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CASUALTIES, SURVIVAL, AND ENTRAPMENT IN HEAVILY DAMAGED BUILDINGS

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

[1]Michael E. Durkin and Associates
School of Architecture, University of Southern California,
Los Angeles, California, USA
[2]Department of Architectural Engineering, Hokkaido University,
Sopporo, Japan

SUMMARY

Following the recent Mexico City and San Salvador earthquakes, we surveyed surviving occupants of two heavily damaged buildings. The survey focused on each occupant's location and actions from the start of shaking until the occupant was safely outside of the building. We also documented the degree of exposure to, incidence of, and severity of injury, and, where appropriate, the circumstances surrounding entrapment.

Table 1 presents some preliminary results. The highest fatality rate was in the "pancaked" dormitory building. Injury rates and severity also varied among the two buildings, with the highest rates and severest injuries in the dormitory building. The percentage of occupants trapped also varied in a similar manner. The office building, which also collapsed, had approximately one half the fatality rate, two thirds the injury rate, one-tenth the hospitalization rate, and one-half the entrapment rate of the dormitory building.

These findings suggest that emergency responders can expect to find survivors in even the worst building collapses. Further, they suggest that fatality, survival, and injury rates vary with different patterns of damage and structural collapse. This paper elaborates those findings examining factors surrounding evacuation and search and rescue.

INTRODUCTION

Complete collapse is the most serious outcome of earthquakes for buildings and occupants. However, despite its obvious implications for life safety, collapse does not result in death for all building occupants. The survival of some occupants raises important research questions. Why did some occupants survive while others perished? Did such factors as location of occupants, actions of occupants, injury type and severity, nonstructural elements and building contents, nature and time of entrapment, and method of rescue play a role in survival - factors which we can learn from and train people about? Or were the survivors mere lucky beneficiaries of circumstances? These questions have an obvious bearing on how we prepare for future earthquakes.

Following the 1985 Mexico and the 1986 San Salvador earthquakes, we surveyed survivors of two collapsed buildings. We interviewed eighteen medical residents who survived the collapse of the Medical Residents Dormitory at the General Hospital in Mexico City. The dormitory became a major focus of search and rescue efforts lasting for several weeks. We also surveyed twenty-six office workers who survived the collapse of the Ministry of Planning Building in the 1986 San Salvador earthquake. The following paper presents, in progress, results of these two case studies.

BACKGROUND

The Buildings The Medical Residents Dormitory was an eight-story, reinforced concrete structure with a rectangular configuration. Seven of the eight floors were allocated to domiciliary space. Each floor in the repeated floor plan had eight bedrooms, four on either side of a doubleloaded corridor. An elevator, fire stair, and multi-purpose room were located in the center of each floor.

The Ministry of Planning Building was a five story reinforced concrete frame structure with a waffle slab floor system. This building completely collapsed. An adjacent but detached tower, containing elevator shaft, firestairs, bathrooms, and some office space, remained standing (Ref.1)(Ref.2).

The Occupants On the morning of September 19th, 1985, the dormitory was home to seventy-six medical residents, ranging in age from 27 to 32 years. Of this number, forty residents ultimately survived, and thirty-six perished from earthquake-related injuries (Ref.3)(Ref.4).

The Ministry of Planning building was occupied by about sixty government office workers when the earthquake struck on a Friday morning at 11:00 A.M. These workers ranged in age from 22 to 65 years. Thirteen office workers perished in this collapse.

TABLE 1 Casualties By Building Type

	A Dormitory		B Office	
	Number	Ratio	Number	Ratio
At Risk Interviewed	18		21	
Fatalities	36	.47	13	.21
Injuries				
Injured	18	1.00	13	.62
Not Injured	0	0	8	.38
Hospitalized	10	.55	1	.05

RESEARCH APPROACH AND METHODS

Historical Cohort Approach In this application, the historical cohort approach considers a population group that experienced an earthquake. It attempts to document injury occurrence as related to different types and levels of exposure. A promising variation of this approach focuses on the performance of a specific building and the fate of its occupants (Ref.5).

Specific Methods We used a semi-structured, self-administered questionnaire to document the residents' and office workers' experience during and following the September 19th quake. The questionnaire covered a number of topics, including personal characteristics; location at the beginning of the earthquake,; actions (from the beginning of the shaking until exiting from the building; where applicable from time of entrapment until rescue); the cause, type, and severity of injury; the search and rescue process; the receipt of medical care; and the longer term impacts of the injury.

We, so far, have interviewed eighteen Residents' Dormitory collapse survivors. We have also, so far, interviewed twenty-one of the fifty-one surviving Planning Ministry occupants.

THE ROLE OF STRUCTURAL AND NONSTRUCTURAL ELEMENTS AND BUILDING CONTENTS IN LIFE PRESERVATION

When reinforced concrete buildings collapse, structural elements, nonstructural elements, and building contents often interact to form space pockets within which occupants might survive (Ref.6). Given this possibility, we asked our eighteen survivors of the dormitory and the twenty-one survivors of the Planning Ministry if building elements, furniture, or equipment prevented a total collapse in their area.

The results showed that building elements and building contents played a clear role in life safety. Ten of the eighteen residents reported such an effect; eight of those ten reported that elements or contents performed a role in survival (Ref.7). In addition, three of the twenty-one trapped in the Ministry of Planning Building reported this effect.

ENTRAPMENT

Duration of Entrapment All of the residents interviewed but the two in basement corridors (eighteen respondents) were trapped. The survivors were mostly rescued quickly. The duration of entrapment ranged from twenty minutes to seventy-two hours, with fifteen of the eighteen trapped for under five hours, and twenty-one of the twenty-two trapped for under twenty-four hours.

Eleven of the twenty-one office workers were trapped. This group was also rescued quickly. Seven respondents were freed within one hour, three others in under ten hours. Only one survivor was trapped for over twenty-four hours.

Who Were the Rescuers? Knowing who actually will likely rescue trapped earthquake victims is important to effective training and preparedness planning. Eighteen of the twenty dormitory respondents were trapped. Of these, only one was able to free himself. Table 2 provides a breakdown of who actually performed the rescues. Twelve residents were freed by fellow residents. Two residents reported being freed by a combination of fellow residents and other hospital workers. Only two trapped residents were freed by search and rescue teams, and these were assisted by coworkers.

Table 2 Rescuers By Building Type

Rescuers By Building Type

	Dormitory (N = 18)	Planning Ministry (N = 11)	Total (N = 29)
Freed myself	1	3	4
Fellow residents or office workers in same building	12	2	14
Fellow residents and hospital personnel from other buildings; fellow office workers and workers from other buildings	2	3	5
Fellow residents and Search and Rescue personnel; fellow office workers and Search and Rescue Personnel	2	3	5
Search and Rescue Personnel alone	0	0	0
Police and/or Fire	1	0	1

Rescue Techniques We also asked what methods were used in finding victims, including how they knew that rescuers were near. In seventeen of twenty-one cases, the method used was human voices - calling out by both the rescuers and by those trapped. Other methods mentioned were knocking and making noise with objects such as an iron bar. No one mentioned sophisticated technology as a method of contact. Voices were likely the predominant method because colleagues performed most of the rescues prior to organized search and rescue and use of sophisticated equipment at these collapse sites.

Key Fears Of Those Trapped We also asked victims if, while trapped, certain factors seriously threatened their survival. Most of the trapped residents indicated that the major threat was the removal of rubble. Those trapped heard the rescue operations occurring and were afraid that they would be crushed as rubble was shifted and removed.

DISCUSSION

The results showed that building elements and building contents clearly played a role in life safety. The data have clear implications for training. Building occupants can be taught to identify possible shelters as well as hazards in the buildings they occupy. The findings also support our contention that occupants can act, and have important implications for training. However, they do not clarify what specific phases or actions helped. We are conducting further investigation of these and other heavily damaged structures to achieve additional results from which such information can be derived.

The length of time of entrapment is crucial to survivability, especially to those who are injured. It's commonly accepted that twenty-four hours is the cut-off time for the survival of large numbers of trapped victims. Because most residents were rescued quickly, our data do not help answer, at present, a key question: When did the people who perished begin to die? We therefore cannot confirm or refute the twenty-four hour cut-off time for survival.

Finally, these data on entrapment and rescue support the view that search and rescue teams, as presently constituted, trained, and managed, save relatively few lives. By the time the teams arrive, especially foreign teams, and have decided on methods, most survivors have been rescued. Both the relatively short duration of entrapment and the frequency of rescue by fellow residents or other hospital personnel underscore the importance of local resources and training.

Because co-workers in the 50 building medical complex and collapsed office building performed most of the rescues (only two respondents were rescued exclusively by search and rescue teams), training should focus on co-workers for essential rescue activities. This training seems essential to survival. The ways that people are entrapped are important to the possible training needs of co-workers.

The rapid rescues also call into question the potential role of foreign rescue teams. We know that foreign search and rescue specialists do in fact rescue people. Since eighteen of our twenty respondents were trapped under five hours, and all but one under twenty-four hours, a rescue team that arrives twenty-four hours after a collapse is not going to be effective. Consequently, foreign teams (depending on the country) may be more important as purveyors of equipment and technology than of manpower.

Durkin Associates is further investigating these and other heavily damaged structures to shed more light on the previous questions. We are locating, contacting, and interviewing additional collapse survivors to develop a more complete basis for survival and injury rates and their attribution. We are also examining the influence of such factors as occupant location, action, evacuation, damage patterns, and available resources on injury, survival, and search and rescue.

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