BEACH EROSION TRIGGERED BY RIVER MOUTH DREDGING AS A MEASURE AGAINST RIVER MOUTH CLOSURE

A. Kobayashi [1], T. Uda [2], M. Endo [1] and Y. Noshi [1]

ABSTRACT: On a pocket beach, the impact of the formation of the wave-shelter zone and the maintenance dredging of a river mouth reaches the entire pocket beach, and overall beach changes are triggered, devastating the natural environment. These topographic changes owing to anthropogenic factors took place at many coasts in Japan with the development of the coastal zone. We investigated this issue, taking the Haraoka and Tatara coasts in Chiba Prefecture as examples. Although several measures have been taken such as the sand back pass to mitigate the erosion, problems have not yet been solved. We discuss the reality and propose several measures to solve these problems.

Keywords: River mouth bar, shoreline changes, longshore sand transport, erosion

INTRODUCTION

Port breakwaters have been constructed at many places in Japan, inducing longshore sand transport from the outside to the inside of the wave-shelter zone, and resulting in severe erosion and accretion outside and inside the wave-shelter zone, respectively (Uda, 2010). In particular, erosion contrasts well to the accretion on a pocket beach because it has a closed system of sand transport, when a breakwater is extended. Also, around the mouth of a small river flowing into a pocket beach, the river mouth closure often occurs owing to the sand deposition by waves, enhancing the necessity of the dredging at the mouth. On a pocket beach, the impact of the formation of the wave-shelter zone and the maintenance dredging of a river mouth reaches the entire pocket beach, and overall beach changes are triggered, devastating the natural environment. These topographic changes owing to anthropogenic factors occurred at many places in Japan with the development of the coastal zone. We investigated this issue, taking the Haraoka and Tatara coasts in Chiba Prefecture as examples. Although several measures have been taken such as the sand back pass to mitigate the erosion, problems have not yet been solved. We discuss the reality of the example and propose measures to solve these problems.

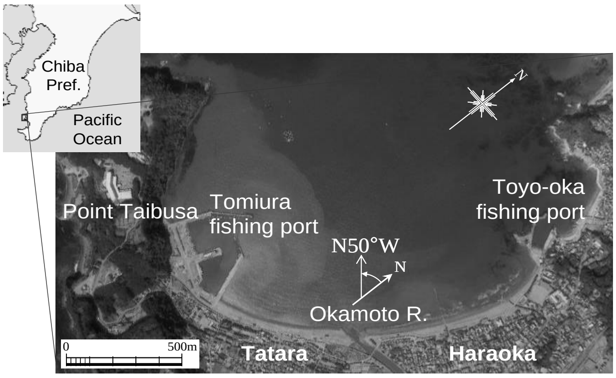

Fig. 1 Location of Haraoka and Tatara coasts in Chiba Prefecture, Japan.

GENERAL CONDITIONS OF STUDY AREA

The study area is a pocket beach of 1.5 km length bounded by Toyo-oka and Tomiura fishing ports at the north and south ends, respectively, as shown in Fig. 1, and is located in the southern part of the Boso Peninsula in Chiba Prefecture. At the central part of the pocket beach, the Okamoto River flows into the pocket beach, and the northern and southern halves of the pocket beach are called the Haraoka and Tatara coasts, respectively. Since these coasts face the Uraga Strait, calm waves are normally incident in contrast to the beaches exposed to the Pacific Ocean in the Boso Peninsula.

[1] Department of Oceanic Architecture & Engineering, College of Science & Technology, Nihon University, 7-24-1, Narashinodai Funabashi City, Chiba 274-8501, JAPAN
[2] Public Works Research Center, 1-6-4 Taito, Taito, Tokyo 110-0016, JAPAN

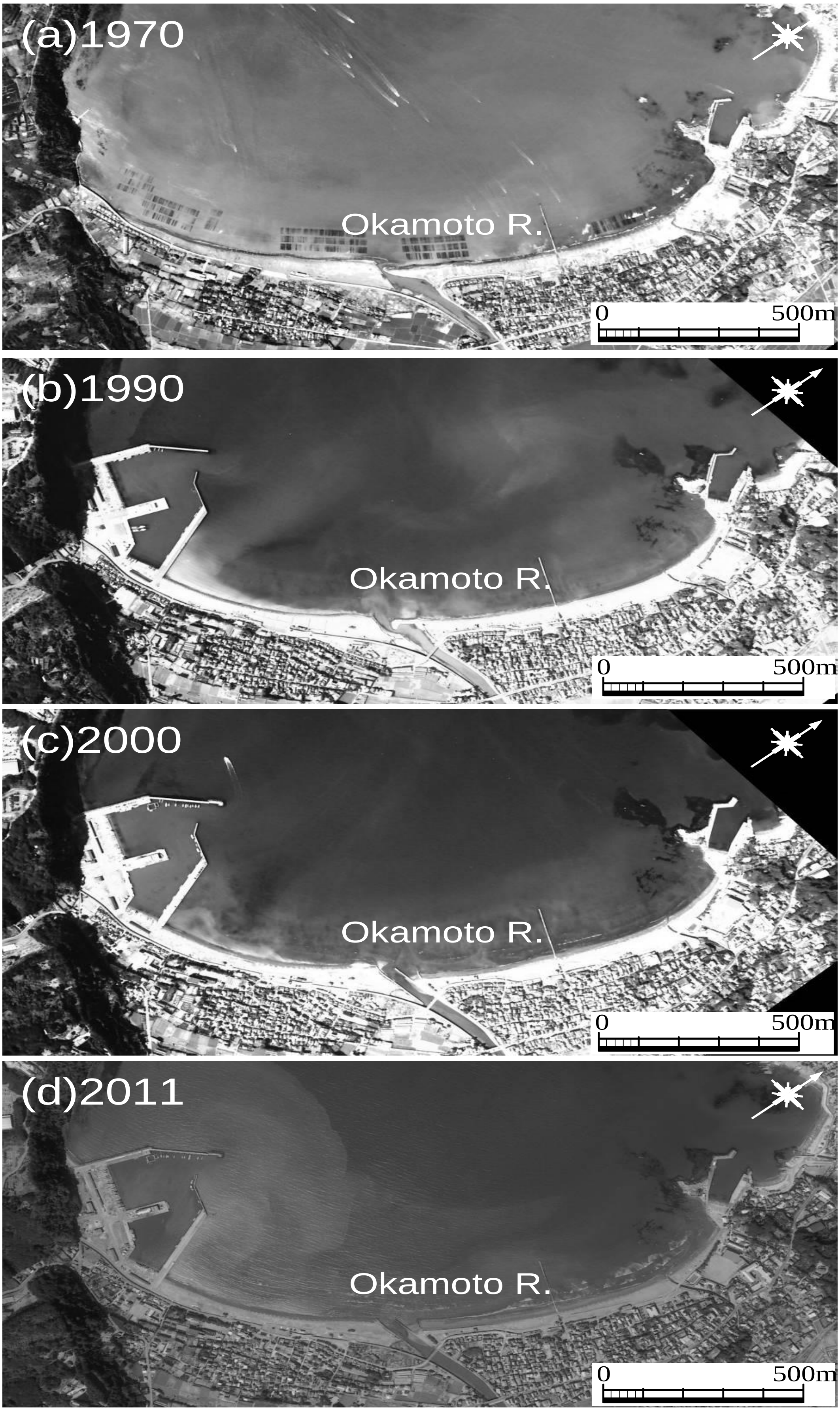

Fig. 2 Shoreline changes on Haraoka and Tatara coasts between 1970 and 2011.

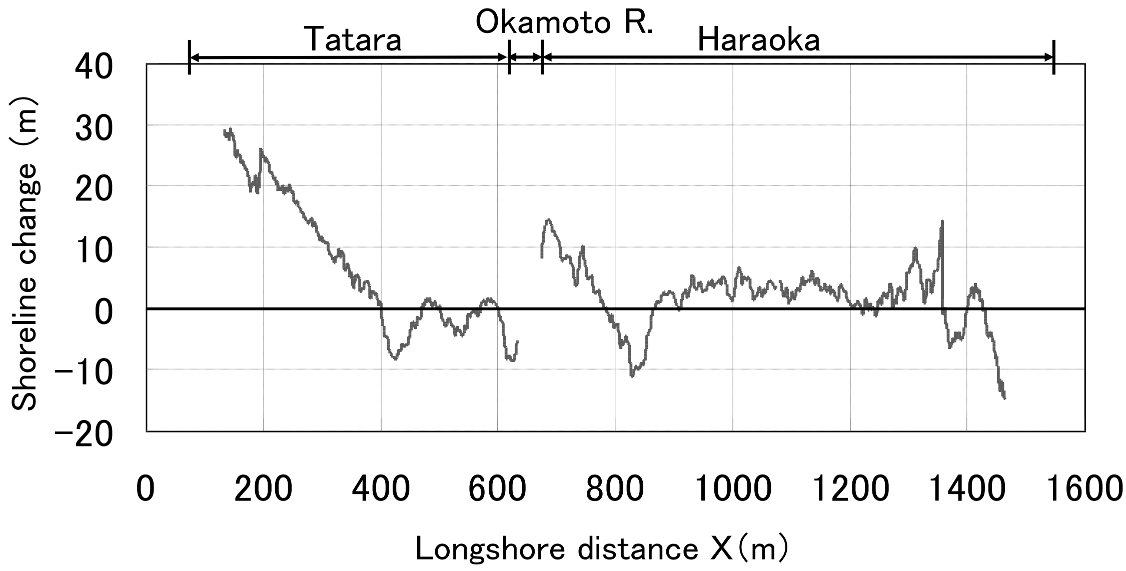

Fig. 3 Shoreline changes on Haraoka and Tatara coasts between 1970 and 2011.

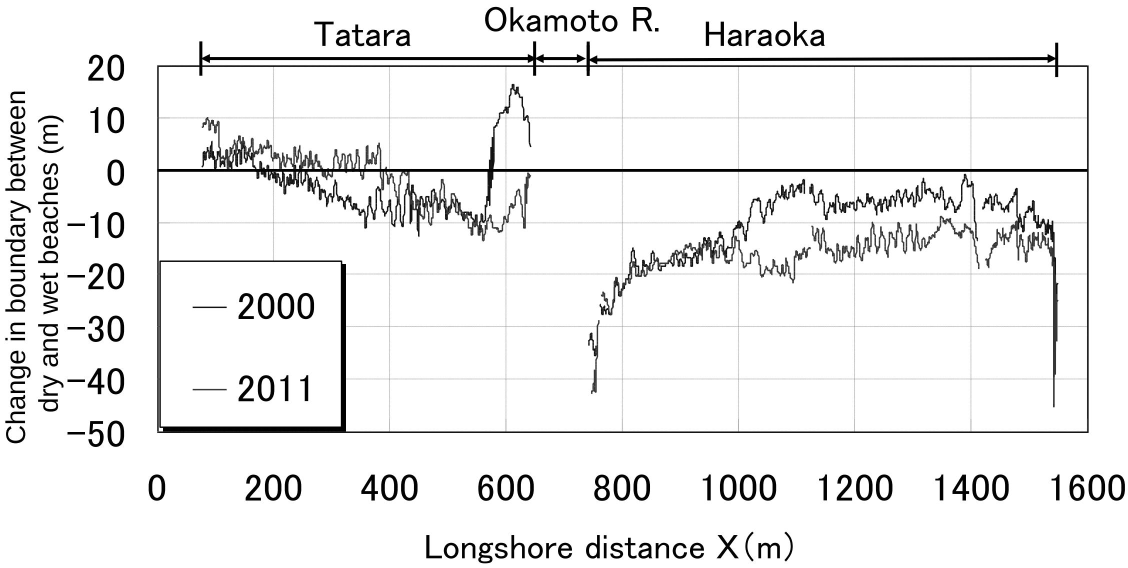

Fig. 4 Change in boundary line between dry and wet beaches.

Direction normal to the shoreline at the center of the pocket beach is N50°W, as shown in Fig. 1. This direction is assumed to be equal to the predominant wave direction to the pocket beach, because the shoreline of this pocket beach has long been stable. Under this wave incidence condition, the wave-sheltering effect of the Taibusa Point at the south end of the pocket beach may reach the entire pocket beach, and therefore, a stable pocket beach was considered to have been formed.

Uda et al. (1997) pointed out that a small river meanders near the river mouth and it tends to open inside the wave-shelter zone formed behind an island or an artificial offshore structure, where the berm height is lower than that in the surrounding area, and the river currents easily flow out into the sea. Taking these features into account, the Okamoto River is assumed to be meandered south while being affected by the wave-shelter zone produced by the Taibusa Point with the southward elongation of the river mouth bar.

AERIAL PHOTOGRAPHS AND SHORELINE CHANGES

Four aerial photographs taken between 1970 and 2011 were compared to investigate the long-term shoreline changes in the study area (Fig. 2). In 1970, a

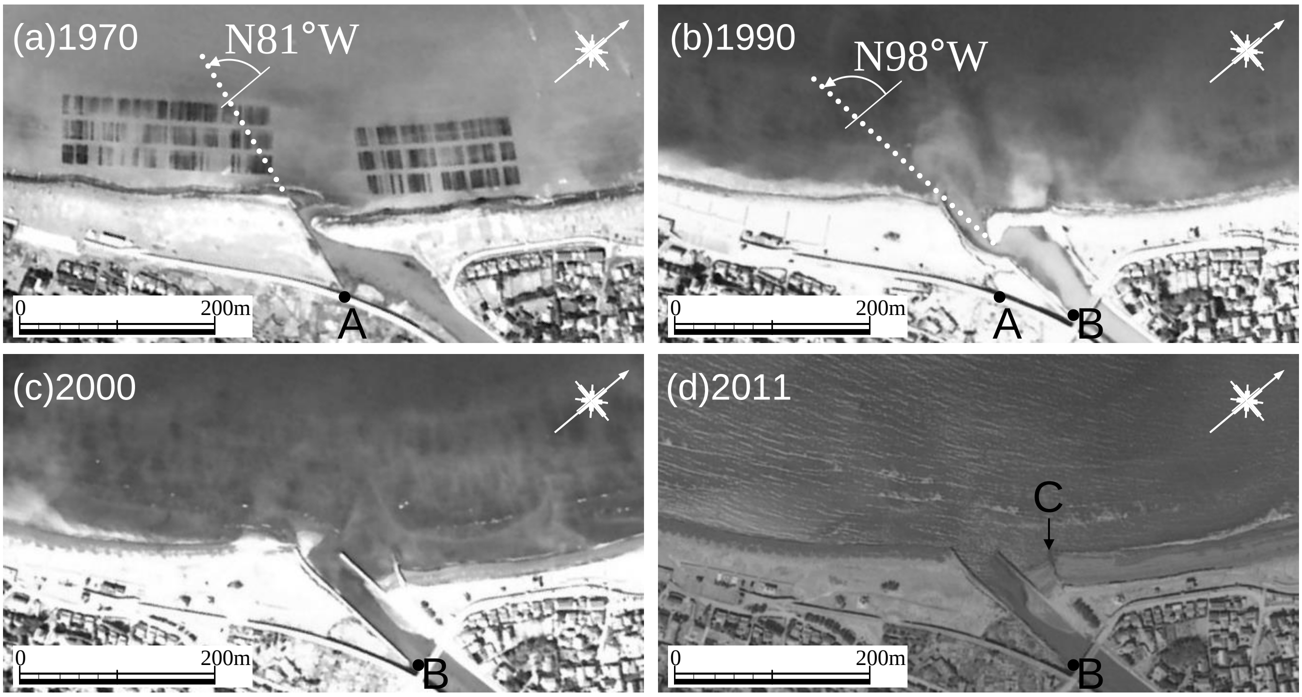

Fig. 5 Change in Okamoto River mouth between 1970 and 2011.

natural sandy beach extended with no structures of the Tomiura fishing port, and the river mouth bar of 108 m length extended southward at the Okamoto River mouth. By 1990, the Tomiura fishing port breakwater was constructed, and a 387-m-long sandy beach was buried under the breakwater out of the 1527-m-long shoreline of the pocket beach, resulting in the narrowing of the opening width of the pocket beach up to 1140 m. After the construction of the fishing port, the wave-shelter zone expanded northward. Despite these changes, the sand bar at the Okamoto River mouth still extended southward. By 2000 and 2011, no changes had occurred on the beach except for the Okamoto River mouth.

Figure 3 shows the shoreline changes in the study area between 1970 and 1990 determined from the aerial photographs. The construction of the Tomiura fishing port breakwater started in 1974 and was completed by 1986. After the extension of the breakwater, the shoreline advanced at a maximum of 30 m at the corner between the breakwater and the sandy beach owing to the effect of the formation of the wave-shelter zone. In addition, the shoreline advanced on the immediate right side of the Okamoto River.

Although beach changes associated with the construction of the Tomiura fishing port breakwater approached a stable condition in recent years, beach erosion occurred in the nearby area of the river mouth associated with the extension of the river mouth jetty and the excavation of sand deposited at the river mouth since 1990. To investigate the beach changes, the location of the boundary line between the dry and wet beaches was read from the aerial photographs, and the change in the boundary line until 2000 and 2011 with reference to that in 1990 was calculated, as shown in Fig. 4.

On the south side of the Okamoto River, a river mouth bar protruded near the river mouth in 2000, and except for this sand bar, the beach near the river mouth was erosive, whereas the beach was slightly accretive at a location very close to the Tomiura fishing port. Until 2011, a protruding sand bar on the south side of the river mouth was eroded. In contrast, on the right side of the river mouth, maximum shoreline recession occurred on the right bank, which gradually decreased eastward in 2000, but the severely eroded area expanded up to the north end of the Haraoka coast until 2011. It is clearly realized that although the Tatara coast south of the river has become almost stable since 1990, the Haraoka coast north of the river mouth has been eroded.

CHANGES IN OKAMOTO RIVER MOUTH

Figure 5 shows the changes in the Okamoto River mouth. In 1970, the left bank jetty of 100 m length was extended from point *A* on the left bank of the river to the direction of N81°W while obliquely intersecting the river. A slender river mouth bar of 108 m length extended from the right bank toward the left jetty, closing the river mouth. Therefore, the channel was located along the left jetty. In 1990, Okamoto Bridge was constructed near the mouth at point *B*, and the revetment of the left bank of 86 m length was obliquely extended from point *B* to the direction of N98°W, which makes an angle of 17° counterclockwise with respect to the direction in 1970.

By 2000, the left bank revetment had been extended by 169 m along with the construction of the right bank revetment of 130 m length in parallel to the left bank revetment. Because the direction of the jetty makes an angle of 48° counterclockwise with the direction normal to the mean shoreline near the river mouth, a wave-shelter zone was formed behind the right bank revetment, inducing marked sand deposition there. The precise investigation of the river mouth bar reveals that the river mouth bar in the lee of the right bank revetment smoothly connected to the shoreline of the sandy beach north of the jetty, implying that the structure of the jetty was insufficient in blocking the longshore sand transport into the river mouth from the Haraoka coast. The same situation continued in 2011, and a large river mouth bar was formed in the lee of the right bank revetment. Thus, sand was considered to be easily deposited at the Okamoto River mouth, and the river mouth dredging had to be recurrently carried out, and the dredged material was transported to the northern Haraoka coast.

Fig. 6 Subsided concrete blocks and erosion along left bank of Okamoto River (October 13, 2011).

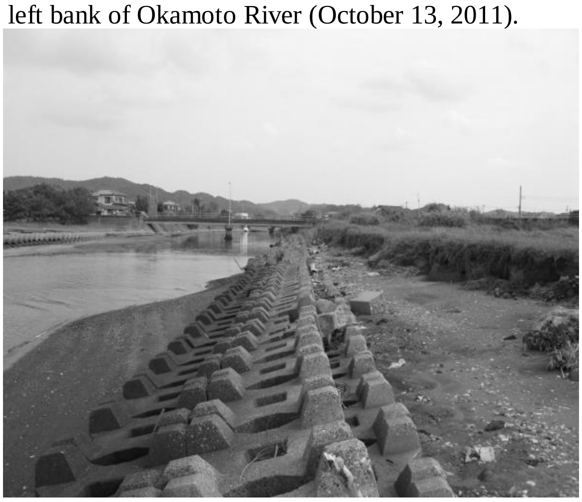
Fig. 7 Concrete blocks inclined toward the channel (October 13, 2011).


Fig. 8 Concrete blocks on right bank of Okamoto River and sand deposition in front of the concrete blocks (June 11, 2011).


Fig. 9 Enlarged river mouth bar (October 13, 2011).

SITE OBSERVATION

Left River Bank

Site observation was carried out on June 11 and October 13, 2011 to investigate the beach erosion of the study area. On September 21, 2011 before the second site observation, storm waves associated with Typhoon 15 hit the study area, and the impact of the storm waves was observed on the beach. Figure 6 shows a photograph of the channel of the Okamoto River taken from the top of the revetment along the left bank, looking upstream. The revetment was permeable and its crown height was so low that the land behind the revetment had been eroded. Figure 7 shows the enlarged photograph of the same site where scarp was formed on the left bank. The concrete blocks significantly subsided and inclined toward the river bed, implying that river bed excavation might have been carried out.

Right River Bank

On the right bank of the river, only a small amount of sand was deposited while forming a sand bar along the inner side of the meandered channel on June 11, 2011, as shown in Fig. 8, but on October 13, the sand bar markedly developed in scale, as shown in Fig. 9. The concrete blocks buried under the ground surface were exposed and the vegetation next to the revetment was eroded, implying that the wave overtopping over the revetment with a low crown height occurred and a large amount of sand was transported from the right bank to the channel. The remains of debris on top of the revetment were further evidence of the wave overtopping over the revetment, and this means that sand could be transported directly into the river mouth while crossing the right revetment.

Fig. 11 Severe erosion with formation of scarp immediately north of the river mouth.

Fig. 12 A mound produced by beach nourishment at northern end of Haraoka coast.

Fig. 13 Cross section of mound.

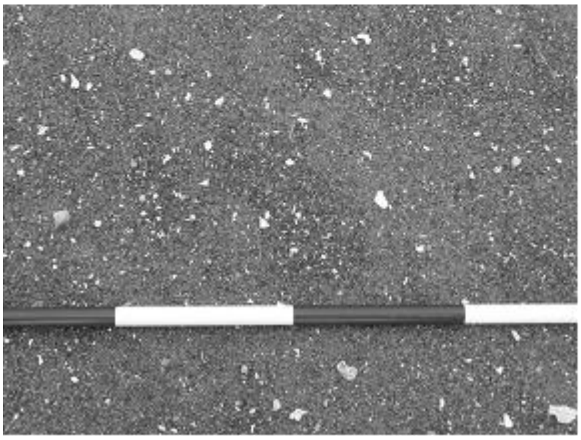

Fig. 14 Shell debris scattered on surface of mound.

Fig. 15 Impermeable jetty constructed.

Fig. 16 Recovery of sandy beach north of the jetty.

Erosion Immediately North Of The River Mouth

Figure 10 shows the tip of the right bank jetty. Although a river mouth bar was formed along the jetty built of concrete blocks, the location of the seaward shoreline of the sand bar coincided with that of the shoreline on the left side of the jetty with no difference in shoreline position on both sides of the jetty, as shown by the dotted line in Fig. 10. Furthermore, the location of the sand bar is away from the tip of the jetty. These points imply that this bar inside the river mouth was not formed by the deposition of sand transported after turning around the tip of the jetty, but formed by the deposition of sand directly transported over the jetty or through the voids of the permeable jetty.

Immediately north of the river mouth, a number of sand bags were continuously placed along the shoreline, as shown in Fig. 11, with scarp formation behind these sand bags. Because the shoreline has retreated by 20 m since 1990 in this area, as shown in Fig. 4, it is reasonable for sand bags to be installed in this area as a measure against beach erosion. On the other hand, a large amount of sand was deposited inside the river mouth next to this area, as shown in Fig. 9. Thus, two opposite features of erosion and sand deposition suggest that both are closely related to each other and erosion immediately north of the river mouth was caused by sand movement from the nearby coast to inside the river mouth.

Fig. 15 Impermeable jetty constructed.

Fig. 16 Recovery of sandy beach north of the jetty.

Sand Mound Formed by Beach Nourishment

Figure 12 shows the beach condition on the northern Haraoka coast taken on October 13, 2011. The backshore is plane, and the lamination, which is usually formed by the sand deposition by waves or wind, was not observed in the cross section of the area, as shown in Fig. 13, implying that this sand mound was artificially produced. The volume of sand of the mound was estimated to be approximately 1500 m^3. Moreover, on the surface of this mound, shell debris was found, as shown in Fig. 14. This strongly suggests that the sand composed of this mound is the beach material once deposited in the nearshore zone.

The local authority responsible for the river management has recently carried out river mouth dredging in the Okamoto River and the dredged material had been transported to the northern Haraoka coast. Thus, the mound shown in Figs. 12 and 13 is assumed to be produced by the dredged materials. The location of the mound on the backshore was far from the shoreline, as shown in Fig. 12, where not only normal waves but also storm waves were difficult to reach the seaward toe of the mound. Every time when the dredging was carried out, a significant volume of beach sand could decrease from the sandy beach, causing beach erosion.

CONCLUSION

In the study area, a wave-shelter zone was formed associated with the construction of the Tomiura fishing port breakwater, resulting in the shoreline advance of maximum 30 m at a location next to the breakwater between 1970 and 1990 on the Tatara coast, but thereafter, the effect of the extension of the breakwater almost ceased. On the other hand, on the right bank of the Okamoto River, a revetment (jetty) was extended in the direction that makes an angle of 48° counterclockwise with respect to the direction normal to the mean shoreline, resulting in the formation of the large wave-shelter zone behind the jetty, which in turn caused sand deposition behind the wave-shelter zone inside the river mouth. Furthermore, because the right river bank jetty had a low crown height and was permeable, beach sand on the Haraoka coast was easily transported into the river mouth.

In the past, the dredging of sand deposited at the river mouth had been recurrently carried out to protect the river mouth against sand deposition, and the excavated sand was transported to the northern Haraoka coast, as a process of sand back pass (recycling of sand). This method was reasonable in principle, but such sand was placed on the backshore with no exposure to waves under the normal wave conditions. Therefore, the loss of sand available for sand movement of the beach occurred every time sand was transported northward. Sand became difficult to be transported along the shoreline to the south by the wave action, and beach erosion with the scarp formation was not mitigated by the successive sand supply from the north part where sand nourishment was carried out. Thus, the present measures against sand deposition at the river mouth and the simultaneous erosion immediately north of the river mouth are considered to be inadequate. The crown height should be raised to prevent the wave overtopping over the crown of the jetty, in particular, near the shoreline, and the structure of the jetty should be impermeable so as not to permit the sand transport across the jetty. In addition, the sand bags placed along the shoreline were ineffective even as a temporal measure against beach erosion and excess accumulation at the river mouth. More reasonable measures such as sand back pass to the shoreline of the northern Haraoka coast along with raising the crown height of the right bank jetty should be taken. As a result of our study, an impermeable jetty had actually been extended by November 2012, as shown in Fig. 15. Soon after the extension, a sandy beach rapidly extended, as shown in Fig. 16, and beach erosion was mitigated without the river mouth closure of the Okamoto River.

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