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HUMAN BEHAVIOR AND CASUALTIES IN WOODEN HOUSES WITH LITTLE DUCTILITY

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SUMMARY

A survey was conducted on the 1948 Fukui Earthquake (MMI of more than 10) to analyze damage to houses, to humans and human behavior during the earthquake. The results show that the casualty rate was 8.4% and the majority of the cases occurred when people failed to escape outdoors. Infants, elderly people and women had higher casualty rates than other age or sex groups. "Rushing out of the house" was the most typical action taken during the earthquake. However, in the case where houses were either "extensively leaned" or "completely destroyed", the strong vibration prevented people from taking any action.

INTRODUCTION

During the past great earthquakes worldwide, many of the casualties have been caused by the structural failure of houses. The studies of these case histories has shown that most of the houses that collapsed had structures with little ductility, such as masonry houses, adobe houses or those with wooden frames having no counter-seismic measures. In order to reduce the number of personal injuries and deaths occurring indoors, it is essential to first examine the case histories in terms of the quake intensity, the types and numbers of casualties, and the indoor human behavior during the quakes. If there is a correlation among these three factors, it becomes possible to develop effective preventive countermeasures as well as emergency medical treatment systems.

The study conducted here focuses first on examining the condition and range of the structural damage and on human behavior and casualties during an earthquake with the locally recorded Modified Mercalli Intensity Scale (MMI) of more than 10. Second, the study identifies the determinants which separate those who were killed or injured from those who survived. The case employed for this study concerns an earthquake called the Fukui Earthquake, which occurred in 1948 in Fukui Prefecture located in the middle of Honshu Island facing the Japan Sea. It should be understood, when studying the damage by the earthquakes in this period, that most of the houses had a wooden frame with no particular consideration given to seismic motion.

OUTLINE OF THE FUKUI EARTHQUAKE AND DETAILS OF SURVEY

The Fukui Earthquake occurred at 4:13 pm on June 28th, 1948, with its

epicenter at Longitude 136.2°E, Latitude 36.1°N. The recorded magnitude was 7.3. The quake caused extensive damage in and around Fukui Prefecture. The final account was to approximately 4,000 dead, 36,000 houses completely destroyed and 4,000 houses lost due to fires resulting from the earthquake (Ref. 1). The strong vibration is said to have lasted for about 30 seconds. Figure 1 shows the extent of the damage to the houses in the vicinity of the epicenter, expressed in the ratio of the number of houses destroyed to the total number of houses.

The area surveyed for this study is Fukui City and the surrounding area, where the recorded MMI was more than 10. A questionnaire was developed for the survey and sent by mail to the group of people selected for the survey. The selection focused on the level of education one had received, assuming those with higher education retain more accurate knowledge of the past. Accordingly, only those who graduated from teachers' colleges (equivalent to the current undergraduate level) were selected.

The questionnaire included questions about: the degree of damage to the furnishings as well as to the houses; human behavior during the earthquake; and personal injuries including those to the participants' family members surveyed. The survey was conducted from July 1984 through October 1985, with 570 answering the survey. Table 1 shows the composition by sex and age of those who responded.

Table 1. Sex and Age of Participants

SEX	AGE							TOTAL
	0-9	10-19	20-29	30-39	40-49	50-59	NA	
MALE	5	75	220	71	15	8	2	396
FEMALE	3	32	111	17	4	2	0	169
NA	0	0	1	0	0	0	4	5
TOTAL	8	107	332	88	19	10	6	570

SEISMIC INTENSITY AND CORRELATION BETWEEN
CHANGES IN INDOOR ENVIRONMENT AND DAMAGE TO HOUSES

The results of the several surveys conducted immediately after the earthquake showed house destruction rates of 40%, 62% and 79%, indicating that the quake intensity was more than 10 (MMI) (Ref. 2). The survey gave a rate of 54.7%, thus proving that the selection of survey population was not prejudiced.

Table 2. Sex and Age of Participants' Family Members

SEX	AGE									TOTAL
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-	NA	
MALE	141	220	315	109	95	122	73	26	20	1121
FEMALE	110	172	288	82	161	117	66	42	26	1064
NA	0	0	6	1	0	4	2	0	7	20
TOTAL	251	392	609	192	256	243	141	68	53	2205

Figure 2 shows a significant correlation between the degree of damage to houses and the movement of heavy furniture. For example, 42.5% of those who answered that the degree of damage to houses is "cracks in the wall" reported

"significant movement or some overturned" of heavy furniture. Heavy furniture is known to be directly related to the injury occurring during an earthquake. The damage by an earthquake due to overturning furniture indicates an intensity of 8(MMI). This implies that the number of indoor injury cases increases markedly from 8(MMI), of which a quake can also be inferred from the "cracks in the wall".

OCCURRENCE RATE OF CASUALTY CASES

Table 2 shows composition by age and sex of the participants' family members who were surveyed. Of a total 2,205 people, 185 were either killed or injured. Of these 185 people, 122 (65.9%) were killed or injured during the earthquake and 35 (18.9%) after it.

Figure 3 shows the occurrence rates by sex and age regarding casualty cases. The figure also includes the rates derived from the data from Noshiro of the Nihonkai-Chubu Earthquake in 1983. The data are regarded as typical examples of the trend seen in earthquakes occurring in Japan in recent years.

In Figure 3, the casualty rate distribution by age is high for those 60 or older. This agrees with the results obtained in other earthquake data. On the other hand, the rate distribution by sex and age shows no significant difference between men and women, despite the commonly held perception that women are more likely to be killed or injured than men.

Concerning the death rate, however, the rates for women are consistently higher than those for men from those 20 through 60. Furthermore, according to Figure 4 which shows the recuperation periods from injuries sustained, men and women separately, nearly one half of the injured women required more than one month to recuperate, in contrast to only less than one fourth for the injured men. The author interprets this to mean that women suffered from more serious injuries than men, rather than that women taking longer to recover from an injury than men. Considering these two findings, the author believes that women are more vulnerable to personal injury than men.

The survey produced a high casualty rate for children of who were younger than 10. In contrast, the surveys conducted for past earthquakes with an intensity of less than 8(MMI) have consistently shown low casualty rates for this age group. The details of this phenomenon are discussed in the following section.

Figure 5 shows the relationship between a quake intensity expressed regarding damage to houses and the corresponding casualty rate. The rate is defined as the proportion of the number of the casualty cases during a certain earthquake condition to the total number of the people subjected to the condition. This figure indicates that the casualty cases begin to occur when the damage to houses exceeds the level of "cracks in the wall". Subsequently, the rate rises as the houses suffer severer damage, reaching the rate of 20% when the houses are completely destroyed. As for death rate, it begins to appear when the houses are leaned greatly, reaching 6% when the houses are completely destroyed.

HUMAN BEHAVIOR AT HOME DURING AN EARTHQUAKE

Intensity of Quake and Human Behavior The motion of an earthquake has a significant influence on human behavior during a quake. Figure 6 shows that all types of activities, except for "remaining in place", have their peak with a

certain degree of damage to houses. The urge to react to an earthquake increases as the intensity becomes greater. However, when it reaches a certain intensity, the motion of a quake effectively restricts activities. Peaks in the occurrence rate of each activity thus appear as a result of the balance between the emotional urge to move and being restricted due to the intensity of a quake.

The urge to "rush out of the house" was highest when the quake intensity was such that "the columns of the house inclined". The other activities had their peaks when "the house somewhat leaned". The difference in the peak positions indicates the difficulty of moving from indoors to outdoors compared with movement within a house.

When a quake intensity is strong enough to destroy houses, people instinctively rushed out of their houses for safety. Table 3 shows the number of those who could escape outside and those who could not, with the existence of serious injuries (requiring a recuperation period of more than 3 weeks) in each case. Showing a significantly low casualty rate for those who managed to escape outdoors, the table affirms the rationale of the commonly practiced above action.

Differences in Activities due to Sex The activities in daily living include several types of activities conducted mostly by those who are socially expected to do so. These activities, called role-behavior include preparation of meals and rearing of children by housewives. Figure 7 shows a similar tendency in people's actions during a quake. In activities such as "turned off the fire" and "protected the children and elders", women were much more alert to these needs than men. The survey, therefore, affirmed that people tend to follow their social roles in types of action they take when faced with an earthquake.

Table 3. "Rushed out of House" and Occurrence of Injury in Destroyed House

		Recuperation Periods over 3 Weeks	
		YES	NO
"Rushing out of House"	COULD	1	27
	COULD NOT	5	7

p < 0.01

The role-behavior mainly by women of "protecting the children" is considered to have contributed to the low casualty rate among children under 10 years old revealed in the study of the Off-Urakawa Earthquake (Ref. 4). In the Fukui Earthquake, the survey showed a comparatively low performance rate for the activity of "protecting the children and the elderly" by women at home, being approximately 60% of the rate obtained in the Off-Urakawa Earthquake, of which the range of MMI is 7 to 8. The rate was especially low where the vibration was so strong that the houses were destroyed. On the whole, the activities of protecting others becomes increasingly difficult when MMI exceeds 10, resulting in distinctly higher casualty rates among the physically disadvantaged groups such as infants and the elderly. The survey of the Fukui Earthquake, with an intensity of more than 10(MMI), confirmed this trait.

CONCLUSIONS

The study centered around the Fukui Earthquake, a major earthquake occurring in 1948 which destroyed 54.7% of the houses in the area. The study analyzed three factors: 1) the damage to wooden structures houses with little ductility to quakes, 2) casualties and 3) human behavior during the earthquake. The following

conclusions were reached as a result of the study:

- (1) Casualty cases rise sharply during earthquakes with a quake intensity of more than 8(MMI).
- (2) In the Fukui Earthquake, the overall casualty rate was 8.4%. The casualty rate of the households whose houses were completely destroyed rose to 20% while the death rate of the same group was 6%.
- (3) 64.5% of the total casualty cases occurred as a result of collapsing housing with the occupants being unable to escape outdoors.
- (4) Infants, the elderly and women had higher casualty rates than other age groups or men. Casualty rates for infants were generally lower during earthquakes with a quake intensity of less than 8(MMI), as other age groups can protect them during less intense earthquake movement.
- (5) "Rushing out of the house" was the most typical human behavior during a quake. However, in areas subjected to severer intensity where houses were either "greatly leaned" or "completely destroyed", the strong intensity of the quake prevented many of them from escaping outdoors.

The meaningful results of the survey proved that a survey using a questionnaire, coupled with a sensible selection of the survey area and population, enables clarification of human behavior and the extent of casualties of earthquakes occurring in the past.

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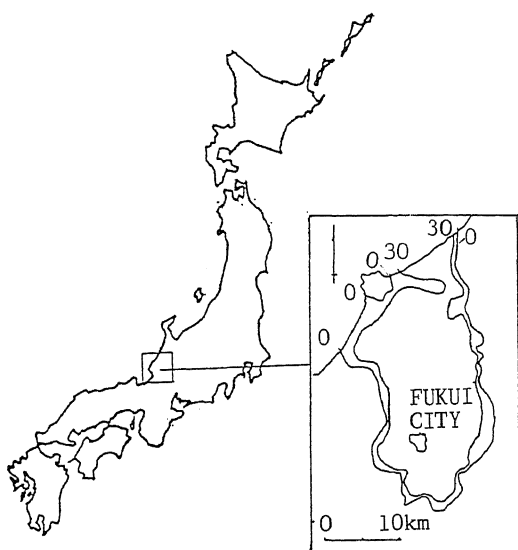


FIG. 1 SURVEY AREA AND DISTRIBUTION OF THE RATE OF DESTROYED HOUSES

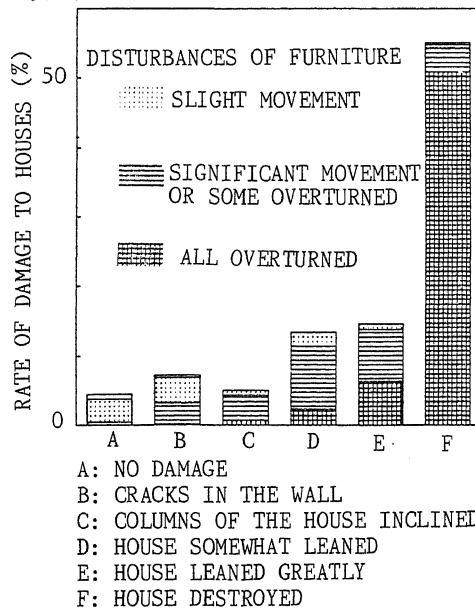


FIG. 2 RATE OF DAMAGE TO HOUSES AND THE MOVEMENT OF HEAVY FURNITURE

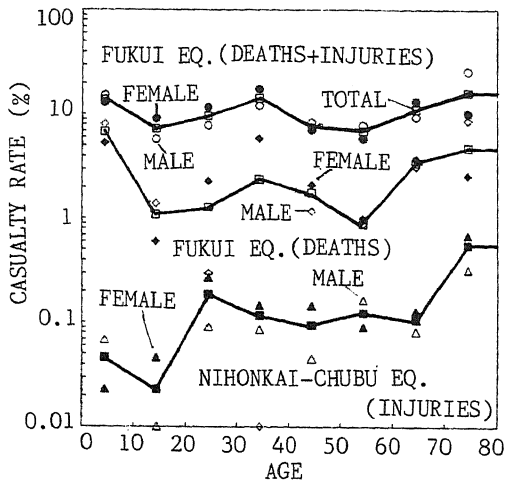


FIG. 3 CASUALTY RATE BY AGE

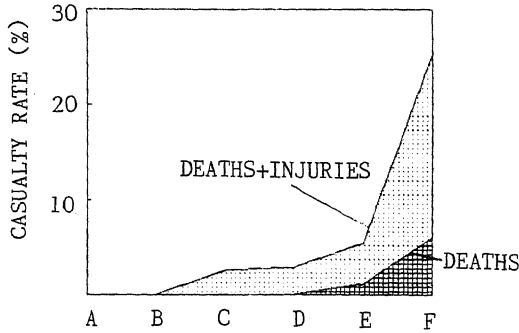


FIG. 5 CASUALTY RATE BY DEGREE TO HOUSES

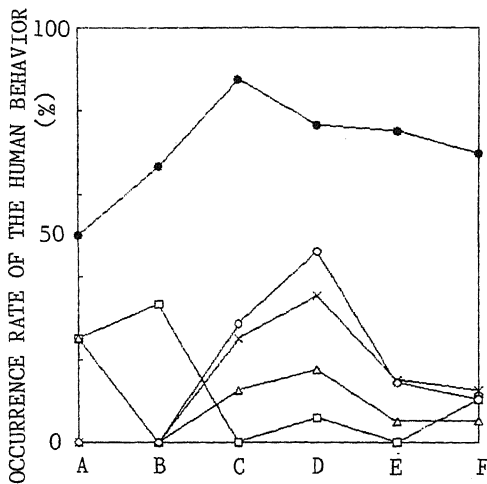


FIG. 6 OCCURRENCE RATE OF HUMAN BEHAVIOR BY DEGREE OF DAMAGE TO HOUSES

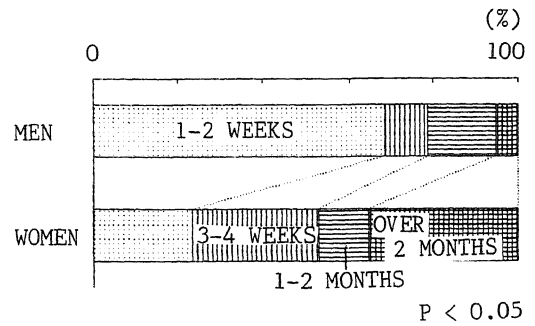


FIG. 4 RECUPERATION PERIODS FOR THE INJURED

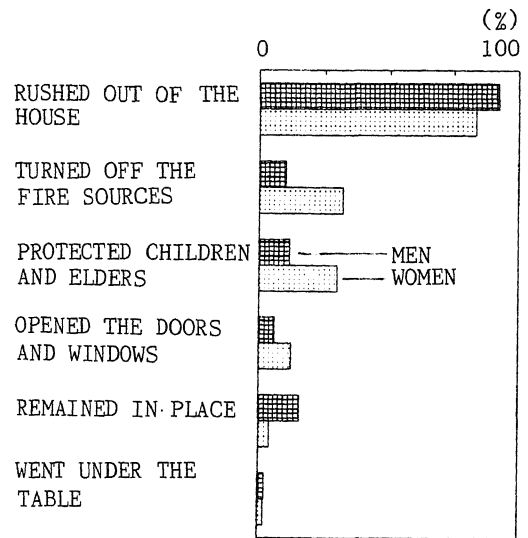


FIG. 7 RATE OF ACTION

- RUSHED OUT OF THE HOUSE
- × TURNED OFF THE FIRE SOURCES
- PROTECTED CHILDREN AND ELDERS
- REMAINED IN PLACE
- △ OPENED THE DOORS AND WINDOWS