DAMAGE TO CIVIL ENGINEERING STRUCTURES DUE TO THE NEAR IZU-OHSHIMA EARTHQUAKE OF JANUARY 14, 1978

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ABSTRACT

A severe earthquake hit the middle part of Izu Peninsula on January 14, 1973, registering a magnitude of 7.0 on the Richter scale. The Public Works Research Institute the Ministry of Construction has conducted field investigations on damages to engineering structures, such as highways, tunnels, bridges immediately after the outbreak of the earthquake.

This paper describes the results of investigations of the earthquake damage, and includes (1) outline of the earthquake, (2) topography and geology of Izu Peninsula, (3) earthquake ground motions, (4) damage statistics, (5) damages to civil engineering structures, and closing remarks

OUTLINE OF THE EARTHQUAKE

The near Izu-Ohshima Earthquake which hit the middle part of Izu Peninsula, can be outlined as follows:

Date : January 14, 1978 Epicenter: N34 45' E139 14' Depth : 1.6 km

Magnitude: 7.0 on the Richter Scale

Seismic intensity on the JMA Scale at the various sites are shown in Fig. 1. definition of the JMA Seismic Scale is tabulated in Table 1.

Many fore-shocks were observed near Izu-Ohshima Island and moreover after-shocks including a shock registering a magnitude of 5.8 occurred in the middle part of Izu Peninsula as shown in Fig. 2.

The fault line of the main shock is directed from Izu-Ohshima Island to the middle part of Izu Peninsula, that is EW direction. Approximate parameters of the fault are as follows:

Length of the fault line : 20km : 90 Dip angle Dislocation

TOPOGRAPHY AND GEOLOGY OF IZU PENINSULA

The central part of Izu Peninsula is a mountainous area with steep hills. Volcanic topography is seen in this area, with a famous volcanic mountion, Mt. Amagi, near the center of the Peninsula. Mountain ridges have a nearly constant height.

As shown in the geological map of Izu Peninsula edited by Shizuoka Prefecture (Fig. 3) the geology of this area is represented by Yugashima Group and Shirahama Group consisting of Neocene volcanic ejects, volcanic lavas on those Groups, and volcanic

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mud flows and pyroclastics covered on the lavas. Yugashima Group and Shirahama Group are surface soil strata made from tuffaceous sandstones, siltstones, breccia, and scoria (volcanic congiomerates) as the results of weathering effects.

In the areas of Inatori, Higashi Izu Town and Mitaka, Kawazu Town, terraces with moderate slopes are made of volcanic mud flows including andesite gravels. In the areas of Naramoto, Higashi Izu Town and Mitaka Iriya Nanamagari, Kawazu Town, pyroclastics cover the surface. These are loose layers made of scoria, loam, and light yellow volcanic ash, with moderate slopes of about 25°.

As in the Off-Izu Peninsula Earthquake of May 9, 1974, fault movement was evident after the recent earthquake. Surface dislocations were found along a line connecting Inatori and Neginota.

Several right lateral dislocations, accounting 18cm on the pavement of National Highway Route 135 (refer to Fig. 4), 18cm on the playground of the High School, and 7cm of a loam layer at Neginota were observed.

It should be noted that considerable damage was concentrated close to the areas where fault movement occurred.

EARTHQUAKE GROUND MOTIONS

Numerous strong earthquake records were obtained at various sites except for Izu-Ohshima Island and for most of Izu Peninsula. The maximum values of the observed earthquake accelerations at the sites are shown in Fig. 5.

The record closest to the fault was obtained on a basement floor of Itoh Telegram $\,$ and Telephone Office where the epicentral distance is nearly 30 km. Time histories and response spectra of the record are shown in Figs. 6 and 7, respectively . The maximum values of accelerations, velocities and displacements of the earthquake motions are as follows:

Accelerations: 101.1 gal (EW), 71.9 gal (NS), 31.9 gal (UD)

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TABLE 1: DEFINITION OF JMA SEISMIC INTENSITY SCALE

| Scale | Definitions | Corresponding Magnitude of Accelerations | | | | |
|-------|---|--|--|--|--|--|
| 0 | No Feeling: Too weak to cause human feeling, to be registered only by seismographs. | 0 - 0.8 gals | | | | |
| 1 | Slight: To be felt only feebly by persons at rest or by those who are observant to an earthquake. | 0.8 - 2.5 gals | | | | |
| 2 | Weak: To be felt by most persons, causing slight shaking doors and Japanese latticed sliding doors (Shoji). | 2.5 - 8 gals | | | | |
| 3 | Rather strong: To cause shaking of houses and buildings, heavy rattling of windows and Shoji, swinging of hanging objects, stopping sometimes pendulum clocks and moving liquid in vessels. Some persons are so freightened as to run out of doors. | 8 - 25 gals | | | | |
| 4 | Strong: To cause strong shaking of houses and buildings, overturning of unstable objects, and spilling of liquid out of vessels. | 25 - 80 gals | | | | |
| 5 | Very strong: To cause cracks in the brick and plaster walls, overturning of stone lanterns and grave stones etc. and damaging of chimneys and mudand-pluster warehouses. Landslides in steep mountains are to be observed. | 80 - 250 gals | | | | |
| 6 | Disastrous: To cause demolition of Japanese wooden houses less than 30%, intense land-slides, fissures on the flat ground accompanied sometimes by spouting of mud and water in low fields. | 250 - 400 gals | | | | |
| 7 | Ruinous: To cause demolition of houses more than 30%, large fissures and faults are to be observed. | 400 gals or more | | | | |

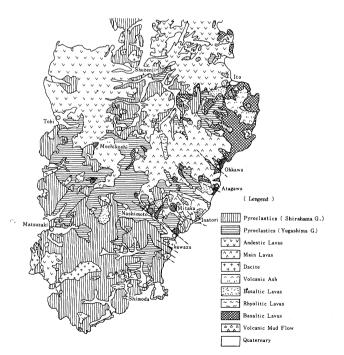


FIGURE 3: GEOLOGICAL MAP OF IZU PENINSULA

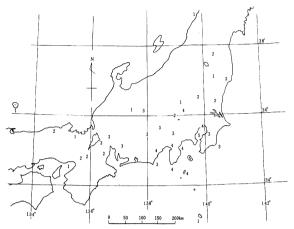


FIGURE 1: SEISMIC INTENSITY (THE NEAR IZU-OHSHIMA EARTHQUAKE OF JANUARY 14, 1978) (AFTER JMA)

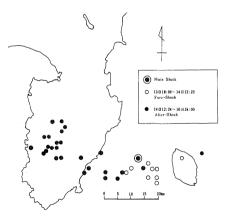


FIGURE 2: DISTRIBUTION OF EPICENTERS OF AFTER SHOCKS (AFTER JMA)

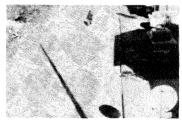


FIGURE 4: TRACESOFEARTHQUAKE FAULT APPEARED ON ROUTE 135 IN FRONTOFINATORI JUNIOR HIGHSCHOOL RIGHT LATERAL DISPLACE MENT WITH A MAGNITUDE OF 18 CM)

TABLE 2: EARTHQUAKE DAMAGES IN SHIZOUKA PREFECTURE (AFTER SHIZUOKA PREFECTURE)

| City, Town & Village Damaged Damages Unit | | | Total | Higashi -Izu T. | Amagi Yugashima T. | Kawazu T. | | Nishi-Izu T. | Matsuzaki T. | Tol T. | Ito C. | Minami-Izu T. | Kamo V. | Atami C. | Naka-Izu T. |
|--|-------------------------------------|--------------------------|--------|--------------------|--------------------------|------------|-----------|-----------------|-----------------|--------|--------|------------------|------------|----------|----------------|
| Damage to Human Beings | Dead | Person(s) | 25 | 9 | 5 | 11 | | | | | | | | | |
| | Heavily Injured | - 11 | 34 | 23 | 3 | 2 | 4 | 1 | | | . 1 | | | | |
| | Slightly Injured | - 11 | 171 | 86 | 5 | 26 | 47 | 1 | 2 | | 3 | 1 | | | |
| | Total | " | 205 | 109 | 8 | 28 | 51 | 2 | 2 | | 4 | 1 | | | |
| Damage to Resi- dential | Completely Collapsed | House(s) | 96 | 56 | | 16 | 12 | 7 | 4 | | 1 | | | | |
| | | Family (ies) | 100 | 56 | | 16 | 16 | | 4 | | 1 | | | | |
| | | Person(s) | 410 | 251 | | 77 | 44 | | 14 | | | | | | |
| | Heavily Collapsed | House(s) | 616 | 460 | | 56 | 24 | 34 | 11 | | 4 | | 27 | | |
| | | Family (ies) | 633 | 478 | | 56 | 25 | 34 | - 11 | | 2 | | 27 | | |
| | | Person(s) | 2,587 | 1,998 | | 236 | 87 | 105 | 41 | | 12 | | 108 | | |
| | Partially Collapsed | House (s) | 4,170 | 2,097 | 124 | 879 879 | | 229 | 195 | 100 | 304 | 29 | 114 | | 21_ |
| | | Family(ies) Person(s) | 4,256 | 2,125 8,053 | 124 521 | 3,581 | 81 291 | 1.023 | 194 701 | 100 | 306 | 119 | 114 392 | 1-1- | 84 |
| Damage to Non-Resi- dential Houses | Public | House(s) | 24 | 6 | 2 | 3,501 | 12 | 1,025 | 701 | 400 | 1,100 | 119 | 394 | - | 04 |
| | Non-Public | House(s) | 538 | 145 | | 78 | 57 | 124 | 9 | 60 | 45 | | 20 | | |
| | Overburden Rice Field | ha | 5,662 | 0.500 | 0.742 | | 1.180 | 1.09 | 0.4 | | | 0.300 | | | 1.45 |
| Other Damages | Overburden Field | ha | 13,112 | 10.500 | 2.012 | | 0.02 | 0.15 | | 0.100 | | 0.300 | | | 1 |
| | Educational Facilities | Point(s) Damaged | 84 | 14 | 5 | 6 | 33 | 7 | 4 | 01100 | 10 | 3 | 1 | 1 | |
| | Hospitals | 11 | 44 | 25 | | 14 | | | 3 | | | | 2 | | |
| | Roads | | 1.126 | 375 | 13 | 494 | 30 | 92 | 4 | 22 | 12 | 3 | 65 | 3 | 13 |
| | Bridges | - 11 | 3 | | | 2 | 1 | | | | | t | | | |
| | Rivers | - 11 | 65 | 18 | 10 | 27 | 2 | 3 | | | | | | | 5 |
| | Fishery Ports | 11 | 12 | 4 | | 1 1 | | 4 | | | 2 | | 1 | | |
| | Sabo | 11 | 2 | | | | | | | | | 1 | | | 1 _ |
| | Waterwork Facilities | 11 | 532 | 78 | 116 | 85 | 31 | 106 | 4 | 12 | 7 | 3 | 90 | | |
| | Cleaningwork Facilities | - 11 | 5 | 1 | | 2 | | 1 | | | | | | | |
| | Slope Failure | - 11 | 191 | 57 | 22 | 38 | 12 | 5 | 21 | 9 | 25 | 2 | | | |
| | Rail Roads Damaged | - 11 | 26 | 12 | | 12 | | | | | 2 | | | | |
| | Communication Service Facilities | No. | 579 | 330 | | 140 | | 109 | | | | | | | |
| Number of Family Damaged House(s) | | 733 | 534 | | 72 | 41 | 41 | 15 | | 3 | | 27 | | | |
| Number of People Damaged Person(s) | | 2,997 | 2,249 | | 313 | 131 | 128 | 55 | | 13 | | 108 | | | |

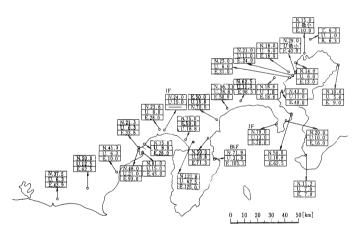


FIGURE 5: THE MAXIUMUM GROUND ACCELERATIONS

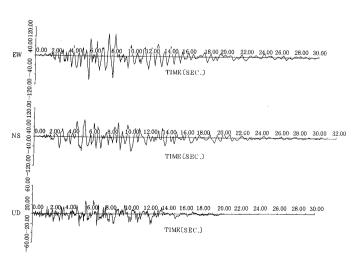
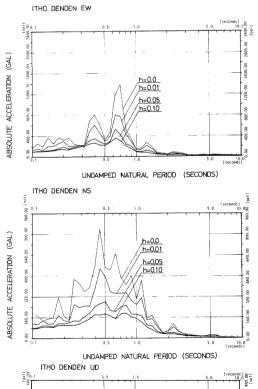


FIGURE 6: ACCELERATION RECORDS MEASURED ON A BASEMENT FLOOR OF ITOH TELEGRAM AND TELEPHONE OFFICE (8)



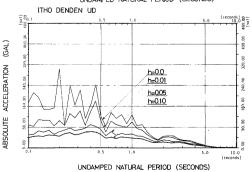


FIGURE 7: RESPONSE SPECTRA OF THE ACCELERATION RECORDS MEASURED ON 1TOH TELEGRAM AND TELEPHONE OFFICE (8)

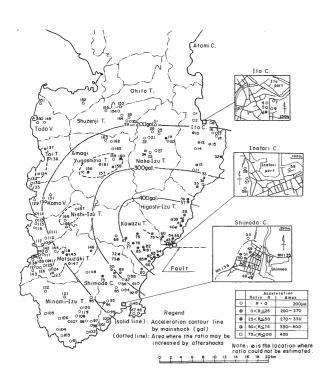


FIGURE 8: LOCATIONS OF 168 CEMETERIES, RATIOS OF OVERTURNING OF TOMBSTONES, AND MAXIMUM ACCELERATIONS ESTIMATED.

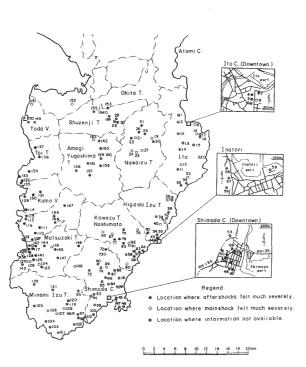


FIGURE 9: COMPARISON OF SEVERENESS OF GROUND-MOTIONS BETWEEN THE MAINSHOCK OF JANUARY 14 AND THE AFTERSHOCKS OF JANUARY 15.

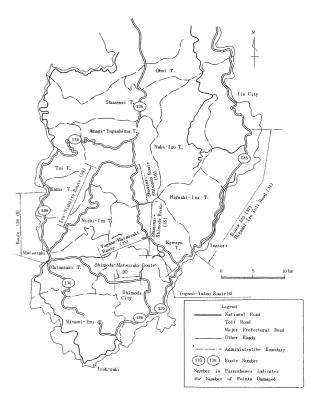


FIGURE 10: DISTRIBUTION OF ROADS DAMAGED

Velocities : 16.2 kine (EW), 10.0 kine (NS),

5.1 kine (UD)

Displacements: 10.5 cm (EW), 2.8 cm (NS),

2.4 cm (UD)

The maximum values of EW component, are considerably larger than those of NS component. On the other hand there are some differences in frequency characteristics between the spectra, as shown in Fig. 7, in EW and NS components. The differences on the maximum values of the motions and the spectra between the both components can be explained by the fact that the earthquake records were obtained near the fault and that the direction of the fault line was EW.

- The duration of strong shaking was 15-20 seconds.
- ii. The predominant periods in the EW component are 0.4 and 0.7 seconds. The maximum amplification factor is 3.07 for 5% of critical damping at the former peak period.
- iii. The predominant period in NS component is 0.5 seconds, at which the maximum amplification factor is 3.9 for 5% of critical damping.
- iv. The predominant period in UD component is 0.4 seconds, at which the maximum amplification factor is 2.9 for 5% critical damping.
- v. The ratio, A_V/A_h , of the maximum acceleration of UD component to that of horizontal components is 0.32 and 0.44 for EW and NS component, respectively. According to the maximum values observed at the various sites as shown in Fig. 5, the ratio, A_V/A_h , is 0.45 on an average.

Furthermore, Fig. 8 indicates locations of 168 cemeterieswhere overturning of tombstones were carefully surveyed. The figure also shows ratios of the number of tombstones overturned to the number surveyed at each cemetery, and peak accelerations of the main shock estimated in view of those ratios. Fig. 9 compares the strength of the ground motions during the main shock of January 14 and the aftershocks of January 15.

STATISTICS OF DAMAGE

Regions hit by the earthquake cover the administrative districts of Shizuoka Prefecture and Tokyo Metropolis (Izu-Ohshima Island).

Twenty-five persons were killed in all by slope failures and landslides. Earthquake damage in Shizuoka Prefecture are summarized in Table 2. A total amount of the damage is estimated to be approximately 36 billion yen (180 million U.S. dollars), which is about 14 times greater than damage due to the Off-Izu Peninsula Earthquake of 1974. Approximately 40 percent of the above amount is caused by damage to road facilities.

On the other hand, there were a few minor damages on roads in Izu-Ohshima. The amount of damage was very small (40 million yen) as compared with the one in Shizuoka Prefecture.

DAMAGE TO CIVIL ENGINEERING STRUCTURES

A feature of civil engineering damage

in the Near Izu-Ohshima Earthquake are landslides of natural slopes. Field surveys after the earthquake indicate that several failures took place in embankments, retaining walls and tunnels. However, highway bridges and pedestrian overcrossings suffered few minor damages.

Earthquake damage on road structures were mainly distributed on Route 135 (national road), Higashi-Izu Toll Road and Shuzenji-Shimoda Route (principal prefectural road) as shown in Fig. 10. The areas heavily damaged are considered to be in good agreement with the distributions of maximum acceleration estimated in Fig. 8.

Landslides

Field observations suggest that slope failure could be classified into three categories, i.e. failures of soil slope, failures of rocky slope and rock falls.

Typical soil failures were observed in Naramoto Area (Higashi-Izu Town), Mitaka-Iriya-Nanamagari Area (Kawazu Town), and Nashimoto Area (Kawazu Town). In the first two cases, surface soils with a depth of 1 to 2 meters were underlaid by scoria with a depth of 2 to 3 meters and loam, respectively. It was observed that the sliding of soils generally took place in the scoria stratum or between scoria and loam strata. The volume of these landslides was estimated to be from several thousands to two hundred thousands cubic meters in this type of failure. In the latter case, it was observed that landslides of weathered surface soils carried lightly rooted trees. The volume of these landslides was estimated to be from several thousands to several ten thousands cubic meters. Fig. 11 shows a representative failure in this type at Nashimoto Area (Kawazu Town).

Failures of rocky slopes could be mostly observed on andesite slopes with steep angles in Higashi-Izu Town and Kawazu Town. The volume of the landslides was estimated to be from several thousands to several ten thousands cubic meters. It was noted from observation that failure was most likely to occur at the convex parts of slopes as shown in Fig. 12.

Falling stones could be observed at slopes consisting of rocks with few joints and volcanic andesite gravels such as Yugashima Group in both Kawazu and Amagi-Yugashima Towns. The volume of rock fall was of the order of several hundreds cubic meters.

In addition to the slope failures described above, failures of cut slopes were also observed. However careful investigation showed that the cut slopes themselves did not generally cause failures but that the natural slopes existing above the cut slopes sometimes fell down on the cut slopes. It was also observed that slopes adequately retained by concrete walls, concrete frames, with concrete or mortar covering could survive satisfactorily against the earthquake.

Embankments and Retaining Walls

to be caused by failures or movements of the soil materials of embankment. In the case of embankments constructed by both cut and fill, filled parts generally settled resulting in pavement cracking. In Yugano Area along Shuzenji-Shimoda Route, failures of embankments took place at several places. Fig. 13 shows one of representative failures with 3.5m in width, 60m in length and maximum settlement of about 60cm.

In the area hit by the earthquake there was a number of retaining walls for cut and embankment slopes. The most common of these retaining walls were made of concrete or masonry. Although some of them were damaged as shown in Fig. 14, many survived safely with minor non-structural damage such as cracks, gaps, small settlements, etc. There were several high embankments with heights of more than 10 to 20 meters in east Izu area as shown in Figs. 15 and 16. It should be noted that these high embankments showed quite a good performance against the earthquake.

Tunnels and Bridges

In the Tormoro Tunnel with a length of 425.5m (Higashi-Izu Toll Road), a piece of lining concrete near the arch crown and side wall fell as shown in Fig. 17. It was also observed that large amounts of soil fell and blocked tunnel entrances in Shirata, Kitoh and Kurone Tunnels on Route 135. In the Inatori Tunnel (Izu-Kyuko Railway) concrete lining was crushed by fault movements, and uplift and bending of the rails took place.

In the Shin-Shimoda Bridge (Shimoda City), it was observed as shown in Fig. 18 that a free end of a prestressed concrete girder moved horizontally about 7cm in the down stream direction and that this lateral movement crushed concrete handrails at both sides since they were rigidly connected between the abutments and the girders in order the support the mermaid statues. It was also observed that several pieces of concrete at parapets and piers fell down in Shimoda Bridge on Route 135 and that a pier of Minato Bridge in Shimoda City settled approximately 0.5 meters.

It should be noted here that two over-crossings for pedestrians survived safely with few minor cracks at parapets, although one of them was located only 20 meters apart from faults near Inatori Junior High-School. Ground motions at the site was estimated to be very severe since several wooden residential houses were collapsed and also most tomb stones around the site were overturned.

Other Damages

Two tailing dams for storing mining wastes were collapsed as shown in Figs. 20 and 21, and the slimes which overflowed from a damaged dam resulted in water pollution in Mochikoshi River, Kano River and Suruga Bay.

CLOSING REMARKS

Characteristics of damage to civil engineering structures due to the Near Izu-Ohshima Earthquake of January 14, 1978 can

be summarised as follows:

- 1. In the vicinity of Inatori area, Higashi Izu Town, surface dislocations resulting from active faults were found along the length of about 1 km. Landslides, slope failures, and stone falls were extensive inside the area of aftershocks. Highway bridges and pedestrian overcrossings near fault traces, however, did not sustain any structural damage.
- 2. A number of failures of natural rocky slopes were generally observed at sharply convex points of steep mountains.
- 3. A number of landslides occurred. Landslides of surface soil strata were observed even at comparatively moderate slopes (approximately 25°). Sliding surfaces were estimated to be near the boundaries between scoria layers and cohesive layers, which are about 4 to 5 meters below the ground surface.
- 4. Damages to cut slopes reinforced by surface works were rather slight. It is recognized that damages were lighter for cut slopes which are well designed and well constructed.
- 5. A number of stone falls from untreated natural slopes were observed. Wire net covering surfaces of rocky slopes could prevent some rockfall.
- 6. Although many of settlements, cracks, and failures of earth banks and retaining walls were observed, there was little severe damage. Earth fills supported by surface frameworks did not sustain heavy structural damages.
- 7. Although some of the tunnels were damaged severely due to either the effects of faults which were active inside tunnels or the effects of landslides occurring at or near the tunnel sections, most of the tunnels were safe.

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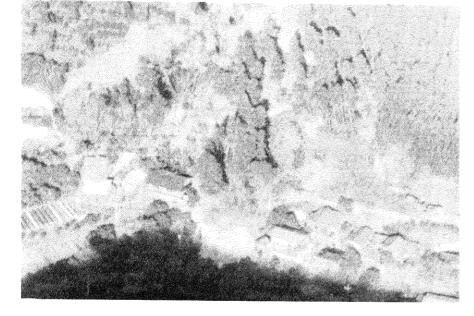


FIGURE 11: SLOPE FAILURE AT NASHIMOTO AREA IN KAWAZU TOWN (SHUZENJI-SHIMODA ROUTE, PHOTOGRAPH AFTER SHIZUOKA PREFECTURE)

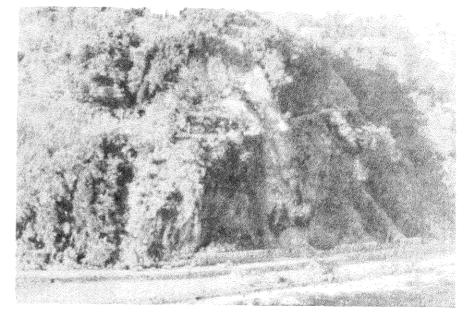


FIGURE 12: SLOPE FAILURE AT OHKAWA AREA IN HIGASHI-IZU TOWN (ROUTE 135. PHOTOGRAPH AFTER SHIZUOKA PREFECTURE)

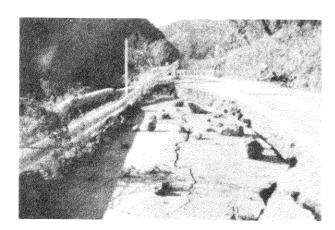


FIGURE 13: SETTLEMENT OF EMBANKMENT IN YUGANO AREA (SHUZENJI-SHIMODA ROUTE)

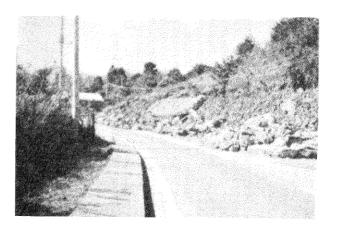


FIGURE 14: FAILURE OF MASONRY WALL AT INATORI AREA IN HIGASHI--IZU TOWN (ROUTE 135)

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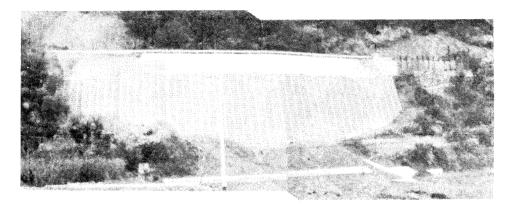


FIGURE 15: PLANE VIEW OF HIGH EMBANKMENT, RETAINED BY CONCRETE FRAME,
WHICH COULD SURVIVE SAFELY AGAINST THE EARTHQUAKE, AT
NASHIMOTO AREA IN KAWAZU TOWN (SHUZENJI-SHIMODA ROUTE)

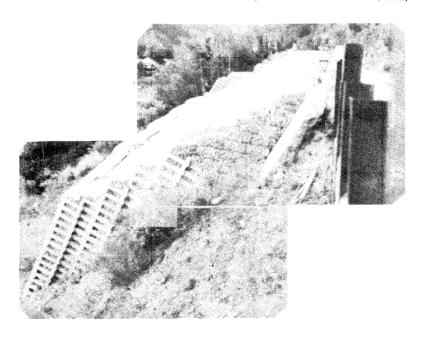


FIGURE 16: SIDE VIEW OF THE HIGH EMBANKMENT (SHUZENJI-SHIMODA ROUTE)

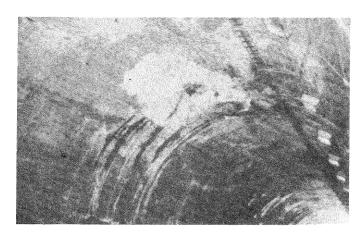


FIGURE 17: FAILURE OF LINING CONCRETE near Arch Crown at Tomoro Tunnel (Higashi-Isu Toll Road).

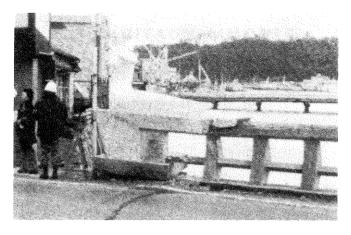


FIGURE 18: FAILURE OF CONCRETE HANDRAIL and Lateral Movement of Concrete Girder (Shin-Shimoda Bridge, Shimoda City).

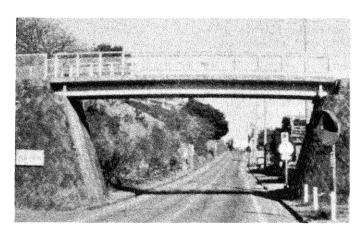


FIGURE 19: OVERCROSSING FOR PEDESTRIAN located only 20m apart from Faults near Inatori Junior Highschool at Inatori Area in Higashi-Izu Town, which survived safely against Earthquake with minor cracks at Parapets.



FIGURE 21: COLLAPSED first Tailings Dam and temporarily repaired Dam.



FIGURE 20: OVERALL VIEW OF COLLAPSED HOHZUKI—KAWA TAILINGS DAMS for storing mining waste — front of the photograph shows the first dam collapsed completely just after the main shocks (January 14, 1978), RIGHT HAND SIDE shows the second dam collapsed by one of after shocks at about noon in January 15, 1978, and LEFT HAND SIDE shows the third dams with no damages.