

CORAL REEF ROCK — A GEOTECHNICAL STUDY

By

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CERTIFICATE

This is to certify that the thesis entitled "CORAL REEF ROCK - A GEOTECHNICAL STUDY," submitted by Mr. Anil Madhao Deshmukh, to the Indian Institute of Technology, Delhi, for the award of Degree of DOCTOR OF PHILOSOPHY is a record of the bonafide research work carried out by him. Mr. Anil Madhao Deshmukh has worked under our guidance for the submission of this thesis, which to our knowledge has reached the requisite standard.

The thesis or any part thereof, has not been submitted to any University or Institution for the award of any degree or diploma.



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ABSTRACT

Coral reefs are extensively encountered throughout the tropical seas of the world. Their study is of particular significance to countries like India which are situated in the tropics. Engineering concern about coral reefs has recently taken on a new dimension with increase in off-shore activities in search of oil and seabed mining.

Present day coral reefs are large masses of carbonate rocks built near the sea surface predominantly by lime secreting marine animals known as corals. Coral reef rocks constitute the primary component of coral reefs. These rocks represent a complex family of carbonate rocks, and are characterized by their organic origin, typical mineralogy, varying degrees of lithification, non-homogeneity, presence of intricate pore patterns and random discontinuities.

Our understanding of the geotechnical characteristics of coral reef rock is far from being adequate. A geotechnical classification system is yet to be evolved. The existing information is insufficient even for identifying the problems likely to be associated with these rocks. An indepth study of the nature and behaviour of coral reef rocks is thus imperative.

Scope of the Thesis

An understanding of the nature and engineering behaviour of coral reef rock can be achieved by -

1. a study of their genesis and nature,
2. an evaluation of their physical and geotechnical properties in the laboratory,
3. an assessment of the influence of genesis, nature and environment on geotechnical properties, and
4. a study of their in-situ behaviour.

This thesis confines itself to the first three points and through a study of these three, a useful classification system from a geotechnical view point is proposed. Further, the extent of anisotropy existing in these rocks has been assessed.

For this study seventy three coral reef rock samples were collected from thirteen different locations in Indian waters including the Gulf of Kutch, the Lakshadweep Islands, the Palk Bay, The Gulf of Mannar, and the Andaman and Nicobar Islands.

Experimental Study

(i) Nature

The nature of these rocks was studied by determining their chemical composition, assessing their mineral composition by using infrared absorption and X-ray diffraction techniques and by examining their form of existence under scanning electron microscope.

(ii) Physical Properties

The study of physical properties included determination of their specific gravity, porosity, and water absorption.

(iii) Geotechnical Characteristics

The geotechnical characteristics were assessed through permeability tests, longitudinal elastic wave velocity tests, uniaxial compression tests, and Brazilian tests, on saturated specimens.

Results

(i) Nature

(a) Visual Observations

Seventy three samples were found to belong to twelve different genera of the most common colonial reef building corals. The skeletal system of these samples is characterized by contiguous cup shaped formations known as corallites. The samples, in general, exhibit variable size, shape, and orientation of corallites, different degrees of lithification and random discontinuities. It was found possible to group these samples into four distinctly different groups.

(b) Chemical and Mineralogical Analysis

Coral reef rock samples were primarily calcium carbonate either in the form of aragonite or calcite. Samples of recently formed coral reef rocks were composed entirely of aragonite, whereas samples of different degrees of lithification generally contained some calcite - the greater the lithification the higher was the percentage of calcite.

(ii) Physical Properties

A very wide range of void ratio was observed. In general, the void ratio was found to decrease with increase in age.

(iii) Geotechnical Characteristics

(a) Permeability

The coefficient of permeability, k generally varies over a wide range for rocks belonging to Groups I, II and III, but for Group IV rocks the k falls in a very narrow range.

(b) Longitudinal Elastic Wave Velocity

The longitudinal elastic wave velocity for all groups falls in a narrow range, it generally increases with decrease in void ratio. Velocity in dry state is generally lower than that in saturated state.

(iii) Uniaxial Compressive Strength

A very wide range of uniaxial compressive strength is obtained. It is found to generally increase as the void ratio decreases for all the four groups. High values of strength are observed consistently for Group IV rocks, and the lowest values are for Group I rocks. The other groups fall in between. In a narrow range of void ratio or at the same void ratio considerable variations in uniaxial compressive strength are observed.

(iv) Brazilian Strength

The Brazilian strength varies over a wide range, and is observed to generally increase as the void ratio decreases for all groups in a manner similar to that found for uniaxial compressive strength. The Brazilian strength is about 4 to 6 times lower than the respective uniaxial compressive strength.

Nature of the skeletal system, categorized by the groups appears to have a significant influence on all geotechnical properties.

Geotechnical Classification

Through a study of literature, five parameters were identified as being relevant to serve as criteria for a geotechnical classification system for coral reef rock. These are :

1. Structure and texture of skeletal system - this has been used to isolate four different groups.
2. Degree of lithification of skeletal system - which is considered herein to fall into three categories - Young, Old and Very Old.
3. Type of coral reef - continental and oceanic.
4. Zonation of coral reef - windward and sheltered.
5. Discontinuities (not considered).

Experimental investigation on intact coral reef rock samples has indicated that the first four parameters are indeed relevant. The fifth, i.e., discontinuities, will, of course, have a marked influence on in-situ behaviour of the rock mass but is beyond the scope of this thesis which confines itself to intact rock. Upon classification using the above parameters one can get an idea of the uniaxial compressive strength and permeability of the intact rock.

Anisotropy

On a visual examination, these biogenic carbonate rocks appear to be highly anisotropic and from a geotechnical view point it is essential to establish the extent of their anisotropy.

Anisotropy has been assessed through measurement of permeability, longitudinal elastic wave velocity, uniaxial compressive strength and modulus of elasticity (at 50 percent of uniaxial compressive strength) in three orthogonal directions. In general, anisotropy effects are maximum for permeability, less for uniaxial compressive strength and modulus of elasticity and minimum for longitudinal elastic wave velocity.

TABLE OF CONTENTS

	Page
CERTIFICATE	i
ACKNOWLEDGEMENTS	ii
ABSTRACT	iv
TABLE OF CONTENTS	ix
LIST OF TABLES	xv
LIST OF FIGURES	xvii
1. INTRODUCTION	1
1.1 Definitions	1
1.2 Importance of Present Day Coral Reefs	2
1.2.1 Engineering Concern	2
1.2.2 Geotechnical Considerations	3
1.2.3 Geographical Distribution	4
1.3 Scope of the Thesis	5
1.4 Organization of the Thesis	8
2. LITERATURE REVIEW	10
2.1 Origin of Coral Reefs	10
2.2 Skeletal System	12
2.2.1 Corals and their Classification	12
2.2.2 Coralline Algae	19
2.2.3 Mineralogical and Chemical Composition	19

	Page
2.3 General Characteristics of Coral Reefs	20
2.3.1 Reef Definition	20
2.3.2 Reef Development Factors	21
2.3.3 Reef Types	21
2.3.4 Zonation	28
2.4 Coral Reef Rock	31
2.4.1 Definition	31
2.4.2 Process of Development	32
2.5 Classification of Coral Reef Rock	34
2.5.1 Biological Approach	34
2.5.2 Geological Approach	34
2.5.3 Engineering Approach	36
3. HYPOTHESIS	39
3.1 Introduction	39
3.2 Classification Parameters	40
3.2.1 Structure and Texture of Skeletal System	40
3.2.2 Degree of Lithification of Skeletal System	47
3.2.3 Type of Coral Reef	47
3.2.4 Zonation of Coral Reef	49
3.2.5 Discontinuities	49
3.3 Anisotropy	50

	Page
4. EXPERIMENTAL WORK	54
4.1 Rock Tested	54
4.2 Testing Programme	55
4.3 Specimen Preparation	60
4.4 Nature	60
4.4.1 Chemical Composition	60
4.4.2 Mineralogical Composition	64
4.4.2.1 Infrared Absorption Spectroscopy	64
4.4.2.2 X-ray Diffraction	64
4.4.3 Scanning Electron Microscopy	71
4.5 Physical Properties	80
4.5.1 Relationship of Void Ratio and Apparent Void Ratio	86
4.6 Permeability	86
4.7 Longitudinal Elastic Wave Velocity	95
4.8 Strength Characteristics	95
4.8.1 Uniaxial Compressive Strength	95
4.8.1.1 Relationship of Uniaxial Compressive Strength and Void Ratio	95
4.8.1.2 Stress-Strain Curves	105
4.8.1.3 Modulus of Elasticity	111
4.8.2 Tensile Strength	111
4.8.2.1 Point-Load Test	111
4.8.2.2 Brazilian Test	118

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5. GEOTECHNICAL CLASSIFICATION	121
5.1 Influence of Structure and Texture of Skeletal System	121
5.1.1 Void Ratio	121
5.1.2 Permeability	123
5.1.3 Longitudinal Elastic Wave Velocity	124
5.1.4 Uniaxial Compressive Strength	124
5.2 Influence of Degree of Lithification	125
5.2.1 Void Ratio	125
5.2.2 Permeability	125
5.2.3 Uniaxial Compressive Strength	125
5.3 Influence of Type of Reef	126
5.3.1 Void Ratio	126
5.3.2 Permeability	126
5.3.3 Uniaxial Compressive Strength	126
5.4 Influence of Zonation	131
5.4.1 Void Ratio	131
5.4.2 Permeability	131
5.4.3 Uniaxial Compressive Strength	131
5.5 Methodology for Evolving a Geotechnical Classification System	131
5.6 Proposed Classification System	138

	Page
6. ANISOTROPY	140
6.1 Permeability	141
6.2 Longitudinal Elastic Wave Velocity	152
6.3 Uniaxial Compressive Strength	152
6.4 Modulus of Elasticity	156
7. INDIAN CORAL REEFS	158
7.1 Introduction	158
7.2 Gulf of Kutch	161
7.2.1 General Description	161
7.2.2 Geotechnical Properties	161
7.3 West Coast	161
7.3.1 General Description	161
7.3.1.1 West Coast	161
7.3.1.2 Southwest Coast	166
7.3.2 Geotechnical Properties	166
7.4 Lakshadweep Islands	167
7.4.1 General Description	167
7.4.2 Geotechnical Properties	167
7.5 Southeast Coast	170
7.5.1 General Description	170
7.5.1.1 Palk Bay	170
7.5.1.2 Gulf of Mannar	173
7.5.2 Geotechnical Properties	173
7.6 Andaman and Nicobar Islands	174
7.6.1 General Description	174
7.6.1.1 Andaman Islands	174
7.6.1.2 Nicobar Islands	175

7.6.2	Geotechnical Properties	177
7.7	Geotechnical Properties of Indian Coral Reefs Vis-a-Vis Other Coral Reefs	177
8.	CONCLUSIONS	181
8.1	Nature	181
8.2	Engineering Behaviour	182
8.3	Geotechnical Classification	183
8.4	Anisotropy	184
8.5	Coral Reef Rocks Vis-a-Vis Other Rocks	187
	REFERENCES	190
	APPENDIX I TEST PROCEDURES	209
	I.A Permeability Test	209
	I.B Corrections for Stress-Strain Curve	209
	APPENDIX II TEST DATA	213
	APPENDIX III REPRODUCIBILITY	231
	APPENDIX IV SIZE EFFECT	233
	APPENDIX V TEST DATA ON ROCKS OF GROUP V	235
	V.A Nature	235
	V.A.1 Visual Observations	235
	V.A.2 Chemical and Mineralogical Analysis	235
	V.B Physical Properties	238
	V.C Geotechnical Characteristics	238
	V.C.1 Permeability	238
	V.C.2 Longitudinal Elastic Wave Velocity	238
	V.C.3 Uniaxial Compressive Strength	242
	APPENDIX VI LIST OF SYMBOLS	243
	BIOGRAPHICAL SKETCH AND LIST OF PUBLICATIONS	244