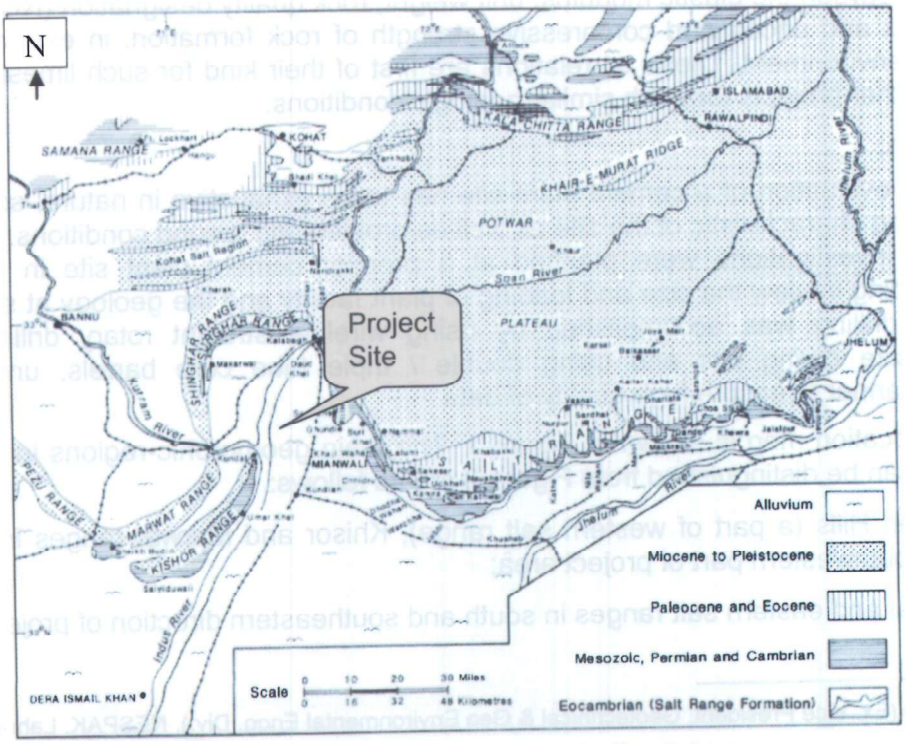


Figure-2: Main Geomorphic Regions Surrounding the Project Area

Regional Geology and Tectonics:

The oldest rock units outcropping in the region are visible in Kalabagh Hills. These belong to the Precambrian Salt Range Formation. Subsurface geology of project area could be visualized from geological section drawn through these Formations (Figure-4). The Formations deposited in the area (Dr. Gee, 1980) from bottom to top are shown in Table-1.

The India-Eurasia collisional event of South Asia begun in middle to late Eocene, producing the world's spectacular Himalayan ranges (Stocklin, 1974 & Stonely, 1974). The northward under thrusting of the Indian Plate underneath the Eurasian Plate have resulted in the formation of a south directed thrust system that constitutes the major tectonic fabric of Pakistan (Powel, 1979). The Salt Range Thrust along with the Trans-Indus Ranges Thrust is the southern most of the Himalayan thrust system of the north Pakistan and places Paleozoic to Eocene platform sequence over the undeformed alluvium covered Punjab Foreland in the south. Right lateral Kalabagh Fault offsets the Western Salt Ranges from its western analogue that is the Trans-Indus Ranges (Figure-3) and is characterized by Quaternary deformation displacing recent terrace deposits, course of Indus River and is considered as active in nature (McDougal and Khan, 1990).

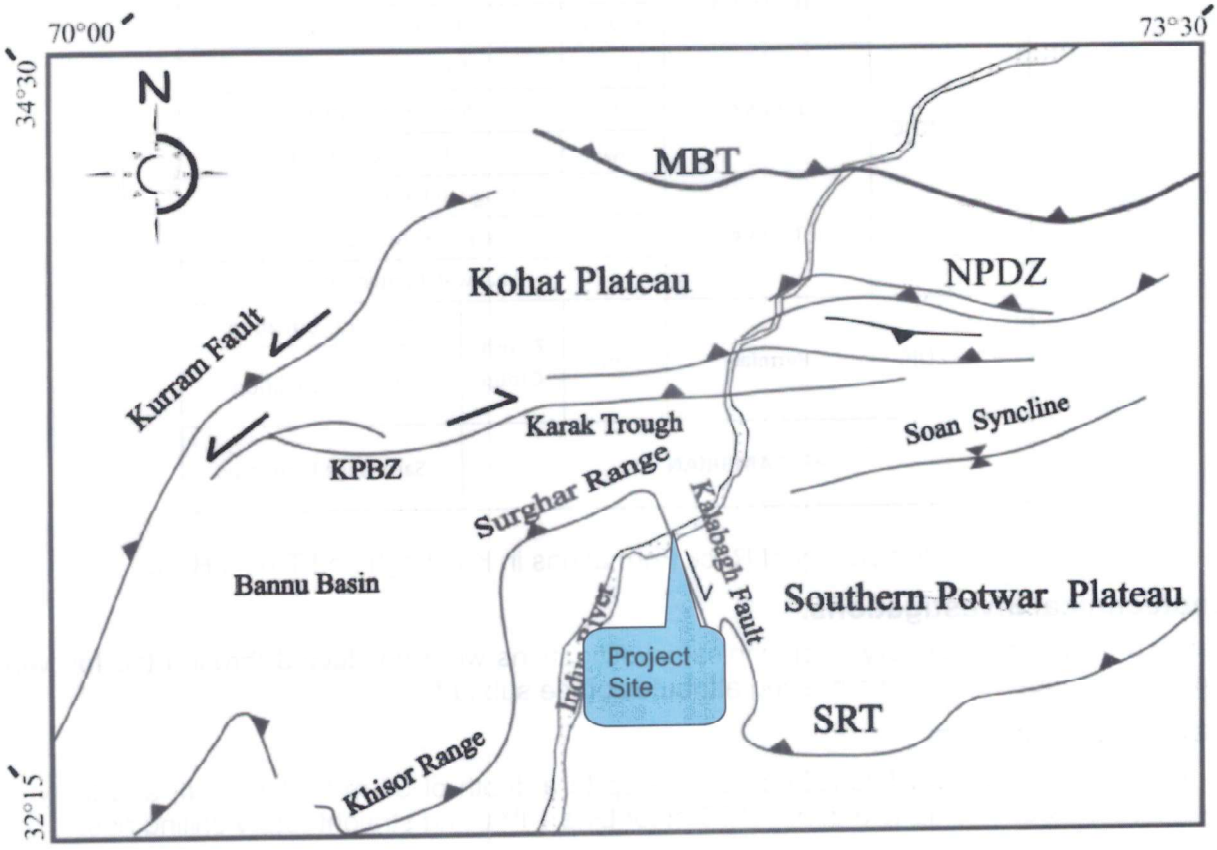


Figure-3: Tectonic Map of Kohat Potwar Plateau

System	Series	Group	Formation
Quaternary	Pleistocene	Siwalik Group	Nagri Formation
	Miocene - Pliocene		Chinji Formation
			Unconformity
TERTIARY	Eocene		Sakessar Formation
			Nammal Formation
	Paleocene		Patala Formation
			Lockhart Limestone
MESOZOIC	Cretaceous	Upper	Lumshiwal Formation
		Lower	Chichali Formation
	Jurassic	Upper	Sama Suk Formation
		Middle	Shinawari Formation
		Lower	Datta Formation
	Triassic		Kingriali Formation
			Tredian Formation
			Mianwali Formation
PALEZOIC	Permian	Late	Zaluch Group: Chhidru Formation
			Zaluch Group: Wargal Formation
PRECAMBRIAN			Salt Range Formation

Table-1: Stratigraphy of Rock Formations in Kalabagh and Tredia Hills.

Geotechnical Investigations:

Detailed field and laboratory geotechnical investigations were conducted through the following process, to study various engineering attributes of the subsurface:

Field Investigations:

- Execution of sixty five (65) boreholes up to a depth of 55 m for Line – III and thirty six (36) boreholes up to a depth of 35 m for Line – IV using straight rotary drilling rigs.
- Pressuremeter testing in the boreholes at 1m to 3m interval, using high stiffness membrane Oyo Elastmeter Pressuremeter.
- Performance of standard penetration test (SPT) and pressuremeter test in the boreholes at 1m interval.
- Collection & preservation of soil and rock samples, where considered necessary.
- Measurement of rock quality designation (RQD) for assessment of rock quality.

- Taking necessary information about groundwater table (GWT).

Laboratory Testing:

- Moisture Content and Density (ASTM D – 2216)
- Uniaxial Compressive Strength (ASTM D – 7012)
- Point Load Strength Index (ASTM D – 5731)
- Brazilian / Tensile Strength (ASTM D – 3967)
- Hoek Shear Test (ASTM D – 5607)

General Lithology for Line – III & Line - IV:

- Overburden material, consisting of Silty Clay / Silty Sand / Poorly graded Gravel, with variable thickness i.e. 0.0 m to 10 m.
- Below overburden material, bedrock mainly precambrian limestone / limestone intercalated with Shale up to maximum drilled depth of 55 m.
- Groundwater not encountered in any of the boreholes.

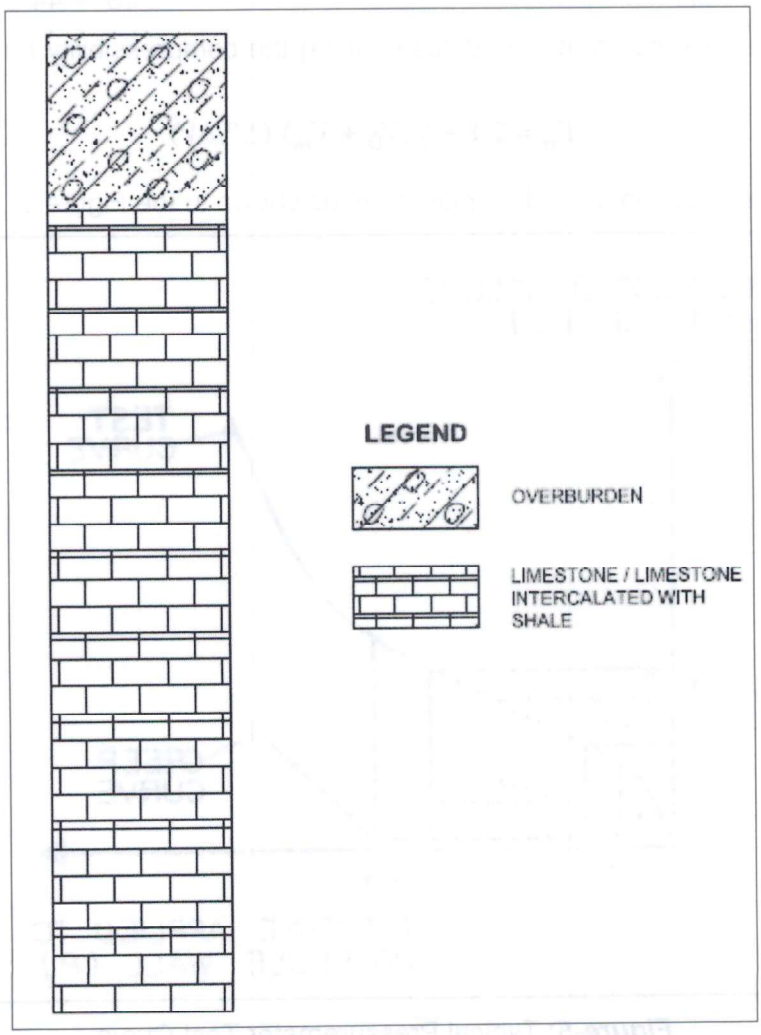


Figure-4: General Lithology of Line-III & Line- IV

Procedure for Development of Correlations:

The field and laboratory data of the tested rock core samples along the two Lines indicated the following range of engineering characteristics:

- Rock Quality Designation (RQD) = 10 – 63 %
- Uniaxial Compressive Strength = 0.1 - 240 MPa
- Point Load Strength Index (I_{S50}) = 0.7 – 6.0 MPa
- Tensile Strength = 2.0 – 14.5 MPa
- Natural Moisture Content = 0.3 – 12.20 %
- Dry Density = 23.0 - 31.0 KN/m^3
- Pressuremeter Modulus (E_p) = 0.45 – 6.1 GPa
- Elastic Modulus (E_i) from Laboratory Tests = 10.0 – 108 GPa
- Undrained Cohesion = 0.02 – 1.1 Mpa
- Angle of Internal Friction = 18° – 44°

It is to be noted that pressuremeter modulus defining the compressibility has been determined as:

$$E_p = 2(1 + \gamma)(V_0 + V_m)\ (\Delta P/\Delta V)$$

The variables in this equation are self-explanatory, as shown in the Figure 5:

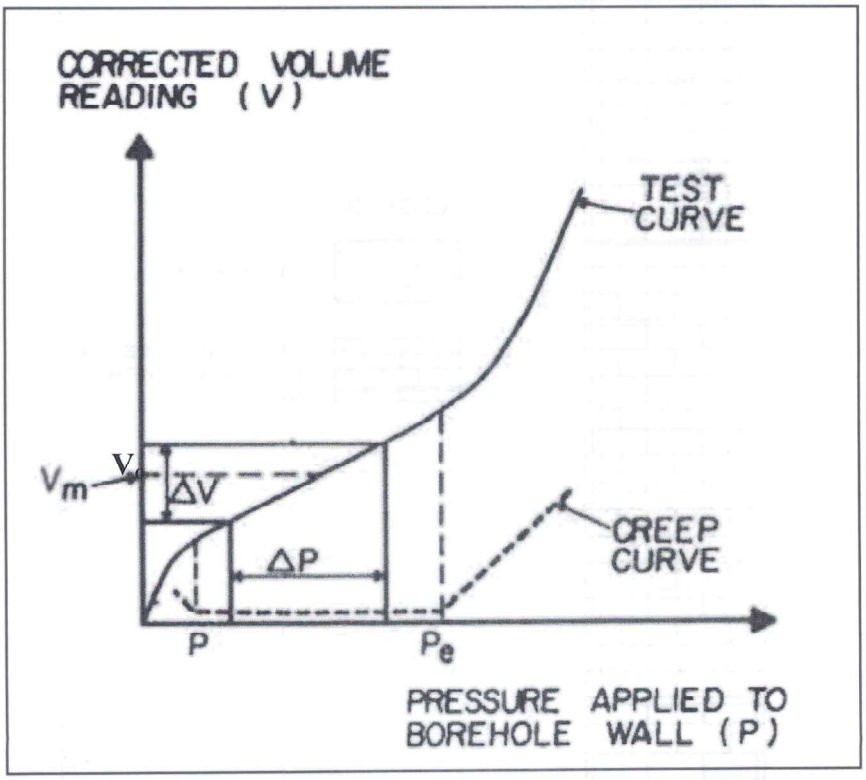


Figure-5: Typical Pressuremeter Test Curve

By comparison of various engineering properties of rock samples, the following trends have been developed. Average graphical trends of data in all the correlations have been shown by linear regression and have been shown in the form of mathematical equations inset in each figure from 6.1 to 6.12.

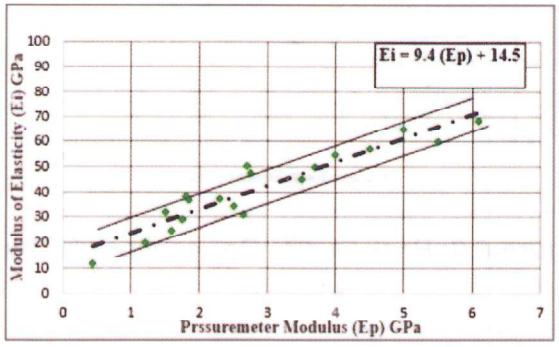


Figure-6.1: Modulus of Elasticity (Ei) v/s Pressuremeter Modulus (Ep)

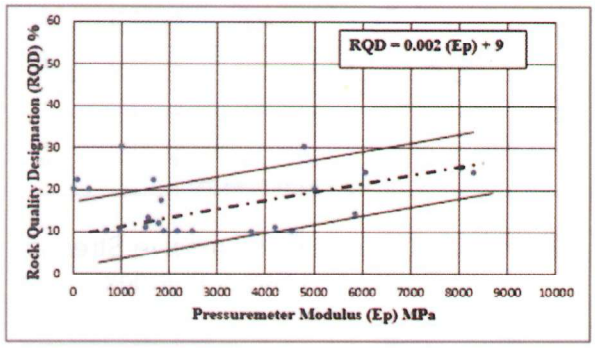


Figure-6.2: Rock Quality Designation v/s Pressuremeter Modulus (Ep)

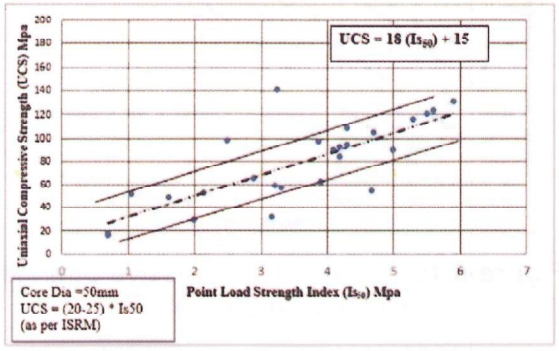


Figure-6.3: Rock Quality Designation v/s Undrained Cohesion

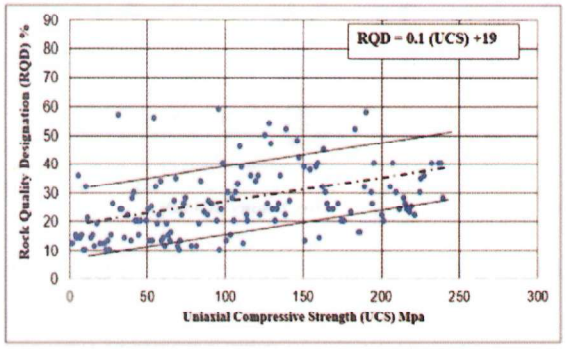


Figure-6.4: Rock Quality Designation v/s Uniaxial Compressive Strength

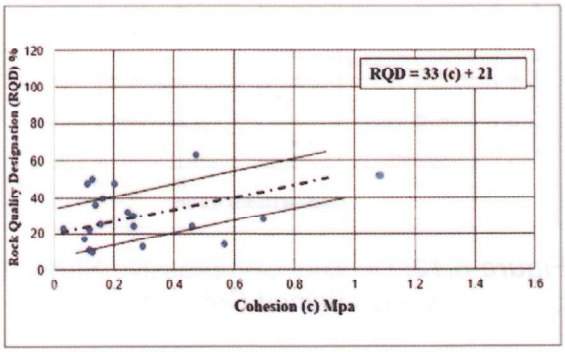


Figure-6.5: Rock Quality Designation v/s Angle of Internal Friction

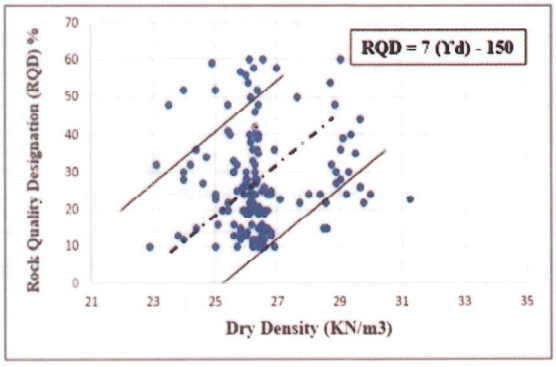


Figure-6.6: Rock Quality Designation v/s Modulus of Elasticity (Ei)

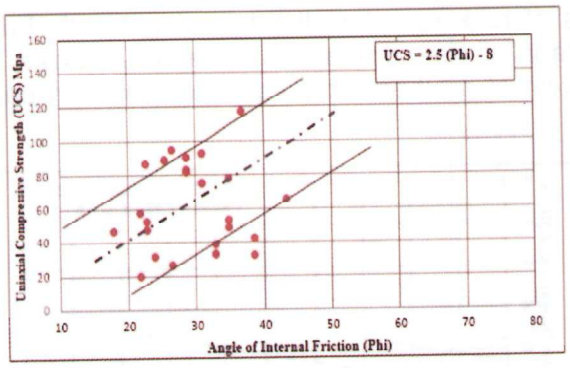


Figure-6.7: Uniaxial Compressive Strength v/s Point Load Strength Index

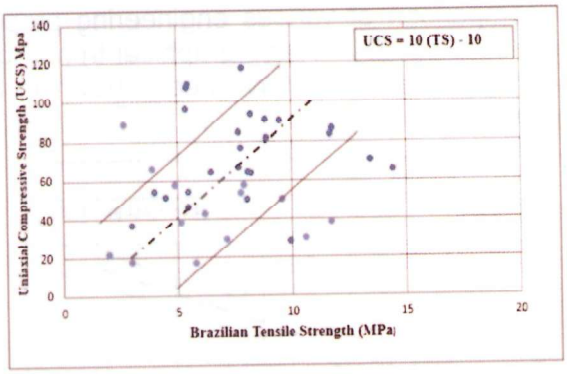


Figure-6.8: Rock Quality Designation v/s Dry Density

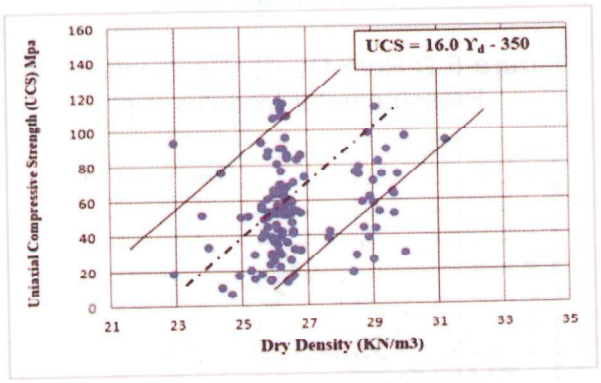


Figure-6.9: Uniaxial Compressive Strength v/s Dry Density

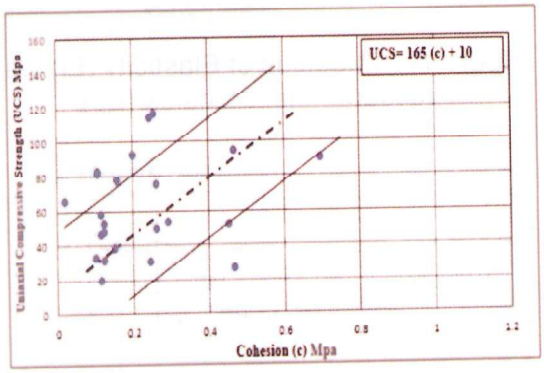


Figure-6.10: Uniaxial Compressive Strength v/s Tensile Strength

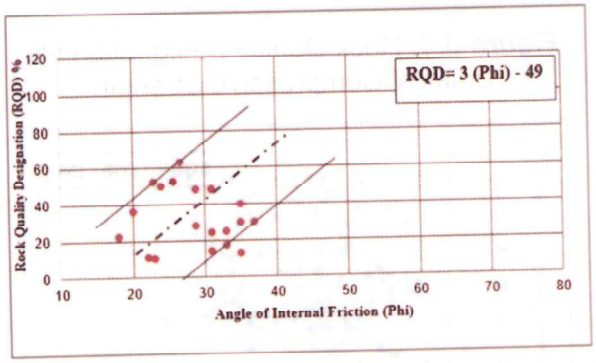


Figure-6.11: Uniaxial Compressive Strength v/s Angle of Internal Friction

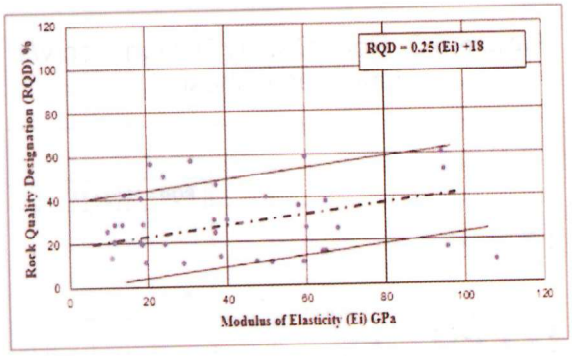


Figure-6.12: Uniaxial Compressive Strength v/s Undrained Cohesion

Discussions on the Data Trends:

- All the plotted trends show a linearly increasing behaviour of the average of data line.
- Rock with a high value of rock quality designation (RQD) generally indicates high shear strength and elastic properties.

- The correlation between uniaxial compressive strength and point load strength index (I_{s50}) as shown on Fig. 6.7 indicates a correlation similar to UCS = 25 I_{s50},as suggested by International Society for Rock mechanics (ISRM).
- A rock with a high value of dry density is likely to have a high value of compressive and tensile strength.

Conclusions and Recommendations:

In this paper an attempt has been made to correlate various engineering characteristics of limestone rock i.e. rock quality designation (RQD), uniaxial compressive strength, elastic modulus etc. These correlations could result into cost effective studies. Besides, less time will be required for estimation of essential properties of similar rock types for the help of design engineer working on projects. These correlations can also be used for bearing capacity and settlement analysis, for preliminary design of foundations.

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