EFFECT OF THE COASTAL CONSERVATION DUE TO BEACH NOURISHMENT OF TOTORI SAND DUNE COAST

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ABSTRACT: Tottori Sand Dune Coast located at western part of Japan is a sandy beach with a length about 8km facing Sea of Japan. The coast has been eroded starting around 1940s and the beach nourishment project has been carried out to restore the shoreline since 2005 at Tottori Sand Dune Coast. In the project, the deposition sands at port and river mouth were transported to the erosional area and injected in the region of the offshore erosional area and the backshore area and the total volumes of the sand are about 400,000m$^3$ from 2005 to 2011. However the effects of the project are not clarified and the detailed examination is not performed. The purpose of this study is to investigate the movement of the injected sand and the effect of the beach nourishment. In this study, using the bottom sounding data from 2002 to 2011, the sand volumes were estimated and the shoreline changes were investigated. Also, at the Tottori Port adjacent to the Coast, the amount of the sediment is estimated as well as Tottori Sand Dune Coast. From these analyses, the beach nourishment are effective and the large amount of the sediment placed at land area restored the shoreline quickly.

Keywords: Beach nourishment, beach erosion, Tottori sand dune, seasonal change

INTRODUCTION

Over the past few decades, beach erosions have become severe at sandy beaches in the world. As the coastal defense work to the beach erosion, various types of structures such as offshore breakwater and jetty have been constructed. However they caused the uneven distribution of sedimentation. Recently the beach nourishment method has been brought to public attention.

At Tottori Sand Dune Coast in Tottori Prefecture located at western part of Japan, the coastal erosion has been serious problems too. The coastal erosions have become more serious since the coastal structures were built around the sandy beach. On the other hand, the port and river mouth have been accumulated the sediment.

In order to solve these problems, the beach nourishment project at Tottori Sand Dune Coast which is the accumulation sand were dredged and the sand were injected in the erosional area has been carried out against erosions since 2005. The project is called ‘Sand recycle Project’.

In spite of the huge volume of the nourished sand, sand dredged from harbor channels and river mouths have been placed in locations that do not optimized beneficial reuse of the materials. The purpose of this study is to investigate the movement of the injected sand and the effect of the beach nourishment.

Fig. 1 Outline of the Tottori Sand Dune Coast

FIELD AND METHOD

Field and Sand Recycle Project

Tottori Sand Dune Coast is a sandy beach with a length about 8km, facing Sea of Japan. At western part of the coast, Tottori Port and Sendai River are located. At the midpoint of the coast sits Tottori Sand Dune, which is the largest coastal sand dune in Japan. Tottori Sand Dune Coast tends to repeat seasonal variation in

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shoreline which is eroded from autumn to winter and is restored between spring and summer by the action of the season waves. The significant wave height and period between 2004 and 2011 are shown in Fig. 2. The waves in winter are higher, whereas summer is quiet. With the large wave energy in winter, the sand moves to east more therefore the direction of the sediment transport should be to east. On the other hand, in summer, the sand does not move much. Therefore the Sand Recycle Project has been carried out during spring and summer. In this project, the deposition sands at the port and river mouth were transported to the erosional area and injected in the region of the offshore erosional area and the backshore area. The total volume of the sand to beach nourishment from 2005 to 2011 is 400,000m³. The outline of the Sand recycle project is shown in Fig. 3. Also, limited to the years 2010 and 2011, the large amount of sand (about 100,000m³) was placed in the area around 4k500m point (in Fig.3).

At the Sand recycle project, the sand has been dredged several tens of thousands cubic meters from Tottori port and several thousands cubic meters from Iwado Fishing Port and Shiomi river mouth once a year.

The dredged sand was transferred to the erosion area of Tottori Sand Dune and the sand injection was done at of the offshore and the backshore areas.

Methodology

In this study, the sand volume of the Tottori Sand Dune Coast and Tottori Port were calculated using the bottom sounding data, measured twice a year, and the shoreline changes were investigated. The bottom sounding data from 2002 to 2011 at Tottori Sand Dune and Tottori Port were interpolated with 10m grid, and the sand volume was estimated respectively. Also, plus or minus 0.25m less were excluded considering survey error, the grid data was created in the range of water depth from 0m to 11m. The sand volumes are calculated by Equation (1) using the water depth in each grid.

\[
V = \frac{1}{4} (h_1 + h_2 + h_4 + h_5) \times A + \frac{1}{4} (h_2 + h_3 + h_5 + h_6) \times A + \frac{1}{4} (h_4 + h_5 + h_7 + h_8) \times A + \frac{1}{4} (h_5 + h_6 + h_8 + h_9) \times A
\]

where, \( V \) is sand volume, \( h_1, h_2, ..., h_9 \) are water depth and \( A \) is grid area.

Fig. 2 The seasonal changes of the significant wave height and period at Tottori Sand Dune Coast

Fig. 3 Outline of the Sand recycle project

Fig. 4 The grid for the calculation of the amount of sand volume
EFFECT OF THE BEACH NOURISHMENT

The changes of the sand volume

The changes of the sand volume at Tottori Sand Dune Coast are shown in Fig. 5 up to March 2011 based on September 2002. From this figure, before the project, the sand volume had been decreasing gradually, however after the beach nourishment project, the sediment transport changed into very active and total volume of the sand are in increasing while increasing or decreasing with seasonal wave. In addition, it was found that the extreme waves that significant wave height over 4m were attacked frequently and the sand volume was declined rapidly. And then the sand volume was gradually recovering with the time.

![Graph showing changes in sand volume](image)

Fig. 5 The change of sand volume at Tottori Sand Dune Coast

The sand volumes in each section are shown in Fig. 6. The section is divided into 500-1000m, 1000-2000m, 2000-3000m, 3000m-5000m, 5000-6000m, 6000-7000m and 7000-7300m in the alongshore direction. The 3000-5000m area is including the injection point of the sand, the changes of the sand volume are dynamic and the incline of the graph is an upward sloping slightly. Also, in other area, since the start of the beach nourishment, the sand volumes are increased. With the result, the beach nourishment is effective.

![Graph showing sand volume in each section](image)

Fig. 6 The sand volume in each section at Tottori Sand Dune Coast

The state of the erosion and the deposition

Using the bottom sounding data interpolated with 10m grid, state of the erosion and deposition is investigated in each term. The changes of the erosion and deposition from 2003 to 2004 are shown in Fig.7. From upper figure (Fig.7(a)), in the term of winter waves acted between autumn and winter, erosion is widespread in the western region. Presumably the sand was moved from west to east. The movement is agreement with the characteristic of seasonal wave. In contrast, the western part of the area was eroded between spring and summer and the eastern was accumulated. These changes are confirmed in other years when the unusual wave does not act.
Fig. 7 The state of erosion and deposition (2003-2004)

Fig. 8 The state of erosion and deposition (2007-2011)
The changes of characteristics are shown in Fig. 8. In Fig.7(a), the bar was eroded and the sand accumulated in offshore, on the other hand, in next term the opposite that the offshore sand was eroded and bar was restored was happen (Fig.7(b)). In both periods, the large waves were acted than normal. It was found that the bar was repeated to erosion and deposition by high waves. From state of the erosion and deposition, it was not confirmed the accumulation by the beach nourishment. However when the large amount of the sand were injected, the accumulation was found around the injection point of the portion surrounded in Fig.7(c). The deposition is seems to be effect of the beach nourishment.

The shoreline changes around injection point of the beach nourishment

From the result of the change of the sand volume, it was found that the total volume of the sand tended to be increasing. How the shoreline near the injection area of the sand still had been eroded. The time variation of the shoreline changes shows in Fig.9. In spite of start of the beach nourishment, the shoreline shows the trend to erosion until 2009. After the large beach nourishment at the land area, the shorelines were restored.

The sand volume of Tottori Port

At the Tottori Port, the dredging is carried out to the maritime routes every year. The sediments that are dredged are injected to beach nourishment. Therefore the sand volume of the Tottori port was investigated. The bottom sounding data in 2008, 2009 and 2010 were used to calculate the sediment. The sand volumes were calculated separating to 6 areas because of the topography of the port is complicated. The outline of the Tottori Port and the separating area are show in Fig.10.

There is Sendai river mouth in Region 1. And dredging area is located in the Region2. The variations of the sediments are extreme in the both area. In this paper, it is considered only Region 2 where dredging point. The volumes of dredged sand are listed at Table 1 and the variations of the sand in the Region 2 are listed at Table 2 at Tottori Port. From Table 1, the volume of dredged sand is about 20,000m³ in every year. Also, focusing on 2009, while the dredging volume is 31,000m³, the erosion volume in the Region 2 is 6,700m³. These results mean that the dredged sand had been backfilled by the action of high waves, and the dredging of the volume with 20,000m³ is needed to keep the maritime route.

Table 1 The volume of dredged sand at Tottori Port

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>16,000m³</td>
</tr>
<tr>
<td>2009</td>
<td>31,000m³</td>
</tr>
<tr>
<td>2010</td>
<td>27,314m³</td>
</tr>
<tr>
<td>2011</td>
<td>46,665m³</td>
</tr>
</tbody>
</table>

Table 2 The variation of the sand in the Region 2 at Tottori Port

<table>
<thead>
<tr>
<th>Term</th>
<th>Region 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008.9-2009.9</td>
<td>-27,700 m³</td>
</tr>
<tr>
<td>2009.9-2010.9</td>
<td>-6,700 m³</td>
</tr>
<tr>
<td>total</td>
<td>-34,400 m³</td>
</tr>
</tbody>
</table>
CONCLUSIONS

In this study, using the bottom sounding data from 2002 to 2011 at Tottori Sand Dune Coast and Tottori Port, the movement of sand and the effect of the beach nourishment are investigated.

The total sand volumes are increasing after beach nourishment. At injection point, the movement of the sand is complicated.

The sand moved west to the east during winter, and in summer the movement is opposite. Also, when the large waves acted, the bar in the offshore area was repeated to erosion and deposition.

By the amount of large beach nourishment at the land area in 2009-2010, the shorelines show trend to erosion after beach nourishment were restored.

From these results, it is confirmed that the beach nourishments are effective. However the injected sediments at Tottori Sand Dune Coast are return to the Tottori Port. It is necessary to reexamine to keep the sediment of the beach nourishment about the location of the sediment injection and the grain size of the sediment. More permanent measures are desired.

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REFERENCES


Tottori Prefecture (2005). The guidelines for comprehensive sediment management. (Japanese)