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The seismic microzoning of source region based on the seismic intensity of 1990 Philippine earthquake (M = 7.8)

T. Mochizuki,[1] N. Abeki,[2] T. Enomoto,[3] H. Ishida,[4] H. Takida,[5] Y. Saito,[6] Y. Nakajima,[2] T. Kobayashi[2] (Japan)
R.G. Valenzuela,[7] N. H. Angeles,[8] B. D. Verdejo,[8] A.G. Lanuza[9] & N.R. Soqueño[10] (Philippines)

ABSTRACT : The large scale damage were happened at many cities in the 1990 July 16th Philippine Earthquake. We made the questionnaire survey in the source region of this earthquake including the five provinces (Nueva Ecija, Nueva Viscaya, Benguet, La Union and Pangasinan Prov.) and five main cities (Baguio, Dagupan, San Carlos, Cabanatuan and Quezon City) in order to evaluate the seismic intensity (MM Intensity Scale) and its distribution. The objects of this paper are to make clear the seismic intensity distribution and to make the seismic microzoning map of investigated source region.

1 INTRODUCTION

The Philippine earthquake hit Luzon Island on July 16th,1990. With a magnitude of 7.8 it is among the world's largest earthquakes to occur on land. The affected area covered 120 kilometers. Left lateral strike slip faults caused a horizontal dislocation extending to 5.0 m. The fault appeared between Gabaldon in Nueva Ecija state and Imugan in Nueva Vizcaya state. This fault is considered to be related to the Digdig Fault, which belongs to the Philippine Fault System. This Philippine Fault System runs through central Luzon to the southeast and northwest.

Unfortunately, this earthquake has not left any record of strong motion seismogram in the seismic source region. This disaster research has to be carried out in the absence of this critical information. Compared to the 1985 Mexico earthquake and the Loma Prieta earthquake we are faced with a significant obstacle in doing this disaster research. The main purpose of this research is to predict the intensity of seismic motion and its effects as accurately as possible;, and try to extract some information in the absence of a strong motion seismographic record. Previous earthquake research has confirmed there are various differences within damaged areas. Even in relatively small areas the extent of damage varies. This earthquake also indicated a similar phenomenon. Therefore, we are aiming to find out the most accurate extension of the motion intensity, and, try to construct a seismic microzoning map.

This research was carried out by the second Philippine damage investigation team by the Architectural *Institute of Japan (1991).*

2 EARTHQUAKE AND DAMAGE DESCRIPTION

The U.S. Geological Survey (USGS) indicated that the earthquake's time of origin was July 26th, 7:26 U.T. Local time was 16:26. USGS said the epicenter of the quake was 110 km. north/northeast of Manila, near Bongabon (north latitude 15.7°, east longitude 121.2°). The depth of source was 25 km, magnitude of 7.8. Strong after-shocks were reported, which were 6.1 and 6.6 in magnitude {recorded at 18:06 and 21:14 on the 17th (UT)}.

Not only in Nueva Ecija and Nueva Vizcaya but in Benguet, Pangasinan, Tarlac, and La Union damage took place. Two thousand people died and thirty-five hundred were injured. Twenty-two thousand buildings were destroyed. Total number of evacuees reached 1,600,000. Though there was damage in a wide range of area along this fault, it was most heavily concentrated away from the epicenter { Baguio in Benguet, Agoo and Aringay in La Union), located near the end of the fault. Reinforced concrete hotels were also damaged. There were many office and university buildings damaged or destroyed. In the mountainous parts of Nueva Ecija, Nueva Vizcaya, and Benguet, numerous landslides occurred and major roads were blocked, which caused a suspension of rescue recovery. The alluvial soft zone of the coastal side of Lingayen Bay experienced liquefaction ; especially at Dagupan city in Pangaisinan. Buildings and pier supports were damaged. Also some bridges were ruined.

3 INTENSITY ESTIMATION BY QUESTIONNAIRE SURVEY

3. I Survey Description

The format of 34 item questionnaire was constructed by Kagami and Murakami (1990). Questions related to: person's location at moment quake occurred; sensation of quaking (i.e. conditions of furniture inside house);

description of damage to buildings; condition of ground failure.

The survey was carried out from the nine day period from September 20th to the 28th of 1990. All survey materials were collected within one month. Participants were mainly teachers from public elementary schools (and partially junior and high schools). Distribution was facilitated principally through the city regional director or the school board superintendent. Distribution to the teachers at each school was assisted through the principals. Collection was through reverse order, and then mailed through Japan.

Philippine elementary school is compulsory. The scale of the school is rather small but in numerous number. The number of teachers differ in urban and rural locations. Rural schools contain six to seven teachers. Urban schools contain on the average around twenty or more. Surveys were distributed to an average of ten or fifteen teachers.

The district distribution is described in Figure 1 {Benguet, La Union, Pangasinan, Nueva Ecija, Nueva Vizcaya}. These elementary schools are basically under the supervision of the school board. Although Baguio, Dagupan, San Carlos, and Cagbanatuan have modified school boards, the same distribution methods were used in these four cities. In Quezon, near the capitol of Manila, surveys were distributed through the PHIVOLCS staff.

By using the method in section 2, we distributed 6000 surveys from Japan, and 14000 printed from the

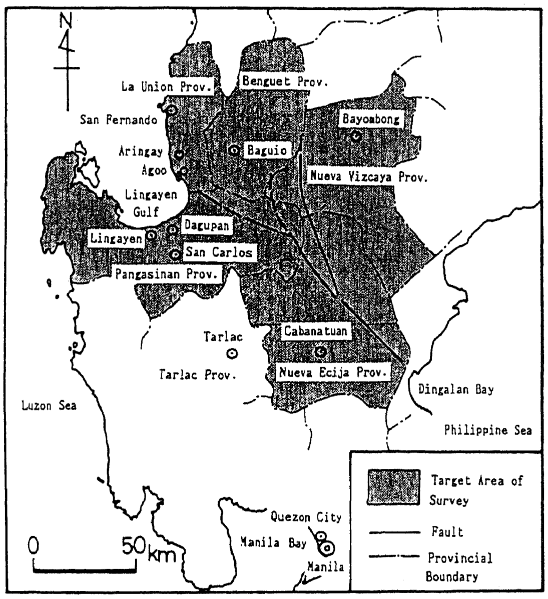


Fig.1 Target area of this survey for the investigation of seismic intensity distribution.

Table 1 Distribution and collection of questionnaires.

Survey Area	Number of Distributed Sheets	Collection
■ Benguet Province (Included Baguio City)	3,000	Completed
■ Pangasinan Province (Not included Dagupan and San Carlos City)	4,304	Completed
■ Nueva Ecija Province (Not included Cabanatuan City)	5,260	Completed
■ La Union Province	3,130	Completed
■ Nueva Vizcaya Province (Requested by mail)	2,000	Not yet
□ Dagupan City	400	Completed
□ San Carlos City	468	Completed
□ Cabanatuan City	705	Completed
□ Quezon City (Near Metro Manila)	200	Completed
● P.I.A	1,360	Completed
Total Number	20,827	

■ : Province
□ : City
● : Philippine Information Agency

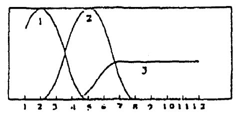
Philippines. The current status is reflected in table 1. Thus far surveys have been collected from four states and five main cities, except Nueva Vizcaya. Nueva Vizcaya is located over the fault and, because of damage to the transportation network, we have been unable to distribute and collect the materials. However, the Philippine coordinators continue to help in this manner. An average of 80 percent of the materials have been collected, except Vizcaya.

3.2 Method of Seismic Intensity Estimation

Among the 34 survey questions there are 21 items related to intensity estimation. Kagami and Murakami are examining the intensity coefficients related to these questions[8]. Through the collected surveys, in order to evaluate the Modified Mercalli Intensity Scale (MM), they are applying fuzzy theory for the intensity coefficient categories. As a result of this method we are more likely to obtain accurate intensity estimates. Through these procedures we are more likely to arrive at a more extended approximation of the membership rating. The membership function is described by a quadratic curve. Z function shows the smaller intensity and S function shows the larger intensity. Canonical P function is a broader measure. Regarding the Z and S functions, the border intensity measurements are emphasized.

Table 2 shows the general relationship of the questionnaire items and the categories. Each questionnaire item contains categories to be selected. The participant chooses from these categories. For each item and

Table 2 List of item category and membership functions.

Item	Category	Membership Function
otehrs fell	1:few 2:many 3:all	
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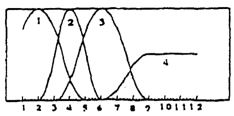
hanging objects	1:no swing 2:slight 3:a lot 4: fell	

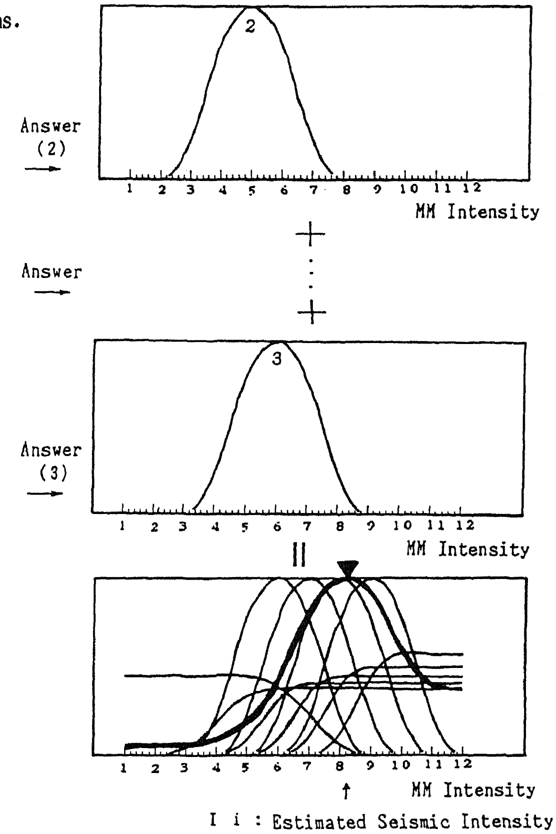


Fig.2 Estimation of seismic intensity by fuzzy intensity calculation method.

category, the intensity coefficients are shown, as in Figure 2. Illustrated in Figure 2 is the total addition of the distribution of the membership functions related to the item categories. So, the largest concentration number from the total distribution is the most likely intensity from the participant responses (Ii Survey Intensity).

One method for estimating the representative seismic intensity is by finding the maximum number of the distribution using the total number of participant responses. From one participant's response an estimate of the intensity was obtained. Then a group intensity method (formula 1) was used with the participant's intensity response.

$$\text{representative seismic intensity} = \frac{\Sigma I_i}{N} \quad \cdots\cdots\cdots (1)$$

I_i: intensity from each survey answer
N: number of participants

By this method the group seismic intensity was obtained from the school, cities, municipalities and states. Each was categorized.

4 ESTIMATION OF INTENSITY

Each city's average intensity was obtained by the method in 3.2. A map of the seismic intensity distribution was completed by district, city, and state. Participation varied according to district. The participants' maps accuracy may be in question. Despite these difficulties, it is possible to make estimates because the responses are highly concentrated in various places and number of participants is large.

4. 1 Intensity of Affected Cities

Table 3 shows the estimation intensity of the affected cities (within the survey's area). To get the average intensity for each city there was sufficient data. The largest average intensity (IMM) is 10.7 in Agoo. Next highest intensities were: 9.8 (Aringay); 8.8 (Baguio); 8.7 Dagupan; 7.8 (Cabanatuan); 7.7 (San Carlos); 6.5 (Quezon, located north of Manila). Judging from the damage these estimates appear highly accurate. In the case of Dagupan, which experienced heavy liquefaction, further study of the seismic intensity and damage caused by liquefaction is needed.

4. 2 Intensity Distribution by District

Additional locations with confirmed damage are shown on the distribution map. Figure 3 shows the intensity distribution of Benguet. Attempts have been made to obtain maps from Baguio, where the heaviest damage occurred, in order to develop a separate map for Baguio. As a result, Baguio is shown in the Benguet distribution map. Figure 4 shows the state of La

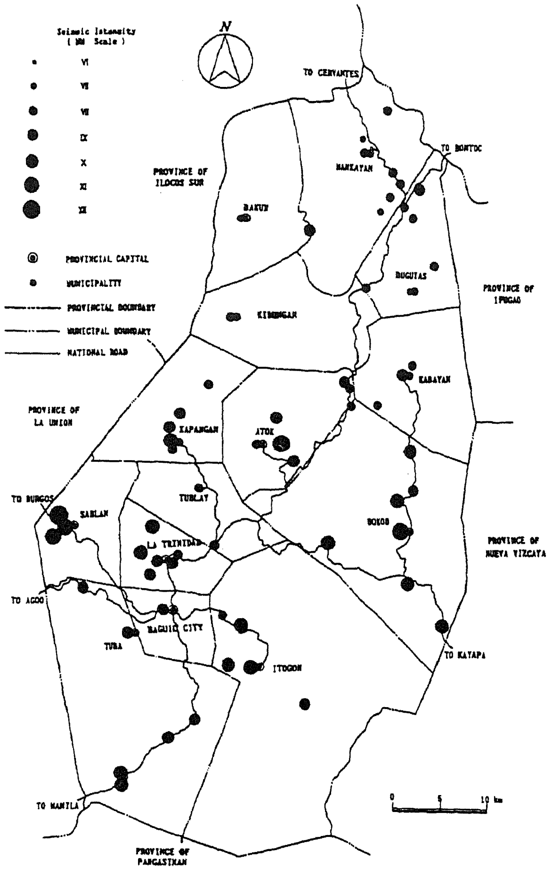


Fig.3 Estimated seismic intensity distribution in Benguet Province.

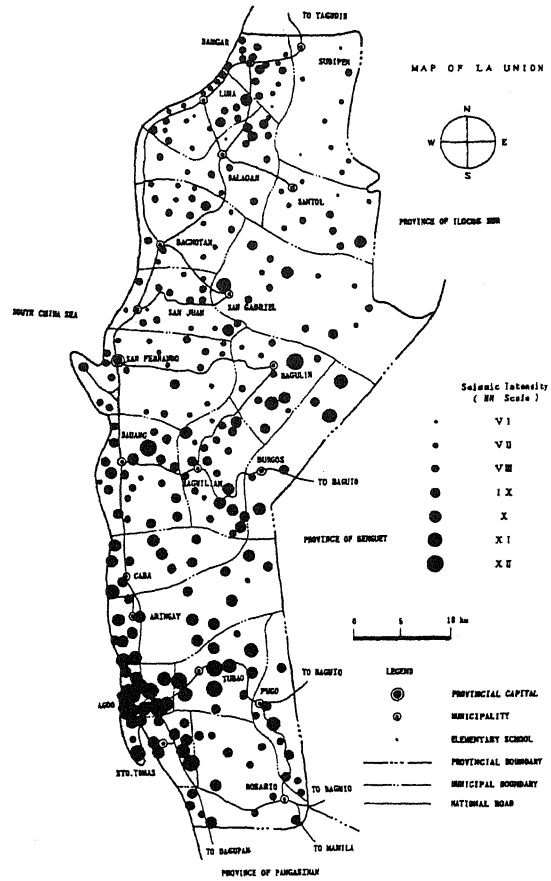


Fig.4 Estimated seismic intensity distribution in La Union Province.

Table 3 Estimated seismic intensities at main cities in MM Intensity Scale.

City	Estimated Intesity (MM Scale)	Number of Data
Baguio	8.8	215
Agoo	10.7	101
Aringay	9.8	117
Dagupan	8.7	396
San Carlos	7.7	463
Cabanatuan	7.8	493
Quezon City	6.5	51
Total	-	1836

Union's distribution. It shows Agoo's and Alingay's outstanding intensity among the others. Figure 5 shows the state of Pangasinan. The eastern part shows a higher intensity than the western state of Dagupan, which had much damage from liquefaction.

Figure 6 shows the distribution of Nueva Ecija, located above the epicenter. According to this figure, the largest intensity is located along the fault near the epicenter. Besides these distribution maps, a general distribution map is shown in figure 7 which was estimated the seismic intensity at each municipality individually by same method. This figure also corresponds with the individual figures; as noted in figure 7 Baguio, Agoo, and eastern Pangasinan are along the fault. Bagio and Agoo are located on the west side of the northwestern end of the main fault.

5 MICROZONING BASED ON SEISMIC INTENSITY

According to the seismic intensity distribution result shown in Figure 7, we drew the isoseismal contour line and investigated the seismic microzoning in source region of this earthquake. As the target area, we used four provinces except Nueva Viscaya and divided this

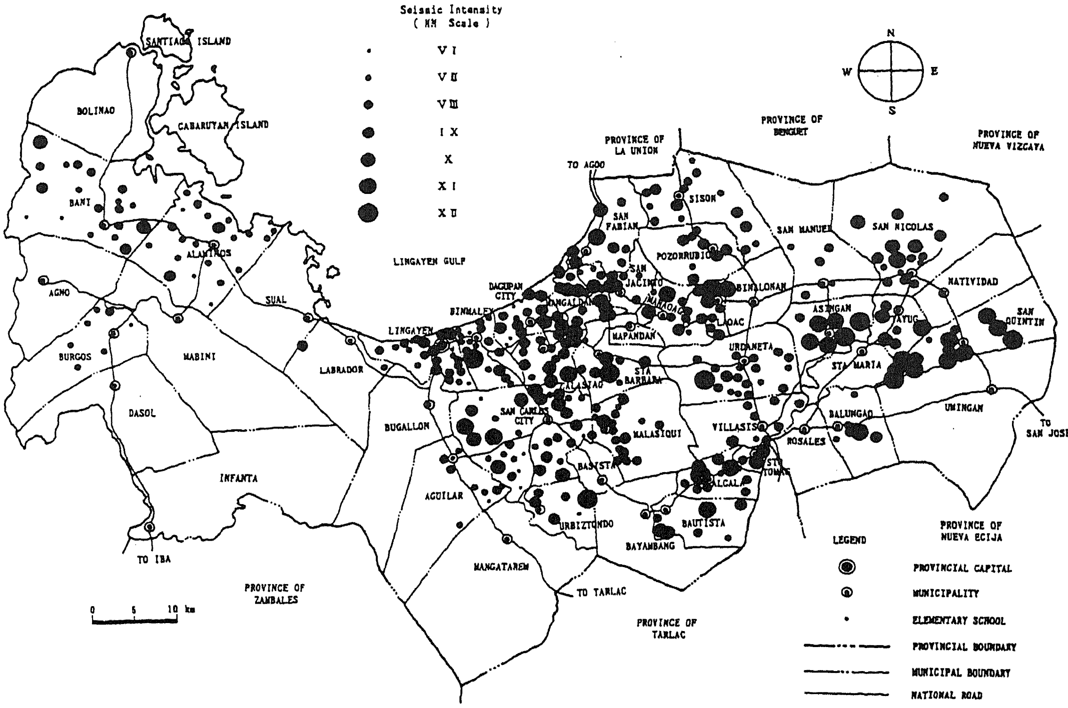


Fig.5 Estimated seismic intensity distribution in Pangasinan Province.

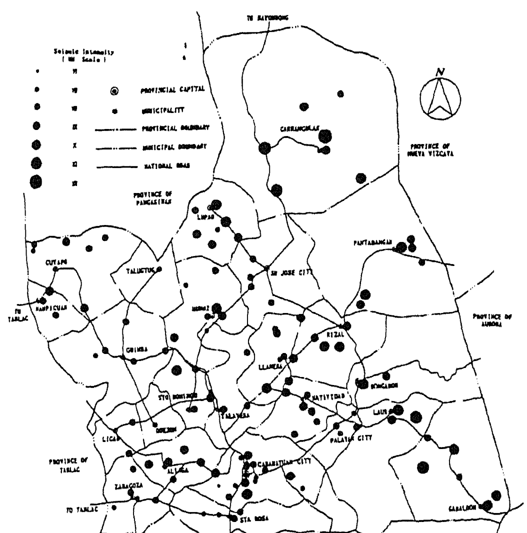


Fig.6 Estimated seismic intensity distribution in Nueva Ecija Province.

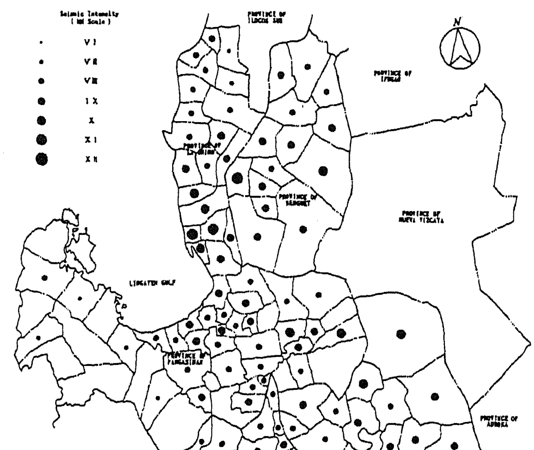


Fig.7 Seismic intensity distribution estimated at each municipality.

area into 4km x 4km meshes as shown in Figure 8. The result is shown in Figure 9. The seismic intensity estimation along the seismic fault was not sufficient because of the lack of questionnaire survey data in Nueva Viscaya. Although, it was recognized clearly that the high seismic intensity zones were distributed along the seismic fault and Agoo and its vicinity in La Union Province.

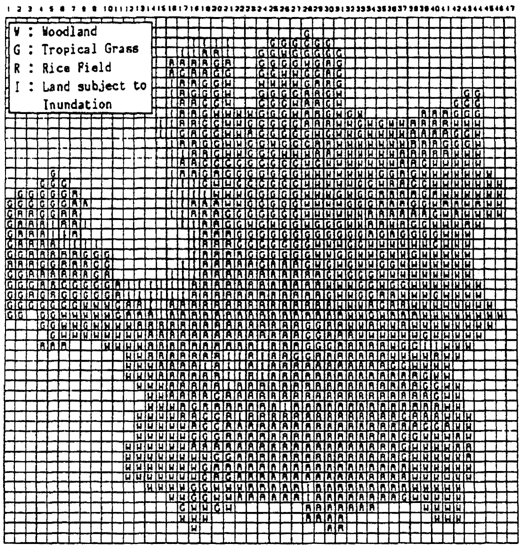


Fig.8 4km x 4km meshed map of the target area for microzoning and its roughly classified topographical features.

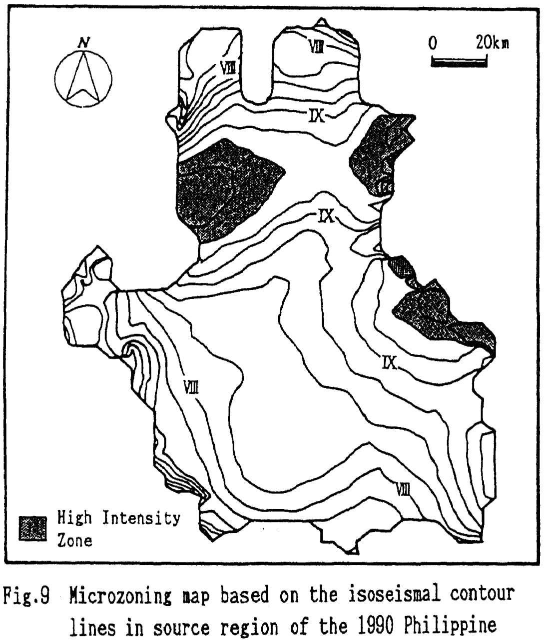


Fig.9 Microzoning map based on the isoseismal contour lines in source region of the 1990 Philippine Earthquake. (This map don't include the analytical results of Nueva Vizcaya Province.)

6 SUMMARY

Using MM intensity prediction among the affected cities we have compiled maps of intensity distribution. As previously noted, these are provisional. Further study may result in some change. Through this research, the Philippine earthquake's intensity distribution has been clarified. The intensity distribution corresponds with the damage distribution. The result provides important data for assessing the intensity of seismic motion. The earthquake's epicentric process influenced this intensity distribution, as analyzed through this survey.To be completed are: examination of the intensity evaluation method, damage distribution comparison, comparison of more accurate maps with geological and topographical maps etc., and further study of localized and broad intensity distribution maps.

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*1 Tokyo Metropolitan University, Japan
*2 Kanto Gakuin University, Japan
*3 Kanagawa University, Japan
*4 Kajima Institute of Construction Technology, Japan
*5 Kumagai Co., Ltd., Japan
*6 Maeda Construction Co., Ltd., Japan
*7 Philippine Atmosphcric Geophysical and Astronomical Services Administration, Philippine
*8 Technological University of Philipines, Philippine
*9 Philippine Institute of Volcanology and Soismology, Philippine
*10 Ministry of Public Works & Highways Bureau of Design, Philippine