CHARACTERIZATION OF DREDGED SAND FROM CHILKA LAKE AS A GEO MATERIAL WITH AND WITHOUT BIOPOLYMER

Harishankar Jeevan Dash[1], Research Scholar and Sarat Kumar Das[2], Associate Professor

[1]Research Scholar, Civil Engineering Department, National Institute of Technology Rourkela, India, Email: harishankar51.bbsr@gmail.com

[2]Associate Professor, Civil Engineering Department, National Institute of Technology Rourkela, India, Email: saratdas@rediffmail.com

ABSTRACT: Chilika lake is a brackish water lagoon as well as the largest coastal lagoon in India and the second largest lagoon in the world, of Odisha state on the east coast of India covering an area of over 1,160 km^2. The size of the lagoon is decreasing over the years due to large siltation of the rivers joining Chilika lake and dredging is required to deal with siltation. Utilization of dredging sand from Chilika for construction purposes is a sustainable method to deal with siltation. In the present study, the dredged sand was collected from Chilika lake (Satapada site) and is characterized as an alternate geo material. The chemical, mineralogical, morphology are also studied. The particle shape parameters analysis was done using optical microscope. The results indicate that Chilika sand is poorly graded sandy soil with of 99.9 % sand with a specific gravity of 2.64, optimum moisture content of 10.3 % and pH 7.72. An effort was also made to use biopolymer for stabilization of sand while using this as barrier in the lake. It was found that biopolymer, guar gum is effective in imparting shear strength of sand. The present study indicates that the Chilika sand can be used in various construction works as well as foundation and fill materials. The use of biopolymer is a sustainable method for stablilization. The present study will help in

effective utilization of the dredged sand; thereby it will not only help in reclamation of the Chilka lake, but also save the natural resources.

Key words: Chilika lake, Dredged sand, physical, chemical, morphological characterization, biopolymer

INTRODUCTION

Chilika lake is a brackish water lagoon of Odisha state on the east coast of India. It is the largest coastal lagoon in India and the second largest lagoon in the world covering an area of over 1,160 km^2 (Sahu et al., 2014). The Chilika lake receives freshwater from 52 rivers and rivulets opening into it from different directions. The rivers on the north-east (e.g. Bhargavi, Daya, luna, Makara) contribute about 60–80 % of total freshwater input, while the western rivers (e.g. Kansari, Kusumi, Janjira, Tarimi etc.) and rivulets contribute the rest with seawater intrusion from two sources. The lake is broadly divided into four different zones based on the water quality, distribution of biotic components and fishery yield, as (i) northern sector, (ii) central sector, (iii) southern sector and (iv) outer channel area. Ecological degradation of Chilika lake had begun since 1970s and then increased rapidly during 1980s and 1990s. Sahu et al. (2014) studied the environmental conditions of Chilika lake during pre and post hydrological intervention in which they studied that the geomorphology, water quality and biological productivity of the lake had undergone significant changes over the years under the influence of natural events and anthropogenic interventions. Depletion of fisheries and loss of biodiversity in 1980s and 1990s have been linked to the northward shifting of lakes inlet and silting up of the outer channel. The lake has emerged as one of the highly degraded and hypersensitive coastal marine ecosystem and recognized as Ramsar site in 1981(Sahu et al. 2014). Siltation of the lagoon basin was identified as the major threat to the ecology of the lake. The amount of silt brought into the lake by the distributaries of the Mahanadi river system is about 1.5 million tons per year , while that from the western catchment stands at 0.3 million tons per year. Land use pattern promoting erosion in the upstream areas has increased the sediment load considerably. Siltation of outer channel restricting the outflux of silt laden freshwater had favoured silting up of the lagoon. In order to restore the biodiversity and to improve the health of the Chilika lagoon, a new mouth at Magarmukha (shark face) is locally known as the inner Channel was dredged in September 2000 and it serves to connect the Outer Channel to the main body of Chilika lake. Opening of the new mouth has resulted in some improvements with substantial increase in capture fishery, reduction in weed infestation, growth of seagrasses, appearance of dolphins and increase in the population of migratory birds.

Now, efforts have been made to maintain the size of the lagoon through dredging at different location on the inlets of the lagoon. The major problem is effective utilization of the dredged soil. The dredged soil consists of sand, silt and clay materials depending upon the dredging point. The properties of the dredged soil depend upon physical properties of parent rock, hydrogeological process and temperature and tidal variations (www.chilika.com).

The investigation related dredged marine sand is limited. Wang et al. (2014) investigated that the Dunkirk marine sediments can be used as an alternative roadbed material. There is also restriction for excavation of river sand as a construction material. Effective utilization of the dredged soil will not only help in reclamation of the Chilka lake, but also the dredged soil can be used as alternate construction material thereby saving the natural resources. Subudhi et al. (2014) studied about the geotechnical characterization of dredged mud from Chilika lake and studied the geotechnical parameters such as void ratio, porosity, particle size analysis, specific gravity, Atterberg's limits, differential free swell index, compaction characteristics.

The dredged sand of the Chilika lake is also being also stored at site to make small (dumps) islands. But, these small dumps are sometimes becoming unstable due to wind erosion and small waves. The stabilization of these mounds is also one of the important issues. Keeping in mind the aqua and fauna sustainability of the lake, chemical stabilization of the sand using cement and others may not be suitable.

Chen et al. (2014) investigated about the feasibility of using two natural and renewable biopolymers, xanthan gum and guar gum, to stabilize Mine tailings for dust control. The results indicate that both xanthan gum and guar gum are effective in enhancing the moisture retention capacity, improving the dust resistance, and increasing the surface strength of Mine tailings beyond that of water wetting. Shashank et al. (2016) investigated about the 'bio-mediated soil improvement techniques' such as bio-cementation, bio-clogging, bio-remediation and phytoremediation on dredged sediments. Hence, in the present study an attempt has been made to characterize dredged sand as an alternate construction material and also to stabilize the dredged sand with biopolymer guar gum, to stabilize the mound made of dredged sand.

MATERIALS AND METHODS

Materials

The dredged Chilika sand collected from Satapada site, which is close to sea (Bay of Bengal) and is shown in Figure 1. The commercially available guar gum is used.

Methods

The present study includes the characterization and use of dredged sand of Chilka lake through physical, chemical and bioremediation. The physical and geotechnical characteristics, such as grain size analysis (ASTM D 422- 63), specific gravity (ASTM D854-14), compaction characteristics (ASTM D1557-12e1), maximum and minimum void ratios (ASTM D4253) and direct shear tests were conducted as per (ASTM D3080/D3080M). The morphological and mineralogical characteristics of dredged sand also determined by scanning electron microscope (SEM) and x-ray diffraction (XRD) analysis. Jeol-840-A model SEM, fitted with electron dispersive X-ray (EDX) analyser was used. The mineralogy of the materials is studied using XRD analysis on a Rich-Siefert X-ray diffractometer using copper target and Ni filter. The pH tests were conducted by digital pH meter (Hach, HQ 40 D).To study the particle shape parameter optical microscope (Axio lab A1, Zeiss) was used. The permeability test according to ASTM D 5084 was conducted using flexible permeameter of Humboldt, USA.

RESULTS AND DISCUSSION

In this present study the physical characterization includes determination of moisture content, specific gravity, grain size distribution characteristics, compaction characteristics, permeability and shear strength of dredged Chilika sand.

Grain size distribution, specific gravity, compaction characteristics and permeability tests without biopolymer

The grain size distribution curves for Chilika sand was compared with dredged marine sand collected from different sources and shown in Figure 2. The Chilika sand is with 80.1% of fine sand and 19.7 % of medium sand and it is poorly graded sand (SP) as compared to other dredged sands. The physical properties of the dredged Chilika sand are shown in Table 1. The specific gravity of sand is 2.64. The standard Proctor compaction curve for Chilika sand is shown in Figure 3. The optimum moisture content (OMC) was found to be 10.3% and maximum dry density (MDD) as 17.03 kN/m^3. The maximum and minimum void ratio values of Chilika sand were found to be 0.91 and 0.66, respectively. Three different direct shear test (DST) tests were conducted at OMC, e_{max} and e_{min} conditions. The angles of friction values (ϕ) were found to be 34.95°, 26.56° and 33.02°, respectively. From the results it is clearly evident that sand having maximum void ratio exhibits less angle of friction values than the sand having minimum void ratio. The constant head permeability test for Chilika sand was also conducted and the permeability value was found to be 1.50×10^{-3} cm/sec.

Morphological Characterization

The morphology of sediments plays an important role in understanding the size, shape of the sample. In this present study the morphology i.e. shape of the grains of Chilika sand was studied by the help of optical microscope. Various surface features of the grains was also studied scanning electron micrographs for Chilika sand was obtained.

Particle shape analysis

The particle shape of Chilika sand sample in terms of roundness index (R_i), elongation (E_R), flatness (F_R), sphericity (ψ), shapefactor (S_F) was determined by optical microscope method using ZEISS Axio optical microscope attached with image analyzer. Generally most of the particles were found to be sub-rounded, sub-angular and angular shaped based on roundness index. According to (Kwan and Mora 2000) the roundess indices ranges from 0 to 1.According to powers (1953) ,the particle is said to be angular if it ranges from 0.17 to 0.25, sub-angular 0.25 to 0.35, sub-rounded 0.35 to 0.49, rounded 0.49 to 0.70 and well-rounded 0.70 to 1.00. In this present study the analysis was done for Chilika sand having particle size of 600 micron and 425 micron. A representative number of particles from each particle sizes were considered for this present study. The results for Identifications of different shape, size, flatness of Chilika sand particles according to shape parameters are given in Table 2 and Identification of the shape of Chilika sand particles based on roundness index are shown in Table 3. Elongation and flatness of Chilika sand was determined and defined as the ratio of intermediate dimension (d_i) of sand grain to largest dimension of sand grain (d_l) and ratio of smallest dimension of sand grain (d_s) to intermediate dimension (d_i) of sand grain respectively. Also the roundness index (R_i) was calculated using Eq. 1 (Wadell, 1932). The shape factor (S_F) and sphericity (ψ) was also determined by using Eq. 2 and Eq. 3 respectively (Yudhbir and Abedinzadeh, 1991).

$$R_i = \frac{\sum\left(\frac{r}{R}\right)}{N} \qquad (1)$$

Where, r is the radious of corners of sand grain, R is the radius of inscribed circle, N is the number of corner.

$$S_F = \frac{d_S}{\sqrt{d_L \times d_I}} \qquad (2)$$

$$\Psi = \sqrt[3]{\frac{d_S \times d_I}{d_L^2}} \qquad (3)$$

Where, d_s is the smallest dimension of sand grain, d_i is intermediate dimension of sand grain , d_l is largest dimension of sand grain. The largest and intermediate dimension of sand particle was calculated and the smallest dimension of sand grain was measured using Vernier scale of optical microscope.

Zingg shape classification

According to Zing (1935) particles are classified in to four categories; flat and elongated, elongated, spherical and flat shaped (Yudhbir and Abedinzadeh, 1991). The classifications of Chilika sand grains are shown in Figure 5 and Figure 6, where most of the sand particles are found to be elongated and few particles are found to be both flat and elongated. Zinggs diagram for different particle shapes belongs to 600 microns and 425 microns (Zingg, 1935) are shown in Figure 5 and Figure6 respectively.

The SEM analysis was done for Chilika sand sample and shown in Figure 7. It was observed that different shape, size and angularity of sand grains are present.

Mineralogical Characterization

The X-Ray Diffraction analysis for Chilika sand is presented in Figure 8 and it was found that the Chilika sand mostly contains quartz , silica and aluminium oxide .

Chemical characterization

The pH of Chilika sand sample was determined as per IS:2720 (Part XXVI)- 1987, and found to be 7.74 and also the pH corresponding to different liquid to solid ratio (L/S) varying between 2 and 10 was measured. The sand sample of about 30 gm is mixed with 30 g sample is mixed and stirred with distilled water. The solution is kept for 1 hour and then the pH value of the solution was determined .The results of pH with different liquid to solid ratios (L/S) are shown in Figure 4. From the Figure 4 it is found that the pH value increases and then decrease with increase in liquid to solid ratios of the Chilika sand.

STABILIZATION USING BIOPOLYMER

The effect of biopolymer stabilization on the Compaction characteristics, Shear strength and permeability tests with biopolymer. The effect of biopolymer stabilization on the wind erosion of the dredged sand was studied in terms of penetration test as per Chen et al. (2014), The guar gum solution was added at the rate of litre per meter square to the sand surface and allowed to penetrate up to depth 4mm. Penetration curve for Chilika sand sample obtained from the test is shown in Figure 9. The permeability test of Chilika sand was conducted in the flexiblewall permeameter with addition of biopolymer guar gum solution. The value of permeability of Chilika sand was found to be 2.4×10^{-4} cm/sec.

The standard Proctor compaction curve with addition of guar gum for Chilika sand is shown in Figure 11. The optimum moisture content was found to be 14.83 % and maximum dry density 16.95 kN/m^3. Results indicate that the value for OMC increases whereas the maximum dry density decreases with addition of biopolymer guar gum.

Also direct shear test (DST) test with addition of biopolymer guar gum was conducted at OMC value obtained with addition of biopolymer guar gum. The angle of friction value (ϕ) was found to be 27.47°. From the result it is clearly evident that sand having less angle of friction value as compared to that value obtained from direct shear test at omc without addition of biopolymer guar gum .

Dispersion test with biopolymer

Dispersion test for Chilika sand was conducted by preparing a sand sample with the 10.9 cm height mould and having dia 4.9 cm by adding two percentage of guar gum solution with the sand. Then submerge the sand sample that was extracted from the mould in a container having water and allowed the sand sample to disperse for an hour or more till it dispersed. The rate of dispersion of sand sample was less as stabilized by biopolymer guar gum and shown in Figure 10.

CONCLUSION

Grain size distribution tests for Chilika sand it was found that the sand is with 80.1% of fine sand and 19.7 % of medium sand and it is poorly graded sand (SP) as compared to other dredged sands. The specific gravity of Chilika sand is 2.64. The optimum moisture content was found to be 10.3% and maximum dry density 17.03 kN/m^3. The maximum and minimum void ratio values of Chilika sand were found to be 0.91 and 0.66, respectively. Three different direct shear test (DST) tests were conducted. The angles of friction values (ϕ) were found to be 34.95°, 26.56° and 33.02°, respectively at OMC, e_{max} and e_{min} values. From the results it is clearly evident that sand having maximum void ratio exhibits less angle of friction values than the sand having minimum void ratio. From the constant head permeability test for Chilika sand the permeability value was found to be 1.50 x 10^{-3} cm/sec. The morphology of Chilika sand was studied by the help of optical microscope. Various surface features of the grains was also studied scanning electron micrographs for Chilika sand was obtained. The particle shape of Chilika sand was studied for various shape parameters. Generally most of the particles were found to be sub-rounded, sub-angular and angular shaped based on roundness index. From the zings shape classification it was found that the sand particles are elongated and few particles are found to be both flat and elongated. The SEM analysis was done for Chilika sand and it was observed that different shape, size and angularity of sand grains are present. The X-Ray Diffraction analysis for Chilika sand is conducted and found that Chilika sand mostly contains quartz , silica and aluminium oxide . The pH value was found 7.72 pH value increases and then decrease with increase in liquid to solid ratios of the Chilika sand.

The effect of biopolymer stabilization on the wind erosion of the dredged sand was also studied in terms of penetration test, permeability and dispersion tests. Penetration curve for Chilika sand sample obtained and maximum depth of penetration was found 1.3 mm. The value of permeability of Chilika sand with biopolymer stabilization was found to be 2.4 x 10^{-4} cm/sec. The rate of dispersion of sand sample was less as stabilized by biopolymer guar gum.

Hence the present study indicates that the Chilika sand can be used in various construction works as well as fill materials. From this present study it can be concluded that the dredged sand from Chilika at Satapada site can also be used as a embankment fill material.

REFERENCES

ASTM D 422- 63, Standard Test Method for Particle-Size Analysis of Soils. ASTM International, West Conshohocken, PA, 2007.

ASTM D2487-11, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM International, West Conshohocken, PA, 2011

ASTM D1557-12e1, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort ((12 400 ft-lbf/ft3(600 kN- m/m^3)), ASTM International, West Conshohocken, PA, 2012.

ASTM D854-14, Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer, ASTM International, West Conshohocken, PA, 2014.

ASTM D4253 Test Methods for Maximum Index Density and Unit Weight of Soils using a Vibratory Table.

ASTM D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.

ASTM D4791, Standard test method for flat particles, elongated particles, or flat and elongated particles in coarse aggregate, ASTM, West Conshohocken, 2005.

Chen, R., Zhang, L. and Budhu, M. (2013). Biopolymer Stabilization of Mine tailings. ASCE. doi:10.1061/(ASCE)GT.1943-5606.0000902

Chilika Development Authority, Bhubaneswar. A publication on strengthening of wetland research & training centre and bio-diversity conservation on Chilika lagoon. www.chilika.com

Kwan, A. K. H., Mora, C. F., Chan, H. C. (2000). Particle shape analysis of coarse aggregate using digital image processing.Scopus. doi: 10.1016/S0008-8846(99)00105-2

Naik, P. K., Pati, G. C., Choudhury, A. and Naik, K. C. (2007). Conservation of Chilika Lake, Odisha, India. Proceedings of Taal 2007.

Powers, M. C. (1953). A new roundness scale for sedimentary particles. Journal of sedimentary petrology. doi: 10.1306/D4269567-2B26-11

Sahu, B. K., Pati, P. and Panigrahy, R.C. (2014). Environmental conditions of Chilika lake during pre and post hydrological intervention. J Coast Conserve, Springer. doi: 10.1007/s11852-014-0318-z

Shashank, B., Sharma, S., Sowmya, S., Latha, R., Meenu, P. and Singh, D.N. (2016). State-of-the-art on geotechnical engineering perspective on bio-mediated processes. Environ Earth Sciences, Springer. doi: 10.1007/s12665-015-5071-6

Subudhi, D. P., Signum, S., Das, A., Asutosh, A. T., Yadav, D. and Das, M. R. (2014). Geotechnical characterization of dredged mud from Chilika lake. International Journal of Advanced Research in Civil, Structural, Environmental and infrastructure Engineering and Developing. ISSN**:** 2320-723X

Wadell, H. (1932).Volume, shape, and roundness of rock particles.The Journal of Geology. doi: 10.1086/623964

Wang, D., Abriak, N. E., and Zentar, R. (2014). One-dimensional consolidation of lime-treated dredged harbour sediments. European Journal of Environmental and Civil Engineering, Taylor and Francis. doi:10.1080/19648189.2014.939309

Yudhbir and Abedinzadeh, R. (1991). Quantification of particle shape and angularity using the image analyzer. ASTM International. doi: 10.1520/GTJ10574J

Zingg, Th. (1935). Beitrage zur schotteranalyse: Min. Petrog.Mitt.Schweiz.,15:39-140

ACKNOWLEDGMENTS

The authors would like to thank Chilika Development Authority, Bhubaneswar, India for providing useful information about Chilika lake which enable us to complete the present study that is based on my research work.

FIGURES

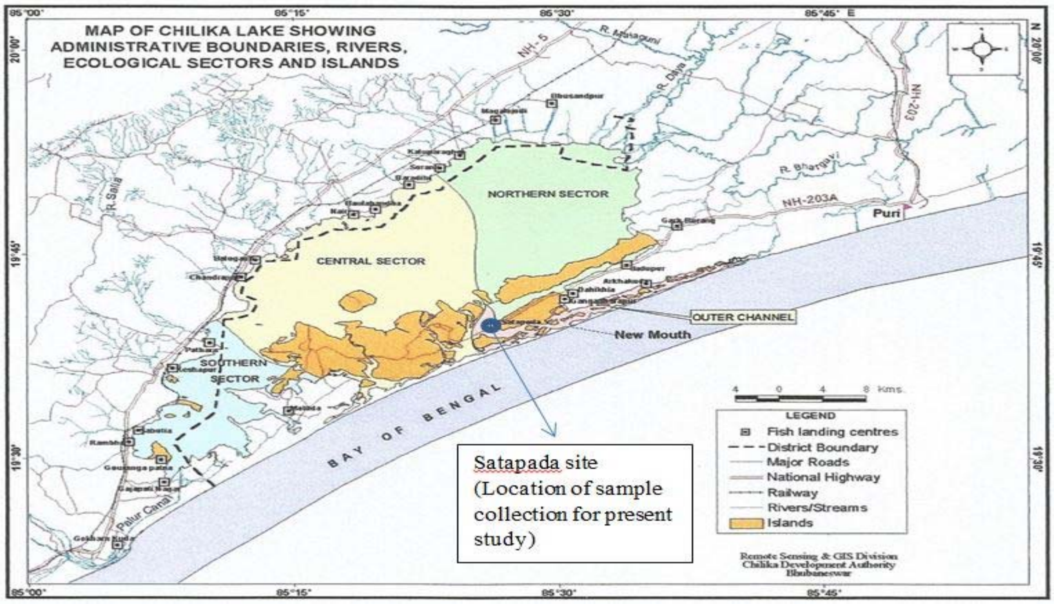

FIG.1. Map of Chilika lake showing satapada site, location of sample collection (Ref: www.chilika.com)

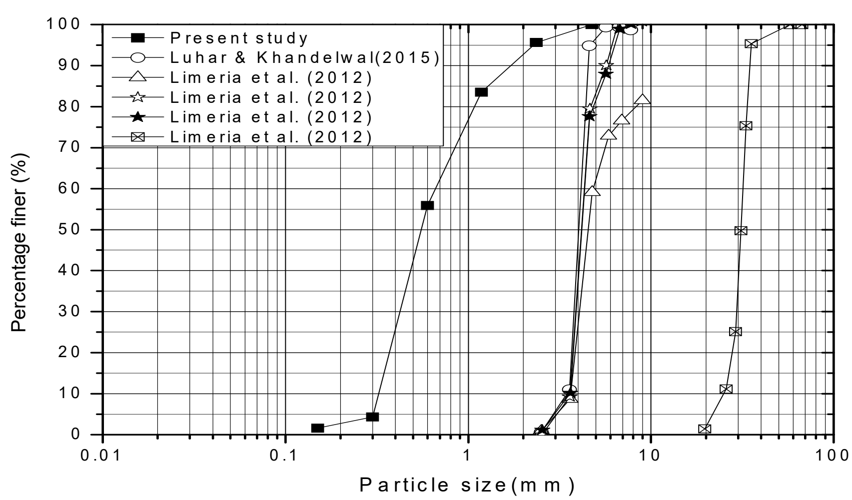

FIG. 2. Grain size Distribution curves for Chilika sand compared with dredged marine sand collected from different sources

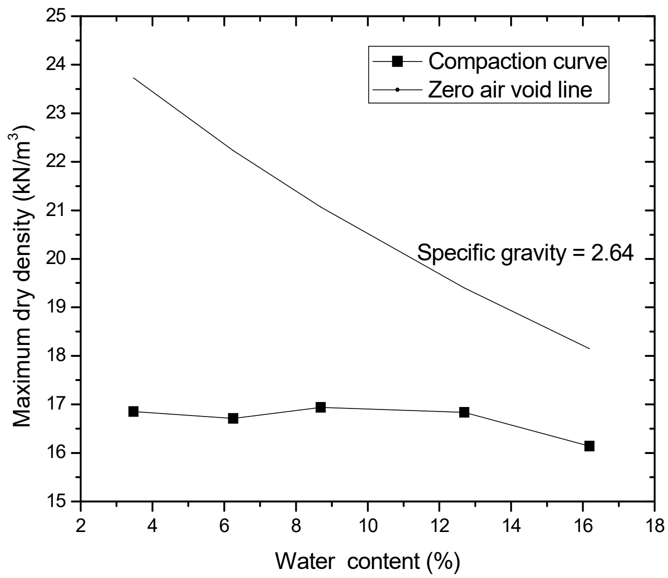

FIG. 3. Compaction curve for Chilika sand

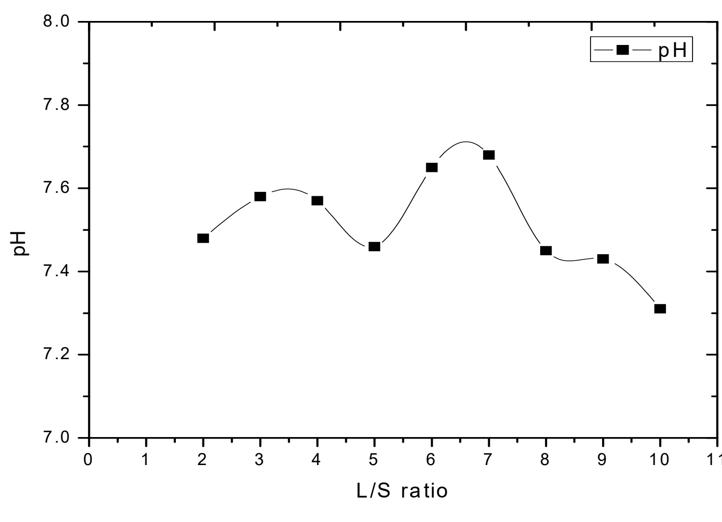

FIG. 4. The variation of pH with liquid to solid ratio for Chilika sand

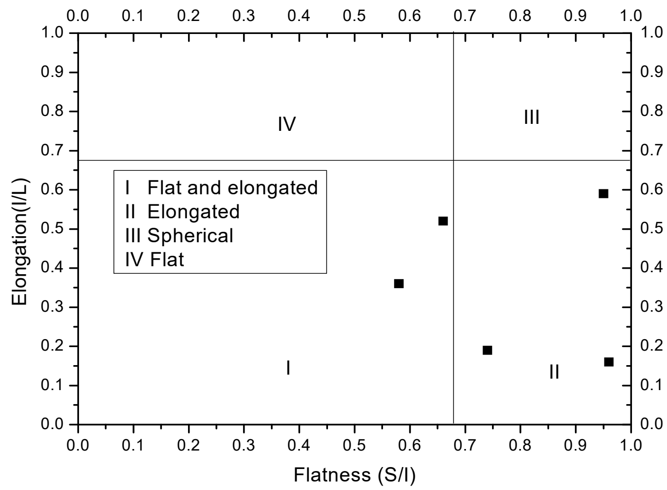

FIG. 5. Zinggs diagram for different particle shapes that belongs to 600 microns (Zingg,1935)

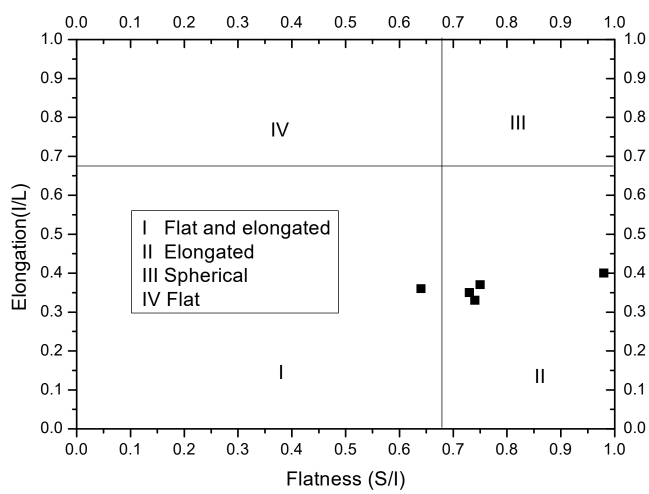

FIG. 6. Zinggs diagram for different particle shapes that belongs to 425 microns (Zingg, 1935)

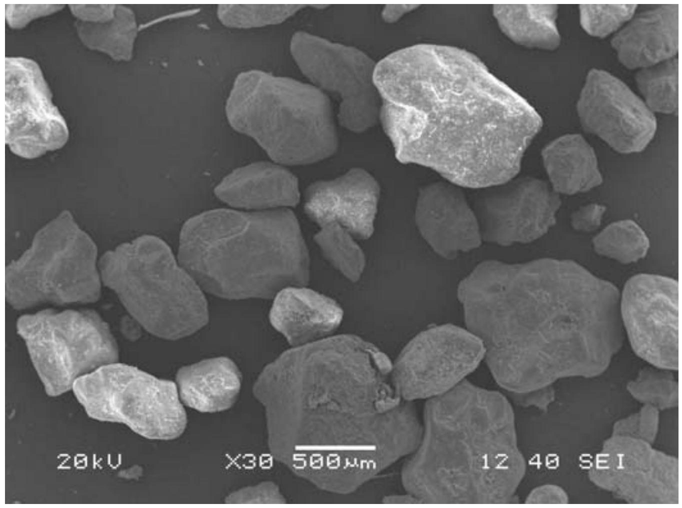

FIG. 7. Scanning electron microscope image of Chilika sand

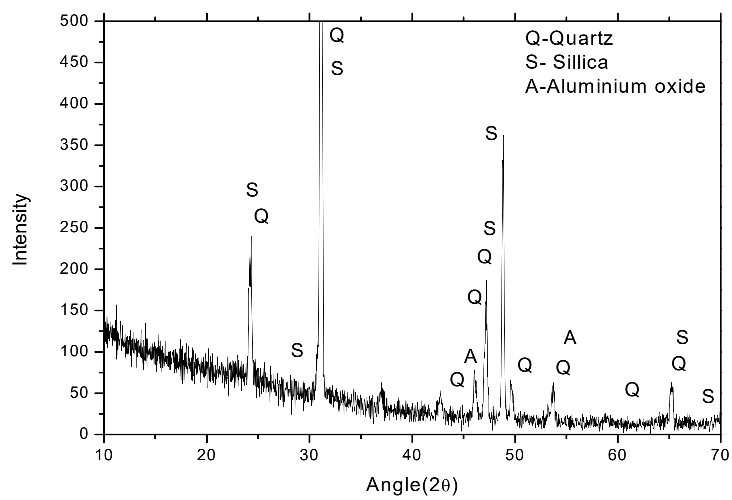

FIG. 8. XRD Analysis for Chilika sand

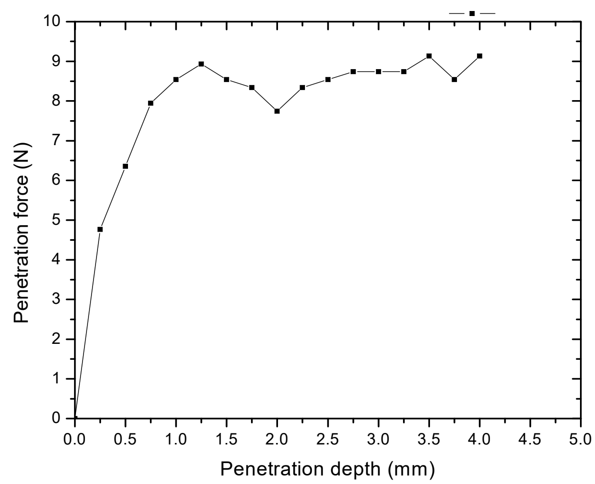

FIG. 9. Penetration curve for Chilika sand with addition of biopolymer

FIG.10. Dispersion test of Chilika sand with addition of biopolymer

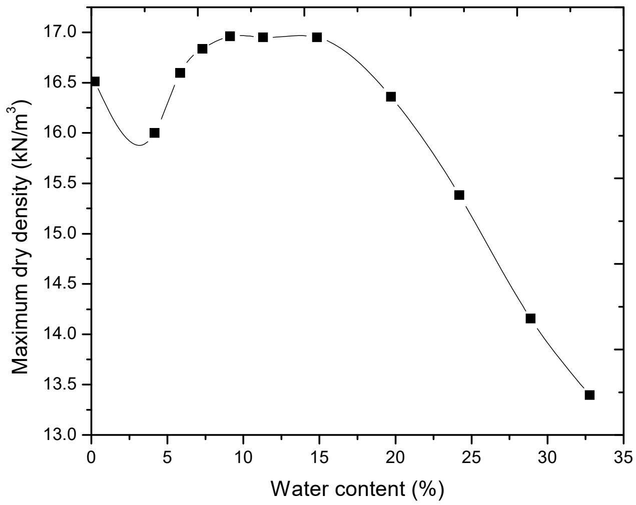

FIG.11. Compaction curve for Chilika sand with addition of biopolymer guargum

TABLES

Table 1. Physical characteristics of Chilika sand

Parameter	Values
Dredged Chilika sand collected from depth (m)	0.6
Specific gravity (G_s)	2.64
Natural moisture content (%)	10.39
e_{max}	0.91
e_{min}	0.66
γ_{dmin} (kN/m^3)	13.53
γ_{dmax} (kN/m^3)	15.59
pH Value	7.72
D_{10} (mm)	0.22
D_{30} (mm)	0.31
D_{60} (mm)	0.37
Uniformity coefficient (C_u)	1.70
Coefficient of curvature (C_c)	1.17
Soil Classification	SP
Optimum moisture content (%)	10.3
Maximum dry density (KN/m^3)	17.03
Permeability (K) cm/sec	1.50 x 10^{-3}

Angle of friction (ϕ) with omc value	34.95^0
Angle of friction (ϕ) with e_{max} value	26.56^0
Angle of friction (ϕ) with e_{min} value	33.02^0

Table 2. Identifications of different shape, size, and flatness of Chilika sand particles according to shape parameters

Particle size	No	Elongation (E_R)	Flatness (F_R)	Sphericity (ψ)	Shape factor (S_F)	Roundness Index (R_i)
600 micron	a.	0.58	0.36	0.60	0.45	0.43
	b.	0.96	0.16	0.30	0.40	0.47
	c.	0.74	0.19	0.36	0.37	0.29
	d.	0.95	0.59	0.71	0.75	0.22
	e.	0.66	0.52	0.74	0.59	0.36
425 micron	a.	0.75	0.37	0.56	0.52	0.29
	b.	0.73	0.35	0.55	0.51	0.20
	c.	0.74	0.33	0.53	0.49	0.27
	d.	0.98	0.40	0.55	0.63	0.32
	e.	0.64	0.36	0.58	0.48	0.30

Table 3. Identification of the shape of Chilika sand particles based on roundness index

Sl.no.	600 MICRON		425 MICRON	
	Particles	Shape	Particles	Shape
1.		sub rounded		sub-angular
2.		sub-rounded		angular
3.		sub-angular		sub-angular
4.		angular		sub-angular
5.		sub-rounded		sub-angular