Siltation and its Countermeasures for the Development of Modernized Port

Isao Irie*

1. INTRODUCTION

Modernization of a port requires a considerable port facility expansion through grading up the cargo handling efficiency, increasing water depth of channels and basins to accomodate large ships, etc. In many ports in the world, the needs of bigger ship calls in excess of conventional capacity of channels and basins demand for capital dredging as well as maintenance dredging resulting from siltation, and those activities are incurring heavy annual expenditure of the ports. Various complicated phenomena such as behavior of very fine cohesive materials and also in most cases hydraulics in the river mouth are incorporated in the problems of siltation, and thus extensive research works concentrated by theoretical, laboratory and field studies are required to find out the most appropriate counter-measures against siltation.

According to Milliman and Meade(1983), sediments of almost 1738 million tons are discharged to the Yellow Sea mainly from the Hwang-Ho River, and thus modernization of the surrounding port would require overcoming those technical difficulties. In the present paper, factors affecting the siltation expenditure which should be considered in the port planning phase are discussed first in general, and a successful example of siltation countermeasure adopted to Kumamoto Port in Japan is introduced. Furthermore, an experience in Banjarmasin Port on the study of siltation will be shown to see how the phenomena are different from those in Japan.

2. FACTORS AFFECTING THE SILTATION EXPENDITURE

Figure 1 illustrates the relative position of the costs of siltation among total port development costs. The total costs for port facilities C_T may be the sum of the costs C_1 of individual port facilities , the costs C_2 of auxiliary facilities against siltation and the costs C_3 of maintenance dredging. The total benefits resulting from port facility expansion B_T will comprise deducted transportation costs B_1, the saved costs B_2 by increased safety and the benefits B_3 due to regional developments. The national economic feasibility is eventually evaluated by comparing the total costs for port development C_T and total benefits B_T. If B_T is excessively large as compared with C_T, the problems due to siltation would be less even if the costs for siltation countermeasure (C_2+C_3), which share a portion of C_T, go up to some significant value. If B_T is less affluent as compared with the value of C_T, that is, the purpose of preserving the port rests only on the national stability or security

* Department of Civil Engineering, Kyushu University, Hakozaki, Higashi-ku, Fukuoka 812 Japan

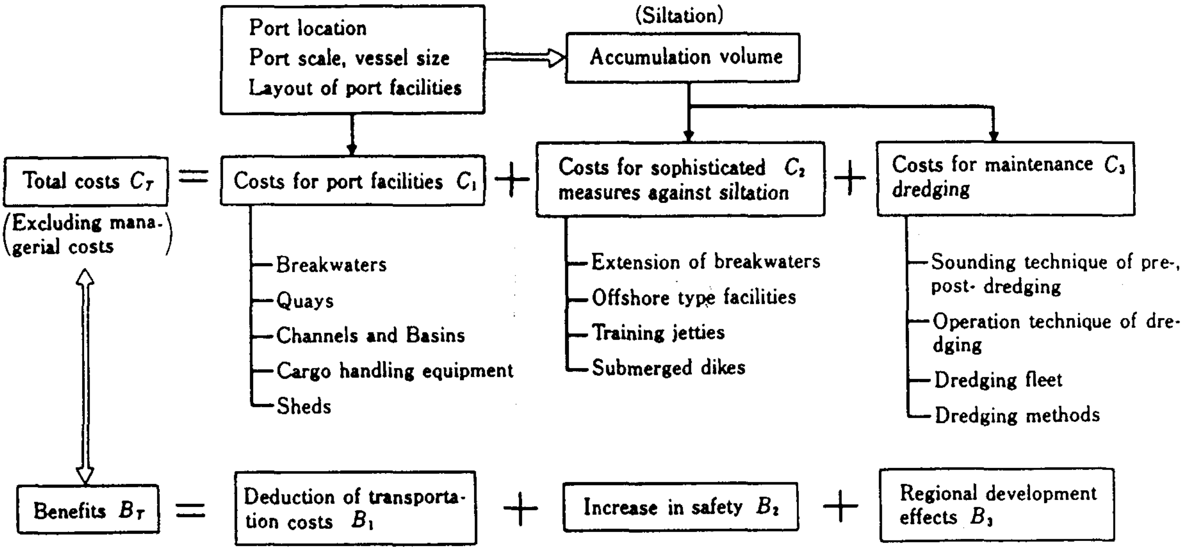

Fig.-1 Relative position of the costs of siltation

for instance, the increase of the costs of countermeasures (C_2+C_3) would result in a serious problem. Most of the ports in developing countries incurred by heavy burden of siltation belong to the latter categories, and it is essentially claimed to decrease siltation volume efficiently by some auxiliary facilities with the cost of C_2 and also to decrease the cost of maintenance dredging C_3 by grading up the efficiency. In Figure 1, port location, port scale and ship size, and layout of port facilities are picked up as the factors significantly affecting the costs C_1 of port facilities. Those factors, however, are also related to siltation problems and affect the costs (C_2+C_3) of siltation countermeasure. The ship size, which is determined from the standpoint of economic shipping technologies, will determine the channel dimensions and this will also affect siltation. As mentioned above, it can be said that siltation problems require the integrated technological approach throughout the stages of planning, design, construction and maintenance of the ports. In most cases, however, port location, port scale and ship size are a given condition, and grading up the dredging efficiency by itself has a limitation. Thus, hydrodynamical approach is expected to be the most powerful measure for decreasing the rate of siltation and also minimizing (C_2+ C_3).

3. THE CASE OF KUMAMOTO PORT

Kumamoto Port is located in the eastern coast of Ariake Bay of Kyushu, and is administered by Kumamoto prefectural government. Being located in the bay, tidal range is 4.5 m, tidal current is more or less 1 knot and wave climate is modest, that is, observed wave height is 1.6 m at highest. As a result of big volume of very fine sediment discharge from two major rivers, the sea bottom is composed of muddy silt

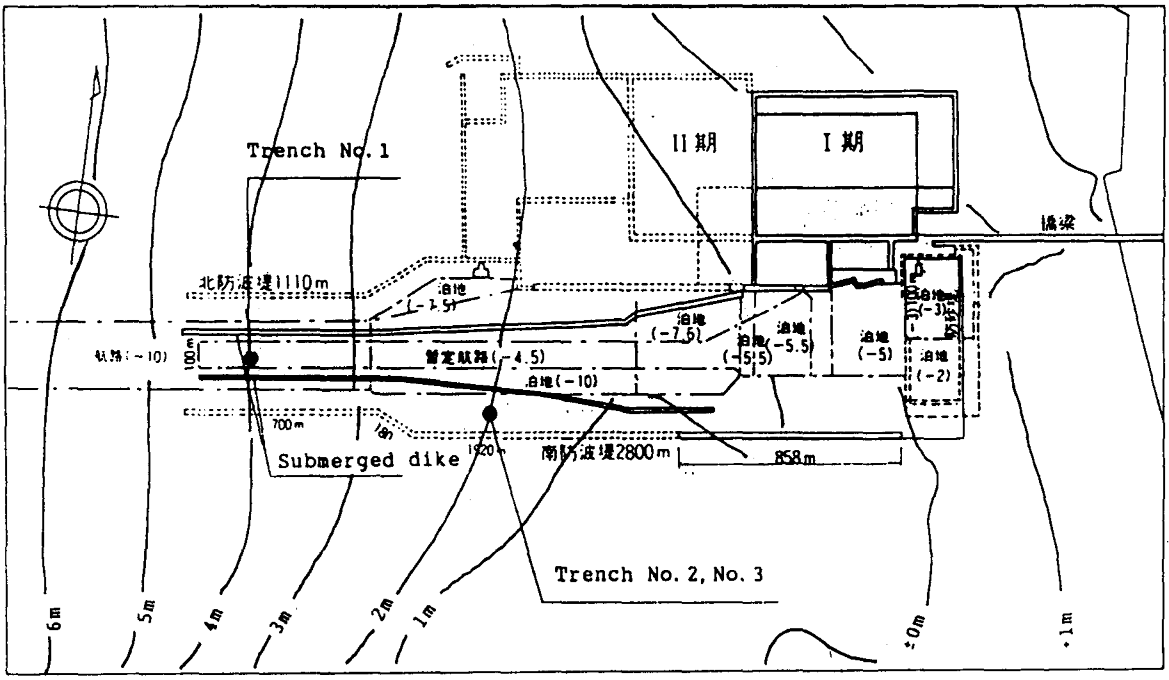

Fig. -2 Layout of facilities of Kumamoto Port

whose sediment size is 15~150μm and moisture content is 50~150% , conforming the soft foundation layer of 40 m in thickness. Thus, the coast has a feature quite similar to the coasts in developing countries and some siltation countermeasure was necessary to maintain channels and basins in 5.5 meters depth(ultimately 10 meters depth for accomodating ocean going ships). After the extensive field study and numerical simulation, a submerged dike was found to be quite effective in reducing siltation rate. The port has been partially put in commerce in April, 1993 and the submerged dike is being adopted as shown in Fig 2.

Before starting construction works of the port, three tenches were excavated at the location shown in Fig 2. Trench No. 1 is located at 4 m water depth, and trenches No. 2 and No. 3 are located at 2 m water depth. More detailed conditions of the trenches at the depth of 2 m are shown in Fig. 3. Two equal size trenches were excavated at the distance within which a common hydrodynamic condition is expected. The size of the trenches was 30 x 50 m at the bottom and the depth was 2 m below the sea bed. As shown in the figure, one of the trenches was surrounded by a submerged dike whose height is 1 m above the sea bottom. Observation of topographic change was carried out at a certain intervals to see how it differs depending on whether or not a submerged dike exists. In Fig. 3, topographic changes after 90 days are shown and it is seen that accumulation of almost 40~60 cm in thickness took place inside the trench without a submerged dike. In the trench enclosed by the submerged dike, however, accumulation was more or less 10 cm. According to the result of observation after one year, total shoaling rate in the trench with the submerged dike was only 0~15 cm in thickness whereas

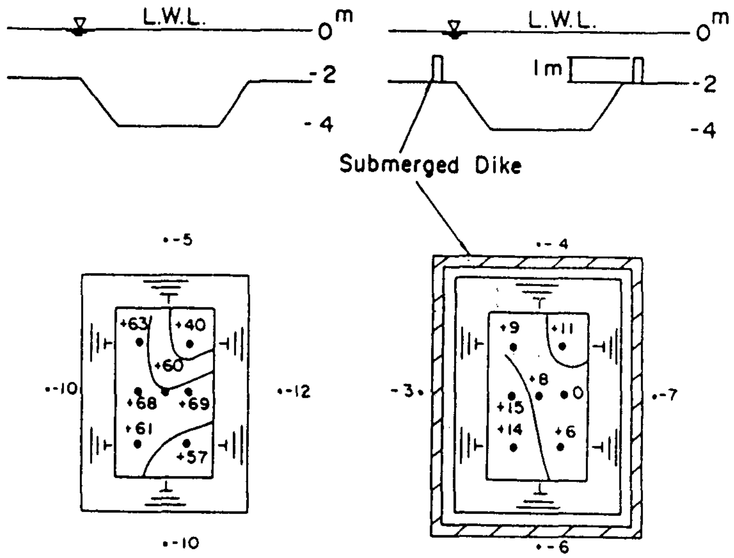

Fig. -3 Two trenches at the depth of 2m

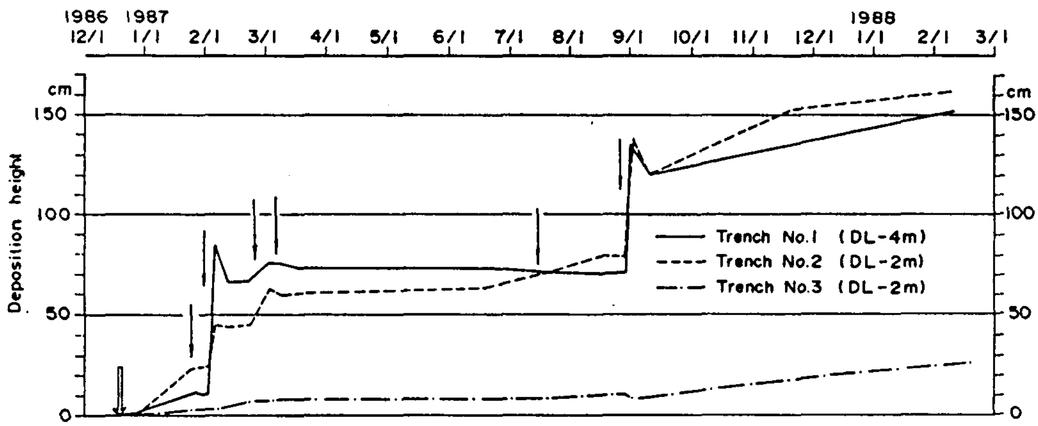

Fig. -4 Deposition at the center of three trenches

the trench without a submerged dike was completely shoaled. The reason of such effectiveness of a submerged dike in reducing accumulation in a trench was studied through hydraulic model experiments and computor simulation.

Figure 4 shows the time variation of the deposition height at the center of three trenches, No. 1, No. 2 and No. 3 measured by using fixed poles set inside the trenches. The left most arrow shows the starting time of observation. It is seen that a severe and sudden deposition occured in trenches No. 1 and No. 2 on February 3rd, and on August 31st respectively whereas very limitted deposition took place in trench No. 3 which is surrounded by a submerged dike. According to the wave observation, the sea was rough on the above two occasions when severe and sudden deposition took place. This shows that the major cause of siltation is due to waves and the effect of tidal current alone is much less and also submerged dike is working effectively as explained before. As seen in Fig. 2, the submerged dikes with height of 1 m above the sea bottom were adopted as the siltation countermeasure by installing on the both side of approach channel. Although the construction of breakwater is ultimately planned as shown in dotted lines in the figure, adoption of submerged dikes enabled early openning of the port, which is very important from the standpoint of cost efficiency.

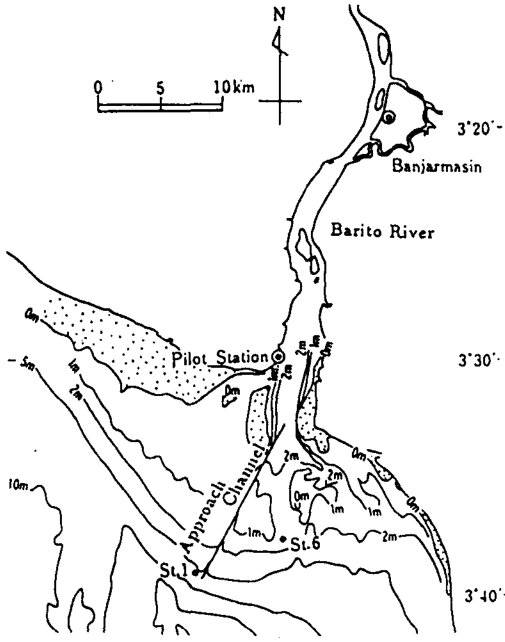

Fig. -5 Banjarmasin Port

4. THE CASE OF BANJARMASIN PORT

Banjarmasin Port is located 26 km upstream of the Barito River in South Kalimantan of the Republic of Indonesia. As shown in Fig. 5, the approach channel which is 14 km in length and 60 m in width passes through a very shallow flat bar and thus maintenance of target water depth (- 6 m) was very hard even with the annual dredging of 2~3 million m^3. In order to find out the most appropriate countermeasure against siltation, its mechanism on the large tidal flat was investigated based on the field data. A numerical simulation is used to reproduce deposition process of the approach channel and to evaluate various alternatives of countermeasures againat siltation. Reproduction of the rate of siltation was quite satisfactory, some essential points of which will be introduced in the conference.

5. CONCLUSION

The increase of ship size is the general tendency in the shipping world and unless the port expansion keeps abreast of the ship size development overcoming such a problem as siltation, the port and its hinterland will be left behind the world economic development. Although mechanism of siltation is not sufficiently cleared, recent experience in Japan seems to pave a way to a solution of siltation problems.

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