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## **Scour of Railway Embankment Foundation Located on Sea-Cliff in Japan**

By

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### **ABSTRACT**

This article depicts a scour damage case of a railway embankment located on sea-cliff and discusses the estimated causes and mechanism of the damage process. The wave protection work with 21.7 m width and 6.5 m height of the railway embankment, which was located on the cliff front of the Sea of Japan between the stations Murakami and Mazima of Uetsu Line, fell down, and the embankment collapsed in December 2000. The main cause of the collapse is presumed to be scour of the wave protection work foundation. The scour seems to be reduced by the high waves attack on the occasion of the seashore retreating at the collapse site judging from the meteorological data analysis and aerial photograph decipher.

### **INTRODUCTION**

It is often the case in Japan that railway tracks located on cliff front have been constructed on embankments protected by retaining walls against the harms of high waves. Score damages of wave protection works are of grave concerns of engineers who take charge of the maintenance of those structures.

Only three cases have been identified that scour by high waves brought about wave protection works of the railway track to fall down in recent two decades. Occurrence dates, sites and high waves causes of three cases are as follows (Figure 1), The first is at Hokuriku Line by winter monsoon on November 2, 1989<sup>1)</sup>, the second at Nemuro Line by typhoon on September 16, 1998<sup>2)</sup>, and the third at Uetsu Line by low on December 19, 2000.

It is important to investigate the cause of the rare and large-scale damage event

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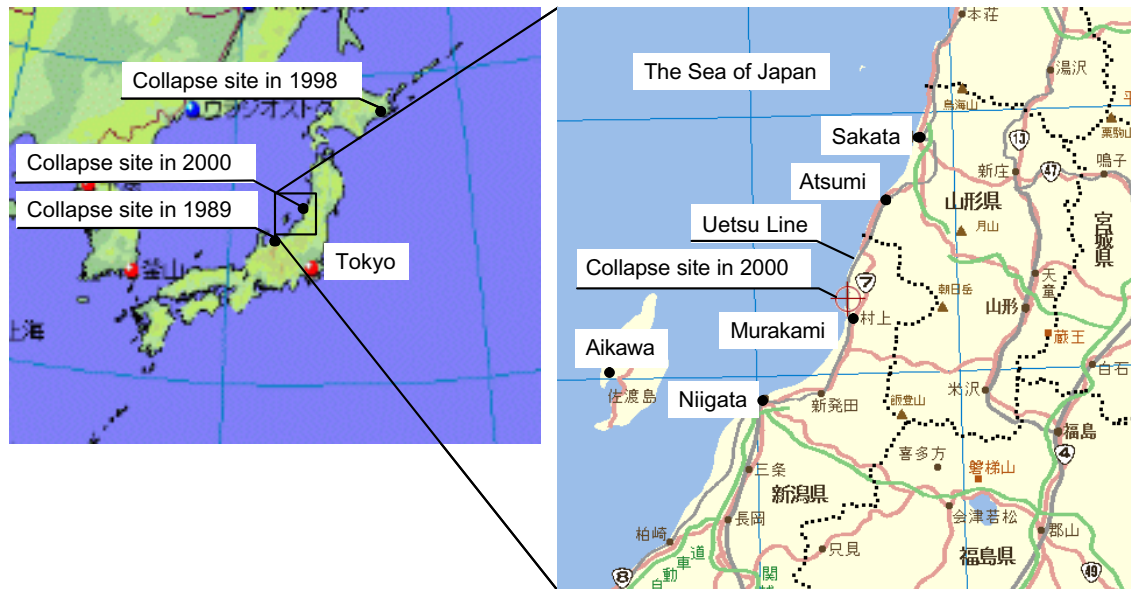


Figure 1 Locations of the collapse site

and to make it known to engineers to reduce the risk of the railway accident. This paper describes the last one among the above three cases and discusses scour problems of the wave protection work located on the cliff front in Japan referring to the weather condition prior to the occurrence of the event and the topography change in and around of the site.

## OUTLINE OF THE COLLAPSE

The wave protection work, which was located on the cliff front of the Sea of Japan between the stations Murakami and Mazima of Uetsu Line in Niigata Prefecture, was scoured, and it and the embankment collapsed presumably at 19:26 on December 19, 2000. Figure 1 shows the location of the collapse site of the wave protection work and the embankment. Uetsu Line links between the stations Niigata and Akita along the Sea of Japan. At the collapse site outbound line and inbound line are about 600 m apart.



Photo 1 The collapse site of the wave protection work and the embankment

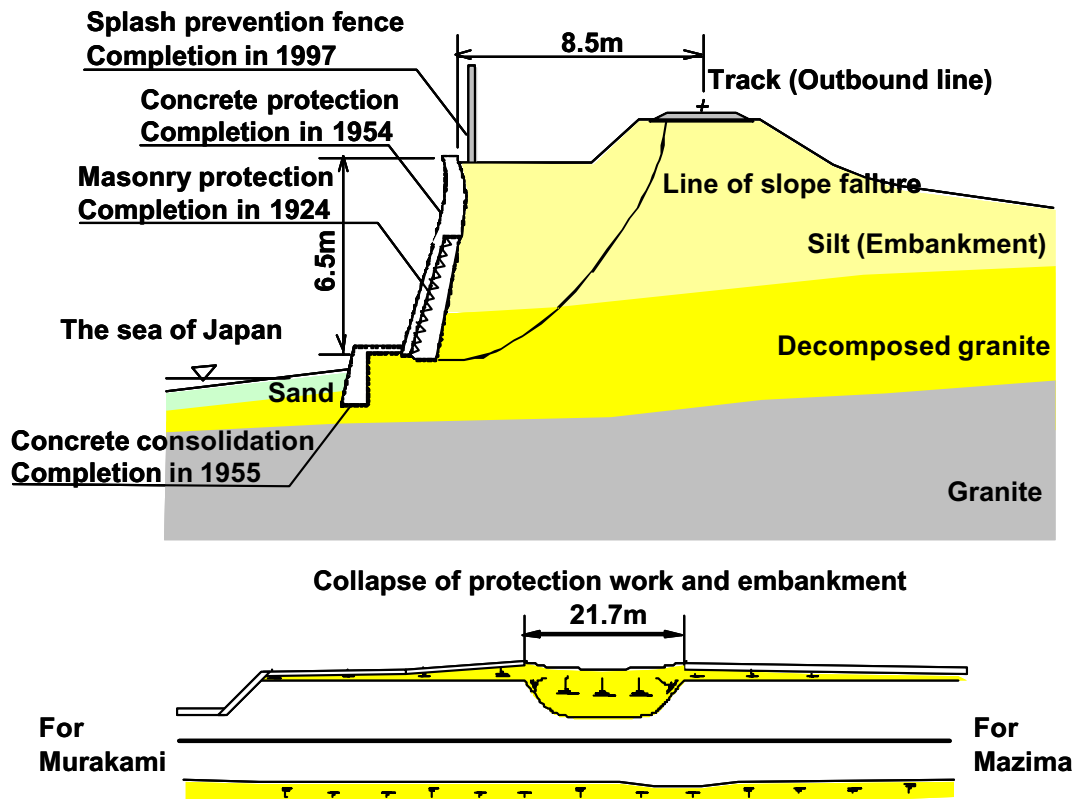


Figure 2 The section and plane diagram of the collapse site

Outbound line, at which the collapse occurred, is laid on the cliff front of the Sea of Japan, and inbound line passes by tunnel in mountain.

Photo 1 is photographs of the collapse site. Figure 2 shows the section and plane diagram of the collapse site of outbound line. The basement rock in and around the collapse site is granite formed from the latter term of Cretaceous period to Paleogene period. Upper layer of it is decomposed granite. The embankment made of silt was constructed on it. This site has 137 m long and from 5 m to 7 m high wave protection work of the railway embankment. The masonry protection work was constructed in 1924, when the present outbound line was laid. In 1954 the front of the masonry protection work was reinforced by concrete and the concrete parapet was constructed, and moreover in 1955 the concrete consolidation of foundation was constructed at the foundation of the wave protection work. In 1997 the splash protection fence was built at the top of the wave protection work, because splash can easily go over the top of the wave protection work, when it was high waves.

The wave protection work and the embankment with 21.7 m width and 6.5 m height collapsed due to scour of the wave protection work foundation. The slope failure reached up to the track ballast layer. The volume of the soil collapsed was about 450 m<sup>3</sup>. Moreover about 30 m section each of both sides of the wave protection work collapse was out of the perpendicular.

Train operation was suspended immediate after the collapse occurred. Train operation could be recommenced by single track operation using inbound line on December 20, the day after the collapse day, because outbound line and inbound line are

apart, Thereafter urgent repair work of the collapse site was completed on February 5, 2001, train operation to use outbound line and inbound line was recommenced. In the present repair work is under construction, and it will be completed on December 2003.

## WEATHER CONDITION OF THE DAY OF THE COLLAPSE

Photo 2 shows the waves condition of the collapse site before 2 hours of the collapse occurrence, at about 17 o'clock on December 19. The sea was rough and splash covered on the railway track. These high waves seem to be the immediate cause of the wave protection work collapse.



Photo 2 The waves condition of the collapse site before 2 hours of the collapse occurrence

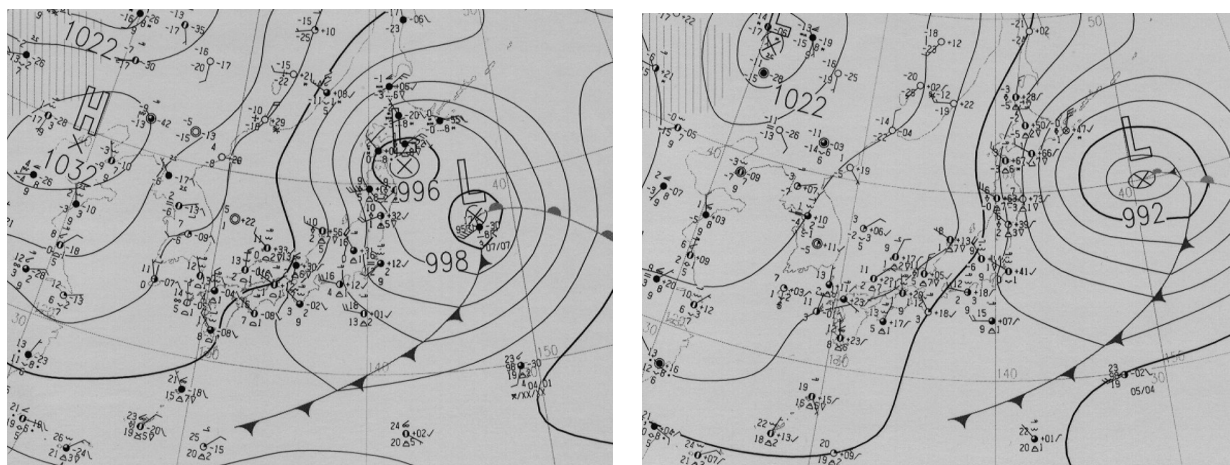


Figure 3 Weather maps at 15 o'clock(left) and 21 o'clock (right) on December 19, 2000. At 15 o'clock there were two deepening lows in the Pacific Ocean which traveled toward the northeast. At 21 o'clock two lows became one and the pressure of low was lower. In the Eastern and Northern Japan it blew strong wind under influence of these lows.

Figure 4 shows time history of wind velocity, precipitation, and temperature at Murakami(Figure 1), where is the nearest meteorological observation site of Japan Meteorological Agency(JMA) from the collapse site. The wind direction changed from east-north-east to south-west, and temperature rose at about 9 o'clock. At that time the low passed over near Murakami. After this the wind velocity grew gradually strong, and

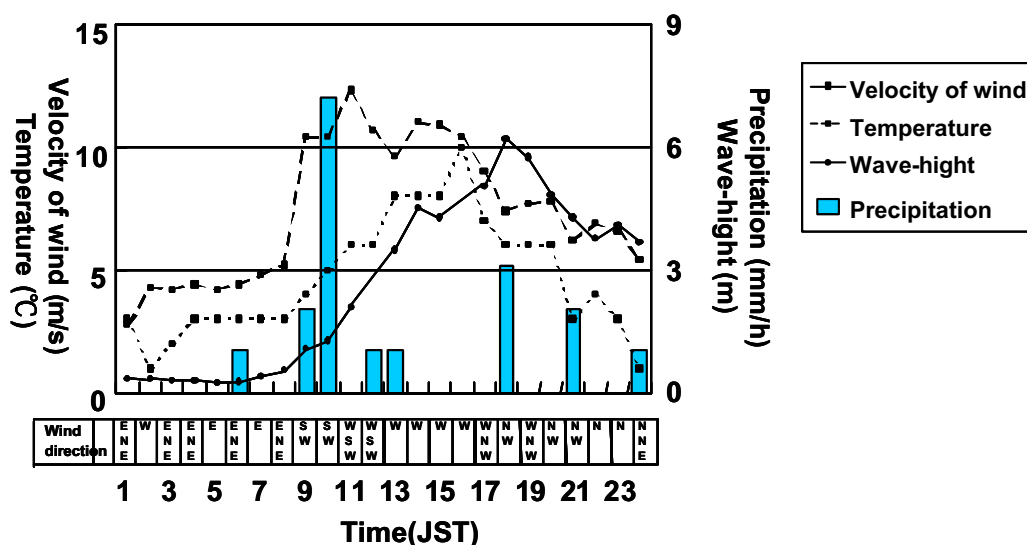


Figure 4 Time history of wind velocity, precipitation, and temperature at Murakami, and significant wave height at Atsumi on December 19, 2000

Table 1 The maximum instantaneous wind velocity of the day of the collapse at Niigata, Aikawa, and Sakata on December 19, 2000 and the return period of it

Observation site	Maximum instantaneous wind velocity (m/s)	Wind direction	Time	Return period (year)
Niigata	30.3	WSW	15:50	Below 2
Aikawa	35.7	W	11:20	7
Sakata	32.1	W	14:05	Below 2

Table 2 The maximum wind velocity of the day of the collapse at Niigata, Aikawa, and Sakata on December 19, 2000 and the return period of it

Observation site	Maximum wind velocity (m/s)	Wind direction	Time	Return period (year)
Murakami	10	W	16:00	5
Niigata	16.4	WSW	11:10	Below 2
Aikawa	21.6	WNW	13:10	3
Sakata	19.1	WNW	15:10	3

the maximum wind velocity which is 10 m/s was recorded at 16 o'clock. 0 to 12 mm hourly rainfall was observed, but it was not a heavy rain to cause of the wave protection work collapse.

Table 1 shows the maximum instantaneous wind velocity of the collapse day at Niigata, Aikawa, and Sakata(Figure 1), where are near meteorological stations of JMA from the collapse site. Table 2 shows the maximum wind velocity at Murakami, Niigata, Aikawa, and Sakata. In the east area of the Sea of Japan the strong wind, the maximum

instantaneous wind velocity is over 30m/s and the maximum wind velocity is over 10m/s. Table 1 and 2 also show return periods of the maximum instantaneous wind velocity and the maximum wind velocity, return periods of them are between below 2 years and 7 years. These high waves like photo 2 were induced by the strong wind in the east area of the Sea of Japan.

Figure 5 is wave maps at 9 o'clock on December 19 and 20, 2000. In the eastern area of the Sea of Japan waves were high. Figure 3 also shows time history of significant wave height at Atsumi (Figure 1), where is the nearest wave observation site of JMA from the collapse site. The significant wave height grew gradually high from 9 o'clock. The maximum significant wave height and wave height, which were 6.19 m and 11.8 m, were recorded at 18 o'clock when almost accords with the time of the wave protection work collapse. Table 3 shows returns period of them, it is below 2 years.

The wind of the collapse day was strong and waves were high, but they were not extremely rough as far as judging from the meteorological data. Though the immediate cause of the wave protection work scour seems to high waves, topography change in and around of the collapse site is presumed to affect the scour.

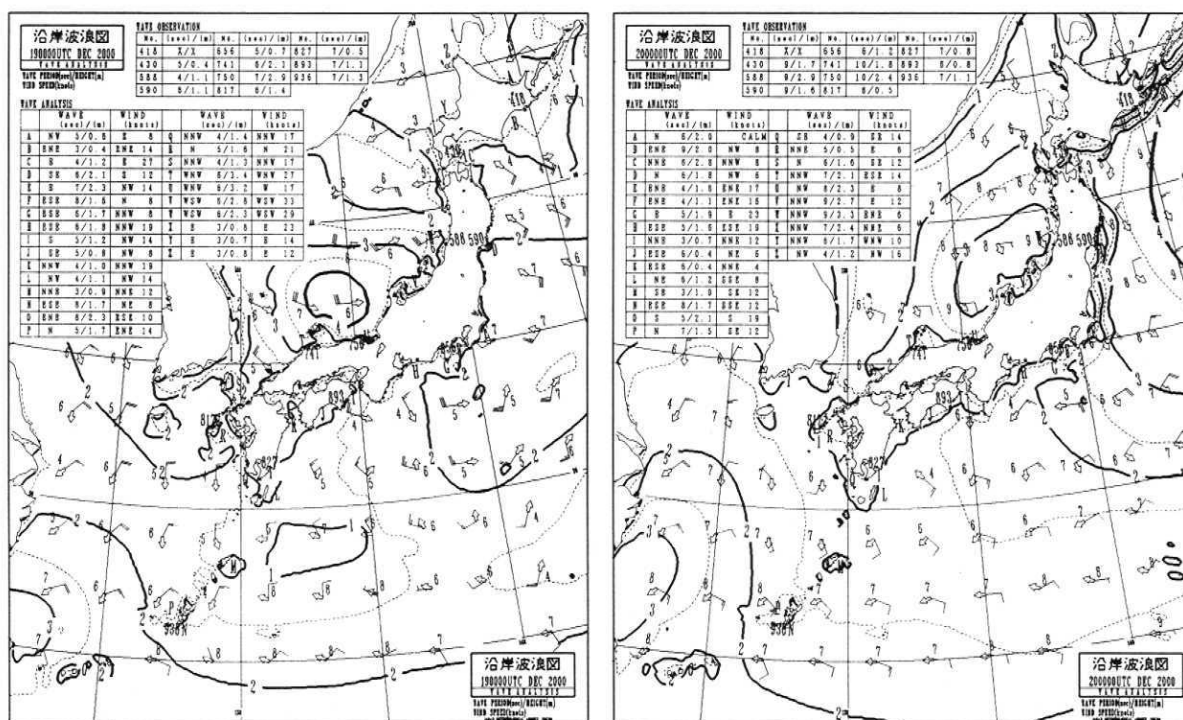


Figure 5 Wave maps at 9 on December 19 and 20, 2000

Table 3 The maximum wave height and the maximum significant wave height at Atsumi, and the return period of it

	Wave height (m)	Time	Return period (year)
Wave height	11.8	18:00	Below 2
Significant wave height	6.19	18:00	Below 2



## TOPOGRAPHY CHANGE IN AND AROUND OF THE COLLAPSE SITE

In Japan, coastal erosion progresses at many places in the present. Though Japan has about 34,000 km coastal line, eroding coast was 32% of the full length of the coastal line in 1965. Moreover it gradually increased, 47% in 1985 and 59% in 1995. The cause of the coastal erosion is decrease in sand supply from rivers, because dams and soil saving dams were constructed in the upper and middle reach of rivers.

Figure 6 is aerial photographs and plane diagram in and around the collapse site. In some place of seashore there are outcrops of granite. But there is no outcrop in front of the collapse site. The length of sandy beach of no outcrop site is shorter than one of outcrop sites. According to photograph decipher, the length from the wave protection work to beach line was 40 m in 1959. However, it gradually decreased, in 1976 it was 20 m, and in 1988 it was 18 m, and in 1996 it became 13 m.

The cause of the seashore retreat seems to be the decrease in sand supply from Miomote river. There is the mouth of this river at a distance of 1 km from the collapse site. At the upper reach of this river, Miomote dam and Saruta dam were built in 1953 and 1957. It is most probable that the decreases in supply of sand from rivers were

caused by the influences of by the construction of these dams. There are no major rivers which can supply a large amount of sand to the seashore in an about 40 km long section



Figure 6 The aerial photographs and plane diagram in and around the collapse site.



in southbound from the site, and in about 80 km long section in northbound. This could accelerate the seashore retreat.

Wave energy hitting the wave protection work gradually increased with the progress of the seashore retreat. From about 1996 splash became to easily go over the top of the wave protection works, when it was high waves, as a result, in 1997 the splash prevention fence was built at the top of the wave protection work. Therefore the seashore retreat seems to work as the indirect cause of the scour and collapse of the wave protection work.

## CAUSE OF THE COLLAPSE

According to the meteorological data analysis and aerial photograph decipher, the immediate cause of the collapse is the attack of high waves reduced by strong wind, and the indirect cause is the seashore retreat at the collapse site. The presumption mechanism of the damage process is as follows (Figure 7):

1. The seashore in the front of the collapse site gradually retreated by decrease in sand supply.
2. Wave energy hitting the wave protection work increased by the seashore retreat. Moreover splash became to easily go over the top of the wave protection work.
3. The foundation of the wave protection work was gradually scoured by high waves. Moreover soil relaxation progressed with sea water by splash.
4. The wave protection work and embankment collapsed by the scour of the wave protection work foundation reduced by high waves attack on December 19, 2000. Moreover the increase of hydraulic pressure in embankment with sea water supplied by high waves is presumed to affect the slope failure.

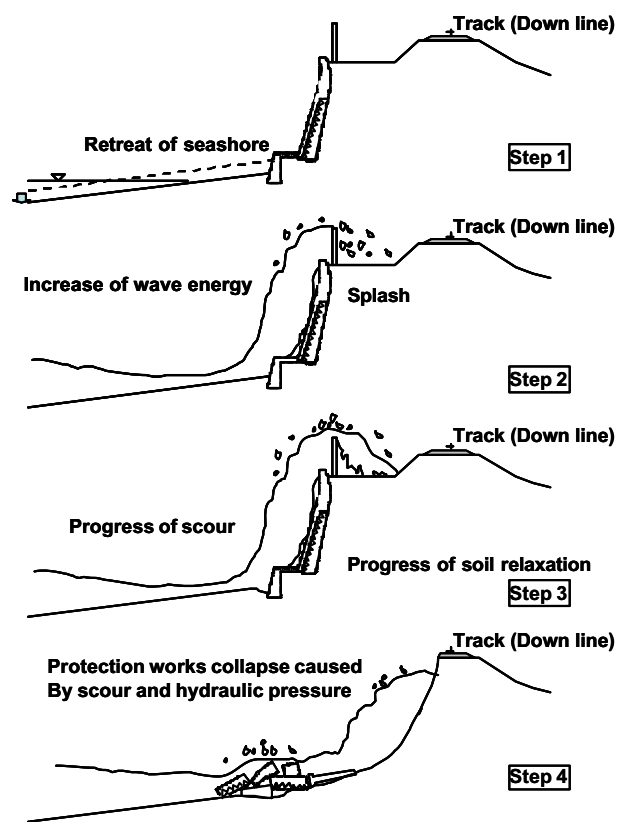


Figure 7 The process of the wave protection work collapse

## CONCLUSION

1. The foundation of the wave protection work of the railway embankment, which was located on the cliff front of the Sea of Japan, was scoured, and the wave protection work and the embankment collapsed on December 19, 2000. According to the meteorological data analysis and aerial photograph decipher, this scour is estimated to be reduced by high waves caused by the low on the occasion of the seashore retreating in front of collapse site. Moreover the increase of hydraulic pressure in embankment with sea water supplied by high waves is presumed to affect the slope failure.
2. This scour occurred by high waves of which return period is below 2 years. On the other hand, in the present, coastal erosion progresses all over Japan. Therefore judging from this study, at the region of seashore retreating, there is a possibility that a wave protection work is scoured by same process of this scour.
3. We investigated all wave protection works of railway tracks in East Japan Railway company area. As a result of the investigation seashore retreating is progress at three sites. We make plan to reinforce foundations of there wave protection works.

## ACKNOWLEDGMENTS

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