International Conference on Estuaries and Coasts
November 9-11, 2003, Hangzhou, China

STUDY ON THE POSSIBILITY OF OCCURRENCE OF FLUID MUD IN THE YANGTZE DEEP WATERWAY

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Abstract: Generally there is a higher sediment deposit rate in the navigation channel on muddy coasts so that the constant dredge is necessary. This usually means more expenditure of the port operation in those areas. In order to reduce the dredge cost, it is important to study the nautical depth, or to determine the critical unit weight of mud for navigation. The deep waterway regulation works is now under construction in the Yangtze Estuary. It is vital to study the characteristic and variation of fluid mud in the Yangtze Estuary. This paper deals with all the aspects of fluid mud in the Yangtze Estuary, including the characteristic、forming conditions and variation、nautical depth, especially analyzing the possibility of fluid mud formation in the North Passage of the Yangtze Estuary. It concludes that the fluid mud may appear in the North Passage after construction of deep waterway regulation works. This should be paid attention to.

Key words: Yangtze Estuary;Fluid mud; Deep waterway regulation; Nautical depth

1. ANALYSIS OF EFFECT OF SHIP NAVIGATION ON FLUID MUD

No direct studying results of effect of ship navigation on fluid mud is reported. But some results of effect of ship propeller motion on harbor basin can give some ideas.

The one of the consequences of the increase of size and speed of sea-borne transport which coincided with much higher installed engine powers can be the increasing attack on the bed and banks of navigation channels and harbor basins by the propeller slipstream. The possible erosion of bottoms and banks of navigation channels or a harbor basin will be higher if the velocities in the propeller slipstreams relative to the bottom are stronger and occur during a longer time. This is in particular the case during mooring and unmooring manoeuvres of ships with a small keel clearance. According to the report of Felkel et al (1972), the slipstream of a ship 's propeller can cause considerable erosion of the bottoms of fairways or harbor basins.

The disturbance of bed sediments by the wash of ship's propellers results in the sediments not easy to silt. There is a need for an accurate method of scour prediction. G.A.Hamill et al (1999) have developed empirical equations for the prediction of the maximum depth scour caused by the ship's propeller motions, for any given exposure period.

According to the results of study by H.G.Blaauw and E.J. Van de Kaa(1978) , it is possible to determine in an approximate way the velocities at the propeller plane as well as in the slipstream of a ship's propeller. With the known mean axial velocity the additional bottom shear stress due to ship's propeller motion can be calculated.

Therefore in the depth-averaged two dimension mathematical model, the effect of the additional bottom shear stress caused by ship's propeller motion on sedimentation can be taken into account only by adding the additional bottom shear stress to the normal bottom shear stress.

2. METHOD OF FLUID MUD CONSIDERATION IN CHANNEL SILTATION CALCULATION

No mature method has been developed in channel siltation calculation considering the effects of the fluid mud. The siltation due to the effects of the fluid mud can only be calculated through modifying a few parameters and analysesing some factors.

An effective width of the channel has been defined for calculating siltation in the depth-averaged two dimension mathematical model in order to considering the material transportation caused by transverse velocity changes. In ordinary condition the width resulting main channel siltation due to transverse velocity changes and turbidity currents (including fluid mud, horizontal gradients in flow velocity) is equal to the slope width. Therefore the effective width of the channel is the addition of the three widths, namely the width of the channel, the width of the slope and the width resulting main channel siltation due to transverse velocity changes and turbidity currents .

The changes of the flow structure caused by the vertical gradients of the salinity and velocity can not be directly considered in the depth-averaged two dimension mathematical model. Due to the vertical gradients in the salinity and velocity profile, the vertical exchange of momentum is damped, resulting in a decrease in bed shear stress. This effect is particularly important during ebb and in turbidity zone, as advective seaward transport and the landward density current counteract. From laboratory experiments and field observations by Delft Hydraulics[15], it is estimate that during ebb the bed shear stress can decrease by about 40% due to this effect. This means, that to a first approximation, the mean bed shear stress, averaged over the tidal period, will decrease by about 20% . The decrease of the actual bed shear stress means the increase of the calculation siltation, including the increase of the fluid mud on channel siltation. This effect can be taken into account in the depth-averaged two dimension mathematical model in a parameterized form. For example, the Chezy values in the hydrodynamic model should be taken higher value during ebb and in turbidity zone in order to model properly the tidal propagation. When formulations of Partheniades and Krone are used to calculate the net siltation /erosion, the threshold value of bottom shear stress for deposion and erosion can be set to proper values.

In the depth-averaged two dimension mathematical model, the effect of the additional bottom shear stress caused by ship's propeller motion on siltation/erosion of sediment can also be taken into account only by adding the additional bottom shear stress to the normal bottom shear stress. Then this synthetic shear stress is applied for calculation. When formulations of Partheniades and Krone are used, the normal bed shear stress is replaced by the synthetic shear stress.

3. DETERMINATION OF THE NAUTICAL DEPTH

It is easy to determine the nautical depth when the bottom of the navigation channel and harbor basin is ordinary sediment. But it is difficult to determine the nautical depth when fluid mud exists in the navigation channel and harbor basin. There are two requirements in determining the nautical depth. One is that ship can not be damaged when the draught reaches the nautical depth. Another is that there is no unfavorable effect on navigation and ship's manoeuvres. The first requirement is easy to satisfy when fluid mud exists in the navigation channel and harbor basin. But the second requirement is rather complex, because it depends on many physical characteristics of fluid mud, for example, the density, shear stress and the inner wave between water and fluid mud interface. Therefor a physical parameter must be selected which can reflect the characteristics of fluid mud and be easy to be measured. The specific gravity of fluid mud is the physical parameter required.

The specific gravity of fluid mud depends on the size, water depth, exist duration, component of fine sediment. But for a given estuary or harbor basin, the specific gravity for determining the nautical depth is usually taken a same value because the forming condition of fluid mud is basically the same and also the source of sediment. The specific gravity is taken to 1.2 as critical criterion for fluid mud and solidified silt in Rotterdam, the Netherlands. The value is used to determine the bottom elevation of the navigation channel. When the silt which the specific gravity value is 1.2 reaches the specified depth, dredging required. The concept of the nautical depth is applied many years in Rotterdam and received enormous economical benefits. If 1.25 or 1.3 as critical specific gravity is permitted, the dredging volume can be considerably decrease. Table 2 is the accepted or studied critical specific gravity of fluid mud in determining nautical in the world.

Table 2 critical specific gravity of fluid mud in determining nautical

Harbor Name	Rotterdam	Bankok	Surina	Tianjing xingang	Yangtze	Liang yungang	Belgium
critical specific gravity	1.2	1.2	1.23	1.2-1.3	1.25	1.25-1.30	1.151-1.347

After determining the nautical depth and critical specific gravity of fluid mud, it is easy to judge whether the water depth of navigation channel is satisfied the requirement or not and whether dredging is needed or not. Therefore it is very important of the technology for fast measuring the specific gravity of fluid mud when the fluid mud is used as the nautical depth.

4. POSSIBILITY OF FLUID MUD FORMATION IN THE NORTH PASSAGE

The flocculation decrease as silt size increase and no flocculation was found for 0.032-0.050mm silt. It has been determined that the critical size of silt flocculation in Yangtze estuary is 0.032mm. The flocculation occurs especially for size less than 0.008mm. The fine sediment in the Yangtze estuary in flood season is enormous. Suspend sediment of size less than 0.008mm in the North Passage is 33.5% , whereas 7.7% in the South Passage. So the content of the fine sediment in the North Passage is much higher than that in the South Passage. According to data of medium tide on site in 1997, the flow ratio of the South Passage and the North Passage is 47% and 53% separately. So the fine sediment ratio of the South Passage and the North Passage is 1:2.48. The quantity of the fine sediment of size less than 0.008mm in the North Passage is much greater than that in the South Passage. According to the results of the mathematical model, the flow ratio of the South Passage and the North Passage is 53.6% and 46.4% and the sediment ratio of the South Passage and the North Passage is 80.7% and 19.3% separately after the construction of deep waterway regulation works. If the contents of the fine sediment in the South and North Passage do not change after the construction of deep waterway regulation works, the ratio of the quantity of the fine sediment of size less than 0.008mm in the South Passage and in the North Passage will be about 1:1.04. So the quantity of the fine sediment of size less than 0.008mm in the North Passage will be a bit greater than that in the South Passage. Whereas the quantity of the fine sediment of size less than 0.008mm in the North Passage after the construction of deep waterway regulation works is 1.32 multiple of the quantity of the fine sediment of size less than 0.008mm in the South Passage in natural state. Therefore it can be conclude that the quantity of the fine sediment of size less than 0.008mm in the North Passage is always more than the quantity in the South Passage before or after the construction of deep waterway regulation works. Due to fluid mud have occurred many times in the South Passage in present fine sediment condition, so the fine sediment of size less than 0.008mm in the North Passage satisfy the requirement of sediment for fluid mud formation.

According to present study of salinity intrusion in the Yangtze estuary, salt water intrusion will aggravate in the South and North Passage after the construction of deep waterway regulation works. The aggravation of the salt water intrusion in the North Passage results in ease to flocculation of fine sediment. The sediment accumulation and the accumulated sediment resuspension in the mouth-bar will occur more frequently. The phenomena is unfavorable to sediment solidification and favorable to turbidity maximum and fluid mud formation.

Therefore the possibility of occurrence of fluid mud can not be excluded in the North Passage after construction of deep waterway regulation works. Attention must be paid to the fluid mud study in the Yangtze Estuary, especially the possibility of occurrence of fluid mud in the North Passage after construction of deep waterway regulation works. The study is necessary and have practical meaning.

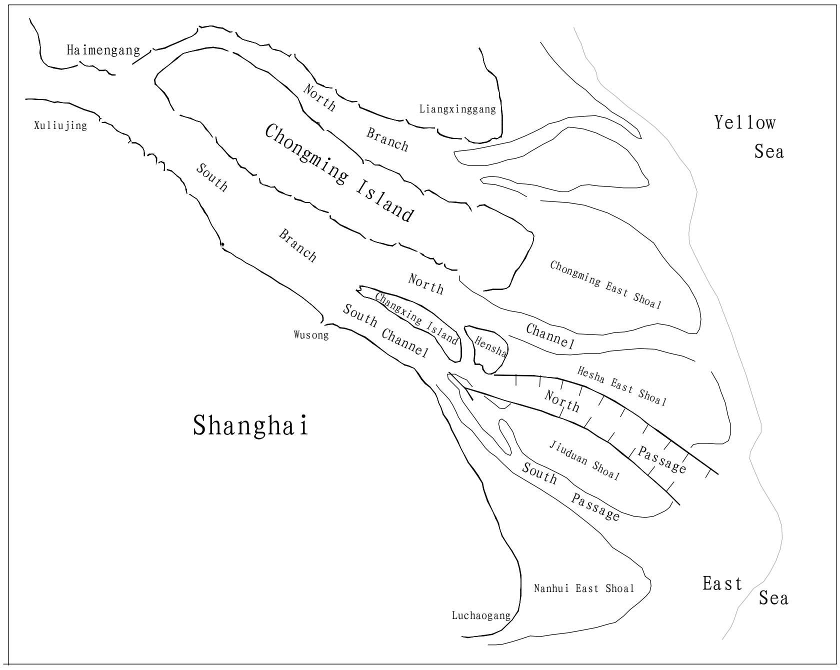

Fig. 1 Sketch of the Yangtze Estuary and deep waterway regulation works

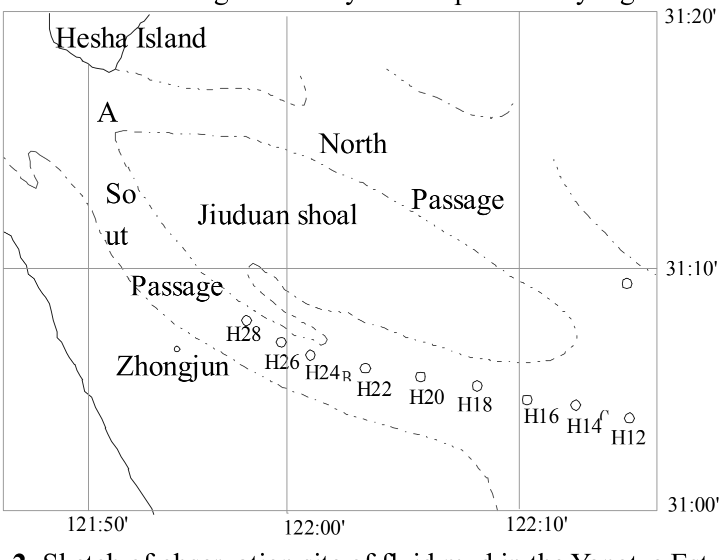

Fig. 2 Sketch of observation site of fluid mud in the Yangtze Estuary

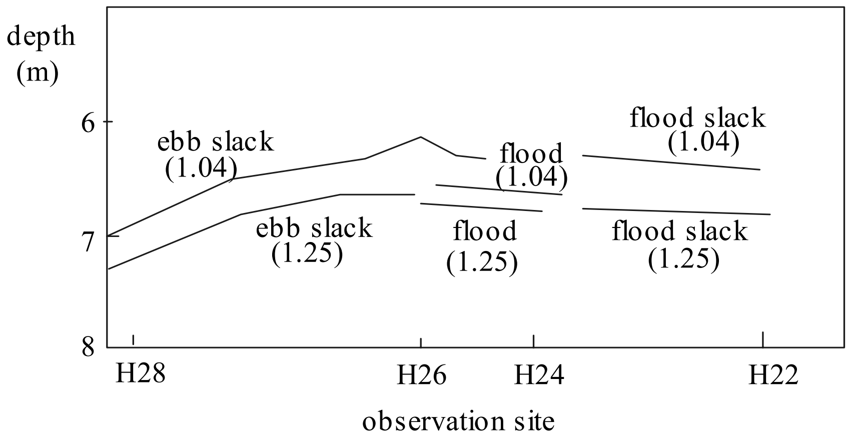

Fig. 4 Variation of fluid mud in a tide cycle

5. CONCLUSION

The characteristic、forming conditions and variation、nautical depth of fluid mud in Yangtze estuary have been investigated and summarized. The possibility of fluid mud formation in the North Passage of the Yangtze Estuary has also been analyzed. The fluid mud will more easy to occur in the North Passage after the construction of deep waterway regulation works than in natural state. Although fluid mud only occurs in the South Passage in natural state, the possibility of occurrence of fluid mud can not be excluded in the North Passage after construction of deep waterway regulation works because of the changes of flow sediment and salt water intrusion.

Important Notes: According to last data on site, the fluid mud **does occur** in the North Passage after the construction of the first stage of deep waterway regulation works and the fluid mud result in unfavorable effects on navigation.