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Short Communication

Geotechnical Properties of Karwar Marine Clay

by

S. T. Bhat*

B. U. Nayak**

R. L. Naik***

Introduction

Sediments off Indian coast are generally reported to be soft and sensitive. But, not much published data are available on geotechnical aspects of the west coast of India. In this paper, a study on the engineering behaviour of marine clays found off Karwar on the west coast of India has been presented.

Collection of Samples

Gravity corer was operated from Ocean Research Vessel Sagar Kanya from a water depth of 30 meters (latitude 14 43.8 N and longitude 74 02.6 E). The PVC liner was of circular cross section with ID of 118 mm The length of the core recovered was 6 m. As soon as the core was recovered it was cut into lengths of 2m to facilitate easy handling and transportation, and each piece was properlv wax sealed at both ends to prevent any loss of pore fluid.

Experimental Methods

The core was cut in the laboratory at every 25cm interval. For each section, different properties were determined. Pocket vane shear test was conducted at each section to find out the undrained shear strength. Then, the soil was remoulded thoroughly and quickly (so that no moisture was lost) and remoulded undrained strength was found out. Undisturbed sample was also taken out for oedometer test.

Atterberg limits were determined by adding distilled water when ever

*Ocean Engineering Division, National Institute of Oceanography, Dona-Paula, Goa 403004

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needed. Bulk density was determined by weighing a particular length of core.

For grain size analysis, moist soil of equivalent dry weight of around 35 gm was taken. The sample was first wet sieved through 63 micron sieve. +63 micron portion was dried and taken as sand.

—63 micron portion was subjected to pipette analysis. Sodium hexametaphosphate was used as dispersing agent (IS : 2720 part IV). Distilled water was used for pipette analysis.

A part of the soil suspension containing less than 2 micron size particles, during pipette analysis was taken for x-ray diffraction studies. To this suspension, acetic acid and hydrogen peroxide were added to remove clacium carbonate and organic matters present in the soil. Excess acid was washed by adding ample distilled water and keeping it for two days. The top water was removed and 5 to 6 drops of the slurry was put on a glass slide removed and was air dried for 24 hours for study under X-ray diffractometer.

To determine the amount of calcareous material, around 25 gm of oven dried sample was taken and was treated with hydrocholoric acid. Hydrochloric acid was added little by little till efflorescence stopped. The concentration of the acid necessary for fully dissolving the calcareous matter was decided by trial and error.

Test Results

Natural water content of the clay sample was very high ranging from 90% to 155%. Liquid limit varied from 90% to 135% and plasticity index from 56 to 95 indicating high plasticity of the clay.

A gradual decrease of water content, liquid limit (Fig. 1) and plasticity index (Fig. 3), were observed with increasing depth.

Bulk density varied from 1.3 to 1.5 gm/cc over the 6 m length of the core. Specific gravity was around 2.6 (Table 1).

Grain size distribution showed that the sand size material was less than 3%, clay fraction (—2 microns portion) varied between 22 to 30% and silt content was the maximum at 67 to 75%.

The amount of calcareous material varied from 15 to 20%, which was present mainly in the form of fragmented shells.

A typical x—ray diffractogram for the sediment is presented in Fig 5. Clay mineral was predominantly found to be kaolinite followed by illite.

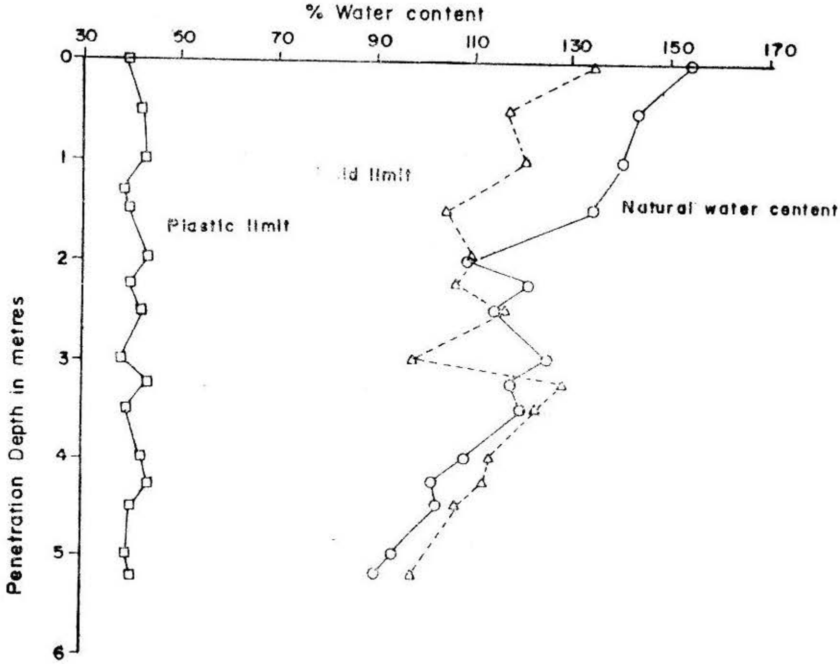

FIGURE 1 Water Content, Liquid Limit and Plastic Limit

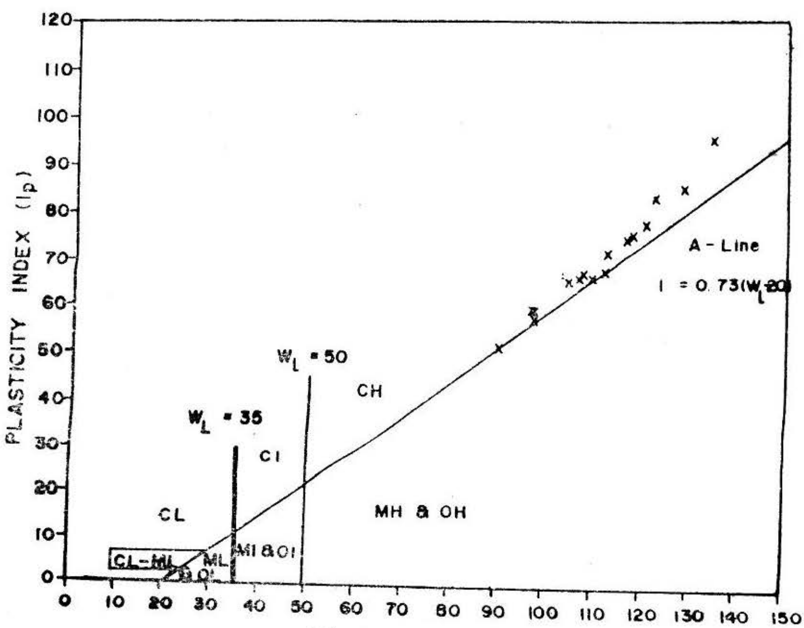

FIGURE 2 Plasticity Chart (After Casagrande)

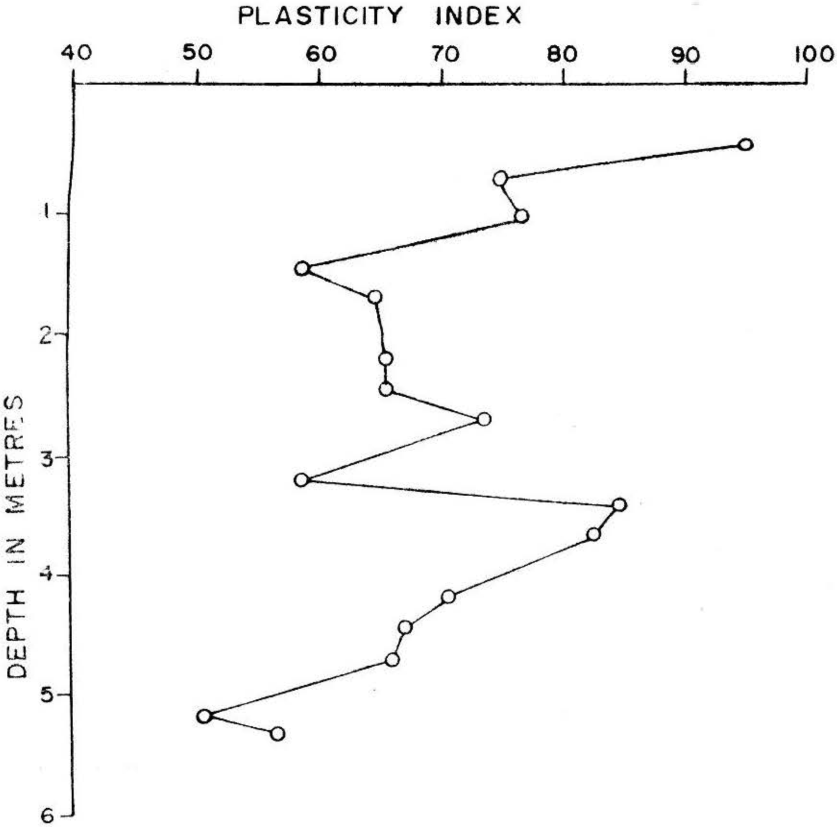

FIGURE 3 Variation of plasticity Index with depth

Undrained Shear Strength and Sensitivity

Undrained shear strength was low with a maximum value of 6 *kPa* at the bottom of the core. There was an increasing trend of shear strength with depth. Remoulded strength was lower as liquidity index was more than one (*i.e.* natural *w.c.* > *L.L.*).

Sensitivity is defined as the ratio of undisturbed shear strength to remoulded shear strength at the same water content. Sensitivity ranged from 2 to 10 (Fig. 4). Sensitivity decreases with depth.

The compression index found from oedometer test was quite high ranging from 0.85 to 1.06. An attempt to correlate liquid limit with compression index showed very low correlation coefficient (0.344).

Discussion

Based on unified soil classification system, the sediment can be classified as inorganic clay with high compressibility. All the samples fall on a narrow

TABLE 1

Properties

Serial no.	Penetration depth in m.	Bulk density gm/cm³	Specific gravity	Compression index Cc	Carbonate content %	Grain size distribution (%) sand	silt	clay
1.	0.0	1.3	2.58	—	20.0	1.0	75.0	24.0
2.	0.5	1.38	2.56	—	19.1	—	—	—
3.	1.0	1.4	2.59	1.06	—	1.4	72.3	26.3
4.	1.5	1.4	2.55	—	15.9	2.0	70.0	28.0
5.	2.0	1.4	2.57	0.99	14.5	—	—	—
6.	2.5	1.4	2.53	0.92	16.2	3.0	71.0	26.0
7.	3.0	1.43	2.54	1.05	18.1	0.0	75.0	25.0
8.	3.5	1.44	2.56	0.96	17.5	2.8	75.6	21.6
9.	4.0	1.48	2.58	0.97	17.8	—	—	—
10.	4.5	1.46	2.55	0.85	18.4	3.0	68.0	29.0
11.	5.0	1.52	2.54	0.92	—	2.5	69.5	28.0
12.	5.5	1.53	2.57	0.98	18.2	1.0	79.0	20.0

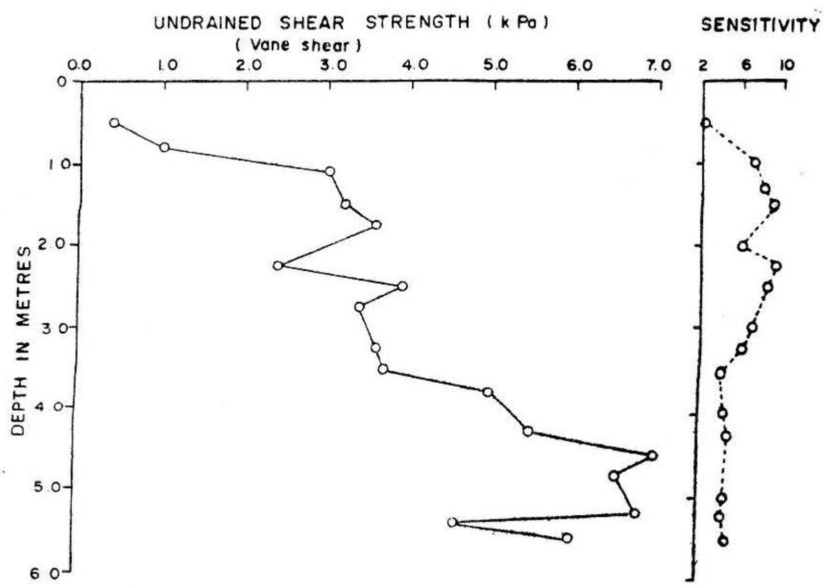

FIGURE 4 Variation of undrained shear strength and sensitivity with depth

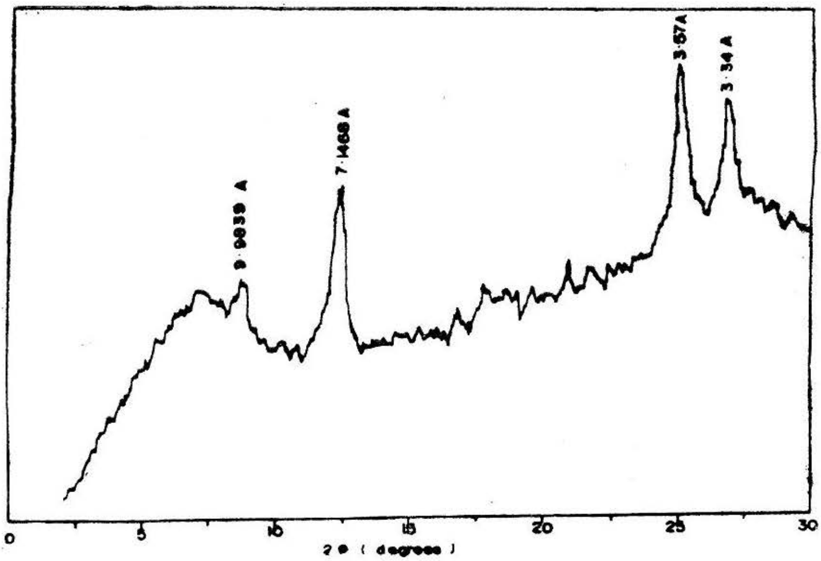

FIGURE 5 X-ray differaction pattern

band parallel to and above the A—line (Fig. 2). The above classification is purely based on plasticity characteristics and it should be noted that though the sediment was classified as inorganic, in reality it contains 15 to 20% organic matter.

Liquidity index, particularly in the top layers was more than unity indicating that natural water content was higher than liquid limit, Soil at such a state would show very low shear strength. Wroth and Wood (1978), based on the test results of Youssef *et al* (1965), concluded that the shear strength at the liquid limit is unique and has a value of about 1.7 *kPa*. Norman (1958) reported a shear strength of 2 *kPa* at the liquid limit. The tests on samples with liquidity index more than 1 showed shear strength higher than the value generally expected at liquid limit (Fig. 4). The increase in strength may be attributed to cementation bonds between particles which are broken while remoulding. As a result, the remoulded strength of sensitive clays would be considerably lower than the undisturbed strength.

The undisturbed strength can be thought of as having two components —one due to cementation (here after referred to as cementation component) and other due to particulate behaviour *i.e.* if there were no cementation bonds (here after referred to as particulate component). For a non sensitive normally consolidated clay, one can expect an increase in undrained strength with depth as overburden pressure increases. This component of strength remains the same even after remoulding. Increase or decrease of sensitivity is attributed to the cementation component of strength. In this case, sensitivity was found to decrease with depth (Fig. 4). When liquidity index is more than one, soil is almost in a fluid state and hence particulate component of strength is negligible and cementation component is more pronounced resulting in higher magnitude of sensitivity. With depth, liquidity index would decrease and particulate component of strength increases whereas cementation component does not necessarily increase. Therefore, particulate component was more pronounced at higher depths, thereby decreasing the magnitude of sensitivity.

Skempton suggested a correlation $Cc = 0.009\,(LL - 10\%)$ for clays of medium sensitivity. Present study however shows that a single parameter, liquid limit, cannot be used to compute the value of Cc for this clay.

Conclusion

Karwar marine clay possesses high plasticity characteristics with natural water content higher than the liquid limit. Liquidity index was as high as 1.7. Predominant clay mineral was kaolinite. Undrained shear strength showed an increasing trend with depth. Sensitivity decreased with depth. Cementation effect seemed to remain constant over the depth. No correlation could be obtained between liquid limit and compressibility index.

Acknowledgement

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References

NAGARAJ, T.S., MURTHY, B.R.S., VATSALA, A. and JOSHI, R.C. (1990) : "Analysis of compressibility of sensitive soils." *J. of Geotech. Engg., ASCE*

NORMAN, L.E.J. (1958): "A comparison of values of liquid limit determined with apparatus having bases of different hardness". *Geotechnique*, 8 : 79-83.

WROTH, C.P. and WOOD, D.M. (1978): "The correlation of index properties with some basic engineering properties of soils". *Can. Geotech. Journal* 15 : 2 : 137-145.

YOUSSEF, M.S., El. RAMLE, A.H. and El. DEMERY, M. (1965) : "Relationship between shear strength, consolidation, liquid limit and plastic limit for remoulded clays". *Proceedings of international conference on soil mechanics and foundation engineering*. 1 : 126-129.