

NATURE AND ENGINEERING BEHAVIOUR OF FINE GRAINED CARBONATE SOILS

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Dedicated
to the
Everlasting Memory of
MY REVERED FATHER

CERTIFICATE

This is to certify that the thesis entitled " NATURE AND ENGINEERING BEHAVIOUR OF FINE GRAINED CARBONATE SOILS", submitted by Mr. M.R. Madhavan Nambiar, 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. Madhavan Nambiar 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 other University or Institution for the award of any degree or diploma.

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ABSTRACT

Carbonate soils are extensively encountered on the ocean floor both in the deep sea and continental margin. Engineering behaviour of carbonate soils has been a subject of study only in the recent past. Attempts have been made to correlate the variation in engineering properties of carbonate soils with quantity of carbonate material present paying scant attention to its form of existence. From a review of literature pertaining to the engineering behaviour of submarine fine grained carbonate soils, one can discern that three types of behaviour have been encountered.

- i) Carbonate materials are present as cementing material and deposits exhibit a behaviour similar to that of overconsolidated clays.
- ii) Carbonate materials are present as inert material and deposits exhibit a behaviour similar to that of normally consolidated clays.
- iii) Carbonate materials are present in large quantities as inert material and these deposits also exhibit overconsolidation behaviour.

These are only inferences based on insufficient information concerning macro-behaviour. For establishing clearly the influence of the presence of carbonate material on engineering behaviour of fine grained soil, a laboratory test programme encompassing a study of both macro-properties as well as micro-structure was designed

for which the following soil-systems were used :

- i) an undisturbed fine grained carbonate soil from off the West Coast of India and
- ii) laboratory prepared carbonate soils obtained by
 - (a) sequential permeation of constituent solutions (of calcium chloride and sodium carbonate) in hand-remoulded specimens of kaolinite to achieve the presence of calcium carbonate as cementing material,
 - (b) mixing reagent grade calcium carbonate powder with kaolinite to achieve the presence of calcium carbonate as inert material in quantities similar to those achieved in (a) above, and
 - (c) precipitating calcium carbonate in kaolinite slurry to achieve the presence of calcium carbonate in a manner similar to that occurring in nature.

To determine the nature of carbonate material present X-ray diffraction patterns, grain size distribution curves, scanning electron micrographs, Atterberg limits and shrinkage characteristics of this soil system were compared with those of their respective non-carbonate components.

To determine the engineering behaviour, permeability tests, consolidation tests, vane shear tests, consolidated drained direct shear tests, conventional consolidated undrained triaxial compression tests and multi-stage consolidated undrained triaxial compression

tests on these soils were conducted. Results of tests on carbonate soils were compared with those from tests conducted on their respective non-carbonate components.

The investigation carried out to study the nature of carbonate material shows that in undisturbed fine grained carbonate soil calcium carbonate exists in large quantities (47 - 55 percent) in the form of inert non-skeletal needle and rod-like particles. Similar particles were formed when calcium carbonate was precipitated in kaolinite slurry. Through successive permeation of constituent solutions only small quantities (about 3 - 5 percent) of calcium carbonate could be deposited. Even though existence of such amounts could not be observed in Scanning Electron Micrographs (SEM), from the macro-behaviour one can conclusively infer that carbonate material did exist as cementing material.

Laboratory investigation carried out to study the engineering behaviour reveals that

- (a) consolidation and shear behaviours of both undisturbed fine-grained carbonate soil and soil obtained by precipitating calcium carbonate in kaolinite slurry are similar. They exhibit behaviour typical of normally consolidated clays. In both soils presence of inert carbonate material increases the angle of shearing resistance, $\bar{\phi}$ and permeability, k .
- (b) Soil obtained by successive permeation of calcium chloride and sodium carbonate solutions in kaolinite exhibited a behaviour, which is totally different from that observed above. Results from consolidation tests show that they

exhibit quasi-preconsolidation pressure. Presence of carbonate material decreases the permeability significantly. Stress-strain behaviour is also indicative of relatively brittle material.

Through this study, the influence of form of existence of calcium carbonate on engineering behaviour has been highlighted.

Focussing attention on the engineering behaviour of fine grained carbonate soil from off the West Coast of India, the present study reveals that

- (i) the ratio of measured to predicted value of permeability using Kozeny-Carman equation is very similar to the ratio obtained for terrestrial kaolinitic soils.
- (ii) the compression index, C_c , is higher than that predicted for terrestrial soils having the same liquid limit.
- (iii) the effective angle of shearing resistance, $\bar{\phi}$, is found to be higher than that predicted using the relation with plasticity index for terrestrial normally consolidated soils.

A rationalized procedure for multi-stage triaxial testing has been evolved and its applicability in submarine soils has been verified.

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