Paper No. 852. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

CHANCES OF OCCUPANT SURVIVAL AND SAR OPERATION IN THE BUILDINGS COLLAPSED BY THE 1995 GREAT HANSHIN EARTHQUAKE, JAPAN

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ABSTRACT

In the 1995 Great Hanshin-Awaji earthquake (M=7.2), 6,335 people were killed mostly by collapse of structures. Damage statistics are examined to find out lethality level, that is risk of fatality in collapsed buildings, in relation to residential types. Lethality is high in wooden detached (3.6%) and tenement (5.8%) dwellings and lower in RC or steel apartments (0.58%). Breakdown of total human loss is estimated as; 46% in detached, 45% in tenement, and 9% in apartments. Search and rescue operation were conducted by local residents as well by fire departments and Self Defense Forces. Records of fire departments indicate chances of alive rescue deteriorates very rapidly after the day of the quake.

KEYWORDS

Casualty; human loss; search and rescue; 1995 Great hanshin earthquake; lethality of building collapse; rescue operation.

EARTHQUAKE AND EXTENTS OF HUMAN CASUALTY

An earthquake of Magnitude 7.2 occurred in Kobe, Hanshin and Awaji region of Western Japan at 5:46 a.m. on January 17, 1995, Tuesday. As of January 1996, that is one year memorial, total damage reported is; 6,335 people killed, 2 missing, 38,507 injured, 182,610 housing units totally collapsed and 244,271 units partially collapsed. The amount of human loss is the third largest in Japan since Meiji revolution in 1868 following the 1923 Great Kanto earthquake (M=7.9, 143,00 killed) and the 1891 Nobi earthquake (M=8.0, 9,273 killed).

This study tries to examine factors which affected human casualty distribution and to find out how and what type of structural collapse caused human loss and how trapped people were rescued from various view points.

Casualty statistics are shown in Table 1 and in the map of Figure 1. Most serious damage occurred in Higashi-nada and Nada wards of Kobe city, Ashiya city, in which seismic intensity 7 was reported by Japan Meteorological Agency. Nagata and Hyogo wards suffered 4,073 and 1,097 structures burned down respectively following the quake, and human loss was serious. Number of injured people is not very reliable, because medical facilities were also severely damaged and local governments had great difficulty to respond this emergencies.

Figure 2 indicates daily change of total human loss reported by police department after the earthquake. In the next day of the earthquake, 1,681 people were reported dead and 1,017 people missing and it took almost a week to recognize enormous extent of human casualty.

Police department reported that out of 5,479 human loss, 4,846 (88 %) was caused by collapse of buildings and houses, 570 (10%) by fire, 17 (0.3%) by collapse of highways and traffic accidents, 11 (0.2%) by landslides, and 65 (1.2%) by other reasons (Yomiuri Newspaper, April 8, 1995). Cause of death is reported by Nishimura et al.

(1995) based upon postmortem examination of 3,651 cases in Kobe city, in which mechanical asphyxia such as on chest, abdomen, head and neck takes majority (53.9%), and crush (12.4%), burn (12.2%) and blunt trauma injury (8.2%) follow.

Table 1 Statistics of human casualty by cities and wards reported by Hyogo Pref., Kobe city and Osaka Pref., as of January 1996

			Regist. 1994.3.31 Population	No.house-holds	Dead	Missing	Injured	Dead %
Hyogo Pref.	Kobe city	Higashi-Nada	186814	75992	1461	0	3383	0.78
		Nada	121126	53819	924	0	1112	0.76
		Chuo	102920	50119	239	0	3782	0.23
		Hyogo	117839	54967	544	0	1755	0.46
		Kita	212209	71733	12	0	817	0.01
		Nagata	124799	53389	911	0	533	0.73
		Suma	184977	66375	393	1	637	0.21
		Tarumi	236175	86876	18	0	1020	0.01
		Nishi	192374	62277	10	0	1640	0.01
	Amagasaki		486938	194837	48	0	3786	0.01
	Nishinomiya		411882	160283	1107	1	6386	0.27
	Ashiya		85196	33381	433	0	2759	0.51
	Itami		185706	68222	19	0	2581	0.01
	Takarazuka		203940	72592	116	0	1100	0.06
	Kawanishi		143604	48421	2	0	485	0.00
	Akashi		280938	99829	8	0	1884	0.00
	Tsuna-dist., Awaji is.		66316	20914	55	0	1104	0.08
	others				7	0	136	
	sub-total				6307	2	34900	
Osaka Pref.	Osaka city				16	0	373	
	Toyonaka		396309	154626	8	0	2504	0.00
	others				4	0	730	
	sub-total				28	0	3607	
total					6335	2	38507	

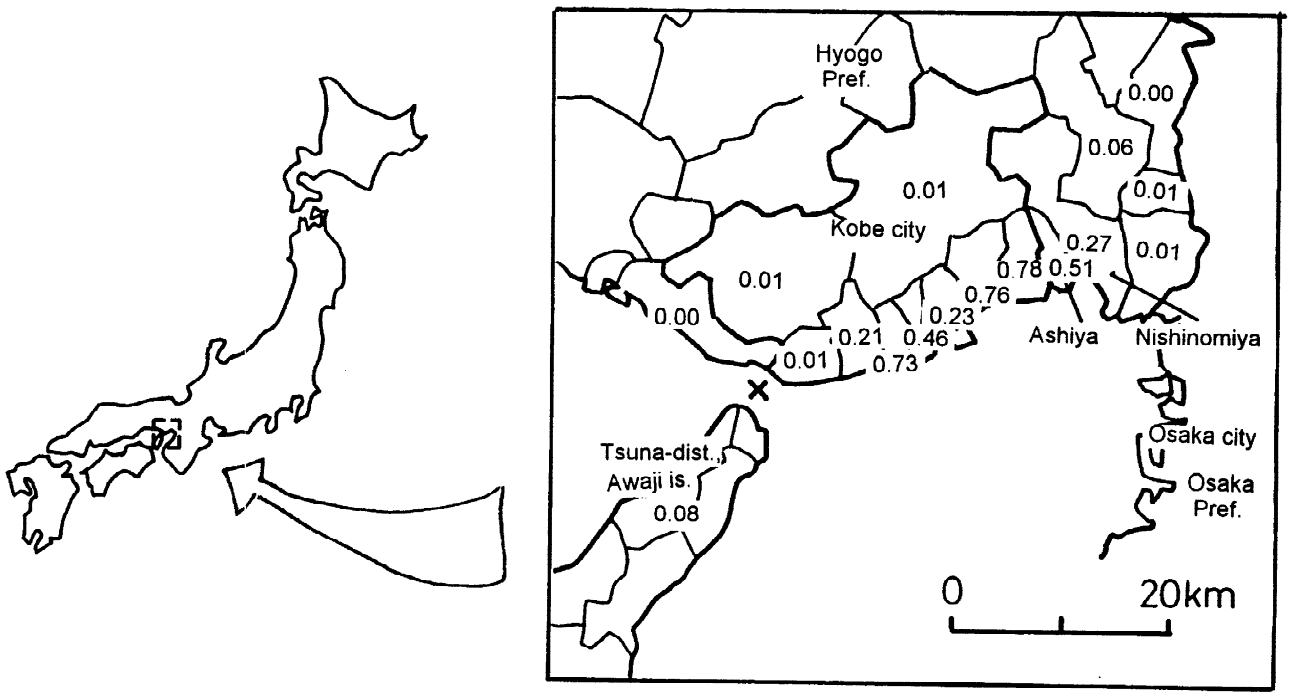

Figure 1 Regional distribution of human loss (%).

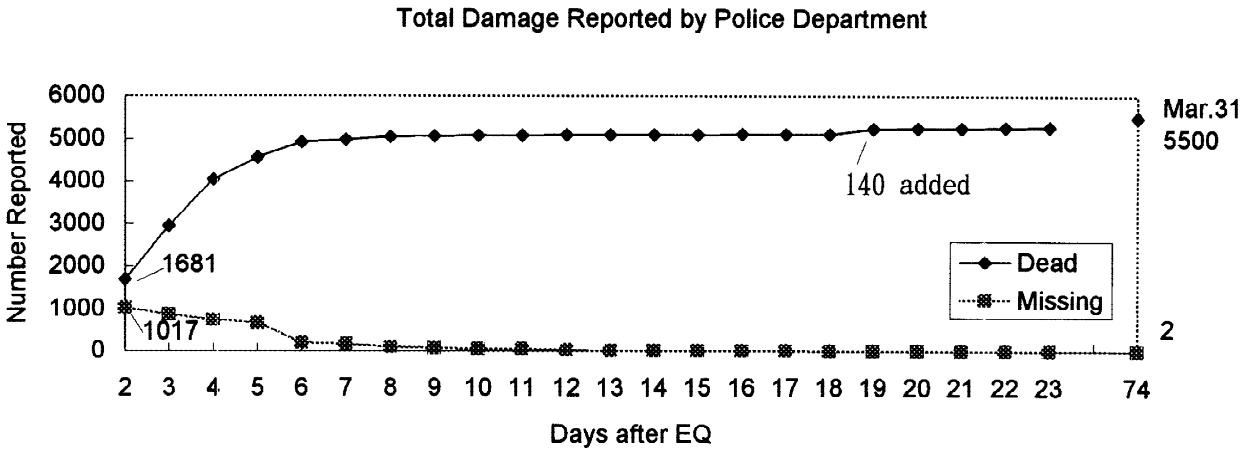

Figure 2. Change of reported number of human lives killed and missing.

Fatality count of 5,502 by Police Department (March 31, 1995) is related to direct cause such as structural damage. Additional 833 human loss admitted as "earthquake driven" by municipal authorities, are related to indirect causes such as diseases, malnutrition, poor environment of emergency shelters, destroyed medical care system, and some collateral accidents and suicides, which tend to hit elderly victims.

MODEL

Murakami (1992) proposed a simulation model to estimate distribution of human loss among different types of buildings collapsed and applied the model to incomplete damage statistics of the 1988 Spitak, Armenia earthquake. Human casualty is affected by location of population at the time and season of an earthquake, distribution of structural types of residences, schools and offices, vulnerability of structures, evacuation possibility, and search and rescue (SAR) operations (Figure 3).

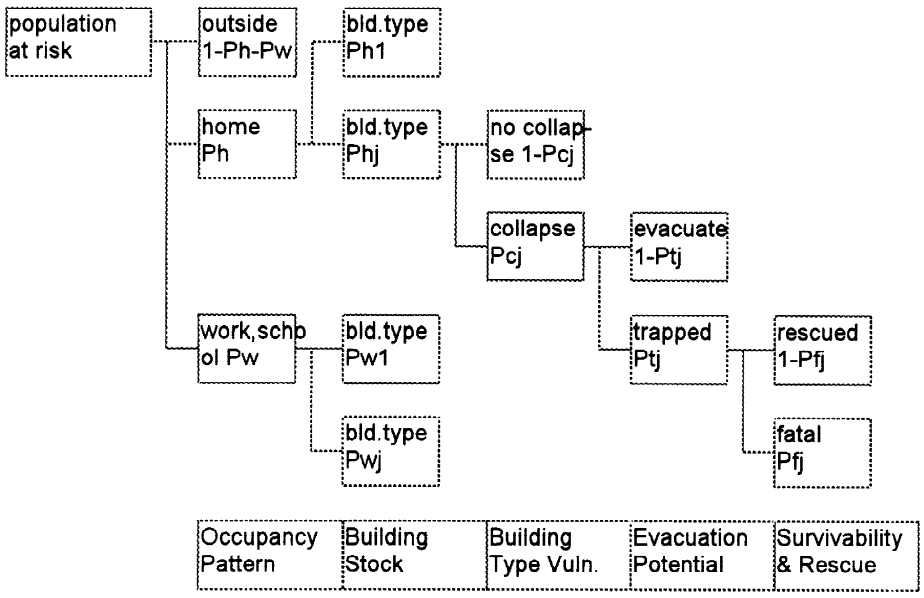

Figure 3. Event tree model of human casualty caused by building collapse.

NHK national census of daily chronological activities indicates that 86.1% are in bed, 11.2% awaken at home, 96.6% at home at 5:45-6:00 a.m. on weekdays in Osaka metropolitan area (NHK, 1991). According to the interview survey by Kobe city fire department, 71.0% of 840 respondents answered that they were asleep when the quake hit at 5:46 in the morning before sunrise.

Based on the housing survey of Japan, Figure 4 shows distribution of housing stock among structural types in disaster region; i.e. six wards in Kobe city, Ashiya and Nishinomiya cities, most severely devastated. Wooden single family detached dwellings cover 27%, wooden tenement houses, so-called "Bunka-Jutaku" or "nagaya" in Kansai region cover 8%, and non wooden apartments, mostly RC, SRC or light steel take 50%. As for the year of construction, 5.3% dates back from prior to 1945, and 11.0% from the period of 1945-1960, though this distribution is different depending on characteristics of the cities. Average size of households in Kobe, Ashiya, and Nishinomiya cities is 2.6 persons per household.

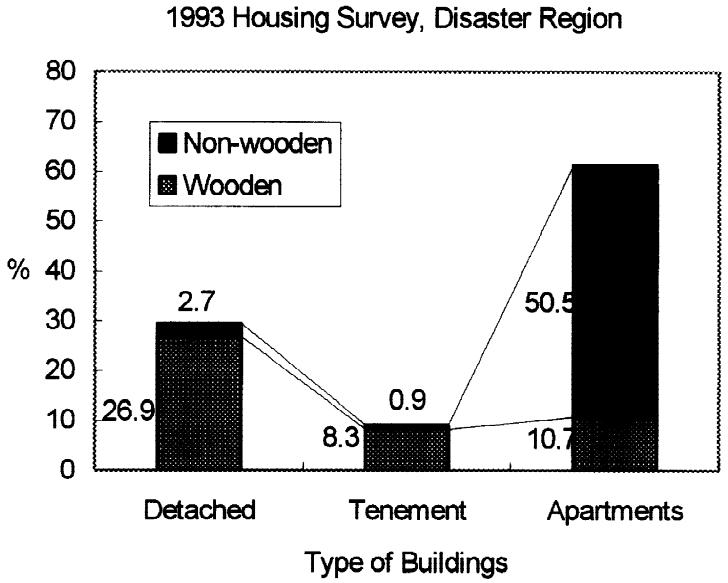

Figure 4. Distribution of residential types in disaster region by the 1993 Housing Survey of Japan

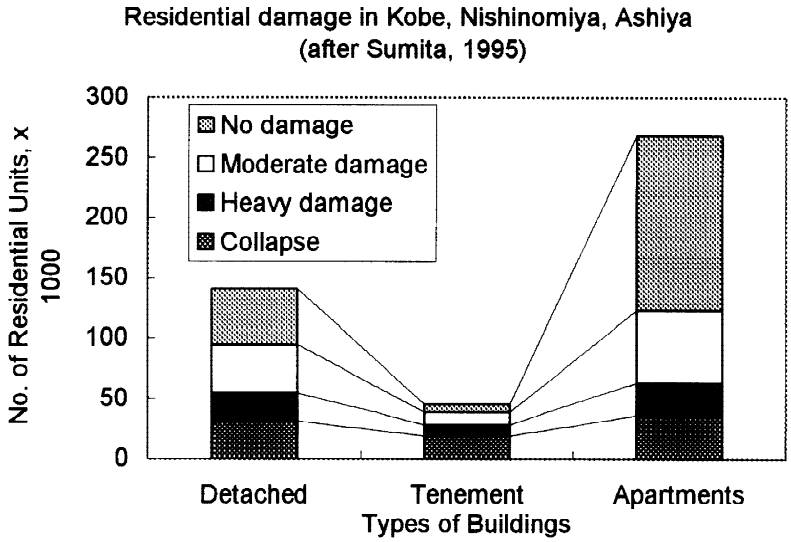

Figure 5. Residential damage distribution by types of buildings.

Detailed residential damage survey was conducted in Kobe, Nishinomiya and Ashiya by Sumita et al. (1995). Figure 5 indicates number of housing units by damage level and by types of buildings. Collapse ratio is 22% for detached, 42% for tenement and 13% for apartments.

EXAMINATION OF LETHALITY AND SAR

Distribution of Human Loss among Types of Dwellings in Ashiya City

Ashiya city with 85,000 population located to the east of Kobe city (Figure 1) suffered 410 people killed and 7,573 residential units housing 17,626 residents completely collapsed. There is a damage statistics for 55 districts reported by the city fire department. Number of occupants in wooden detached dwellings collapsed are correlated with number of fatality (Figure 6). Assuming the following equation, multi-regression analysis is conducted for this within-city district statistics.

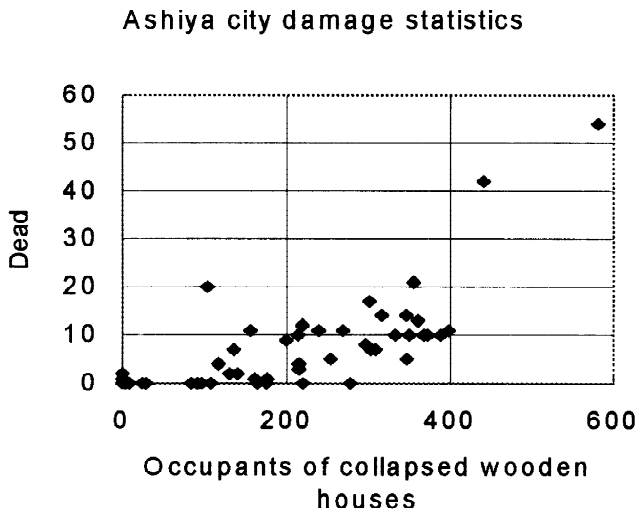

Figure 6. Relation of occupants of wooden single family dwellings and number of fatalities in Ashiya city.

$$FAT = K0 + K1 * WS + K2* WM + K3*NWS + K4 *NWM$$

where WS: number of occupants in wooden single family dwellings collapsed
WM: number of occupants in wooden multi-family ones collapsed
NWS: number of occupants in non-wooden single family ones collapsed
NWM: number of occupants in non-wooden multi-family ones collapsed

In the obtained equation (R=0.74), the coefficients are as follows;

K0 = -2.14, Standard error = 1.52
K1 = 0.036, Standard error = 0.009
K2 = 0.058, Standard error = 0.025

Regression coefficients K3 and K4 are not reliably obtained for Non-wooden types in the analysis. This means that lethality of occupants in wooden single family dwellings is 3.6%, while that in multi-family wooden apartments (Bunka jutaku) is 5.8% and is higher.

SAR record of Ashiya City Fire Department indicates that 28 people were dead among 4,789 occupants in non-wooden apartments suggesting 0.58% lethality. Non-wooden houses are few in number and in general more expensive structures, so that their collapse are not as lethal as other types. From this result, it is estimated that 71% of human loss in the city occurred in detached houses, 22% in tenement houses and 7% in non-wooden apartments.

Using number of collapsed dwellings in Figure 5 and the following relation;

Human loss estimate = Number of collapsed dwellings * Average size of household (2.6) * Average lethality factor

Human loss in detached	= 31148 * 2.6 * 0.036 =	2915 (46%)
Human loss in tenement	= 18865 * 2.6 * 0.058 =	2845 (45%)
Human loss in apartment	= 35528 * 2.6 * 0.0058 =	536 (9%)
total	=	6296 (100%)

are obtained and total of 6296 agrees with observed count. Most fatality seem to have occurred in detached and tenement types rather than in apartments.

Database of Collapsed Structures where Some Occupants were Killed

Records of collapsed buildings were collected in relation to characteristics of a building and damage pattern, number of occupants, numbers of people survived and killed, from newspaper and magazine articles, damage reports and various documents. Figure 7 indicates total number of people killed by types of dwellings. SAR activity in multi-family, multi-story apartments are more often reported. Therefore detached dwellings seem to be most responsible for human loss. Average number of fatality per collapsed structures is high for apartments, though not as expected by number of occupants.

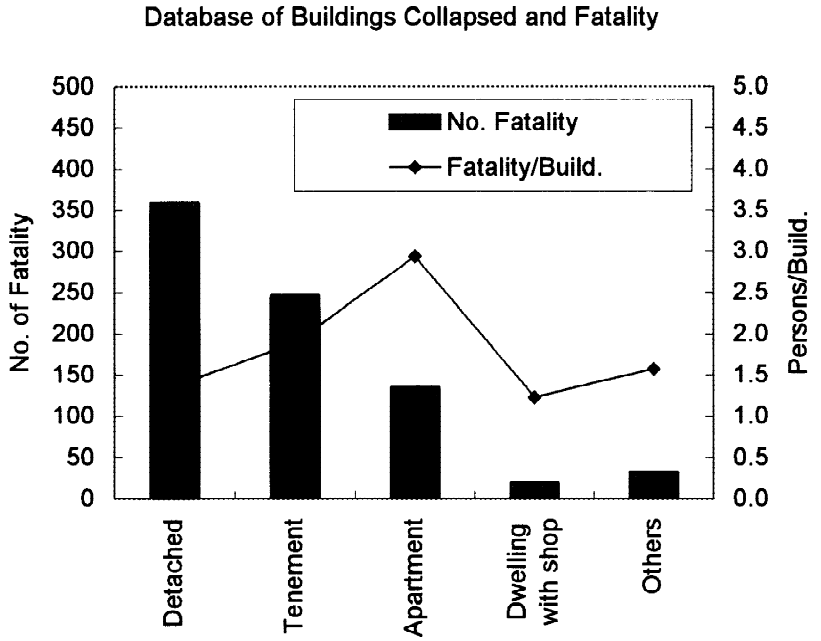

Figure 7. Residential types and fatality count in the database.

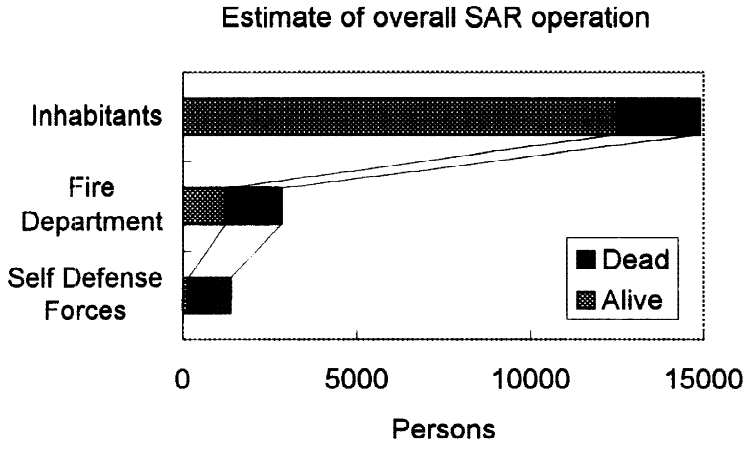

Figure 8 Estimate of overall number of people rescued alive and ead by neighborhood residents and response organizations.

Search and Rescue Activities

UNCRO report describes search and rescue activities (Kaji et al., 1995). While number of people rescued by fire departments and Self Defense Forces are better documented, though not complete, number of people rescued by local inhabitants and families are very difficult to evaluate. It is roughly estimated that about 20,000 people (about 10% of occupants of collapsed dwellings) were trapped under debris and 15,000 people were rescued by inhabitants (Figure 8). Chances of success is higher in inhabitants' rescue, because they were quick to respond, and they could not manage deeply buried cases.

Municipal fire departments are principally responsible for SAR operation in daily occasions such as traffic accidents, elevator accidents and of course conventional fires, so that they have more rescue equipments than police and SDF. After the earthquake, however, fire departments were overwhelmed by simultaneous fire occurrence in the area and enormous numerous collapsed houses. Assistance teams from fire departments of other municipalities arrived in a day or two from all aver the country. Figure 9 depicts changing rate of SAR survival along days after the earthquake. Survival chance is high on the first day of disaster, though it deteriorates quickly later on. This result can be compared with that by Coburn et al. (1992) for other earthquakes. Kobe attenuation is found similar to that of weak stone masonry in China or in Italy, while RC buildings in Mexico city indicate 5 or 6 days of survival. This difference can be explained by severity of collapse and by lost survival space in debris.

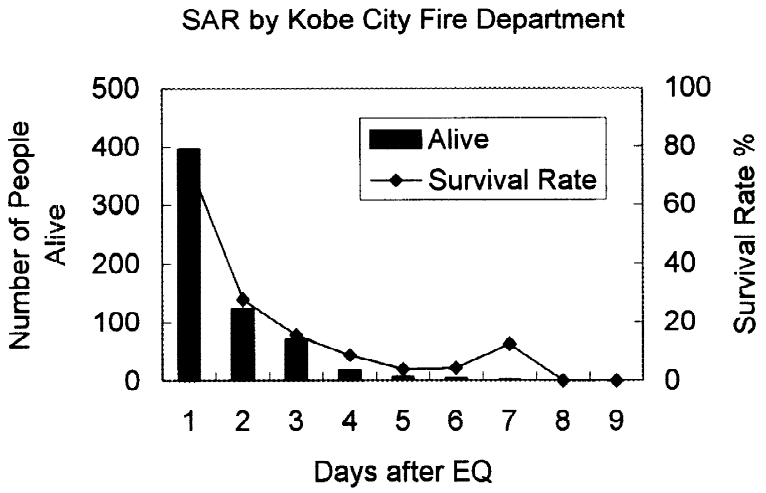

Figure 9. Survival rate along days after earthquake.

CONCLUDING REMARKS

Distribution of human casualty was examined in relation to structural types of dwellings using various source of data. Using damage statistics of Ashiya city, lethality factor is estimated as 3.6% for detached, 5.8% for tenement and 0.058% for apartments. In the disaster region, number of collapsed apartment units are higher than those of detached and tenement units. However, most human loss occurred in the latter wooden types.

As for the SAR operations, more people were rescued by community inhabitants and families. SAR records of Fire Departments indicate that chances of survival is high on the day of the quake, and quickly fades away on the following days. It is important to prepare urgent SAR response capabilities in community level as well as effective organizational assistance for future earthquakes.

In order to clarify complicated factors affecting human casualty patterns, detailed investigation has been conducted by a multi-disciplinary research group, of which the author is a member.

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