II -82

The effect of littoral drift on the stability of natural tidal inlets

Meng Zhaowu,S.M., Dept. of Civil Eng. and Arch., Muroran Institute of Technology
Hideo KONDO, F., Dept. of Civil Eng. and Arch., Muroran Institute of Technology
Satoshi TOHMA, M., Dept. of Civil Eng. and Arch., Muroran Institute of Technology

1. Introduction

Many researches have been carried out on the stability of tidal inlets using various methods. On the relationship between tidal prism and cross-sectional area , the ratio of annual littoral drift M_t around inlet and peak discharge Q_{max} is proposed by KONDO[1),2)] from data of USA and Japan. In order to widely identify its applicability, the recent data of natural inlets which are rare presently in Japan, from Northern Island of New Zealand and Southern China are analyzed and their stability are evaluated using this method.

2. Analytical Method

The inlet channel characteristics depend upon the balance between longshore sediment transport and wave acting to choke the inlet and the scouring action of tidal flows and discharges acting to erode the inlet channel. The balance between deposition and erosion is manly reflected on the velocity of tidal flow. If the velocity is larger than it in equilibrium as current can carry much more sediments, the inlet and the region around it are being eroded. Whereas, if the velocity is smaller than it in equilibrium, correspondingly the force of tidal flows to carry sediments become smaller, so the inlet is being choked. Meanwhile the velocity is controlled by the water level difference between the bay and the sea. When the depth of entrance channel or the cross-sectional area is varied, the peak current velocity changes. Since too small depth makes the bottom resistance greater and much greater depth does the water surface gradient along the channel more gentle, the peak current velocity must take the maximum value of it at some depth. That means in the channel with a stable cross-sectional area for a long time, the deposition and the erosion are counteracting or in dynamical equilibrium. Based on the ratio of the annual littoral sediment transport and river sediment discharge M_t to Q_{max}, the peak tidal current discharge, the following formula has been derived, and its relationship is shown in Fig.1,

$$\left(\frac{\mathcal{P}}{\mathcal{A}}\right)_{max} = \frac{\mathcal{U}T}{\pi} = K_s\sqrt{a_s g T}$$

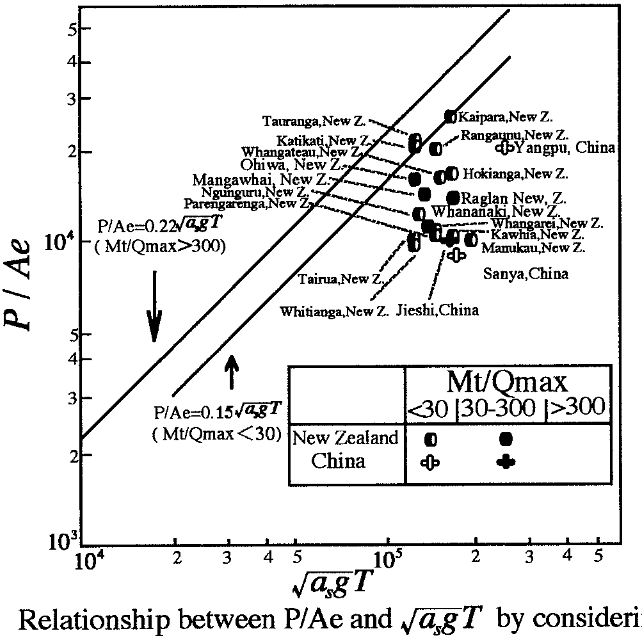

Fig. 1 Relationship between P/Ae and $\sqrt{a_s g T}$ by considering Mt/Qmax

Keyword: littoral drift, tidal prism, cross-sectional area.

Address: Mizumotocho 27-1, Muroran, 〒050-8585. Fax: 0143-47-3406. Phone: 0143-44-4181(interior line 2388)

where P: tidal prism, A: cross-sectional area, U, the velocity of tidal flow, a_s: the amplitude for simple harmonic tides in the sea; g: acceleration of gravity, T: tidal period. In Fig.1 the line Ks is drawn semi-empirically from data of USA and Japan. In equilibrium Ks =0.15 if M_t/Q_{max}<30, and Ks =0.22 if M_t/Q_{max}>300. As the velocity is $Ks\sqrt{a_s g}\pi$, Ks can be explained as the relative velocity(or dimensionless velocity). For a tidal inlet, if M_t/Q_{max}>30, while data under the line Ks=0.15, the velocity that corresponding to Ks is smaller than that it in equilibrium, so deposition is stronger than erosion. Whereas, if M_t/Q_{max}<30, but data is over the line Ks=0.15, the velocity is so rapid that the inlet is being eroded. Hence, a dredging to navigational depth does the inlet in danger of erosion, revetment may be necessary at inlet and downdrift. The same explanation can be done if M_t/Q_{max}>300 or M_t/Q_{max}<300.

Using analysis above, data(see Table 1) from 17 inlets of New zealand and 3 inlets of China are plotted in Fig.1. As shown in Fig.1, since Manganwhai, Ohiwa, Raglan, Whananaki of which M_t/Q_{max} is 120, 37, 49,38 respectively, and lie under the line Ks=0.15, the inlets are being choked. Whereas, Tauranga and Katikati of which M_t/Q_{max} is 11,15 respectively, and lie over the line Ks=0.15. That means the current velocity is somewhat greater than it in equilibrium. In order to maintain navigational conditions nowadays, the inlets and their downdrift should be revetted. Due to land reclamation in Jieshi of China, P/A decreased and M_t/Q_{max} relatively increased, so the inlet is unstable. The other inlets which data under the line Ks=0.15 is smaller is stable as little M_t/Q_{max} value.

Table 1. Chracteristics of tidal inlets of Northern New Zealand (From Hick,D.M. and Hume,T.M.,1996)and Southern China

	Mean Spring Tidal Range (m)	Mean Spring Tidal Prism ($10^6 m^3$)	Mean Throat Width (m)	Mean Throat Area (m^2)	Mean Throat Depth (m)	Annual Littoral Drift (m^3)	Daily Mean Runoff (m^3/s)	Maximum Velocity (m/s)
Hokianga	2.77	228	1,090	13,000	11.9	175,000	38	—
Kaipara	2.68	1990	5,600	82,000	14.6	175,000	16	—
Katikati	1.6	95.8	380	4,680	12.3	70,000	9.4	—
Kawhia	2.9	121	600	11,000	18.3	175,000	30	—
Mangawhai	1.8	6.55	216	500	2.31	60,000	1.6	—
Manukau	3.38	918	1,900	46,000	24.2	175,000	28	—
Ngunguru	1.71	3.83	109	310	2.84	5,000	2.8	—
Ohiwa	1.6	28.1	308	1,880	6.10	70,000	6.5	—
Parengarenga	2.13	73.0	500	7,000	14.0	30,000	7	—
Raglan	2.8	46.0	640	3,600	5.63	175,000	18	—
Rangaunu	2.0	134	1,012	6,490	6.41	20,000	6.2	—
Tairua	1.6	5.02	130	430	3.31	5,000	15	—
Tauranga	1.6	131	480	6,260	13.0	70,000	37	—
Whananaki	1.8	1.46	79	130	1.60	5,000	1.6	—
Whangarei	2.1	155	790	14,600	18.5	20,000	12	—
Whangateau	2.2	10.5	174	660	3.79	13,000	1	—
Whitianga	1.6	12.6	240	1,300	5.42	1,000	2.3	—
Yangpu, China	1.82	100	550	5000	—	91,000	—	1
Sanya,China	0.82	1.74	—	430	—	2417	—	1
Jieshi,China	0.8	1.56	—	150	—	—	—	—

3. Conclusion

① Comparing the field data or bathymetry of the natural inlets with this analysis they are in close agreement .

② It is useful to assess the stability of tidal inlets intuitively with relationship between P/Ae and $\sqrt{a_s g}T$ by considering the M_t/Q_{max} value.

References

1) Hideo Kondo(1975): Depth of Maximum Velocity and Minimum Flow Area of Tidal Entrances. Coastal Engineering in Japan, Vol.18, JSCE, pp. 167-183.

2) Hideo Kondo(1990): Flow Area Prediction of Tidal Inlets After Sea Level Rise. Proc. of 22nd ICCE, Vol.4, ASCE,3063-3072.

3) Hicks, D.M, and Hume, T.M.(1996):Morphology and Size of Ebb Tidal Deltas at Natural Inlets on Open-sea and Pocket-bay Coasts, North Island, New Zealand. Journal of Coastal Research, 12(1),47-63. Fort Lauderdale(Florid),ISSN,0749-0208.