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

EROSION-RESISTING CHARACTERISTICS OF LARGE-SCALE MATERIALS UNDER TIDAL BORE

Huoqi YANG & Wenjie WANG
Zhejiang Institute of Hydraulics of Estuary, Hangzhou, 310020

Abstract: The tidal bore generates in the shallow water region. There are many engineering measures for toe protection, such as sheet piles, small open caissons and the indirect protection of groin group. Before these measures were used, people normally used rock riprap and other large-scale materials (in this paper the large-scale materials refer to riprap、concert or reinforced concrete block and other kinds of frame). But their effects are not good for resisting toe scour, although it is successful when this materials are used in the Yangtze and Yellow rivers in China. The characteristics of erosion-resisting of different materials (including block stone, reinforced concrete block and frame) were studied in physical tidal bore model experiment. It is shown from the experimental results that the large-scale materials can be successfully applied in the cutoff and blocking.

Key words: Erosion-resisting, Tidal bore, Toe protection, Large-scale material, Physical model

1. BRIEF INTRODUCTION ABOUT LARGE-SCALE MATERIALS THRESHOLD VELOCITY FROM DOMESTIC AND OVERSEA

Many researchers or researching units have put forward different threshold velocity formulas according to their different studying object. The formulae table 1 is the collection from different researcher or researching units . It is shown that the threshold velocity is relative with the material size, unit weight, water depth and material weight, the foundation material size and stable coefficient etc.

Except the C.B. Izbash formula， the others are indicated to the vertical mean velocity. In addition, the formula put forward by Liu Daming etc.(belong to Yangtze River Scientific Research Institute) has considered many factors. That is to say, his formula includes the foundation material size. Our research is based on this formula.

2. EXPERIMENTAL RESULT OF THE SCOUR RESISTANCE ABOUT LARGE-SCALE MATERIALS

The hydrodynamic conditions in the tidal bore area are quite special. The velocity is very high (maximum velocity up to 12m/s).This kind of current doesn’t happen in the general rivers. Therefore, we can’t do as experiments with the normal methods. As we know, there exist high speed velocity under the cutoff and closure condition, according to domestic and oversea model experiment(the model scale range from 20 to 80), we choose the model scale of 30 in our tidal flume experiment. The chosen material weights ranged from 50kg to 8000kg, especially, we studied the reinforced concrete tetrahedron-like penetrating frame in detail because this kind of frame had been used on the toe-protection on Yangtze and Yellow river in China.

From the experiment we concluded that: (1)To any kind of shape and weight material, the threshold velocity is extremely relative with the water depth before the bore comes, with increasing of the fore-bore water depth , the stability can increase rapidly; (2)As the material weight increases ,the resistant capacity to scour of large-scale material can be strengthened a little, on the contrary, for a few kinds of materials(for example tetrahedron-like penetrating frame) , the material stability maybe reduced with the increase of its size.

Table 1 Collection of threshold velocity of large scale material

Authors or units	Expression form	Accounting for the application
Former-Russia C.B. Izbash	$V_c = K\sqrt{2g\frac{\gamma_s-\gamma}{\gamma}D}$	K=1.2（sliding），K=0.86（rolling）
YRSRI Zhang Zhitang	$V_c = K\sqrt{2g\frac{\gamma_s-\gamma}{\gamma}D}(\frac{h}{D})^{\frac{1}{m}}$	Summarize pebble threshold velocity that came from many researcher on the upper Yangtze river，m=6～7(refer to the wide river valley)，K=3.11～4.60
Corps of Engineers	$V_c = K\sqrt{2g\frac{\gamma_s-\gamma}{\gamma}}(\frac{6W}{\pi\gamma_s})^{1/6}$	（Coefficient of stability） K=0.86～1.20
Holland *F.Gerritsen*	$V_c = K\sqrt{2g\frac{\gamma_s-\gamma}{\gamma}D}\log\frac{5.5h}{D}$	Holland, design model about delta blocking the velocity distribution accord with logarithm rule,K=1.0
ZECER	$V_c = K\sqrt{2g\frac{\gamma_s-\gamma}{\gamma}D}(\frac{h}{D})^{\frac{1}{4}}$	K=3.11，this formula had been verified at the Xiangshan County closing in zhejiang province.
YRSRI Liu Daming	$V_c = \sqrt{2g\frac{\gamma_s-\gamma}{\gamma}D(\frac{h}{D})^{\frac{1}{7}}\left[0.4+0.85(\frac{\Delta}{D})^{1/2}\right]}$	Take into account the material shape and the relation between the material and its foundation

3. STABILITY ANALYSIS THE OF THE LARGE-SCALE MATERIAL UNDER TIDAL BORE

As to large material, it can reflect the real stability when we use the acting velocity rather than the vertical mean velocity. Normally the vertical distribution velocity is accorded with power-type or logarithm form. But, the tidal bore velocity distribution is special, we had tested the tidal bore velocity on the Qiantang River in Zhejiang province.(Fig. 1)

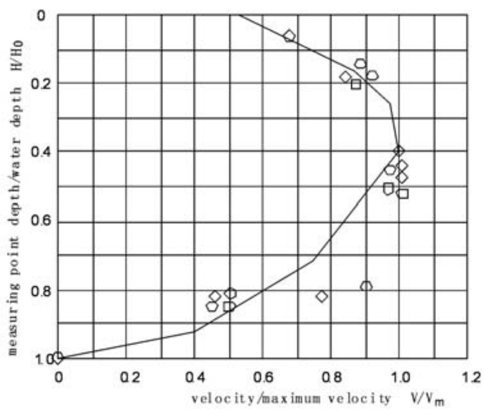

Fig. 1 $H/H_0 \sim V/V_m$ curve in Qiantang eatuary dyke slope

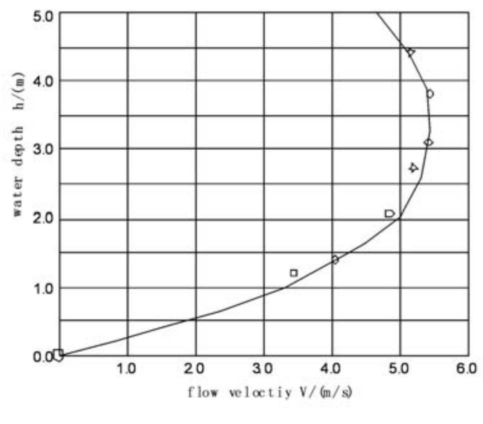

Fig. 2 Vertical distribution of velocity after bore in flume

Professor Linbinyao (Zhejiang Provincial Institute of Coast and Estuary) fitted these datum and concluded the experiment relation(formula 1),

$$v_d / v_s = 9.68\varepsilon - 17.36\varepsilon^2 + 14.03\varepsilon^3 - 5.36\varepsilon^4 \quad (1)$$

v_s—surface velocity; $\varepsilon = t/h$, t—the length from the center of gravity to the bed, h—water depth, v_d—the integral acting velocity (from the material bottom to its top).

In the tidal flume experiment, we test the vertical velocity distribution(Fig. 2), the two curves are similar with each other , the maximum velocitys appear at the relatived depth of 0.6 (from the bottom to the top).

By Liu Daming formula (Table 1) and the formula 1, we can get the following formula 2,

$$V_s = \left(0.4 + 0.85\left(\frac{\Delta}{t}\right)^{\frac{1}{2}}\right)\left(\frac{1}{A_d}\right)^{\frac{1}{2}} \sqrt{2g\frac{\gamma_s - \gamma}{\gamma}V} \cdot \frac{1}{\kappa} \qquad (2)$$

in formula 2 ,the κ is equal to 9.68 ε-17.36 ε2+14.03 ε3-5.36 ε4, Δ—foundation material size(sphericial diameter); A_d—the upstream facing area; γ_s—the material gravity; γ—the water gravity; V—the material's actual volume; and other symbols are the same with the formula 1.

Utilizing the above formula 2, we can calculate threshold velocity of the large materials, for example, we can get that tetrahedron-like penetrating frame threshold velocity is opposite to its frame size(at the depth of 2m),the reason is that the acting velocity increase rapidly when the frame size increase. From the Fig. 3, we can understand it more clearly.

The cutoff model experiment about the concrete tetrahedron scour resistance have proved that: when the concrete tetrahedron weight is up to a definite value, the scour resisting velocity increase very slowly (Fig. 4). In contrast to the tetrahedron-like penetrating frame, as its weight increase, its frame size increase rapidly, so sometimes the stability is down when its size is up.

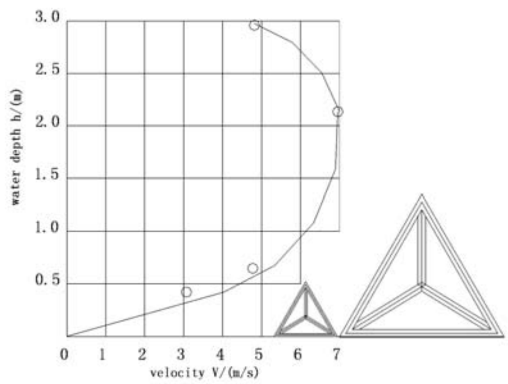

Fig. 3 Comparative chart of velocity on the fram tetrahedron-like penetration-frame

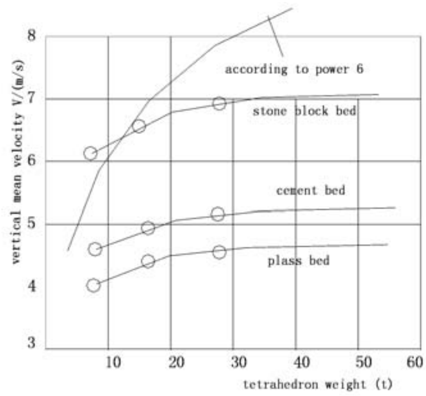

Fig. 4 Relations between moving velocity and weight of four-faced block

4. CONCLUSION AND SUGGESTION

(1)The vertical velocity distribution that happen in the tidal bore river is different from that in common river, the maximum velocity point appear at the point of half depth.

(2)As to the large-scale material, we should make use of the acting velocity to study their scour resistance, especially, when the tidal bore propagates in a shallow water region, the material size must be considered.

(3)From the model experiment and theoretic analysis, we know that the large material's scour resistance depress as the fore-bore water depth become shallower and shallower.

(4)When the material weight or size is up to a definite value, the threshold velocity increases slight, so we think that it is not a good method by raising the block's weight and size.

(5)Now we can improve its stability by changing dumped methods, on the other hand , if we can find cheap high-gravity stone block(such as the diabase, its gravity is more than 3.0, then the threshold velocity can improve 10 percent).

REFERENCES

Gerritsen F.，Topic in Ocean Engineering. Texas. Gulf Publishing Company 1969.363-389.

Izbash C.B., river cutoff hydraulics. Beijing：Chinese industy press.1964(in Chinese).

Liu Daming，Wang Dingyang，Wang Xianming etc.. Experiment study and the basic conclusion about some cutoff hydralic problems in Gezhouba. China Science(A)，1982.Volume 10：page :951-962.

Wang Nanhai,Zhang Wenjie, Wang Bin，Application of a New Technology of Bank Protection Employing Tetrahed-like Penetrating Frame Groups in Yangtze River[J]. Journal of Yangtz River Scientific Research Institute，1999,16(2):11-16 (in Chinese).

Zhang Zhitang,Yao Yuli Research on Starting Velocity of the Bed Gravel in Upper Yangtze River[J]. Journal of Yangtz River Scientific Research Institute，1989,6(2):1-10. (in Chinese).