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RECONNAISSANCE REPORT ON THE 2000 KOHZUSHIMA KINKAI EARTHQUAKE

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An M_J6.4 earthquake occurred on July 1, 2000 offshore of Kohzushima Island in the Tokyo municipal jurisdiction. Large tremors also were felt on Kohzushima on July 9 and on Niijima on July 15. This is the damage investigation report on the 2000 Kohzushima Kinkai earthquake made by a JSCE reconnaissance team. Earthquake swarms continued near Kohzushima, Niijima, and Shikinejima islands for about three months. A JMA seismic intensity of lower 6 was recorded twice on Kohzushima during July, 2000. An outline of the earthquake and aftershocks and the damage done to civil structures is given. Slope failures, damage to retaining walls and disaster responses, in particular, are focused on.

Key Words : *the 2000 Kohzushima Kinkai earthquake, reconnaissance report, seismic ground motion, damage to civil structures, slope failure, disaster responses*

1. INTRODUCTION

An M6.4(M_J) earthquake occurred at 16:02 July 1, 2000 in offshore of Kohzushima Island. Its epicenter was located at 34.2N, 139.2E. A JMA (Japan Meteorological Agency) seismic intensity of lower 6 was recorded on the island. There was one death (by landslide) and the complete collapse of one shrine. Partially collapsed houses numbered 15.

The Japan Society of Civil Engineers (JSCE) dispatched a reconnaissance team in cooperation with its Earthquake Engineering Committee (Chair as of 2000: Tsuneo Katayama, President of National Research Institute for Earth Science and Disaster Prevention). Four members investigated from July 14 to 17, 2000 (the initial schedule, July 7 to 22, was delayed due to a typhoon). The team consisted of Junji Kiyono (Team leader: Kyoto University), Masakatsu Miyajima (Kanazawa University), Takao Hashimoto (Chiyoda Engineering Consultants Co., Ltd.), and Tomohiro Kimura (the University of Tokyo).

Intense shaking of a JMA seismic intensity of lower 6 also was recorded on Kohzushima on July 9, and the reconnaissance team's mission was to investigate the damage done by the two earthquakes. A seismic intensity of lower 6 (M6.2) also was recorded on Niijima Island during our investigation. On August 18, a seismic intensity of upper 5 (M6.0) was recorded on Kohzushima. Intensities of upper 5 (M4.9), upper 5 (M5.9), lower 5 (M5.6), upper 5 (M4.7) and lower 6 (M6.0) were recorded on July 20, 24, 27, and on August 3 and 18 on Shikinejima Island; upper 5 (M5.6) on July 27 on Niijima Island; and upper 5 (M5.8) and lower 6 (M6.4) on July 30 on Miyakejima Island. Earthquake swarms occurred around the islands continued intermittently through September 2000. The Headquarters for Earthquake Research Promotion of the Japanese Government

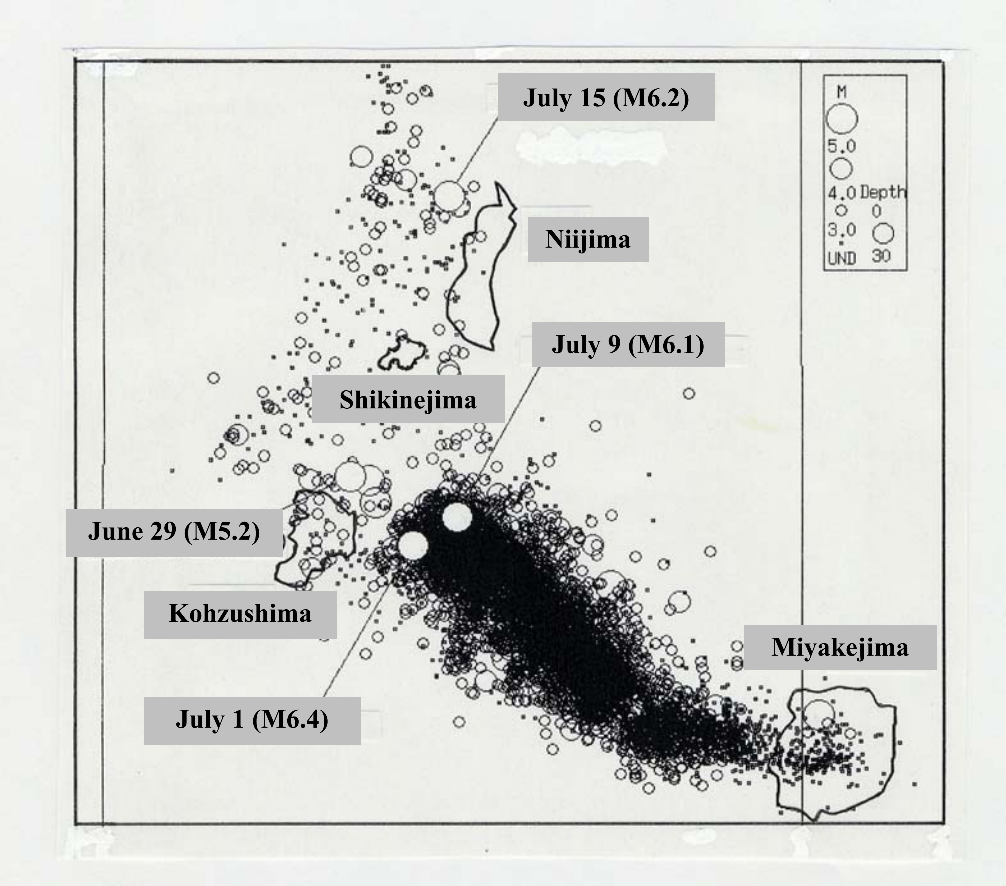


Fig.1 Seismic activities near Kohzushima Island

declared that sequential seismic activities had terminated on October 11, and the local Kohzushima government rescinded its evacuation orders. We here provide an outline of the damage done based on information collected at affected sites.

2. TOPOGRAPHY AND GEOLOGY FOR KOHZUSHIMA ISLAND

Kohzushima, located in the Mt. Fuji volcanic zone, was created by the eruption of a submarine volcano. Its geologic structure consists of rhyolitic lava flows and extrusive rocks and the bedrock is first-period lava. Plagioclase rhyolite and hypersthene are present along its coastline.

Second-period lava consisting of pumice and biotite strata is covered by plagioclase rhyolite from the third-period lava. The upper stratum is composed of rhyolitic volcanic gravel, sand, and lava extruded in the eruption of Mt. Tenjo (574m), located at the center of the island, in A.D.838. North and south of it, respectively, are Mt. Kobe (268m) and Mt. Takoh (304m). A dale was formed between Mt. Chichibu and Mt. Takoh, and a village spreads out in the dale down stream of the Kohzu Marsh. The coastline is almost completely precipitous cliffs. The few beaches formed are white sand ones.

3. EARTHQUAKE AND STRONG GROUND MOTION

Offshore of the Miyakejima, Niijima, Shikinejima, and Kohzushima islands, continuous earthquake swarms occurred starting on June 26, 2000, and more than 6,000 earthquakes (including 721 felt earthquakes) were recorded on June 27. A seismic intensity of lower 5 was recorded on 29 June on Kohzushima. Two days later (July 1 at 16:02) an M6.4 earthquake occurred at 34.2N, 139.2E at a depth of 10km. The seismic intensity at Kohzushima was lower 6. More than 1,000 earthquakes (including 100-300 felt ones) per day occurred thereafter, and an M6.1 earthquake was recorded on July 9 at 34.1N, 139.3E at a depth of 10km, and a second seismic intensity of lower 6 was recorded at Kohzushima. The sequential earthquake swarms were induced by magma beneath the eastern sea off of Kohzushima[2]. **Fig.1** shows seismic activities reported by the Japan

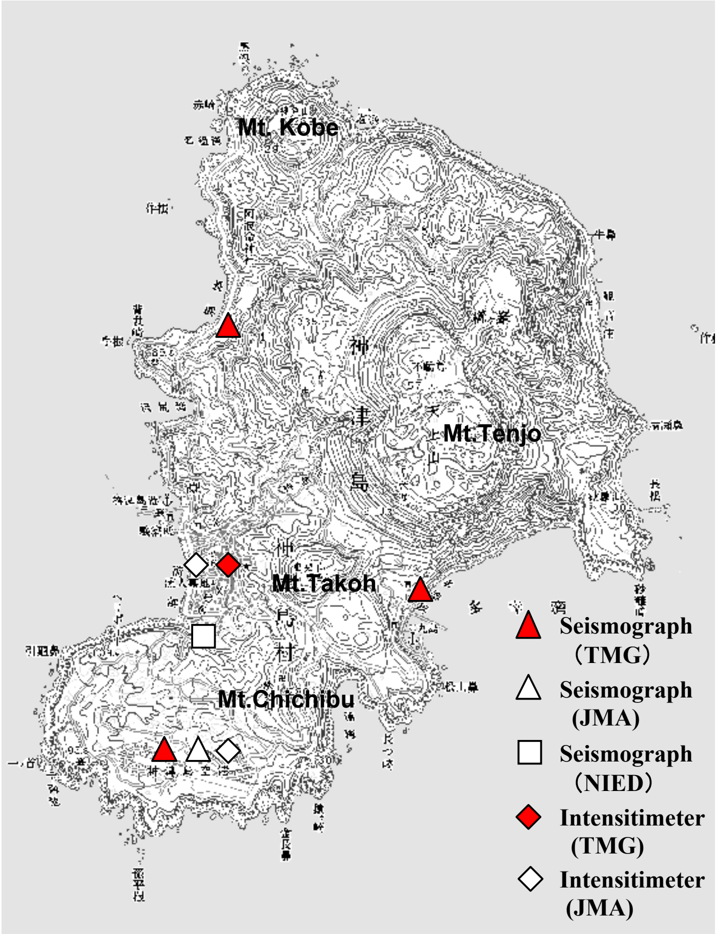


Fig.2 Locations of seismographs and seismic intensity instruments

Meteorological Agency (JMA) around Kohzushima Island from June 29 to July 15.

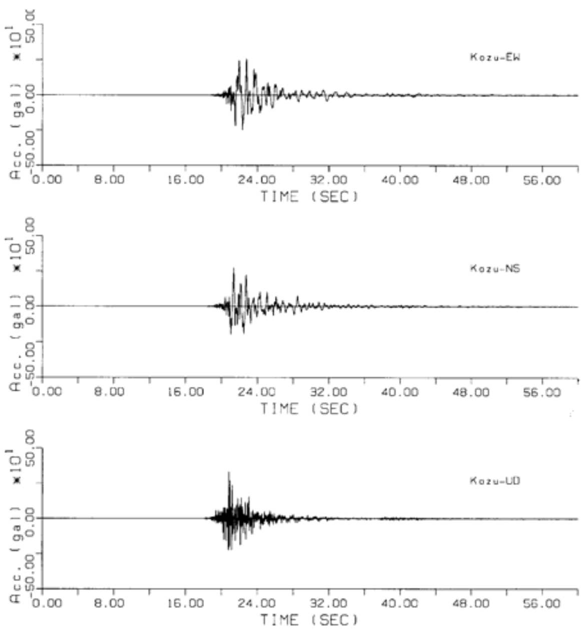
Totally, five seismographs and three seismic intensity meters have been installed in Kohzushima by the JMA, Tokyo Metropolitan Government (TMG), and the National Research Institute for Earth Science and Disaster Prevention (NIED) (**Fig.2**). The JMA seismograph is located at the airport together with a seismic intensity meter. A seismic intensity meter also is in the local government office, and the intensity recorded there is the authorized seismic intensity. The TMG seismographs are at the Nagahama Dam located in the northeast part of the island, at Kohzushima Airport, and on the mountainside near Takoh Bay. Records could not be collected from the instrument near Takoh Bay because of line trouble. The NIED seismograph is installed in an observation room near Kohzu Junior High School.

Earthquake records obtained by the TMG at the village office are shown in **Fig.3** with their Fourier spectra. Only base-line corrections were made to these records. Peak accelerations for the EW, NS, and UD components respectively are 256, 273, and 334gal. The instrumental seismic intensity calculated from these three components is 5.2. Predominant frequencies based on the Fourier spectra are 1-2 (Hz) for the horizontal components and 6-7 (Hz) for the vertical component. For reference, the peak accelerations for the July 15 earthquake, recorded on Niijima, were 422gal (NS), 500gal (EW), and 509gal (UD) .

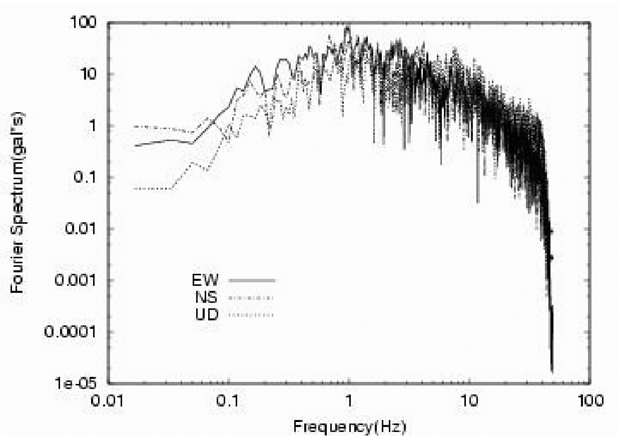
4. OUTLINE OF DAMAGE DONE BY THE EARTHQUAKE AND A TYPHOON

Two major earthquakes, which caused casualty and damage to structures, are focused on. Rain often become a direct and/or indirect trigger of a slope failure. We had much rain in the island on July 8 because of the typhoon. On the contrary, the strong motion sometimes loosens the soil. That increases the chance of the slope failure. We here describe an outline of the damage due to the earthquakes and the typhoon.

(1) Damage done by the Earthquake of July 1, 2000



(a) accelerograms



(b) Fourier spectra

Fig.3 Observed records and their Fourier spectra at the Kohzushima village office July 9, 2000.

There were no injuries, but one person died when his car was engulfed by debris from a slope failure. Ten dwellings and 2 other buildings/structures partially collapsed; 9 concrete block walls and 19 roads were damaged; 27 slopes failed; and the water supply to 18 households was cut off.

(2) Damage done by the Typhoon of July 8, 2000

Typhoon 0003 struck Kohzushima directly on July 8. Damage to slopes was extensive due to the heavy rainfall from the typhoon because the ground had been loosened by the continuous earthquakes. Ten large slope failures (height, H, of more than 10m), five intermediate slope failures (H<10m), and one rock fall occurred. Three buildings (one shrine and two dwellings) were completely destroyed by moving soil. The base of one concrete retaining wall collapsed, and one concrete block wall was damaged. Three retaining walls and one house foundation cracked. All that damage occurred because of the earthquake that had struck a week previously.

(3) Damage caused by the Earthquake of July 9, 2000

Additional damage detected included 6 house-wall cracks, 5 slope failures, 3 rock falls, 5 stone-wall cracks, and 1 break of water pipes.

5. SLOPE FAILURE

Slope failures were concentrated on the cliffs bordering the island, the outskirts of the village, and along municipal roads. The surface layer of the soil on Kohzushima, composed of volcanic gravel, sand, and lava from the Mt. Tenjo eruption, is easily eroded. Due to the cracking and dislocation of concrete frames constructed for slope protection during the earthquake, slopes were at risk of retaining so much rain water that should a typhoon arrive, a large failure might occur. Emergency restoration activities for preventing a secondary disaster were made only in areas in which evacuation orders or directives had been given. In the 1995 Hyogo-ken Nanbu earthquake, there were many instances in which slight damage to a slope resulted in large slope failure because of delays in emergency restorations. Restoration is very difficult when earthquake swarms are continuous, therefore pre-earthquake countermeasures are needed to provide strengthened roadsides that protect against slope failure and to construct an alternative route to prevent isolation of inland areas.

Soils at sites where most of the slope failures occurred, along Maehama Beach, Sawajiri Bay, and Nagahama Beach (**Photo 1(a)**), mainly are composed of pyroclastic flow sediments and rhyolitic rocks with many cracks. Traces of many previous slope failures can be seen along the pyroclastic cone of Mt. Tenjo, and a huge slope failure was caused by the July 2000 earthquake (**Photo 1(b)**).

Methods used to protect slope surfaces on the island:

(1) Natural slopes: As the surface layers on this type of slope were thin and steep, shaking easily caused even slopes with trees to fail.
(2) Mortar (Concrete) blasting: Cracks in and separation of the mortar from slopes were caused by the strong earth pressure produced by the earthquake.

(a) Slope failure along the road from Sawajiri Bay to Nagahama Beach

(b) Slope failure of the pyroclastic cone of Mt. Tenjo facing Takou Bay

Photo 1 Slope failures on Kohzushima Island

Photo 2 Failure of molded blocks used for slope protection (Miura Harbor)

Photo 3 Collapse of a stone masonry retaining wall

(3) Concrete lattice frame: Concrete lattice frames were constructed by spray blasting with concrete or borrow material. This protection method worked better than methods (1) and (2). Overhanging areas along the coast, however, sustained severe damage due to the surface slope failures (**Photo 2**).
(4) Concrete lattice frame with ground anchor: This method is used on slopes close to such important structures as a school or hospital and on river banks as well. No failures occurred, and slope safety was preserved.
(5) Rock fall protection net: Protection nets were installed along the island's circuit road. Some were broken by huge rock falls. Their posts and anchors could not resist such strong forces.

6. DAMAGE TO BRIDGES AND ROADS

There are five road bridges on the island. None sustained severe damage, but a small offset of several centimeters was generated between bridge beams and abutments. Most of the damage done to roads was caused by slope failures and the collapse of retaining walls (**Fig. 4**). Large cracks were present at many places on the road along the dale of the Kohzu Marsh and on the circuit road.

7. DAMAGE TO RETAINING WALLS

There are many retaining walls on Kohzushima Island because of the limited amount of level ground. Most are stone masonry constructions. The following are the types of retaining walls and typical damage incurred:

(1) Stone masonry retaining walls: Stone blocks for these masonry walls are quarried on the island. As these stone masonry retaining walls are very

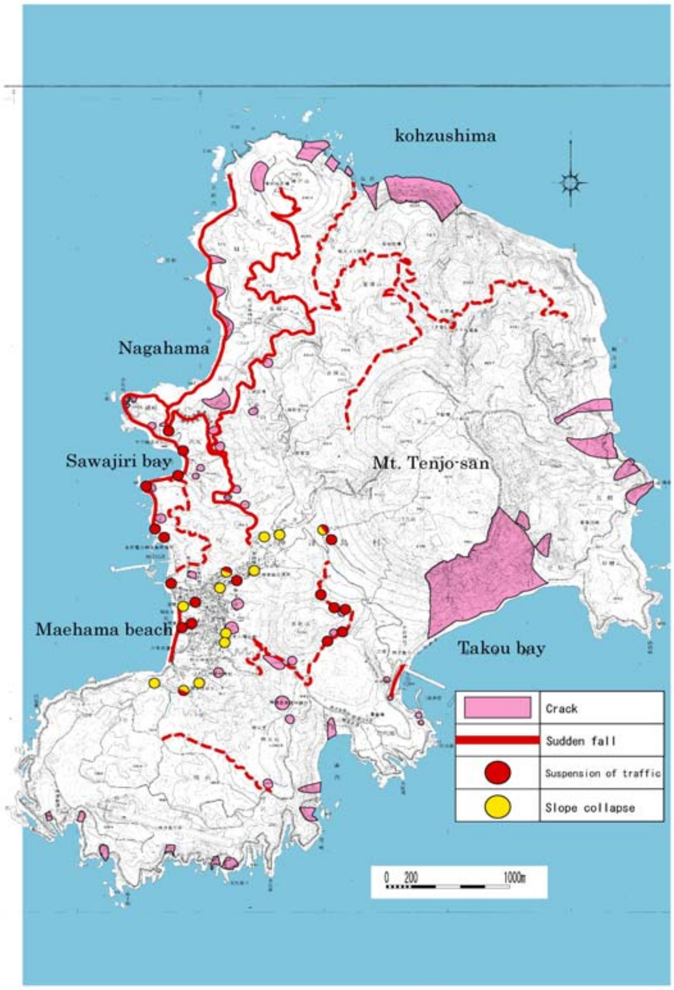


Fig.4 Sites where slope failures occurred

old, previously degraded ones were re-damaged by the earthquake's force. Longitudinal, transversal, and diagonal cracks, as well as bulging and collapse were all generated. A corner of the retaining wall in **Photo 3** shows severe damage.

(2) Gravity retaining walls: This type of retaining wall in combination with a rock fall protection fence was installed at places where countermeasures against steep slope failure had been undertaken. No damage occurred to this type of the retaining wall.

(3) Terre Armee retaining walls: Terre Armee is an earth reinforcement method. This type of retaining wall was present at several sites in the southern part of the village. There was almost no damage Terre Armee walls, but an old blasted part of the basement of one showed slight damage. Terre Armee reinforcement also was feasible and stable against earthquake ground motion in the 1995 Hyogo-ken Nanbu earthquake. The degree of damage done in that earthquake was that a corner of the concrete skin was chipped.

(4) Reinforced concrete block walls: Reinforced concrete block walls were few. Many non-engineered concrete block walls collapsed because of strong ground motion.

8. DAMAGE TO LIFELINES

Damage to drinking water supplies consisted of the breakage of 35 supply pipes and 2 transmission and distribution pipes. The supply pipes damaged were fabricated of vinyl chloride and had diameters of ϕ20-25mm. The damaged transmission and distribution pipes were iron or ductile cast iron, both with a diameter of ϕ100mm. The population of 2,500 is served by the small water-supply system of the village and the planned maximum water supply is 4,100m^3/day. Spring water from an aquifer also is used. Eighteen households experienced water cut-offs after the July 1 earthquake, but daily life in the village was not greatly affected by the interrup-

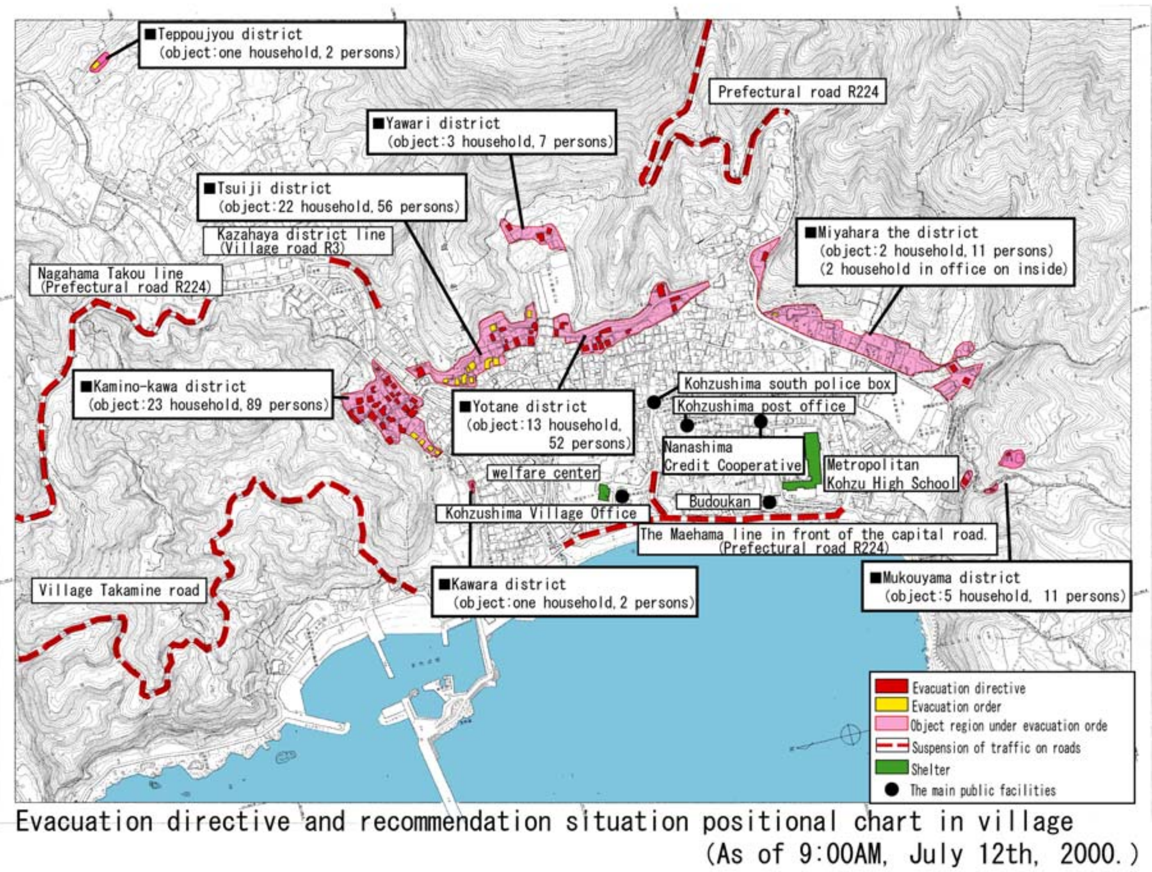


Fig.5 Places where evacuation orders and directives were issued

Table 1 Changes in evacuation orders and directives

	4:00pm, July 1	8:30am, July 7	10:00am, July 9
Evacuation orders	29 households 106 persons	31 households 98 persons	51 households 161 persons
Evacuation directives	34 households 101 persons	285 households 851 persons	14 households 50 persons
Evacuation shelter	13 households 34 persons	69 households 133 persons	28 households 72 persons
Evacuation off- island	53 persons (during 2 days)	suspension	179 persons

tion.

Electricity cut-offs occurred in the northern part of the island just after the July 1 earthquake. Seven households, including a special-care home for aged persons, were effected, but they overcame the difficulty by using private power generation. The effect of the interruption to the electricity supply was minimal because there were few dwellings in the northern part of the island. Temporary cut-offs also were caused by earthquakes on July 7 and 13.

Difficulties in daily life mainly were caused by loss of community functions due to damaged roads. The garbage-burning plant, bulk-refuse dump, and human waste treatment plant are all located in the northern part of the island. Roads to these facilities were dislocated by rock falls, slope failure, and other calamities. The local government dealt with one inconvenience by establishing a temporary refuse dump in the southern part of the island near the airport.

No damage to telecommunication facilities was reported. As a sewage line was currently under construction, and the gas used was propane gas, no damage was incurred by these lifelines.

Photo 4 The Kohzushima Village Office, in which the disaster countermeasures headquarters was set up

9. DISASTER RESPONSES

(1) Evacuation orders and directives

About 400 people out of the total population of 2,277 had been evacuated from the island as of July 7. **Table 1** shows the time history of the number of households and persons receiving evacuation orders and directives. The evacuation situation as of 9am, July 12 is shown in **Fig.5**.

(2) Response just after the earthquake

On July 1, thirty-three people were evacuated to the Welfare House behind the village hall, fourteen remained there as of July 15. This Welfare House constituted the main shelter although a gym at Kohzu High School also was designated as a refuge. Evacuees were confined to a wide 78-mat room, in which there were 3 beds for handicapped, aged evacuees.

There was a disorganized rush to the village hall in the evacuation of July 1, whereas there was a well-organized, speedy response on July 9 owing to people's experience of the previous earthquake. Village officials concerned with welfare affairs were sent to four houses to assist in the evacuation of elderly residents, indicative that the local government well understood the circumstances of the citizens. The Women's Society of the village distributed cooked rice to the evacuees three times a day for 3 to 4 days after July 1. Distribution twice a day was continuing as of July 16. As most evacuees were aged people who were concerned about their health, 4 persons, including two nurses, were dispatched by the Ohshima branch office of the Tokyo Metropolitan Government to care for them two or three times a day for about two weeks. The two doctors and two nurses working on the island often conducted medical checks assisted the evacuees. Sufficient mental help however, could not be provided because of continuing earthquake swarms.

(3) Responses of people vulnerable to the disaster

The steep topography hampered the movement of the elderly residents. They must traverse steep slopes even when walking around in their yards. Drills on what to do in an emergency therefore are indispensable for disaster prevention. People older than 65 accounted for 22.5% of the island's population as of March 1999. The respective numbers of fire rescue workers, fire-fighting vehicles, and ambulances available are 228, 17, and 1. Disaster prevention drills are held every two or three years, but they mainly focus on evacuation in case of volcanic eruption. An emergency assembly drill for village officials is held once a year. There was growing motivation among citizens and village officials for the promotion of these kinds of drills in order to avoid human problems and errors in a future earthquake.

A special-care house for aged persons is located in the Sawajiri area, in which about 50 persons, including 30 handicapped ones, were living. The earthquake severely damaged the 3km-long prefectural road from Kuwasawa to Nagahama, including the Sawajiri strip. The road became filled with fallen rocks and soil, severing the connection between the village center and the care house. This interfered with the transmission of daily goods and the commuting of the home's personnel. A power generator, fuel, propane gas, foods, etc. had been assembled at that facility in case of disaster. Ships can not always dock at the island in winter because of stormy weather and high seas, therefore emergency stocks need to be increased in preparation for a disaster. Because of commuting difficulties due to road damage and the exhaustion of staff members, the village government requested volunteer workers be sent by the Welfare Committee of the Tokyo Metropolitan Government. Consequently, 3 groups of volunteers (each group 6 persons) were dispatched to the care house in shifts lasting 3 or 4 days. Some residents of the care house became upset due to the marked change in their environment. Psychological stress counseling therefore will be needed when coping with a future disaster.

(4) Future countermeasures for disaster responses

Earthquake swarms with seismic intensities of lower 5 or more continued on Kohzushima, Niijima, and Shikinejima islands after the reconnaissance period. The local governments not only made disaster responses but undertook preparations against future earthquakes (**Photo 4**). Residents appeared very exhausted by the continuing series of earthquakes. Village officials actively worked, made adequate judgments of what should be done, and set up a counseling corner in the village hall. They also tackled reconstruction problems affecting agriculture, fishing, and minor enterprises. Periodic evacuation focused on the elderly, stocking goods against times of emergency, and adequate psychological stress care are needed not only for these disaster victims but for preparedness against future disasters.

10. CONCLUDING REMARKS

We here reported an outline of the damage done based on information collected at affected sites. Especially two major earthquakes (July 1 and 9) that caused casualty and damage to structures were focused on. Results and findings of the reconnaissance activities on the 2000 Kohzusima Kinkai earthquake, and issues to be solved:

(1) It took three months for the sequential earthquake swarms which occurred near the islands of Kohzushima, Niijima, and Shikinejima to abate. Kohzushima Island, in particular, sustained severe damage owing to two intensity 6^- earthquakes that occurred during July 2000.

(2) Peak accelerations for the July 9 earthquake obtained by the Tokyo Metropolitan Government were 256gal (EW), 273gal (NS), and 334gal (UD). The predominant frequency was 1-2 (Hz) for the horizontal components, a severe frequency range for general structures.

(3) As the surface soil layer on Kohzushima is composed of volcanic gravel, sand, and lava produced by the eruption of Mt. Tenjo, it is easily eroded. Many slope failures and rock falls were triggered by the strong seismic loads that acted on the steep slopes and their rhyolitic rocks.

(4) Roads reconstruction was difficult because of the continuous earthquake swarms. Future earthquake countermeasures needed are aseismic reinforcement of important town roads in order to prevent slope failures, and construction of an alternative route to avoid isolation of inland areas.

(5) As level areas are few due to the steep topography, retaining walls were present in many places. Most of them were stone masonry constructions. Many cracks, bulges, and collapses were generated. Deterioration of the retaining walls due to age was another reason for their being damaged.

(6) Damage to the drinking water supply consisted of the breakage of 35 supply pipes and 2 transmission and distribution pipes. Because of speedy restoration the daily lives of residents of the village, however, were not much affected by the water cut-off.

(7) A special-care house for aged persons, located in the Sawajiri area, serves about 50 persons, including 30 who are handicapped. It became isolated after the earthquake on July 1 because the prefectural roads were severely damaged by rock falls and slope failures. Periodic evacuation drills focused on the elderly, the stockpiling of goods against emergencies, and the adequacy of psychological stress care need to be improved.

(8) The island sustained both direct physical damage and indirect damage to its agriculture, fishing, and minor enterprises which support the lives of its residents. The tourist business also received a serious set back due to continued earthquake activity. It is important to help the islanders and to guarantee their livings by means of self-, mutual-, and pubic aid.

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REFERENCES

1) Tokyo Metropolitan Government: About the response of the headquarters for countermeasures against disaster of the TMG, No.198, 2000 (in Japanese).
2) Japan Meteorological Agency: About the earthquake near Niijima and Kohzusima islands, description for the press conference, 9:30am, July 24, 2000 (in Japanese).
3) Japan Meteorological Agency: About the earthquake near Niijima and Kohzusima islands, description for the press conference, 00:30pm, July 15, 2000 (in Japanese).
4) National Research Institute for Disaster Prevention: Kyoshin Net (K-net), http://www.k-net.ostec.or.jp/k-net_docs/kyoshin.html (in Japanese).
5) Tokyo Metropolitan Government: About the response for the earthquakes near Niijima and Kohzusima islands, http://www.metro.toko.jp/miyatop.htm (in Japanese).

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