Physical and Mechanical Behaviour of Dredged Soil acquired from Dal Lake-A Laboratory Study

Rakshanda Showkat [1][0000-0002-4953-8595], Bashir Ahmad Mir [1] and K. M. N. Saquib Wani[1]

[1] National Institute of Technology Srinagar, J&K 190006, India
rakshandashowkat07@gmail.com

Abstract. This study deals with the characterization of dredged material obtained by dredging the World famous Dal Lake. Due to the non availability of suitable dumping sites for the wastes generated around Dal Lake and owing to the concern of environmental and health issues of waste material obtained by dredging, geotechnical engineers have been under tremendous pressure from geo-environmentalists for the characterization of this dredged material. Therefore, in this study, an attempt has been made to characterize the waste material generated from Dal Lake by studying its various physical and mechanical properties. In this study, dredged material has been collected from three different sites viz Nishat, Shalimar, Telbal located on catchment of Dal Lake to conduct various field and laboratory tests for the determination of field density, soil classification, compaction characteristics, strength parameters like unconfined compressive strength, direct shear test, California bearing ratio. On the basis of results, it has been found that dredged material mostly comprises of silt, clay and sand and also strength parameters revealed that dredged material cannot be used as construction and foundation material in its in-situ state. Therefore, suitable and feasible treatments should be provided to dredged material so that it can be used for geotechnical applications.
Keywords: Dredged material, solid waste, foundation material, Characterization, geotechnical applications, Geoenvironmentalists.

1 Introduction

Dal Lake (located at 34° 07′ N, 74° 52′ E, 1584 m above MSL), in Srinagar, Jammu & Kashmir, India, is the second largest Lake in state and has been integral to tourism and recreation in Kashmir, hence named as "jewel in the crown of Kashmir". The Lake having a total catchment area of 316 sq. km., maximum depth of 6 meters and shore length of 15.5km is located in the Zabarwan mountain valley, in the foothills of the Shankracharya hills, which surrounds it on three sides. The Dal Catchment consists of mountain ranges on its North and North-East and on the other sides it is enclosed by flat arable land as shown in Fig. 1. The Lake receives large quantity of sediments and nutrients with the runoff from its catchment through Telbal Bota Khul during the downward movement of water from Marsar. The major silt and sediment load enter the water body from the critical zone on north western portion of the catchment. A large amount of sewage from the settlements around the Lake and the habitation living on hamlets within the Lake, on floating islands and houseboats enters the Lake without treatment. Huge quantity of solid wastes and superfluous fertilizers from inlet channels produces algal blooms which ultimately results in eutrophication. Thick mats of red bloom and weeds give ugly look to the Lake besides affecting its flora and fauna. About 156 tons of Phosphorus and 380 tons of nitrogen are estimated to flow into the Lake from various sources. The drains also carry sludge and solid wastes from the surrounding areas into the Lake. The interior channels connecting Dal with its other basins like Nagin, Pokhribal, were found chocked due to the regular disposal of solid wastes. Also, vegetable growers regularly encroach into the Lake, planting trees. Because of urbanization, multi storey buildings and small craft factories have been erected on the banks of Dal. In September 2014, the massive flood which occurred when the river Jhelum rose to the dangerous level due to intense rainfall from 1st to 7th of September 2014, a huge amount of water entered the Dal Lake due to breech in embankment at Ram Munshi Bagh. This water brought large amount of silt and biological load in the Lake, thus causing siltation and pollution of Dal. As a result of this continuous disposal of wastes, silt deposition and encroachment, the load carrying capacity of the Lake has been reduced. The problems of Dal Lake and its importance to the people, tourists, sustainable development have been well recognized, and efforts are being made to clean the Lake which has been polluted as a result of rapid urbanization and disposal of solid wastes. The scheme for shoreline dredging of Dal Lake has been formulated with the primary objective to increase the clear water expanse of the Lake, improve water circulation and help in Eco regeneration of Lake (Mir and Jan 2018).

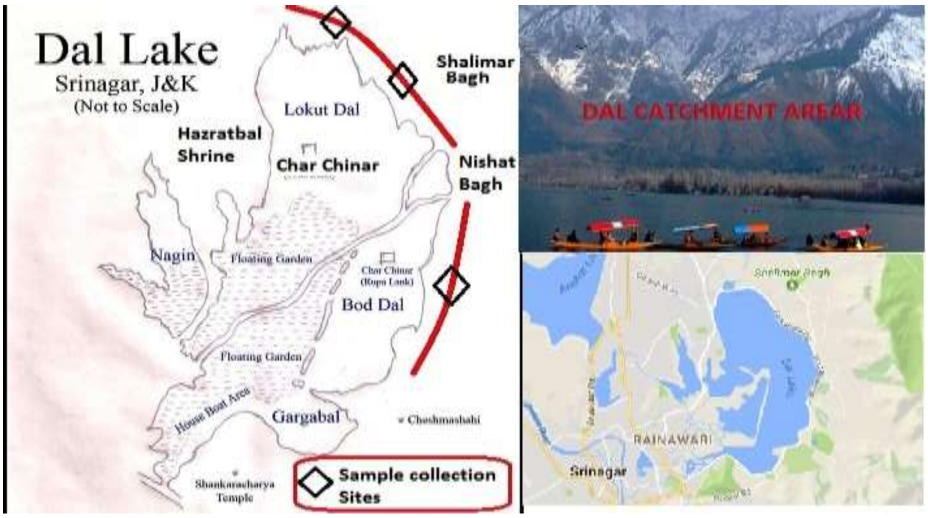

Fig. 1. Sample collection sites from the catchment area of Dal Lake

2 Dredging of Dal Lake

Dredging is the operation of removal of sediments and debris from the bottom of lake, river, harbor and other water bodies. It is the form of excavation carried underwater or partially underwater in shallow water bodies. It is a routine necessity in water bodies because sedimentation gradually fills the channels. Dredging is focused on maintaining or increasing the depth of navigation channels, anchorages, or berthing areas to ensure the safe passage of boats and ships. The sediment removal process uses a machine known as a dredge to excavate the accumulated sediment and debris. A dredge is equipped with a powerful submersible pump that relies on suction to excavate the debris. A long tube carries the sediment from the bottom to the surface. Due to the rapid urbanization and population explosion particularly in developing countries, there is shortage of construction materials as well as scarcity of suitable construction sites. Thus, it forces the geotechnical engineers and specialists to adopt such soft soil sites for construction. Soft soil deposits which are very weak having low bearing capacity and undergo settlement for a considerable period of time. To assess the mechanical behavior of such soils, Geotechnical engineers face a difficult task (Mir 2017). Using these spoils as construction material, foundation medium, backfill, in dykes and embankments, becomes a substantial problem for geotechnical engineers. The large quantities of dredged material obtained after carrying out dredging operation of Dal Lake also belongs to the category of soft soils, enhancing load on engineers to use these deposits for constructional purpose. Since the capacity of Dal has tremendously decreased due to siltation, it becomes necessary to carry out dredging in order to maintain the Lake. Hence, there should be proper management of dredged material so that health and environmental hazards can be minimized (Mir 2005).Based on characterization, dredged material is now treated as a resource rather than waste. It can be used in the manufacture of large number of high value and beneficial products based on its mineralogical composition and geotechnical properties (Bartos 1977; Mir and Mir 2004). It can be used in a number of ways such as fill material, sub-grade construction, reclamation, landscaping, agriculture, covers for landfills, and raw material for the production of riprap or blocks for the protection of dikes and slopes against erosion (Aarninkhof and Luijendijk 2010; Mir and Mir 2004), constructing wet- lands for water quality improvement, bank stabilization, creation of islands, wildlife habitat wetlands, etc. (DOER 1999). Two broad categories of proposed uses are often distinguished: Engineering uses and Environmental uses (Mir et al. 2013).Hence, this study becomes important for bulk utilization of dredged material obtained from Dal Lake and also assesses the geotechnical properties of dredged soil. A number of techniques are available for dewatering and improving engineering properties of dredged material and other soft soils (Haliburton 1978; Chan et al. 2011).

3 Materials and Methods

3.1 Materials

The soil samples for the present research study were taken from three different sites on the famous Dal Lake viz: site 1-Shalimar, site-2-Nishat, site 3-Telbal as shown in Fig. 1. At each site, soil samples were collected, sealed and transported with utmost precaution for studying their various geotechnical properties and behavior as per relevant testing standards.

3.2 Testing Methodology

Physical Properties

a) Field moisture content and dry unit weight. Field moisture content and bulk unit weight of samples of dredged material collected from three different sites was determined on undisturbed samples collected using core cutter method as per IS: 2720 part 2 and IS: 2720 part 29. The in-situ samples were possessed high moisture content. The dry unit weight of in situ samples was also low as compared to the maximum dry unit weight of the dredged samples.
Average values of moisture content and in situ dry unit weight were 33.12%, 35.2%, 34.7% and 13kN/m3, 10.3 kN/m3, 10.6 kN/m3 for Shalimar, Nishat, and Telbal respectively.
b) Specific gravity. Specific gravity was determined as per IS: 2720 (part 3) - 1980 using density bottle method with distilled water. The average value of specific gravity of Shalimar, Nishat and Telbal, is 2.4, 2.43, and 2.6 respectively.
c) Particle size analysis. For measuring the distribution of particle sizes in a soil sample, it is necessary to conduct different particle-size tests. It expresses quantitatively the proportions by mass of various sizes of different particles present in a soil, represented graphically on a particle size distribution curve. It is done in two stages: Sieve analysis and Sedimentation analysis.

Wet sieving is carried out for separating fine grains from coarse grains by washing the soil specimen on a 75 micron sieve mesh. Dry sieve analysis is carried out on particles coarser than 75 microns. Sedimentation analysis is used only for the soil fraction finer than 75 microns. Soil particles are allowed to settle from a suspension.
In the present study, soil grading of dredged material from Shalimar, Nishat and Telbal basin of Dal Lake was carried out on an oven dried sample by dry and wet sieve analysis as per IS: 1498-1970 followed by sedimentation analysis as per IS: 2720 (part 4) - 1985 using a hydrometer. The particle size distribution curves of the dredged material from three different sites (Site 1, Site 2, and Site 3) are given in Fig. 2.

The particle size distribution curve is used to know the classification of coarse grained soils and has a limited application for fine grained soils like clay and silts, since the behavior of fine grained soils (FGS) depends upon the plasticity characteristics and not on the particle size. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained from particle size distribution (PSD) curve represent the range and shape of PSD curve, thereby help in analyzing the gradation of soil. The particle size analysis is used to know the susceptibility to frost action, required for the design of drainage filters, an index to coefficient of permeability and the shear strength of the soils. The suitability of the backfill material also depends on gradation.

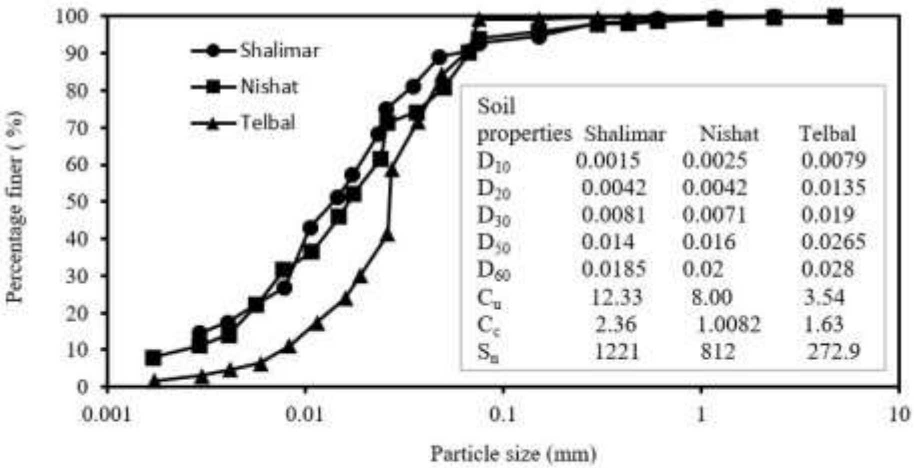

Fig. 2. Particle size distribution curves of different soil sample

d) Index properties

Index properties are the properties of soil that help in identification and classification of soil and are indicative of the engineering properties of the soil. These properties are generally determined in the laboratory. The main index properties of fine-grained soils are Atterberg's limits which include liquid limit, plastic limit, shrinkage limit.

Liquid limit tests.

The Atterberg's limits were determined on oven-dried dredged soil samples passing through 0.425 mm IS sieve by wet to dry process using Casagrande's apparatus as per IS 2720-Part 5, (1985). The flow curves for the dredged material of the three sites are shown in Fig. 4 As can be seen from Fig. 3, the dredged material under investigation possesses medium compressibility and depict that the soil obtained from Nishat is highly compressible with high rate of loss of shear strength. Furthermore, the in-situ water content of the dredged material is more than its plastic limit resulting in a wet and sticky condition, impossible to compact and traffic.

Plastic limit tests.

The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. If the soil is at moisture content where its behavior is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remolded, and the test repeated The PL values were determined using standard relevant testing procedures as per IS 2720-Part 5, (1985). The plastic limit values reported in Table 1 are an average of the three trial determinations. Based on the values of A-line and U-line in the plot of liquid limit vs plasticity index, mineral present in all three soil was found to be kaolinite.

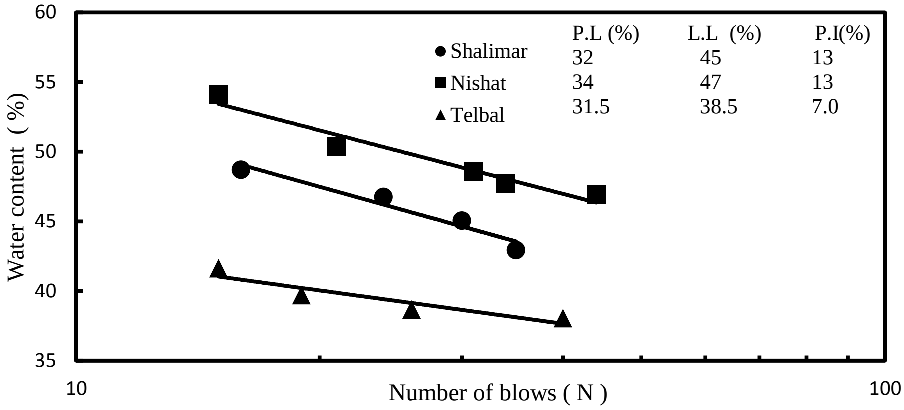

Fig. 3. Atterberg's Limits for three sites (Site 1, Site 2, Site 3)

Shrinkage limit tests.

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid and plastic limits. It is used for understanding the shrinkage and swell characteristics of the cohesive soils. Soil samples as prepared for the liquid limit are taken in a shrinkage dish without inclusion of air bubbles, weighed and kept for air drying until the colour of the soil pat changes and then the dishes are oven dried at 110˚ C for 24 hours. Shrinkage limit was determined using the standard testing method as per IS 2720-Part 5, (1985).

Table 1. Physical properties of dredged soil from three different sites on Dal Lake

Properties	**Shalimar**	**Nishat**	**Telbal**
Natural moisture content (%)	33	35.2	34.7
Bulk unit weight (kN/m^3)	15.5	14	14.3
Insitu dry unit weight (kN/m^3)	13	10.3	10.6
Specific gravity (G)	2.4	2.43	2.6
% Finer than 75 µm	92.94	93.93	99.25
Clay (%)	12	10	3
Silt (%)	80	83	96
Sand (%)	7.06	6.06	0.745
Gravel (%)	0	0.07	0
Coefficient of uni-	12.33	8	3.54

formity, C_u			
Coefficient of curvature, C_c	2.36	1.008	1.63
Suitability number, S_n	1221	812	272
Liquid limit (%)	45	47	38.5
Plastic limit (%)	32	34	31.54
Shrinkage limit (%)	18.0	17.0	17
Plasticity index (%)	13	13	6.96
P.I, A-line	18.25	19.71	13.505
P.I, U-line	33.3	35.1	27.45
Classification	MI	MI	MI
Clay mineral	Kaolinite	Kaolinite	Kaolinite
Flow index, I_f	11.11	25.4	8.96
Toughness index, I_t	0.85	1.95	1.28
Activity	1.08	1.3	2.32
Consistency index, I_c	0.92	0.90	0.54
Liquidity index, I_L	0.07	0.09	0.45

Engineering Properties.

Strength characteristics.

In the present investigation unconfined compression test and direct shear tests are performed on the in-situ samples of the dredged materials of all three sites. Each site was tested for two samples and the weakest soil samples were compared for assessment of shear strength parameters. The test samples were tested in an unconfined compression testing (UCT) machine as per relevant standard testing procedures IS 2720-Part 10 (1991) These test values suggest that the soil under undrained condition is in soft state as shown in fig. and need treatment before being used for any engineering purpose. Direct shear tests were conducted on direct shear test machine under drained condition, as per standard testing procedures IS 2720-Part 13, (1986). The stress strain behavior for all the three sites is shown in Fig. 4, Fig. 5, Fig. 6 and Fig. 7 respectively. The test results conducted under drained condition indicate angle of internal friction of Shalimar soil was found to be comparatively lower than other two sites which shows that it is possesses more cohesion than other two sites and that the dredged soil in natural condition is very soft and in very loose state.

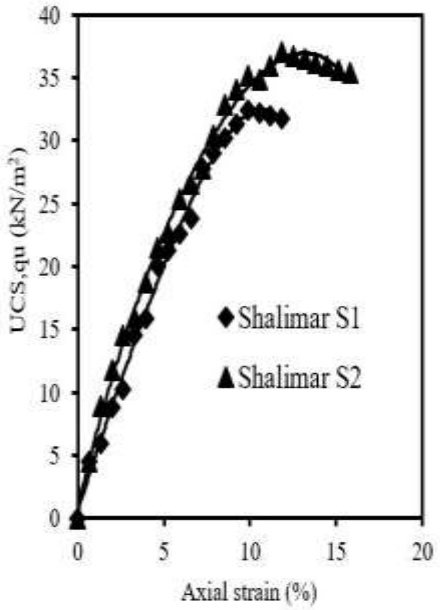

Fig. 4. In-situ stress strain curves for site 1**.**

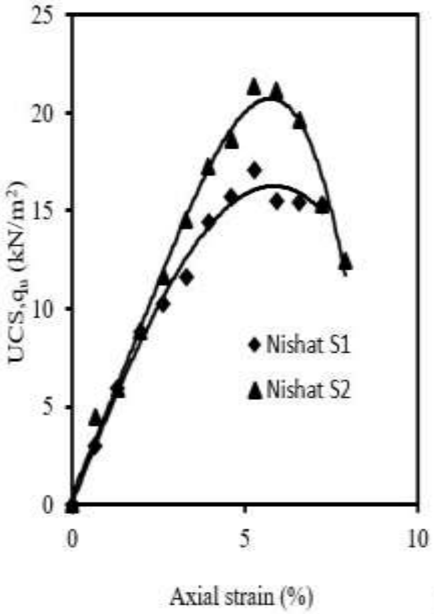

Fig. 5. In-situ stress strain curve for site 2

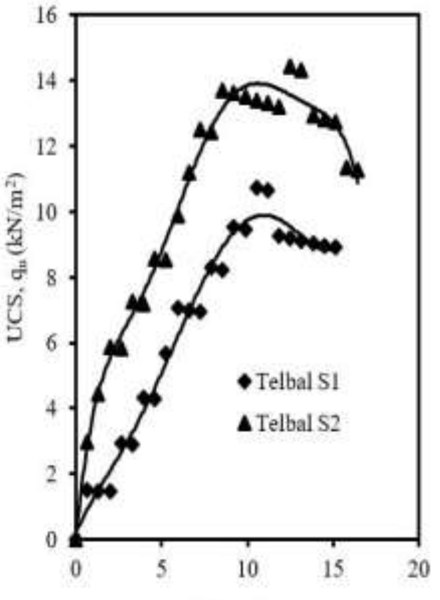

Fig. 6. In-situ stress strain curves for site 3

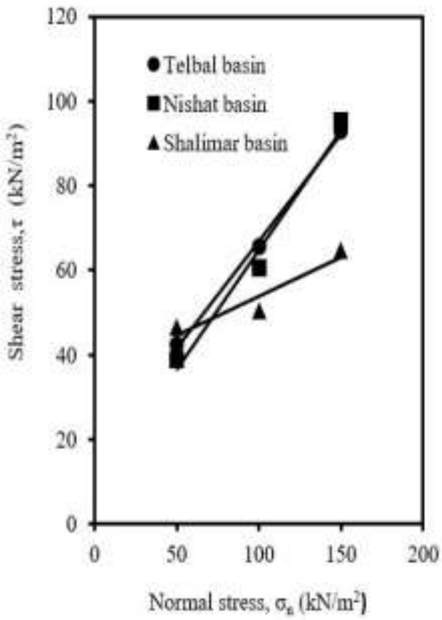

Fig. 7. Mohr failure envelopes for 3

Compaction characteristics.

In the present study, the compaction was done by standard proctor test (light compaction test) in the laboratory by following proper codal provisions as per IS 2720-Part 7, (1980). The results of the standard proctor tests are presented in a plot between moisture content (OMC) as abscissa and the corresponding dry unit weight as the ordinate (Fig. 8).From the graph, OMC value of Shalimar soil was found to be comparatively lower than other two sites because OMC of highly cohesive soils is usually found to be very low. The zero air void line (ZAVL) based on specific gravity values of three sites is shown in fig.8.

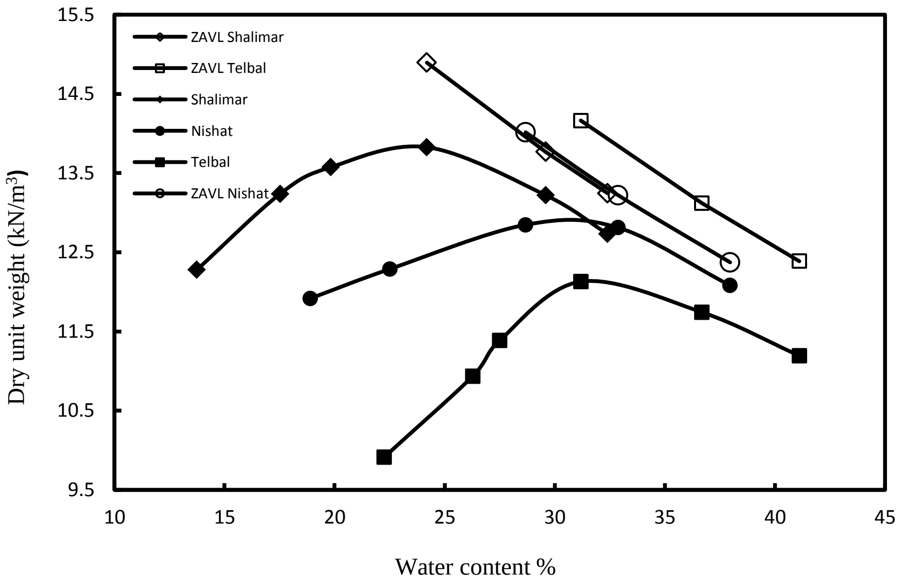

Fig. 8. Compaction curves for three different sites

CBR on dredged soil compacted on OMC.

The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. In the present study CBR tests were conducted on three soil samples compacted at OMC using relevant codal procedure IS 2720-Part 16 (2002). Fig. 9 and Fig. 10 show the load-deformation curves of dredged soil samples from three different sites of the Dal Lake.

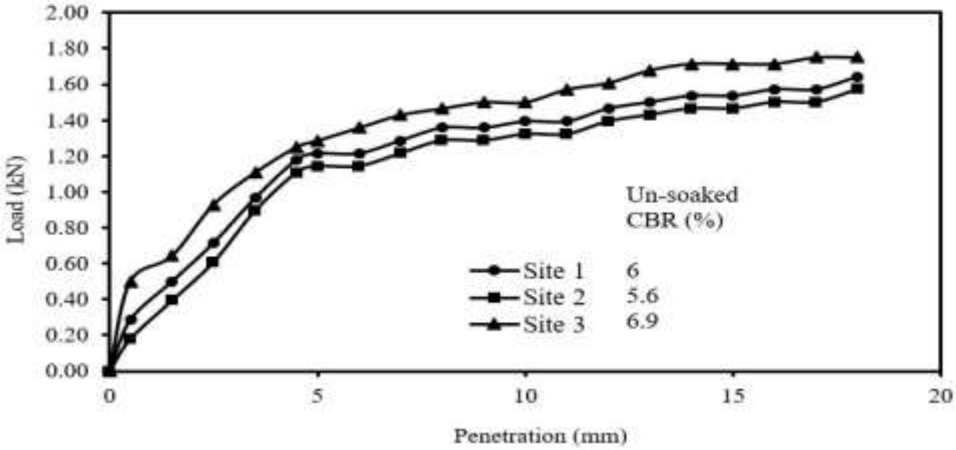

Fig. 9. Load vs deformation curves for CBR (un-soaked condition)

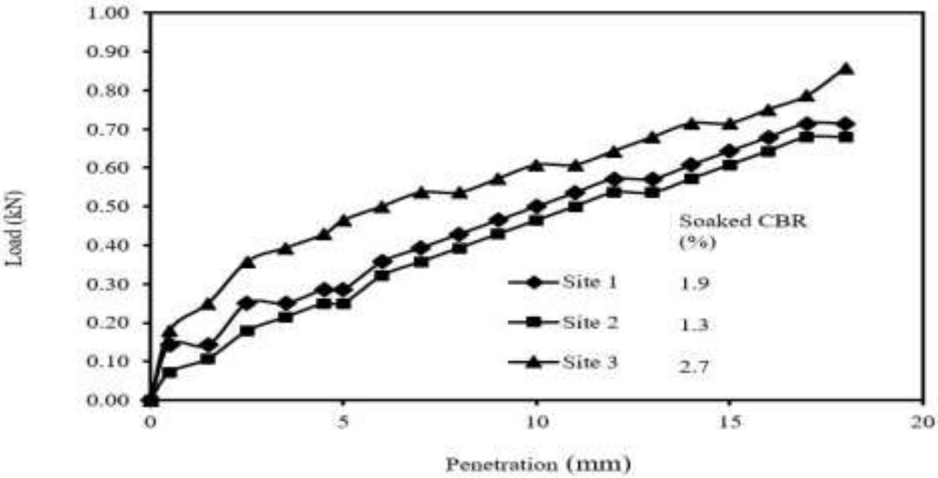

Fig. 10. Load vs deformation curves for CBR (soaked condition)

Table 2. Mechanical properties of dredged soil from three different sites on Dal Lake

Properties		Shalimar	Nishat	Telbal
DST @ In-situ	Cohesion, c (kN/m^2)	35.69	8.57	16.35
	Angle of internal friction, Φ (Deg)	10.31	29.4	26.83
UC-test @	Unconfined compressive	34.17	19.17	12.57

In-situ strength, q_u (kN/m^2)			
Optimum moisture content (%)	25	32	31
Maximum dry unit weight (kN/m^3)	13.67	12.8	12.12
California bearing ratio un-soaked (%)	6.0	5.6	6.9
California bearing ratio soaked (%)	1.9	1.3	2.7

4 Conclusion

1. Based on some of the physical properties of the dredged material investigated, the material from three different sites of Dal Lake has been classified as inorganic silt-MI of medium plasticity as per Indian Standard Soil Classification System.
2. The specific gravity values are very low (2.4, 2.43 and 2.6 for Shalimar, Nishat and Telbal respectively) which is a cause of concern.
3. The compaction curves show that soil has a low dry density ranging between 14kN/m^3 to 12kN/m^3 at OMC varying between 27 to 32%.
4. The dredged material is weak and has low values of shear strength parameters (UCS values being 34kN/m^2, 19.17kN/m^2, 12.57kN/m^2 for Shalimar, Nishat and Telbal).
5. The CBR values are also low ranging between 5% to 6% and hence the soil cannot be used as a construction material in sub grade or for heavy construction work.

Dredged material collected from the Dal Lake is not suitable as an engineering material in its present in-situ condition and hence needs stabilization before being able to be used as a construction material.

References

1. Aarninkhof, S., Luijendijk, A. (2010): Safe disposal of dredged material in an environmentally sensitive environment. Port Technol. Int. 47, pp. 39–45.
2. Bartos, M. J. Jr. (1997): Classification and engineering properties of dredged soil. Technical Report D-77-18, U.S. Army Waterways Experiment Station, Vicksburg, MS.
3. DOER-C2 (1999): Dredged soil characterization tests for beneficial use suitability. Technical Note. U. S. Army Corps of Engineers.
4. Haliburton, T.A. (1978): Guidelines for Dewatering/Densifying Confined Dredged Material, Synthesis Report, Technical Report DS-78–11, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
5. Jan, O. & Mir, B.A. (2018): Strength Behavior of Cement Stabilised Dredged Soil. International Journal of Geosynthetics and Ground Engineering.
6. Mir, B. A. (2017): Some studies on mechanical behavior of cement stabilised dredged soil from flood spill channel of Jhelum River Srinagar. In: Singh D, Galaa A (eds) Contempo-

rary issues in geoenvironmental engineering, sustainable civil infrastructures. Springer, Cham, pp 386–406.

7. Mir, B.A. and Mir, F. A (2004): Applications and geotechnical evaluation of dredged soil obtained from Dal Lake in Srinagar. Proc. National Conf. on Soils and their applications in Civil Engg., pp. 26-37.
8. Mir, B.A., Amin, F. and Majid, B. (2016): Some studies on physical and mechanical behavior of dredged soil from flood spill channel of Jhelum river, Srinagar. Acta Ing Civil 1(1):1–7
9. Mir, B.A., Wani, B.A., Ahmad, N., Ayoub, R., Dar, L.A., Rashid, S.U., Aziz, J. (2013): Physical and compaction behavior of dredged material from Dal Lake, Srinagar. International Journal of Civil Eng Appl 3(7):4–8.
10. IS: 2720-part 3(1) (1980): Determination of specific gravity of fine grained soils. BIS, New Delhi.
11. IS: 2720-part 3(2) (1980).:Determination of specific gravity of fine, medium and coarse grained soils. BIS, New Delhi
12. IS: 2720-part 4 (1985): Determination of grain size distribution. BIS, New Delhi.
13. IS: 2720-part 5 (1985). Determination of Atterberg limits. BIS, New Delhi.
14. IS: 2720-part 6 (1972): Determination of shrinkage factors. Bureau of Indian standards, New Delhi.
15. IS: 2720-part 7 (1980): Determination of water content-dry density relation using light compaction. BIS, New Delhi.
16. IS: 2720-part 8 (1980): Determination of water content-dry density relation using heavy compaction, BIS, New Delhi.
17. IS: 2720-part 10 (1973).:Method of Test for Soils: Determination of Shear Strength Parameter by Unconfined Compression Test. New Delhi: Bureau of Indian Standards.
18. IS: 2720-part 39 (1977).:Method of Test for Soils: Determination of Shear Strength Parameter by Direct Shear Test. New Delhi: Bureau of Indian Standards.
19. IS: 2720-part 16 (1979): Method of Test for Soils: Laboratory Determination of CBR. New Delhi: Bureau of Indian Standards.
20. IS: 9669(1980): Specification for CBR Moulds and Iits Accessories. New Delhi: Bureau of Indian Standards.