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STABILIZATION OF DREDGED SOIL BY USING HYDRAULIC CEMENT (OPC)

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ABSTRACT: *Dredged soil is a solid waste generated from the dredging of a river, having low bearing capacity and high compressibility. Dredged material in huge quantity poses serious disposal and environmental problems all around the area which puts pressure for its characterization. This material can be a valuable resource for many practical purposes such as fill material, sub grade construction, etc. In this study soil samples at four different locations of a flood channel were collected. Soil tests like gradation, specific gravity, consistency indexes, light compaction, unconfined compressive strength, CBR and direct shear tests were performed. The results of four samples were compared and the weakest soil sample was selected. The mechanical properties of the soil were improved using ordinary Portland cement at varying percentages of 0%, 5%, 10% and 15% respectively. Compaction characteristics, Consistency limits, UCS and DST values of the treated soil samples were studied. The UCS and DST values showed significant increase with increasing cement percentage, also the P.L and L.L increased considerably.*

Keywords: *Dredged soil; Solid waste; Flood channel; Mechanical properties; Cement; Compaction; Unconfined Compression; DST.*

INTRODUCTION:

Cement is often used as an additive to improve the strength and stiffness of soft clayey soils ~Lee and Yong 1991; Tatsuoka et al. 1997; O'Rourke et al. 1998!. The increase in strength of soft clay from the introduction of cement is well established ~Mitchell 1981; Uddin et al. 1997; Chew et al. 1997; Yin and Lai 1998!. This increase in strength is often accompanied by an increase in modulus ~Asano et al. 1996; Futaki et al. 1996; Lee 1998! and a decrease in the ductility of the soil, which is manifested by a large post peak reduction in the strength of the treated soil ~Uddin et al. 1997; Balasubramaniam et al. 1999!. All these features are characteristic of naturally structured soils ~Lacasse et al. 1985; Lerouiel and Vaughan 1990; Burland 1990! and indicate that introduction of cement into the soil leads to the formation of a structure within the soil grain assemblage. Improvement of the properties of cement-treated soil has been attributed to the soil cement reaction ~Mitchell 1981!, which produces primary and secondary cementitious materials in the soil–cement matrix ~Kezdi 1979; Schaefer et al. 1997; Cokca 2001!. The primary cementitious materials are formed by hydration reaction and are comprised of hydrated calcium silicates, calcium aluminates, and hydrated lime ~Bergado et al. 1996; Schaefer et al. 1997!. A secondary pozzolanic reaction between the hydrated lime and the silica and alumina from the clay minerals leads to the formation of additional calcium silicate hydrates and calcium aluminate hydrates. This soil–cement reaction provides a clear basis by which to explain the improvement in strength of stabilized soil.

According to the ideal specifications given by the United Nations, in "Soil-cement: Its use in Building, (1964)", as quoted by (Gooding, 1993), the best soil composition for soil-cement is as follows; 75% sand, 25% silt and clay, of which more than 10% is clay. This composition will yield a sandcrete product if mixed with cement and will exhibit good structural characteristics. According to (Norton, 1997), a suitable particle size distribution for building with earth is Sand/fine gravel 40 - 75%, Silt 10 - 30%, Clay 15 - 30%. Ordinary Portland cement type 1 is one of the most suitable materials used for road stabilization (Ruenkrairergsa T, 1982; Anon, 1990; Mitchell JK, 1981). The reduction in water affinity and water holding capacity together with a strong matrix help solidify the soil aggregates with the resulting increase in strength of the stabilized soil (Huangjing S and Gasaluck W, 2010). Since 1915, more than 100,000 miles of equivalent 7.5 m (24 ft) wide pavement bases has been constructed from cement-stabilized soils. According to Sherwood (1993) fine-grained granular materials are the easiest to stabilize due to their large surface area in relation to their particle diameter. A clay soil compared to others has a large surface area due to flat and elongated particle shapes. On the other hand, silty materials can be sensitive to small change in moisture and, therefore, may prove difficult during stabilization (Sherwood, 1993). Peat soils and organic soils are rich in water content of up to about 2000%, high porosity and high organic content. The consistency of peat soil can vary from muddy to fibrous, and in most cases, the deposit is shallow, but in worst cases, it can extend to several meters below the surface (Pousette, et al 1999; Cortellazzo and Cola, 1999;

Åhnberg and Holm, 1999). Organic soils have high exchange capacity; it can hinder the hydration process by retaining the calcium ions liberated during the hydration of calcium silicate and calcium aluminate in the cement to satisfy the exchange capacity. In such soils, successful stabilization has to depend on the proper selection of binder and amount of binder added (Hebib and Farrell, 1999; Lahtinen and Jyrävä, 1999, Åhnberg et al, 2003). The hydration reaction is slow proceeding from the surface of the cement grains and the centre of the grains may remain unhydrated (Sherwood, 1993).

Extensive studies have been carried out on the stabilization of expansive soils using various additives such as cement, lime, fly ash, industrial waste products, lime-cement-fly ash admixture, cement kiln dust, emulsified asphalts, geofiber and polymer stabilizers which improve engineering properties of soil having high water content and low worability that poses difficulties for construction projects (Croft, 1967; Basma and Tuncer, 1991; Nelson and Miller, 1992; Al-Zoubi, 1993; Abdullah et al., 1999; Feng, 2002).The choice and effectiveness of an additive depends on the type of soil and its field conditions. The role of hydraulic cement such as Portland or slag cement is to bind soil particles together, improve compaction, and decrease void spacing, improve the engineering properties of available soil such as, unconfined compressive strength, modulus of elasticity, compressibility, permeability, the drying rate, workability, swelling potential, frost susceptibility and sensitivity to changes in moisture content (Leonards, 1962; Woods, 1960; Robert et al., 1971). Cement can be used to stabilize any type of soil, without those having organic content greater than 2% or having pH lower than 5.3 (ACI 230.1R-90 1990). Fully hydrated cement takes up about 20% of its own weight of water.

One of the most pressing needs for research in the geotechnical area is on the issue of the use of weak soils for fills and as backfill material for walls and bridge abutments. The lack of availability of higher quality materials and the added costs for these materials will eventually force engineers to use these soils when in the past these soils were replaced with materials of better quality. Often however, high water content and low strength of these soils pose difficulties for construction projects. Frequently, additives such as lime, cement, fly ash, lime-cement-fly ash admixture, cement kiln dust, emulsified asphalt, Geo fiber, and polymer stabilizers are used to improve their engineering properties. The choice and effectiveness of an additive depends on the type of soil and its field conditions. Nevertheless knowledge of mechanistic behavior of treated soil is equally important as selecting the stabilizer. The main contributions of this study to practice are on quantifying improvement in mechanical behavior due to cement treatment and highlighting the fact that higher percentages of cement could turn stabilization from beneficial to an uneconomical practice. Thus the optimum percentage of cement is to be used for stabilization practice that would be required for a particular soil and would be different for different projects.

Mechanism of cement reactivity:

Cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.Cements used in construction are usually inorganic, often lime or calcium silicate based.

Hydraulic cement hardens by hydration when water is added. Hydraulic cements (such as Portland cement) are made of a mixture of silicates and oxides, the four main components being:

Belite ($2CaO\cdot SiO_2$);
Alite ($3CaO\cdot SiO_2$);
Tricalcium aluminate ($3CaO\cdot Al_2O_3$);
Brownmillerite ($4CaO\cdot Al_2O_3\cdot Fe_2O_3$).

Materials and methods:

In this study, the soil samples were collected from four different sites in Bemina area of srinagar along the flood channel, Kashmir. OPC was procured from structural lab, NIT Srinagar. The disturbed samples were subjected to various soil tests like gradation, specific gravity, light compaction tests, Consistency limits etc . Unconfined compressive strength, CBR and direct shear tests were conducted on in-situ samples to determine shear strength parameters as per the Standard Codal procedures. The physical properties of the selected soil sample are given in Table 1.The samples were prepared by varying the cement content by 5%, 10%, 15% respectively and a series of DST tests, atterberg limit tests and compaction tests were performed.

TABLE 1 Physical properties of the weakest soil sample.

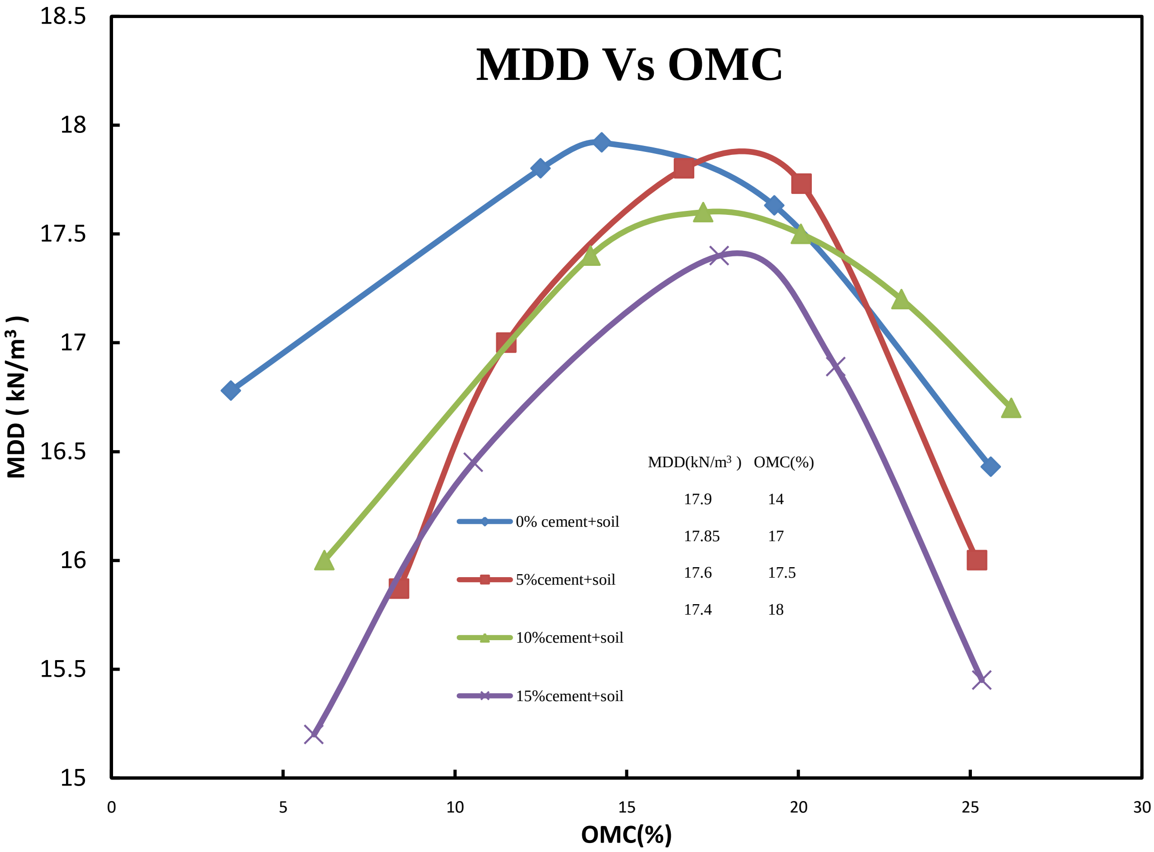
S.No	Properties		Weakest soil, Bemina Area along flood channel
1.	Natural Moisture Content (%)		22.27
2.	Bulk Density (kN/m^3)		18.8
3.	Insitu dry density (kN/m^3)		15.34
4.	Specific Gravity (G)		2.65
5.	% Finer than 75 µm		91.55
6.	Clay (%)		4
7.	Silt (%)		87.55
8.	Sand (%)		8.45
9.	Gravel (%)		0
10.	Coefficient of uniformity, Cu		5.11
11.	Coefficient of curvature, Cc		1.63
12.	Suitability Number, Sn		472
13.	Liquid Limit (%)		24.82
14.	Plastic Limit (%)		21.39
15.	Plasticity Index (%)		2.78
16.	P.I, Aline		3.52
17.	P.I, Uline		15.14
18.	Classification		ML
19.	Clay Mineral		kaolinite
20.	Flow index, If		4.20
21.	Toughness index, It		0.66
22.	Activity		0.68
23.	Consistency index, Ic		0.917
24.	Liquidity index,		0.25
25.	DST @ OMC	Cohesion,C(kN/m^2)	12
		Angle of internal friction, Φ (Deg)	20
26.	UC-Test @ In-situ	Unconfined compressive strength,q_u(kN/m^2)	34.8
27.	UC-Test@ OMC	Unconfined compressive strength,q_u(kN/m^2)	98.6
28.	Optimum Moisture Content (%)		14
29.	Max^m. Dry Density (kN/m^3)		17.9

Results and discussions:

Effect of cement on compaction characteristics of the soils :

Generally, a high level of compaction of soil enhances the geotechnical parameters of the soil, so that achieving the desired degree of relative compaction necessary to meet specified or desired properties of soil is very important. The comparison of various compaction curves depicts that addition of cement increases the optimum moisture content and decreases the maximum dry density as shown in fig.1. Maximum reduction in MDD and max. Increase in OMC was observed on the addition of 10% by weight of cement and hence can be regarded as the optimum content for improvement of the soil.

Fig 1 Effect of cement on compaction characteristics of soil



Effect of cement on consistency limits :

A series of liquid and plastic limit tests were performed on the untreated and cement treated soil samples. It is observed that the value of liquid limit and plastic limit increased with the increasing percentage of cement content, whereas the value of plasticity index shows different characteristics. The liquid limit of host soil was observed to be 28.73% and it increased with increase in cement content. The plastic limit of soil was 21.05% and it increased with addition of cement. However the plasticity index decreased. The pozzolanic behavior of cement makes the treated soil coarser than original soil samples due to the agglomerations of cement and soil particles as shown in fig.2.

Effect of cement on the DST parameters :

Direct shear tests were conducted on untreated and treated test specimens. The specimens were prepared, compacted under standard compaction at γ_d max and optimum moisture content. The test results reveal that in- situ dredged soil exhibits soft consistency. The angle of internal friction of 20 degrees indicates loose denseness of the soil. However, cement treatment drastically improves both cohesion (C) and frictional shearing angle (φ) .The results of adding cement in increments of 5%, 10% and 15% can be seen in fig.3.

Effect of cement on the UCS value :

Unconfined compression test is the simplest and quickest method to determine the shear strength of cohesive soils. Test specimens were prepared, compacted under standard compaction at γ_d max and optimum moisture content. The samples were tested immediately. The test results revealed that addition of cement has significant effect on the strength gain of the dredged soil. The optimum optimum content has been found out to be 15% as it showed the highest value of UC strength.

The unconfined compressive strength was observed to increase by the addition of cement to the soil. The UCS value of the soil at OMC was 0.0986 MPa and it increased by a great extent as the percentage of cement added to the soil was increased as 5%, 10% and 15% as can be seen in fig.4.

Fig.2 Effect of cement on consistency limits

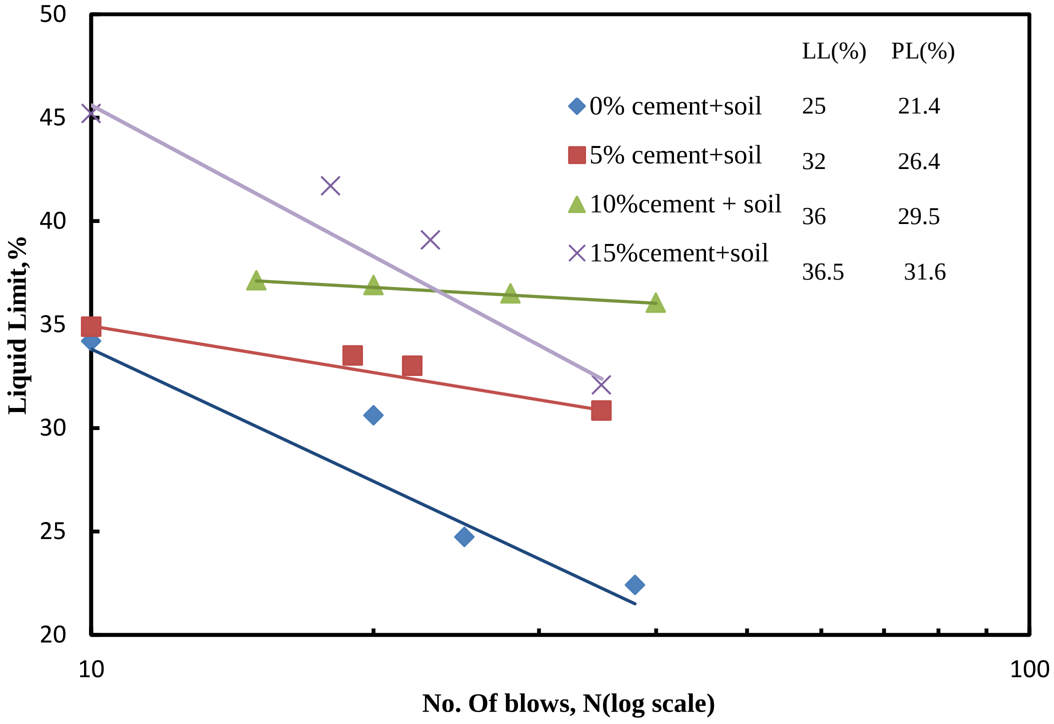


Fig.3 Effect of cement on the DST parameters

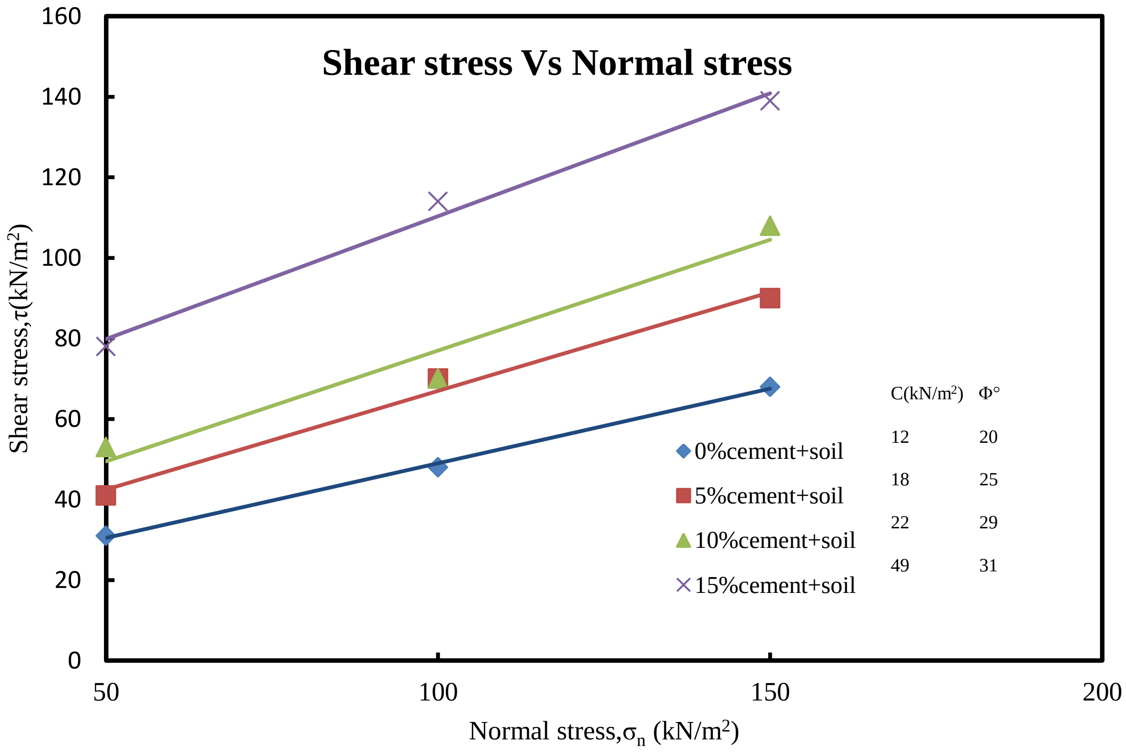
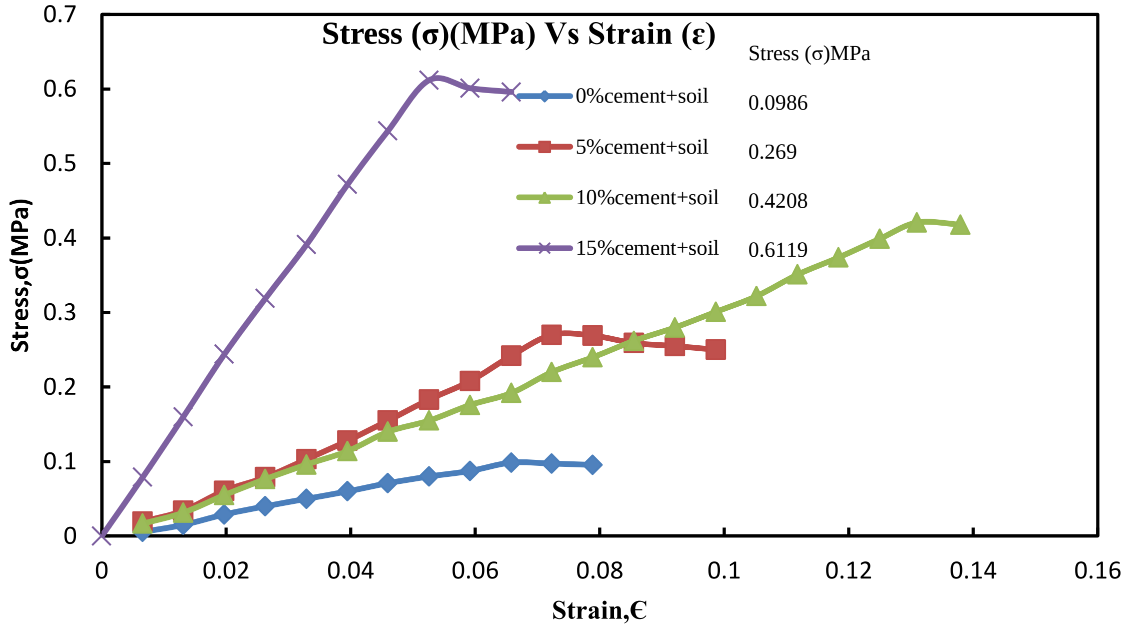


Fig.4 Effect of cement on the UCS



Conclusions:

The stabilization of the solid waste soils such as dredged soil with cement is an effective means of chemical stabilization of soils. It is seen that engineering properties of dredged soil have significantly improved by the addition of cement. The plasticity index of the soil decreased thereby making the soil more workable and the UCS and DST parameters also increased, which clearly indicates that the shear strength of the soil has enhanced and hence makes it most useful in application to slope stability, backfills etc

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