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STUDIES OF OCCUPANT BEHAVIOR IN EARTHQUAKES - REVIEW AND PERSPECTIVES -

Hitomi Ohashi MURAKAMI[1] and Michael E. DURKIN[2]

[1] Department of Architectural Engineering, Hokkaido University, Sapporo, Japan
[2] School of Architecture, University of Southern California, Los Angeles, U.S.A.

SUMMARY

This paper reviews about 60 studies of occupant behavior and human casualty in earthquakes performed since mid 1970s. Problem area, survey methodology, and analytical procedure are critically examined and compared. Hypothesis and the major findings are discussed referring to the framework of occupant behavior research. Development of comprehensive and knowledge based model is recommended for simulation, factor analysis and advanced application.

INTRODUCTION

Studies of occupant behavior during earthquakes were started in Japan by Ohta et al. (Ref. 1) as a part of seismic intensity surveys. At that times, Horiuchi et al. (Ref. 2) investigated the 1974 Izu-hanto-oki earthquake by interview method in view of fire prevention behavior. In the United States, a retrospective study was started in 1979 on personnel responses in the hospitals damaged at the 1971 San Fernando earthquake (Ref. 3). Since then, a growing number of these studies have been performed at a variety of damaging earthquakes in different parts of the world. This area of study is interdisciplinary in nature, and got interests by engineers, architects, social scientists, epidemiologists and others. Thus, exchange of ideas and research findings are important.

The authors reviewed 38 related studies from Japan, 12 from U.S. and 8 from other countries and constructed data base which includes location of the study, events (earthquakes) surveyed, approach, topic of interest, environment, discipline, abstract and comments. The whole volume will be published as a separate issue. This paper critically examines the survey method, analysis, hypothesis and findings and aims to clarify research needs, strategy and perspective for future developments.

SCOPE OF PROBLEM

Fig. 1 indicates the problem area occupant behavior research concerns. Major interest is to predict and explain behaviors of the individual people located in specific environment such as buildings and streets, during strong earthquake shaking, and immediately after shaking. Time range covered may extend to several hours or a day, in case evacuation from conflagration or from tsunami inundation occurs.

Medical disciplines have been concerned with extent of trauma and illnesses caused by earthquakes to prepare better emergency medical system (Refs. 4, 5). These medical studies are strongly inter-related with occupant behavioral research, which tries to answer the question "what kind of people in what kind of environment suffer casualties."

Social scientists also have traditionally studied human behavior under the impact of natural disasters, though, their interest is rather in emergency response and recovery of community level, communication of predicted hazard, and decision making processes (Refs. 6, 7). Our studies of occupant behavior in earthquakes are different from these socio-psychological approach, because we are more concerned about physical environment, their seismic performance, safety of occupants against the strong impact of earthquake motions.

SURVEY METHOD

Field investigations after significant earthquakes are important to accumulate variety of human responses in different settings and to find out the influential factors. Questionnaire method is most frequently used to ask conditions prior to earthquake occurrence, behaviors during strong shaking, behaviors immediately after shaking, physical and architectural environment, shaking intensity and level of damage.

Various research groups classified occupant actions during and after shaking based on purpose of the study and considered environment. Typical actions are: unable to react, wait for a while, reduce fire risk, protect others, give order to others, protect property, protect oneself, and seek safe refuge or exit. Ohashi and Ohta (Ref. 8) interpreted occupant behavior as a sequence of 3 fundamental unit processes, that is, unit work, place to place movement and stand-by posture. It is beneficial to establish standardized actions for comparison of different studies.

Interview method is effective for detailed case studies, but is limited in number of cases available. Occasional use of interview is recommended to search new area of problems, and possibility of new factors affecting.

These survey are better performed soon after the earthquake, before the memory of people fades away. However, enthusiastic efforts to be mentioned here are to retrieve experiences of old, but further more important historical earthquakes. Horiguchi et al. (Ref. 9) investigated the people who experienced the 1948 Fukui earthquake, which killed 4000 people, collapsed 36000 houses and burnt 4000 houses. In the U.S., there is a study of the 1906 San Francisco earthquake to clarify the real number, cause, location of fatalities from variety of information sources (Ref. 10).

Video recording method proposed (Ref. 11) is an innovative field observation of occupant behaviors during earthquake shaking itself. Real sequence of disordered actions in the midst of disaster can be interpreted, and reasoned by interviewer or interviewee, and there is a risk of modified behavior to be reported by questionnaire and interview methods. Video recording is advantageous in objectivity of the data and can be promoted to obtain more records and to develop analysis methods.

Laboratory experiment of human operability using shaking tables was performed to examine the safety of industrial plants and nuclear power plants (Ref. 12). These studies are few and have limited usage, because surprise and fearful emotion to motivate behaviors can hardly be realized in the artificial shakings. Effectiveness of shaking table as an earthquake drill is to be evaluated.

ANALYTICAL PROCEDURE

Sampling strategy affects choice of survey methods and analytical procedure. In order to limit the number of independent variables, it is effective to sample the occupants of specific building type (ex. RC apartment building, and typical wooden dwellings), or certain age and sex group such as housewives at home. Occupant survey of the same apartment plan at the 1978 Miyagi-ken-oki earthquake (Ref. 8) and of Imperial County Services building at the 1979 Imperial Valley earthquake (Ref. 13) tried to relate occupant response and evacuation routes with architectural setting of the building. Drawing trajectories of individual movement and evacuation path in a plan is helpful.

Aiming at more general results, Omi et al. (Ref. 14) took a large number of stratified random samples, which are 1% of 600,000 population in Sendai city. Diversity of physical surroundings people can be located complicated the questionnaire format and increased the number of variables in multivariate analysis.

Epidemiological approach is effective for studying cause of casualties and patterns of other actions, which are not very frequent but important. Durkin et al. (Ref. 15) surveyed the injured cases and their controls who were not injured but matches the location, or age and sex at the 1983 Coalinga earthquake. Kosaka and Shiono (Ref. 16) took the similar approach in the interview survey.

Discriminant analysis is used to examine if certain action will occur for a given attribute and physical settings. Percentage of successful discrimination is not very high, because many alternate actions are possible. Most of independent and influential factors are not quantitative but categorical data, so that methods such as Hayashi's Quantification Theory are effective.

MODELS, HYPOTHESIS AND FINDINGS

Fig. 2 indicates a range of factors correlated with occupant behavior and casualty occurrence. Many studies examine specific aspects of behavior such as behavioral type, fire extinction, driving by factor analysis.

Strength of input ground motions is certainly one of the major factors affecting occupant behaviors. Under the weakest shaking, people are fully capable of acting according to one's own intention. While shaking getting stronger, motivation for safety and protection becomes more urgent, however, behavioral performance and calm control of response deteriorates rapidly. Ohta and Ohashi (Ref. 17) measured seismic intensity in a number of earthquakes in Japan by questionnaire method and correlated human behavior with intensity. This is a remarkable approach to explain different earthquakes by single parameter, while other studies usually analyze individual earthquakes separately.

Japanese studies indicate that usage of fire sources motivates fire extinction behavior and presence of young children and the elderly urges adults of the family to take protective actions (Refs. 17, 14). Fire prevention response is peculiar in Japan, because of earthquake preparedness education and the memory of disastrous earthquake conflagration warning people that fires are much more hazardous than shaking itself.

Physical environment is related with occupant behaviors. For example, smaller size of dwellings results in higher injury rates (Ref. 18). Studies of the 1978 Miyagi-ken-oki earthquake indicate that more casualties occurred at home than at offices and schools (Ref. 19).

Personal attributes affect behaviors. Older people tend to be inactive and unable to move during severe shakings, and result in higher casualty rate and severer injuries (Ref. 19). Babies and infants, who are another segment of population also incapable to interpret the emergent situation and to move quickly, show lower injury rates because of protection by patents. Role behaviors are often observed in a family or in a work place. Safety of many people depends on appropriate responses of a teacher in a classroom, nurses in a hospital, a manager in a market, and an operator of industrial plants.

Ohta et al. (Ref. 20) combined these factors and proposed a comprehensive and semi-empirical model to explain the risk of casualty as a function of seismic intensity, personal attributes, size of environment, and time of earthquake occurrence. The model is not yet numerically finalized, however, this gives a good framework to interpret the phenomina.

APPLICATIONS

The knowledge of occupant behavior in earthquakes is essential to improve the safety of physical environment. Examples are securing evacuation path, fixing furniture and building contents to the wall, and developing automatic extinguisher for kerosene stoves. Examination of capability to evacuate a building can be related with occupants' performance (Ref. 21).

Providing guidelines for better earthquake preparedness and education is another task. It is important to answer such a question if hiding under the desk or standing in a doorway is really recommendable and safe, and at what intensity level fire extinguishing is possible. Occupant casualty studies are crucial for reliable estimation of casualties in family and in a community affected. This can be the basis for emergency medical service.

CONCLUDING REMARKS

Fig. 3 shows schematic course of the research targeting human safety. Reviewing the accomplishment of studies of occupant behavior and earthquake casualties, the following issues are recommended for further development.

(1) Construction of knowledge based occupant response model which combines decision making process, environmental changes during shaking, contact with people in presence and other related factors.
(2) Communication of research methodology and findings among earthquake countries in the world.
(3) Promoting communication between researchers and practitioner such as earthquake safety planners, public and private agencies.

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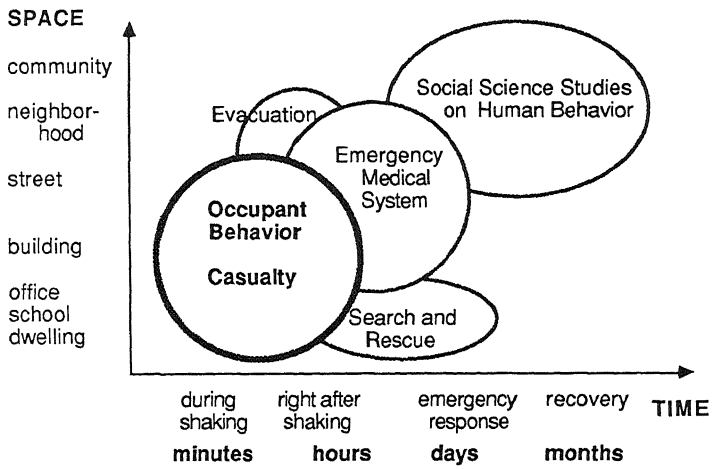

Fig. 1 Research Area of Occupant Behavior in Earthquakes and Related Issues

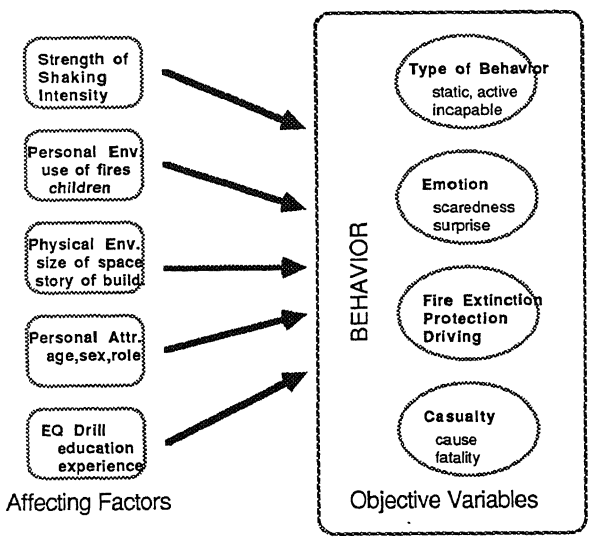

Fig. 2 Factors Explaining Various Aspects of Occupant Behavior

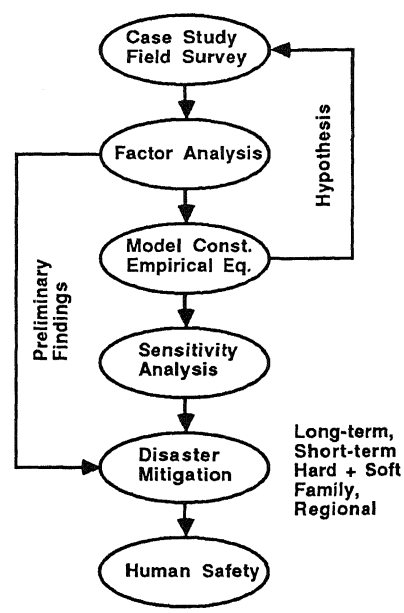

Fig. 3 Course of Occupant Behavior Research