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The July 1997 Landslide Disaster at Harubun, Sasebo, Japan

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ABSTRACT

Japan is a country of many geological hazards, including volcanic activity, earthquakes, and landslides. Of these, landslides triggered by heavy rainfall tend to occur during the yearly rainy season from early June through the middle of July. Sasebo City, located in the northwest part of Kyushu Island, is one of the most landslide-prone places in Japan.

Results of a series of investigations done to establish an outline of a landslide and its causes are reported. This information provides some important factors in disaster prevention for the Hokusho-type of landslide. The landslide described here is a typical, secondary sliding Hokusho-type, the result of erosion caused by rainfall on weak strata. It occurred on a gentle, concave hillslope, on which both surface and ground water tend to concentrate.

On the basis of its characteristics, the main causes and mechanism of this landslide is described and some lessons learned discussed. Constructive proposals and countermeasures to be taken to prevent the occurrence of landslides, which are based mainly on an effective drainage system are considered.

1. INTRODUCTION

Heavy seasonal rainfall fell over a wide area of western Japan on July 6, 1997, causing a landslide in the residential area of Harubun-cho, Sasebo City, Nagasaki Prefecture (Figure 1). It was believed to be a small-scale landslide at first because little damage was done to houses. Over time, however, some houses located in the landslide area gradually began to tilt. This landslide therefore attracted much public and media attention despite its small scale and was recognized as a major danger to this densely populated residential area.

2. DESCRIPTION OF THE LANDSLIDE

2.1. Occurrence of cracks and movement of the ground mass

Figure 1 shows the location of the landslide at Harubun-cho, Sasebo City, and the outline of the sliding is shown with detailed topography in Fig. 2. The landslide took place on a gentle hillslope in a landslide-prone area where many potential landslides have been predicted topographically (Nagasaki Pref. Forestry Consultant Co., 1987).

Table 1 lists the damage caused by this landslide. One hundred forty-six persons were evacuated. Heavy rainfall, which started on July 6, 1997 in this region, triggered the landslide at Harubun-cho on the afternoon of July 7. Cracks suddenly appeared on the gentle slope on July 7, indicative that the surface block moved. The landslide was estimated to be about 30m long, and the crack only 20cm wide. At first it was believed to be a comparatively small-scale slide, but further movements occurred in relation to continuous rainfall. As a result, the local government called for evacuation from some houses located on the moving mass, and emergency works such as installing drainage pipes and spreading vinyl sheets to prevent the inflow of rainwater to some cracks were undertaken on July 8. On July 9 measurement of the slide distance was begun using an electro-optical method, and apparatuses to monitor land movement were set up at some points. On July 10, reconnaissance made by the Ministry of Construction confirmed that the moving mass was 40m wide, 60m long and 5–10m deep (Yomiuri Newspaper, 1997). The cracks widened, causing two houses that were displaced more than 1m after the rainfall of July 11 to tilt and come together, causing imminent collapse. Due to continuous land movement, several drainage drillings were conducted as a countermeasure on July 14.

The cracks began to open rapidly at the rate of 2.6cm per hour due to heavy rainfall during the early morning of July 17, and houses in the area were expected to collapse. The local government canceled the residents temporary return home scheduled for the 18th and 19th of July.

The rainfall stopped, and horizontal drilling to drain much of the groundwater stored along the slip plane of 5–10m was

KEY WORDS: landslide, damage survey, land developement, countermeasure works, evacuation.

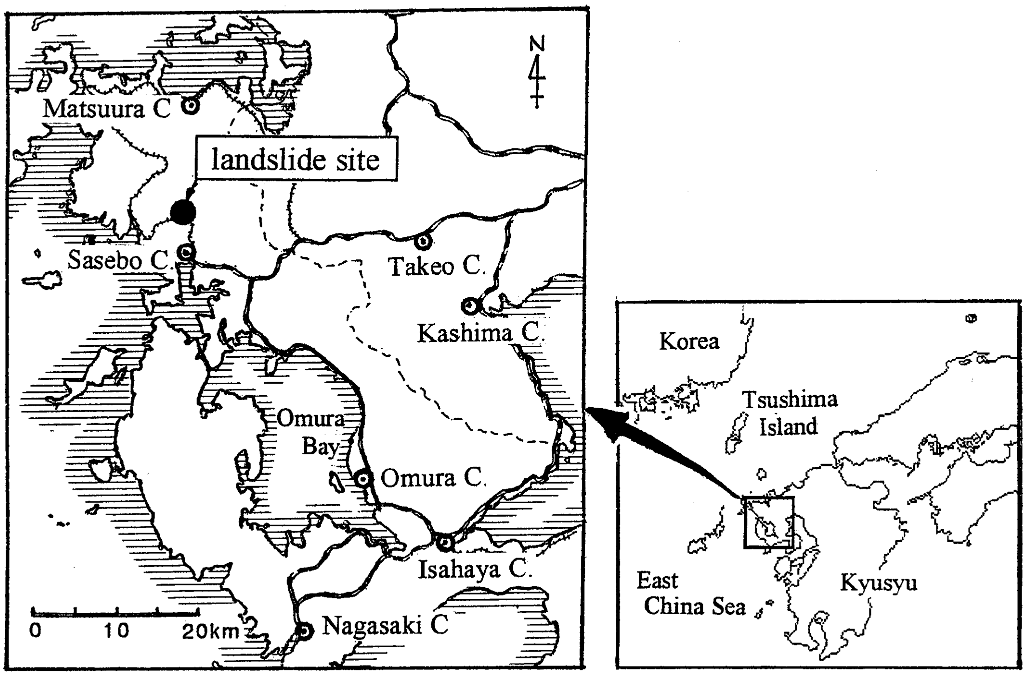

Fig. 1. Site of the landslide.

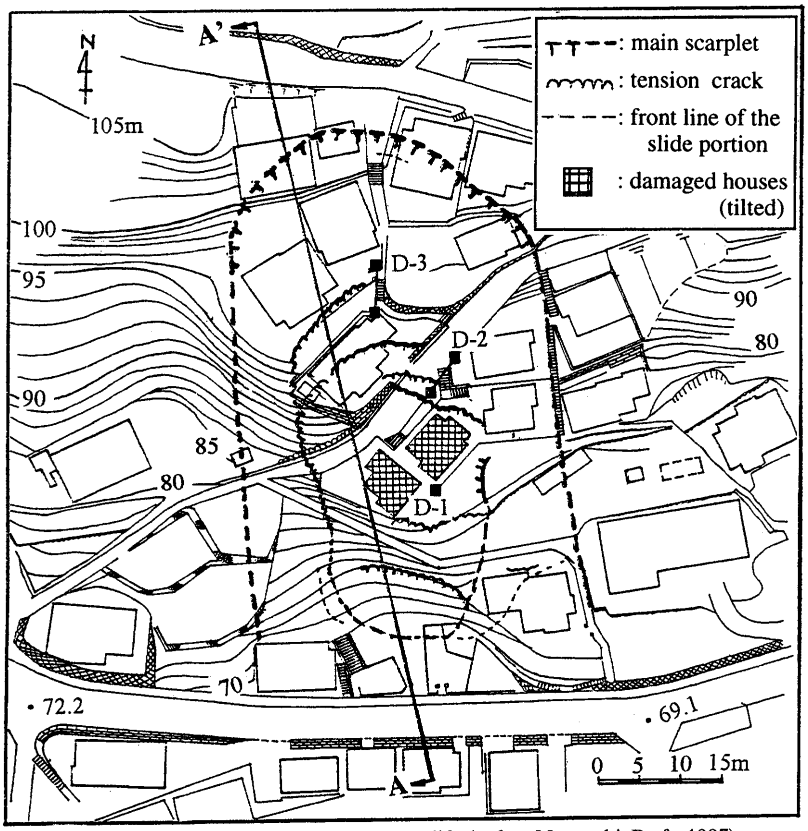

Fig. 2. Outline of the landslide (Modified after Nagasaki Pref., 1997).

restarted on July 18. Horizontal drains 50m long that radiated fanwise were planned from two points in the site. Thereafter, the movement rate decreased as drainage progressed. Three houses, however, had to be removed on July 25 because of expected damage from Typhoon 9709. Complete financial compensation for these damaged houses was made by the companies that had constructed them.

2.2. Scale and estimated slip plane of the landslide

The moving mass is shown in the plan in Fig.2 and in cross-section in Fig.3. The two houses damaged by this landslide are indicated by a hatched symbol. The 40m wide,

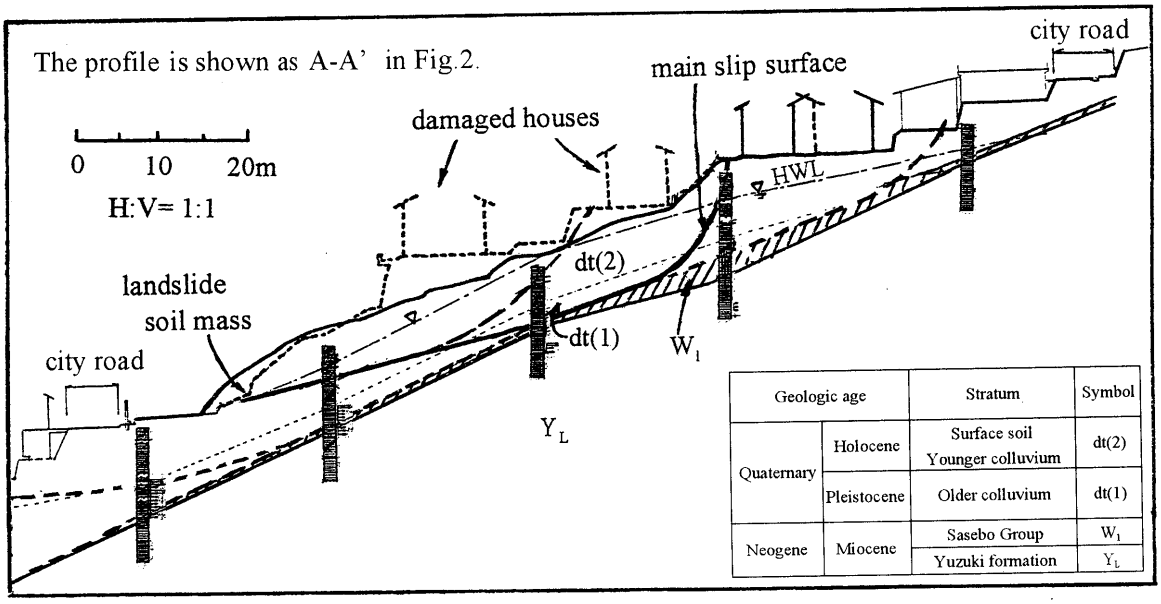

Fig. 3. Profile A-A' of the landslide (Modified after Nagasaki Pref., 1997).

Table 1. Damage and evacuation (Modified after Nagasaki Pref., 1997).

occurrence of landslide		about 13:30, July 7, 1997.
damage	human loss	none
	house damage	completely destroyed ; 3
		partially destroyed ; 0
		partially damaged ; 1
evacuation	based on the proclamation of the evacuation counsel (17:00 July, 24.)	
	warning area	households ; 14 persons ; 46
	evacuation-counselled area	households ; 37 persons ; 100
	after cancellation of the evacuation order (15:00 Aug., 2.)	
	warning area	households ; 14 persons ; 46
	evacuation counsel area	households ; 6 persons ; 16
	after cancellation of warning area (10:00 Sept., 6.)	
	self-imposed evacuation	household ; 1 persons ; 6

60m long, 5–10m deep mass was classified as a shallow type landslide. The configuration of the topography, including the damaged area, is not clear because of the many houses present, but it seems to consist of a gentle concave slope.

The slip plane appears to be circular at the top and flat at the bottom (Fig. 3). According to Varnes' (1978) classification of slope movement, this landslide would be the slump type, a rotational landslide. As shown by the symbol dt(2), the top layer is composed of agricultural soil or soil fill added for the housing development. It is a cohesive, brownish soil containing large fragments of basaltic rocks that is soft and easily punched by a finger. The groundwater level is within the deposits shown in dt(2), 3 meters below ground surface. This was confirmed one month after the sliding.

Symbol dt(1) represents a cohesive colluvium soil, which may be reworked deposits of weathered Pleistocene sandstone and shale, distributed below the ground water level. W_1 is a gravelly cohesive Miocene strata which is markedly weathered. It is about 0.4 meter thick, and is a confined aquifer. This thin layer may constitute the slip plane. Y_L is a solidified deposits composed of chert, sandstone, and a thin coal layer with lignite. The horizontal distribution of these strata, it is not yet clear.

3. INVESTIGATIONS OF THE LANDSLIDE

3.1. The primary investigation

An investigation to determine the outline of the landslide and depth of the slide plane was started on July 19, 1997 after movement had ceased. Because of the danger to the area, local government permission was required to enter it.

Photo 1 shows the two markedly tilted houses on the

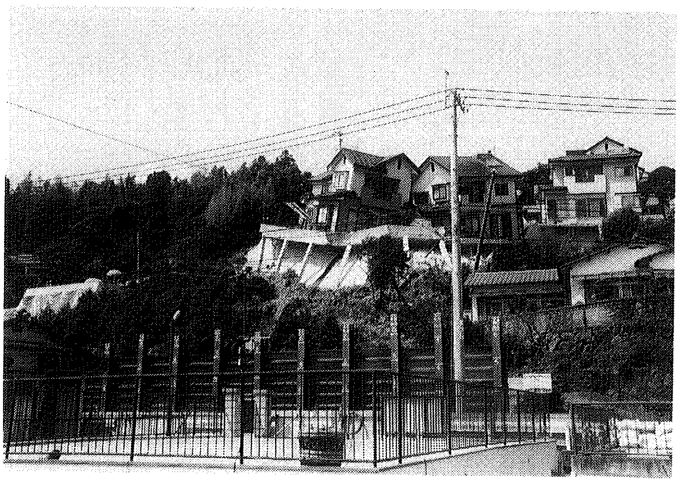

Photo 1. Far view of houses titiled by the landslide (Photo July 19, 1997).

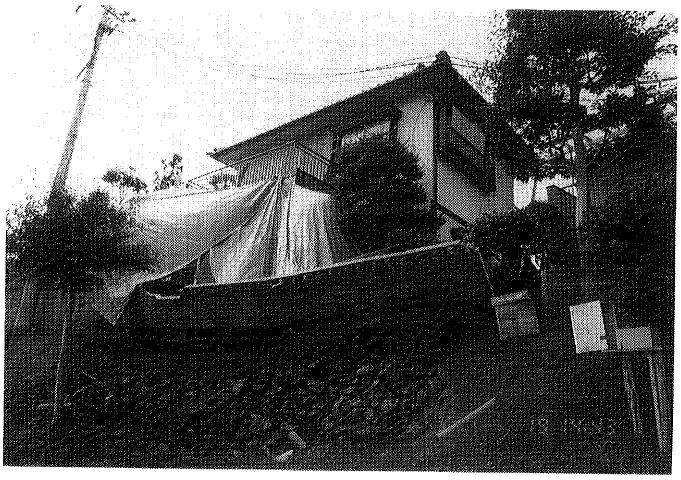

Photo 2. Collapse of a concrete block wall at the top of the landslide (Photo July, 1, 1997).

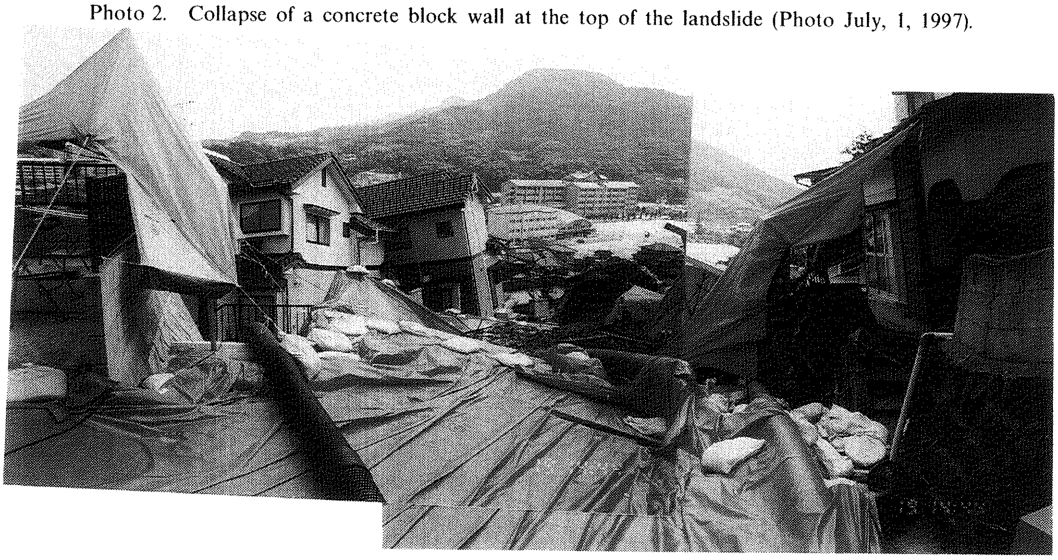

Photo 3. Close-up of the area damaged by the landslide (Photo July 1, 1997).

moving mass. The concrete block retaining wall that supported the damaged houses is cracked and broken into two parts. Below the wall, a temporary protection wall consisting of a steel sheet-pile was built to prevent further downward movement of the houses.

Photo 2 shows the collapse of a concrete block wall at the top of landslide where the main scarp appeared. A pole supporting power transmission lines and a wall have fallen forward and are seriously damaged. A crack about 30cm wide that occurred in the wall has been covered with vinyl sheets

Photo 4. View from below of the collapsed-houses site (Photo Nov. 10, 1997).

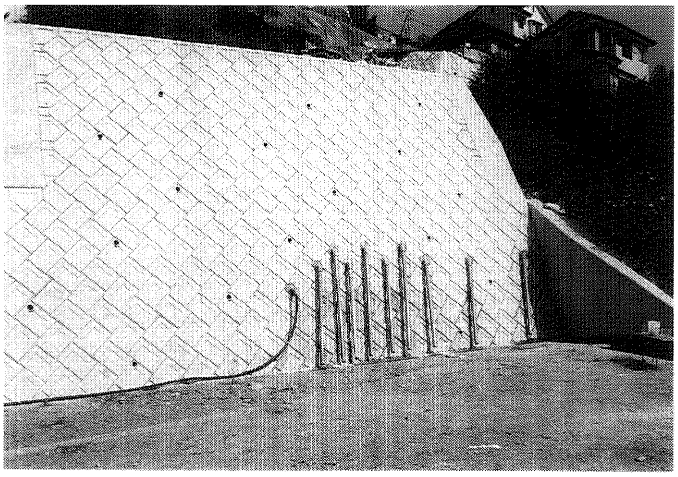

Photo 5. Location of drainage pipes (Photo Nov. 10, 1997).

as protection against seepage of rain water.

Photo 3 shows the inner appearance of the damaged area. Due to the settlement of fill, the two houses at the back have tilted until they are standing side by side. A large pipe was installed on this side to serve as a by-pass drain in place of the former waterway.

3.2. The second investigation

A second investigation was made on Nov. 10, 1997 to assess recovery three months after the initial landslide movements.

Photo 4 shows an upward shot taken from the site of the temporary protection wall. Because of the danger of collapse, the two houses together with a third house located at an upper elevation, a total of three completely damaged houses.

Photo 5 shows drainage pipes installed to reduce the potential of sliding. Although there was fine weather after 9mm of rain on Nov.2, there was still some water outflow from the many drainage pipes.

4. CAUSE OF THE LANDSLIDE

4.1. General

Nagasaki Prefecture, including the landslide site, is a mountainous area underlaid by rock strata that include volcanic rocks, sedimentary rocks of the Tertiary Period, and a crystalline schist. Sliding often has occurred in the Tertiary strata in a characteristic structure capped by jointed basaltic rocks. Landslides of this type are called Hokusho-typed landslides (Land Bureau, National Land Agency, Government of Japan, 1988) and tend to occur repeatedly.

Figure 4 shows a schematic sketch of secondary sliding in a Hokusho-type landslide (Yamasaki, 1966). It occurred in the basalt erosional layer, and frequently along the gentle slope on the glide erosional layer. When rain water reaches the gravel layer of the basalt plateau through the joints within the basaltic rocks, it gushes out at ground surface as seepage. As this usually is followed by softening of the ground, the procedure is called the first landslide. After a first landslide, because of the seepage of rain water inside the soil a second landslide is likely to happen.

The landslide type described in this paper can be classified as the secondary sliding of a Hokusho-type landslide.

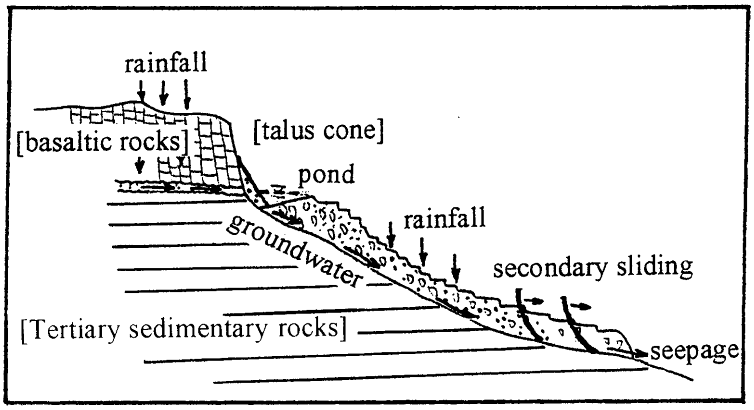

Fig. 4. Schematic diagram showing the sliding of a Hokusho-type landslide (Modified after Yamasaki, 1966).

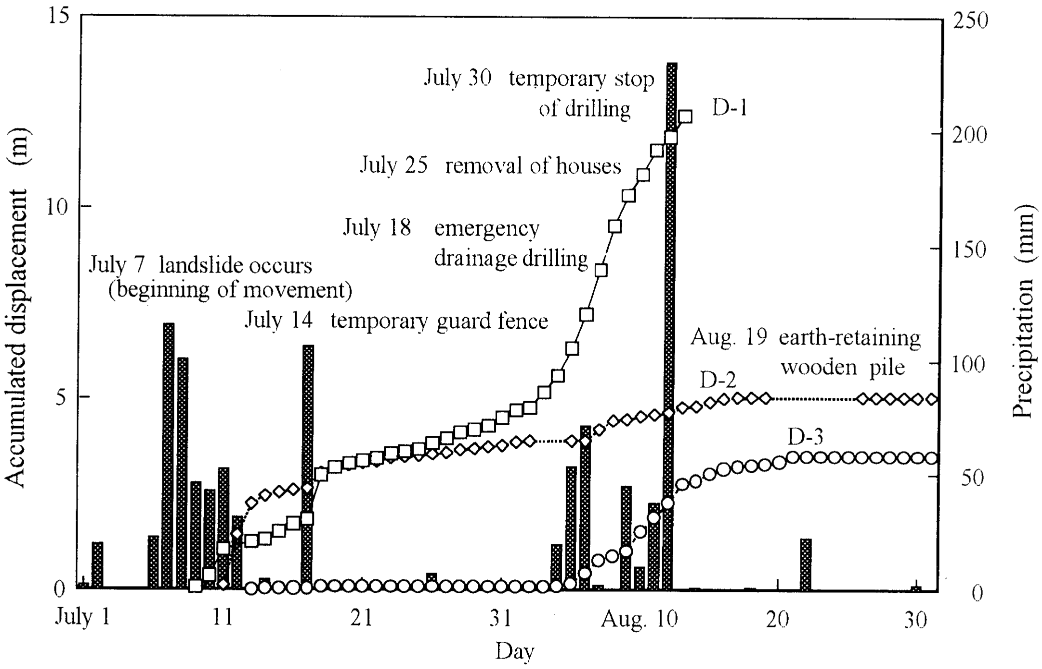

Fig. 5. Relationship between daily precipitation and displacement (Modified after Nagasaki Pref., 1997).

4.2. Primary cause

The characteristics of the landslide and its primary causes were estimated from the topography, geology, results of movement monitoring, and rainfall:

1) The materials in this site are composed of colluvium soil which may be old slid materials.

2) Because weathering and the oxidation process are closely related to ground water, a potential discontinuity plane may exist within the upper part of the movement.

3) The groundwater flows around the boundary between the upper and lower colluvium layers.

4) A groundwater path that separates the sliding masses vertically was detected by measuring the groundwater flow in some bore holes.

4.3. Initiating causes

Figure 5 shows the precipitation before and after July 7, 1997 and the lateral displacement measured when the landslide occurred. Typhoon 9708 traveled north through the East China Sea and crossed north Kyushu on June 28, 1997, 116mm/day precipitation being recorded in Sasebo City (Nagasaki Branch of the Japan Weather Association, 1997). In early July, due to movement of the seasonal rain front from the Tsushima Island Strait to north Kyushu, rainfall became heavy, 410mm being recorded during the 6 days from July 6 to 12 (Nagasaki Branch of the Japan Weather Association, 1997). The maximum precipitation of 20.5mm per hour was recorded on July 7, the day the landslide occurred. Thus, an initiating cause is considered to have been this heavy rainfall. There was no rainfall after July 12.

Figure 5 also shows the accumulated displacement (D-1,

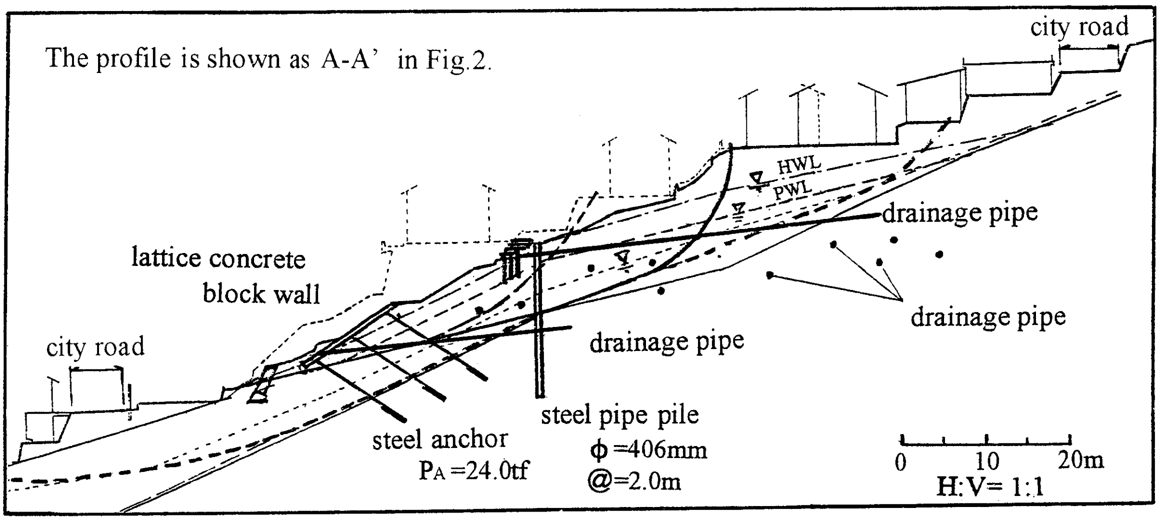

Fig. 6. Works undertaken to control the landslide (Modified after Nagasaki Pref., 1997).

D-2 and D-3) of the sliding soil mass. D-1 is the accumulated displacement measured by the movable pile technique. D-2 and D-3 were measured by inner wire extensometers installed at the points shown in Fig.2.

Displacement clearly was closely related to rainfall. Therefore it is necessary to protect against permeation by rainwater through dt(2) and to discharge the groundwater stored in dt(2).

5. IMPLEMENTED COUNTERMEASURES

Figure 6 shows the results of the landslide-control works. To reduce further movement of the mass, several preventative measures were made based on the designed safety factor of Fs = 1.20. Lattice concrete block walls and steel anchors were installed at the toe of the landslide, and drainage pipes were set so as to discharge water from the soil mass. In addition, steel pipe piles 40cm in diameter were inserted in the middle part of the landslide area to provide passive resistance.

To ensure a design safety factor of Fs = 1.20, drainage drilling was done, and a drainage pipe installed to reduce the groundwater level to about 2 meters. Other countermeasures also were carried out.

6. LESSONS LEARNED FROM THIS DISASTER

Fortunately, no human lives were lost in this landslide, and only three houses were completely destroyed. This shows that much effort should be made to predict the occurrence of landslides and to monitor their movements. The findings of the series of investigations indicate that an integrated monitoring and warning system should be installed in all landslide-prone areas. The main cause of most landslides is the flow of water inside the soil which builds enough hydrostatic pressure to cause the soil to slide. This can be prevented by installing a good drainage system or by preventing water from entering the soil mass by using water-proofing materials on the soil surface. All landslide-prone areas should be immediately designated, and construction permits from the city office should be required before construction activities take place.

The area adjacent to this landslide was classified as steep slope land by Nagasaki Prefecture (Sabo Division, Nagasaki Prefectural Office, 1971), but because no houses had been built in the slide area at that time, that land was not classified as steep slope land. Residents who have lived in the surrounding area for a long time ago appear to have built their homes away from the landslide-prone area, thereby avoiding possible disaster. It would be the best to consult the city office and a design company before building a house in such a slide-prone areas.

Lastly, this landslide raised very important questions, "Are we prepared?" and "What immediate countermeasures and actions should be taken in case of a sudden landslide".

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