Development of portable earthquake simulator for enlightenment of disaster preparedness

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SUMMARY:

For earthquake disaster prevention it is important for the public to think by themselves of taking measures what they can do in their home as well as in their community, by comprehending possible quakes that might occur in their living place. We have developed a portable earthquake simulator which can provide experiences of various horizontal shakes of ground and buildings. In addition we have developed programs of disaster drill.
We propose an experience-based method to appeal to the public even if they are uninterested in earthquake disaster prevention. The experience of real shake with the simulator motivates people to think of disaster reduction by themselves.

***Keywords** : disaster enlightenment simulator prevention drill*

1. INTRODUCTION

For earthquake disaster prevention, it is greatly important in reducing damage for the pubic to think of damage in advance and to prepare for a disastrous earthquake. Virtual experiences of quakes and repeated dills for disaster prevention are necessary.
The Great East Japan Earthquake revealed functional failure of existing disaster-preparedness drills.
We propose new method of the drill by introducing a portable earthquake simulator developed as an apparatus to provide experiences of quakes to the public.

2. EXISTING DISASTER DRILLS

Conducting a disaster drill is ordered by decree in Japan. The majority of disaster reduction activities for ordinary citizens are carried out based on participation of volunteers. In general, they are planned and held once a year by municipalities and neighborhood associations. These include a variety of programs such as emergency life-saving drills, meal distribution drills, evacuation drills, explanations of hazard maps and experiencing vibrations of earthquakes and most of the drills combine a few programs in a set. Of course, these drills serve a critical role in promoting appropriate evacuation responses by residents and decreasing the number of victims in case of a disaster.
In fact, it was revealed that participants by ordinary citizens (in particular people from their early teens to their early thirties) are quite small in number, however, only officials of neighborhood associations and elders who have lived in the region for many years (who have a general awareness regarding disaster control) participate. As pointed out by Katada *et al*.(2011), we cannot expect people, who do not inherently have much interest in disaster reduction, to participate in disaster reduction activities if

they are held on a voluntary basis.
In almost all drills, an earthquake simulation vehicle is used for providing an experience of quake. The vehicle is a kind of cargo truck that has a vibration stage on its rear deck. As the vehicle needs enough wide space to park, it can be operated only outside but not indoor space where most programs of disaster learning are carried out. The vehicle cannot produce actual shakes of land or buildings that is necessary to educate the relationship between shaking and damage.

3. AIMING AT DISASTER DRILLS OF RESIDENT PARTICIPATION

3.1. A positive sign

Recently, particularly since the Great East Japan Earthquake in 2011, NPO corporations and private companies have increasingly carried out activities for disaster reduction by inviting employees, business partners and local residents to participate. The activities are held in various places such as an office and an amusement facility, where people uninterested in the disaster reduction are easily gathering.

3.2. Portable earthquake simulator

We have developed a portable self-motion earthquake simulator (Matsudaira et al., 2009, Yamaguchi et al., 2009, Hirayama et al., 2009, and Adachi et al., 2010). Fig. 1. shows the appearance of the simulator body.

Figure 1. Appearance of the earthquake simulator

The platform of the simulator body is a movable platform 80cm by 80cm and 15cm thick and weighs 80kg, and is comprised of crawlers to which free rollers, driven by four direct current motors, are attached. Fig. 2 shows the arrangement of VUTON crawlers (Hirose et al., 1993). As shown in Fig. 3, the VUTON crawler functions as a driving mechanism in the direction of roller axes and functions as a driven support mechanism in the direction perpendicular to the roller axes. As diagonal movement is realized by combination of both movements without sliding of the rollers, the simulator can move in any direction while supporting a large load.
For motor control, a multi-purpose servo-amplifier is used and speed command data is transmitted in real time from a PC via serial communication by CAN bus. The speed command data is the speed

record by time-step of 0.01 seconds, which is a text file in CSV format. Therefore, simulation records of a certain point can be used for input waveform in addition to observation records of past earthquakes and building responses.

Figure 2. Appearance of the bottom of the simulator

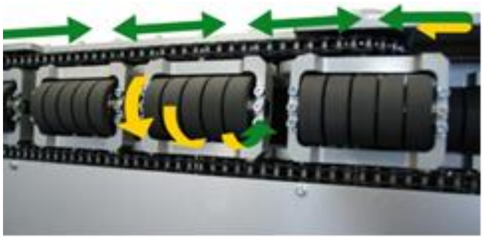

Figure 3. Enlarged view of VUTON crawler

We built the trial model, aiming at reproducing violent motions with an intensity level of 7 at maximum at a cycle of less than one second and reproducing vibrations over 100cm/s in the long-period motion at a cycle of several seconds. As shown in Fig. 4., we confirmed that both waveforms were correctly reproduced in acceleration waveform of two horizontal components of JMA Kobe, which was recorded during the Southern Hyogo Earthquake of 1995, and the building response of two horizontal components on the 30th floor of super higher building forecasted for the future Tokai Earthquake (hereinafter referred to as “Shinjuku Wave”).

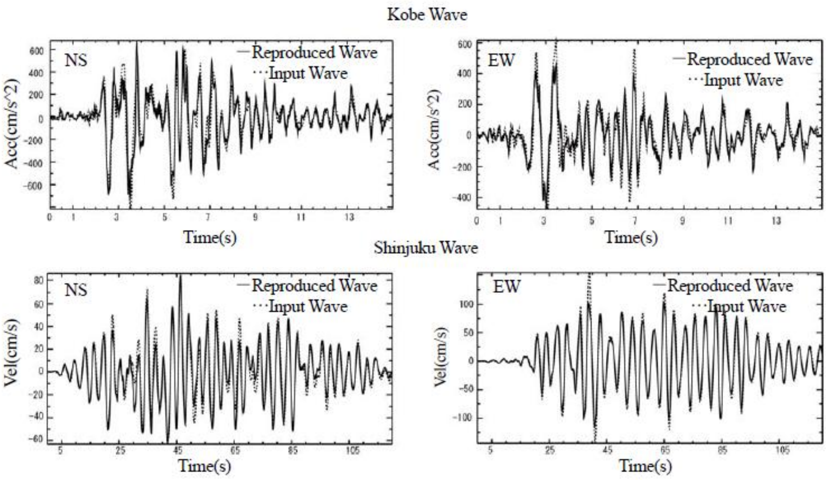

Figure 4. Comparison between input earthquake motions (dotted line) and the earthquake motions reproduced by Jishin The VUTON (solid line)

There is no such portable earthquake simulator that can be driven by the electric power supply from a domestic household wall socket and can produce motions of strong quakes with short frequency as well as long period ground motion. Table 1. shows major specifications of the simulator.

Table 1. Specifications of Earthquake Simulator

dimensions / weight	Width 80cm, depth 82cm, height 125cm / 93kg
Power source	100V AC, 15KW
Driving Method	All direction moving mechanism, "VUTON Crawler"
Control Method	Serial communication by CAN bus
User Interface	Touch panel
Maximum displacement	±500cm
Maximum speed	120cm/s
Maximum acceleration	1000gal
Safety Equipment	Seatbelt, two emergency stop buttons

3.3. Various types of earthquake

In order to reproduce the earthquake response that depends on mechanisms of earthquake and on response characteristics of buildings, we introduced various quake motions and movies of indoor damage by the corresponding quake. Scenes of inside damages by the earthquake motions were filmed, using the two-dimensional vibration platform, similar to the experiment by Adachi et al (2010) and the film was filed in wmv video format.

Simultaneously with operation of the earthquake simulator, video is projected on a large screen which is set in front of the experiencer. During this time, vibrations of the device and video are synchronized. Table 2. shows the list of earthquake motion provided by the system.

Table 2. Earthquake motion provided by the simulator system

name of earthquake and observation site	type of earthquake	magnitude
El Centro 1940	near-field earthquake	6.4
Takatori 1995	near-field earthquake	7.3
Kobe JMA 1995	near-field earthquake	7.3
Ojiya, The 2004 Mid-Niigata Earthquake	near-field earthquake	6.8
Fukuoka CTI, The 2005 Fukuoka Earthquake	near-field earthquake	7.0
Kikukawa, The 2009 Suruga Bay Earthquake	interplate earthquake	6.5
Sagara, The 2009 Suruga Bay Earthquake	interplate earthquake	6.5
JMA Furukawa, The 2011 Off the Pacific Coast of Tohoku Earthquake	plate-boundary earthquake	9.0
K-NET Sendai, The 2011 Off the Pacific Coast of Tohoku Earthquake	plate-boundary earthquake	9.0
K-NET Motegi, The 2011 Off the Pacific Coast of Tohoku Earthquake	plate-boundary earthquake	9.0
Shinjuku Ground, Tokai Earthquake	plate-boundary earthquake	8.0
Shinjuku 30th Floor, Tokai Earthquake	plate-boundary earthquake	8.0
Ground floor of super higher building in Shinjuku, The 2011 Off the Pacific Coast of Tohoku Earthquake	plate-boundary earthquake	9.0
Upper floor of super higher building in Shinjuku, The 2011 Off the Pacific Coast of Tohoku Earthquake	plate-boundary earthquake	9.0

3.4. A learning tool

As is clear from the questionnaires on earthquake damage in recent years, it is known that about 40% of all injuries were caused by furniture and other household goods falling over or dropping (Tokyo Fire Department, 2012). Based on this knowledge, it is important, first, to remain in a safe building and second, to fix furniture so that it will not fall over in order to minimize damage from an earthquake. We assume that the above two actions are expected to be presented in an understandable way to bring attention to many people.

Accordingly, we created the disaster control learning tool, which can be used with the earthquake simulation system.

As shown in Fig. 5. and Fig. 6., a partition containing illustrations useful for disaster control learning is set around the earthquake simulator. On the outer wall, illustrations showing the importance of self-help and mutual-help are arranged, which aims at improving awareness by watching before experiencing earthquake motions. On the internal wall, photos of collapsed houses and rooms where furniture has fallen or scattered as was the case during the Southern Hyogo Earthquake are arranged and comments from victims are attached. This is for participants to specifically imagine the damage situations after experiencing earthquake motions. Fig. 7. and Fig. 8. shows the outside illustration and the inside one, respectively.

The illustration on the partitioning boards provide important knowledge not only for one sitting in the simulator but also for people gathering to see the simulator.

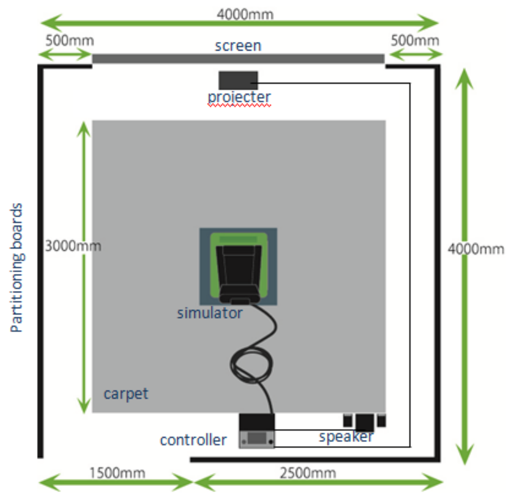

Figure 5. Appearance of earthquake simulation system

Figure 6. Partitioning screen

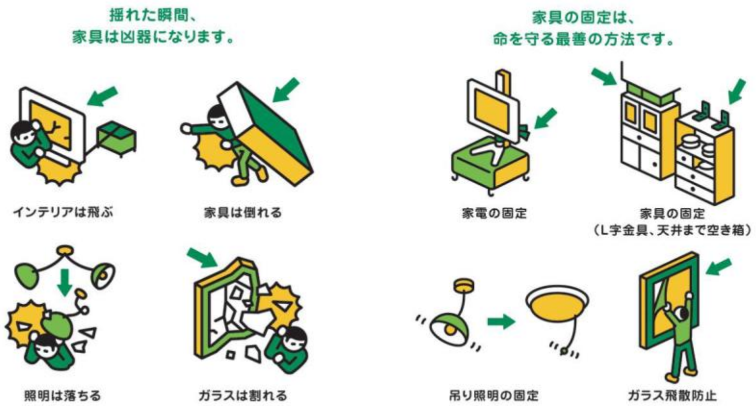

Figure 7. Outside illustration

Figure 8. Inside picture

3.5. Disaster drill

We hold workshops using a furniture falling prevention experience kit developed by Plus Arts NPO. Fig. 9. shows the kit consisting of a doll and miniature of furniture and fixing devices. After we explained the important points of how to fix furniture by a picture-card demonstration, the experiencer fixes the model furniture by the model fixing devices. Then a check of the correct fixing method is made at the end. The workshop is shown in Fig. 10. Based on our experience, when we introduce furniture fixing devices used in homes, participants find this extremely valuable.

Lastly, we deliver leaflets summarizing the illustrations used on the partitions to the participants who completed all the experiences in the order of preliminary learning, earthquake motion experience and the furniture falling prevention workshop. Fig.11. shows the leaflet. We deliver as many leaflets as necessary for the number of families and friends. We take care so that participants can easily remember the series of experiences and share these with the people around them.

Figure 9. Furniture falling prevention experience kit

Figure 10. Workshops

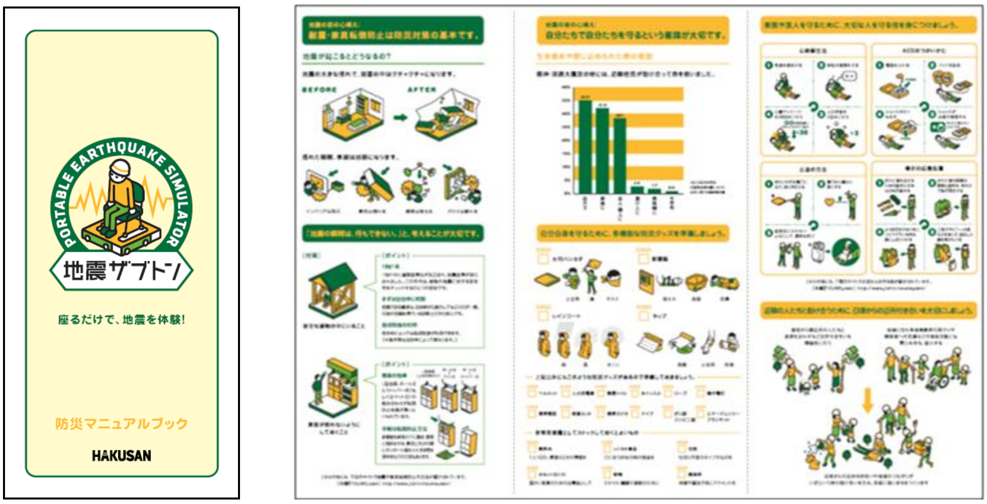

Figure 11. Leaflet

4. Disaster reduction enlightenment activities

We have carried out activities in many parts of Japan, using the forementioned earthquake simulation system and disaster reduction learning content. From September 2009 to the present, we have interacted with more than 4,000 people at more than 60 locations. Here we show examples of unique use. Table 3. shows the list of activities.

Table 3. Disaster reduction enlightenment activities

Date	City	Site	Purpose	Target	Partici-pants	Earthquake data
March 2010	Tokyo	Lobby of live music club	Haiti earthquake aid charity	Singer, artist, and their fans	3000	Takatori 1995, Ojiya 2004
October 2010	Niigata	Elementary School gymnasium	disaster prevention event	residents, students	30	Ojiya 2004
November 2010	Tokyo	Office lobby	disaster prevention course	employee, customer	200	Tokai 30th floor
January 2011	Hyogo	museum	disaster prevention event	residents	1200	Takatori 1995, Kobe JMA 1995
September 2011	Tokyo	meeting room	policy making commission	councilors	30	Takatori 1995, Shinjuku Upper floor 2011, Tokai 30th floor
March 2012	Tokyo	entrance of condominium	disaster drill	residents	30	Takatori 1995, Shinjuku Upper floor 2011, Tokai 30th floor
March 2012	Tokyo	show room of condominium	disaster drill	residents	50	Kobe JMA 1995, 50th floor: Seismic Isolation, 50th floor: Earthquake Resistant
April 2012	Ibaraki	entrance space of research institute	outreach activity	residents	2000	Motegi 2011, Sine wave

5. Concluding remarks

In this study, we built an earthquake simulation system using a portable earthquake simulator developed by us. In addition, we created disaster control learning content and have participated in disaster control activities held in local communities.

The system provides experiences of various shakes, which depend on the mechanisms of the earthquake and on the response characteristics of the building. With the system, we proposed new method of disaster drills for the public to think of disaster reduction.

By carrying a system into company offices in high-rise buildings and entertainment facilities such as live music clubs and shopping centers, we showed it was possible for people who have not participated in disaster drills in their communities to learn disaster control, including experiencing earthquake motions.

We are now commercializing the earthquake simulation system, including the portable earthquake simulator, and two systems are operated by a person other than us. Specifically, the Tokyo Fire Department leases a device to each Fire Station in Tokyo and puts it to use during enlightenment of countermeasures for long-period ground motion and a metropolitan inland earthquake. The Chuetsu Organization for Safe and Secure Society is equipped with the device at “Sonaekan,” Ojiya Earthquake Disaster Museum and puts it to use handing down the disaster experiences from the Niigata Chuetsu Earthquake to future generations. It is an advantage that it is easy to arrange the input data depending on the content to be highlighted.

In the future, we would like to contribute to further future disaster reductions, by increasing opportunities for more people participating in disaster control activities to use the system, corresponding to the objectives of each activity and target, and by increasing the interest of the public regarding disaster control.

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