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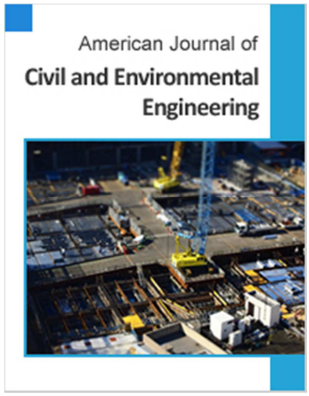

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On Integrated Testing and Performance Assessment of Dredged Solid Waste from Dal Lake for Sustainable Environment in Srinagar

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Abstract
Dal Lake, one of the most beautiful lakes of J&K State. During the past few years, large areas of the lake have been reclaimed and the lake has become shallow due to siltation and accumulation of debris. During the past few years, it has been estimated that about 90,000 ton's of silt flows annually into the lake resulting in large quantities of silt deposits in the Dal Lake. For sustainable development of the lake, dredging of the Dal Lake generated the dredged material in large quantity posing serious disposal and environmental problems all-around the Dal Lake. The problems of Dal Lake and its significance have been well recognized and the scheme for shoreline dredging of Dal Lake has been formulated which generates a huge quantity of solid waste material. Solid wastes are all the wastes arising from human and animal activities that are normally solid and are discarded as unwanted material posing serious disposal 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. The main objective of this study is to successfully manage dredged solid waste material in a manner that is protective of human health and the environment in and around the world famous Dal Lake.

1. Introduction

Knowledge of the sources and types of solid wastes is basic to the design and operation of the functional elements associated with the management of solid wastes for sustainable development of environment. The main objective of a solid waste material characterization is to identify the sources, characteristics, and quantities of the waste generated, and the goal of a waste diversion study is to identify the types and quantities of waste materials that are now separated for recycling or otherwise diverted from disposal in Lakes. There are various types of solid wastes generated in a community such as residential, commercial, institutional, construction and demolition, municipal services, treatment plant sites, industrial, and agricultural. But this study deals with the solid waste generated by dredging the world famous Dal Lake, one of the most beautiful lakes of India and the second largest in the J&K State. The Dal Lake has shrunk more than 15 km over the last 60 years. Denudation of forests is the outcome of human activity and excessive siltation, variation in run-off and changing land use in the watersheds have contributed to depletion of this water body. It has been estimated that on an average

90,000 ton's of silt flows annually into the lake resulting in excessive growth of the weeds, unwanted aquatic life and large quantities of silt deposits, which tends to reduce the depth of lake and affecting its ecology. Major interventions for improving the lake systems include Watershed Management, Dredging operations, emphasis on treatment of effluents before discharge into the lakes and disposal of solid wastes away from the shores of the lakes.

Therefore, shoreline dredging of Dal Lake has been taken-up to restore the Dal Lake area and its surrounding environment. But the Dredged material has generated a huge quantity of solid waste material posing not only disposal problems but also serious health and environmental problems. Due to severe environmental problems and disposal of dredged material, and the increasing unavailability of suitable disposal sites, has put pressure for characterization of this material as a resource for various beneficial uses/engineering applications [1]. Environmental and economical aspects have grown the interest on development of technical alternative that fulfill rational waste utilization. However, Dredged material is no longer being regarded as a "spoil" or "waste" but as a resource [2]. Its mineralogy and Geotechnical properties qualify it for use in the manufacture of high value, beneficial use products [3]. The beneficial uses of dredged material for different uses are- Engineered uses, environmental enhancement of wetlands, fisheries, and other habitats for wildlife utilization, and beneficial use end products including topsoil, construction-grade cement, lightweight aggregate, bricks, architectural tile and can be recommended as fill material for low-lying areas, land improvement [4-6]. The range of engineering applications for dredged material is diverse, being limited only by the ingenuity of the designer. Laboratory tests involved determination of some physical and mechanical properties and the test results indicated that in-situ state of dredged solid waste material is not suitable for using it as a foundation or construction material. Therefore, for an integrated testing and performance assessment of dredged solid waste collected from Dal Lake, some studies on characterization of Geotechnical properties of this material with particular reference to the unconfined compression strength characteristics and its effect on the CBR Behavior of fined grained soils (ES), which will help in proper and bulk use of this unwanted material without adversely affecting the environment and landscape have been carried out [7-8]. Therefore, this paper presents a brief review on characterization of Geotechnical properties of dredged material with particular reference to the unconfined compression strength characteristics and CBR Behavior of fined grained soils (ES). From test results, it has been observed that using dredged solid waste material as a resource will help in proper and bulk utilization of this unwanted material without adversely affecting the environment all-around Dal Lake and in the vicinity areas, but also help in sustainable development of the world famous lake in the capital City Srinagar.

2. Environmental Issues and Problems

Environment is explored through topics covering air, water, land, sea, climate, wild life, pollution, people and our life style, impact of business and industry, how we use resources and how we deal with waste. Man's mad race for acquiring power has posed greatest danger to environment and Eco-system. Increase in population and quest for higher living standards caused greater demand for earth's natural resources. The human activities have thus been altering the atmospheric composition, which in turn affects the regional or even global climate. Therefore, environmental issues are multidimensional, multidisciplinary, and dynamic and require an integrated approach to examine the state of environment and to achieve sustainable industrialization.

3. Materials Used and Experimental Programme

In this study, disturbed and undisturbed samples of Dredged material (DM) from two different locations of Dal Lake were collected for conduct of various field and laboratory tests. Portland cement and Lime have been chosen for improving the properties of dredged material for its effective use as well as bulk utilization. In addition, both disturbed and undisturbed natural earth soil samples (ES) were collected for carrying out CBR tests for Bemina Bypass Road, Srinagar. The Road traverse through flat terrain surrounded by paddy fields and is exposed to extreme moisture conditions due to irrigation waters, precipitation (rain/snow) and submergence during floods. The soil at the site appears to be cohesive materials composed of silt-clay mixture. All the tests were conducted as per standard codal procedures [9-15] and the physical properties of the soils used in this investigation are listed in Table 1.

Different percentages (% age by weight) of Portland cement (4%, 8% and 12%) and Lime (3%, 6% and 9%) were mixed in the dry state with the dredged material and their Geotechnical properties were determined. The test specimens were prepared in the static compaction at 0.95 γ_{dmax} and corresponding water content on the dry side of optimum [16-17]. The particle size distribution curves are shown in Figure 1 and the effect of lime and cement on compaction characteristics is explained in Figure 2.

Table 1. *Physical properties of untreated soils used.*

Property	Natural earth material (soil)	Dredged solid waste material		Stabilized Soil (Recommend for Roads)
		L-I	L-II	
Specific Gravity	2.70	2.54	2.48	2.65
Clay Size (%)	81	72	36	09
Silt Size (%)	18	23	54	16
Sand Size (%)	01	05	10	75
Liquid Limit (%)	57	58	43	25
Plastic Limit (%)	33	27	31	19
Plasticity Index (%)	24	31	12	06
Shrinkage limit (%)	15	11.9	14	---
Classification	CH	CH	MI	SW
Free Swell Index (%)	09	11	---	---
Natural Moisture Content (%)	28	35	27	---
Field Dry Density (kN/m^3)	15.5	12.8	13.2	---
Max^m. Dry Density (kN/m^3)	18	14.5	14.9	17.5
Optimum Moisture Content (%)	21	30.5	25	18.5

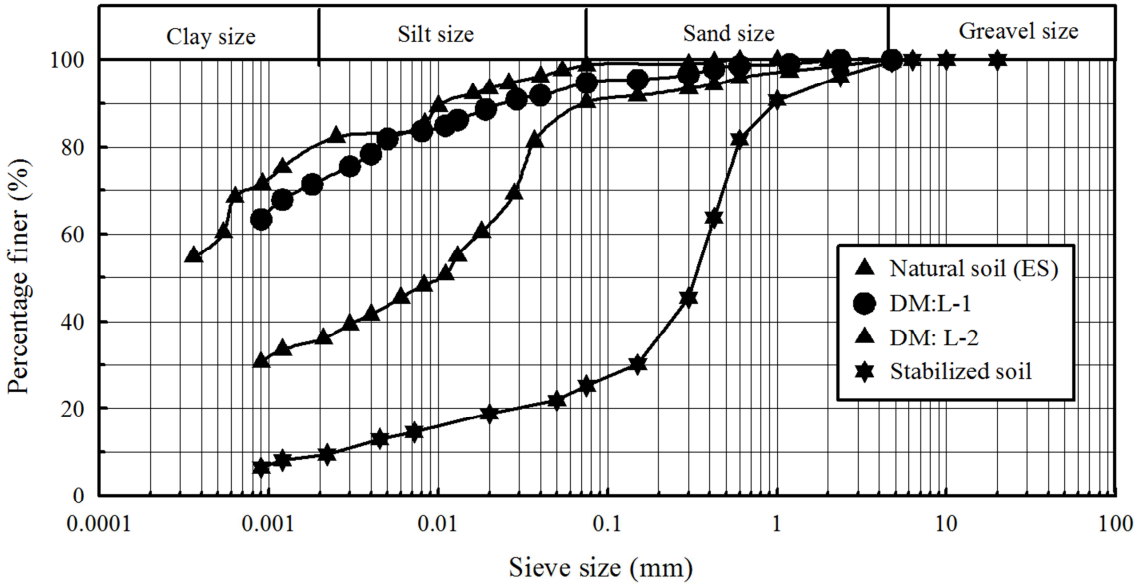

Figure 1. *Particle size distribution curves for different soils.*

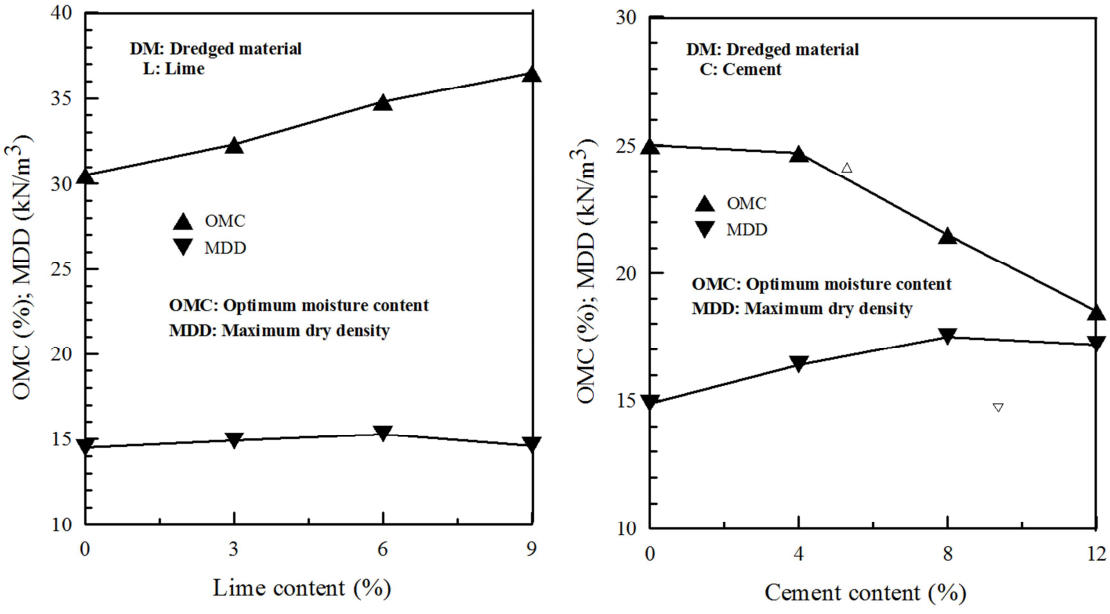

Figure 2. *Effect of lime and cement on the compaction parameters (OMC and MDD) of dredged material.*

4. Results and Discussions

4.1. Effect of Lime and Cement Stabilization on Unconfined Compressive Strength of Dredged Solid Waste Material

For any engineering application of soil, its strength characteristics are essential. In some special cases, as for checking the short-term stability of foundations and slopes where the rate of loading is fast but drainage is very slow, one of the most common shear tests is the unconfined compression test (UCT). The test samples were tested in an unconfined compression testing machine [18]. Clays generally show a significant increase in strength when lime is used for stabilization. The strength of lime-soil mixtures is influenced by several factors such as soil type, curing time and method, unit weight, moisture content, mixing, compaction, the optimum amount and the quality of lime. On addition of small amounts of lime, the immediate unconfined compressive strength (UCS) of soil remains essentially unaffected, whereas there is a significant increase in the UCS for 7 days curing period and a marginal increase for 28 days curing period. While lime contributes to initial stabilization by Ca^{2+} ion exchange, the gain in strength of the treated soil after several days is dependent upon the pozzolanic nature of cement. It is observed that due to the influence of pozzolanic reaction between soil lime and cement, all the cementitious compounds are developed within 7 days curing period. Hence this is of vital importance for field engineers from time and economical point of view. Figure 3 presents effect of lime and cement on the strength behavior of dredged material with different curing periods. Due to higher reactivity, the effect of pozzolanic reactions over-rides the effect of silty behavior of untreated soil and hence significant increase in strength due to the influence of pozzolanic reaction between cement and siliceous soil. It has also been observed that the strain corresponding to the peak stress decreases with curing period (Figure 4). Hence, care has to be taken for higher strains in case of higher curing periods where ucc strength decreases considerably. The unconfined compression tests were conducted mainly to observe the effect of the additives and the curing time on the strength development of the treated dredged material. Thus, the use of pozzolznic additives in ground improvement is an effective means of waste management. Similar results have been also reported by many researchers that a reactive soil exhibits higher unconfined strength after lime treatment (e.g. 19 – 21]. The stabilizing effect depends on the reaction between lime, cement and the clay minerals (22-26].

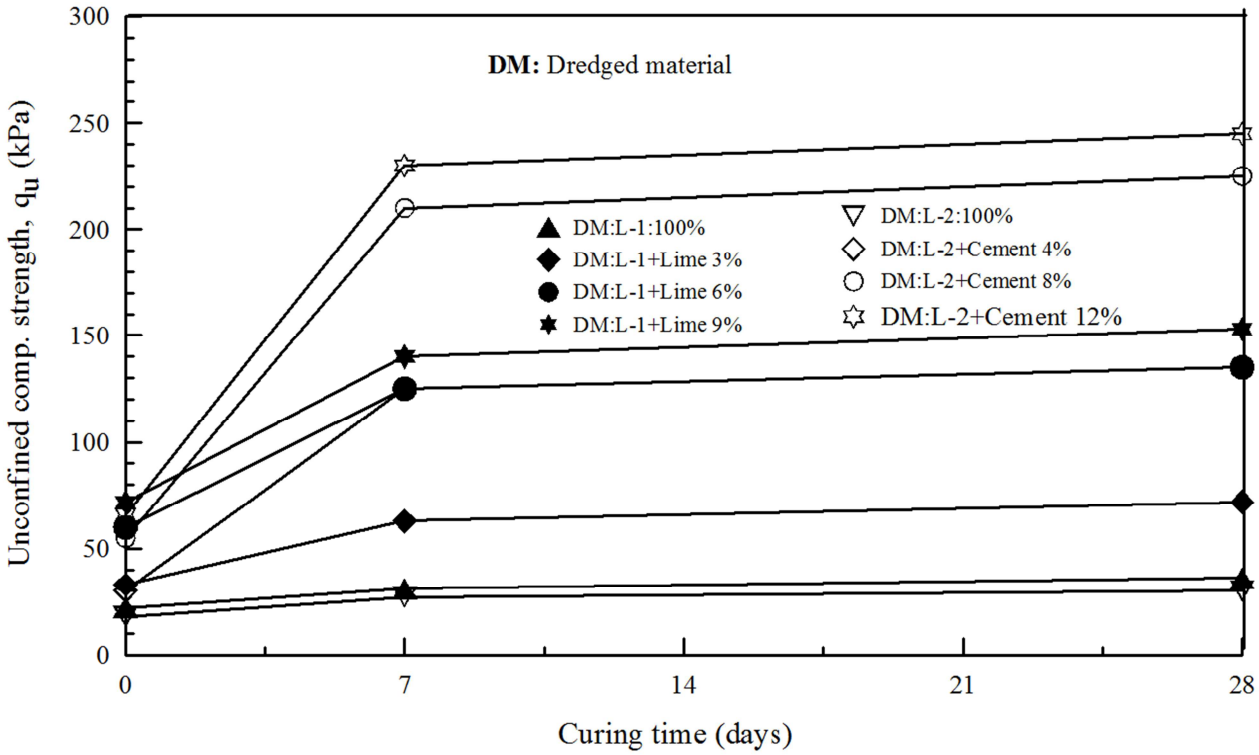

Figure 3. *Effect of curing time on the "UCS" of soil-lime-cement mixes.*

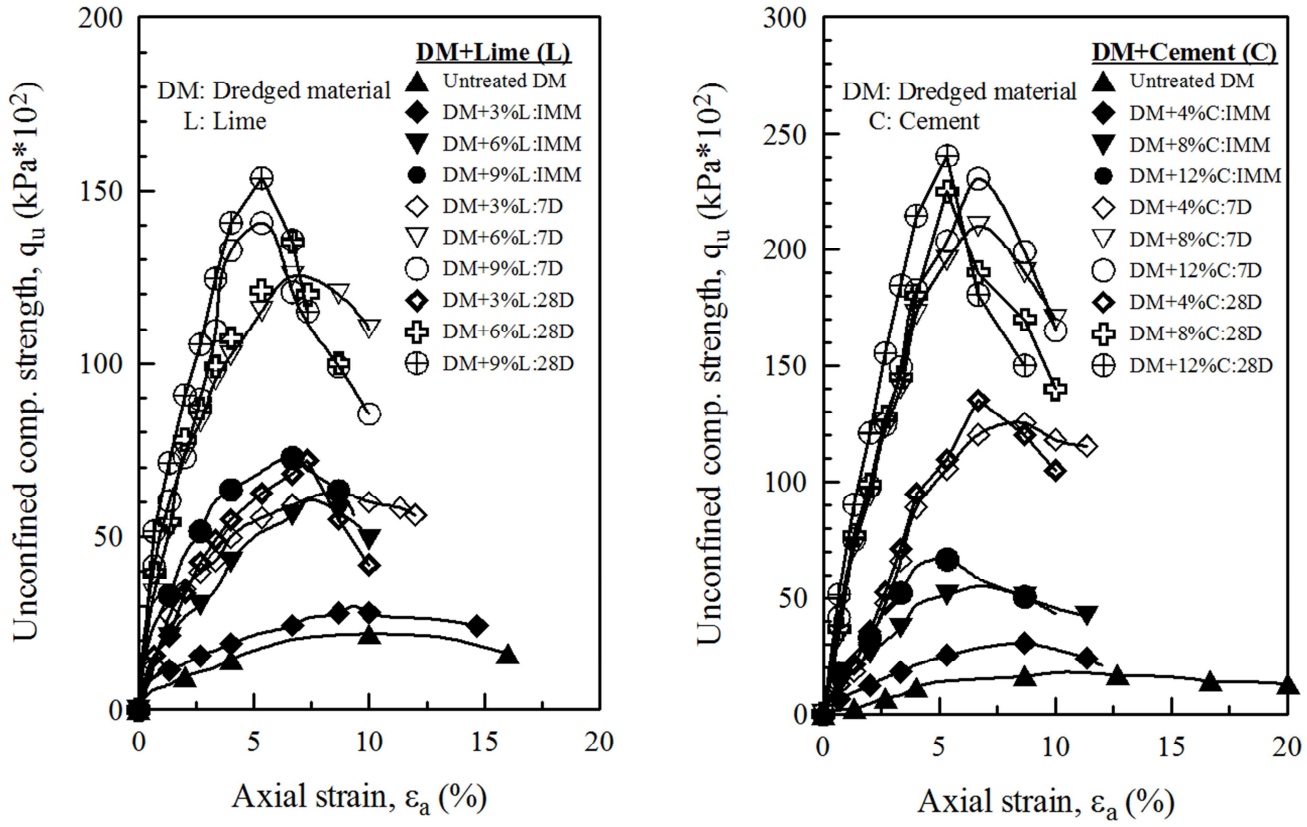

Figure 4. *Stress-strain plots for lime and cement treated dredged solid waste material for different curing periods.*

4.2. Effect of Dredged Solid Waste Material on the CBR Behavior of Natural Earth Soil (ES)

An extensive road network is one of the major indicators of a nation's economic prosperity, and soil is used as construction materials for roads and airfield pavements. Of all the available methods of design, the CBR (California Bearing Ratio) method [27-28] has been found the most reliable practical method of designing the flexible pavements. The design of flexible pavement is generally guided by the criterion of CBR test, which is a measure of the load carrying capacity (resistance to direct penetration) of any soil or granular material. The CBR of fine-grained soil (ES) and dredged solid waste material (DM) are found to be 2.6% and 4.5% for soaked conditions. The decrease in CBR upon soaking is due to the decreased effective stress and loss of surface tension forces. The CBR of the material is contributed by its cohesion and friction components. For earth soil (fine-grained soil obtained from road site), mainly cohesion contributes and for dredged solid waste material, the friction due to the coarse particles mainly contributes to the mobilization of strength. Due to the dominance of clay fraction, natural earth soil has low CBR attributed to its inherent low strength. Addition of 75% dredged material to the earth soil increases the CBR due to the frictional resistance from dredged material in addition to the cohesion from the earth soil. The addition of dredged material beyond 75% causes a little reduction in the CBR value due to the reduction in cohesion because of decreasing earth soil (i.e. reducing clay fraction) inspite of the increase in strength due to increase in dredged material. The experimental program and the results are shown in Table 2, and the variation of unsoaked and soaked CBR for natural earth soil admixed with dredged material is shown in Figure 5.

Table 2. *CBR of earth soil-Dredged material mixes for soaked conditions.*

CBR (%)	100% ES (Earth Soil)	75% ES+25% DM	50% ES+50% DM	40% ES+60% DM	25% ES+75% DM	10% ES+90% DM	*100% DM* (Dredged Material)
Soaked	3.8	4.5	5.9	6.8	7.5	5.9	3.9
Un soaked	6.3	7.7	10.3	11.3	12.6	8.7	5.3

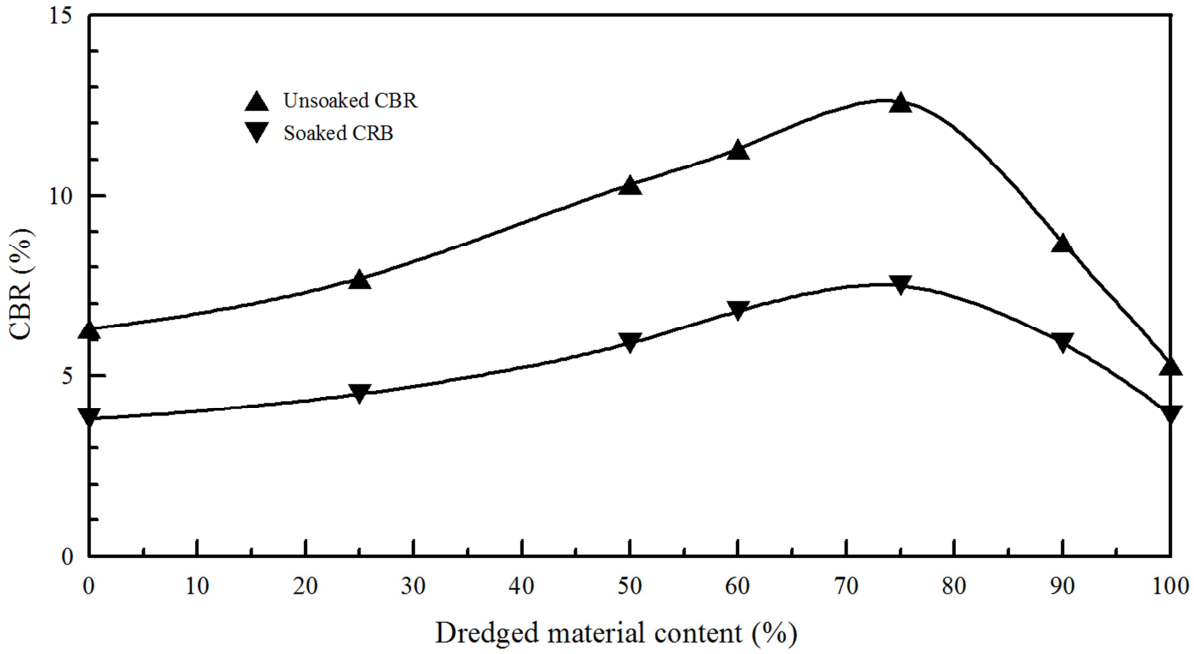

Figure 5. *Variation of CBR value for natural earth soil admixed with dredged material.*

5. Conclusions

Based on the results obtained, the following conclusions can be made:

1. The dredged solid waste material is a problematic soil due its wet and sticky condition. When dry, it is very dusty, being transported by mild wind.
2. Admixing stabilizers (Lime and Cement in the present case) can modify these undesirable properties. To restore the balanced ecological environment, effective management system, effective minimization process and proper disposal techniques are to be adopted.
3. The index properties of both earth soil and dredged solid waste material are significantly altered by the addition respective stabilizers. The extent of variation depends on the particle size distribution.
4. It has been observed that 6% of lime, 8% of cement and 75% of dredged solid waste material are the optimum amounts required to improve the undesirable properties of dredged solid waste material and to maximize the CBR of fine-grained soil.
5. If the objective is the bulk utilization of dredged solid waste material, the addition of about 25% of fine-grained soil (ES) to dredged material is very effective. In other words, it is the proper mix proportion that optimizes the frictional contribution of dredged solid waste material and the cohesive contribution from earth soil leading to maximization of CBR.
6. Thus, this study has shown that treatment of fine-grained soils using dredged solid waste material can be used in bulk as a sub base/base material in Road construction. Hence, using dredged solid waste material as a resource has a two-fold advantage. First, to avoid the tremendous environmental problems caused by large scale dumping of dredged material and second, to reduce the cost of stabilization of soils and bulk utilization of dredged material. Different improvement techniques are being applied to this material for its bulk utilization without adversely affecting the environment and landscape. Due to various constraints, other tests could not be presented in this paper, but the investigation is being continued for a comprehensive characterization and diversion studies of dredged material in a manner that is protective of human health and the environment in and around the world famous Dal Lake.

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