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Engineering Behavior of Sand – Bentonite Mixtures: A Review

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Abstract- ***Sand-bentonites mixtures are usually used as a liner material in several geotechnical engineering applications including landfill, earth - backfilled trench slurry cutoff walls, and hydraulic waste containments due to its low permeability. The sands - bentonite barriers is a way for controlling the effects of waste disposal materials on ground water by mixing sand soil with a small amount of bentonite. This paper presents the previous researches in the direction of physical behaviors and application of sand-bentonite mixture. It was observed that the mixtures of sand and bentonite improved the maximum dry density, compressibility, strength, and hydraulic conductivity.***

Keywords:- Sand-bentonite mixtures, compaction, shear strength, hydraulic conductivity.

I. INTRODUCTION

Sand and bentonite mixtures are commonly used as a liner material in various engineering applications such as for waste containment, cutoff walls, and earth dams. Several researchers have worked on the possible use of sand – bentonite mixtures as barriers for various geotechnical and geo-environmental application (Gueddouda et al., 2008; Kenney et al., 2009; Shirazi et al., 2010; Khan et al., 2014; Ali F. G., 2015; Sumanta Rakshit et al., 2016; and Ojuri and Oluwatuyi, 2017). The liner of sand-bentonite mixtures includes two different soils regarding the grain size, chemical activity, permeability, strength which when mixed in optimum proportion gives brilliant seepage barrier with low hydraulic conductivity (Kenney et al., 2009 and Wang et al., 2012) with reduction of cost of project (Mollins et al., 2006). The percentage of the clay reduces the shrinkage crack with increase in the strength as the load is taken by the sand matrix; however, it decreases the ductility with an increase in permeability (Mollins et al., 2006; Meier and Shackelford, 2017). The paper presents the summarized result of the previous work in the direction of geotechnical characterization and utilization of sand-bentonite mixtures for various geotechnical and geo-environmental purposes.

II. LITERATURE REVIEW

2.1 Characterization of Sand-Bentonite Mixture

2.1.1 Compaction behavior of sand-bentonite mixtures

Chalermyanont and Arrykul (2005) investigated the compacted sand soil and bentonite clay mixtures. The various experimental tests were conducted by Proctor tests and the bentonite content was taken at 0%, 3%, 5%, 7%, and 9%.The compaction test showed that with the variation of bentonite content from 0 to 9%, the MDD reduced as 19.47, 19.35, 19.10, 18.68, 18.56 kN/m^3.

Akgun et al. (2006) investigated the sand-bentonite sand mixtures for underground waste repository through compaction and flow test. The shear strength and swelling tests was conducted to choose the optimum mixtures and to prescribe a stable bentonite/sand seal. Based on the study, 20% bentonite was suggested to achieve the minimum hydraulic conductivity.

Tiwari et al. (2016) made an investigation on compacted sand-bentonite mixtures with bentonite content varying from 0% to 6% with an increment of 3% as material of low hydraulic conductivity liner waste disposal. Based on the investigation, it was concluded that the compacted mixtures can be utilized as buffer and backfill materials for designing barriers for hazardous waste.

Proia et al. (2016) investigated the suitability of sand-bentonite embankment and landfill materials. Based on the result, it was observed that the lower quantity of the bentonite in mixture shows the property of granular soil which starts behaving like plastic soil with an increase in bentonite content. The interactions between sand and bentonite were examined using scanning electron microscope.

Srikanth and Mishra (2016) carried out laboratory investigation on geotechnical characteristics of sand-bentonite mixtures by considering the particle sizes, Atterberg's limits, and compaction characteristic with varying the sand content from 50% to 90%. Mixing the sand in bentonite was observed to give high compact density and lower drying shrinkage. Based on laboratory result, it was observed that the sand content below 20% is not sufficient for filling the voids due to lack of swelling. It was also concluded that the mixtures with fine sand shown higher liquid limits, plasticity, and swelling with low maximum dry unit weight and hydraulic conductivity as compared to medium sand.

Ojuri and Oluwatuyi (2017) carried out experimental work on compaction behaviors of sand soil–bentonite clay mixtures. The amount of bentonite content was varying from 0% to 10% by the weight of sand with an interval of 2%. It was observed that with the increase in bentonite content, the value of MDD increased from 16.04 kN/m^3 to 17.75 kN/m^3.

Thakur (2018) examined on geotechnical characteristic of compacted sand-bentonite mixture containing sodium bentonite from 0% to 25% at 5% interval. Various tests such as compaction test, unconfined compression strength test, and falling head test were conducted. Based on the investigation, substantial increase in maximum dry unit weight was observed along with the decrease in hydraulic conductivity ($10^{-6} < k < 10^{-8}$ cm/s) at 20% bentonite content.

Meier and Shackelford (2017) examined the compacted sand-bentonite mixtures. The membrane tests were performed on two specimens of the compacted sand– bentonite mixtures involving 15% bentonite showed with adequately low permeability (10^{-9} m/s) which is appropriate for use as a as liner material for waste containment.

2.1.2 Shear strength behavior of sand and bentonite mixtures

Several researchers worked on the shear strength behavior of sand-bentonite mixture. The results of the researches are summarized below.

Ali (2015) performed various laboratory tests for UCS and direct shear test, compaction test, and permeability test with bentonite content at 5%, 10% and 20%. The results observed from strength tests shown that the UCS, cohesion and the modulus of elasticity increase with the increase in bentonite content, but the value of internal friction decreases.

Kalita et al. (2017) investigated the impact of curing period on strength of sand bentonite mix. In the study, 80% of sand sample and 20% of bentonite was used. The prepared compacted samples were cured for 3, 7, 14 and 28 days. The maximum compressive strength was observed for the sample containing 3% bentonite and cured for 14 days.

Gueddouda et al. (2008) studied the hydraulic conductivity and shear strength of dune sand soil–bentonite mixtures containing different percentage of bentonite (3%, 5%, 10%, 12% and 15%). The minimum hydraulic conductivity (10^{-6} cm/s) was observed between 12% and 15% bentonite.

Thakur and Yadav (2018) investigated the shear strength behavior of sand and bentonite mixture by conducting the direct shear test on Narmanda sand and with different proportions of bentonite from 5% to 25% at the interval of 5%. The laboratory test was evaluated at 50, 100 and 150 kPa normal stress. The result shown that as bentonite content increases in the mix, the value of cohesion increases and angle of internal friction reduces. It was suggested to use 15% to 25% bentonite in sand for landfill design.

2.1.3 Hydraulic conductivity behavior of sand and bentonite mixtures

Gleason et al. (2002) analyzed the impact of changes in bentonite type on the permeability of compacted sand-bentonite mix. Two different types of air-dry bentonite such as sodium bentonite and calcium bentonite were mixed with graded sand or well graded sand or silty sands with varying percentages (6%, 12%, 20%, and 30%). Two different permeants such as tap water and 0.25 M calcium chloride was used. The was observed that the sample subjected to calcium chloride shows higher permeability as compared to the sample tap water followed by calcium chloride.

Ameta and Wayal (2008) investigated the influence of bentonite on permeability of dune sand with bentonite content of 2%, 4%, 6%, 8% and 10% by weight of dune sand. Similarly study was also performed by Prasad et al. (2017) with bentonite content of 2.5%, 5%, 7.5%, 10% and 12.5%. The results showed that the coefficient of consolidation, coefficient of volume change, and permeability decreases.

Xu et al. (2016) conducted a series of one-dimensional consolidation tests on clayey (Kaolin)-bentonite and sand-bentonite mixtures in order to find out the influences of sand fraction and moisture content on the permeability property. The range of the grain size of the sand used was 0.075-1 mm. The bentonite contents used in the soil (Kaolin)-bentonite mixtures and sand-bentonite mixtures were (5, 10, and 15%) and (3, 5, 8, and 11%), respectively. They indicated that the permeability was greatly controlled by the bentonite content.

Tiwari et al. (2016) performed the permeability on saturated sample under the falling head condition. The amount of bentonite was used at interval of 3% from 0% to 24% by the weight of sand. The results showed that the values of coefficient of permeability were decreased from 10^{-5} m/s at 0% to 10^{-10} m/s at 24% bentonite mix.

Komine (2004) investigated the hydraulic conductivity of sand and bentonite mixture with the varying quantity of bentonite contents. The hydraulic conductivity of the mixed was found to vary from 10^{-10} m/s to 10^{-12} m/s for bentonite content varying from 5% to 50%.

Castelbaum and Shackelford (2009) conducted on the permeability of bentonite slurry and sand mixture with 1%, 3% and 5% bentonite content was conducted. The permeability of the material was divided in to three zones. In zone 1, bentonite content was less than 1% and the permeability was found greater than 10^{-6} cm/s. Whereas; in zone 2, the bentonite content was in between 1% and 3%, and the permeability was found in between 10^{-6} cm/s to 10^{-3} cm/s which is called as transition zone. The zone 3 was called as sufficient and uniform distribution with bentonite content of greater than 3% which gives the permeability greater than10^{-6} cm/s.

2.2. Application of the Sand and Bentonite Mixtures

Several kinds of isolated barriers have been recommended, such as compacted clay liners, geosynthetic clay liners and sand soil-bentonite liners by several researchers (Katsumi et al., 2001; Kumar and Yong, 2005; Chapuis, 2008; Gueddouda et al., 2008; Mochamad Arief Budihardjo et. al., 2012; and Thankam et al. 2017). The sand-bentonites barriers/liners is a way for controlling the effects of leachate generated from waste materials on underground soil and water. This is prepared by mixing

sand, small amount of bentonite, and water which is used as liner to prevent migration of contaminated fluid from the landfill to groundwater (Chapuis, 2008, Gueddouda et al., 2008; Mochamad Arief Budihardjo et. al., 2012; and Srikanth and Mishra, 2016); Tay et al. 2001).

2.2.1 Earth – Backfilled slurry trench cut of wells

Cutoff wells are commonly used in geo-environmental engineering to monitor the waste contaminants. Various types of cut off walls are used, such as earth-backfilled slurry trench cut off walls (SB), CB cut off walls soil-cement-bentonite (SCB), concrete cut off walls including plastic concrete cut off walls, Geomembrane cutoff walls, and deep soil mixing cut off walls etc. Many researchers were studied on those types of cutoff wells (C.A. Spaulding 2004, Jeffrey C. Evans et al., 2008; Jeffrey C. Evans et. al., 2016; Anna Norri et al., 2018) along with the possibility of cutoff wall using sand-bentonite mix (Komine 2004; Baxter et al., 2014, and Fan et al.; 2014). However, the study on the slurry trench cutoff walls is limite (Anna Norri et al. 2018; C.A Spaulding., 2004; R.D. Fan et al.; 2014; and F. G. Ali, 2015).

III.CONCLUSION

This literature survey of geotechnical properties on sand-bentonite mixtures based on the results of laboratory tests has been presented in this paper. After rigorous review of the previous researches, it was observed that the permeability of sand-bentonite mixture decreases with an increase in bentonite content, however, the other property of the same is required to study. It was also found that the increasing content of bentonite gives higher UCS but the deformation increases with the increase in bentonite content. In overall, the sand-bentonite mixture can be used as liner material with optimum content of bentonite in mixture.

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