INFLUENCE OF STONE COLUMNS ON ENGINEERING PROPERTIES OF DREDGED SOIL-AN EXPERIMENTAL INVESTIGATION

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ABSTRACT

Dredging of the river bed and flood channels produces dredged soil in large quantity posing severe health and environmental problems. Concern over environmental effects of dredging, disposal and the increasing unavailability of suitable disposal sites, has put pressure for characterization of this material. Therefore, the present study investigates the behaviour of dredged soil reinforced with stone columns. The dredged soil samples for the present study were collected from different locations of flood spill channel and characterised through laboratory testing. Test specimens were prepared with dredged soil at 0.95_{dmax} and Optimum moisture content and subjected to different tests as per relevant standard procedures. In addition to this, a series of model footing load tests were carried out on stone column reinforced dredged soil bed to understand the load deformation behaviour. The parameters varied in this study were length and diameter of stone column. It was observed that the bearing capacity of the stone column reinforced soil bed increases with increase in the area replacement ratio along with significant reduction in settlement. In addition to this, the optimum length of the stone column was also obtained from the test results. A group based test was also done and compared with single stone column tests with similar area replacement ratio. Hence, due the inclusion of stone columns to the dredged soil, there is improvement in the bearing capacity and reduction in settlement.

INTRODUCTION

There are a number of techniques available to develop ground conditions such as stone columns, jet grouting, compaction grouting, short pile, dynamic compaction, lime stabilization etc. Before using any of these methods, it is required to know the local ground conditions in detail. Even though methods are expensive and time consuming they must be done in order to choose a most suitable and applicable ground improvement method to mitigate the undesirable consequences caused by loads and earthquakes. Stone column is an satisfactory technique for refining soil conditions. This method has been used since late 1950s. Through the use of this technique, it may be possible to limit settlement and increase the strength of foundation. During an earthquake stone columns can also act as a gravel drain column to discharge pore water pressure and the liquefaction potential of a ground can be decreased. One of the methods broadly used in soft soils is vibro-replacement, which consists of substituting some of the soft soil with crushed rock or gravel to form an array of stone beneath the foundation. The use of conventional stone column in soft soil deposits was found to benefit the foundation. The use of conventional stone columns in soft deposit was found to benefit foundations in many respects.

The use of stone columns as a ground improvement technique is of resent origin. The main purpose of soil improvement by stone column technique is mainly to increase the bearing capacity of foundation soil and to decrease post construction settlement. Stone columns are constructed by making holes in the deposit and filling these holes with gravel (or small stones) of size 6 to 100mm. Stone columns act as vertical drains, increasing rate of consolidation. They reinforce the soft soil deposit because the soft soil is replaced by strong stone columns at discrete points. This action is somewhat similar to that of vertical steel bars in a R.C.C column. The stiffness of the stone columns is very large as compared to that of the soft soil nearby; a large portion of the superimposed load is carried by stone columns. Thus the bearing capacity of the clay deposit is increased and the settlement are reduced.

This method can be treated as the extension of technique of densification of cohesionless soils by vibroflot. Earlier stone columns were formed by vibroflot but now they are formed by forming a bore as in bored cast-in-situ concrete piles. The method has been mainly used to improve subsoil below buildings, embankments etc. In recent years, Stone columns have also been used in pre-bored holes by compacting the granular fill material by a rammer. This method has been developed in India and has been gaining importance in Indian practice. In this method ordinarily bored pilling equipment is used. The details of the installation techniques and the performance of these granular piles are discussed in the following sections.

MATERIALS AND METHODOLOGY

Material Used

Dredged soil

In the present investigation, samples of dredged soil have been collected from the flood spill channel. To determine the in-situ parameters of soil, undisturbed samples were collected in core-cutters and UCS test samples at each site at a depth of 0.3m. Besides, adequate quantity of disturbed samples were also collected and transported to the lab.

Stone aggregates

Crushed stone was used as a backfill material. The size was chosen such that the particle size is about (1/6 t*o 1/7*) of the diameter of stone columns. The minimum particle size is 2mm and maximum particle size is 10mm.

Testing Program

Two series of tests were carried out in this work. The first series of tests meant at estimating the physical, index and engineering properties of dredged soil. Further the compatibility of dredged soil under different compactive energy levels was determined with the help of compaction tests. The shear strength parameters of compacted dredged specimens at 0.95*MDD and optimum moisture content were also determined from Direct shear test and UCS. The second series of tests were carried out to evaluate the reinforcing effects of stone columns in improving the load carrying capacity of compacted dredged soil.

Soil Characterisation Tests

Grain sieve analysis

For determination of grain size distribution, the dredged soil was passed through an IS test sieve set. Sieve analysis was performed for coarser particles as per IS: 2720 part (IV), 1975 and hydrometer analysis was performed for finer particles as per IS: 2720 part (IV).

Index properties/Atterberg Limits

Atterberg limits such as liquid limit, plastic limit and shrinkage limit are extensively used in geotechnical engineering. The values of liquid limit and plastic limit are valuable in the classification of soils. They also provide complete indication for the engineering properties of the soils. Atterberg limit tests were conducted as per relevant standard procedure

Specific gravity

The specific gravity of dredged soil was determined according to IS: 2720 part (III).

Compaction characteristics of dredged soil

The compaction characteristics of dredged soil was found by using compaction tests as per IS: 2720 (Part VII) - 1980 and IS: 2720 (Part VIII)-1980. The moisture content of the compacted mixture was determined as per IS: *27*20 (Part II) 1973. From the moisture content and dry density relationship, optimum moisture content (OMC) and maximum dry density (MDD) are determined.

TEST RESULTS AND DISCUSSIONS

General

This chapter explains the general characterization results and test results conducted on soil samples at 0.95*MDD and OMC. In the present study an attempt has been made to evaluate the various engineering properties in addition to bearing capacity of unreinforced and reinforced soil.

Soil Characterization Tests

Grain sieve analysis

The particle size distribution curves for dredged soil are given in Fig. 1. Particle size distribution analysis revealed that the dredged material contained about 60% silt with appreciable fines and sand content. Hence the soil is silt dominated.

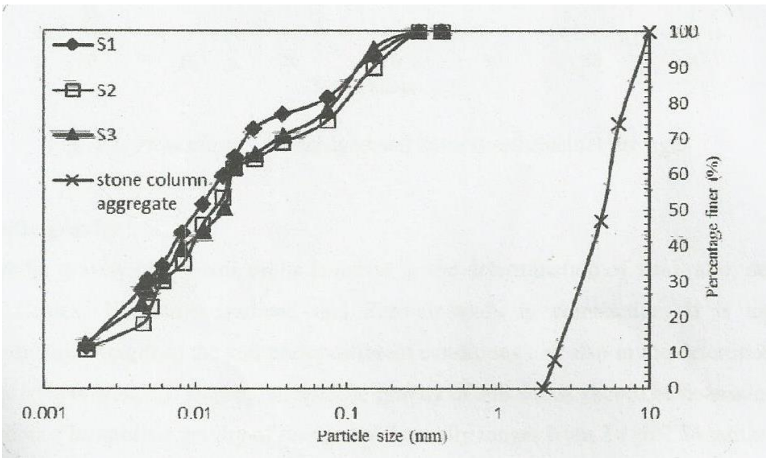

Fig.1. Grain size distribution curves of dredged soil and stone column aggregate

Index properties/Atterberg Limits:

Since, the dredged soil is silty in nature, therefore, liquid limit tests were conducted by means of cone penetration method for cross-check. However, there was negligible variation between test values. The plastic limit and liquid limit (air dried) of the dredged material varies in the range of 24-28 and 34 - 39 % respectively. Based on test results, dredged soil can be classified as silty sand with medium plasticity. The test results are presented in Table l. The flow curves of dredged soil are illustrated in Fig.2.

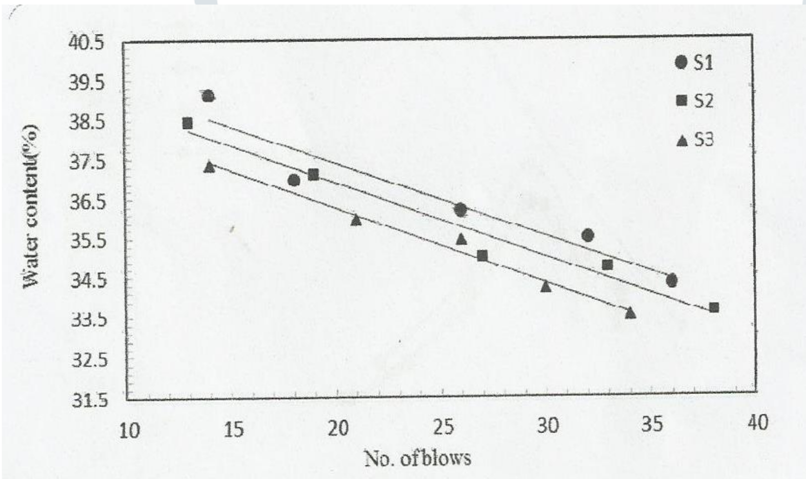

Fig.2. Flow curve for dredged soil from flood channel Srinagar

Specific gravity

Specific gravity of the soil solids is useful in the determination of void-ratio, degree of saturation, Critical Hydraulic gradient, and Zero-air-voids in compaction. The specific gravity of dredged soil usually ranges from 2.1 to 2.54 unlike natural soils (2.65 to 2.85.). The specific gravity of dredged soil lies in the narrow range from 2.58 to 2.61. The soil is generally silt dominated with specific gravity values in the range of 2.52 to 2.59. Low specific gravity and a relatively uniform grain size distribution will result in lower earth pressure.

Compaction characteristics of dredged soil

From the dry density and moisture content relationship, optimum moisture content (OMC) and maximum dry density (MDD) were calculated. The compaction curves are shown in Fig.3. and the test results are given in the Table1

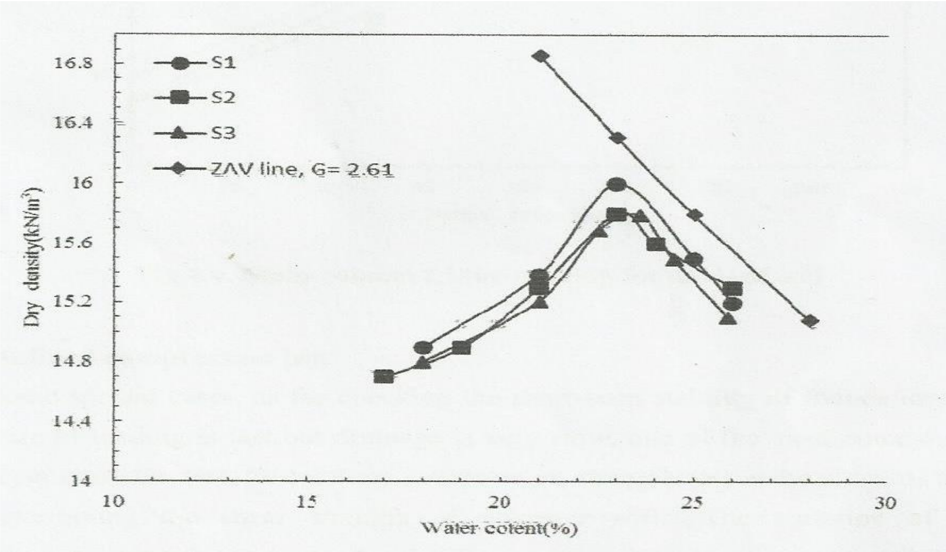

Fig.3. Compaction curve for dredged soil samples

PROPERTY	SAMPLE-1	SAMPLE-2	SAMPLE-3
Sand(%)	18.5	25	22
Silt(%)	67.5	62	64
Clay(%)	14	13	15
Coefficient of curvature, C_C	0.92	1.5	1.3
Coefficient of uniformity, C_U	9.375	10.66	11.45
Suitability number	>50	>50	>50
Specific gravity	2.60	2.63	2.62
Liquid limit(%)	36.05	35.32	34.78
Plastic limit(%)	25.20	25.80	25.0
Shrinkage limit(%)	13.09	12.56	12.39
Plasticity limit(%)	10.85	9.50	9.78
Classification	ML/MI	ML/MI	ML/MI
Flow Index	10.42	11.05	10.64
Toughness Index	0.95	0.90	0.92
Activity	0.78	0.70	0.75
MDD(KN/m^2)	16	15.9	15.6
OMC(%)	22.92	23.0	23.4
In-situ coefficient of permeability(m/s)	$1.48*10^{-8}$	$6.75*10^{-8}$	$2.3*10^{-8}$
Coefficient of permeability(m/s) at MDD, OMC	$3.48*10^{-9}$	$4.66*10^{-9}$	$2.5*10^{-9}$
In-situ dry density (KN/m^2)	12.3	11.4	11.3
In-situ water content(%)	42	48	47
Direct shear test parameters	C_u =16.4 KPa Φ =23.6°	C_U=14.5 KPa Φ =24.8°	C_u = 13.6 KPa Φ`* = 23.7°

Table 1: Test results in tabular form

CONCLUSIONS AND FUTURE SCOPE

Based on the tests conducted on the dredged soil collected from Rambagh flood spill channel and the model footing load tests conducted on compacted dredged soil beds reinforced with stone columns of different area ratios and different length to depth ratios the following main conclusions are drawn:

1. Particle size distribution analysis revealed that the dredged material contained about 60% silt with appreciable fines and

sand content. Hence the soil is silt dominated.

2. The Atterberg limits show that the liquid limit (air dried) and plastic limit of the dredged material varies in the range of 34 - 39 % and 24-28 respectively. Based on this, the dredged soil can be classified as ML-MI. In addition to this, the flow curves reflect that the rate of loss of shear strength is high.

3. The atterberg limits of oven dried dredged sample shows a very small variation from results obtained on air dried sample. Hence contains negligible amount of organic content.

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