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Performance of Ganga Sand with Bentonite as a Landfill Liner Material

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Abstract
The earliest method of waste disposal is dumping waste in landfills. The liner is one of the most important components of the landfill which prevents the passage of leachate to the subsoil. A landfill liner of specific properties in terms of swelling behavior, strength, and permeability is placed down beneath constructed landfills. The present study discusses the experimental investigation of Ganga sand and bentonite mixtures to obtained specific properties of landfill liners. Various laboratory investigations are carried out on the different proportions of sand-bentonite mixtures to evaluate the optimum mix proportion which meets the specified properties of landfills liner. It is found that the liquid limit and plastic limit of the sand–bentonite mixture increase as the percentage of bentonite increases but there is a sharp increase after 20% bentonite content. The experiment findings indicate that the permeability and compressibility of the soil are significantly influenced by the soil type used in the mixtures. The optimum quantity of bentonite for river sand to attain very low permeability has been discovered to be 20%. Therefore, bentonite can be added as active clay to sandy soil in a suitable quantity to produce a cost-effective liner/barrier material, particularly for landfill applications.

Keywords: Bentonite, Permeability, Landfill liner, Sand, Triaxial Test, Compaction.

1. Introduction

A landfill is a site where waste materials have a dumped. India is a developing country. The population is very rapping increasing with waste generation is also increasing as municipal solid waste, industrial waste, and hazardous waste are increasing in very large amounts. So, firstly disposal problem of the waste, and create pollution in the environment as well as soil contaminant, so, resolved this problem to construct

engineered landfill where wastes are disposed of properly. In landfills, one of the important components is liner materials. It has a very big role to control the leachate for contaminants in the groundwater.
The liner is one of the most important components of the landfill which prevents the passage of leachate to the subsoil. A landfill liner of specific properties in terms of swelling behavior, strength, and permeability is placed down beneath constructed landfills.

Hydromechanical properties and microstructure of compacted sand and bentonite mixtures. The particle shape, size, sorting, and fine fraction are controlling factors for the hydro-mechanical response of composite geomaterials [2]. Experimental work on the standard Compaction test on a series of sand bentonite mixtures found that when bentonite content is increased up to 30%, the maximum dry density enhances, and optimum moisture content is reduced [3]. A linear relationship was established between void ratio and logarithm of effective vertical stress for all bentonite contents atparticular effective stress. Also, the authors proposed the effective clay dry density concept to estimate the permeability of mixes with various dry densities and broken rock contents [4]. The UCS parameter and young's modulus of elasticity of bentonite and sand mix with various dry density, moisture content, and sand content and are suggested by [5] as a buffer material in high-level radioactive repositories. Unconfined compression strength and young's modulus reduced as the percentage of sand in the mixture enhance. The performance of marine clay is used as a liner material in comparison with bentonite clay. Sundried marine clay with 20% sand was found to meet the requirements of liner soils specified by EPA [6]. The geotechnical parametersfor two types of sand are fine sand-bentonite and medium sand-bentonite. The results showed that variation in liquid limit is not linear; mixtures with fine sand had larger liquid limits than medium sand equivalents. Fine sand mixes had a low maximum dry density and a high optimal moisture content. Mixtures with fine sand had higher swelling pressure and lower hydraulic conductivity for the same bentonite content [7].The permeability behavior of dune sand-bentonite mixtures. It was found that the permeability reduced significantly with the addition of bentonite. The variation in stresses significantly affects the coefficient of volume change based on four models [8].Industrial waste was also used to improve the geotechnical properties of clay-type of soil such as foundry sand and fly ash mixed with glass waste and plastic strips were used as reinforcement materials to improve the geotechnical properties. [9] [10] [11].

Many researchers have performed experimental investigations with a variety of soils and synthetic materials such as geosynthetic clay liners (GCL) using geotextiles and geomembranes. The use of Compacted Clay Liners have been started three decades before. The main requirement for any material to be used as a liner is that it should have a hydraulic conductivity value of less than 10^{-7} cm/s. At some sites, suitable soils may not be available locally or in nearby areas. In such cases, the barrier layer may be made of local soil mixed with a low-permeability additive such as bentonite to get a mixture of amended soil having permeability less than 10^{-9} m/sec [1]. Therefore, most of the researchers have worked on an experimental setup to find a suitable material that fulfills this requirement.

The present paper summarized the detail of the different materials and their behavior which satisfy the criteria of landfills liner. Along with this, an experimental investigation was also carried out on sand-bentonite mixtures. The Atterberg's limit, Free Swell index, Compaction, Permeability, and Triaxial tests were performed on the various proportions of sand-bentonite mixtures to evaluate the optimum mix proportion which meets the specified properties of the landfill liner.

2. Materials used

2.1. Bentonite

The bentonite clay was purchased from a local market in Patna, Bihar. Various geotechnical parameters tests were conducted to find out clay behavior like specific gravity, consistency limit, and standard compaction test. The physical properties are summarized in Table 1.

2.2. Sand

In this study the use of sand which is Ganga sand. The sand is collected from the banks of the Ganga river located in Patna, Bihar. The geotechnical properties of sand that were obtained be performed through various tests like grain size distribution tests, and specific gravity tests. The properties of sand are also shown in Table 1. Grain size distributions of these sand are shown in Figure 1.

Table 1. Properties of the Ganga River sand and bentonite

PROPERTY	RIVER SAND	BENTONITE CLAY
Specific Gravity	2.65	2.24
Maximum Dry Density (kN/m^3)	14.48	11.16
Optimum Moisture Content (%)	-	36.28
Effective Diameter D_{10} (mm)	0.24	-
D_{60} (mm)	0.74	-
Coefficient of Uniformity	3.08	-
Coefficient of Curvature	0.89	-
Liquid limit (%)	-	562
Plastic Limit (%)	-	51
Plasticity index (%)	-	511

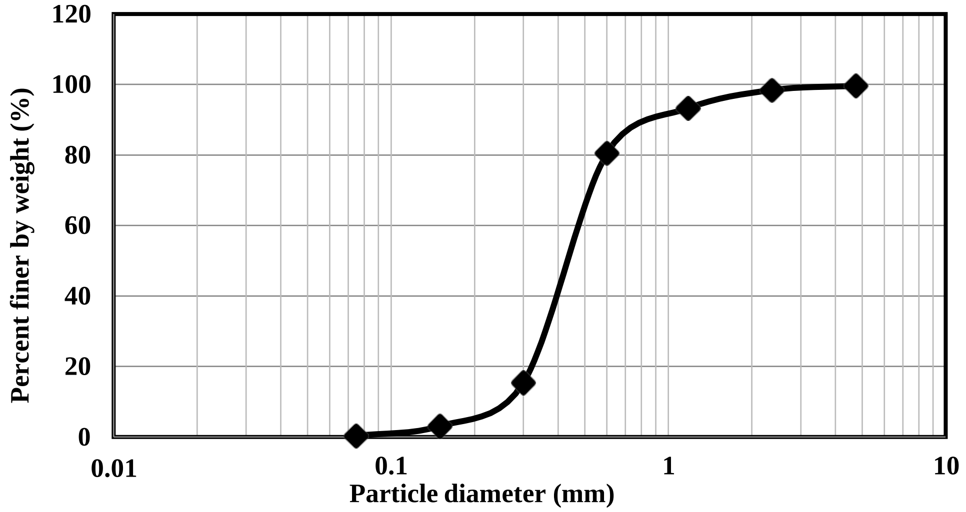

Fig. 1. Particle Size Distribution Curve for Ganga Sand

3. Methodology

First of all, find out the geotechnical parameter of individual materials after different percentages of bentonite clay mixed with sand. Bentonite was used in this study with four different proportions such as 10, 20, 30, and 40% of their dry weight. The materials were dry in the oven for 24 hours at 105^0C – 110^0C before the conduct any laboratory tests. Various parameters are determined by performing laboratory tests such as specific gravity, grain size analysis, consistency limit, compaction characteristics, free swell index, permeability behavior, and Triaxial characteristics these tests are done according to guidelines IS:2720 part 3 1980, IS:2720 part 4 1985, IS:2720 part 5 1985, IS: 2720 part 7 1980, IS: 2720 part 40 1970, IS: 2720 part 17 1981, and IS: 2720 part 12 1986 respectively.

4. Results and discussion

4.1. Consistency limit

Liquid limit is considered purely the soil's water-holding capacity, and the surface area plays a primary role. Compared to the other soils, bentonite has the highest optimal water content. The interparticle forces in the non-clay fraction are negligible and there are insignificant amounts of adsorbed water associated with the individual particles in this fraction. Adding sand to bentonite decreases water content by decreasing the region responsible for water absorption compared to pure bentonite. The Sand-Bentonite mix rises the liquid limit and plastic limit as shown in Fig. 2 and 3.

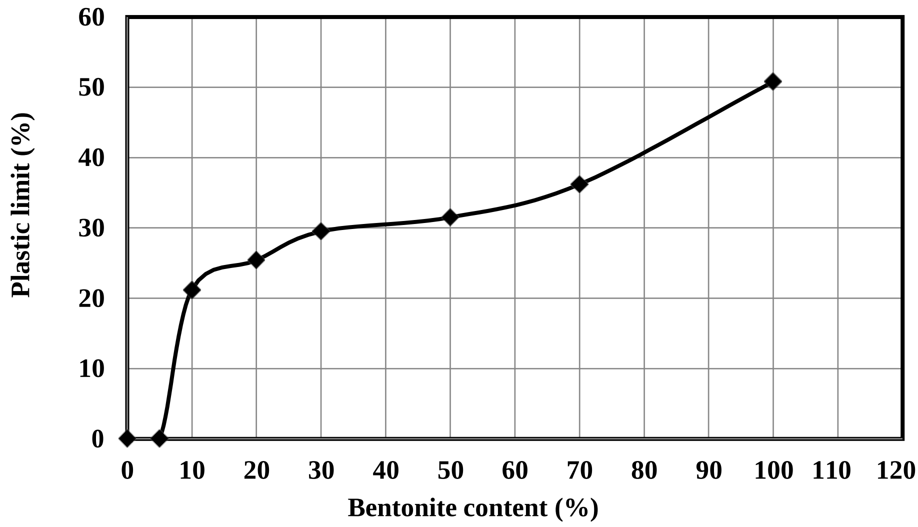

Fig. 2. Effect of Sand-Bentonite mix on Plastic Limit

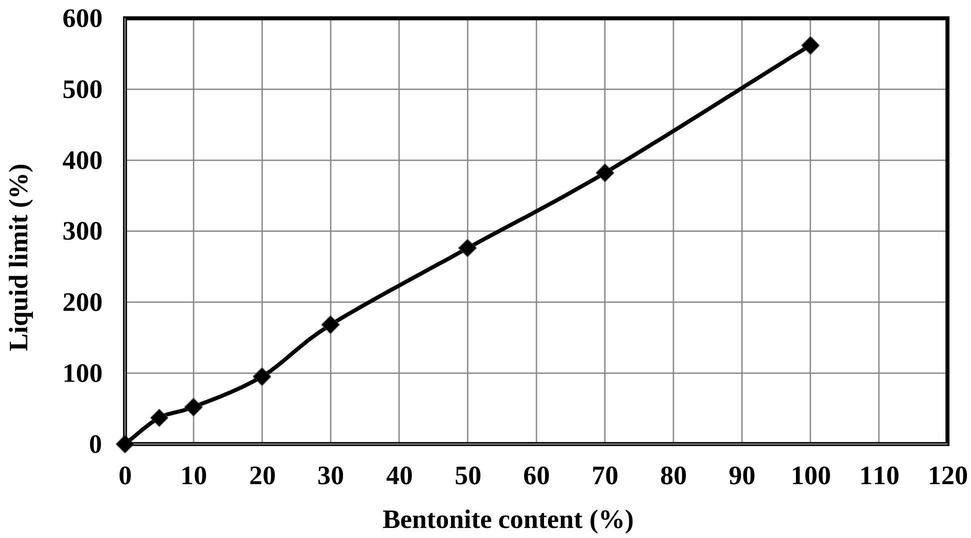

Fig. 3. Effect of Sand-Bentonite mix on Liquid Limit

Since there is a big rise in the liquid limit as the content of Bentonite is increased beyond 20 percent. Also, the plastic Limit is under satisfactory limits which also proves that 20% bentonite content is the most optimum bentonite content because beyond this there is a large increase in the plastic limit.

4.2. Compaction Characteristics

Sand-bentonite compaction test outcomes are plotted on the graph in Figures 4 and 5. The dry unit weight of the sand-bentonite mixture rises with increased water content for each compaction curve. After reaching the optimum water content, the weight of the dry unit reduces as the water content continues to rise. It was observed that when the bentonite content rises from 0 to 20 percent, the maximum dry density continues torise from 14.48 kN/m^3 to 17.12 kN / m^3. Initially adding water to the mixture, the waterhelps the soil particles move to a denser structure, thus reducing the void ratio and achieving a higher unit weight.

The dry density of the compacted sand-bentonite mixtures drastically decreased when additional water was added after optimum water content because the additional water and swelled bentonite, which was lighter than sand, occupied more space in the compaction mould resulting in a reduction in the dry unit weight of the mixtures.

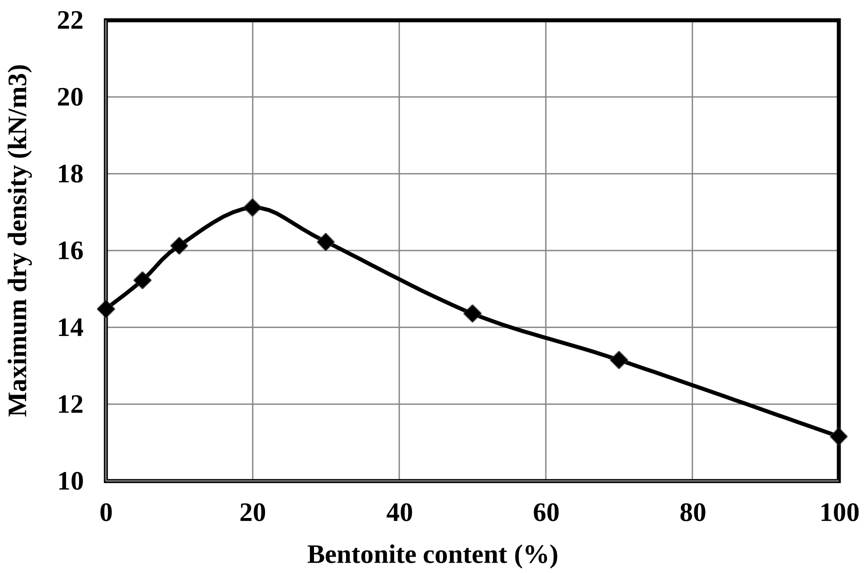

Fig. 4. Effect of Sand-Bentonite mix on MDD

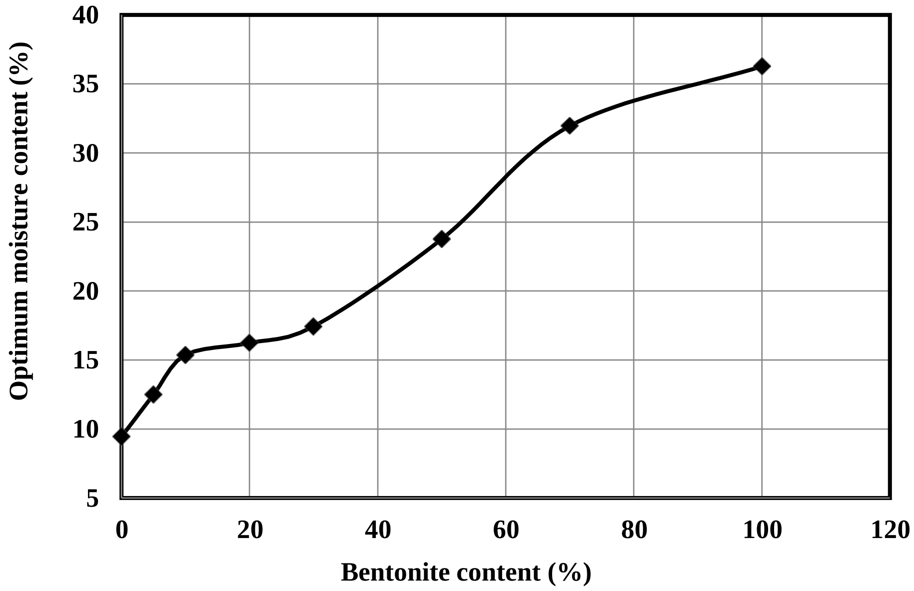

Fig. 5. Effect of Sand-Bentonite mix on OMC

4.3. Free Swell Index Characteristics

When the compacted sand-bentonite mixture is permitted to hydrate, the montmorillonite absorbs water into the montmorillonite interlayers resulting in volume increases as shown in Fig 6. The magnitude of volume change depends heavily on the mixture's bentonite content. The free swell index has risen from 18% at 5% bentonite content to 105% at 50% bentonite content. Swelling in the sand-bentonite blend is risingas the content of bentonite increases from the swelling index test. But the swelling is mild up to the 20% bentonite blend, indicating that the 20% bentonite is the most suitable bentonite content.

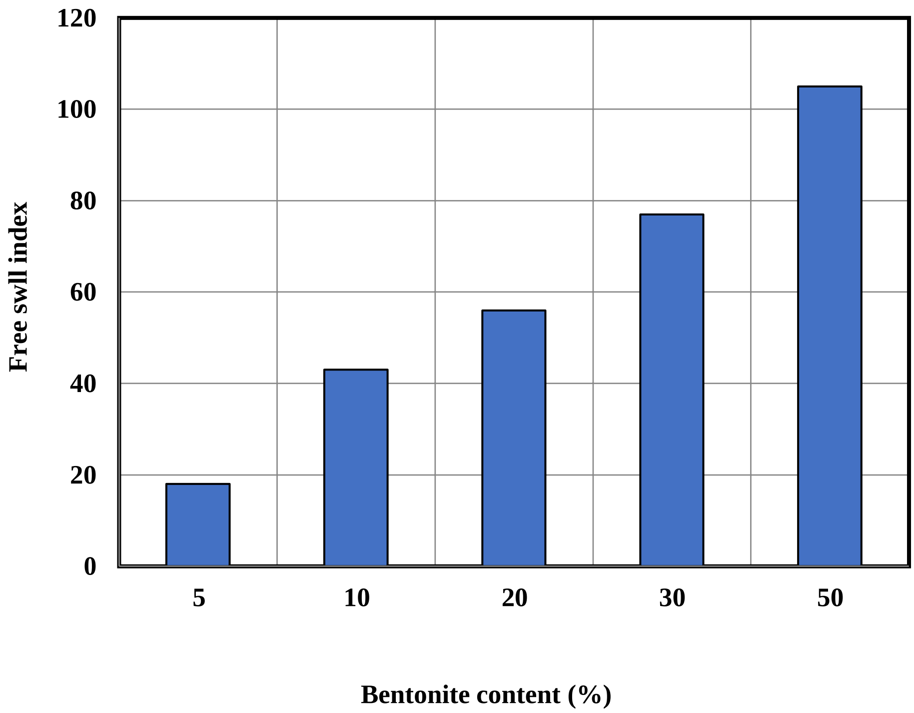

Fig. 6. Effect of Sand-Bentonite mix on FSI

4.4. Permeability Characteristics

Permeability is one of the important properties of the material which allows the free seepage of water through its voids, so to check the permeation of the mixture of sand and bentonite with different contents of bentonite ranging from 0% bentonite to 50% bentonite. Performed a constant head permeability test. As in our case, it is coarse-grained soil The first law for the flow of water through the soil is given by Darcy who experimentally suggested that the rate of flow of discharge per unit of time is directly proportional to the hydraulic gradient.

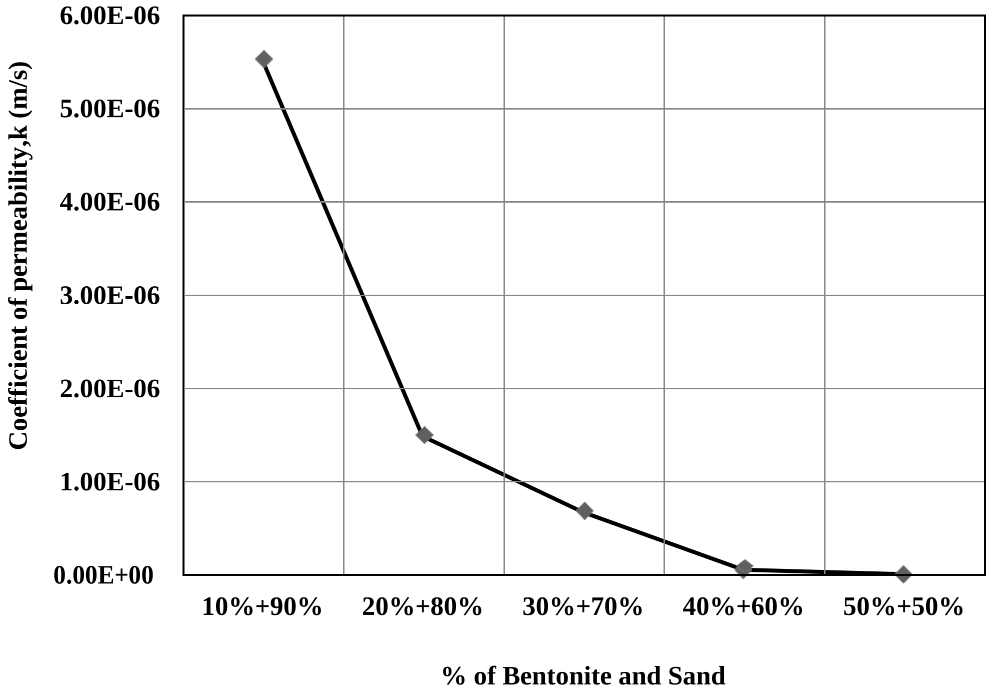

Fig. 7. Effect of Sand-Bentonite mix on Coefficient of Permeability

The coefficient of permeability for pure sand is 0.02 cm/s, after the addition of 10% of bentonite in the mixture the coefficient of permeability comes out to be 5.52×10^{-6} cm/s. With the further addition of bentonite up to 20%, the coefficient of permeability comes out to be 1.49×10^{-6} cm/s. Increasing the amount of bentonite from 30% to 50%,the coefficient of permeability goes on decreasing from 6.77×10^{-7} cm/s-10.08×10^{-8} cm/s. So there is almost a linear relationship between the percentage of bentonite in the mixture with the coefficient of permeability. Increasing the content of bentonite in the mixture the coefficient of permeability goes on decreasing. In the graph between bentonite content and coefficient of permeability as shown in Fig. 7 increasing the bentonite content, the coefficient of permeability goes on decreasing but increasing the bentonite content also lowers the maximum dry density of the mixture so we have to adopt that bentonite content which favors both the property namely permeation and strength of the mixture

4.5. Unconfined compressive strength characteristics

Unconfined compressive strength is one of the important parameters which determines the strength of the mixture also the bearing capacity and the stability of the liner. The shear strength of sand is 29.42 kPa obtained from the direct shear test. After that, the unconfined compressive strength of the mixture containing bentonite content up to 10% is 75.21 kPa with an increase of 139.69%. with further addition of bentonite up to 20%, the strength comes out to be 84.92 kPa with an increase of 170.60%. with further addition of bentonite, the UCS value comes out to be 84.23 kPa for 30% bentonite content having an increase of 168.4%. similarly, the strength of the mixture containing bentonite content up to 40 and 50% is 77.66 and 75.11 kPa respectively as shown in Fig. 8. The mixture containing 20% bentonite has a maximum unconfined compressive strength of 84.92 kPa with an increase of 170.63%. Thus 20% bentonite content is appropriate regarding the UCS parameter.

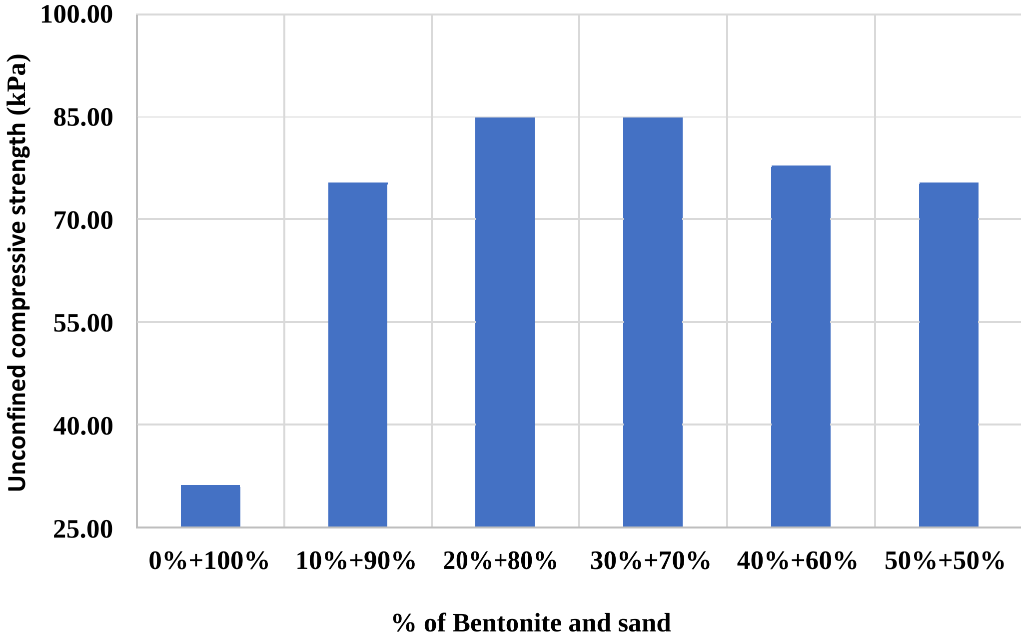

Fig. 8. Effect of Sand-Bentonite mix on UCS

5. Concluding remarks

In most states, where Sandy soils are found in abundant quantity. Engineers face problems in using pure compacted clay as a liner or barrier in various applications, as there is a continuous cyclic drying and wetting of soil which produces cracks that's why engineers face difficulties with economically sourcing clay for Liner/barrier applications. The present study emphasizes the optimum bentonite content to be used in the mixture which is suitably used for landfill Liners.

- The Proctor test shows that the maximum dry density of 17.12 kN/m^3 and OMC of 16.24% occurred at 20% Bentonite content. So it is an appropriate proportion of bentonite to be mixed with sand because up to 20% bentonite mix, the swelling is moderate. Also, it is seen that there is no volume change & hence crack development.
- The liquid limit and plastic limit of the sand–bentonite mixture goes on increasing as the percentage of bentonite increases but there is a sharp increase after 20% bentonite content.
- It is observed that the swelling index of the mixture goes on increasing as the percentage of bentonite goes on increasing, hence the optimum amount of mix may

be suggested based on other geotechnical properties. The maximum increase in shear strength is 170.63% for a specimen having 20% bentonite.

- The shear strength obtained for different mixes represents that it is maximum at 20% bentonite mix. This reflects the good bearing capacity of the mix for sustaining waste loads.
- Also, the coefficient of permeability is decreasing with the increasing % of bentonite.

The experiment findings indicate that the permeability and compressibility of the soil are significantly influenced by the soil type used in the mixtures. The optimum quantity of bentonite for river sand to attain very low permeability has been discovered to be 20 percent. Therefore, it is suggested that bentonite can be added as active clay to sandy soil in a suitable quantity to produce a cost-effective liner/barrier material, particularly for landfill applications.

References

1. S.K.G.M. Datta, Geotechnical Engineering - Sahashi K Gulhati Manoj Datta - Google Books, Tata McGraw-Hill. (2005) 738.
2. S. Ghadr, A. Assadi-Langroudi, Structure-based hydro-mechanical properties of sand-bentonite composites, Eng. Geol. 235 (2018) 53–63. https://doi.org/10.1016/j.enggeo.2018.02.002.
3. H. komine and N. Ogata, Experimental study on swelling characteristics of compacted bentonite, Can. Geotech. J. 1 (1994) 478–490.
4. D.I. Stewart, L.H. Mollins, Predicting the properties of bentonite-sand mixtures. Clay minerals, 31(2), (1996) 243–252.
5. Cho, W. J., Lee, J. O., & Kang, C. H. (2002). A compilation and evaluation of thermal and mechanical properties of bentonite-based buffer materials for a high-level waste repository. Nuclear Engineering and Technology, 34(1), 90-103.
6. Babu T.Jose, Solly George and Sridharan, A. 2004. “Suitability of Cochin marine clay as a liner material.” *Proc. Indian Geotech. Conf. Allahabad*.
7. Srikanth, V., and A. K. Mishra. 2016. “A Laboratory Study on the Geotechnical Characteristics of Sand–Bentonite Mixtures and the Role of Particle Size of Sand.” *Int. J. Geosynth. Gr. Eng.*, 2 (1): 1–10. Springer International Publishing. https://doi.org/10.1007/s40891-015-0043-1.
8. Ameta, N., and A. W. Ejge. 2008. “Effect of bentonite on permeability of dune sand.” *Citeseer*, 13: 1–17.
9. Kumar, A., Kumari, S., & Sharma, R. K. (2016, September). Influence of use of additives on engineering properties of clayey soil. In Proceedings of National conference: Civil Engineering Conference-Innovation for Sustainability (CEC).
10. Ghani, S., Kumari, S., Choudhary, A. K., & Jha, J. N. (2021). Experimental and computational response of strip footing resting on prestressed geotextile-reinforced industrial waste. Innovative Infrastructure Solutions, 6(2), 1-15.
11. Ghani, S., & Kumari, S. (2022). Consumption of Industrial Waste in Sustainable Development of Clean and Environmentally Friendly City Near an Industrial Area. Facets of a Smart City: Computational and Experimental Techniques for Sustainable Urban Development, 103.