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Vorgeschlagene Zitierweise/Suggested citation:
Suzuki, Hiroto; Shimmura, Makoto (2002): Scour of Railway Embankment Foundation Located on Sea-Cliff in Japan. In: Chen, Hamn-Ching; Briaud, Jean-Louis (Hg.): First International Conference on Scour of Foundations. November 17-20, 2002, College Station, USA. College Station, Texas: Texas Transportation Inst., Publications Dept.. S. 945-953.

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

By

Hiroto Suzuki [1], Makoto Shimmura[2]

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[1)], the second at Nemuro Line by typhoon on September 16, 1998[2)], 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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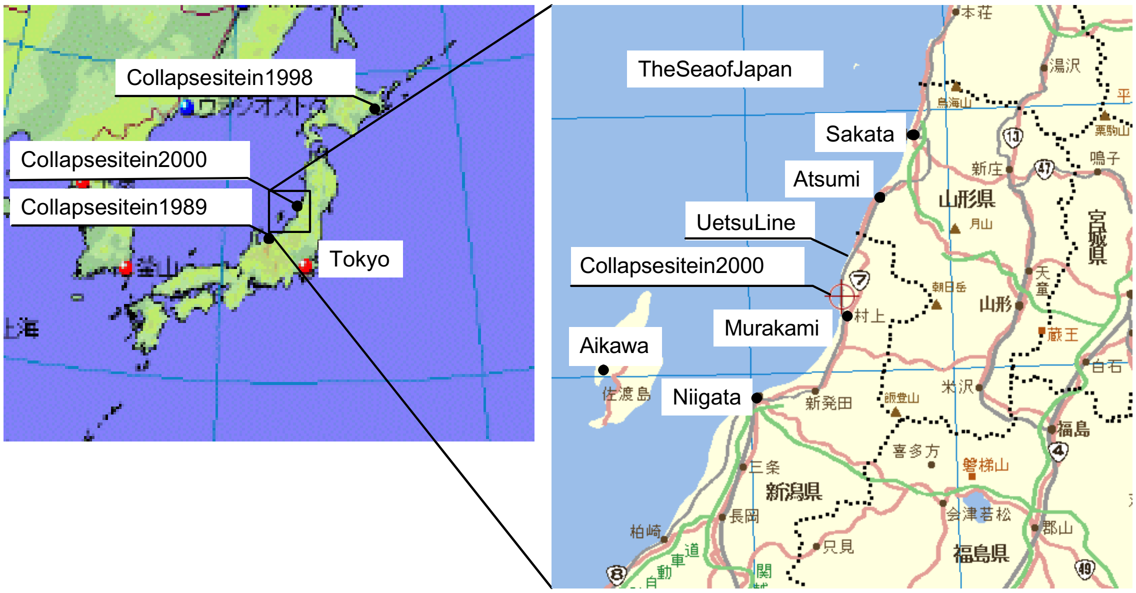

Figure1 Locationsofthecollapsesite

andtomakeitknowntoengineerstoreducetheriskoftherailwayaccident.Thispaper describesthelastoneamongtheabovethreecasesanddiscussesscourproblemsofthe waveprotectionworklocatedonthecliffrontinJapanreferringtotheweather conditionpriortotheoccurrenceoftheeventandthetopographychangeinandaround ofthesite.

OUTLINE OFTHEC OLLAPSE

Thewaveprotectionwork,whichwaslocatedonthecliffrontoftheSeaofJapan betweenthestationsMurakamiandMazimaofUetsuLineinNiigataPrefecture,was scoured,anditandtheembankment c ollapsedpresumablyat19:26onDecember19, 2000. Figure1showsthelocationofthe collapse site ofthewaveprotectionworkand theembankment. UetsuLine li nksbetweenthestations NiigataandAkitaalongthe SeaofJapan.Atthecollapsesite outboundline andinboundlineare about600mapart.

Photo1 The collapsesiteofthewaveprotectionworkandthee mbankment

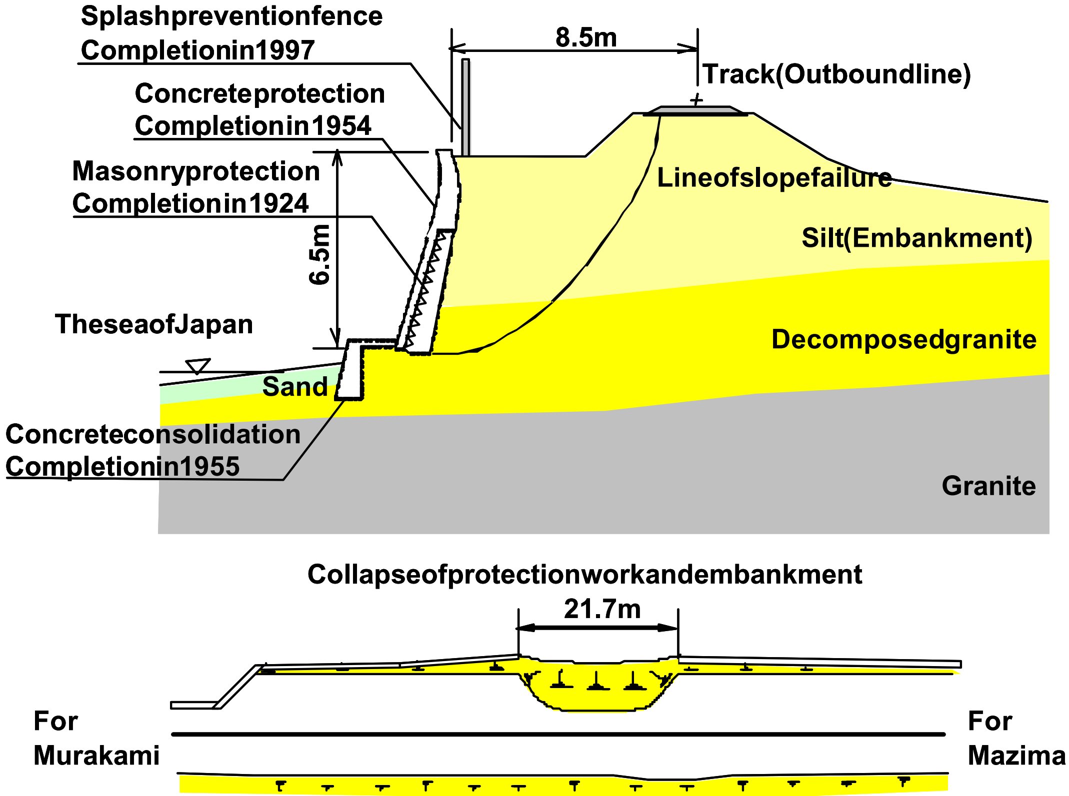

Figure2 Thesectionandplanediagramofthecollapsesite

Outboundline,atwhichthecollapseoccurred, is laid onthecliffrontoftheSeaof Japan,andinboundlinepassesbytunnelinmountain.

Photo 1 isphotographsofthecollapsesite.Figure2 showsthesectionandplane diagramofthe collapsesiteofoutboundline.Thebasementrock inandaroundthe collapsesiteisgraniteformedfromthel attertermofCretaceousperiodtoPa leogene period.Upperlayerof it isdecomposedgranite.The embankment madeofsilt was constructed onit. Thissitehas 137mlongandfrom5mto7mhigh waveprotection workof therailwaye mbankment. Themasonry protectionworkwas constructed in 1924, whenthepresent outboundline waslaid. In 1954 thefrontof the masonry protectionworkwas reinforced by concrete andthe concrete parapetwas constructed, and moreover in1955 theco ncreteconsolidationoffoundationwasconstructedat the foundationofthewaveprotectionwork. In1997thesplashprotectionfence was builtat the topofthe wave protectionwork,because splash can easilygooverthetopofthe waveprotectionwork,whenitwashighwaves.

The wave protectionwork andtheembankmentwith 21.7m width and 6.5 m height collapsed duetoscour ofthe waveprotectionworkfoundation. Theslopefailure reached uptothetrackballastlayer. Thevolumeofthesoilcollapsed wasabout450m ^{2}. Moreoverabout30msectioneach ofbothsidesofthe waveprotectionwork collapsewas outoftheperpendicular.

Train operation was suspended immediate after the collapse occurred. Train operation couldbe recommenced by single track operationusinginbound line on December 20,thedayafterthecollapseday, becauseoutboundlineandinboundlineare apart, Thereafterurgentrepairworkofthe collapsesitewascompletedonFebruary5, 2001,trainoperationtouseoutbo undlineandinboundline wasrec ommenced.Inthe present repairworkisunderconstruction,anditwillbecompletedonDecember2003.

WEATHERCONDITIONOFTHEDAYOFTHECOLLAPSE

Photo2 showsthe waves condition ofthe collapse site before2hoursof the collapse occurrence, at about 17o'clock onDecember 19.Theseawas roughand splash coveredon the railwaytrack. Thesehigh waves seem to be the immediatecauseofthe wave protectionworkcollapse.

Photo2 The wavescondition ofthe collapse site before 2 hours of the collapse occurrence

Figure3isweather maps at 15 o'clockand 21 o'clock of thecollapseday,on December 19,2000.At 15 o'clock therewere two deepeninglowsin thePacificOcean which traveledtowardthenortheast. At21 o'clock twolows becameoneandthe pressure of lowwaslower.IntheEasternandNorthernJapanitblewstrongwindunderinfluence oftheselows.

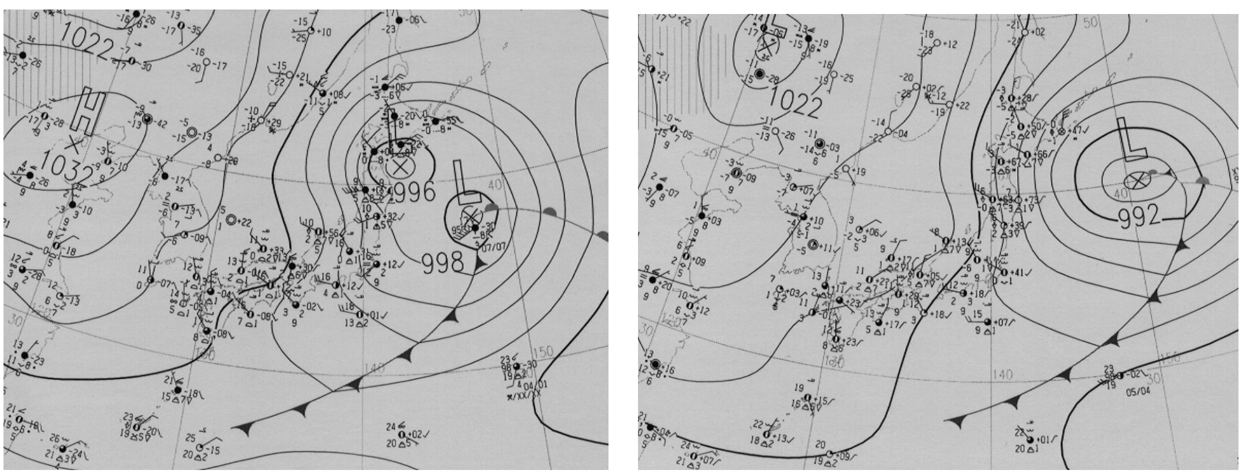

Figure3 Weather mapsat15o'clock(left)and21o'clock (right) on December19, 2000

Figure4showstimehistoryofwindvelocity,precipitation,andtemperatureat Murakami(Figure 1), whereis thenearestmeteor ologicalobservationsiteofJapan MeteorologicalAgency(JMA)from thecollaps esite. Thewinddirection changedfrom east-north-easttosouth-west,andtemperatureroseatabout9o'clock.Atthattimethe lowpassedovernearMurakami.Afterthisthewindvelocitygrewgraduallystrong,and

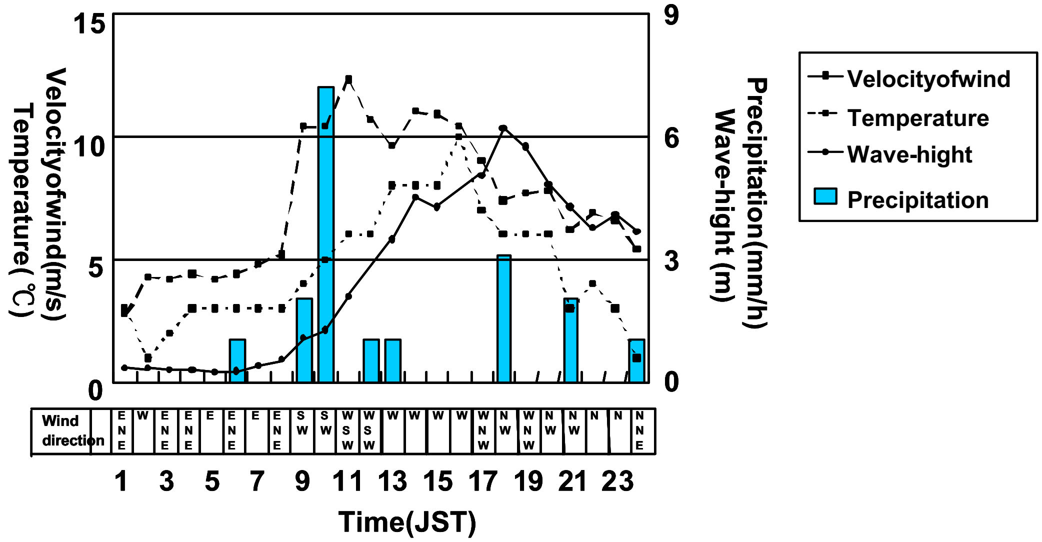

Figure 4 Time history of wind velocity, precipitation, and temperature at Murakami, andsignificantwaveheight atAtsumion December19, 2000

Table1 Themaximum instantaneouswindv elocityofthedayofthecollapseat Niigata, Aikawa,andSak ataon December19,2000and the returnperiodof it

Observation site	Maximum instantaneous windvelocity(m/s)	Wind direction	Time	Returnperiod (year)
Niigata	30.3	WSW	15:50	Below2
Aikawa	35.7	W	11:20	7
Sakata	32.1	W	14:05	Below2

Table2 Themaximumwindvelocityofthe dayofthecollapseatNiigata, Aikawa, andSakataon December19,2000and the returnperiodofit

Observation site	Maximumwind velocity(m/s)	Wind direction	Time	Returnperiod (year)
Murakami	10	W	16:00	5
Niigata	16.4	WSW	11:10	Below2
Aikawa	21.6	WNW	13:10	3
Sakata	19.1	WNW	15:10	3

themaximumwindvelocitywhichis10 m/s wasrecordedat16 o'clock. 0to12mm hourlyrainfallwasobserved,butitwasnotaheavyraintocauseof thewaveprotection workcollapse.

Table1showsthemaximum instantaneouswindvelocityofthe c ollapse dayat Niigata, Aikawa,andSakata(Figure1),wherearenearmeteorologicalstationsofJMA from thecollapsesite.Table2showsthemaximumwindvelocityatMurakami,Niigata, Aikawa,andSakata.IntheeastareaoftheSeaofJapanthestrongwind,the maximum instantaneouswindvelocityisover30m/sandthemaximumwindvelocityisover10m/s. Table1and2alsoshowreturnperiods ofthemaximum instantaneouswindvelocity andthemaximumwindvelocity,returnperiodsofthem arebetweenbelow2yearsand 7years. Thesehighwaveslikephoto2wereind ucedbythestrongwindintheeastarea oftheSeaofJapan.

Figure 5 iswavemaps at 9 o'clockon December19and20, 2000. In theeastern areaoftheSeaofJapanwaveswerehigh. Figure 3 alsoshowstimehistoryofsignificant waveheight atAtsumi(Figure1), whereisthenearest waveobservationsite of JMA from thecollapsesite. The significantwaveheightgrewgraduallyhighfrom9o'clock. Themaximumsignificantwaveheightandwaveheight, whichwere6.19mand11.8m, wererecordedat18o'clock whenalmostaccordswiththetimeofthewaveprotection workcollapse. Table3showsreturnsperiodofthem, itisbelow2years.

The wind ofthecollapsedaywasstrongandwaveswerehigh, but theywere not extremely roughasfarasjudgingfromthemeteorologicaldata. Thoughtheimmediate causeofthewaveprotectionworkscourseemstohighwaves, topographychangeinand aroundofthecollapsesiteis presumedtoaffectthescour.

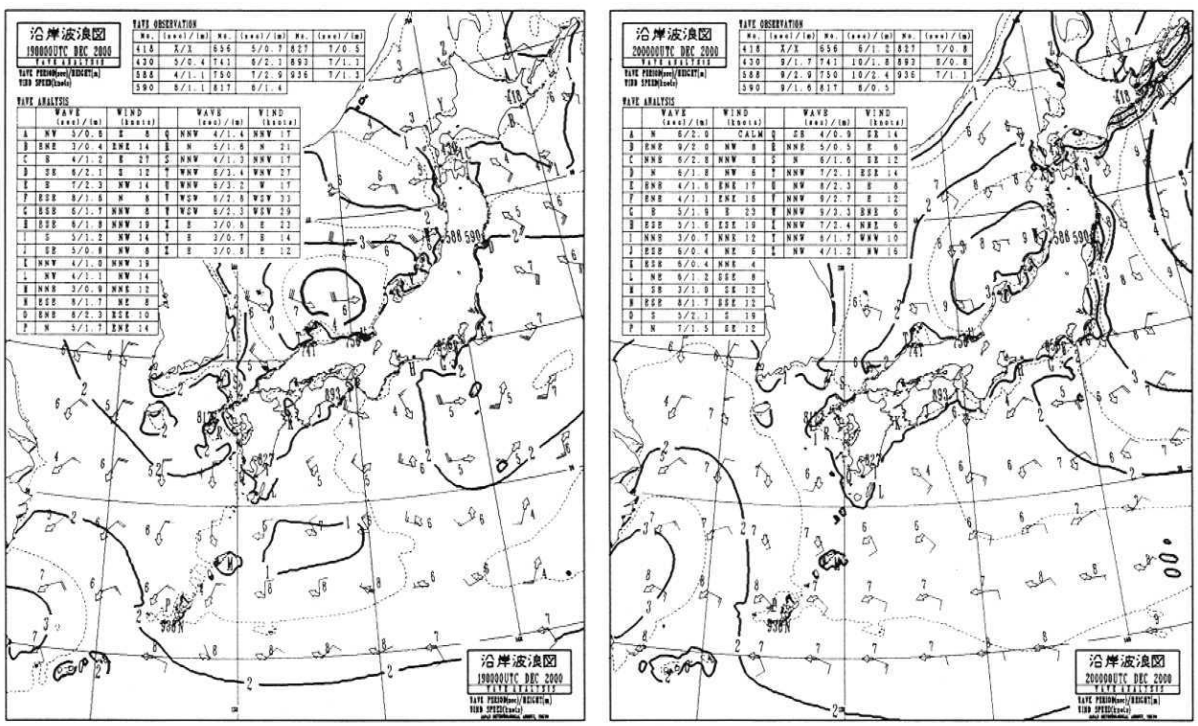

Figure5 Wavemapsat9onDecember19and20,2000

Table3 Themaximum waveheightandthemaximum significantwaveheightat Atsumi, andthe returnperiodofit

	Waveheight(m)	Time	Returnperiod(year)
Waveheight	11.8	18:00	Below2
Significantwaveheight	6.19	18:00	Below2

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.

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

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 in southboundfromthesite,and in about 80kmlongsectioninnorthbound.Thiscould acceleratetheseashore retreat.

Wave energy hitting the wave protection work gradually increased with the progressoftheseashoreretreat.Fromabout 1996splashbecametoeasilygooverthe topofthe waveprotectionworks,whenitwashighwaves,asaresult,in1997the splash preventionfencewasbuiltatthe topofthe waveprotectionwork.Thereforethe seashoreretreatseemstoworkastheindirectcauseof thescourandcollapseofthe waveprotectionwork.

CAUSEOFTHEC OLLAPSE

Accordingtothemeteorologicaldataanalysisandaerialphotograph decipher, the immediatecauseofthecollapseisthe attack ofhighwavesreducedbystrongwind,and the indirect cause is the seashore retreat at the collapse site. The presumption mechanismofthe damageprocessisas follows(Figure7):

1. Theseashoreinthefrontofthe collapsesitegraduallyretreated bydecreaseinsandsupply.
2. Wave energy hitting the wave protectionworkincreasedbythe seashore retreat. Moreoversplash became to easily gooverthetopof the wave protectionwork.
3. The foundation of the wave protection work was gradually scouredby highwaves. Moreover soil relaxation progressed with seawaterbysplash.
4. The wave protection work and embankment collapsed by the scourofthe wave protectionwork foundationreducedbyhighwaves attack on December 19, 2000. Moreover the increase of hydraulic pressure in embankment with sea water suppliedbyhighwavesispresumedtoaffecttheslopefailure.

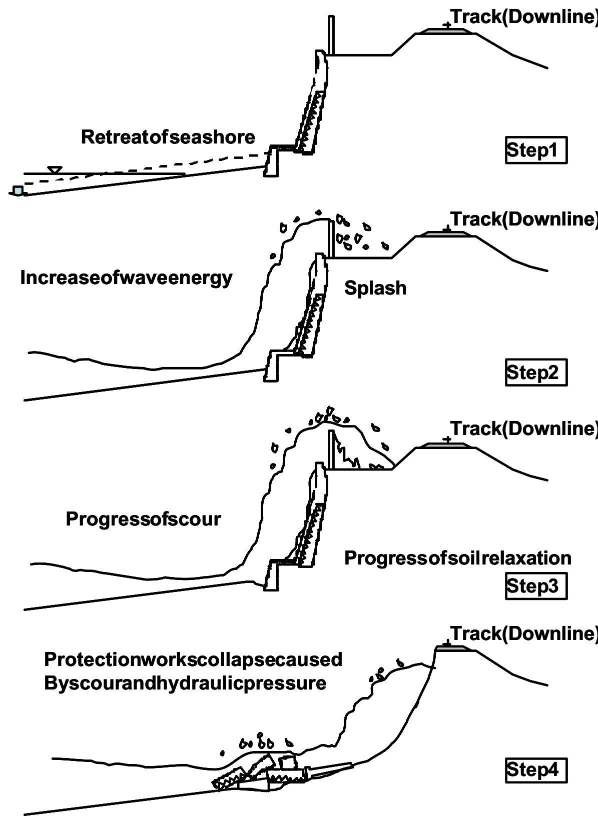

Figure7Theprocessofthewaveprotection workcollapse

CONLUSION

1. The foundationofthe waveprotectionworkoftherailway embankment, which waslocatedontheclifffrontoftheSeaofJapan, wasscoured,and thewave protectionworkandtheembankmentc ollapsedonDecember19,2000. According tothemeteorologicaldataanalysis andaerialphotograph decipher,thisscouris estimatedtobereducedby highwavescausedbythelowontheoccasionofthe seashoreretreatinginfrontofcollapsesite. Moreovertheincreaseofhydraulic pressureinembankmentwithseawatersuppliedbyhighwavesispresumedto affecttheslopefailure.
2. Thisscouroccurredbyhighwavesofwhichreturnperiodisbelow2years.Onthe otherhand,inthepresent,coastalerosionprogressesalloverJapan. Therefore judgingfromthisstudy,attheregionofseashoreretreating,thereisapossibility thatawaveprotectionworkisscouredbysameprocessofthisscour.
3. We investigated all wave protection works of railway tracks in East Japan Railwaycompanyarea. Asaresultoftheinvestigationseashore retreatingis progressatthreesites.Wemakeplantoreinforcefoundationsoftherewave protectionworks.

ACKNOWLEDGMENTS

We thankMr.HisashiMuraishiof Railway TechnicalResearchInstituteforhis usefuladviceandagreathelpespecially inthepresumptionofthemechanismofthe collapse. In this study, we used the weather and wave maps drawn by Japan MeteorologicalAgency(JMA),andused themeteorologicaldataobservedbyJMA.

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