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A consideration of earthquake vibration sense of human by using real-time questionnaire

H. Yoneda & M. Yoshizawa
Takenaka Institute of Technology, Japan.

H. Koike & A. Kuriyama
RC Solution, Japan.

ABSTRACT

In Japan, social needs for the building seismic performance are changing not only to the life safety but also to the maintenance of functionality after the earthquake. The human condition during building shaking by earthquakes is also beginning to be considered as a part of the functionality of the building. Japan Meteorological Agency (JMA) seismic intensity scale is known for index of intensity of earthquake motion. Although it might not be fully expressed the shake of high-rise building during a long-period earthquake motion, it helps common people understand the severity of earthquakes in Japan. Authors compared seismic intensity scale and the vibration sense of human using data of real-time questionnaire about earthquake. In addition, free description type questionnaire answer sentences were analysed. Two types of real-time questionnaires are used in this paper. One is a function of an earthquake early warning system for mobile devices many and unspecified persons can use. The other is a web questionnaire system for specific people in the building with seismographs. As the vibration sense of human, it was found that people begin to feel fear from about JMA seismic intensity 3 and that even people far from the seismic centre feel slowly shaking during a long-period earthquake motion. Fear for quake is thought to be promoted by not only a shaking but also the surrounding circumstances. It seems that data from real-time questionnaire can be used to understand the damage situation and to use for disaster response immediately after an earthquake.

1 INTRODUCTION

Japan Meteorological Agency (JMA) seismic intensity scale, which is used as a disaster prevention index to comprehensively express the intensity of shaking caused by earthquakes, originally indicates the intensity of shaking on the ground surface, and does not evaluate the shaking in buildings. But even so, it can be one of the indices that many people can share in the absence of guidelines on how to feel the shaking of earthquakes. However, it has been pointed out that it is difficult to evaluate the difference between the shaking of the ground surface and the shaking which people feel in the high-rise buildings. There have been many researches on the quantification of the degree of human anxiety and the degree of behavioural difficulty by the subject experiment using a shaking table (e.g., Takahashi 2010). On the other hand, it has been pointed out that the results of the shaking table test don't agree with the results of the questionnaire at the time of the great earthquake (Sakamoto 2016). Questionnaire surveys regarding the Great East Japan Earthquake have provided valuable information on the shaking of buildings and indoor damage (e.g., Hida 2012). However, since such questionnaires had been conducted only in large scale earthquakes, there are two problems that it is not possible to obtain an answer for relatively small earthquake and that it is not possible to be conducted immediately after an earthquake. The effects of the shaking on human exercise physiology and psychological anxiety may not be answered correctly over time. In this study, the authors aim to investigate the human sense of vibration by comparing the seismic intensity with the response of the experienced shaking and by analysing additional comments. The purpose in future is to improve the index of human vibration sense about earthquake and use it as an earthquake-resistant performance of buildings.

2 OUTLINE OF ANALYSIS OF REAL-TIME QUESTIONNAIRE

In this study, two types of real-time questionnaire were used. One of them is "Earthquake Shaking Feeling" a function (hereinafter referred to as ESF) included in the earthquake early warning system app. developed for mobile devices (RCS 2018). The users of this app. can post how they felt the shaking by selecting icon from five levels such as "Not felt", "Might felt", "Weak", "Moderate", "Violent" and share it on the map (Fig. 1). And the users can also post floor where they are and comment (up to 17 characters). Floor and comments are optional. This function has been equipped since Nov. 2015, more than 920,000 data has been accumulated. It may be noted that neither the USGS "Did You Feel It?" nor New Zealand's GeoNet equivalent ask for the observers floor level but just the location.

Figure 1: "ESF" function (a) "ESF" display (b) Posting display (c) Comment display

The other is a web Earthquake Questionnaire system for Building user (hereinafter referred to as EQB) which is conducted using an earthquake observation system for office buildings of Takenaka corporation (Yoneda 2017). When an earthquake is observed in a building and exceeds the observation trigger level (about 1 ~ 2 cm/s^2), the EQB system sends an email immediately to the registered collaborators in the building and prompts a response to the questionnaire page. The expiration date of the questionnaire is set to be one week after the occurrence of the earthquake in order that the sensitivity to the shaking does not become dull. Table 1 shows the questionnaire items. Questionnaire items are up to 10 selection formula and they are based on past studies. Questionnaire participants are asked to register their age, sex, and past earthquake experience in advance. The respondents

Table 1: Questionnaire items.

No.	Question	Answer Choices
Q1	Where did you feel the shaking of the earthquake?	Nth floor/ Not in the building/ Not remembered
Q2	What was your situation during the earthquake?	Sitting/ Standing/ Walking/ Lying/ Others /I don't know, I don't remember well.
Q3	How did you respond?	I did nothing/ I hided under the table/ I protected myself from falling objects /etc.
Q4	How big was the earthquake you felt?	I felt a slight shake/ felt a clear shake, but I didn't have any trouble with my behaviour/ etc.
Q5	What kind of shake did you feel? (Multiple answers allowed)	Slow/ Rotated that goes around north, south, east, and west/ Rattled that moves from side to side/ etc.
Q6	How long did you feel the shaking?	Less than 10 seconds/ about 30 seconds/about 1 minute/ about 2 minutes/ more than 2 minutes/etc.
Q7	Did you feel fear during the earthquake?	I wasn't scared/ I was a little scared/ I was scared/ I was very scared/ etc.
Q8	Did you feel sick during the earthquake?	There was nothing wrong/ I felt a little sick/ I felt very sick because of dizziness or nausea/ etc.
Q9	How much did you feel on the seismic scale?	Seismic intensity < 1 to > 6/ I don't know, I don't remember well/ I didn't feel the shaking.
Q10	Additional comments	(Optional)

Table 2: Earthquakes for analysis.

No.	Time and Date (JST)	Hypocentre Region Name	Magnitude (Mj/ Mw)	Maximum Seismic Intensity	Maximum Intensity Scale on long-period ground motion
1	2016/4/1 11:39	South eastern Mie Prefecture	6.5/ 5.9	4	1
2	2016/4/14 21:26	Kumamoto Prefecture	6.5/ 6.2	7	3
3	2016/4/16 1:25	Kumamoto Prefecture	7.3/ 7.0	7	4
4	2016/10/21 14:07	Central Tottori Prefecture	6.6/ 6.2	6 lower	3
5	2018/6/18 7:58	Northern part of Osaka Prefecture	6.1/ 5.5	6 lower	2
6	2018/9/6 3:07	Middle East part of Iburi	6.7/ 6.6	7	4

are provided with an incentive to get preliminary report. Earthquakes selected for analysis of this study are shown in Table 2. In addition to those recorded seismic intensity 6 lower and 7, earthquakes recorded

intensity scale on long-period ground motion (Nakamura 2013) 1 or more observed on office hours were selected, and a long-period shaking was felt even in low-rise buildings.

3 ANALYSIS RESULTS OF "ESF"

3.1 Results of the Questionnaire

The ESF data includes latitude and longitude location data. Using these location data, we compared the ESF answers with the instrumental seismic intensity distribution map (hereinafter, referred as QuakeMap) published on QuiQuake (Quick estimation system for earthQuake map triggered by observed records) (AIST 2013). Figure 2 shows overlay map of QuakeMap and the ESF answers obtained for 10 minutes after No.3 earthquake. "Not felt" is distributed throughout Japan, and "Might felt" is a bit narrower, and the ESF answers from populous urban areas stand out. As for "Weak", the ESF answers from the area adjacent to the hypocentre increased, and "Moderate" "Violent" are concentrated near the hypocentre and in urban areas. In the following study, we analysed the data posted within one hour after the earthquake within QuakeMap.

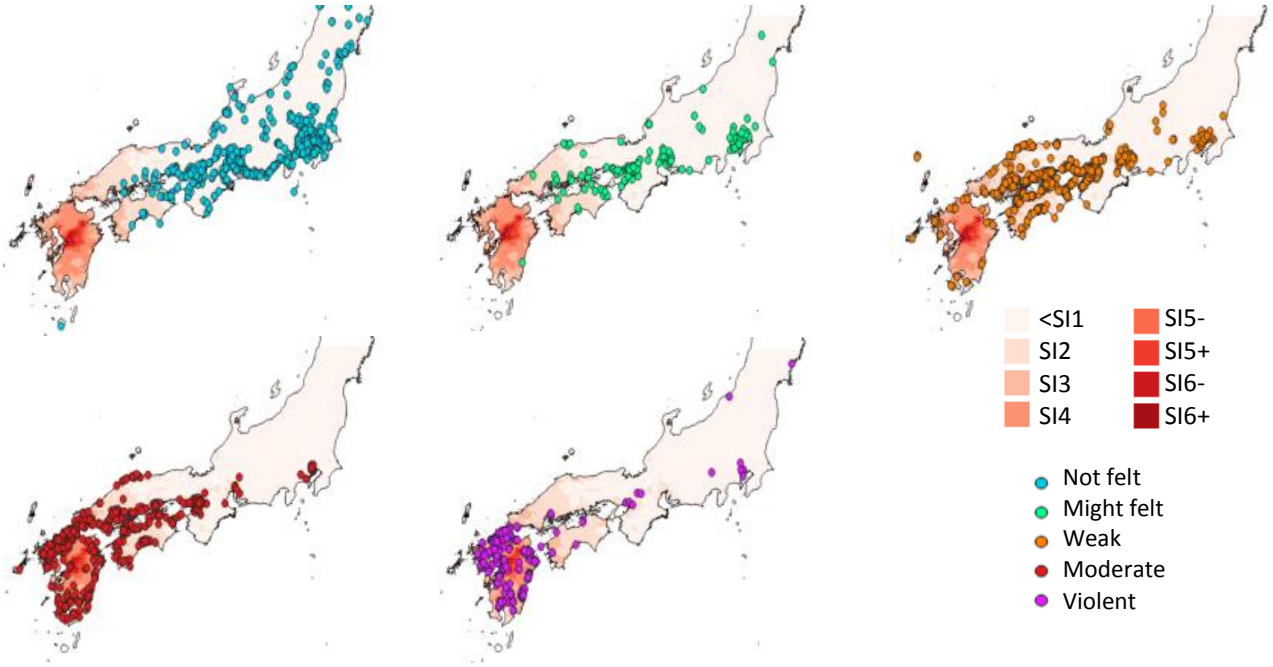

Figure 2: Overlay map of instrumental seismic intensity distribution and ESF answers for No. 3

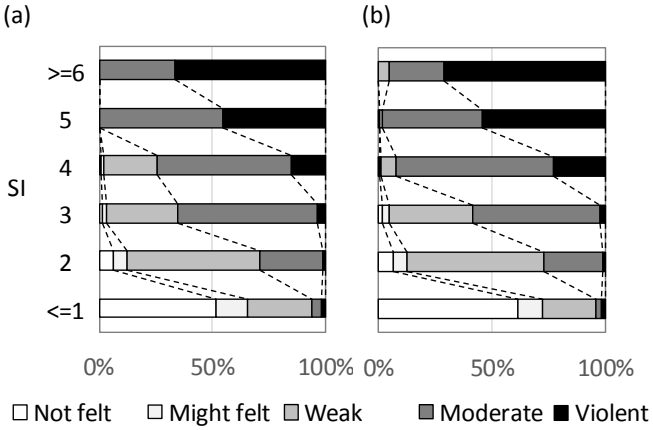

Figure 3: Relationship between ESF answer and seismic intensity (a) No.4 (b) No.5

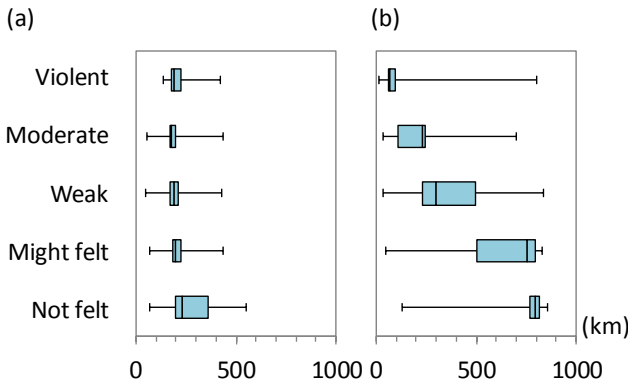

Figure 4: Relationship between ESF answer and epicentre distance (a) No.1 (b) No.6

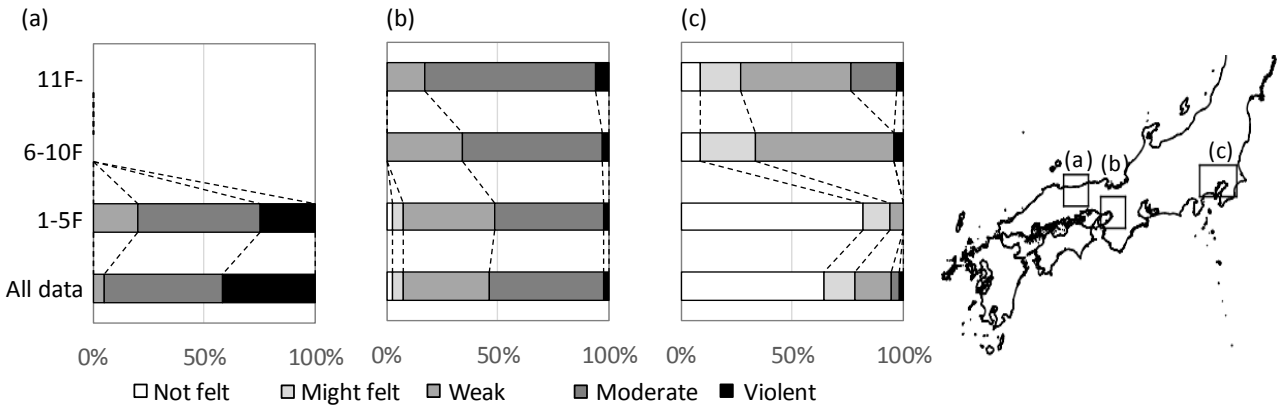

Figure 5: Relationship between ESF answer and floor where respondents were for No.4 (a) Near hypocentre (b) Kansai area (c) Kanto area

In case the ESF answers were posted multiple times by the same respondent, the one with the fastest posting time was applied. Figure 3 shows the relationship between the ESF answer and instrumental seismic intensity. For example, "Moderate" were the most respondents in seismic intensity 3 or 4 areas. A correlation between the ESF answers and instrumental seismic intensity was observed, although some data showed discrepancies. Figure 4 shows the box-and-whisker chart of the epicentre distance for each ESF answer. For No. 1 and No. 4, many people felt "Violent" even in the distance of 200 km from the epicentre, while in No. 2, 3, 5 and 6, they were concentrated within about 100 km. Figure 5 shows the relationship between the floor where respondents were and the ESF answers by regions and the location of regions. Of course, near the hypocentre and the Kansai area, even the Kanto area whose seismic intensity was 1 or less, more people felt "Moderate" in the sixth or more floor.

3.2 The number of responses and additional comments

Figure 6 shows a plot of responses versus time for each earthquake in the one hour after the earthquake. For No. 1, 4, 5 and 6, in the first 10 minutes, a lot of people posted their ESF answers, and then gradually increased. As for No. 2 and 3, the aftershock with the maximum seismic intensity of 6 lower, which occurred about 40 minutes after No. 2 and about 20 minutes after No. 3, increased the number compared with other earthquakes. Including No. 2 and No. 3 in the period from April 14 to April 30, a total of 103,201 pieces of ESF answers were posted. The number of additional comments input was approximately 40% of the number of total posted data for all earthquakes. Figure 7 shows plot of time versus the percentage of the categories of additional comments, such as "Situation", "Sense/Emotion", "Support/Concern" and "Others". "Situation"

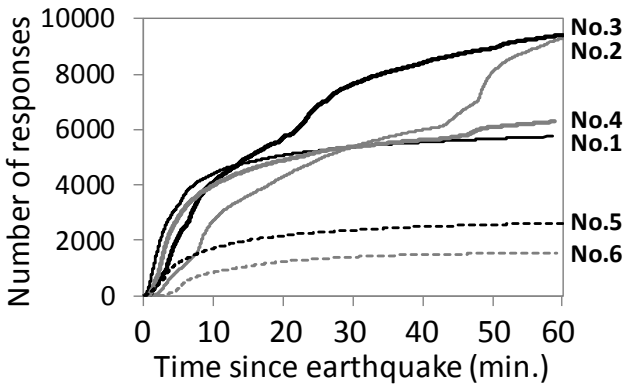

Figure 6: Plot of responses versus time

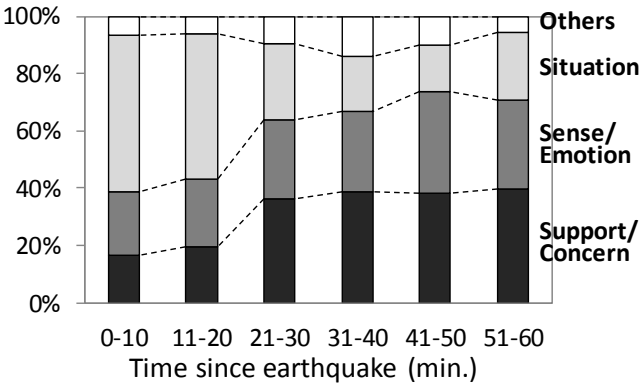

Figure 7: Plot of time versus percentage of categories of additional comments for No. 3

was the most at first, but "Support/Concern" increased over time. The number of comments, such as "I was scared." has been increasing from seismic intensity 3.

4 ANALYSIS RESULTS OF "EQB"

4.1 Earthquake observed records in Building

Table 3 shows the observed records of the earthquakes at the M-building (RC, B4F9) in Chuo-ku, Osaka City. Since No. 1 and No. 4 occurred on office hours, relatively many answers were obtained. As for No. 5, in addition to the web questionnaire, an offline questionnaire was conducted, and a total of 156 responses were obtained over a period from June 18 to June 27.

Table 3: Observation records at the M-building

No.	Floor	Instrumental Seismic Intensity	Maximum Acceleration (cm/s^2)		
			NS	EW	UD
1	9th floor	3.1	19.3	10.5	4.2
	B4 floor	2.3	4.9	3.2	2.4
4	9th floor	3.7	23.5	29.0	11.0
	B4 floor	2.3	6.4	6.6	5.2
5	9th floor	5.2	88.0	268.7	151.6
	B4 floor	4.5	61.5	164.9	102.2

4.2 Results of the Questionnaire

Some of the answers in No. 1 and No. 4 are shown in Figure 8. All respondents were on the fifth floor at the time of the earthquakes. The answer to No. 1 took one week, but the answer to No. 4 ended during the day of the earthquake. The seismic intensity of both earthquakes was as small as 2. There were many responses that felt the shaking slow. The epicentre distances of both earthquakes were about 170 km.

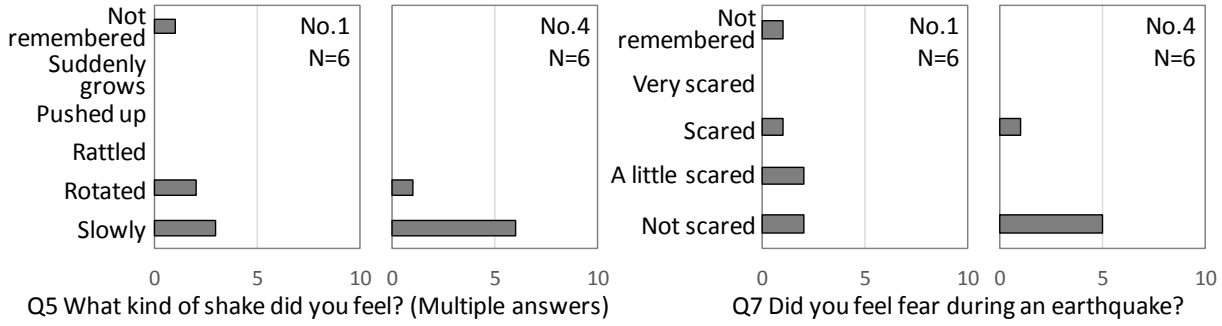

Figure 8: Results of the questionnaire for No. 1 and No. 4

Figure 9 shows the answer to the questionnaire of No. 5. The male to female ratio of respondents in the questionnaire was approximately 7: 3. There were most respondents in their 20s, 30s and 50s, and those in their 40s were less than half of them. The earthquake occurred just before the start of work. Therefore, 66 people felt the shaking in the M-building, and 90 people were not in the M-building (hereinafter referred to as Others). There were many people in the train, so there were 15 people who did not feel the shaking.

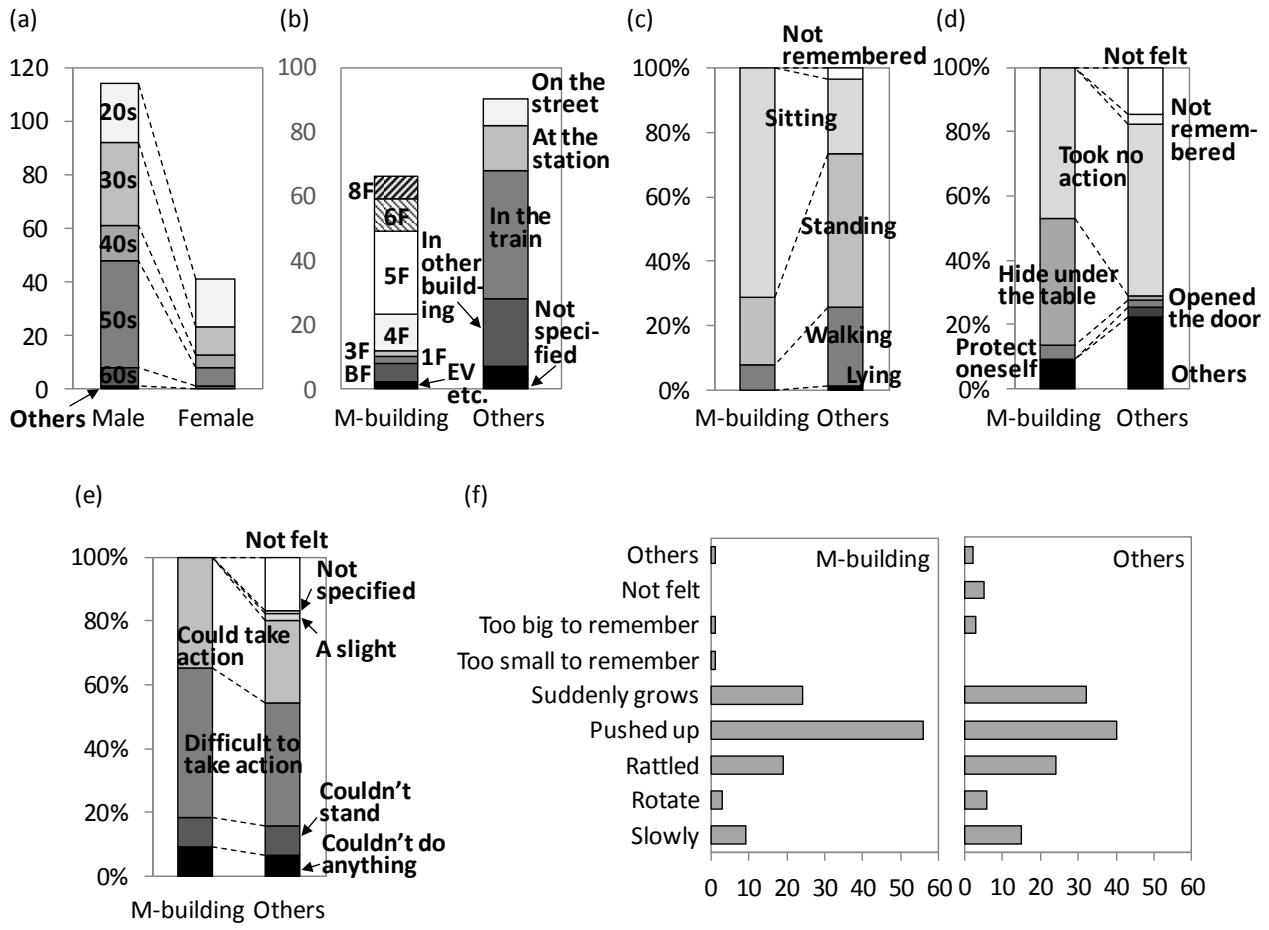

Figure 9: Results of the questionnaire for No.5 (a) Respondent attributes (b) Q1 Location (c) Q2 Posture (d) Q3 Respond (e) Q4 Difficulty in action (f) Q5 Shaking (multiple answers)

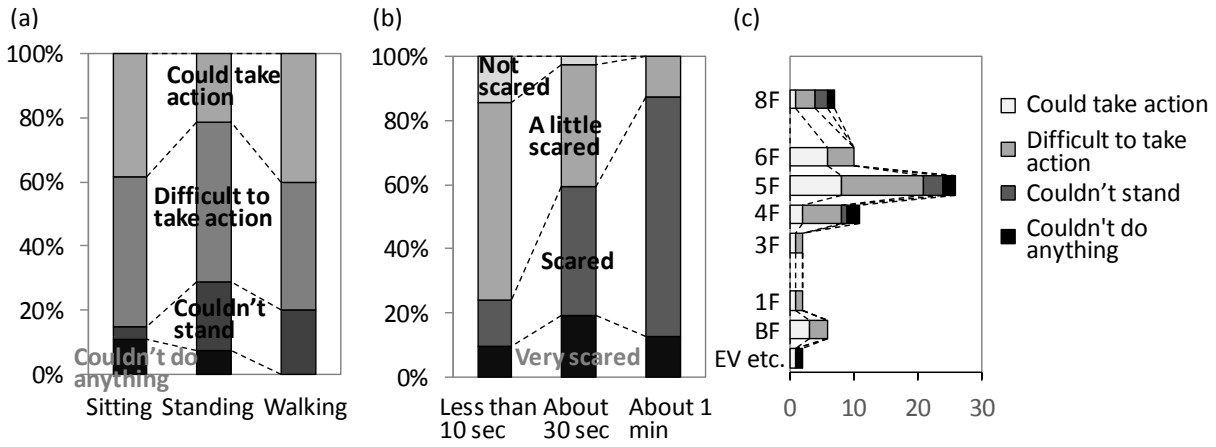

Figure 10: Relationship between questions for No.5 (In the M-building) (a) Posture and difficulty in action (b) Perceived time and fear (c) Floor and difficulty in action

As for Q2 Posture, Q3 Respond and Q5 Shaking, there were some differences between M-building and Others. There were more "I was scared." in Q7 and more "I felt sick." in Q8 in the M-building. Figure 10 shows the relationship between the questionnaire results in the M-building. In this earthquake, it was more likely to feel the shaking when standing or walking. A correlation between perceived time and fear was observed. On the fourth floor and above, the respondents felt difficulty in taking action are increasing.

4.3 Additional comments about the shaking

Additional comments of No. 5 were analysed and about 60% of the respondents commented with a range of 18 ~ 749 characters and an average of just under 100 characters. As for situation, there were many comments which almost agreed with the answers of the selection formula. As for action and emotion, people with past experience and knowledge of earthquakes seemed to be calm. There was no serious damage in the room, but some people panicked and felt fear seeing the situation of the furniture, not the shaking itself.

5 DISCUSSION AND SUMMARY

Using the results of the real-time questionnaire on the shaking of the earthquake experienced by oneself, this paper compares JMA instrumental seismic intensity with the answers of the vibration experienced by oneself, and examines the sense of vibration of human. As for the human sense, it started to feel "Moderate" from the JMA seismic intensity 3, and it tended to feel fear. From the results of two questionnaires, it was found that the earthquake with long period earthquake motion felt a slow vibration even at a far distance. On the sixth floor and above, more respondents felt difficulty in taking action even in the place where seismic intensity was small. From the result of questionnaire for office buildings, the difference appeared in the feeling of shaking in the target building and outside the building. It is considered that the fear for the earthquake is promoted not only by the shaking itself but also by the imagination of how the environment in which the person is in becomes. In addition, it seems that data from real-time questionnaire can be used to understand the damage situation and to use for disaster response immediately after an earthquake in combination with the observed records of earthquake.

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