

DAMAGE OF BUILDINGS AND ACTIONS TAKEN DURING THE 2011 GREAT EAST JAPAN EARTHQUAKE IN THE DISASTER PREVENTION FACILITIES

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ABSTRACT: Questionnaire survey was conducted in nine disaster prevention facilities in Miyagi, Saitama, Tokyo, Kanagawa and Osaka Prefectures about damage of buildings and actions taken during the 2011 Great East Japan Earthquake on March 11, 2011. All facilities are located in high-rise buildings. Questionnaire to building administrators consists of questions about the damage of building and countermeasures taken at the moment of earthquake. Questionnaire to staff in the facilities includes questions about the behavior and emotion (fear and anxiety) during earthquake shaking and damage of contents in the office. Finally, suggestions to improve countermeasures in the disaster prevention facilities in high-rise buildings are pointed out.

Key Words: Great East Japan earthquake, Questionnaire survey, Disaster prevention facilities, High-rise buildings

INTRODUCTION

Building Research Institute has conducted strong-motion observation of buildings on a nationwide scale to examine the behavior of buildings during earthquakes. At the 2011 Great East Japan Earthquake that occurred on March 11, 2011, it is known that high-rise buildings in Tokyo moved largely responded by long-period component of earthquake ground motion. Also, the 52-stories office building in Osaka, located more than 700 km far from the epicenter, moved around 137 cm at the top of the building because of the long-period ground motion generated in the Osaka Plain.

In order to reduce damage caused by the Tokai, Tonankai and Nankai Earthquake which have been noted to occur in the near future, it is important to examine the damage or malfunction of buildings during the earthquake and find out necessary means to improve its safety and continue the business in the building. Also, actions taken during the earthquake by disaster prevention facilities should be examined to take advantage of future measures. In addition, it is also important to understand behavior and anxiety level of residents during an earthquake to avoid confusion and ensure the safety of evacuation of residents.

For this purpose, questionnaire survey was conducted in nine disaster prevention facilities in Miyagi, Saitama, Tokyo, Kanagawa and Osaka Prefectures about damage of buildings and actions taken during the 2011 Great East Japan Earthquake on March 11, 2011. All facilities are located in

high-rise buildings. Questionnaire to building administrators consists of questions about the damage of building and countermeasures taken at the moment of earthquake. Questionnaire to staff in the facilities includes questions about the behavior and emotion (fear and anxiety) during earthquake shaking and damage of contents in the office.

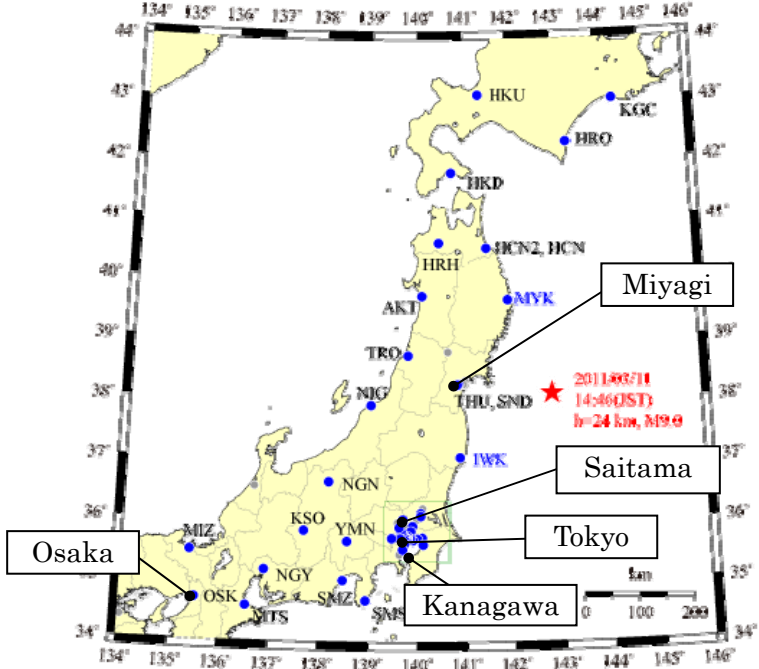


Figure 1 Location of recorded buildings at the 2011 Great East Japan Earthquake

Table 1 List of buildings targeted for questionnaire survey

| No. | Location | Structural Type | Structural system | Floor | Height (m) | Year | Location | Acc. (cm/s ²) | | |
|-----|----------|-----------------|----------------------|-------------------|------------|----------------|----------|---------------------------|-----|-----|
| | | | | | | | | H1 | H2 | V |
| 1 | Miyagi | S | Normal | 15F B2F | 62.7 | 1973 | B2F | 163 | 259 | 147 |
| | | | | | | | 15F | 361 | 346 | 543 |
| 2 | Saitama | S | Control | 26F P2F | 139 | 2000 | B3F | 74 | 63 | 42 |
| | | | | | | | 10FS | 119 | 138 | 62 |
| | | | | | | | 10FN | 118 | 155 | 66 |
| | | | | | | | P1FS | 248 | 503 | 106 |
| | | | | | | | P1FC | 265 | 686 | 185 |
| 3 | Tokyo | SRC | Isolation (Retrofit) | 11F B2F | 53.63 | 1973 (2003) | B2F | 104 | 91 | 58 |
| | | | | | | | B1F | 55 | 55 | 55 |
| | | | | | | | P1F | 94 | 82 | 104 |
| 4 | Tokyo | S | Normal | 20F B4F P1F | 86.52 | 1994 | 01F | 91 | 85 | 45 |
| | | | | | | | 20B | 210 | 150 | 173 |
| | | | | | | | 19C | 177 | 135 | 130 |
| 5 | Tokyo | S | Control | 21F B4F | 99.5 | 2000 | B4F | 75 | 71 | 49 |
| | | | | | | | 13F | 137 | 113 | 72 |
| | | | | | | | 21F | 121 | 131 | 104 |
| 6 | Tokyo | S | Normal | 18F | 75.4 | 1983 | - | - | - | - |
| 7 | Tokyo | SRC | Normal | 26F B3F | 111.2 | 1983 | - | - | - | - |
| 8 | Kanagawa | S | Normal | 23F B3F P1F | 96 | 1994 | B2F | 60 | - | 30 |
| | | | | | | | 23F | 162 | - | 72 |
| 9 | Osaka | S | Normal | 15F 3F | 76 | 1973 | B3F | 11 | 9 | 5 |
| | | | | | | | P3F | 65 | 38 | 7 |

S: Steel / SRC: Steel Reinforced Concrete
Control: building with response control devices / Isolation: building with seismic isolation/

QUESTIONNAIRE SURVEY TO BUILDING ADMINISTRATORS

Damage to building structures

Table 2 summarizes the damage situation of structural members and exterior walls. The answer of “Miyagi” reported crack propagation on the surface of columns. Other answers reported “none” or “unknown” because of the difficulty to inspect damage at the high position of the building by eye sight.

Table 3 summarizes the damage situation of non-structural elements. Except answer of “Osaka,” there are some reports of damage in all buildings. In particular, many building suffered damage to ceiling panels.

Table 4 shows the damage situation of lifeline facilities and elevators. Elevator suffered various damage including twine rope and damage to baskets. Table 5 shows the situation of stop of elevator and recovery process and answers to whether trap happened and time to rescue. The elevators stopped on all buildings and one person was trapped in Tokyo.

Actions taken at the moment of earthquake

About business continuity

There are checklists and manuals for disaster or business continuity plans for all facilities, which could act as planned except one building answered failed to plan because of shortage of staff. “Miyagi” answered that damage was beyond the expectation in the manual.

Table 2 Damage of structural members and exterior walls

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--------------------|------------------|---------|-----------|---------|---------|--------|---------|----------|--------|
| | Miyagi | Saitama | Tokyo | Tokyo | Tokyo | Tokyo | Tokyo | Kanagawa | Osaka |
| | Normal | Control | Isolation | Normal | Control | Normal | Normal | Normal | Normal |
| Structural members | Crack on columns | None | None | Unknown | None | None | Unknown | None | None |
| Exterior walls | None | None | None | Unknown | None | None | None | None | None |

Table 3 Damage of non-structural members

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----------------------|---|--------------------------------------|-----------|------------------------------------|---------|--------------------------------|--|------------------------------------|--------|
| | Miyagi | Saitama | Tokyo | Tokyo | Tokyo | Tokyo | Tokyo | Kanagawa | Osaka |
| | Normal | Control | Isolation | Normal | Control | Normal | Normal | Normal | Normal |
| Partition board panel | Detached from joint | Peeling off | None | Crack and peeling | None | Crack | Crack | None | None |
| Ceiling | Damage to part of the ceiling panels in office area and all panels in hall area | Detachment of speaker at the ceiling | None | Fall of part of the ceiling panels | None | Displacement of ceiling panels | Peeling of the board and sealing of asbestos | Fall of part of the ceiling panels | None |
| Door | None | Damage to the release of fire door | None | Damage to door of the sink | None | None | Damage to the release of fire door | None | None |

Table 4 Damage of lifeline facilities and elevators

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|----------------------------------|--------|---|-----------|--------|---------|--|---|----------------------------|--------|
| | Miyagi | Saitama | Tokyo | Tokyo | Tokyo | Tokyo | Tokyo | Kanagawa | Osaka |
| | Normal | Control | Isolation | Normal | Control | Normal | Normal | Normal | Normal |
| Water and electricity facilities | None | None | None | None | None | None | None | Damage to lid of roof tank | None |
| Elevator (rope and basket) | None | Entangled main rope of two EVs, destroy of floor plates | None | None | None | Distortion in the EV car luggage, broken limit switches, bracket deformation | Damage of governor wire, main rope, selector tape of one EV | None | None |

Table 5 Situation of stop of elevator and recovery process

| | | | Stop of elevator and recovery process | Occurrence of trap and time to rescue |
|---|----------|-----------|---|---|
| 1 | Miyagi | Normal | No. 1-3 elevator malfunction, repair work continued one year. | None |
| 2 | Saitama | Control | Emergency stop of all EVs for safety. Resumption of operation after inspecting four hours. | None |
| 3 | Tokyo | Isolation | Emergency stop of all EVs for safety. Resumption of operation after inspection until 16:15 | None |
| 4 | Tokyo | Normal | Emergency stop of all EVs for safety. Resumption of operation after inspection until 21:54. | None |
| 5 | Tokyo | Control | Emergency stop of all EVs for safety. Resumption of operation after inspection (No.1~No.12 until 15:30 and No.13~No.24 until 20:30) | None |
| 6 | Tokyo | Normal | Emergency stop of all EVs for safety. Resumption of operation after inspection until 18:30 except the EV failed | One person was trapped and rescued after 30min. |
| 7 | Tokyo | Normal | Emergency stop of three EVs. One week to 1.5 months to recovery. | None |
| 8 | Kanagawa | Normal | Emergency stop of all EVs for safety. Resumption of operation after inspection | None |
| 9 | Osaka | Normal | None | None |

Evacuation after earthquake

All staff of the facility were evacuated in “Miyagi” and some staff were evacuated in one facility in “Tokyo”. "Miyagi" decided to evacuate from the damage and "Tokyo" decided from the magnitude of the tremor. Both cases canceled evacuation in 2 hours after inspection of damage. Among the facility which did not evacuate, there are the cases making announcement saying "there is no need for evacuation" and those without any announcement.

Damage inspection

All facilities conducted emergent inspection after the earthquake by local staff or professional contractor stationed in the building. They insist to reduce time to determine the damage and resumption of elevator as soon as possible to have a task force immediately.

QUESTIONNAIRE SURVEY TO STAFF IN THE FACILITIES

Figure 2 shows the number of persons who answered questionnaire in each facility. Respondents were selected from the upper, middle, lower floors of each building.

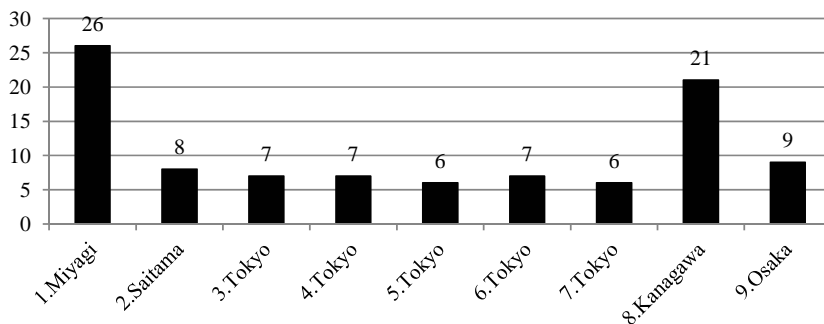


Figure 2 Number of respondents in each facility

Time to notice the earthquake

Ratio of answers to the question “How did you notice the earthquake?” is shown in Figure 3. The facilities near the epicenter such as “Miyagi” and “Saitama” show high rate of answers noticed earthquake by “Earthquake Emergency Alarm.”

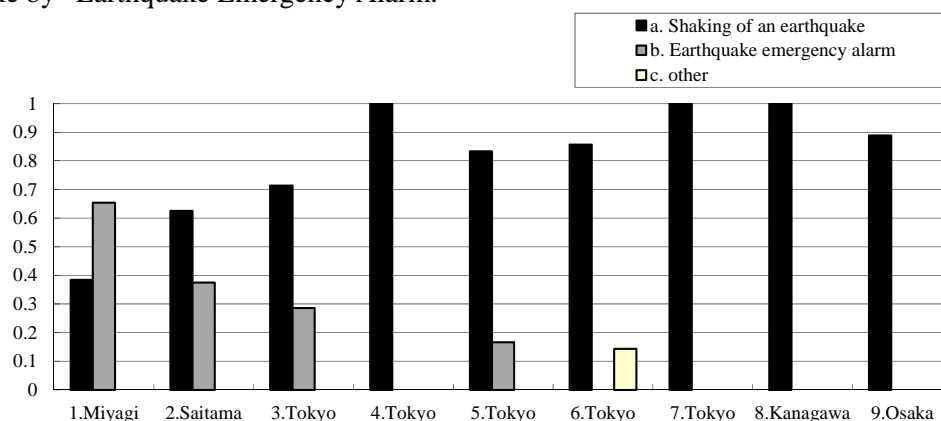


Figure 3 How did you notice the earthquake?

Actions at the moment of earthquake

From Figure 4, the most frequent action during earthquake is “Stop working, wait and see” and the next frequent answer is “Hide under the desk.”

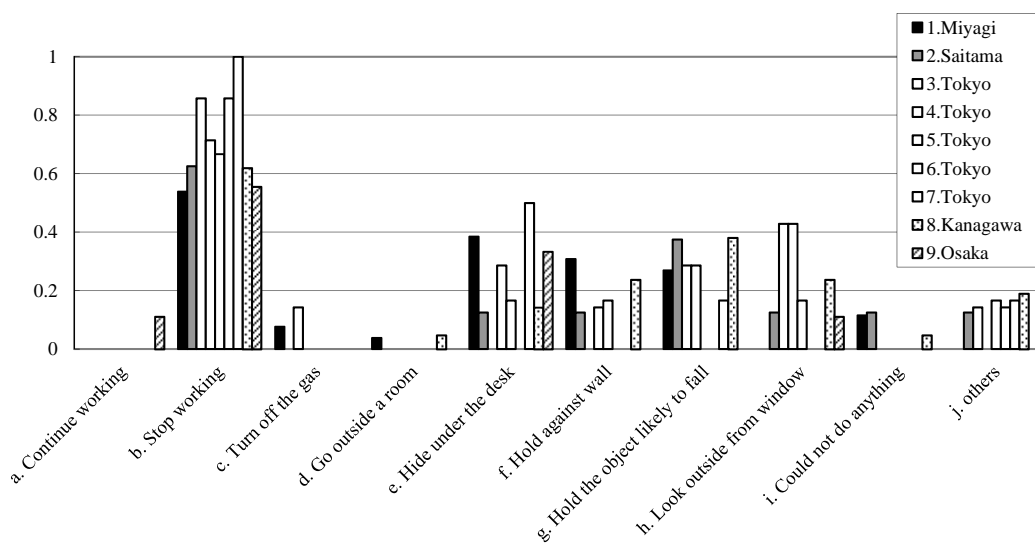


Figure 4 What is the action taken at the moment of earthquake?

Intensity of shaking

As for the intensity of shaking, the most frequent answer in “Miyagi” is “Could not do anything.” On the other hand, “Osaka” answered “no trouble for walking.” It reflects the difference in distance from the epicenter.

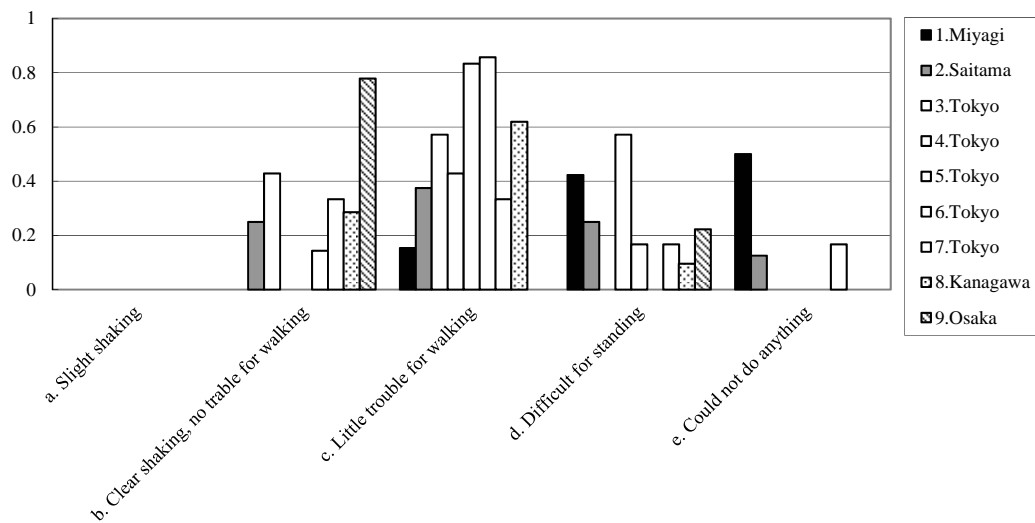


Figure 5 How was the intensity of shaking?

Sense of fear

The ratio of the reply of a sense of fear is shown in Figure 6. Most of the answers of "Miyage" and "Osaka" were "felt strongly." It seems that people feel fear not only by the intensity of shaking, but also long duration of shaking.

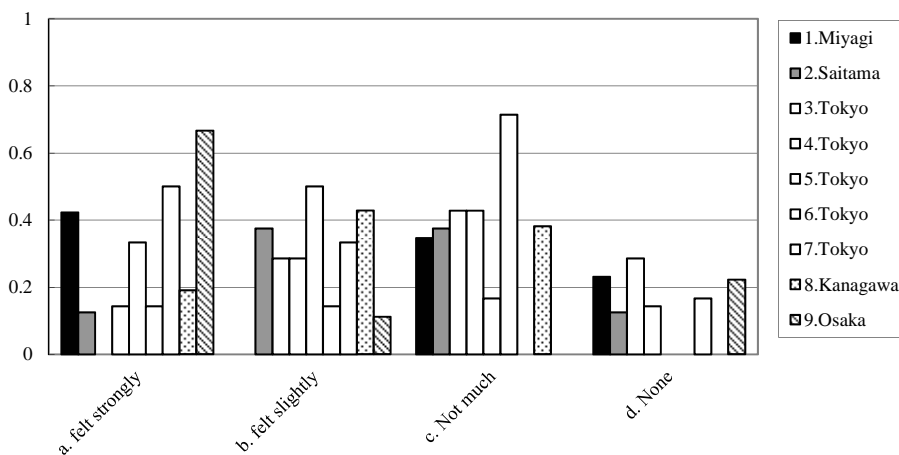


Figure 6 How was a sense of fear during shaking?

Damage inside building

Figure 7 shows the answers about the damage inside building. Many facilities answered “Shaking largely” for hanging objects which is inferred the effect of long period components of tremor. As for dishes in the cabinet, many answers of “Fallen” and “Partially fallen” are observed in the facilities near the epicenter, “Miyagi” and “Saitama.” Falling furniture did not happen so much except “Miyagi.” On the other hand, there are answers of “A lot” for the movement of furniture such as a copy machine with casters. It also reflects the fact of long duration of tremor.

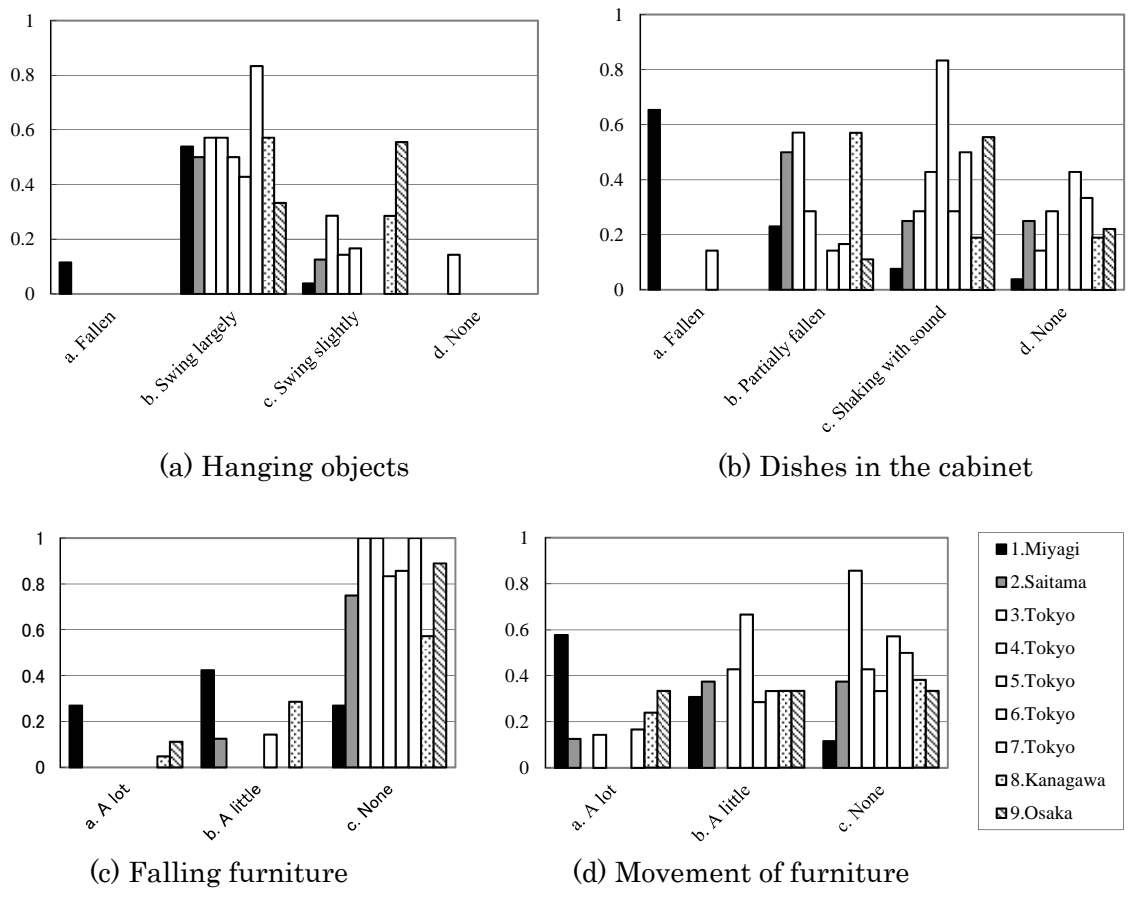


Figure 7 How was the damage inside of building?

Information source

Figure 8 shows the information sources of earthquake. In “Miyagi”, available information sources were “Radio” or “TV of cellphone” since massive power failure occurred in the area. For other facilities without power failure, “TV” is the most frequent answer and the next answer is “Internet.”

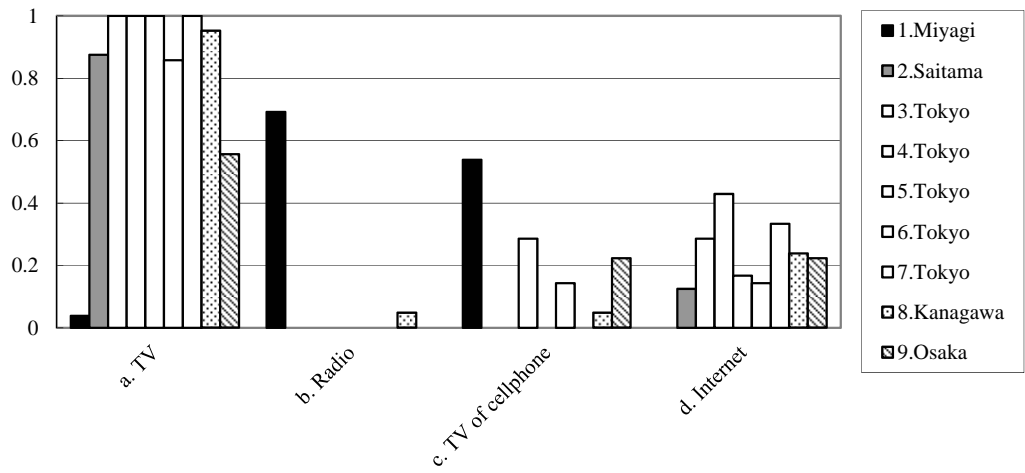


Figure 8 How did you get information about earthquake?

Preparedness before the earthquake

As shown in Figure 9, for prevention of furniture falling, not all facilities were prepared by fixing furniture. Stockpiling water and food was done well in "Saitama" and "Osaka" facilities, but around half answers did nothing. For emergency drills, many respondents had participated, but some did not.

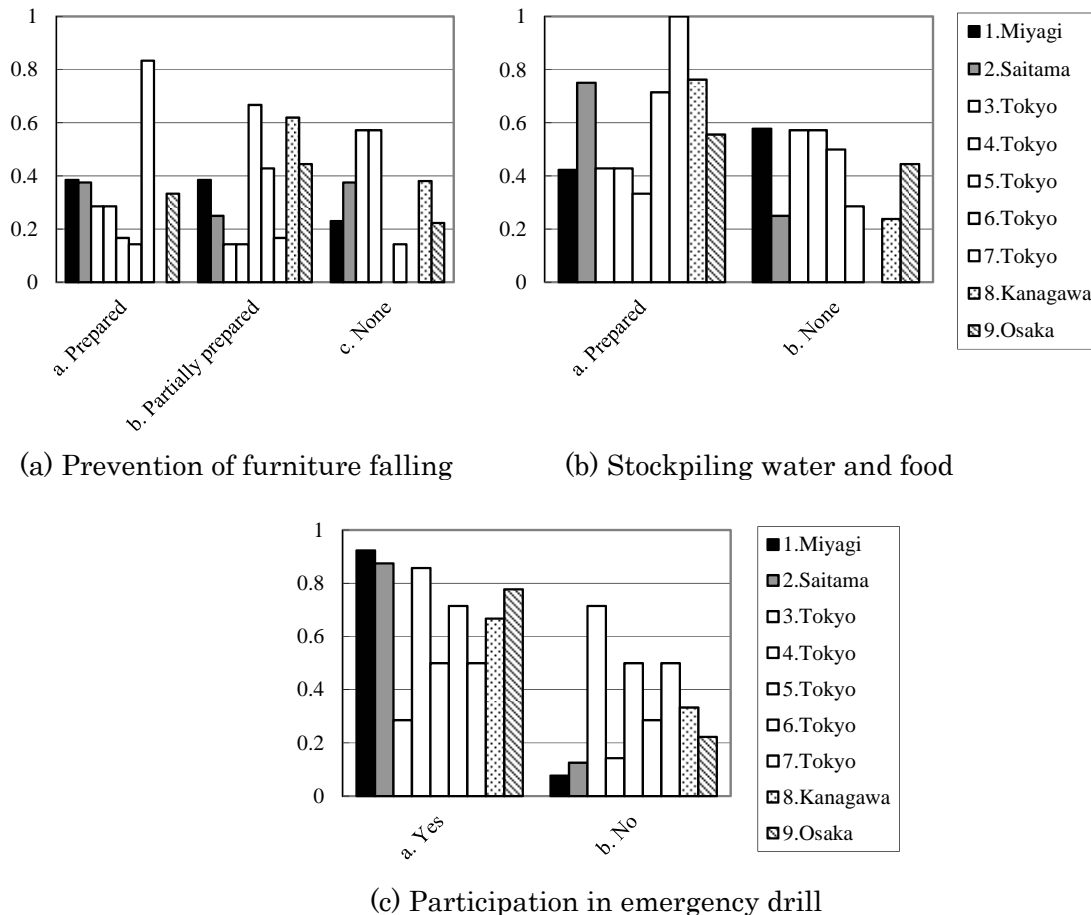


Figure 9 Have you prepared for the earthquake?

CONCLUSIONS

Questionnaire survey was conducted for nine disaster prevention facilities in different regions of Japan regarding the damage and actions during the 2011 Great East Japan Earthquake Disaster. It was found that there was the difference in decision making for evacuation instruction. Less information after the earthquake to determine the necessity of evacuation could be one reason. Stop of elevators was the most sensitive for the immediate action and hampered inspection work and quick formulation of a task force. Disaster prevention facilities must be safer than other buildings and prepared well, however, preparedness such as fixing furniture and stockpiling water and food was not sufficient.

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