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Dredged sea sand as an alternate material for use in internal drainage system in dyke embankment

Sable de mer dragué comme matériau alternatif à utiliser dans le système de drainage interne dans le remblai de digue

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ABSTRACT: In India, at the ash disposal areas, storage space is created by constructing dyke embankments for sustainable storage of coal ash. Dyke embankment is a water retaining structure to contain ash slurry and settled ash. The basic requirements for design of dyke embankments are to ensure; safety against stability, internal erosion and overtopping. To ensure safety against internal erosion; in the internal drainage system of dyke embankments, natural river sand or crushed stone sand is generally used. However, to create sustainable and environment friendly infrastructure, NTPC has recently explored the use of dredged sea sand in the internal drainage system of dyke embankment. The dredged sea sand samples evaluated with respect to base material as coal ash to explore suitability as an alternate of sand filter. coal ash is a combination of both bottom ash and fly ash and therefore contains much higher percentage of fines than bottom ash alone. Based on laboratory tests, it is established that dredged sea sand possess the required filter ability, drainage capacity, self-healing properties and does not segregate. Its use as filter material would also save time and cost over runs due to unexpected delays in procurement of natural river sand and most importantly it is environment friendly too.

RÉSUMÉ: En India, au niveau des aires de stockage des cendres, un espace de stockage est créé en construisant des digues pour le stockage durable des cendres de charbon. Le remblai de la digue est une structure de rétention d'eau pour contenir la boue de cendres et les cendres décantées. Les exigences de base pour la conception des remblais de digues sont d'assurer; sécurité contre la stabilité, l'érosion interne et le franchissement. Pour assurer la sécurité contre l'érosion interne; dans le système de drainage interne des remblais de digues, on utilise généralement du sable de rivière naturel ou du sable de pierre concassée. Cependant, pour créer une infrastructure durable et respectueuse de l'environnement, la NTPC a récemment exploré l'utilisation de sable de mer dragué dans le système de drainage interne du remblai de la digue. Les échantillons de sable de mer dragués ont été évalués par rapport au matériau de base sous forme de cendres d'étang afin d'explorer l'adéquation en tant qu'alternative de filtre à sable. Les cendres de bassin sont une combinaison de cendres résiduelles et de cendres volantes et contiennent donc un pourcentage de fines beaucoup plus élevé que les cendres résiduelles seules. Sur la base d'essais en laboratoire, il est établi que le sable de mer dragué possède la capacité de filtration, la capacité de drainage, les propriétés d'auto-guérison requises et ne se sépare pas. Son utilisation en tant que matériau filtrant permettrait également d'économiser du temps et des surcoûts en raison de retards inattendus dans l'approvisionnement en sable de rivière naturel et, plus important encore, il est également respectueux de l'environnement.

KEYWORDS: Dyke embankment, dredged sea sand, filter material, coal ash.

1 INTRODUCTION

In Indian thermal power plants, unutilized ash is disposed of in well designed, constructed and maintained Ash Ponds in slurry form. The most economic and commonly used method to dispose ash is by hydraulic transport, in the form of slurry, to the ash disposal areas. At the disposal areas, storage space is created by constructing dyke embankments all around, within which ash particles will be allowed to settle and the decanted water is allowed to escape for recirculation back to plant.

In the internal drainage system of dyke embankments, natural river sand or crushed stone sand is generally used. However, to create sustainable and environment friendly infrastructure, NTPC has recently explored the use of dredged sea sand in the internal drainage system of dyke embankment. The dredged sea sand samples tested with respect to base material as coal ash from ash pond to explore suitability as an alternate of sand filter. Here, coal ash is a combination of both bottom ash and fly ash and therefore contains much higher percentage of fines than bottom ash alone.

2 DYKE EMBANKMENT

Dyke embankment is a retaining structure to contain ash slurry and settled coal ash till it is evacuated for any beneficial purpose. The dyke embankment is designed with sufficient strength and safety features to avoid breaching at any point of time. Based on the type of the soil available for the embankment construction,

mostly, it is a homogeneous section with internal drainage arrangement of sand chimney and sand blanket.

2.1 Internal drainage system

The basic requirements for design of dyke embankments are to ensure; safety against stability, safety against internal erosion and safety against overtopping. To ensure safety against internal erosion; internal drainage system is provided. As the dyke embankment constructed with earth/ coal ash is a porous structure, it allows a gradual movement of water through its pores. In order to keep the downstream slope dry, stable and safe, internal drainage arrangement in the form of chimney and blanket are provided to intercept the seepage, if any and channelize the same through the rock-toe and toe-drain.

2.2 Filter material

In the internal drainage system of dyke embankments, natural river sand or crushed stone sand is generally used. However, to create sustainable and environment friendly infrastructure, NTPC has recently explored the use of dredged sea sand in the internal drainage system of water retaining structures like dyke embankment. NTPC have got the dredged sea sand samples checked with respect to base material as coal ash to explore suitability as an alternate of conventional material in internal drainage system of dyke embankment.

3 SUITABILITY OF DREDGED SEA SAND AS FILTER MATERIAL

The suitability of dredged sand from sea as filter material and coal ash samples from ash pond from Vallur Thermal Power plant, as a base material is investigated. Following are the brief details of investigation:

- Carrying out the laboratory tests to determine the index properties of dredged sea sand and coal ash (base material) proposed to be used for constructing the dyke embankment.
- Evaluating the suitability of dredged sea sand samples as per Indian Standard (IS) Code.
- Determination of chloride, sulphate and carbonate contents in dredged sea sand samples.
- Identifying the necessary modification to dredged sea sand for making them suitable for use as an alternate filter material.

3.1 Filter Criteria

The evaluation of suitability of filter material for filter ability, internal stability, drainage capacity and self-healing with respect to base material is checked in line with filter criteria specified in IS Code (IS:9429). The material for blanket filter, chimney filter and toe-filters shall consist of clean sound and well graded sand. The materials shall be free from debris, wood, vegetable matter and other deleterious matter.

3.2 Criteria for Chemical characterization

Chemical characterization (Sulphate, Chloride, and Carbonate content) of dredged sea sand samples were determined as per requirement. Brief description and criterion for required chemical characterization are described in subsequent sections.

3.3 Sulphate Content

Sulphate content was determined using Turbidimetric method as per IS 2720-27 and APHA Method 4500-SO₄²⁻. Sulphate ion (SO₄²⁻) is precipitated in an acetic acid medium with barium chloride (BaCl₂) so as to form barium sulphate (BaSO₄) crystals of uniform size. Light absorbance of the BaSO₄ suspension is measured by a photometer and the SO₄²⁻ concentration is determined by comparison of the reading with a standard curve. As per IS 456 and Liu et al (2018), soluble sulphate content in aggregates should be less than 0.5% and respectively.

3.3.1 Chloride Content

Chloride content was determined using Titrimetric analysis as per ASTM D512 and TxDOT 620-J. Water eluent of soil was adjusted to approximately pH 8.3 and is titrated with silver nitrate solution in the presence of potassium chromate indicator. The end point is indicated by persistence of the brick-red silver chromate colour. As per Liu et al (2018), chloride content in aggregates should be less than 0.18%.

3.3.2 Carbonate Content

Carbonates of calcium were determined using titrimetric analysis as per IS 2720-23. Acid (HCl) eluent of soil was titrated with sodium hydroxide solution in the presence of bromothymol blue indicator. The end point is indicated by persistence of the blue colour.

4 INVESTIGATION AND RESULTS

4.1 Coal ash (Base Material)

The coal ash samples were collected from ash pond of Vallur thermal power plant. 8 representative samples of coal ash were collected from one lagoon of about 320 acres and labelled as PA1, PA2, PA3, PA4, PA5, PA6, PA7, and PA8 respectively.

4.2 Dredged sea sand (Filter Material)

The source of sea sand is stockyard of Kamarajar port, Chennai where the sand dredged from port area in the sea is stocked outside as unused material. 24 representative samples of dredged sea sand were collected from stockyard at varying depth of 1m to 3m. The collected samples were further screened in the laboratory for removal of big lumps of fine-grained materials (clay) as well as shell fragments from each sample. These are removed by hand picking and they are found to have size approximately greater than 10 mm based on visual observation. It is observed that all samples of dredged sea sand consist of lumps of different sizes (more than 4.75 mm). Therefore these lumps are removed before carrying out further investigation. The picture of lumps collected from each sample is shown in following figure 1.



A-1/I



A-2/I



A-3/I



A-4/I



A-5/I



A-1/III



A-2/III



A-3/III



Figure 1. Pictures of lumps collected from dredged sea sand samples.

4.3 Grain size analysis of materials

The grain size analysis of all samples of base material and filter materials was carried out. For base material samples, hydrometer analysis was also carried out, since the material has significant amount of fine content. However, for samples of filter material, i.e. dredged sea sand, only dry sieve analysis was carried out. The grain size distribution (GSD) curves of all samples of base and filter materials, as obtained from tests were analyzed. Parameters obtained from GSD of base material is presented in following table 1.

Table 1. Parameters from GSD for evaluation of suitability of base material

Material id	% Particles > 4.75 mm	% Particles < 0.075mm	D ₁₅ (mm)	D ₃₀ (mm)	SD ₁₅ (mm)	Soil category as per IS 9429
PA-1	As per IS code, GSD Curves regraded neglecting gravel fraction	83.78	0.0050	0.080	0.03	Category 2
PA-2		28.47	0.0450	0.290	0.23	Category 3
PA-3		85.64	0.0050	0.073	0.03	Category 2
PA-4		76.29	0.0052	0.140	0.03	Category 2
PA-5		77.66	0.0065	0.095	0.03	Category 2
PA-6		26.71	0.0310	0.350	0.16	Category 3
PA-7		44.18	0.0170	0.220	0.09	Category 2
PA-8		50.63	0.0130	0.180	0.07	Category 2

5 EVALUATION OF SUITABILITY

The suitability of base material and filter materials for meeting the filter criteria is evaluated as per IS 9429. The parameters obtained from GSD required for evaluation of the suitability of filter material is presented in following table 2.

Based on the above data, it can be concluded that the dredged sea sand samples can be used as filter material, provided the lumps are removed by sieving through 4.75 mm size sieve and it is ensured that the fine content is less than 5%, by proper quality control. Majority of dredged sea sand samples are meeting the above condition can be used as filter material against base material of coal ash.

6 CHEMICAL ANALYSIS OF DREDGED SEA SAND

Based on results of GSD curves, 24 samples of dredged sea sand were mixed to make 12 samples. Chemical analysis was carried out on a total 8 samples and the results are summarized in following table 3. It is observed that chemical contents are within the limits and are not harmful while the dredged sea sand is used as filter material. High carbonate content indicates the

presence of calcareous shell fragments and other carbonate materials.

Table 2: Parameters from GSD for evaluation of suitability of filter material

Filter Material (Dredged Sea sand)	Material Id	%Particles>4.75 mm	%Particles<0.075mm	D ₁₅ (mm)	5D ₁₅
	A1/I	11.14	9.31	0.080	0.40
	A2/I	0.15	4.67	0.080	0.40
	A3/I	2.09	1.22	0.170	0.85
	A4/I	0.51	0.76	0.250	1.25
	A5/I	4.49	0.93	0.300	1.50
	A1/III	1.04	10.58	0.080	0.40
	A2/III	0.55	10.63	0.080	0.40
	A3/III	0.49	5.86	0.090	0.45
	A4/III	0.95	2.68	0.105	0.53
	A5/III	0.31	3.55	0.090	0.45
	B1/I	0.00	4.72	0.095	0.48
	B2/I	0.34	2.96	0.100	0.50
	B3/I	1.50	3.14	0.150	0.75
	B4/I	0.30	1.01	0.180	0.90
	B5/I	1.27	1.54	0.200	1.00
	B1/III	0.60	3.91	0.100	0.50
	B2/III	0.46	1.81	0.190	0.95
	B3/III	0.08	4.46	0.100	0.50
	B4/III	0.84	11.47	0.080	0.40
	B5/III	0.73	4.33	0.095	0.48
	C2/I	0.19	10.77	0.080	0.40
	C4/I	0.39	0.62	0.160	0.80
	C2/III	1.18	1.64	0.210	1.05
	C4/III	1.15	3.26	0.100	0.50

7 CONCLUSION

To ensure sustainable and environment friendly infrastructure, the suitability of dredged sea sand as filter material with respect to coal ash as base material has been explored by NTPC for use in dyke embankment. From the laboratory investigations, it is established that dredged sea sand possess the required filter ability, drainage capacity, self-healing properties and does not segregate. All samples of dredged sea sand are found to have lumps of fine-grained materials of different sizes that have to be completely removed before use by sieving through 4.75 mm size sieve. Based on the same, it is confirmed that the dredged sea sand can be used as filter material, provided the lumps and fine contents are screened and removed. This also saves time and cost over runs due to unexpected delays in procurement of natural river sand or manufactured sand and most importantly it is eco-friendly too. Based on the same, NTPC has finally proposed

dredged sea sand as a filter material in construction of the raising dyke embankment of one of the ash pond of thermal power plant.

Table 3: Results of chemical analysis of dredged sea samples

Sample Name	pH	O.C (%)	Chlorides (%)	Sulphate (mg/kg)	Sulphate (%)	Carbonates (%)
A1	8.09	0.543	0.0419	885.078	0.089	17.88
A2	8.10	0.258	0.0288	548.226	0.055	23.99
A3	8.50	0.239	0.0195	165.100	0.017	22.02
A4	8.31	0.150	0.0228	161.084	0.016	18.67
B1	8.27	0.318	0.0237	224.078	0.022	18.41
B3	8.52	0.263	0.0284	186.718	0.019	22.11
B5	8.08	0.302	0.0206	276.173	0.028	25.68
C2	8.26	0.246	0.0210	170.426	0.017	20.97

8 REFERENCES

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