NATURE AND SHEAR BEHAVIOUR OF CARBONATE SOILS

By

MANOJ DATTA

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CERTIFICATE

This is to certify that the thesis entitled "NATURE AND SHEAR BEHAVIOUR OF CARBONATE SOILS", submitted by Mr.MANOJ DATTA 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. Manoj Datta 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.

Prof. Shashi K. Gulhati
Professor and Head
Department of Civil Engineering
Indian Institute of Technology, Delhi

Dr. G. Venkatappa Rao
Assistant Professor
Department of Civil Engineering
Indian Institute of Technology, Delhi

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ABSTRACT

Carbonate soils are encountered on about 35 percent of the ocean floor, both, in the deep sea as well as on the continental shelves. They are found in abundance off the east and west coasts of India. The engineering behaviour of carbonate soils has been a subject of study only in the recent past. A review of literature reveals that, (a) there exists ambiguity in classification of such soils and many different terms of geologic origin are being used to designate the same soil, (b) there is inadequate data on shear behaviour of carbonate sands, which it is believed, will differ from that of non-carbonate terrigenic sands on account of the former's higher susceptibility to crushing or on account of cementation in carbonate sand strata, and (c) piles driven in carbonate sands show peculiar behaviour - more specifically : low axial capacity, low resistance to driving and increased resistance to redriving after stoppages.

In view of the inadequate appreciation of behaviour of carbonate soils, a laboratory test programme was designed , in which eight carbonate sands and four fine grained carbonate soils were investigated to :

(a) Study the nature of carbonate soils and identify parameters relevant for classifying them from an engineering viewpoint. This was done by studying the engineering behaviour of the soils

in relation to their carbonate content and mineralogy as determined by chemical analysis, X-ray diffraction analysis and infrared spectra analysis, as well as in relation to the form of existence of carbonate material as studied through a scanning electron microscope.

(b) Understand the shear behaviour of carbonate sands with particular emphasis on evaluating their susceptibility to crushing under stress and to isolate the influence of crushing on shear behaviour. This was achieved by performing drained and undrained triaxial shear tests on carbonate sands at low and elevated cell pressures as well as by performing cyclic triaxial tests and static sand-to-steel direct shear tests at low confining pressures.

The thesis also attempts to rationally explain the observed behaviour of piles driven in carbonate sands and reviews the existing design practice of estimating the axial capacity of piles driven in such sands. This was done on the basis of results of tests listed above as well as through a review of literature on pile load tests in cemented carbonate sands and chalk.

The investigations conducted to study the nature of carbonate soils show that in coarse grained soils, skeletal carbonate particles are often characterised by the presence of large intraparticle voids and thin walls, whereas nonskeletal carbonate particles do not have intraparticle voids and are usually round/oval in shape or comprise of a conglomeration of small grains cemented together. In fine grained soils, carbonate material was observed to exist as nonskeletal needles or coating and it was sometimes responsible for microlevel cementation, resulting in the formation of coarser aggregates. Skeletal carbonate soils contained calcite and aragonite as the carbonate minerals whereas nonskeletal carbonate soils contained dolomite also.

Laboratory tests conducted to study the particle crushing and shear behaviour of carbonate sands reveal that skeletal carbonate sands with large intraparticle voids and plate-like shell fragments crush easily whereas nonskeletal carbonate sands do not crush readily. Nonskeletal carbonate sands with low susceptibility to crushing behave quite similar to non-carbonate terrigenic sands. The behaviour of skeletal material which crushes readily, is markedly different from that of non-carbonate terrigenic sands. For example :

(a) During drained shear, crushing causes the dilatancy rate at failure to change from positive to negative with increasing confining stress, and hence results in a significant reduction in the drained angle of shearing resistance.

(b) During undrained shear, crushing causes the pore water pressure response to change from negative to positive with increasing confining stress, without significantly altering the undrained angle of shearing resistance.

(c) Crushing of particles results in reduced drained and undrained strengths at elevated confining stresses.

(d) During cyclic undrained shear, the pore water pressures induced depend upon the static pore water pressure response of the sand and hence sands which crush easily develop higher positive pore water pressures.

(e) During sand-to-steel shear, carbonate sands with high susceptibility to crushing show a significant reduction in the angle of skin friction with increase in normal stress, for rough steel surfaces, as well as lower ratio of angle of skin friction to angle of shearing resistance in comparison to non-carbonate terrigenic sands.

Crushing appears to be the single major factor responsible for the observed peculiar behaviour of piles driven in carbonate sands. Existing practice of classifying carbonate soils and of estimating the axial load capacity of piles driven in carbonate sands are not totally satisfactory since they do not take cognizance of two important relevant factors, namely crushing of particles and degree of cementation, and instead, tend to give importance only to the carbonate content of the soil which is not an adequate indicator of the susceptibility to crushing and degree of cementation. Some suggestions for improving the existing practice of soil classification and of estimating the axial pile capacity are presented.

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