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Stabilization of Dredged Soil by Compensating the Sand Content in the Jhelum River

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ABSTRACT

River dredging is crucial for mitigating the risk of floods by enhancing the water-carrying capacity of rivers. Nevertheless, the key difficulty lies in the appropriate disposal of dredged material, resulting in escalated costs. Predominantly consisting of silt, the dredged material demonstrates constrained bearing capacity and strength. Nonetheless, there is a prospect to derive value from excavated sediments, with potential applications in diverse public works projects. The processed product derived from dredged material can serve diverse purposes, such as filling railway and highway embankments, as well as the subgrade of pavements. The comprehensive study involved analyzing the fundamental properties of the dredged material collected from the Allochibagh flood channel of the Jhelum River. The analysis focused on determining the basic geotechnical properties of the soil mass. The tests unveiled the fine and cohesive nature of the dredged soil. To enhance its properties, sand was introduced as a stabilizing agent in varying proportions. The investigation revealed an initial augmentation in compressive strength as the proportion of sand increased, attaining an optimal mixture whereafter the strength declined. This study explores the utilization of sand as a stabilizing agent for dredged soil to enhance its strength and optimize its application. The process of stabilizing dredged soil with sand demands a thorough examination of hydrogeological processes, the specific characteristics of the dredged soil, and the intricate transport of contaminants. This formal and multidisciplinary effort seeks to elevate the overall stability of the soil.

INTRODUCTION

River dredging involves the extraction of sediment and debris from a river's bed and banks to uphold navigability, prevent flooding, and support water infrastructure. One of the elements that exacerbated the flood scenario in Kashmir in September 2014 has been identified as the increased siltation in the river bed of the river Jhelum. As a result, experts have been urging for immediate dredging of the rivers and its spillway to boost its capacity. Two sections of the Dredging have been separated. The Irrigation and Flood Control department is in charge of the first component, which requires dredging of approximately 9,50,000 m^3 of material. In the second phase, the Irrigation and Flood Control department contracted with a private company to remove 16 lakh cubic meters of silt by dredging the Jhelum and its spillway. According to estimates, Jhelum's dredging will boost the river's carrying capacity from 34000 to 45000 cusecs and the flood spillway's capacity from 5000 to 10000 cusecs PTI (2016), Amin (2016) However, because poorly graded silt makes up the majority of the dredged material, it has a relatively poor bearing capacity and strength (Mir et al. 2016) and cannot be used directly for different types of building. The disposal of substantial volumes of dredged material in landfills poses significant environmental challenges and hence it must be properly disposed of, which raises the price even more (Nassar et al. 2023). The valorization of excavated sediments and their use in public works, however, offers an option. The processed product can be used for a variety of things, like filling up pavement (subgrade) and railroad and highway embankments. The geotechnical attributes of dredged material make it essential to employ strategies for stabilizing the soil mass, thereby improving its characteristics, particularly its strength, to enable its practical application. This objective can be achieved through diverse techniques, including the introduction of stabilizing agents such as cement, lime, fly ash, and fibers. The selection of a particular additive is contingent upon factors such as the soil type, intended purpose, and prevailing environmental conditions. The primary mechanisms employed by these stabilizers encompass cation exchange, flocculation and agglomeration, pozzolanic reaction, and carbonate cementation (Croft 1967, Firoozi et al. 2014, Puppala & Musenda 2000, Firoozi et al. 2015, Little 1998, IS 13094 1992). Sand, a naturally occurring granular material, is valuable for its high load-bearing capacity in confined conditions. As a filler material, it can be added in various proportions to cohesive soils, effectively modifying plasticity, compaction, and strength in the mixtures (Kollaros & Athanasopoulou 2016). This versatile use of sand contributes to the overall enhancement of soil properties.

The current study focuses on the valorization of dredged material, specifically through the exploration of stabilization methods. This study delves into the potential enhancement of dredged material by incorporating an inert additive, namely sand. The key aspect under investigation is the engineering characteristics of the soil before and after the additive mix. Through systematic experimentation, varying concentrations of sand were introduced as additives, and a thorough analysis was conducted to assess their influence on the engineering properties of the dredged material. The primary objective of the study is to illustrate the impact of different percentages of sand content on the characteristics of dredged material.

OBJECTIVE AND SCOPE OF THE STUDY

The primary focus of this study is the geotechnical characterization of dredged material, examining its properties at various locations along the flood-sensitive channel. Through detailed analysis, the study aims to understand the unique geotechnical characteristics of the dredged material. The investigation encompasses aspects such as composition, particle size distribution, moisture content, and other relevant properties. Building on this characterization, the study provides prospective recommendations for the practical application of dredged material based on its distinct properties. These recommendations are designed to guide decisions on the utilization of dredged material, taking into account factors such as its stability, strength, and environmental impact. The overarching goal of this research is to contribute to the effective management of dredged soil along the Jhelum River, ensuring that the handling and application of this material safeguard both human health and the broader ecosystem. By combining geotechnical insights with practical recommendations, the study aims to offer a holistic approach to the responsible use of dredged material in this crucial environmental context.

MATERIALS AND METHODS

Methodology

The research commenced with the retrieval of soil samples from the Jhelum flood channel of Allocha Bagh in Srinagar, with the primary objective being the comprehensive assessment of the essential properties inherent in the dredged soil to gain insights into its fundamental characteristics. This involved a systematic series of tests and analyses, commencing with the determination of the specific gravity through a density bottle test. Subsequently, the soil's maximum dry density was established via a proctor compaction test. The particle size distribution was scrutinized using both sieve analysis and hydrometer analysis. The liquid index and plastic index were ascertained utilizing Casagrande's apparatus and the 3mm rolling thick thread rod method, respectively. Following the comprehensive understanding of the soil's intrinsic attributes, the investigation progressed to evaluate its shear strength through the unconfined compression strength (UCS) test. All examinations and sample preparations were carried out in compliance with the established procedures of CE, as cited (Reddy 2022, IS 1498-1970, IS 2720-1980, Punmia 2007). In a subsequent phase, sand was introduced as a stabilizing agent to the dredged soil in varying proportions of 1.5%, 3%, 5%, and 7.5%. Post the sand incorporation, the soil's strength was reevaluated by employing the unconfined compression strength test. The overarching goal of the study was to systematically observe and quantify variations in soil strength corresponding to different proportions of added sand, thereby offering significant insights into the stabilizing effects exerted by sand on the dredged soil.

Analysis

The specific gravity of a soil sample was determined through the utilization of the density bottle method. Three distinct empty-density bottles denoted as D1, D2, and D3, each initially weighing 32g, were employed in the procedure. Subsequently, 10g of dry soil mass was added to each bottle. The density bottles were then saturated with distilled water, and the resultant masses, encompassing the density bottle, soil, and water, were meticulously recorded for each bottle as 104.31g, 104.5g, and 104.8g respectively. Following this, the density bottles were emptied, and filled solely with distilled water, and the corresponding masses were recorded as 98.12g, 98.3g, and 98.6g respectively. Consequently, the specific gravity values for soil in D1, D2, and D3 were calculated to be 2.62, 2.63, and 2.63, respectively. Upon incorporating temperature corrections, the final average specific gravity of the dredged soil at 27°C was computed as 2.63.

Particle size distribution of soil refers to the relative proportions of sand, silt, and clay particles within a soil sample, determining its texture. With sand particles ranging from 2.0 to 0.05 millimeters, silt between 0.05 and 0.002 millimeters, and clay particles smaller than

0.002 millimeters, the combination of these soil separates influences essential soil properties. This distribution is crucial for soil classification, influencing water retention, drainage, and aeration. It also impacts nutrient availability, with clay particles having a greater surface area for nutrient retention. Engineering properties of soils, such as compressibility and shear strength, are dependent on particle size distribution, making them important in construction. Additionally, understanding soil texture aids in land use planning, agricultural management, and environmental conservation, guiding decisions on crop selection, irrigation practices, and erosion control. Laboratory methods: sieve analysis and hydrometer analysis were employed to assess the particle size distribution, providing valuable insights for a range of applications in soil science.

Sieve analysis serves to ascertain the particle size distribution of granular substances like soil or aggregate. This method entailed passing a sample through a sequence of sieves arranged in decreasing mesh size. After sieving, the material retained on each sieve was weighed, and the percentage within each size range was determined from the total sample. The outcomes offered crucial insights into particle size distribution, facilitating soil classification, evaluating engineering characteristics, and informing decisions in construction, agriculture, and environmental applications. The study involved sieving a dried dredged soil sample of 500g on a sieve set from 4.75mm to 0. 075mm. The results obtained are shown in Table 1.

Hydrometer analysis is employed to assess the particle size distribution of fine-grained soils, particularly those with sizes smaller than those examined through sieve analysis. In this analysis, a mixture of soil and water was created, and a hydrometer was utilized to gauge the settling speed of particles in the suspension. The underlying principle relies on Stokes' Law, connecting particle settling velocity to size and density. By monitoring settling rates over different time intervals, the soil's particle size distribution was determined. This analysis was done to complement sieve analysis, offering valuable insights into soil characteristics, notably soil texture, which holds significance in agricultural and engineering applications. The study involved the analysis of 50g of dredged on a hydrometer, and the analytic data so obtained is shown in Table 2.

Table 1: Sieve analysis of the pure dredged soil sample.

Sieve Size (mm)	Mass of Soil Retained (g)	Percentage Retained	Cumulative Soil Retained	Finer
4.75	0	0	0	100
2	0	0	0	100
1	0	0	0	100
0.6	1	0.2	0.2	99.8
0.3	4.5	0.9	1.1	98.9
0.212	9	1.8	2.9	97.1
0.15	13.5	2.7	5.6	94.4
0.075	8	1.6	7.2	92.8
Pan	0	0	7.2	92.8

Atterberg limits comprise three moisture content points that define soil consistency: the Liquid Limit (LL), indicating the transition from plastic to liquid state; the Plastic Limit (PL), marking the moisture content at which soil can no longer form threads without crumbling; and the Shrinkage Limit (SL), denoting the moisture level at which further loss does not induce additional volume reduction.

The determination of the liquid limit of soil was conducted through the Casagrande method, a standardized

Table 2: Hydrometer analysis of the pure dredged soil sample.

Time	Hydrometer Reading G (RH')	Water Temperature (°C)	Room Temperature (°C)	Corrected Reading (RH)	Effective Height (H_e)	Diameter	% Finer
0.5 min	29	18.5	21.3	27	9.8	0.064	92.61
1 min	28	18.4	21.3	36	10.1	0.048	89.18
2min	26	18.5	21.3	24	10.7	0.035	82.32
4 min	24	18.5	21.4	22	11.4	0.025	75.46
8 min	22	18.6	21.4	20	12.1	0.018	68.6
15 min	19	18.6	21.5	17	13	0.014	58.31
30 min	16	18.7	21.5	14	14.1	0.01	48.02
1 hr	13	18.8	21.7	11	15.1	0.008	37.73
2 hr	9	18.9	21.7	7	16.4	0.006	24.01
4 hr	5	19.2	22.5	3	17.6	0.004	10.29
8 hr	0.996	19.8	23.6	1	18.3	0.003	3.43
12hr	-	-	-	0	18.7	0.002	0

procedure widely employed in soil mechanics. Initially, a representative soil sample was meticulously prepared, involving air-drying to eliminate excess moisture and subsequent pulverization for homogeneity. The Casagrande cup was then filled with the prepared soil, and a groove was established along its center. Employing a liquid limit device or Casagrande plunger, water was incrementally added to the soil along the groove, and the plunger was dropped at regular intervals. The count of drops required for the soil to close a specified distance against a specific moisture content was noted as shown in Table 3.

The plastic limit (PL) of soil indicates the moisture content at which the soil transitions from a plastic to a crumbly, semi-solid state. The determination of the plastic limit involves initially air-drying a representative soil sample to eliminate excess moisture, followed by pulverizing the soil into a fine powder. Water was then gradually added to the powdered soil, and the mixture was kneaded to form a 3mm thread. This thread was carefully rolled on a flat glass plate until it reached a point of crumbliness. The moisture content at which this crumbliness occurs was identified as the plastic limit (Table 4).

The Atterberg limits calculated provide insights into the soil's characteristics, revealing a plasticity index (PI), which is the difference between the liquid limit (LL) and plastic limit (PL), determined to be 17.172. Additionally, the plastic index (PI) of the A-line, expressed as 0.73(LL-20), was calculated as 14.085. A comparison with the plasticity index of dredged soil indicates that the soil was clayey. The liquid limit of the soil falls within the range of 35-50 at 39.3, suggesting a medium compressibility. Further analysis reveals a flow index, representing the difference in moisture at ten and hundred blows, as 31.37. Moreover, the toughness index, defined as the ratio of the plasticity index to the flow index, was determined to be 0.55. These findings collectively characterize the soil as clayey with medium compressibility, contributing to a comprehensive understanding of its engineering properties.

Table 3: Moisture content of samples at different Casagrande's blows.

Sample	A	B	C
No. of blows	39	29	21
Mass of container + Wet soil	41.55	43.1	44.9
Mass of container +Dry soil	39	40	41.5
Mass of water	2.55	3.1	3.4
Mass of container(g)	31.5	32	33
Mass of dry soil(g)	7.5	8	8.5
Moisture content	34	38.75	40.17

Table 4: Plastic limit of pure dredged soil samples.

Sample	A	B	C
Mass of container + wet soil	41	39	38.5
Mass of container + dry soil	39.5	38	37
Mass of water	1.5	1	1.5
Mass of container	32.5	33	31
Mass of dry soil	7	5	6
Plastic limit	21.4	20	25
Average Plastic limit	22.13		

Dry density refers to the mass of soil per unit volume when the soil is completely dry. It is a crucial parameter used to characterize the compaction and density of soils. The dry density of soil is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content. The determination of dry density through light and heavy compaction is a fundamental process in geotechnical engineering. In light compaction, a specified weight was dropped onto a soil sample in a mold, while heavy compaction involves a more significant compaction effort. After compaction, the dry density was calculated by measuring the weight and volume of the compacted soil. The standard proctor test was employed for light compaction, contributing to effective soil compaction control in engineering applications. A soil sample of 100 cc was tested for light compaction and compacted, and the moisture content was varied to identify the maximum dry density. Results obtained to get the optimum moisture content and maximum dry density as shown in Table 5.

Conversely, heavy compaction involving a higher compaction energy on the soil samples was tested using the modified proctor test. To find the maximum dry density, a 100 cc soil sample was compacted and its moisture content was adjusted. Findings that led to the ideal moisture content and highest dry density are displayed in Table 6.

The shear strength of soil is a critical property that influences the stability of slopes, foundations, and other geotechnical structures. The shear strength of soil is typically determined through laboratory tests such as the Triaxial Shear Test and Unconfined Compressive Strength (UCS) test. For the current study, the UCS test was adopted for the determination of the strength of the pure dredged samples and samples mixed with sand in different proportions. The test started with the pure dredged soil specimen's initial length of equal to 7.6cm, initial diameter of 3.8cm, and initial area equal to 11.34 cm^2. The specimen under UCS showed a typical strain behavior at various stresses as shown in Table 7.

RESULTS AND DISCUSSION

In accordance with the analyzed data, Fig. 1 illustrates a particle size distribution curve, depicting the distribution of

Table 5: Dry density of pure dredged soil samples during light compaction.

Sample	A	B	C	D	E
Water content	8	11	14	17	20
Mass of empty mold	4370	4370	4370	4370	4370
Mass of mold +compacted soil	6080	6170	6350	6340	6230
Mass of compacted soil	1710	1800	1980	1970	1860
Wet density	1.71	1.8	1.98	1.97	1.86
Crucible no.	C1	C2	C3	C4	C5
Mass of crucible + wet soil	52.5	48.5	77.4	48.5	74.5
Mass of crucible + dry soil	50	45.5	68	42.5	63
Mass of water	2.5	3	9.4	6	11.5
Mass of crucible	34.5	28	26	20	25.5
Mass of dry soil	15.5	17.5	42	22.5	37.5
Water content	16.13	17.14	22.38	26.67	30.67
Dry density	1.47	1.53	1.62	1.56	1.42

Table 6: Dry density of pure dredged soil samples during light compaction.

Sample	A	B	C	D	E
Water content	8	11	20	26	20
Mass of empty mold	4390	4390	4390	4390	4370
Mass of mold +compacted soil	6140	6320	6380	6250	6230
Mass of compacted soil	1750	1930	1990	1860	1860
Wet density	1.75	1.93	1.99	1.86	1.86
Crucible no.	H1	H2	H3	H4	H5
Mass of crucible + wet soil	62	33	67.5	54	74.5
Mass of crucible + dry soil	58	30.5	61	48.5	63
Mass of water	4	2.5	6.5	5.5	11.5
Mass of crucible	23.5	9.5	33	29	25.5
Mass of dry soil	34.5	21	28	19.5	37.5
Water content	11.59	11.9	23.21	28.2	30.67
Dry density	1.57	1.72	1.61	1.45	1.42

soil particles across various sizes within a dredged sample. The gradual rise observed at the initial segment of the curve indicates a heightened presence of fine particles (clay and silt) in the soil. Nevertheless, the incline diminishes as one proceeds toward the coarser segment of the curve.

The examination of soil samples using Casagrande's method revealed that when the relationship between moisture content and the number of blows needed to close the groove was graphically represented in Fig. 2. It showed that at 25 blows, the moisture content is 39.3 percent. Consequently, the liquid limit of the dredged soil is determined to be 39.3 percent.

The outcomes of the compaction analysis, as illustrated in Fig. 3, indicate that in the case of light compaction, the dredged soil exhibits an optimal moisture content of 23.2%, resulting in a maximum dry density of 1.6 $g.cc^{-1}$. Conversely, under heavy compaction conditions, the optimal moisture content for the dredged soil is 12%, leading to a maximum dry density of 1.72 $g.cc^{-1}$.

The UCS test of the pure dredged soil sample showed that the Unconfined Compressive Strength (q_u) of the sample is 1.077 $kg.cm^{2-}$, indicating the maximum compressive stress the soil can withstand without confinement. The Strain at failure was measured as 6.9%, representing the extent of deformation the soil undergoes at the point of failure. The Failure angle (α) was calculated to be to be 84°, while the Angle of internal friction (∅) calculated as 20°. Additionally, the Cohesion (C_u) computed as half of the unconfined compressive strength, was found to be 1.191 $kg.cm^{2-}$. After the addition of sand in different mixes to the soil (1.5%,

Table 7: Strain at various loads of a pure dredged soil sample.

S.No.	Deformation		Strain	Corrected area	Loa d		Compressive stress
	div.	mm	-	cm^2	div.	kg	kg.cm²⁻
1	0	0	0	11.34	0	0	0.000
2	25	0.25	0.003	11.377	2	1.25	0.110
3	50	0.5	0.007	11.415	2	1.25	0.110
4	75	0.75	0.01	11.453	5	3.125	0.273
5	100	1	0.013	11.491	7	4.375	0.381
6	125	1.25	0.016	11.53	8	5	0.434
7	150	1.5	0.02	11.568	12	7.5	0.648
8	175	1.75	0.023	11.607	13	8.125	0.700
9	200	2	0.026	11.646	15	9.375	0.805
10	225	2.25	0.03	11.686	16	10	0.856
11	250	2.5	0.033	11.726	17	10.625	0.906
12	275	2.75	0.036	11.766	18	11.25	0.956
13	300	3	0.039	11.806	18	11.25	0.953
14	325	3.25	0.043	11.847	18	11.25	0.950
15	350	3.5	0.046	11.887	19	11.875	0.999
16	375	3.75	0.049	11.929	19	11.875	0.995
17	400	4	0.053	11.97	19	11.875	0.992
18	425	4.25	0.056	12.012	19	11.875	0.989
19	450	4.5	0.059	12.054	19	11.875	0.985
20	475	4.75	0.063	12.096	19	11.875	0.982
21	500	5	0.066	12.139	20	12.5	1.030
22	525	5.25	0.069	12.181	21	13.125	1.077
23	550	5.5	0.072	12.225	21	13.125	1.074
24	575	5.75	0.076	12.268	21	13.125	1.070
25	600	6	0.079	12.312	20	12.5	1.015
26	625	6.25	0.082	12.356	20	12.5	1.012
27	650	6.5	0.086	12.401	20	12.5	1.008
28	675	6.75	0.089	12.445	21	13.125	1.055
29	700	7	0.092	12.49	21	13.125	1.051

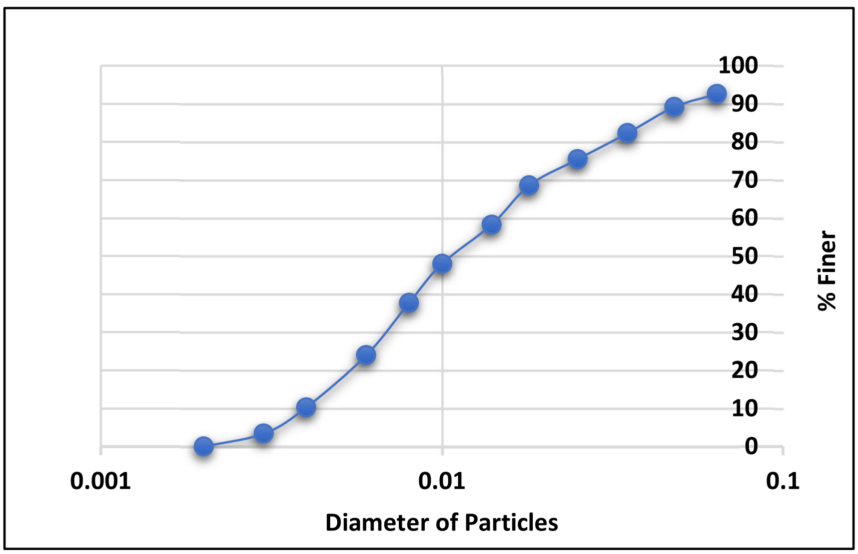

Fig. 1: Particle size distribution curve of pure dredged soil.

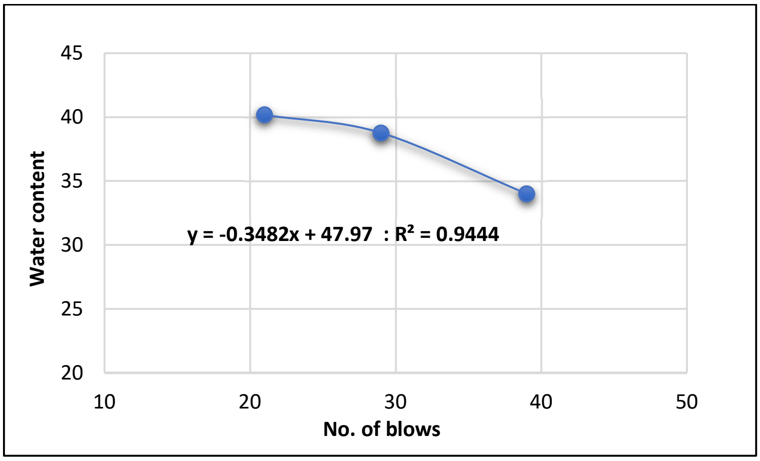

Fig. 2: Liquid limit calibration curve for pure dredged soil.

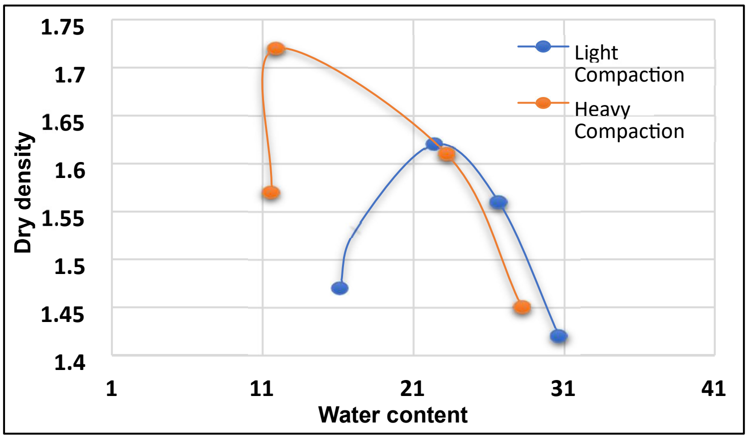

Fig. 3: Optimum dry density of pure dredged soil.

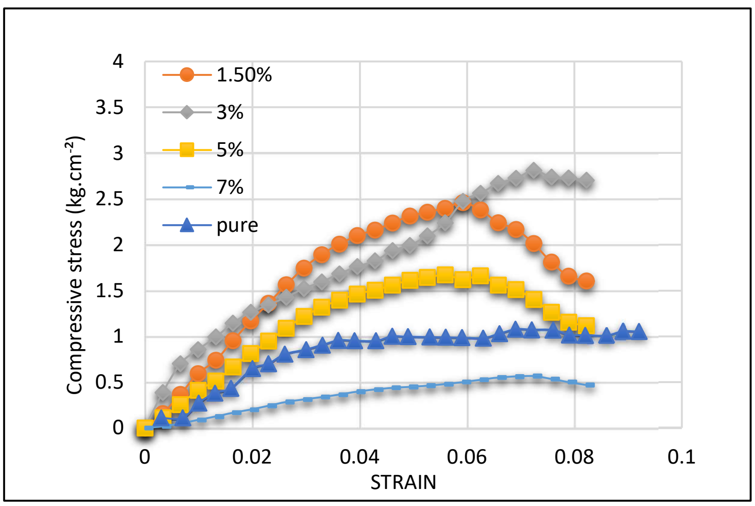

Fig. 4: Stress-strain curve.

3%, 5% & 7%), the unconfined compressive strength was determined in the same way as that done for pure dredged soil. The results obtained when plotted in Fig. 4, showed that for a 1.5% mix of sand to soil Unconfined compressive strength was observed to be 2.4610 $kg.cm^{2-}$ with strain at failure equal to 5.9%. For a 3% mix of sand to the soil, unconfined compressive strength was observed to be 2.8102 $kg.cm^{2-}$ with strain at failure equal to 7.24%. Likewise, a 5% mix of sand to soil unconfined compressive strength was observed to be 1.6595 $kg.cm^{2-}$ with Strain at failure equal to 5.92%. Finally, for a 7% mix of sand to the soil, unconfined compressive strength was observed to be 0.566 $kg.cm^{2-}$ with strain at failure equal to 7.24%.

CONCLUSION

The properties of the pure dredged material under consideration are crucial indicators for understanding its behavior and suitability for various applications. By considering various tests in the study, it was concluded that the specific gravity of the material was 2.63. The liquid limit was measured to be 39.3, while the plastic limit was found to be 22.133, resulting in a plasticity index of 17.172. The material was classified as medium compressible CM, indicating its cohesive and silty nature. The flow index, representing the material's ability to deform under load, was recorded at 0.55. The toughness index, indicative of its resistance to deformation, was found to be 1.623 $g.cc^{-1}$. The maximum dry density under light compaction was 1.6 $g.cc^{-1}$, with an optimum moisture content (OMC) of 23.2%. For heavy compaction, the maximum dry density was 1.72 $g.cc^{-1}$, with an OMC of 12%. The unconfined compressive strength, a critical parameter for assessing its structural integrity, was measured at 1.077 $kg.cm^{2-}$. The material exhibits a stiff consistency, with a consistency index falling within the range of 75-100%. The detailed properties, when examined collectively, provided a comprehensive understanding of the physical and mechanical characteristics of the dredged material. This information guided decisions to utilize material coarser than the dredged soil for stabilization, with sand being employed for this purpose.

After the determination of the basic engineering properties of the pure dredged soil, the effect of sand addition to dredged material on soil strength was investigated. As shown in Fig. 5, It was observed that the initial soil strength of soil increased to 2.461 $kg.cm^{2-}$ at a 1.5% sand mix. The strength increased to 2.810 $kg.cm^{2-}$ at a 3% sand mix, indicating the stabilization of the soil mass. This increase in the shear strength can be accounted for by several mechanisms occurring due to the mixing. The enhancement of shear strength in very fine clayey soil through the addition of sand involves a multifaceted process. Initially, the incorporation of sand brings about a structural transformation in the soil, fostering a more granular arrangement. This alteration in structure facilitates improved interlocking of particles, consequently diminishing the soil's susceptibility to deformation and elevating its overall shear strength. Notably, clay soils, characterized by their high water-holding capacity, induce heightened pore water pressure and diminished shear strength. The introduction of sand addresses this by enhancing soil permeability and drainage, thereby mitigating excess pore water pressure and fortifying soil stability. Moreover, the augmentation of interparticle friction through added sand contributes to an increased friction angle, ultimately bolstering the soil's shear strength. This augmented resistance to sliding along soil particles culminates in enhanced stability. Furthermore, the inherent cohesion of clay soils, attributed to fine particles, experiences a noteworthy improvement with sand addition, fostering superior particle interaction. The synergistic effect of heightened friction and cohesion collectively fortifies the shear strength of the soil. In summary, the incorporation

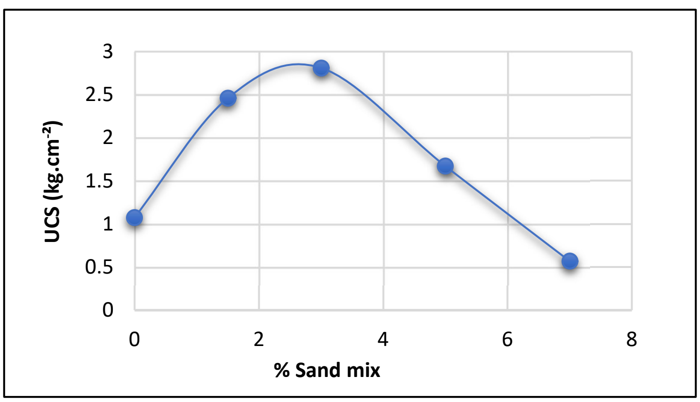

Fig. 5: Unconfined compressive strength at various mixes.

of sand into very fine clayey soil orchestrates a series of interconnected mechanisms that collectively optimize shear strength, encompassing alterations in soil structure, improved drainage, and heightened interparticle interactions. It was observed that further addition of sand beyond 3% resulted in a decline in the soil strength of the mix. The soil strength of the mix was found to be 1.671 $kg.cm^{2-}$ at 5% sand mix which was further reduced to 0.57 $kg.cm^{2-}$ at 7% mix. This may be due to the push of sand to make the soil mix a more granular mass, leading to reduced interlocking making the packing arrangement less favorable, and, consequently, decreased strength. The study concluded by suggesting the utilization of sand as a soil stabilizer, with the highest strength observed at a 3% mixture in this particular scenario.

REFERENCES

Amin, Z. 2016. Dredging of river Jhelum in J-K to prevent flood situation in future: Govt. The Indian Express. Available at: https://indianexpress.com/article/india/india-news-india/dredging-of-river-jhelum-in-j-k-to-prevent-flood-situation-in-future-govt/

Croft, J. B. 1967. The influence of soil mineralogical composition on cement stabilization. Geotechnique, 17(2): 119-135.

Firoozi, A. A., Taha, M. R. and Firoozi, A. A. 2014. Analysis of the load-bearing capacity of two and three-layered soil. Electron. J. Geotech. Eng., 19: 4683-4692.

Firoozi, A. A., Taha, M. R., Firoozi, A. A. and Khan, T. A. 2015. The influence of freeze-thaw cycles on unconfined compressive strength of clay soils treated with lime. J. Teknologi, 76(1): 107-113.

IS 13094: 1992, Reaffirmed 2011. Selection of ground improvement techniques for foundations in weak soils-guidelines.

IS: 1498-1970. Classification and identification of soils for general engineering purposes. New Delhi: Bureau of Indian Standards.

IS: 2720-part 1 1980. Indian standard code for preparation of soil samples. Bureau of Indian Standards, New Delhi.

IS 13094: Selection of ground improvement techniques for foundations in weak soils-guidelines (1992, Reaffirmed 2011).

IS: 1498 -1970. Classification and identification of soils for general engineering purposes. Bureau of Indian Standards, New Delhi.

IS: 2720-part 1 1980. Indian standard code for preparation of soil samples. Bureau of Indian Standards, New Delhi.

Kollaros, G. and Athanasopoulou, A. 2016. Sand as a soil stabilizer. Bull. Geol. Soc. Greece, 50(2): 770-777.

Little, D. N. 1998. Evaluation of structural properties of lime stabilized soils and aggregates. Arlington: National Lime Association.

Mir, B. A., Amin, F. and Majid, B. 2016. Some studies on physical and mechanical behaviour of dredged soil from flood spill channel of Jhelum river, Srinagar. Acta Ing. Civ., 1(1).

Nassar, S., Saliba, J. and SaiyourI, N. 2023. Investigation of the possible valorization of dredged sediments in compressed earth blocks. Mater. Today: Proc.

PTI 2016. JK Governor to Centre: Release of funds for Jhelum River dredging. Times of India. Available at: https://timesofindia.indiatimes.com/city/jammu/JK-Governor-to-Centre-Release-of-funds-for-Jhelum-river-dredging/articleshow/51251620.cms

Punmia, B. C. 2007. Soil Mechanics & Foundations. Laxmi Publications, New Delhi.

Puppala, A. J. and Musenda, C. 2000. Effects of fibre reinforcement on strength and volume change in expansive soils. Transp. Res. Rec., 1736(1): 134-140.

Reddy, E. S. 2002. Measurement of Engineering Properties of Soils. New Age International, New Delhi.

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