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Effect of Turbulence on Deposition of Cohesive Sediments

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Abstract— Depositional characteristics of marine sediment occupy a paramount position in the field of Coastal Engineering and Environmental Engineering. The knowledge of Deposition, Transportation and Consolidation of fine sediment is very essential in design and dredging of navigation channels and development of ports for sustainable growth of any country. Deep water ports have played a significant role in improving the economy of all the rich countries in the world. One would intuitively think that that the rate of deposition of sediment would be higher under still water condition than under turbulent condition. Turbulence is expected to bring bottom sediment in suspension and keep it in suspension for longer duration. This is true for non-cohesive sediments. However, fine sediments flocculate and form larger and heavier flocs due to increased inter-particle collision rate resulting from low turbulence. Hence the micron-sized cohesive sediment flocs settle faster under low turbulence than under static condition. The results of experiments reported in this paper provide experimental proof for this interesting phenomenon.

Laboratory facility in the form of Jar Test apparatus was used in the present study. In addition, another set-up in the form of twelve glass cylinders of 250 ml capacity was also used. Borosilicate beakers of 1 litre capacity were used in the jar test apparatus to evaluate the effect of turbulence on cohesive clay minerals as well as natural sediment. Varying suspensions of sediment concentrations were prepared by using a) Sea water, b) Tap water, and c) Reconstituted Sea water. Natural sediment obtained from Rohini Port, located on the west coast of India was used for experimental work. This sediment prevailing in saltwater of the ocean contained about 50 percent of clay particles with size less than 12 microns.

Experimental results with 1 litre beakers kept in the quiescent condition showed that the minimum sediment concentration needed for forming an interface was 3 gm/l for natural sediment. Effect of low turbulence generated in 1 litre capacity beakers gave very important conclusions. When the vanes were rotated at varying low speeds, effect of turbulence on cohesive sediments and natural sediment gave clear and defined results indicating that lower the RPM for rotating vanes, higher was the sediment settlement rate. Also rotation speeds varying between 5 and 20 RPM, 5 RPM gave the highest rate of sediment settlement.

Graphs of % deposition with and without turbulence were plotted for the cohesive sediments as well as for the natural sediment with varying concentration. This paper is an Interim stage of research work, which has been undertaken and only the results available as of now are reported.

Keywords-Turbulence, cohesive sediments, floc, inter-particle collision.

I. INTRODUCTION

Depositional characteristics of marine sediment surely occupy a major place in the field of Ocean Engineering and Environmental Engineering. The knowledge of Deposition, Transportation and consolidation of fine sediment is very essential in design of docks and harbours, navigation channels, sewage disposal plants, water treatment plants, irrigation channels and dams, nuclear power stations, and for planning and disposal of radioactive waste in the ocean.

With a huge percentage of silt, marine sediments also consist of clay and organic matter. Presence of even a small (15 to 20) percentage of clay in non-cohesive sediments, changes the property of deposition and transport of sediments. Also, no reliable and universally applicable formulae are available for cohesive sediment deposition and erosion. Hence their characteristics and significance needs to be determined through laboratory experiments. In the past few years there has been rapid development of estuarial and coastal harbours and there is increasing demand for bigger harbours as well as for wider and deeper navigation channels too. Hence it becomes evident and important to predict the transport and deposition of cohesive sediment. Also huge amount of money is spent in dredging activities. Saving in the cost of maintenance dredging can be achieved by selecting proper technique for which knowing the precise movement of cohesive sediments is very much important.

In the last few years, study of fine sediments has assumed an important role in pollution control measures. Sediments are considered pollutants because they adsorb and carry bacteria as well as toxic elements and increase turbidity. Deposition of cohesive sediment may create serious engineering and environmental problems. Fine sediments adsorb other pollutants very effectively and transport them along. The content of heavy metals adsorbed to the sediment is found to depend on the particle size of the sediment. Due to a very large specific surface area and presence of electrical charge, the smaller the grain size, the higher is the contamination of heavy metals. The bulk of the pollutants may be carried on the sediments rather than in water. It is essential to understand the depositional and re-suspension characteristics of the fine sediments for obtaining better solutions to engineering problems and in effective pollution control.

In the present study, laboratory facility in the form Jar Test apparatus was used. Varying suspensions of sediment concentrations were prepared by using Sea water and Tap water. Clay minerals as well as natural sediment obtained from Rohini port were used for experimental work. This natural sediment was partially cohesive with 50 percent clay particles less than 12 microns.

II. LITERATURE REVIEW

Studying cohesive sediment flocculation and in the process of determining its application to settling flux modelling, A.J Manning and R. J. S. Whitehouse (2000) found that cohesion arises through the combined efforts of both electrostatic charging of clay minerals and flow parameters. The degree of flocculation is highly dependent upon both SPM (suspended particulate matter) and Turbulence Shear[1]. In addition to it, Emmanuel Partheniades (1987) derived theory stating that, the distribution of the sizes, settling velocities, strength and densities of the flocs depend not only on the physico-chemical properties of the sediment water system, but also on the flow parameter. Interparticle and/or interfloc collisions can be effected by (a) Brownian motion, (b) velocity gradients, and (c) differential settling. It has been demonstrated that Brownian motion can be of dominant importance only in the first stage of flocculation when individual particles collide to form primary flocs[2].

III. LABORATORY SETUP

Firstly the experimental matrix was prepared which consisted of number of experiments wherein the major governing parameters like RPM, time, additives, and type of water were altered and several combinations were used for different type of clay minerals. The present work includes determining the rate of deposition for different clay minerals with and without turbulence. For low suspension concentration a domestic mixer grinder was used which had 300 ml capacity. Mixing of sediment and water was done at 1000 rpm speed for 10 minutes before each experiment in order to break any small lumps of sediment and achieve uniform suspension in the cylinders. Six beakers with varying concentration were used on the Jar-Test Apparatus under low turbulence and similar set of beakers was kept undisturbed and percentage deposition was observed in both the cases. Turbulence is calculated in the form of Reynold’s no. using the formula $\rho vD/\mu$ and is found out to be 2475 which indicates low turbulence.

A. Jar-Test Apparatus

Jar Test Apparatus is mostly used for conducting laboratory measurements to correctly estimate the Dosing of alum and such other coagulants for treatment of water and sewage. The first step of the jar test involves adding coagulant to the source water and mix the water rapidly (as it would be mixed in the flash mix chamber) to completely dissolve the coagulant in water. Then the water is mixed more slowly for a longer time period, imitating the flocculation basin conditions and allowing the formation of floc particles to cluster together. Finally, the mixer is stopped and the flocs are allowed to settle out, as they would in the sedimentation basin

Figure 1. Jar-Test Apparatus

Figure 2. Jar-Test Apparatus with samples

B. Experimental Matrix

PARAMETERS USED FOR EXPERIMENTS								
SR	TYPE OF	SUSPENSION CONC	RPM		SEA WATER	FRESH WATER	TIME	ADDITIVES
1.1	SODIUM BENTONITE	3 gm/L	5	0	NO	YES	45 MIN	NO
		6 gm/L	5	0	NO	YES	45 MIN	NO
		9 gm/L	5	0	NO	YES	45 MIN	NO
		12 gm/L	5	0	NO	YES	45 MIN	NO
		15 gm/L	5	0	NO	YES	45 MIN	NO
1.2	SODIUM BENTONITE	3 gm/L	3	0	NO	YES	45 MIN	NO
		6 gm/L	3	0	NO	YES	45 MIN	NO
		9 gm/L	3	0	NO	YES	45 MIN	NO
		12 gm/L	3	0	NO	YES	45 MIN	NO
		15 gm/L	3	0	NO	YES	45 MIN	NO
1.3	SODIUM BENTONITE	3 gm/L	5	0	NO	YES	60 MIN	NO
		6 gm/L	5	0	NO	YES	60 MIN	NO
		9 gm/L	5	0	NO	YES	60 MIN	NO
		12 gm/L	5	0	NO	YES	60 MIN	NO
2.1	NATURAL SEDIMENT	15 gm/L	5	0	NO	YES	60 MIN	NO
		2 gm/L	10	0	NO	YES	60 MIN	NO
		4 gm/L	10	0	NO	YES	60 MIN	NO
		6 gm/L	10	0	NO	YES	60 MIN	NO
		8 gm/L	10	0	NO	YES	60 MIN	NO
		10 gm/L	10	0	NO	YES	60 MIN	NO

IV. RESULTS

Comparison is made for the % deposition with and without turbulence and the respective measurement of the % deposition was made on weight basis by drawing a sample and filtering it through "Whatman" 0.42µ filter paper. One reading was taken at the start of the experiment and two were taken at the end for "with and without" turbulence respectively. Graphs of % deposition v/s sediment concentration were plotted and conclusions were derived.

4.1 Graphs of %Deposition vs Sediment Concentration.

(Note: Series 2 is with Turbulence, Series 1 is without turbulence)

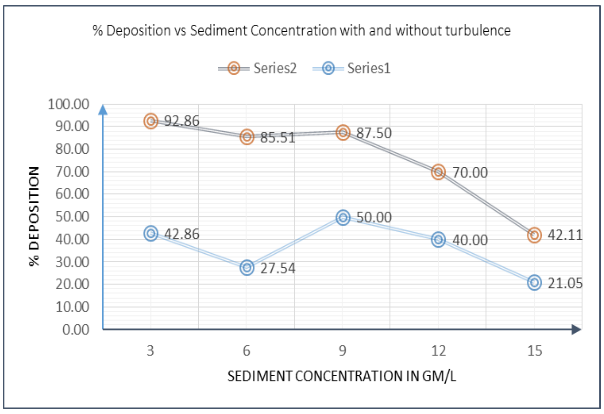

Figure 3. Graphical results for set 1.1

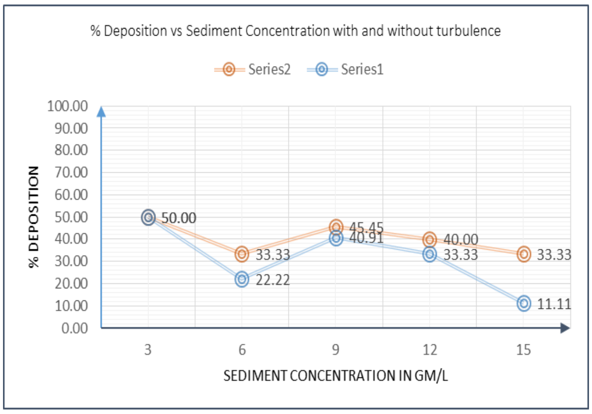

Figure 4. Graphical results for set 1.2

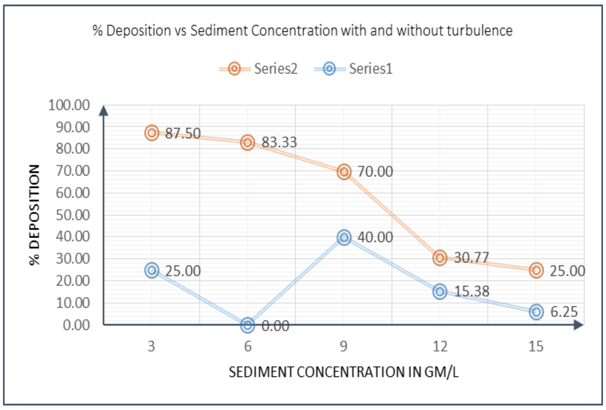

Figure 5. Graphical results for set 1.3

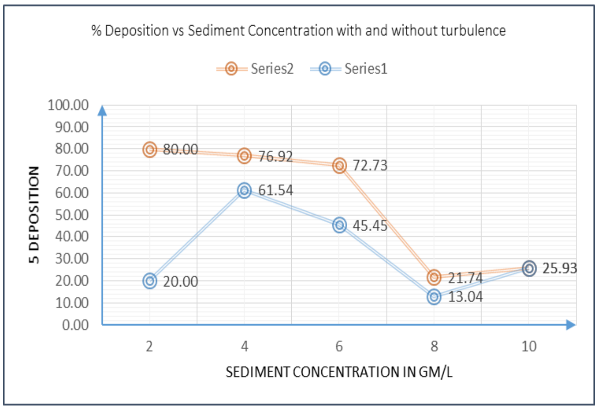

Figure 6. Graphical results for set 2.1

The above graphs shows results of % deposition versus sediment concentration for the sets of experiments shown in the experimental matrix respectively. Every graph has a combined result of both, the set which was induced to turbulence and same set which was in quiescent condition (0 RPM). The series 2 which is in red shows the result for the set with turbulence and series 1 which is in blue shows the result for the same respective set without turbulence.

V. CONCLUSIONS

- The rate of deposition of the cohesive sediments depend not only on the physico-chemical properties of the sediment water system, but also on the flow parameter (turbulence).
- Brownian motion, Turbulent shear and Differential settling concentration provide Turbulent Shear Stresses which are responsible for flocculation.

- For speed less than 5 RPM for sediment suspension concentration, the sediments are flocculated but floc size and composition are fairly constant. Significant deposition is not observed for speed of 3 RPM.
- Relation between flocculation and residence time in a specific turbulent environment becomes an important parameter. Minimum time for maximum deposition is found out to be 45 min-60 min.
- Concentration above 20 gm/L of sediment suspension dampens the turbulence which results in less deposition.

REFERENCES

[1] A.J. Manning, J.V. Baugh, R.L Soulsby, J.R. Spearman, R.J.S Whitehouse, “Cohesive Sediment Flocculation and the Application to Settling Flux Modelling” (2000).

[2] Emmanuel Partheniades, “Turbulence, Flocculation and Cohesive Sediment Dynamics”. *Nearshore and Estuarine Cohesive Sediment Transport, Vol 4, (1987).*

[3] A.J. Manning, J.C> Winterwerp, C. Martens, T,de Mulder, J Vanlede, “A heuristic formula for turbulence-induced flocculation of cohesive sediments” *Estuarine, Coastal and Shelf Science 68 (2006) 195e207. (2006).*

[4] C. V Gole (Director), Z. S Tarapore (Chief Research Officer)S.B Brahme (Assistant Research Officer), “Prediction of Siltation in Harbour basin and channel” Central Water and Power Research Station, Pune, India, (1993)

[5] E.A Toorman, A.W Bruens, C Kranenburg & J.C Winterwrep, “Interaction of Suspended Cohesive Sediment and Turbulence”, *Fine Sediments Dynamics in Marine Environment., Elsevier Sciences, (2002).*

[6] Emmanuel Partheniades and A.J Mehta, “Deposition of Fine Sediments in Turbulent Flows”. *Environment Protection Agency, Project #16050 ERS. (1971).*