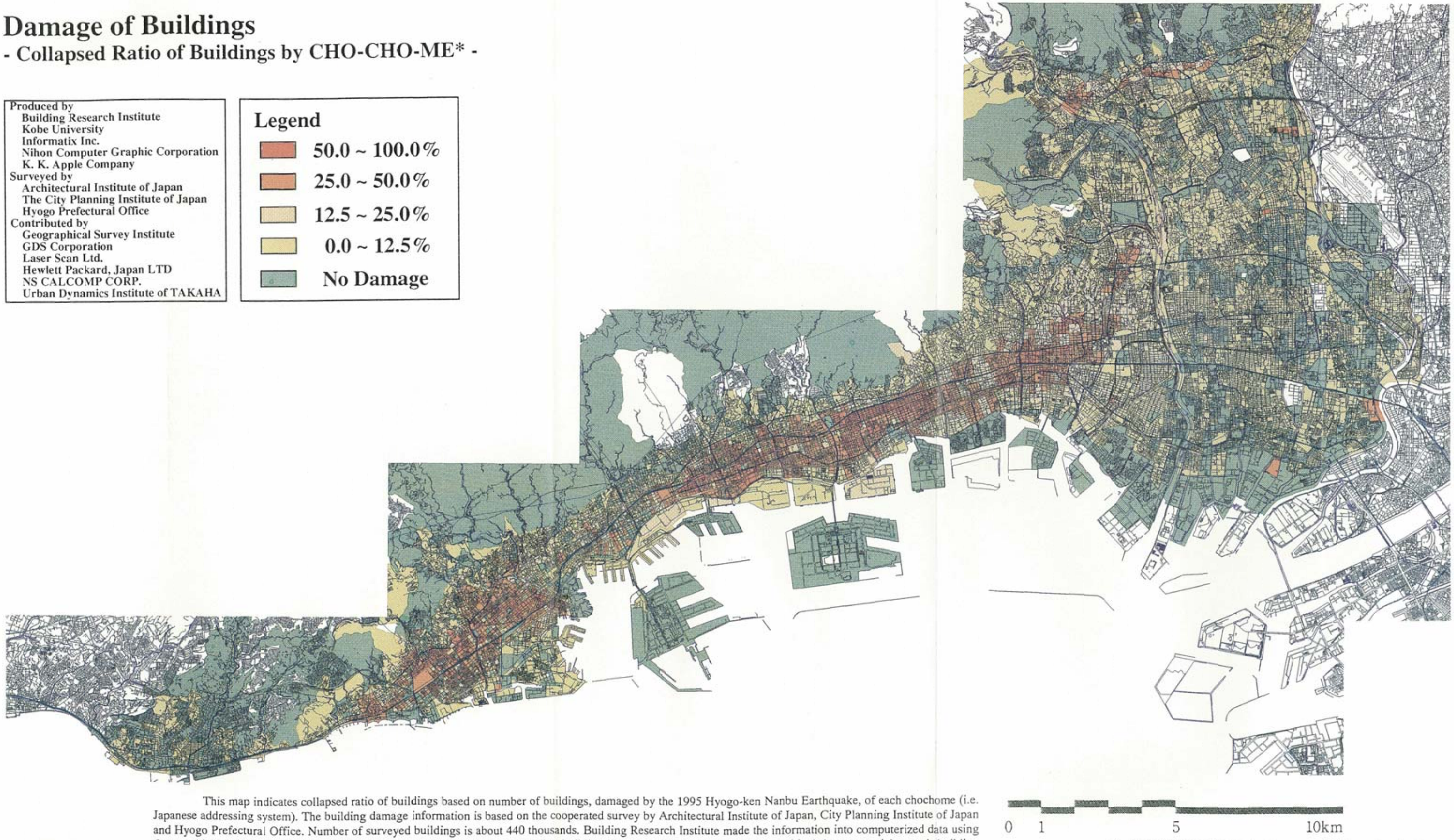
A SURVEY REPORT FOR BUILDING DAMAGES
DUE TO
THE 1995 HYOGO-KEN NANBU EARTHQUAKE

March 1996

Building Research Institute

Ministry of Construction

Damage of Buildings
- Collapsed Ratio of Buildings by CHO-CHO-ME* -



This map indicates collapsed ratio of buildings based on number of buildings, damaged by the 1995 Hyogo-ken Nanbu Earthquake, of each chochome (i.e. Japanese addressing system). The building damage information is based on the cooperated survey by Architectural Institute of Japan, City Planning Institute of Japan and Hyogo Prefectural Office. Number of surveyed buildings is about 440 thousands. Building Research Institute made the information into computerized data using Geographical Information System (GIS), and generated some indices regarding building damage ratio of each chochome or block by summarizing each building damage in cooperation with Kobe University et al.

* : CHO-CHO-ME is the Japanese Addressing System.

PREFACE

The Hyogo-ken Nanbu earthquake on the 17th of January 1995 caused huge human and physical damage in the Hanshin and Awaji area in Japan. During this one year, structures such as roads and bridges which were severely damaged, were demolished and their quick restoration work is being under development. However, urban tuning up for an urban rebirth against disasters, such as land readjustment projects and insurance of more permanent housing and buildings take much more time.

In Japan, the building design code is controlled by the Building Guidance Division, Housing Bureau, Ministry of Construction. Our Building Research Institute (B.R.I.), Ministry of Construction supports the back up of the code's maintenance from the viewpoint of research. Recognizing this as an important part of our institute, many of our researching staff tackled this large earthquake. BRI published the prompt report "The damage survey of the Hyogo-ken Nanbu Earthquake 1995", in February 1995, and published the interim report which contained research and analysis work from the results of the survey. Then, in March 1996, a series of continuous surveys and analytical work were summarized as the final report. (These are all written in Japanese)

B.R.I investigated many items such as input ground motions,condition of structural damage to housing, buildings, foundations, damage behavior of urban fires and fire stop factors. These results were also reported as the Interim Report for the Survey Committee of Earthquake Damaged Buildings.

This committee was organized by Headquarters of the Ministry of Construction. Based upon the suggestions described in this report, new laws and other administration countermeasures were enforced. In relation to large earthquake disasters, several research projects are still now progressing in BRI. It is desired that the publication of our further research work will be helpful for the future realization of disaster prevention in cities.

The English version of this report contains the main parts of the Interim Report and includes the final report from the Survey Committee of Earthquake Damaged Buildings. I hope this report will be useful not only to Japan but also to many other earthquake prone countries in the world .

March, 1996

Yoshio MIMURA
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TABLE OF CONTENTS

1. The Response to the Earthquake

Introduction

Already more than one year has passed since the Hyogo-ken Nanbu Earthquake occurred on Jan. 17th 1995. The Building Research Institute has investigated the cause of the building damage and at the same, related research projects also have been progressed in BRI for the restoration of the damaged area and the countermeasures for disaster prevention against further earthquakes . Hereinafter , the activities of the Building Research Institute are introduced.

1.1 The Response of the Building Research Institute

1.1.1 Organization in the Building Research Institute

(1) The Headquarters for the Countermeasure to the Hyogo-ken Nanbu Earthquake

The headquarters for the countermeasure to the Hyogo-ken Nanbu Earthquake were established at13:00 17th of January. And the director general of BRI took up the chaimans' post. Until the abolition of these headquarters , the meetings of the headquarters committee were held twelve times. The members list of this headquarters committee is shown in Table 1.1.1.1 .

(2) Investigation Project Team (Structure)

This team was organized on March 3 rd 1995 to investigate structural damage causes and possible countermeasures . This team was composed of many staff from various research departments in BRI. Such members are listed in Table 1.1.1.2 `

1.1.2 Support for the Emergency Risk Assessment

The emergency risk assessment method for urgent risk structures was developed in the national overall research project " Restoration Technology for Earthquake Damaged Structures" (1981- 1985) promoted by BRI. From the day after the earthquake occurred, BRI staff participated on the spot to give technical guidance for the emergency risk assessment being done by the voluntary building engineers who came from all over the country . Twenty seven researchers were dispatched there (average six days) . The total number of working days reached to 159 per researcher. Finally, the total number of working days of voluntary building engineers became 6,000 in total and they assessed about 46,000 buildings. Subsequent analysis of the inspection data was done by BRI.

1.1.3 The Enforcement of Site Reconnaissance by BRI

Followings are the breakdown :

First Survey	Jan. 18 - 20	9 persons
Second Survey	Jan. 25 - 29	27
Second Survey (Supplementary)	First week Feb.	15
Third Survey	Feb, First week - March middle ten days	37
Third Survey (Supplementary)	March last ten days	8
others		10
Total		106

After April , some researchers visited damage sites as when required.

1.1.4 Implementation of Macro Analysis and Research Work Based on Site Inspection

The macro analysis and the discussions on the cause and condition of the damage were executed at BRI based on the investigated data.

At BRI the Geographical Information System was adopted for the urgent support of the restoration planning at an early stage. Further preparation is now progressing for the implementation of the restoration planning.

1.1.5 BRI Activities of the Survey Committee of Earthquake Damaged Building

(1) Foundation of the Survey Committee of Earthquake Damaged Buildings

At a special meeting of the committee of Building Technology Examination Committee under the Housing Bureau,Ministry of Construction, the Survey Committee of Earthquake Damaged Buildings was established on January 31 st chaired by Prof. Kouichi Kishitani of Nihon University.

The Building Research Institute managed this committee, detailed the site investigation, the preparation for their report to this committee and other clerical work.

(2) Activity of the Committee

The committee meetings were held five times,and concluded the interim report on July 28th,1995 and the final report on Dec. 27 th. Basing upon these reports, the new law " the law on the promotion of seismic improvement for existing buildings" was enacted . And further, notice for the revision of the Building Standards Law and related notification were issued.

1.1.6 Publication of the Damage Survey Report by BRI

"The Damage Survey Report of the Hyogo-ken Nanbu Earthquake " (Prompt Report) was published in February 1995 (about 350 pages in Japanese). In August 1995,"The Interim Report of the Damage Survey of the Hyogo-ken Nanbu Earthquake was also done . (Color print, about 700 pages and appendix ;A1 size 7 color maps also in Japanese) And the Final Report was published in March 1996.(appendix : CD-ROM)

1.1.7 Implementation of Research and Development in BRI for Earthquake Disaster Prevention (fiscal year 1995)

(1) Projects Done by the First Revised Budget

a) Development of Urgent Strengthening Technology for Damaged Buildings

b) Development of Design Engineering for Function Preservation Complying with the Important Factors of Buildings Under Large Earthquakes

c) Development of Technology of Base Isolation and Seismic Control for Housing and other Buildings

d) Establishment of the Reproduction Apparatus of Structure

e) Establishment of the High Density Earthquake Observation System in a Metropolitan Area

(2) Projects Done by the Second Revised Budget

a) Research and Development on Seismic Improvement to Existing Buildings

b) Basic Research on Seismic Strengthening by Connecting Buildings in an Urban Area

c) Fundamental Research on an Early Stage Catching System for the condition of Damage Using High Technology for Data Processing

d) Establishment of Research Center for Urban Disaster Prevention

Furthermore, additional related research works are also being carried out using another research budget.

Table 1.1.1.1 Members of BRI Headquarters

Chairman	S.Okamoto			
Vice Chairman	Y.Mimura			
Members	J.Nishimoto,	Y.Yamazaki,	M.Suda	H.Takahashi
	H.Yamanouchi	S.Nakata	K.Nakamura	H.Kato
	H.Suzuki			
Secretary General	Y.Yamazaki			
Secretariat	H.Tanaka	T.Ogawa	T.Kanda	H.Matsumoto
	M.Ohashi	T.Hayashi	T.Sotoike	K.Takano
	K.Otaka	H.Nagahashi		

Table 1.1.1.2 Member List of B.R.I. Investigation Team

Project Team														
S.Nakata (Assistant : Y.Hirano)														
Macro Analysis Team		Damage Investigation Team						Code Maintenence Team						
H.Kobayasi		Y.Yamanouchi (Assistant :H.Hiraishi)						Y.Yamanouchi (Assistant : Y.Ohashi)						
Data Acquisition W.G.	Data Analysis W.G.	Evaluate Seismic Force W.G.	Foundation W.G.	Reinforced Concrete W.G.	Steel W.G.	Wooden W.G.	Non-structure W.G.	Evaluate Seismic Force W.G.	Foundation W.G.	Reinforced Concrete W.G.	Steel W.G.	Wooden W.G.	Non-structure W.G.	Construct System W.G.
H.Kobayashi T.Iwata K.Isizaka K.Sano E.Itoigawa A.Teraki Y.Wakiyama	T.Kaminosono M.Midorikawa W.Okada H.Ito M.Inukai N.Inoue	I.Okawa S.Koyama T.Kashima	H.Mizuno M.Futaki M.Tamura M.Iiba	H.Hiraishi M.Tashigawara H.Kuramoto T.Fukuta Y.Masuda M.Abe	I.Nishiyama A.Mukai T.Hasegawa	W.Okada N.Kawai S.Yamaguchi	H.Ito K.Nishida	I.Okawa S.Koyama	M.Futaki H.Mizuno M.Tamura	H.Hiraishi T.Kaminosono H.Shiobara	M.Midorikawa T.Fukuta	W.Okada M.Yasumura N.Kawai	H.Ito K.Nishida	Y. Hirano Y.Ohashi T.Hayashi H.Fujitani S.Takahash K.Sato T.Yamamoto

◎Project Team Command and Sectariant

Y.Yamazaki, H.Matsumoto, etc. (Research Planning Section)

1. 2 The Activity of the Survey Committee of Earthquake Damaged Buildings

Introduction

"Hyogo-ken Nanbu Earthquake", a strong earthquake whose epicenter is the northern Awaji Island, occurred on January 17, 1996,at 5:46 am. It caused the largest scale of damage since after the second world war : over 6,300 persons of fatalities and the lost, over 43,000 persons of the wounded, about 400,000 damaged buildings. Therefore immediately after this earthquake a committee for surveying damaged buildings due to the earthquake was planned to set up led by Housing Bureau and Building Research Institute of Ministry of Construction. After its preliminary meetings held on January 26 and 31, 1996, as an Adhoc Committee of the Evaluation of Building Technology in Ministry of Construction. The Survey Committee of Earthquake Damaged Buildings (Hereinafter referred to as "the Committee") started officially on January 31, 1996. The plan of its activity is as follows:

1. Urgent survey of damaged situation
2. Collection of relevant survey data
3. Analysis of survey results, relevant data and others
4. Identity of cause of damage
5. Suggestion of necessary enforcement of measures

1.2.1 Organization of "the Committee"

The members of the "the Committee" are as follows:

(In the order of the kana syllabary. ◎Chairman ○Vice Chairman)

Name	Title	Field of speciality
○Tsuneo Okada	Professor, Research Institute of Production & Technology, University of Tokyo	Seismic engineering
Shin Okamoto	Director General Research Institute of Building Technology,Building Center of Japan	RC Structure
◎Koichi Kishitani	Professor Science and Engineering Dept Nihon University	Fire prevention of buildings
Hitoshi Kunigou	Chairman of the Board of Directors, Building Center of Japan	Technical evaluation
Yoshio Kumagai	Associate Professor, Systems of Social Engineering,	Planning of Disaster prevention

	University of Tsukuba	
Kazuo Saita	Vice Chairman Japan Structural Consultant Association	Structural design
Isao Sakamoto	Professor Dept. of Engineering University of Tokyo	Wooden structure
Hideo Sugiyama	Professor Dept. of Engineering Tokyo Science University	Wooden structure
Koichi Takanashi	Professor Research Institute of Production & Technology ,University of Tokyo	Steel structure
Isao Tsukagoshi	Prof. Keio University	Urban planning
Toshikazu Takeda	Chairman Building Construction Society	Seismic engineering
Tadao Minami	Prof. Earthquake Research Institute University of Tokyo	Earthquake engineering
Yoshio Mimura	Director General Building Research Institute Ministry of Construction	Fire prevention of buildings
Yoshio Murata	Chairman Japan Structural Consultant Association	Structural design
Makoto Watabe	Professor Keio University	Seismic engineering

1.2.2 Activity of the Committee

The Committee held five meetings and an investigation at the site:

January 31, 1995	The Committee was organized.
February 2	The 1st meeting
February 28	The 2nd meeting
March 18	Investigation at the site (Kobe)
March 28	The 3rd meeting
July 28	The 4th meeting (Interim Report)
December 27	The 5th meeting (Final Report)

The activity is outlined hereinafter.

1.2.2.1 Urgent Investigation Conducted by the Committee

Immediately after the earthquake the first emergency risk assessment for buildings was implemented by Kobe Municipal Government. This investigation was conducted on more than 4 story apartment housing and office buildings made of reinforced (steel-framed) concrete or steel structures. The label printed "usage prohibit" were put on the buildings which were decided as unsafe by an investigator. However any questionnaire documents were not made during the assessment work . Therefore the locations and the names of such buildings were not fully recorded except for approximately 1,000 buildings. Therefore the committee requested Local Public Bodies and other organizations for the cooperation of investigating the actual conditions and the characteristics of the damaged buildings. Thus the urgent investigation was conducted on the buildings of which the locations and the names were recorded (and some other unrecorded buildings corresponded to "usage prohibit") in cooperation with Local Public Bodies, The Architectural Institute of Japan, "Kozai Club " (Association of Steel Mill Makers and Trade Companies) and other organizations as of February 3, 1995. The outline of the investigation is as follows:

Period:	February 20, 1995 - March 3, 1995
Staff:	184
The number of buildings:	1,231
The objects:	Buildings condemned as "prohibited to use" during the first urgent risk Assessment for the damaged buildings (including some other the buildings founds as "prohibited to use" buildings)
Area:	Kobe City, Ashiya City, Part of Nishinomiya City

1.2.2.2 Summary and Analysis of the Results Obtained by the Relevant Organizations

In order to give the full picture of damage, 95 relevant organizations were requested by the committee to answer the questionnaire whether their individual damage investigations were conducted or not and to offer their investigation results if any. 46 organizations answered. Investigation results and relevant various data from the Architectural Institute of Japan, The Urban Planning Institute of Japan, Association of Construction Companies and others were summarized and used for Macro analysis. The answers from the organizations were as follows:

The number of organizations that the questionnaires were mailed	Answered	
	Investigated	Not investigated

Central government offices	4	3	0
Corporations having a special status	2	2	0
Incorporated bodies	21	7	11
Foundations	6	2	0
Optional organizations	5	3	0
Prefectures	46	4	11
Ordinance cities	11	1	1
others	0	1	0
		23	23
Total	95	46	

Note: Planning and arranging of investigation are included in "Investigated" category.

1.2.2.3 Site Investigation Conducted by the Committee Members

The site investigation was conducted by a total of 16 people from both the Committee and the Ministry of Construction. The result was compiled into the report on the site investigation:

Date of investigation: March 18, 1995

Attendants: The Committee

Chairman	Koichi Kishitani	Professor Department of Science and Engineering Nihon University
Vice Chairman	Tsuneo Okada	Professor Production Industry Research Institute of Production & Industry University of Tokyo
Member	Shin Okamoto	Director General(At that time) Building Research Institute Ministry of Construction
	Yoshio Kumagai	Associate Professor Social Engineering System Tsukuba University
	Isao Sakamoto	Professor Department of Engineering University of Tokyo

	Hideo Sugiyama	Professor Department of Engineering Tokyo Science University
	Isao Tsukagoshi	Professor Keio University
	Toshikazu Takeda	Chairman Building Engineering Committee Building Construction Society
	Tadao Minami	Professor Earthquake Research Institute University of Tokyo
	Yoshio Murata	President Japan Structural Council
Association		
	Makoto Watabe	Chairman Earthquake Disaster Committee Architectural Institute of Japan (at that time)
Ministry of Construction Housing Bureau		
	Shouichirou Umeno	Director
	Yoji Habu	Head (At that time) Building Guidance Section
Building Research Institute		
	Yutaka Yamazaki	Director Information and Research Planning Department
	Hiroyuki Yamanouchi	Director Structural Department
	Shinsuke Nakata	Director Production Department

The sphere of investigation: Kobe City(Nagata Ward, Chuo Ward and and Nada Ward)
Following points were emphasized for this investigation:

- To find the damage cause of the relatively big damaged buildings
- To find the correlation between the seismic design and the damage compared the above buildings with non-damaged buildings
- To find the characteristic damage situation of the buildings using each of

the three building systems; reinforced concrete, steel and wood , designed after the new seismic code enforced in June, 1981.

- To investigate the buildings designed before the new seismic code, the middle stories of which were collapsed such as the old Kobe city office building.

- To investigate the city fire area(Nagata Ward)

2. Macro Analysis of Damage Situation

2.1 Outline of Earthquake Damage and the Emergency Risk Assessment

In order to prevent the secondary disaster after the Hyogoken-nanbu Earthquake the emergency risk assessment was conducted in Kobe City, 6 cities between Osaka and Kobe (Amagasaki City, Nishinomiya City, Itami City, Takarazuka City, Kawanishi City and Ashiya City), Akashi City and Awaji District. The governmental groups assessed "usage prohibit" buildings among the over 4 story buildings and assessed apartment houses having risk. The Architectural Institute of Japan, The Urban Planning Institute of Japan, The Building construction Society and other organizations investigated damage situations independently. The macro analysis by the Committee is based on the data from the assessment work done by governmental groups such as Hyogo Prefecture for the emergency risk of buildings and the data from the the result of the investigation by each organization such as the Architectural Institute of Japan. The earthquake , the damage and the emergency risk assessment are outlined in this chapter.

2.1.1 The Outline of the Earthquake and Damage

(1) The outline of the damage (The announcement of the Meteorological Agency)
Date of occurrence: January 17, 1995, at approximately 5:46 a.m.
The seismic center: Awaji Island
The depth of the seismic center: 14km
Magnitude: M=7.2
(2) Seismic intensity in each area (The announcement of the Meteorological Agency)
Seismic intensity of 6: Kobe, Sumoto
5: Kyoto, Hikone, Toyooka
4: Gifu, Yokkaichi, Ueno, Fukui, Tsuruga, Tsu, Wakayama, Himeji, Maizuru, Osaka, Takamatsu, Okayama,Tokushima, Tsuyama, Tadotsu, Tottori, Fukuyama, Kochi, Sakai, Kure, Nara
Seismic intensity of less than 3 is omitted. (According to the site investigation, the seismic intensity in

the part of Hanshin Area including Kobe City and Awaji Island was 7 on the Japanese seven-stage scale.)

(3) Damage condition (Investigated by the Fire Defense Agency and summing up on December 27, 1995)

	Number
Fatality	6,308 *
Missing	2
Injured	
Serious	1,883
Slight	26,615
Under investigation	14,679
Total	43,177
Housing damage	
Complete destroy	100,302
Partial destroy	108,741
Slight damage	227,373
Total	436,416
Public building	750
Other building	3,952
Numbers of fires	294
Damage portions of Roads	9,948

* Number of 789 dead people related to this earthquake are included.

2.1.2 The Assessment of "Usage Prohibit" Buildings

"Usage prohibit" buildings were assessed as the first stage of emergency risk assessment of damaged buildings from January 16 -22. The label printed "Usage prohibit" was put on the buildings which were condemned unsafe. 2,825 buildings were applied to "Usage prohibit". However the questionnaires were not made for the buildings assessed as "usage prohibit". The locations and the names of such buildings were not recorded except for approximately 1,000 buildings.

2.1.3 The Emergency Risk Assessment

(1) Outline

Buildings will be slightly or severely damaged or collapsed in accordance with their seismic performance due to earthquake motion. The slightly damaged or collapsed buildings will be easily assessed by anybody as "safe buildings" or "unsafe buildings" against aftershocks. However buildings with medium level damage are difficult to be judged. Special knowledge will be required for these buildings to assess the questions such as "safe for living or not", " safe for entering to carry out belongings or not", "dangerous to enter for a short term or not" and others. These assessment will be urgently required after the earthquake. "The Emergency Risk Assessment" is a method for the above assessment. The concept of this assessment was devised during the total project of technical development by Ministry of Construction called "Development of Restoration Technology for Damaged Buildings due to Earthquakes"in 1981-1985. This method was utilized in overseas such as after the Roma Prieta Earthquake. In Japan this method had never been utilized until the end of last year. Only the assessment method of damage grade by region were formulated in Shizuoka and Kanagawa prefectures. It was the damage investigation for Hyogo-ken Nanbu Earthquake that this method was actually applied in Japan for the first time. Therefore in parallel with considering the assessment system and the indicating and arranging method of results the actual assessing work was conducted. However a lot of experience which is not written in the manual was gained. Figure 2.1.3 shows the result announced by each city and town government bodies which conducted the emergency risk assessment . Among 46,610 apartment houses 6,476 were "unsafe", 9,302 were "precautions"and 30,832 were "investigated". "Investigated" houses were considered to be "safe", however only the exteriors of the houses were investigated this time, the expression of "investigated" was used instead of "safe".

(2) Outline of the Emergency Risk assessment (The case of RC structures)

"The judging criteria on damage grade of buildings due to earthquakes and the guideline on restoration technique" edited by The Building Disaster Prevention Society of Japan deals with RC, steel and wooden buildings and consists of 3 volumes by structure. Followings are the outline of criteria on emergency risk assessment for RC buildings for example:
The outline, exterior and inside of buildings were investigated according to the questionnaire for emergency risk assessment. The investigation of the outline of buildings includes names of buildings, addresses, structural types, patterns and scales. The investigation of the exteriors of buildings includes indication and subside of buildings, damage condition of structural members, damage condition of dropping and falling down of dangerous articles. As for the structural members the stories having the heaviest damage are investigated. Damage level (I-V) of mainly vertical members, columns among structural members and walls among wall panel structures are investigated and the damage grade (A-C) of structural members are assessed according to the rate of each damage level. The damage grade (A-C) of dropping and falling down articles are also assessed. Using these damage grade the risk assessment (unsafe, precaution and safe) of structural members and dropping and falling down articles are conducted. "Unsafe" means "prohibited to enter", "Precaution" means "be careful to enter" and "Safe" means "possible to enter". The damage grade of structural members takes preference for the risk assessment over that of dropping and falling down articles. "Partially prohibited to enter", "partially careful to enter" and others are considered appropriate for the latter assessment.

2.2 Investigation of Building Damages by the 1995 Hyogoken-Nanbu Earthquake

2.2.1 Macro Analysis based on the Urgent Investigation by the Committee

Just after the earthquake, staffs of Kobe city patrolled and inspected around suffering area for the safety of citizens. At that time the staffs put a paper labeled ''Usage Prohibit'' on the building which seemed to be severely damaged.

The Survey Committee of Earthquake Damaged Buildings (the Committee) decided to re-investigate the damage of such buildings because the inspection by staffs of Kobe city was carried without any investigation sheet. For this re-investigation, i.e. the Urgent Investigation, the main objective was to investigate characteristics of buildings and damage features of the ''Usage Prohibit'' buildings and buildings which correspond to the same condition. The investigation was done from the late in February to the beginning of March.

The investigation area of the Urgent Investigation was Kobe city and a part of Ashiya and Nishinomiya city. In this section, the result of Kobe city is analyzed.

(1) Result of the Investigation

a) Items in the Investigation Sheet

Table 2.2.1.1 shows the item and content in the investigation sheet.

b) Totalization

In Kobe city, 1,231 buildings have been investigated and totalized according to above items. The result of totalization is discussed in this section.

The following features are found:

[Address] Most of the investigated buildings located in six wards from Higashi-nada to Suma out of eight wards of Kobe city. Especially, 386 buildings (about 30%) were in Chuo ward.

[State of building] About 80%, 970 buildings were remains as once damaged by the earthquake. It is said that this investigation shows an outline of damages almost equal as just after the earthquake though the investigation has been done one month later.

[Construction year] The presumption of construction year has been successfully done with about 70%, 856 buildings. The largest content is ''before 1971'' of 535 buildings. The entry ''from 1972 to 1981'' is in the next place with 218 buildings and ''after 1982'' follows with 103 buildings.

[Usage] Buildings are mainly used as combined use (451 buildings), then ''house or condominium'' (265 buildings) follows.

Table 2.2.1.1 investigation sheet

ITEM		CONTENTS
Building		
(1)	Address	
(2)	State of building	removed, about to remove, reinforcing, remain as damaged
(3)	Construction year (Presumptive)	before 1971, from 1972 to 1981, after 1982 (new structural provision was released), unknown
(4)	Usage	hotel, office, house or condominium, store, factory, warehouse, other(___)
(5)	Existence of piloti	yes, no
(6)	Structure	reinforced concrete (RC), precast RC, steel and reinforced concrete (SRC), steel (S), other(___)
(7)	reinforcement (main)	deformed bar, plain bar, unknown
	reinforcement (confinement)	deformed bar, plain bar, unknown, pitch ___mm
(8)	form of structure (NS direction)	Rahmen, wall, core, brace, other(___)
(9)	form of structure (EW direction)	Rahmen, wall, core, brace, other(___)
(10)	Number of floors	___ floor(s)
(11)	Penthouse floors	___ floor(s)
(12)	Basement floors	___ floor(s), unknown
Damage		
(13)	Damage level	collapse, severe, middle, minor, entirely burnt, partially burnt
(14)	Scale of fire	alone, spreading, no fire
(15)	Structural damage	collapse of 1st story, collapse of medium story, yielding of column, other(___)
(16)	Gradient	equal or more than 1/30 (2 degree), less than 1/30 (2 degree), no gradient
(17)	Damage of gas-pressure welded splices of reinforcement	ruptured, not ruptured, no such splices, unknown
(18)	alkali aggregate reaction of concrete	yes, no, unknown
(19)	Damage of joint (steel structure)	fracture of welding, rupture of high-tension bolt, no fracture
(20)	Damage of column foot	crush of concrete, elongation or rupture of anchor bolt, no damage, unknown
(21)	Damage of foundation (sinking)	yes, no, other(___)
(22)	Damage of ground	sinking, not sinking, liquefaction, not liquefaction, other(___)
(23)	ALC curtain wall	dropped out over 1/3, dropped out less than 1/3, broken, cracking only, no damage, no such members, unknown
(24)	Broken grass	over 50%, every floor, partially, no damage, no such grasses
(25)	Cause of grass damage	earthquake, fire, unknown
(26)	Precast curtain wall	dropped out (___of___walls), about to drop, needs to repair, no damage, no such walls
(27)	lath sheet mortar or lath mortar	dropped over 50%, partially dropped, cracking only, no damage, no such members
(28)	RC base tile	dropped over 50%, partially dropped, cracking only, no damage, no such members

[Structural type] Reinforced concrete structure is the largest (516 buildings), and then comes steel structure (316 buildings) and the others (most of them are wood structure, 162 buildings) in order.

[Structural form] About 80% of buildings are the Rahmen structure for both direction.

[Number of floors] 4-story building is the largest (355 buildings) and then comes 5-story (196 buildings), 2-story (161 buildings) 3-story (131 buildings) in that order.

[Damage level] Two levels, ''collapse'' (399 buildings) and ''severe'' (389 buildings) occupy about 60%, the investigation was mainly done for seriously damaged buildings. On the other hand, the number of ''entirely burnt'' and ''partially burnt'' buildings are 28 and 15 respectively.

[Structural damage] Collapse of story (collapse at the 1st and/or middle story, 340 buildings) and ''yielding of columns'' (166 buildings) occupy about 40%.

For presumption of construction year, the data from monumental plate and official resources are used.

c) Cross totalization

For the buildings in Kobe city, cross totalization is carried out to clear the relationship among each investigation item. The result is visualized as Fig. 2.2.1.1 to Fig. 2.2.1.11.

(i) address and state of building (Fig. 2.2.1.1)

In each ward, about 80% of buildings are remains as it was damaged. And 10% are removed or just removing, 5% are under reinforcing. Restoring has been in progress one month after the earthquake.

(ii) usage and structural type (Fig. 2.2.1.2)

Though the main object of this investigation was for severely damaged buildings, there include some middle or minor damaged buildings. Reinforced concrete (RC) buildings and steel (S) buildings are the major because this investigation was for the buildings over 4-story in principle. In addition, steel and reinforced concrete (SRC) structure may have classified as RC because it was difficult to distinguish the difference between RC and SRC by looking.

For the wood buildings residential use is the major of the usage and for the other structures mixed usage is the major. It can be said that there are many condominiums combined with the other usage, see Fig. 2.2.1.2.

(iii) structural type and damage level (Fig. 2.2.1.3)

More than half the number of buildings suffered collapse and severe damage. The ratio of such buildings is 70% for the RC structure, 60% for the SRC structure and 55% for the S structure respectively. It can be said that this investigation has been done for severely damaged buildings.

(iv) usage and damage level (Fig. 2.2.1.4)

For every usage, more than half the number of buildings also suffered collapse and severe damage.

(v) damage level and construction year (Table 2.2.1.2, Fig. 2.2.1.5)

Buildings are identified into three groups depending on the presumptive construction year because the structural provisions of the Building Standard Law Enforcement Order were revised in 1971 and 1981. The distribution of construction year is 535, 218 and 103 buildings for before 1971, from 1972 to 1981 and after 1982 respectively. The number of buildings decrease to about a half according to the construction year. But, comparing the collapsed buildings with the severely damaged buildings, the number of building is 183(collapse)/174(severely damaged), 62/71 and 15/25 for each period. The newer buildings is less damaged and the ratio of damaged building decreases according to the period.

The activities of Building Research Institute had inspected completion, structural type and damage of collapse or severely damaged buildings which were built after 1982, under the new structural provisions. Finally, 39 buildings are in such conditions. See Table 2.2.1.2. For the buildings the damage is independent of structure and story, there are many buildings having piloti or discontinuity of stiffness (for example, stiffness of one story is less than above story) in the table. For the SRC structure of collapse or severely damaged, yielding or rupture of the main reinforcement can be seen at the foot of columns of the first story.

(vi) structural damage and construction year (Fig. 2.2.1.6)

In structural damage, ratio of collapse of first and middle story decreases according to construction year. On the other hand, relatively slight damages (shear cracking of column and/or shear wall, rupture of brace etc.) do not show such tendency.

(vii) structural form and structural damage (Fig. 2.2.1.7)

For the RC structure, the major damages are collapse of story and yielding of column while for the S structure the other damages (rupture of brace, fracture of welding and clash of column foot) are remarkable.

(viii) damage level and piloti (Fig. 2.2.1.8)

Among the collapsed and severely damaged RC structure, before 1971, 33 buildings have piloti and 79 buildings not. On the other hand, from 1972 to 1981, 33 have and 4 not, after 1982, 4 have and 1 not. From this result it can be said that the damage of building depends on existence of the piloti. About a half of the collapsed and severely damaged buildings have the piloti and after 1982 the damage decreases.

(ix) damage of joint and construction year (Fig. 2.2.1.9)

The number of the steel and steel related structures are 113 before 1971, 54 from 1972 to 1981 and 47 after 1982. The fracture of welding is detected on 17, 4 and 11 buildings according to the construction year. Damage of joint is year-independent.

(x) damage of column foot and construction year (Fig. 2.2.1.10)

This damage is seen about 20% of buildings for every construction year.

(xi) comparison with the whole buildings in Kobe city (Fig. 2.2.1.11)

The Fig. 2.2.1.11 shows the comparison of damage level with construction year according to structural type (overall, non-wood and wood structure). This figure is not so referable because it is impossible to estimate both the exact suffering area and number of buildings in the area.

The number of entire buildings in Kobe city has been estimated from the statistical yearbook of buildings etc. In these figures, the number of non-wood buildings constructed before 1981 is set to 79,000, non-wood buildings constructed after 1982 is 40,000, wood buildings constructed before 1981 is 224,000 and wood buildings constructed after 1982 is 52,000. From Fig. 2.2.1.11(b) it can be seen that the ratio of middle or less damaged buildings after 1982 is similar to the entire Kobe city while the ratio of collapse and severely damaged buildings is about a half of that for Kobe city. The building constructed after 1982 (under the new structural provisions) is hard to be damaged seriously.

	Address (ward)						
State	Suma	Nagata	Hyogo	Chuo	Nada	Higashi-nada	Total
removed	15	20	20	20	2	3	80
about to r	8	6	15	35	10	19	93
reinforcin	2	7	8	20	10	10	57
remain	145	163	113	290	119	140	970
unknown	3	3	2	21	0	2	31
Total	173	199	158	386	141	174	1231

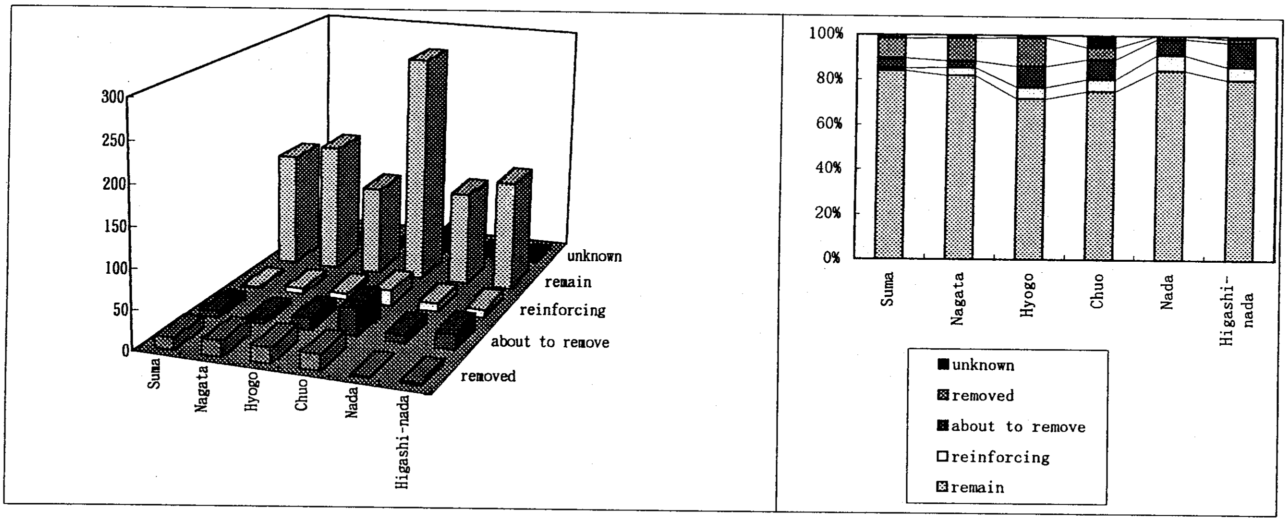


Fig. 2.2.1.1 relationship between address and state of building

	Usage									
Structure	hotel	office	house	store	factory	warehouse	other	mixed	unknown	Total
RC	8	73	120	48	11	0	30	222	4	516
SRC	1	16	7	4	1	0	0	13	0	42
S	1	23	56	54	11	5	8	155	3	316
wood	6	2	70	15	1	3	31	31	3	162
combined	5	7	9	9	1	0	9	26	0	66
unknown	0	4	3	7	0	0	2	4	109	129
Total	21	125	265	137	25	8	80	451	119	1231

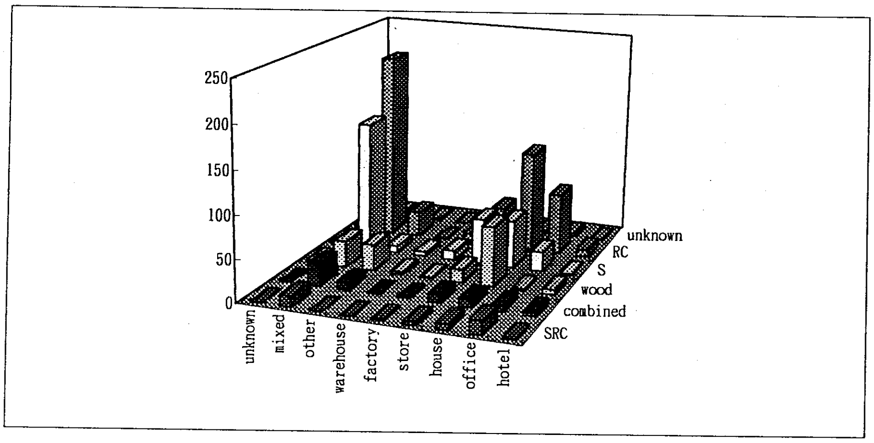


Fig. 2.2.1.2 relationship between usage and structural kind

Damage level	Structural kind RC	SRC	S	wood	combined	unknown	Total
collapse	214	10	43	49	21	2	339
severe	153	17	131	65	21	2	389
middle	60	9	49	11	10	4	143
minor	71	6	86	16	13	3	195
unknown	18	0	7	21	1	118	165
Total	516	42	316	162	66	129	1231

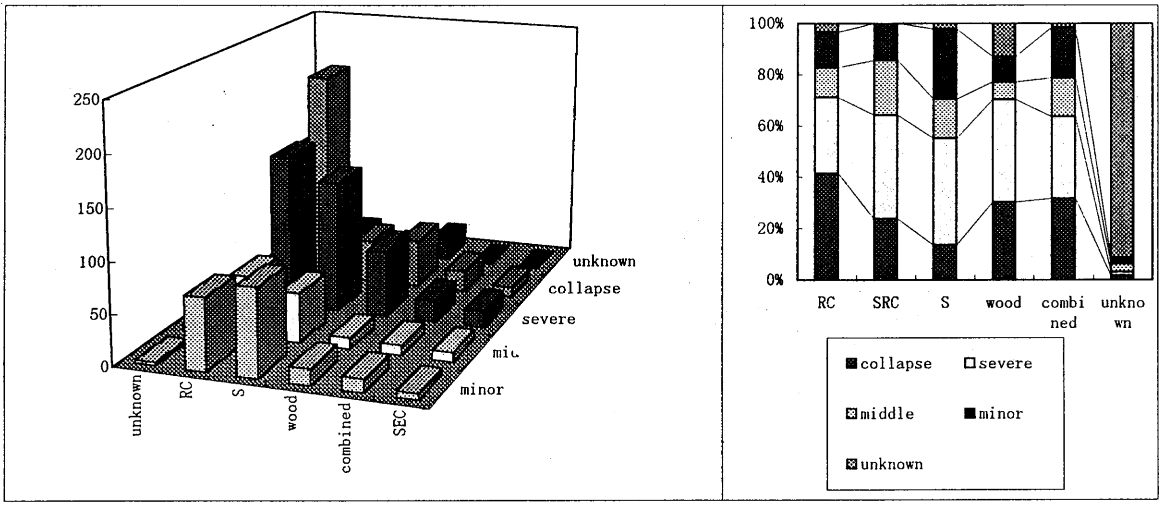


Fig. 2.2.1.3 relationship between structural kind and damage level

Damage level	Usage hotel	office	house	store	factory	warehouse	other	mixed	unknown	Total
collapse	5	43	89	36	10	3	24	126	3	339
severe	8	38	88	52	12	3	30	155	3	389
middle	4	22	29	18	1	0	8	61	0	143
minor	4	17	42	22	2	2	8	98	0	195
unknown	0	5	17	9	0	0	10	11	113	165
Total	21	125	265	137	25	8	80	451	119	1231

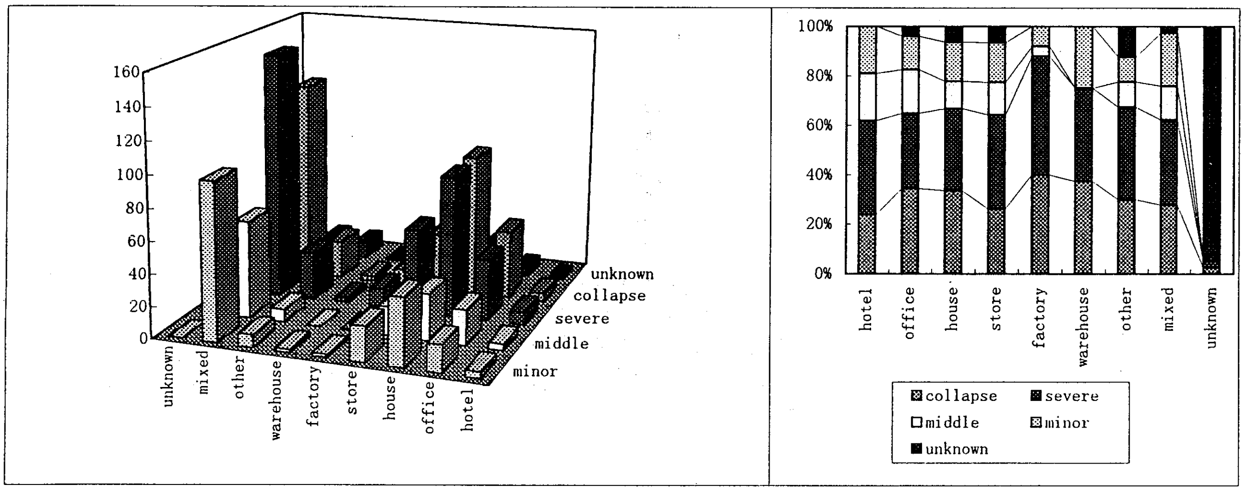


Fig. 2.2.1.4 relationship between structural kind and damage level

	Damage level					
Construction year	collapse	severe	middle	minor	unknown	Total
before 1971	183	174	42	63	73	535
1972 to 1981	62	71	37	42	6	218
after 1982	15	25	29	29	5	103
unknown	79	119	35	61	81	375
Total	339	389	143	195	165	1231

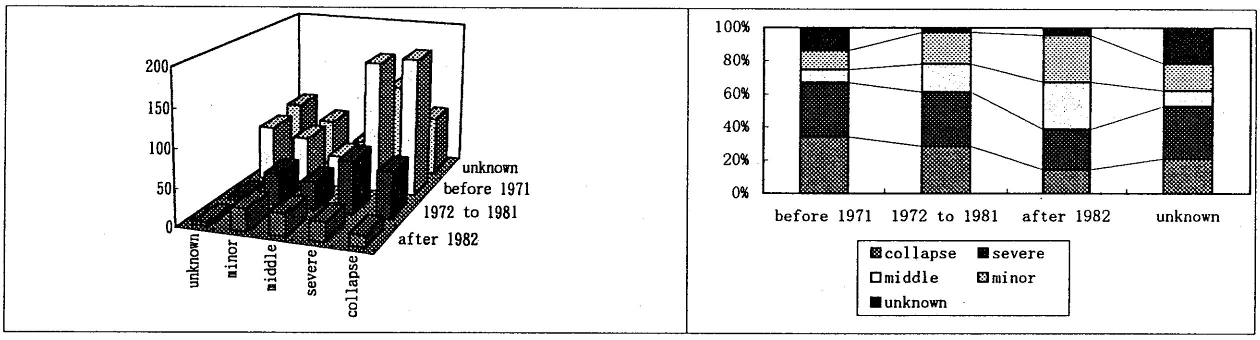


Fig. 2.2.1.5 relationship between damage level and construction year

	Structural damage						
Construction year	collapse (1st story)	collapse (med. story)	yielding of column	other	combination	unknown	Total
before 1971	148	22	74	150	28	113	535
1972 to 1981	55	6	34	86	10	27	218
after 1982	13	2	15	49	5	19	103
unknown	55	20	43	130	9	118	375
Total	271	50	166	415	52	277	1231

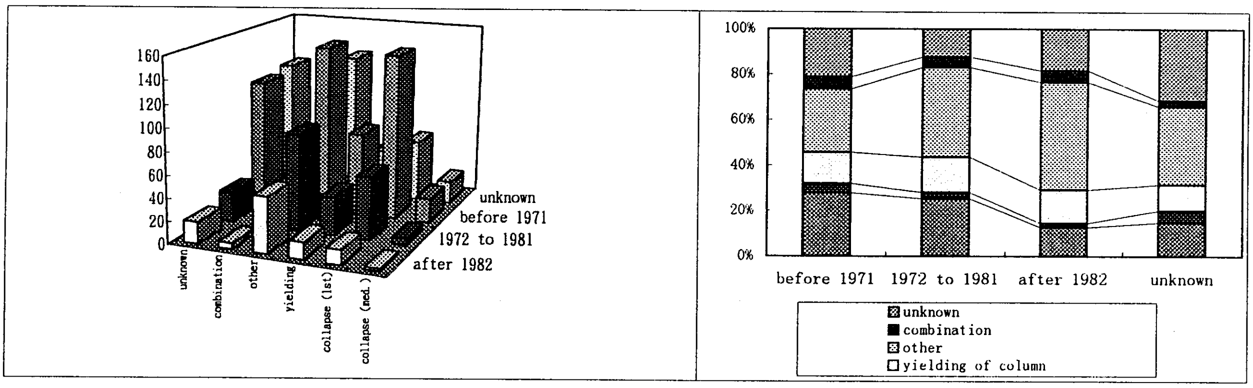


Fig. 2.2.1.6 relationship between structural damage and construction year

Structural damage	Structure RC	SRC	S	wood	combined	unknown	Total
collapse (1st)	169	8	38	40	13	3	271
collapse (med.)	30	5	7	2	6	0	50
yielding of column	100	8	38	12	8	0	166
other	129	15	166	69	29	7	415
combination	31	4	12	1	4	0	52
unknown	57	2	55	38	6	119	277
Total	516	42	316	162	66	129	1231

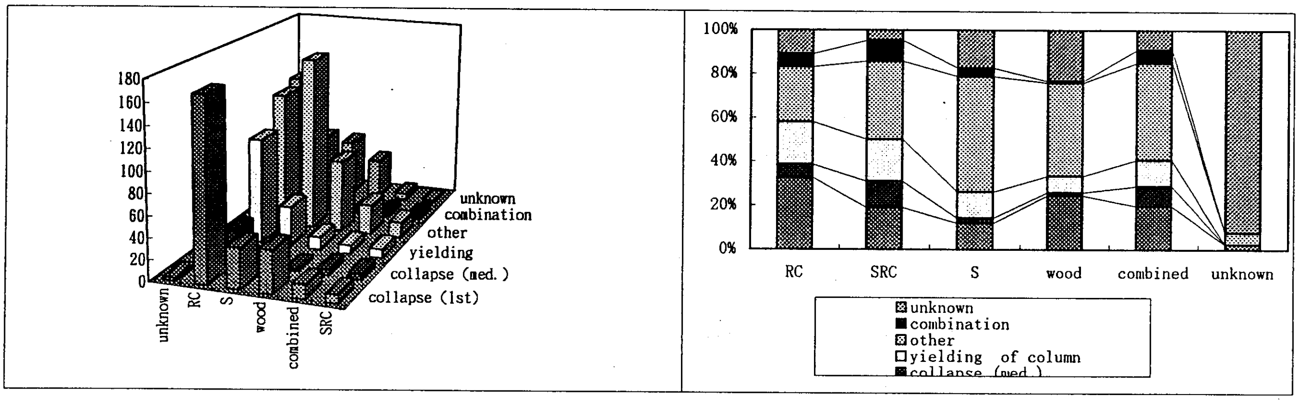
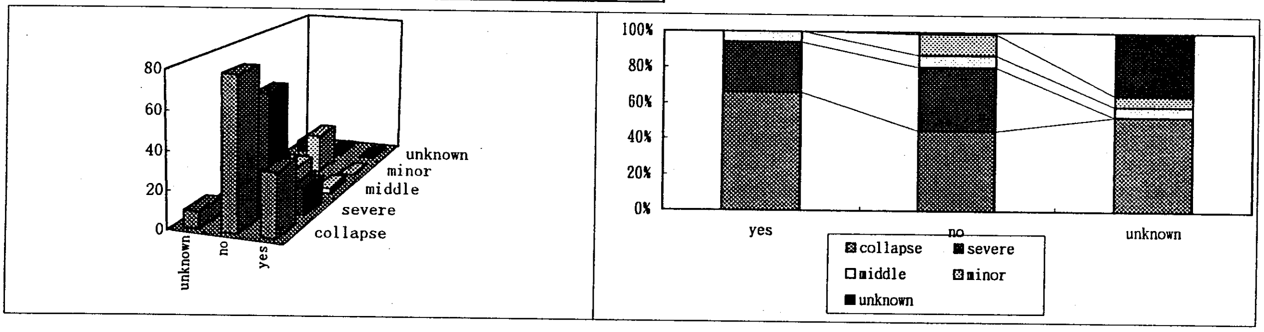


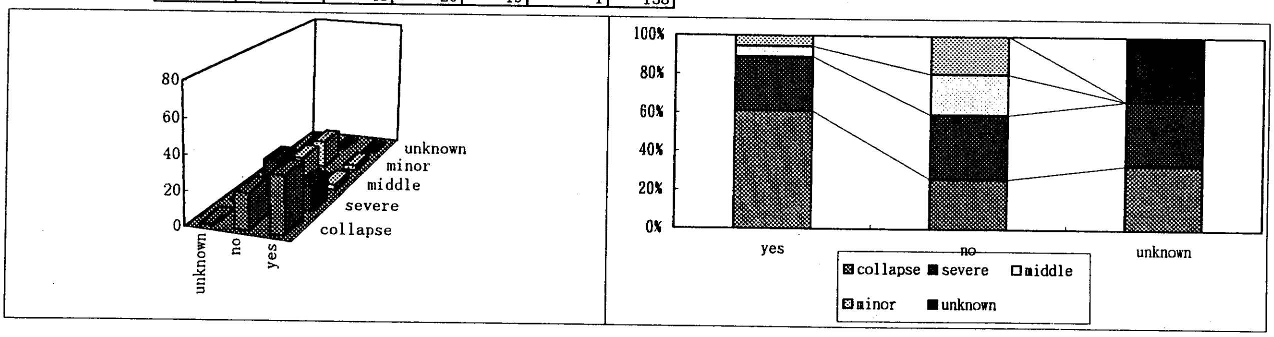
Fig. 2.2.1.7 relationship between structural form and structural damage

	Damage level					
Piloti	collapse	severe	middle	minor	unknown	Total
yes	33	14	3	0	0	50
no	79	62	12	21	2	176
unknown	9	0	1	1	6	17
Total	121	76	16	22	8	243



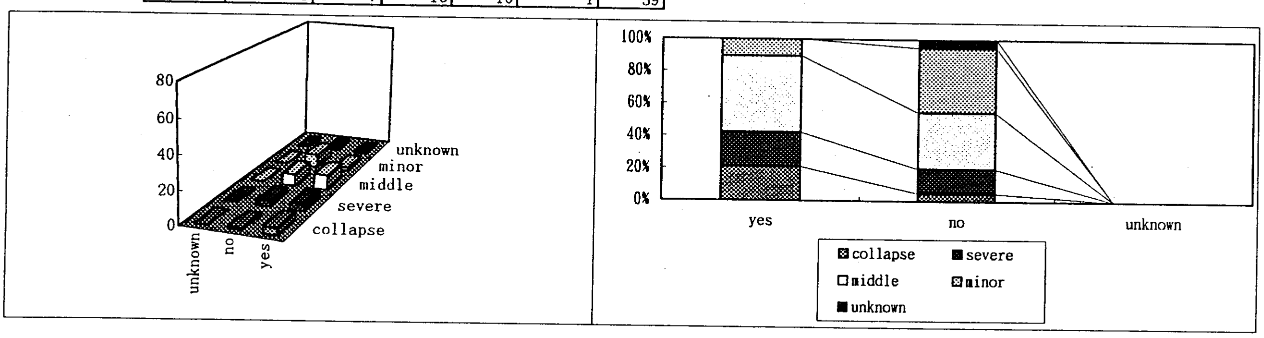
(a) constructed before 1971

	Damage level					
Piloti	collapse	severe	middle	minor	unknown	Total
yes	33	15	3	3	0	54
no	21	27	17	16	0	81
unknown	1	1	0	0	1	3
Total	55	43	20	19	1	138



(b) constructed from 1972 to 1981

	Damage level					
Piloti	collapse	severe	middle	minor	unknown	Total
yes	4	4	9	2	0	19
no	1	3	7	8	1	20
unknown	0	0	0	0	0	0
Total	5	7	16	10	1	39



(c) constructed after 1982

Fig. 2.2.1.8 damage level and piloti (RC structure)

(steel and steel related structure)

	Damage of joint				
Construction year	fracture of welding	rupture of high-tension bolt	no fracture	unknown	Total
before 1971	17	7	32	57	113
1972 to 1981	4	1	21	28	54
after 1982	11	1	10	25	47
unknown	20	2	34	80	136
Total	52	11	97	190	350

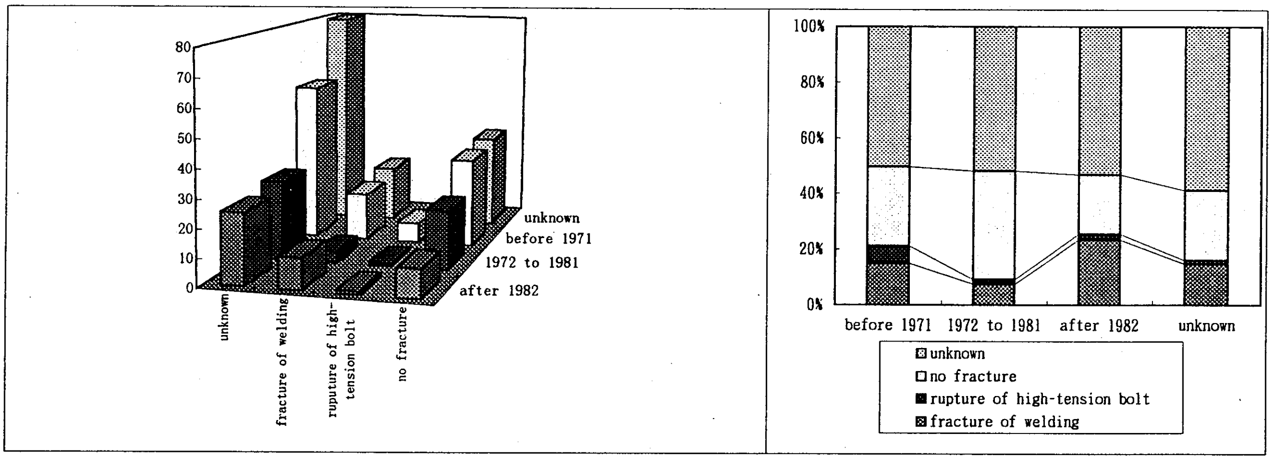


Fig. 2.2.1.9 relationship between damage of joint and construction year (S structure)

(steel and steel related structure)

	damage of column foot					
Construction year	crush of concrete	rupture of anchor bolt	both	no damage	unknown	Total
before 1971	9	17	1	38	48	113
1972 to 1981	3	6	0	20	25	54
after 1982	2	7	1	9	28	47
unknown	12	16	2	32	74	136
Total	26	46	4	99	175	350

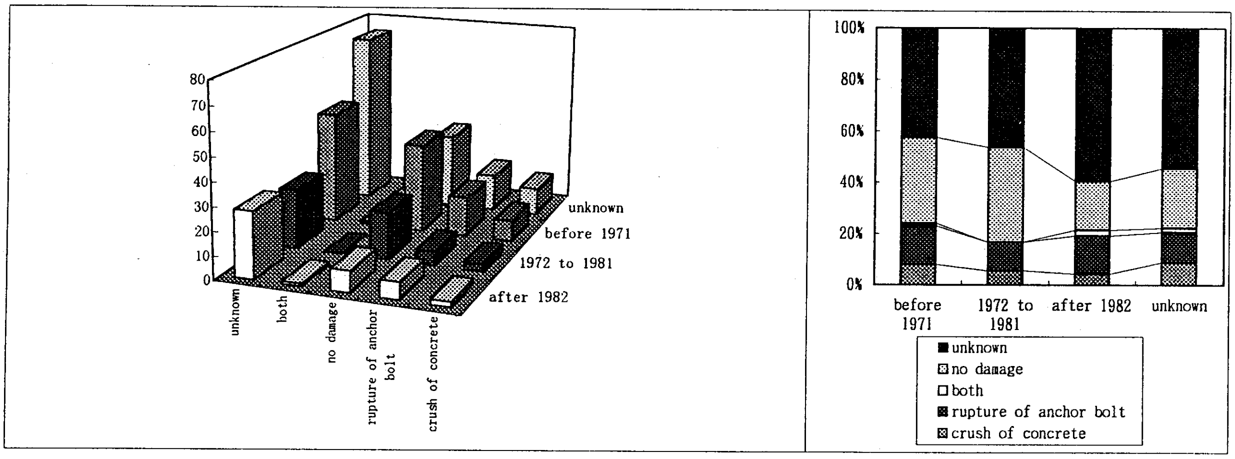
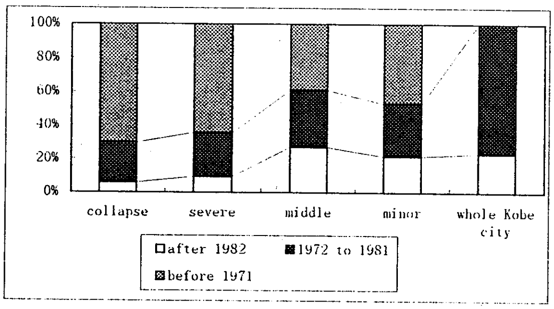


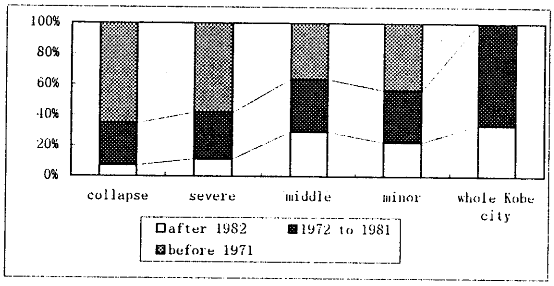
Fig. 2.2.1.10 relationship between damage of column foot and construction year

Construction year	Damage level collapse	severe	middle	minor	unknown	Total	Total (whole Kobe city)
before 1971	183	174	42	63	73	535	
1972 to 1981	62	71	37	42	6	218	303000
after 1982	15	25	29	29	5	103	92000
unknown	79	119	35	61	81	375	0
Total	339	389	143	195	165	1231	395000



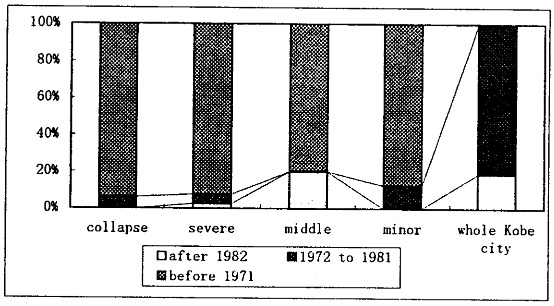
(a) overall

Construction year	Damage level collapse	severe	middle	minor	unknown	Total	Total (whole Kobe city)
before 1971	138	124	34	51	8	355	
1972 to 1981	58	65	32	40	1	196	79000
after 1982	15	24	27	26	2	94	40000
unknown	56	88	25	46	14	229	0
Total	267	301	118	163	25	874	119000



(b) non-wood structure

Construction year	Damage level collapse	severe	middle	minor	unknown	Total	Total (whole Kobe city)
before 1971	30	36	4	7	17	94	
1972 to 1981	2	2	0	1	1	6	224000
after 1982	0	1	1	0	1	3	52000
unknown	17	26	6	8	2	59	0
Total	49	65	11	16	21	162	276000



(c) wood structure

Fig. 2.2.1.11 relationship between damage level and construction year (compare with whole Kobe city)

Table 2.2.1.2 collapse and severely damaged buildings constructed under present structural provisions

No.	ADDRESS	USAGE*)	PILOLI	STRUCTURAL FORM	FL.	DAMAGE LEVEL	DAMAGE DESCRIPTION
1	1 Tanaka, Higashi-nada	S	no	RC Rahmen	4	severe	other
2	1 Tanaka, Higashi-nada	S	no	RC Rahmen	5	severe	collapse of first story
3	Ishiya Mikage, Higashi-nada	H	yes	RC Rahmen	5	collapse	collapse of first story
4	3 Moto-yamanaka, Higashi-nada	H	yes	RC Rahmen	6	severe	collapse of first story
5	1 Kita-nagasa DOri, Chuo	S	no	RC Rahmen	6	severe	
6	2 Oishi-Minami, Nada	O/H	yes	RC Rahmen	6	severe	yielding of column
7	7 Nakamichi DOri, Hyogo	H/S	yes	RC Rahmen	7	severe	yielding of column
8	2 Shin-zaike Minami, Nada	H	yes	RC Rahmen	7	collapse	yielding of column
9	2 Tsutsui, Chuo	O	no	RC Rahmen	7	severe	yielding of column
10	8 Motoyama Minami, Higashi-nada	H	yes	RC Rahmen	8	collapse	other
11	1 Naka-yamate, Chuo	S	no	SRC Rahmen	9	severe	other
12	1 Edo, Chuo	O	no	SRC Rahmen	9	severe	collapse of first story
13	6 Wakana DOri, Chuo	H/x	yes	RC Rahmen	10	collapse	collapse of first story
14	4 Ekimae DOri, Hyogo	H	yes	RC Rahmen	10	severe	yielding of column
15	1 Hiyoshi, Nagata	S	no	S Rahmen	2	severe	
16	4 Mikageishi, Higashi-nada	S	yes	S Rahmen	3	severe	collapse of first story
17	2 Honjou, Higashi-nada	O/S	no	S Brace	4	collapse	other
18	3 Mikage-naka, Higashi-nada	O	no	S Rahmen	4	severe	collapse of first story
19	7 Shimozawa DOri, Chuo	O/H	no	S Rahmen	4	collapse	collapse of first story
20	7 Kamizawa DOri, Chuo	H/S	no	S Rahmen	4	collapse	collapse of first story
21	7 Shimozawa DOri, Chuo	H/x	no	S Rahmen	4	collapse	collapse of first story
22	4 Shin-kaichi, Chuo	HT	yes	S Rahmen	4	collapse	collapse of first story
23	1 Kagura, Nagata	O/F	no	S Rahmen	4	severe	other
24	4 Nishidai DOri, Nagata	O/S	no	S Unknown	4	severe	other
25	7 Hosoda, Nagata	O/S	no	S Rahmen	4	severe	other
26	7 Ota, Suma	H/O	no	S Rahmen	4	severe	other
27	2 Oishi Minami, Nada	O	yes	S Rahmen	4	severe	yielding of column
28	6 Wakamatsu, Nagata	S	no	S Rahmen	4	severe	collapse of first story
29	4 Oishi Higashi, Nada	H	yes	S Rahmen	4	collapse	collapse of first story
30	6 Sumiyoshi-miya, Higashi-nada	O	no	S Rahmen	5	severe	other
31	1 Naka-yamate DOri, Chuo	O/S	no	S Rahmen	5	severe	other
32	8 Shimozawa DOri, Hyogo	H/S	no	S Rahmen	5	severe	other
33	3 Terada, Suma	S	unknown	S Rahmen	5	collapse	collapse of first story
34	4 Warizuka DOri, Chuo	H	no	S Rahmen	5	severe	yielding of column
35	3 Kita-nagasa DOri, Chuo	S	no	S Rahmen	6	severe	
36	4 Kanou, Chuo	S	no	S Rahmen	7	collapse	collapse of first story
37	2 Kita-nagasa DOri, Chuo	S	no	S Rahmen	8	severe	
38	4 Kotono'o, Nagata	x	no	S Rahmen	8	collapse	other
39	1 Kita-nagasa DOri, Chuo	x/S	no	S Rahmen	10	collapse	collapse of medium story

*) H:House, S:Store, O:Office, F:Factory, HT:Hotel, x:other

2.2.2 Macro Analysis based on the Investigation by Building Contractors Society

In this section, macro analysis of the investigation by Building Contractors Society (BCS) is carried out.

(1) Outline of the Investigation

The BCS investigated many buildings in the Kobe and Hanshin area since January to March 1995 after the earthquake. The result of the BCS investigation is translated into the investigation items shown in Table 2.2.1.1 and analyzed (see Fig. 2.2.2.1). This result is useful for the macro analysis because the buildings investigated are widely covered with those from slightly damaged to severely damaged and for many of those buildings the construction year is known.

a) Totalization

The total number of the BCS investigation is 3,062 buildings and totalized according to items listed in Table 2.2.1.1.

The following features are found:

[Address] The area of this investigation is widely expanded, for example, 2,928 buildings are in Hyogo prefecture, 631 buildings are in Osaka prefecture and 18 buildings are in Kyoto prefecture. In Kobe city 1,775 buildings were investigated and especially 561 buildings of them were in Chuo ward.

[State of building] About 60%, 2,040 buildings were remains as damaged by the earthquake. On the other hand, 1,267 buildings were the state ''unknown''.

[Construction year] The presumption of construction year for about 65%, 2,325 buildings has been successfully done. The largest content is ''after 1982'' of 1,403 buildings. The entry ''from 1972 to 1981'' is in the next place with 537 buildings and ''before 1971'' follows with 385 buildings.

[Usage] Buildings are mainly used as ''house or condominium'' (1,249 buildings), then ''office'' (624 buildings) follows.

[Structural type] Reinforced concrete structure is the largest (2,007 buildings), and then comes steel structure (752 buildings) and the SRC (429 buildings) in order.

[Structural form] About 60% of buildings are the Rahmen structure for both NS and EW direction.

[Number of floors] A 3-story building is the largest (596 buildings) and then comes 4-story (512 buildings), 2-story (469 buildings) and 5-story (445 buildings) in that order.

[Damage level] Two levels, ''collapse'' (67 buildings) and ''severe'' (161 buildings) occupy about 6%. The number of ''entirely burnt'' and ''partially burnt'' buildings are 2 and 2 respectively.

[Structural damage] Collapse of story (79 buildings collapsed at the 1st and/or middle story) and ''yielding of columns'' (138 buildings) occupy about 6%.

b) Cross totalization

Cross totalization is carried out to clear the relationship among each investigation item. The result is visualized in Fig. 2.2.2.1 to Fig. 2.2.2.11.

(i) address and state of building (Fig. 2.2.2.1)

In each ward, about 50% of buildings are remains as it was damaged. And 10% are removed or just removing and 5% are under reinforcement works.

(ii) usage and structural type (Fig. 2.2.2.2)

For every structure, buildings are mainly used as a house or a condominium.

(iii) damage level and structural type (Fig. 2.2.2.3)

For every structure, the largest content of damage of building is ''minor'', then comes ''middle'', ''severe'' and ''collapse'' in order. Ratio of middle or less damaged buildings is about 70% and it can be said that most of the buildings are not so damaged.

(iv) damage level and usage (Fig. 2.2.2.4)

For every usage, as well as structural type, the most of buildings suffers ''minor'' damage, then comes ''middle'', ''severe'' and ''collapse'' in order. Buildings used as a hotel, an office or a store is highly damaged than a house building.

(v) damage level and construction year (Fig. 2.2.2.5)

The number of buildings are 385, 538 and 1,402 buildings for the construction year before 1971, from 1972 to 1981 and after 1982 respectively. But, comparing the collapsed buildings with the severely damaged buildings, the number of buildings is 28(collapse)/47(severely damaged), 9/39 and 2/22 for each period. The ratio of ''collapse'' and ''severely damaged'' buildings are, 7% and 12% before 1971, 2% and 7% from 1972 to 1981, and, 0.1% and 2% after 1982 respectively. The newer buildings is less damaged and the ratio of damaged building decreases according to the period.

(vi) construction year and structural damage (Fig. 2.2.2.6)

Though some of damages such as collapse of story (at first and/or middle stories) and yielding of columns also decrease according to the period, the ratio of the other structural damage is not so varied with period.

(vii) structural form and structural damage (Fig. 2.2.2.7)

For every structure, the item ''other'' for structural damage exceeds because buildings themselves are not highly damaged.

(viii) damage level and piloti (Fig. 2.2.2.8)

The damage ratio of buildings having piloti is some more larger than that of buildings without piloti. But, the effect of existence of piloti is not clear because the number of damaged building is limited.

(ix) damage of joint and construction year (Fig. 2.2.2.9)

Though the damage of joint decreases according to the construction year, fracture of welding is seen in many buildings even after 1982.

(x) damage of column foot and construction year (Fig. 2.2.2.10)

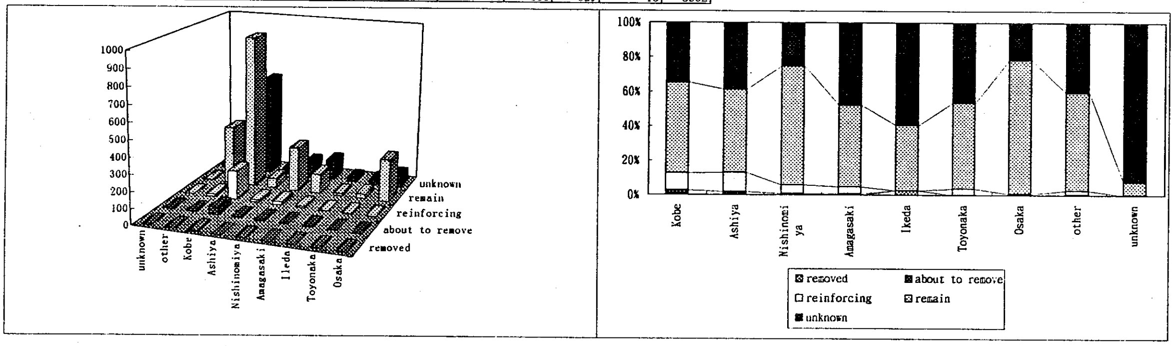
Though the damage of column foot decreases according to the construction year, elongation or rupture of anchor bolt is seen in many buildings even after 1982.

(xi) compare with the whole buildings in Kobe city (Fig. 2.2.2.11)

The Fig. 2.2.2.11 shows the comparison of damage level with construction year according to structural type (overall, non-wood and wood structure). This figure is not so referable because it is impossible to estimate both the exact suffering area and number of buildings in the area. The number of entire buildings in Kobe city is the same as section 2.2.1.

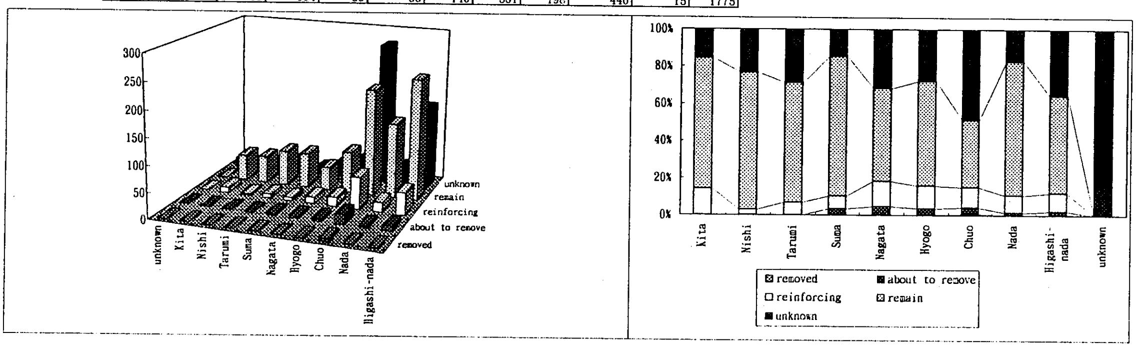
From Fig. 2.2.2.11(b) it can be seen that the ratio of middle or less damaged buildings built after 1982 is larger than the entire Kobe city while the ratio of collapse and severely damaged buildings is less than a half of that for Kobe city. The building constructed after 1982 (under the new structural provisions) is hard to be damaged seriously.

	Address (city)									
	Hyogo pref.				Osaka pref.					
State	Kobe	Ashiya	Nishinomiya	Amagasaki	Ikeda	Toyonaka	Osaka	other	unknown	Total
removed	5	0	0	0	1	0	0	0	0	6
about to remove	43	2	3	2	0	0	0	1	0	51
reinforcing	175	13	20	10	0	2	3	15	0	238
remain	936	56	270	119	14	27	260	357	1	2040
unknown	616	45	98	121	22	25	72	256	12	1267
Total	1775	116	391	252	37	54	335	629	13	3602



(a) whole area

	Address (ward : in Kobe city)										
State	Kita	Nishi	Tarumi	Suma	Nagata	Hyogo	Chuo	Nada	Higashi-nada	unknown	Total
removed	0	0	0	0	0	0	4	0	1	0	5
about to remove	0	0	0	3	4	5	19	3	9	0	43
reinforcing	10	2	7	6	12	17	61	18	42	0	175
remain	50	51	67	67	44	79	204	143	231	0	936
unknown	11	16	30	13	28	39	273	34	157	15	616
Total	71	69	104	89	88	140	561	198	440	15	1775



(b) Kobe city

Fig. 2.2.2.1 relationship between address and state of building

	Usage									
structure	hotel	office	house	store	factory	warehouse	other	mixed	unknown	Total
RC	20	272	957	69	42	52	394	116	85	2007
precast RC	0	1	17	0	0	0	1	1	1	21
SRC	14	122	160	26	5	6	38	38	20	429
S	4	160	29	79	152	95	109	99	25	752
wood	2	17	22	4	4	1	12	4	4	70
combined	4	27	31	15	8	16	47	28	7	183
unknown	2	25	33	7	12	5	24	8	24	140
Total	46	624	1249	200	223	175	625	294	166	3602

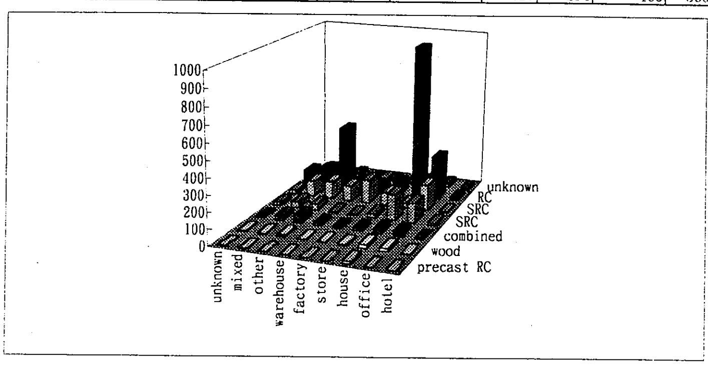


Fig. 2.2.2.2 relationship between usage and structural kind

	Structure							
Damage level	RC	precast RC	SRC	S	wood	combined	unknown	Total
collapse	33	0	19	9	3	3	0	67
severe	63	1	26	48	6	9	8	161
medium	161	2	72	93	7	29	13	377
minor	1317	15	250	401	26	82	71	2162
unknown	433	3	62	201	28	60	48	835
Total	2007	21	429	752	70	183	140	3602

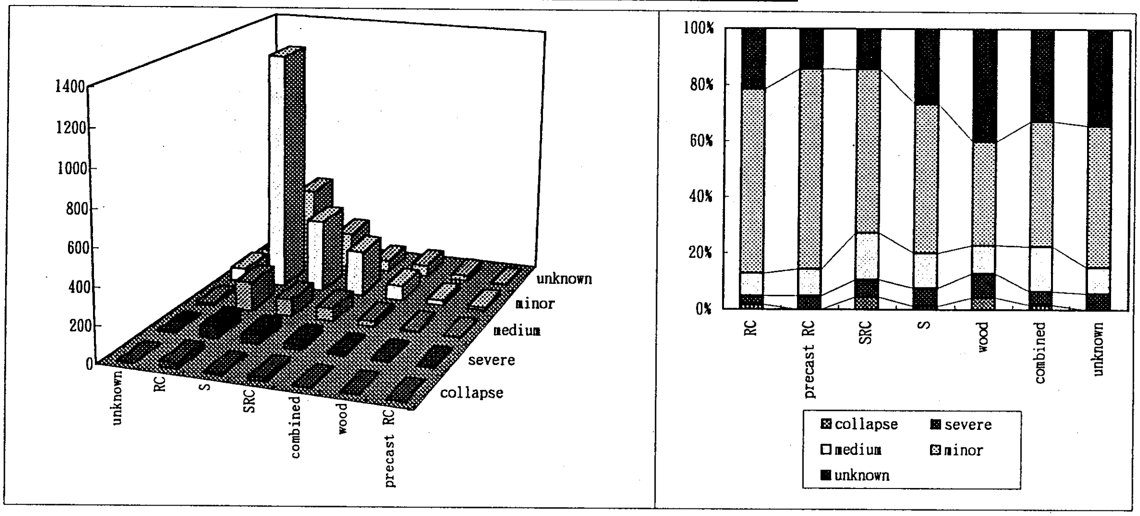


Fig. 2.2.2.3 relationship between damage level and structural kind

	Usage									
Damage level	hotel	office	house	store	factory	warehouse	other	mixed	unknown	Total
collapse	2	18	14	17	2	0	9	3	2	67
severe	3	28	36	17	10	18	16	24	9	161
medium	4	79	99	21	33	26	58	49	8	377
minor	25	354	899	101	94	90	373	157	69	2162
unknown	12	145	201	44	84	41	169	61	78	835
Total	46	624	1249	200	223	175	625	294	166	3602

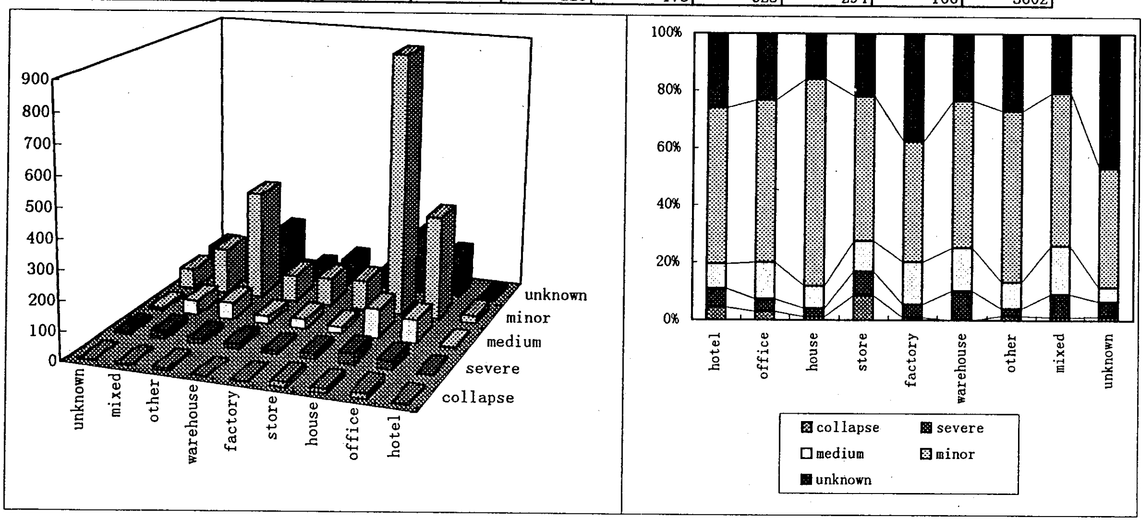


Fig. 2.2.2.4 relationship between damage level and usage

	Damage level					
Construction year	collapse	severe	middle	minor	unknown	Total
before 1971	28	47	66	193	51	385
1972 to 1981	9	39	62	386	42	538
after 1982	2	22	90	1197	91	1402
unknown	28	53	159	386	651	1277
Total	67	161	377	2162	835	3602

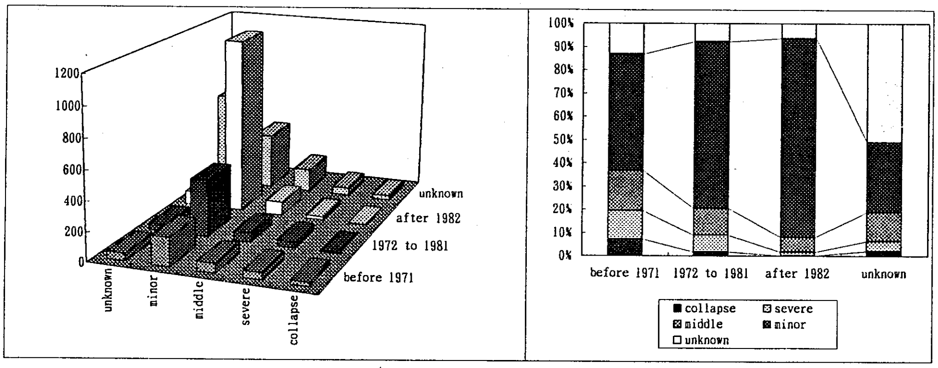


Fig. 2.2.2.5 relationship between damage level and construction year

	Structural damage						
Construction year	Collapse (1st story)	collapse (mid. story)	yielding of column	other	combination	unknown	Total
before 1971	14	16	31	192	5	127	385
1972 to 1981	6	2	15	308	5	202	538
after 1982	2	0	12	763	6	619	1402
unknown	23	12	79	615	12	536	1277
Total	45	30	137	1878	28	1484	3602

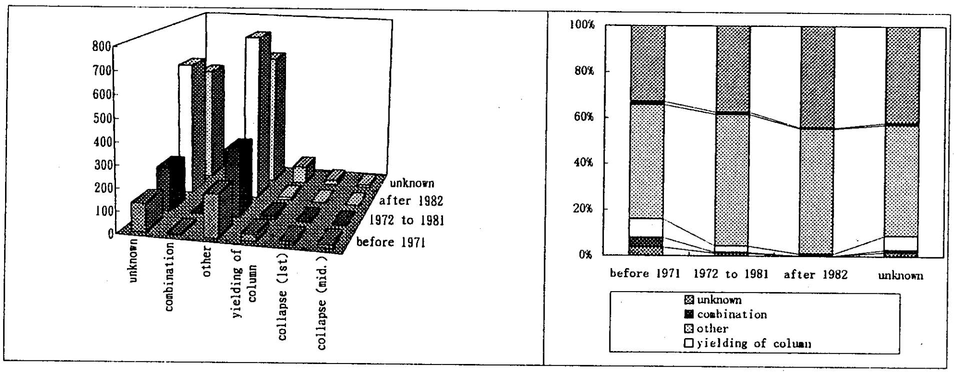


Fig. 2.2.2.6 relationship between construction year and structural damage

	Structure							
Structural damage	RC	precast RC	SRC	S	wood	combined	unknown	Total
collapse (1st story)	20	0	6	11	0	7	1	45
collapse (mid. story)	12	0	15	2	1	0	0	30
yielding of column	71	1	29	22	2	8	4	137
other	1117	9	219	345	39	110	39	1878
combination	11	0	9	6	0	1	1	28
unknown	776	11	151	366	28	57	95	1484
Total	2007	21	429	752	70	183	140	3602

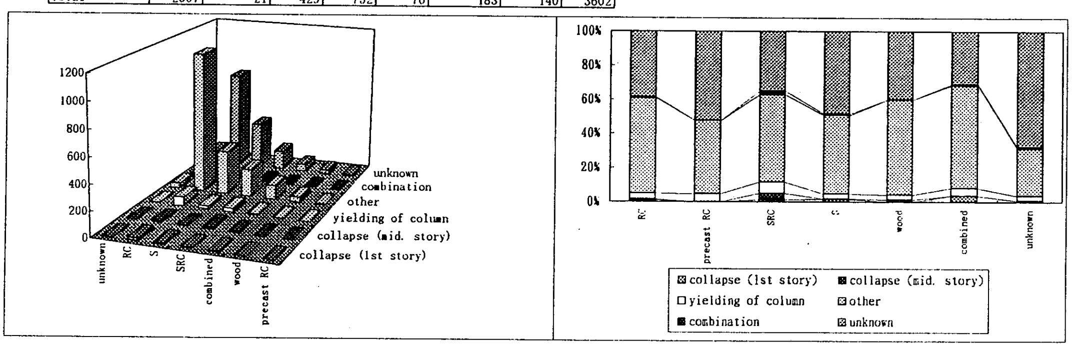
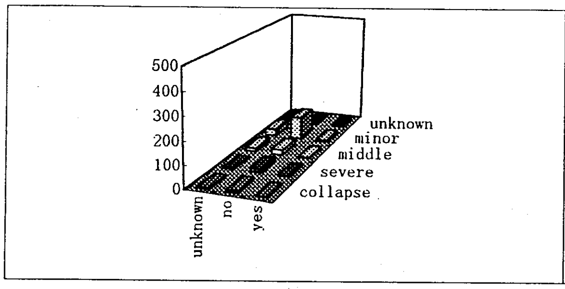
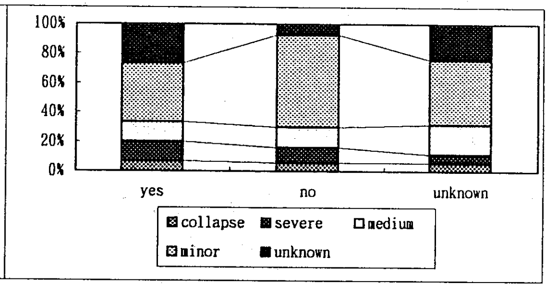


Fig. 2.2.2.7 relationship between structural form and structural damage

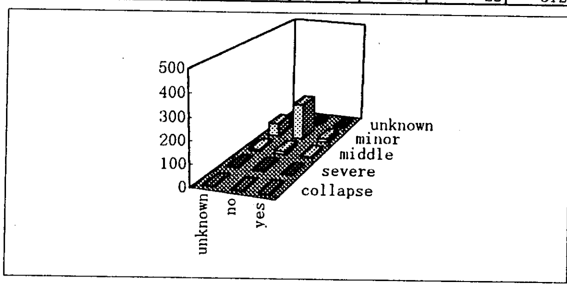
	Damage level					
Piloti	collapse	severe	medium	minor	unknown	Total
yes	1	2	2	6	4	15
no	9	16	22	99	12	158
unknown	4	4	14	31	17	70
Total	14	22	38	136	33	243

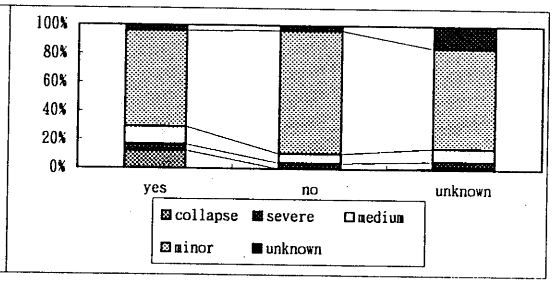




(a) constructed before 1971

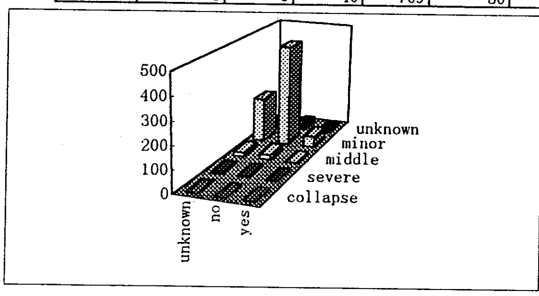
	Damage level					
Piloti	collapse	severe	medium	minor	unknown	Total
yes	3	1	3	16	1	24
no	0	8	13	171	7	199
unknown	1	4	8	62	14	89
Total	4	13	24	249	22	312

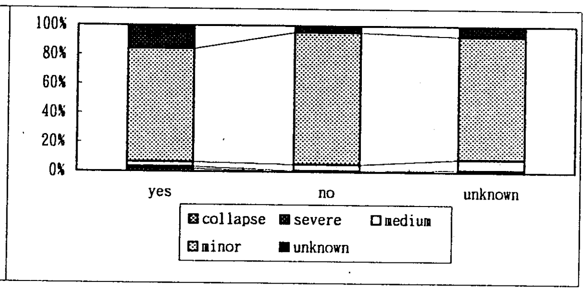




(b) constructed from 1972 to 1981

	Damage level					
Piloti	collapse	severe	medium	minor	unknown	Total
yes	1	1	2	48	10	62
no	0	4	21	460	23	508
unknown	0	3	17	201	17	238
Total	1	8	40	709	50	808





(c) constructed after 1982

Fig. 2.2.2.8 relationship between damage level and piloti (RC structure)

	Damage of joint				
Construction year	fracture of welding	rupture of high-tension bolt	no fracture	unknown	Total
before 1971	5	5	12	15	37
1972 to 1981	4	5	44	33	86
after 1982	7	1	184	99	291
unknown	11	12	103	212	338
Total	27	23	343	359	752

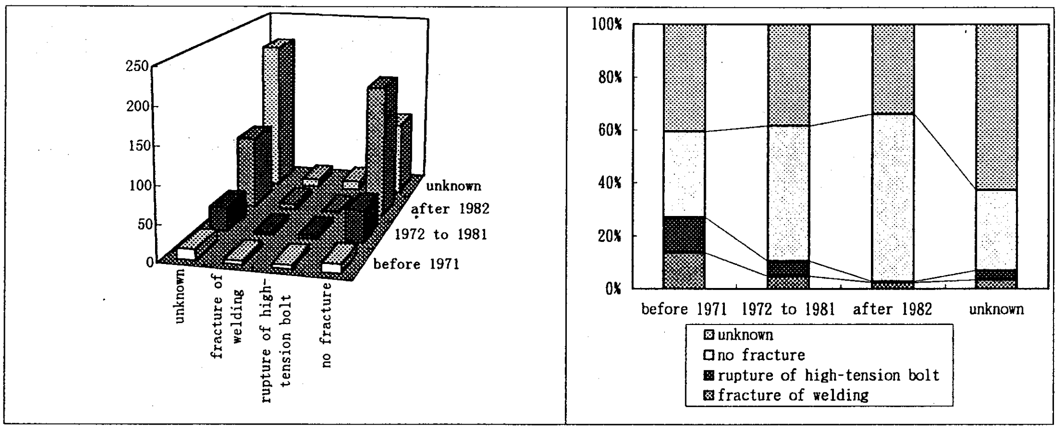


Fig. 2.2.2.9 relationship between damage of joint and construction year (S structure)

	Damage of column foot				
Construction year	crush of concrete	rupture of anchor bolt	no damage	unknown	Total
before 1971	7	5	11	14	37
1972 to 1981	3	6	42	35	86
after 1982	2	5	191	93	291
unknown	25	9	89	215	338
Total	37	25	333	357	752

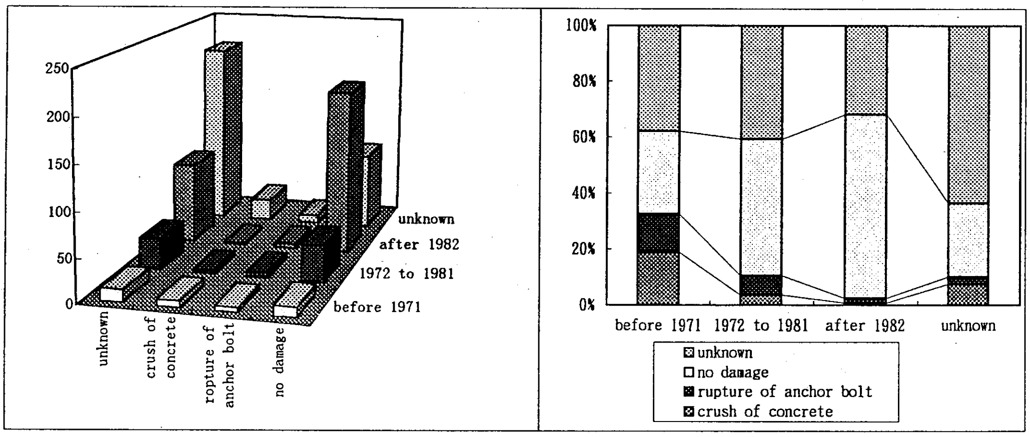
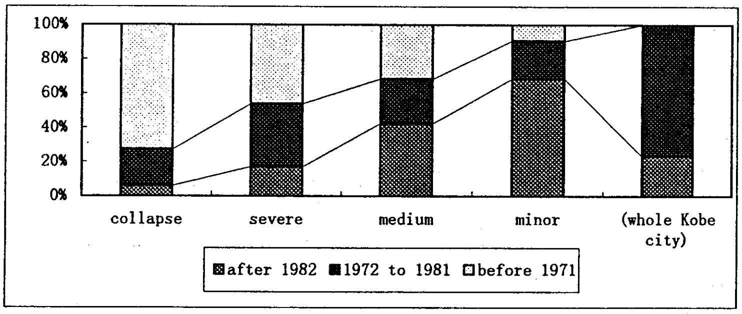


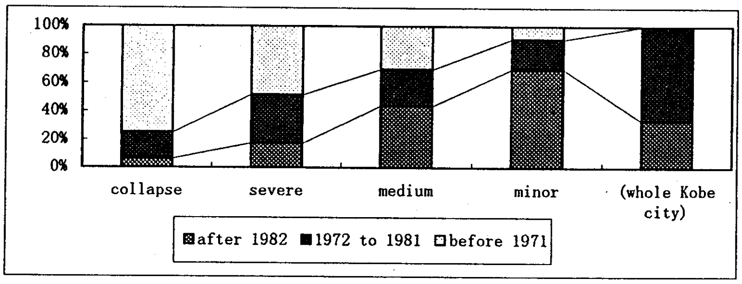
Fig. 2.2.2.10 relationship between damage of column foot and construction year (S structure)

	Damage level						Total
Construction year	collapse	severe	medium	minor	unknown	Total	(whole Kobe city)
before 1971	24	35	48	71	30	208	
1972 to 1981	7	28	40	171	19	265	303000
after 1982	2	13	65	526	33	639	92000
unknown	27	45	114	181	296	663	0
Total	60	121	267	949	378	1775	395000



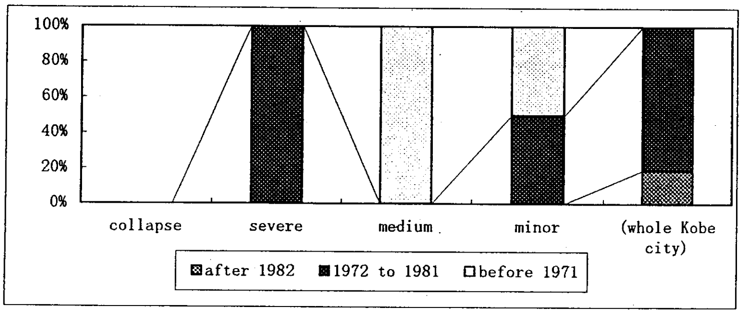
(a) overall

	Damage level						Total
Construction year	collapse	severe	medium	minor	unknown	Total	(whole Kobe city)
before 1971	24	31	41	64	22	182	
1972 to 1981	6	22	35	150	14	227	79000
after 1982	2	11	59	489	26	587	40000
unknown	24	40	98	160	261	583	0
Total	56	104	233	863	323	1579	119000



(b) non-wood structure

	Damage level						Total
Construction year	collapse	severe	medium	minor	unknown	Total	(whole Kobe city)
before 1971	0	0	1	2	0	3	
1972 to 1981	0	1	0	2	0	3	224000
after 1982	0	0	0	0	0	0	52000
unknown	2	1	3	5	4	15	0
Total	2	2	4	9	4	21	276000



(c) wood structure

Fig. 2.2.2.11 relationship between damage level and construction year (compare with whole Kobe city)

2.2.3 Macro analysis based on the Emergency Risk Assessment

(1) Introduction

Using the data of Emergency Risk Assessment, the macro analysis was performed to understand the outline and the tendency of damage.

The meaning of notes and terms in this report is as follows.

- **Object building**

  Because of the main object building of the Emergency Risk Assessment was a condominium, "House" and "Condominium" occupy the majority of the usage of investigated buildings.

  In assessment, buildings are classified into three groups, i.e. reinforced concrete (RC) structure, steel (S) structure and wood structure. RC structure also includes the steel and reinforced concrete (SRC) structure. Each building was inspected by using the investigation sheet.

- **Assessment result ''X''**

  The buildings are automatically classified into three categories; those are ''Safe'', ''Damaged'' and ''Fatal'' according to totalization of the description in investigation sheet. Since there were some incompleted sheets in which only a few items like address or building name, automatic judgement was impossible for such buildings. Among of them, if there were no special description in the margin of the sheet, the building is assumed ''Safe'' and the rest are labeled ''X''. The real damage level of ''X'' buildings is decided later from special description and other source etc. However, in this report ''X'' remains ''X'' as it was firstly classified. It will be done after the Emergency Risk Assessment data used in the Geographic Information System (GIS) is fixed.

- **Lack of data**

  The investigation sheet of some "Safe" buildings was not made in Akashi-city and Amagasaki-city (a total number of such buildings is uncertain). It is understood that the data and the result of analysis about both cities are less reliable.

- **Suffering rate**

  The suffering rate R_s shows the rate of unsafe buildings and is calculated from following expression.

$$R_s = \frac{N_F + N_D}{N}$$

N : total number of buildings
N_F : number of ''Fatal'' buildings
N_D : number of ''Damaged'' buildings

- **Assessment area**

  Following names are used to divide the Hyogo prefecture into the Mainland side and Awaji island.

  Hyogo area 8 cities: Akashi, Kobe, Ashiya, Nishinomiya, Takarazuka, Itami, Amagasaki and Kawanishi on the Mainland.

  Awaji area 7 towns: Awaji, Hokudan, Higashiura, Ichinomiya, Tsuna, Sumoto and Seidan on the Awaji island.

  For each figures and tables in this report, the name of the cities and towns are arranged sequentially from west to east (Akashi to Kawanishi) in Hyogo area and north to south (Awaji to Seidan) in Awaji area according to the distance from the epicenter.

This report begins with an analysis about whole area (see above) and then add an analysis of the Kobe-city where a lot of building exists.

(2) Analysis by whole area

a) General

Fig. 2.2.3.1 and Fig. 2.2.3.2 show the number of buildings according to the structure and the Emergency Risk Assessment result in each area. The ratio of RC building is higher in the Awaji area as compared with the Hyogo area. It is mentioned that this assessment is basically for the condominium, then the ratio calculated in this report does not show the actual ratio of structure.
In Awaji area ratio of wood building increases in Tsuna and Sumoto where the number of inspected buildings is much more than the other towns in Awaji area.
In Hyogo area the value of R_s decreases from Kobe-city toward the east according to the distance from the epicenter. In Awaji area R_s is high in Hokudan (relatively near the epicenter), Ichinomiya and Tsuna. A low R_s of Awaji (town, not area) maybe comes from higher ratio of the RC building compared with the other towns in Awaji area. The RC buildings are not so much damaged over the whole area. However, the analysis about Awaji area is not certain because there are few buildings inspected.

area	city	structure RC	S	wood	total
Kobe	Akashi	316	151	803	1270
	Kobe	6863	2452	7919	17234
	Ashiya	681	171	248	1100
	Nishinomiya	2894	1316	2031	6241
	Takarazuka	516	596	927	2039
	Itami	676	554	623	1853
	Amagasaki	104	188	2714	3006
	Kawanishi	276	295	1926	2497
Awaji	Awaji	21	5	5	31
	Hokutan	24	10	13	47
	Higashiura	26	4	9	39
	Ichinomiya	24	2	4	30
	Tsuna	37	29	108	174
	Sumoto	96	95	148	339
	Seidan	33	9	4	46
(none)			17	51	68
	total	12587	5894	17533	36014

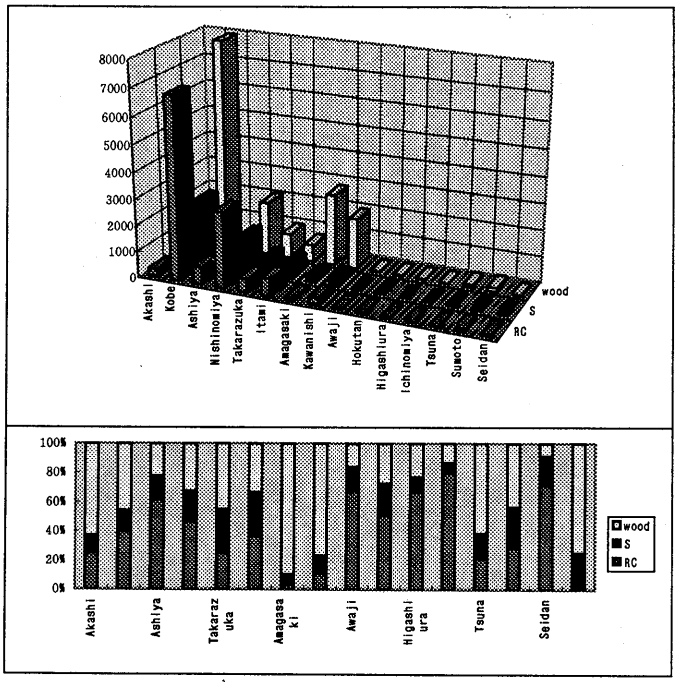


Fig. 2.2.3.1 number of building (whole area)

area	city	emargent assessment Fatal	Damaged	Safe	X	total
Hyogo	Akashi	92	639	538	1	1270
	Kobe	3980	3345	9847	62	17234
	Ashiya	189	110	766	35	1100
	Nishinomiya	997	842	4388	14	6241
	Takarazuka	217	388	1432	2	2039
	Itami	54	260	1538	1	1853
	Amagasaki	547	2022	437	0	3006
	Kawanishi	98	666	1731	2	2497
Awaji	Awaji	1	1	29	0	31
	Hokutan	11	7	29	0	47
	Higashiura	1	8	30	0	39
	Ichinomiya	4	0	26	0	30
	Tsuna	26	35	113	0	174
	Sumoto	2	28	309	0	339
	Seidan	1	1	44	0	46
(none)		22	25	21	0	68
	Total	6242	8377	21278	117	36014

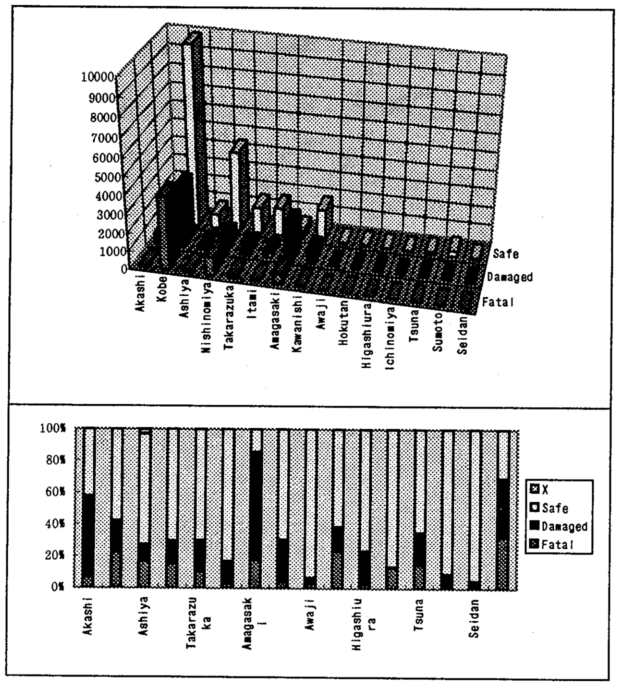


Fig. 2.2.3.2 assessment result (whole area)

b) Damage of the Reinforced Concrete Buildings

The following six items are extracted from the investigation sheet for the RC building to carry out macro analysis.

1. **city or town**
2. **usage**
3. **type of structure**
4. **system of structure**
5. **number of stories**
6. **assessment result**

Table 2.2.3.1 shows the result of totalization item by item. The parenthesized number is the percentage to the total number of the RC buildings (it is the same as follows). The bold-faced number means the largest content of each item.

According to Table 2.2.3.1 about a half of all RC buildings concentrates in the Kobe-city and the ratio reaches 3/4 if Nishinomiya-city was also considered. The RC building does not exist so much in Awaji area. The value of R_s of the entire RC building is 5.5%.

cross totalization (RC structure)

Various pairs from six items (see above) were chosen for cross totalization to understand the tendency and the characteristic of structural damage.

The suffering of RC building decreases according to the distance from the epicenter (Fig. 2.2.3.3). Such tendency also can be seen in Fig. 2.2.3.2 of general analysis. However, R_s is relatively low because many RC building were "Safe". In Kobe-city the number of the ''Fatal'' building was more than that of ''Damaged'' one. It is necessary to examine why such phenomenon was happened. (This trend is undesirable because the number of ''Safe'' buildings should be larger than that of ''Damaged'' ones, and that of ''Fatal'' ones be least.)

From Fig. 2.2.3.4, the Emergency Risk Assessment result of each type of structure, damage of the SRC structure is larger than that of the RC. The damage of the Rahmen structure is the largest (Fig. 2.2.3.5) and these results are due to the scale of building. In Fig. 2.2.3.6 R_s rises according to the number of the stories and reaches its peak about ten-story building. The SRC structure and the Rahmen structure are many at high stories (see Fig. 2.2.3.7 and Fig. 2.2.3.8), therefore the R_s might have been high. From Fig. 2.2.3.6 it is understood that the ratio of "Damaged" building rises while the building becomes higher. The largest content of stories among each type of structure is 4 about RC (29.2%), 11 about SRC (17.6%), 2 about concrete block (72.2%), 5 about precast concrete (33.0%) and 4 about mixed structure (24.2%) as shown in Fig. 2.2.3.7.

Table 2.2.3.1 totalization of each item (RC structure)

area

	city	number
Hyogo	Akashi	316 (2.5)
	Kobe	**6863 (52.5)**
	Ashiya	681 (5.4)
	Nishinomiya	2894 (23.0)
	Takarazuka	516 (4.1)
	Itami	676 (5.4)
	Amagasaki	104 (0.8)
	Kawanishi	276 (2.2)
Awaji	Awaji	21 (0.2)
	Hokutan	24 (0.2)
	Higashiura	26 (0.2)
	Ichinomiya	24 (0.2)
	Tsuna	37 (0.3)
	Sumoto	96 (0.8)
	Seidan	33 (0.3)
total		12587 (100.0)

usage

usage	number
house	363 (2.9)
condominium	**8914 (70.8)**
office	25 (0.2)
store	30 (0.2)
hospital	1 (0.0)
school	6 (0.0)
public hall	7 (0.1)
factory	1 (0.0)
gymnasium	2 (0.0)
mixed	2571 (20.4)
other	153 (1.2)
(none)	514 (4.1)
total	12587 (100.0)

number of stories

stories	number
1	32 (0.3)
2	570 (4.5)
3	3427 (27.2)
4	**3486 (27.7)**
5	2244 (17.8)
6	651 (5.2)
7	531 (4.2)
8	280 (2.2)
9	136 (1.1)
10	166 (1.3)
11	154 (1.2)
12	48 (0.4)
13	32 (0.3)
14	45 (0.4)
15or more	33 (0.3)
other	4 (0.0)
total	12587 (100.0)

system of structure

system	number
Rahmen	**7840 (62.3)**
wall	3382 (26.9)
mixed	98 (0.8)
others	12 (0.1)
(none)	1255 (10.0)
total	12587 (100.0)

type of structure

type	number
RC	**10952 (87.0)**
SRC	465 (3.7)
concrete block	36 (0.3)
precast concrete	182 (1.4)
mixed	120 (1.0)
(none)	832 (6.6)
total	12587 (100.0)

assessment result

result	number
Fatal	355 (2.8)
Damaged	340 (2.7)
Safe	**11828 (94.0)**
X	64 (0.5)
total	12587 (100.0)

Conclusion

Though there are a little differences between each R_s for every picked item, the rate changes almost below 20% and it is thought that a serious problem does not occur. However, there is some result where the number of "Fatal" buildings exceed "Damaged" ones and this means detailed examination is required. Moreover, the investigation sheet used in Emergency Risk Assessment has no contents about existence of piloti, construction year or story where the system of structure is changed, then it is preferable to take other investigation results into consideration.

		emargent assessment				
area	city	Fatal	Damaged	Safe	X	total
Hyogo	Akashi	2	10	303	1	316
	Kobe	274	224	6327	38	6863
	Ashiya	24	31	612	14	681
	Nishinomiya	43	46	2799	6	2894
	Takarazuka	1	7	506	2	516
	Itami	1	13	661	1	676
	Amagasaki	8	5	91	0	104
	Kawanishi	0	0	274	2	276
Awaji	Awaji	0	0	21	0	21
	Hokutan	2	2	20	0	24
	Higashiura	0	1	25	0	26
	Ichinomiya	0	0	24	0	24
	Tsuna	0	0	37	0	37
	Sumoto	0	1	95	0	96
	Seidan	0	0	33	0	33
	Total	355	340	11828	64	12587

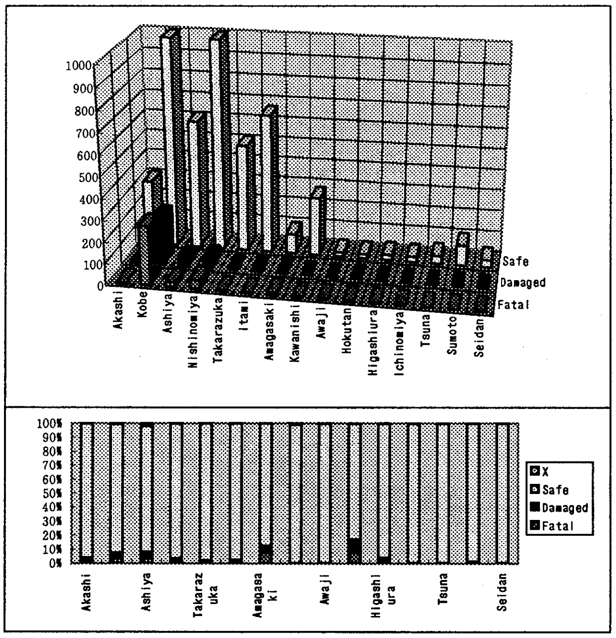
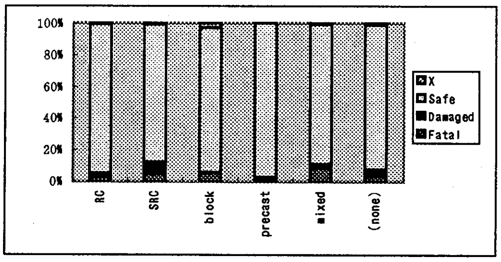


Fig. 2.2.3.3 city and assessment (RC structure)

	assessment result				
type	Fatal	Damaged	Safe	X	total
RC	289	267	10345	51	10952
SRC	22	34	406	3	465
concrete block	2	0	33	1	36
precast concrete	2	3	177	0	182
mixed	10	3	106	1	120
(none)	30	33	761	8	832
total	355	340	11828	64	12587



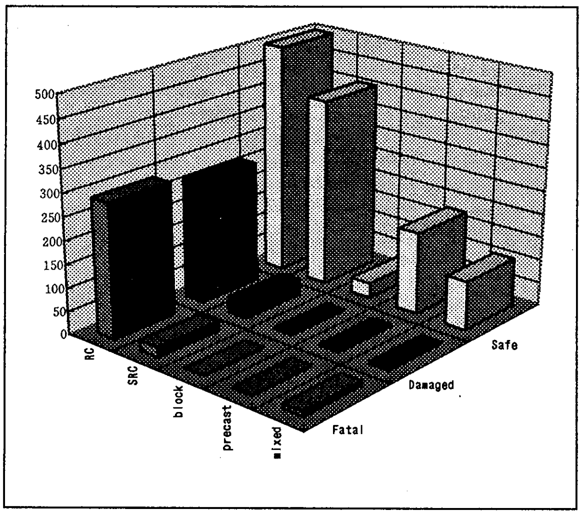
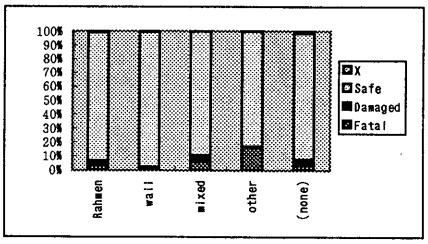


Fig. 2.2.3.4 type and assessment (RC structure)

	assessment result				
form	Fatal	Damaged	Safe	X	total
Rahmen	273	249	7277	41	7840
wall	30	41	3302	9	3382
mixed	6	4	88	0	98
other	2	0	10	0	12
(none)	44	46	1151	14	1255
total	355	340	11828	64	12587



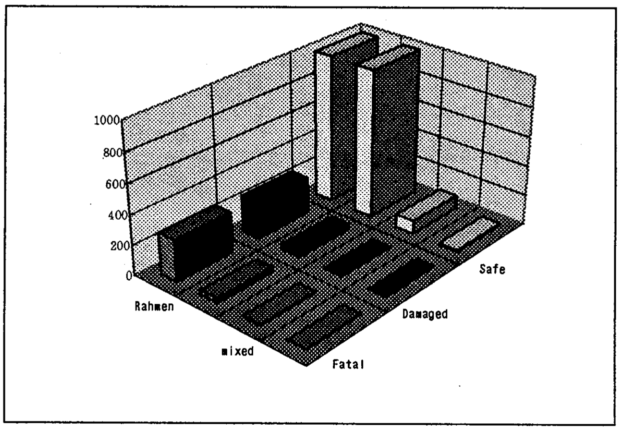


Fig. 2.2.3.5 system and assessment (RC structure)

story	assessment result				total
	Fatal	Damaged	Safe	X	
1	0	1	31	0	32
2	12	7	549	2	570
3	44	43	3326	14	3427
4	95	72	3307	12	3486
5	74	78	2077	15	2244
6	29	24	597	1	651
7	23	31	472	5	531
8	19	14	244	3	280
9	9	7	119	1	136
10	9	22	134	1	166
11	6	11	135	2	154
12	3	4	41	0	48
13	1	3	28	0	32
14	0	1	44	0	45
15 or more	0	2	31	0	33
other	0	0	9	0	9
(none)	31	20	684	8	743
total	355	340	11828	64	12587

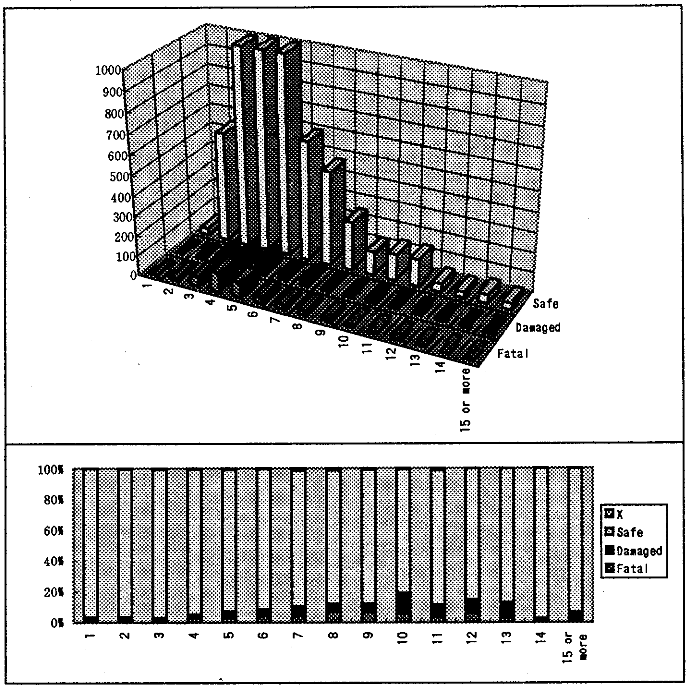


Fig. 2.2.3.6 story and assessment (RC structure)

story	type of structure						total
	RC	SRC	concrete block	pracast concrete	mixed	(none)	
1	15	0	3	11	1	2	32
2	475	1	26	36	8	24	570
3	3172	13	3	27	24	188	3427
4	3200	10	0	30	29	217	3486
5	2031	20	0	60	9	124	2244
6	590	8	0	1	4	48	651
7	450	30	0	1	7	43	531
8	180	76	0	0	6	18	280
9	71	54	0	1	5	5	136
10	82	68	0	0	8	8	166
11	58	82	0	3	4	7	154
12	13	29	0	0	4	2	48
13	13	14	0	0	0	5	32
14	16	23	0	0	4	2	45
15 or more	9	24	0	0	0	0	33
other	8	0	0	0	0	1	9
(none)	569	13	4	12	7	138	743
total	10952	465	36	182	120	832	12587

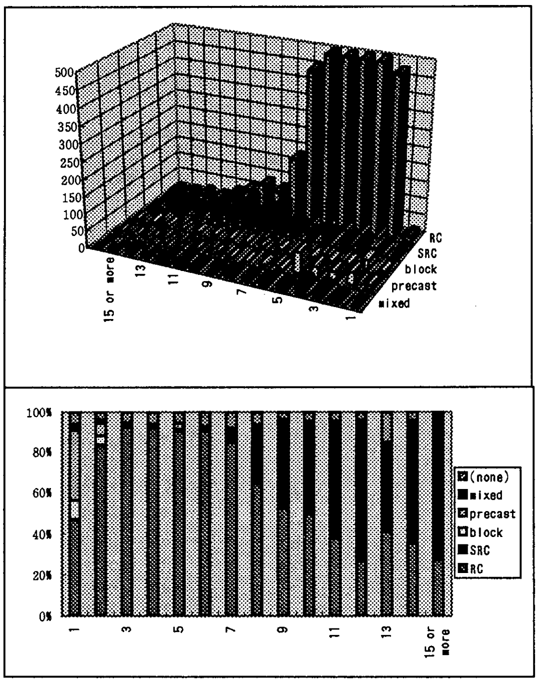


Fig. 2.2.3.7 type and story (RC structure)

	form of structure					
story	Rahmen	wall	mixed	other	(none)	total
1	13	16	1	1	1	32
2	150	371	2	2	45	570
3	1884	1266	33	1	243	3427
4	2230	947	27	1	281	3486
5	1538	484	14	1	207	2244
6	535	38	1	0	77	651
7	445	12	3	1	70	531
8	227	4	2	0	47	280
9	101	5	0	0	30	136
10	133	3	0	1	29	166
11	121	6	0	1	26	154
12	35	0	0	0	13	48
13	20	2	0	1	9	32
14	36	0	0	1	8	45
15 or more	30	0	0	0	3	33
other	5	2	1	0	1	9
(none)	337	226	14	1	165	743
total	7840	3382	98	12	1255	12587

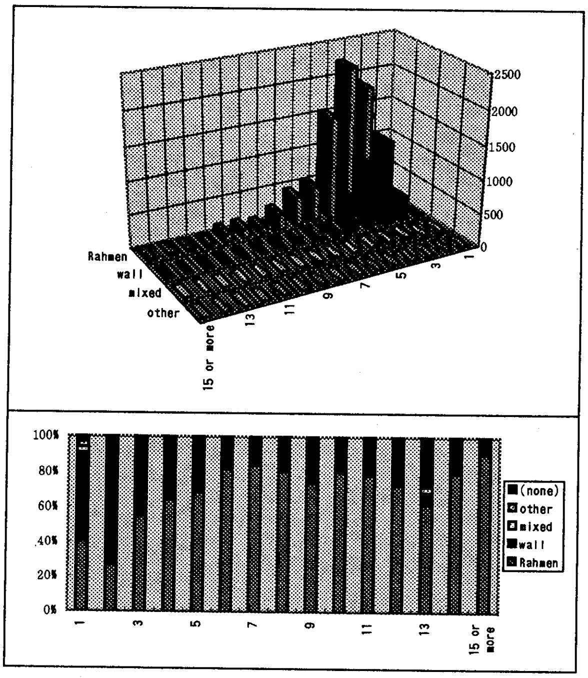


Fig. 2.2.3.8 system and story (RC structure)

c) Damage of the Steel Buildings

The following five items are extracted from the investigation sheet for the S building to carry out macro analysis.

1. **city or town**
2. **usage**
3. **system of structure**
4. **number of stories**
5. **assessment result**

Table 2.2.3.2 shows the result of totalization for each item.

Table 2.2.3.2 totalization of each item (S structure)

area

	city	number	
Hyogo	Akashi	151	(2.6)
	Kobe	**2452**	**(41.6)**
	Ashiya	171	(2.9)
	Nishinomiya	1316	(22.3)
	Takarazuka	597	(10.1)
	Itami	554	(9.4)
	Amagasaki	188	(3.2)
	Kawanishi	294	(5.0)
Awaji	Awaji	5	(0.1)
	Hokutan	10	(0.2)
	Higashiura	4	(0.1)
	Ichinomiya	2	(0.0)
	Tsuna	29	(0.5)
	Sumoto	95	(1.6)
	Seidan	9	(0.2)
(none)		17	(0.3)
total		5894	(100.0)

usage

usage	number	
house	**2786**	**(47.3)**
condominium	1656	(28.1)
office	3	(0.1)
store	13	(0.2)
school	1	(0.0)
mixed	1189	(20.2)
other	107	(1.8)
(none)	139	(2.4)
total	5894	(100.0)

number of stories

stories	number	
1	34	(0.6)
2	**2532**	**(43.0)**
3	2052	(34.8)
4	720	(12.2)
5	247	(4.2)
6	56	(1.0)
7	33	(0.6)
8	22	(0.4)
9	13	(0.2)
10 or more	13	(0.2)
other	172	(2.9)
total	5894	(100.0)

system of structure

system	number	
Rahmen	**3693**	**(62.7)**
brace	1201	(20.4)
mixed	260	(4.4)
other	1	(0.0)
(none)	739	(12.5)
total	5894	(100.0)

assessment result

result	number	
Fatal	644	(10.9)
Danger	981	(16.6)
Safe	**4248**	**(72.1)**
X	21	(0.4)
total	5894	(100.0)

The R_s of the entire S building is 27.6% and it is higher than that of the RC. The ratio of each result of risk assessment is different from RC and becomes sequentially large in order of "Safe", "Danger" and "Fatal".

cross totalization (S structure)

The risk assessment result of each city (Fig. 2.2.3.9) is a little different from the result of the RC and in general, the rate rises in the Ashiya-city for instance. Though in Awaji area R_s seems to be irregular, but it may come from that there were few buildings. The R_s of each system of structure (Fig. 2.2.3.10) rises in order of the mixed structure, the Rahmen structure and the brace structure. A further examination must be required because the mixed structure is rather less at high story buildings (Fig. 2.2.3.11, Fig. 2.2.3.12).

The R_s of each number of stories (Fig. 2.2.3.11) has two characteristics: 1) it is large at a one-story building and 2) increases from two-story one towards high-rise one. But R_s is highest at six- and seven-story buildings because the ratio of ''Damaged'' buildings decreases rapidly there. Moreover, it is interesting that a big difference of R_s is seen between two- and three-story buildings though the number of the building does not change so much. The reason will be related that there were especially a lot of three-story buildings in Kobe city where R_s was high. See Fig. 2.2.3.9 and Fig. 2.2.3.13.

area	city	assessment result Fatal	Damaged	Safe	X	total
Kobe	Akashi	6	57	88	0	151
	Kobe	394	497	1547	14	2452
	Ashiya	33	32	101	5	171
	Nishinomiya	114	200	1000	2	1316
	Takarazuka	68	39	489	0	596
	Itami	3	26	525	0	554
	Amagasaki	20	94	74	0	188
	Kawanishi	3	27	265	0	295
Awaji	Awaji	0	1	4	0	5
	Hokutan	0	1	9	0	10
	Higashiura	0	1	3	0	4
	Ichinomiya	1	0	1	0	2
	Tshna	1	4	24	0	29
	Sumoto	0	0	95	0	95
	Seidan	0	0	9	0	9
(none)		1	2	14	0	17
total		644	981	4248	21	5894

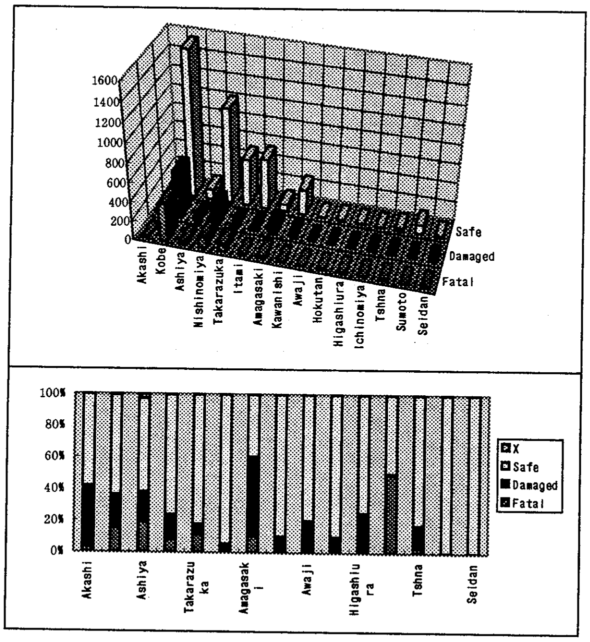
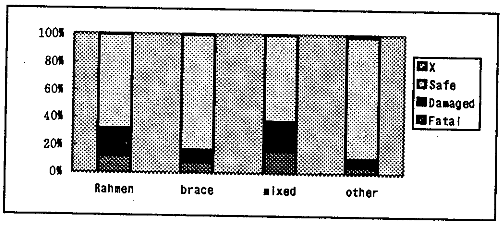


Fig. 2.2.3.9 city and assessment(S structure)

form	assessment result Fatal	Damaged	Safe	X	total
Rahmen	435	712	2491	8	3646
brace	89	103	962	3	1157
mixed	56	75	220	0	351
other	14	17	255	3	289
(none)	50	74	320	7	451
total	644	981	4248	21	5894



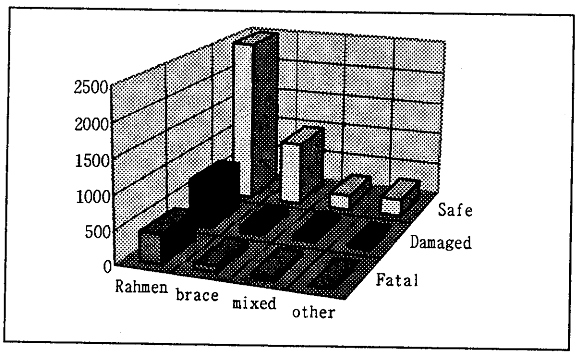
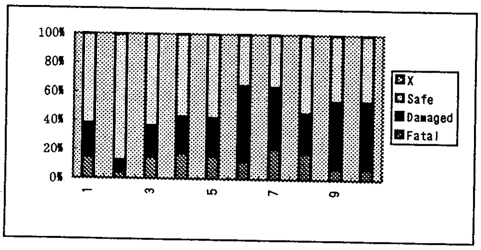


Fig. 2.2.3.10 system and assessment(S structure)

story	assessment result Fatal	Damaged	Safe	X	total
1	5	8	21	0	34
2	122	198	2199	13	2532
3	304	438	1303	7	2052
4	126	181	413	0	720
5	39	65	143	0	247
6	7	29	20	0	56
7	7	14	12	0	33
8	4	6	12	0	22
9	1	6	6	0	13
10 or more	1	6	6	0	13
(none)	28	30	113	1	172
total	644	981	4248	21	5894



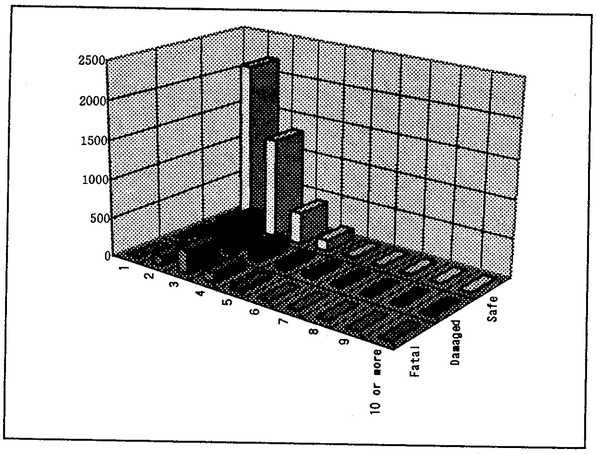
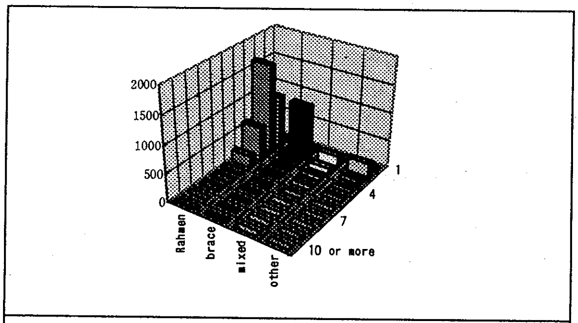


Fig. 2.2.3.11 story and assessment(S structure)

story	form of structure Rahmen	brace	mixed	other	(none)	total
1	15	9	6	1	3	34
2	948	941	192	255	196	2532
3	1643	140	113	12	144	2052
4	624	25	25	3	43	720
5	223	10	4	0	10	247
6	50	0	2	0	4	56
7	30	0	1	0	2	33
8	20	0	0	0	2	22
9	13	0	0	0	0	13
10 or more	11	0	1	0	1	13
(none)	69	32	7	18	46	172
total	3646	1157	351	289	451	5894



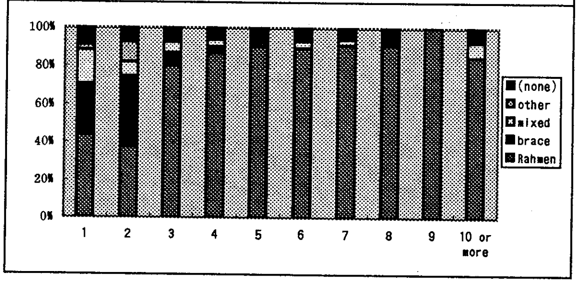


Fig. 2.2.3.12 system and story (S structure)

area	city	number of stories 1	2	3	4	5	6	7	8	9	10	(none)	total
Kobe	Akashi	3	71	50	14	6	3	0	1	1	0	2	151
	Kobe	13	764	947	425	151	29	17	16	10	10	70	2452
	Ashiya	1	74	56	18	11	2	0	0	0	0	9	171
	Nishinomiya	2	542	534	121	48	13	12	3	2	1	38	1316
	Takarazuka	3	414	124	23	4	2	1	1	0	1	23	596
	Itami	0	349	149	41	6	4	2	1	0	0	2	554
	Amagasaki	0	42	83	47	8	1	1	0	0	1	5	188
	Kawanishi	2	160	77	26	11	2	0	0	0	0	17	295
Awaji	Awaji	0	3	1	1	0	0	0	0	0	0	0	5
	Hokutan	5	2	1	0	1	0	0	0	0	0	1	10
	Higashiura	0	4	0	0	0	0	0	0	0	0	0	4
	Ichinomiya	2	0	0	0	0	0	0	0	0	0	0	2
	Tsuna	1	20	7	0	0	0	0	0	0	0	1	29
	Sumoto	0	80	12	0	0	0	0	0	0	0	3	95
	Seidan	0	6	2	1	0	0	0	0	0	0	0	9
(none)		2	1	9	3	1	0	0	0	0	0	1	17
	total	34	2532	2052	720	247	56	33	22	13	13	172	5894

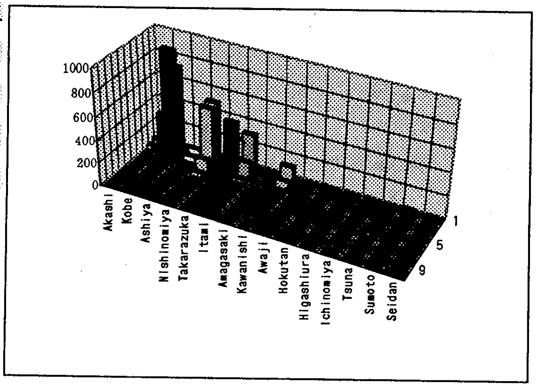


Fig. 2.2.3.13 city and story (S structure)

d) Damage of the Wood Buildings

Four items from the investigation sheet for the wood building are used for macro analysis.

1. **city or town**
2. **usage**
3. **number of stories**
4. **assessment result**

The result of totalization of each item is shown in Table 2.2.3.3.

Table 2.2.3.3 totalization of each item (wood structure)

area

	city	number
Hyogo	Akashi	803 (4.6)
	Kobe	**7919 (45.2)**
	Ashiya	248 (1.4)
	Nishinomiya	2031 (11.6)
	Takarazuka	927 (5.3)
	Itami	623 (3.6)
	Amagasaki	2714 (15.5)
	Kawanishi	1926 (11.0)
Awaji	Awaji	5 (0.0)
	Hokutan	13 (0.1)
	Higashiura	9 (0.1)
	Ichinomiya	4 (0.0)
	Tsuna	108 (0.6)
	Sumoto	148 (0.8)
	Seidan	4 (0.0)
(none)		51 (0.3)
total		17533 (100.0)

usage

usage	number
house	2169 (12.4)
apartment	**12266 (70.0)**
office	2 (0.0)
store	13 (0.0)
store + house	221 (1.3)
school	1 (0.0)
factory	1 (0.0)
hotel	3 (0.0)
combined	1215 (6.9)
other	1112 (6.3)
(none)	530 (3.0)
total	17533 (100.0)

number of stories

story	number
one	820 (4.7)
two	**15326 (87.4)**
mixed	30 (0.2)
other	33 (0.2)
(none)	1324 (7.6)
total	17533 (100.0)

assessment result

assessment	number
Fatal	5243 (29.9)
Damaged	**7056 (40.2)**
Safe	5202 (29.7)
X	32 (0.2)
total	17533 (100.0)

The R_s of entire wood buildings is 70.1% and considerably high compared with the RC and S buildings. The largest content of risk assessment result is ''Damaged''. Then ''Fatal'' and ''Safe'' comes in order. Ratio of the wood building becomes especially high in Amagasaki and Kawanishi-city compared with the other types of building.

cross totalization (wood structure)

Though there were few samples in Awaji area. it seems that R_s decreases in western Hyogo and southern Awaji (see Fig. 2.2.3.14), and the ratio of ''Damaged'' has not so changed while ''Fatal'' decreases. However, the ratio of ''Fatal'' rises in the Ashiya-city. It can be said from Fig. 2.2.3.15 that R_s is not varied with stories.

		assessment result				
area	city	Fatal	Damaged	Safe	X	total
Kobe	Akashi	84	572	147	0	803
	Kobe	3312	2624	1973	10	7919
	Ashiya	132	47	53	16	248
	Nishinomiys	840	596	589	6	2031
	Takarazuka	148	342	437	0	927
	Itami	50	221	352	0	623
	Amagasaki	519	1923	272	0	2714
	Kawanishi	95	639	1192	0	1926
Awaji	Awaji	1	0	4	0	5
	Hokutan	9	4	0	0	13
	Higashiura	1	6	2	0	9
	Ichinomiya	3	0	1	0	4
	Tsuna	25	31	52	0	108
	Sumoto	2	27	119	0	148
	Seidan	1	1	2	0	4
(none)		21	23	7	0	51
	total	5243	7056	5202	32	17533

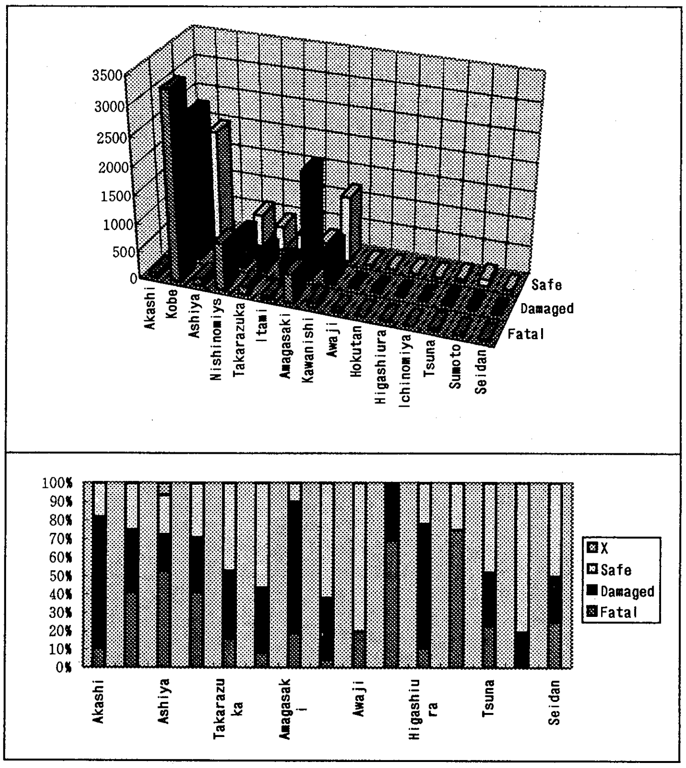
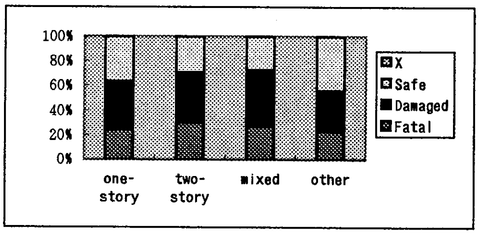


Fig. 2.2.3.14 city and assessment (wood structure)

	assessment result				
story	Fatal	Damaged	Safe	X	Total
one-story	197	314	298	0	809
two-story	4528	6166	4517	12	15223
mixed	38	66	40	0	144
other	26	36	50	0	112
(none)	454	474	297	20	1245
total	5243	7056	5202	32	17533



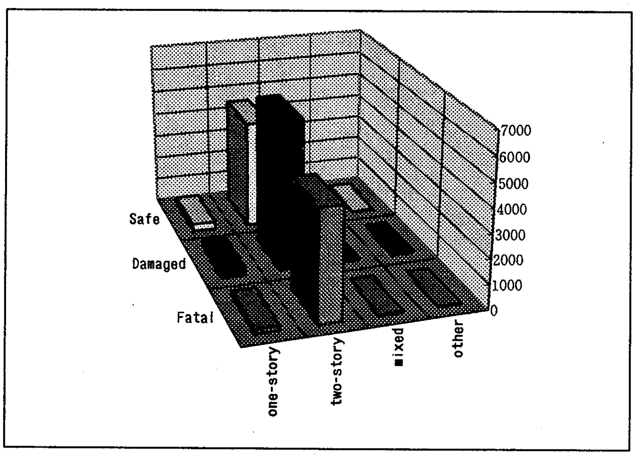


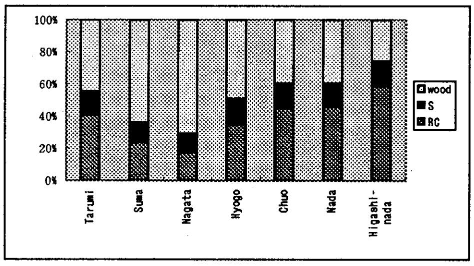
Fig. 2.2.3.15 story and assessment (wood structure)

(3) Analysis for Kobe city

a) General

The object of the Emergency Risk Assessment in the Kobe city was for six wards; those are Tarumi, Suma, Nagata, Hyogo, Chuo, Nada and Higashi-nada in order from west. Among the totalization about Kobe city, the number of buildings according to the structure and the assessment for each ward are shown in Fig. 2.2.3.16 and Fig. 2.2.3.17.

	structure			
ward	RC	S	wood	total
Tarumi	820	286	899	2005
Suma	379	198	1024	1601
Nagata	435	277	1758	2470
Hyogo	788	361	1116	2265
Chuo	1308	434	1152	2894
Nada	1394	445	1199	3038
Higashi-nada	1739	451	768	2958
(none)	0	0	3	3
total	6863	2452	7919	17234



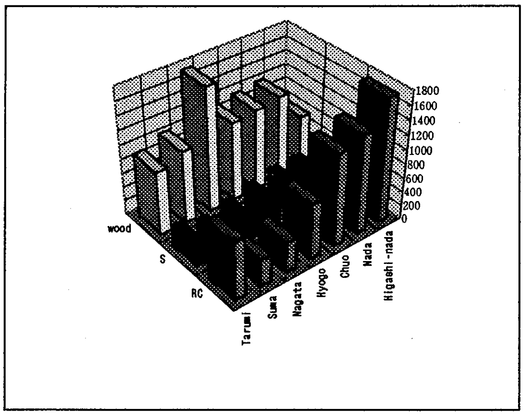
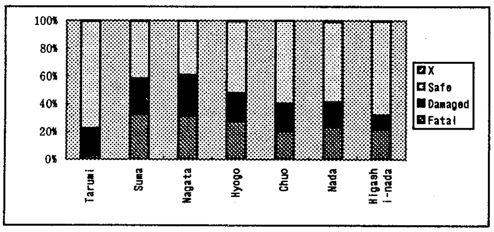


Fig. 2.2.3.16 number of buildings (Kobe city)

	assessment result				
ward	Fatal	Damaged	Safe	X	Total
Tarumi	63	384	1551	7	2005
Suma	525	407	664	5	1601
Nagata	774	726	969	1	2470
Hyogo	617	463	1179	6	2265
Chuo	612	554	1727	1	2894
Nada	731	520	1763	24	3038
Higashi-nada	656	290	1994	18	2958
(none)	2	1	0	0	3
total	3980	3345	9847	62	17234



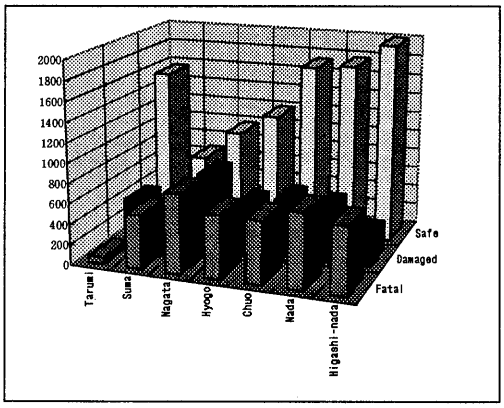


Fig. 2.2.3.17 assessment result (Kobe city)

Around Nagata, the ratio of RC building is low and the one for wood building is high. The ratio of S building might not depend on the district and be almost constant. In Suma and Nagata the R_s is higher than peripheral wards contrary to the distribution of the structure. The ''Fatal'' buildings decrease especially in Tarumi. As the whole analysis, the tendency that the number of ''Fatal'' buildings exceeds to ''Damaged'' ones is also seen.

b) Damage of the Reinforced Concrete Buildings

Table 2.2.3.4 totalization of each item (Kobe city: RC)

area

ward	number
Tarumi	820 (11.9)
Suma	379 (5.5)
Nagata	435 (6.3)
Hyogo	788 (11.5)
Chuo	1308 (19.1)
Nada	1394 (20.3)
Higashi-nada	**1739 (25.3)**
total	6863 (100.0)

usage

usage	number
house	194 (2.8)
condominium	**4620 (67.3)**
office	19 (0.3)
store	15 (0.2)
hospital	1 (0.0)
factory	1 (0.0)
mixed	1648 (24.0)
other	62 (0.9)
(none)	303 (4.4)
total	6863 (100.0)

number of stories

stories	number
1	7 (0.1)
2	214 (3.1)
3	1328 (19.4)
4	**2103 (30.6)**
5	1423 (20.7)
6	409 (6.0)
7	333 (4.9)
8	202 (2.9)
9	100 (1.5)
10	120 (1.7)
11	103 (1.5)
12	26 (0.4)
13	17 (0.2)
14	34 (0.5)
15or more	21 (0.3)
other	421 (6.1)
total	6863 (100.0)

type of structure

type	number
RC	**5877 (85.6)**
SRC	342 (5.0)
concrete block	15 (0.2)
precast concrete	54 (0.8)
mixed	84 (1.2)
(none)	491 (7.2)
total	6863 (100.0)

system of structure

system	number
Rahmen	**4516 (65.8)**
wall	1516 (22.1)
mixed	47 (0.7)
others	3 (0.0)
(none)	781 (11.4)
total	6863 (100.0)

assessment result

assessment	number
Fatal	274 (4.0)
Damaged	224 (3.3)
Safe	**6327 (92.2)**
X	38 (0.6)
total	6863 (100.0)

The R_s of the RC building in Kobe city is 7.3% and higher than that of whole area (5.5%). The RC building exists more in eastern.

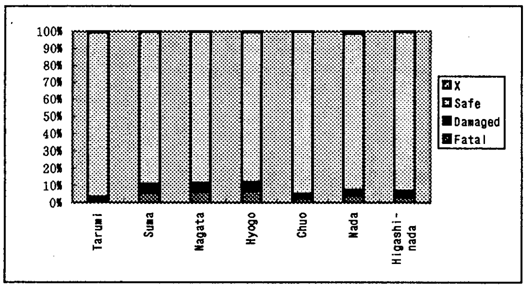
cross totalization (Kobe city: RC)

When the risk assessment result is examined to every ward, the R_s is high at Suma, Nagata, and Hyogo in order (Fig. 2.2.3.18). However, in all the wards R_s remains within low range and most of the RC buildings are ''Safe''. The R_s of each type of structure is almost the same level as result for the whole area (Fig. 2.2.3.4) excluding the concrete block structure with few number of samples (Fig. 2.2.3.19). But in Kobe city R_s is slightly high.

Totalization of the risk assessment result for each system of structure is also the same as the one for whole area (Fig. 2.2.3.20). The R_s of the mixed structure is high though the number of samples is few.

Comparing Fig. 2.2.3.21 for Kobe area with Fig. 2.2.3.6 for whole area, the ratio of ''Damaged'' building in Kobe is higher about the low-rise buildings and that of ''Fatal'' buildings in Kobe is higher about high-rise buildings. The largest content of stories of each type of structure is 4 about RC (32.8%), 8 about SRC (17.3%), 2 about concrete block (93.3%), 5 about precast concrete (50.0%) and 4 about mixed structure (23.8%). See Fig. 2.2.3.22. In the case of system of structure the largest is 4 about all systems i.e. Rahmen, wall and mixed structure (and also 3 about mixed structure). See Fig. 2.2.3.23.

	assessment result				
ward	Fatal	Damaged	Safe	X	Total
Tarumi	12	13	789	6	820
Suma	24	17	336	2	379
Nagata	28	21	386	0	435
Hyogo	57	36	694	1	788
Chuo	38	29	1241	0	1308
Nada	59	45	1270	20	1394
Higashi-nada	56	63	1611	9	1739
total	274	224	6327	38	6863



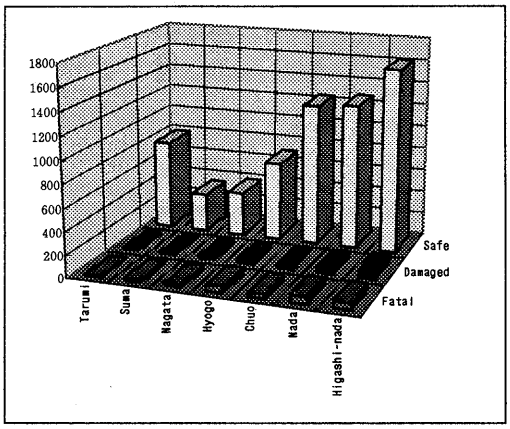
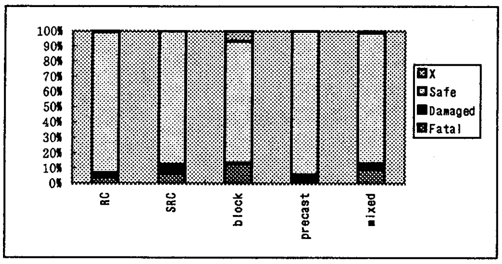


Fig. 2.2.3.18 ward and assessment(Kobe city: RC)

	assessment result				
type	Fatal	Damaged	Safe	X	total
RC	220	173	5454	30	5877
SRC	21	22	299	0	342
concrete block	2	0	12	1	15
precast concrete	1	2	51	0	54
mixed	8	3	72	1	84
(none)	22	24	439	6	491
total	274	224	6327	38	6863



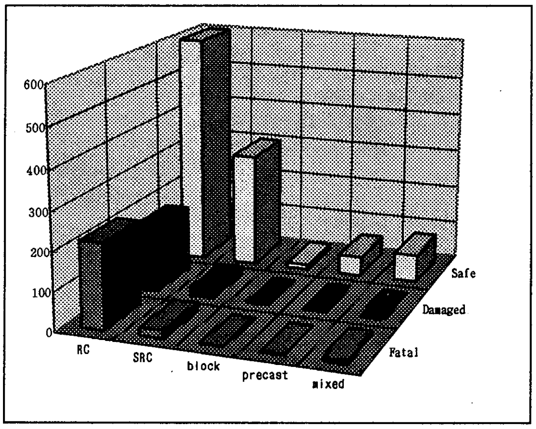
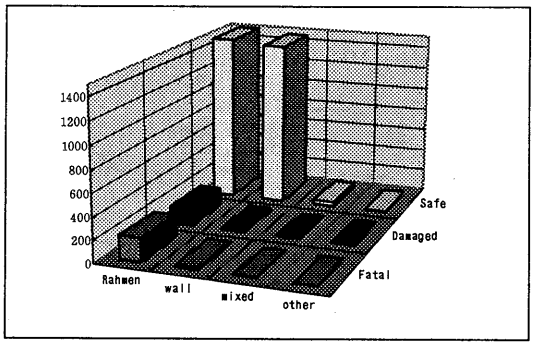


Fig. 2.2.3.19 type and assessment (Kobe city: RC)

	assessment result				
form	Fatal	Damaged	Safe	X	total
Rahmen	211	164	4117	24	4516
wall	20	24	1468	4	1516
mixed	5	3	39	0	47
other	1	0	2	0	3
(none)	37	33	701	10	781
total	274	224	6327	38	6863



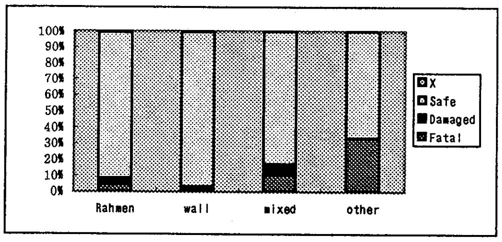


Fig. 2.2.3.20 system and assessment (Kobe city: RC)

	assessment result				
story	Fatal	Damaged	Safe	X	total
1	0	1	6	0	7
2	8	6	199	1	214
3	36	24	1262	6	1328
4	75	51	1971	6	2103
5	55	51	1307	10	1423
6	23	14	371	1	409
7	15	20	294	4	333
8	16	10	175	1	202
9	6	6	87	1	100
10	9	15	96	0	120
11	5	8	88	2	103
12	3	2	21	0	26
13	1	0	16	0	17
14	0	1	33	0	34
15 or more	0	1	20	0	21
other	0	0	3	0	3
(none)	22	14	378	6	420
total	274	224	6327	38	6863

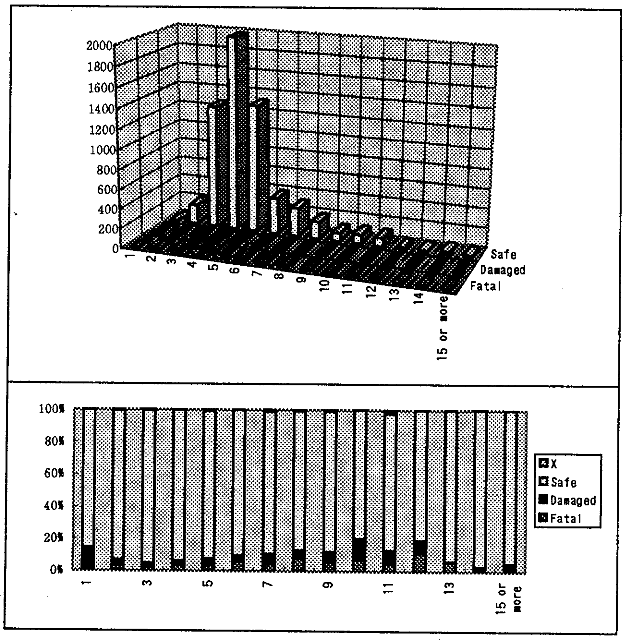


Fig. 2.2.3.21 story and assessment (Kobe city: RC)

	type of structure						
story	RC	SRC	concrete block	precast concrete	mixed	(none)	total
1	7	0	0	0	0	0	7
2	177	1	14	6	5	11	214
3	1218	4	1	11	15	79	1328
4	1929	10	0	6	20	138	2103
5	1304	13	0	27	6	73	1423
6	362	6	0	0	2	39	409
7	275	23	0	0	5	30	333
8	121	59	0	0	5	17	202
9	46	45	0	0	5	4	100
10	53	52	0	0	8	7	120
11	38	58	0	0	2	5	103
12	6	16	0	0	2	2	26
13	5	11	0	0	0	1	17
14	11	18	0	0	4	1	34
15 or more	6	15	0	0	0	0	21
other	2	0	0	0	0	1	3
(none)	317	11	0	4	5	83	420
total	5877	342	15	54	84	491	6863

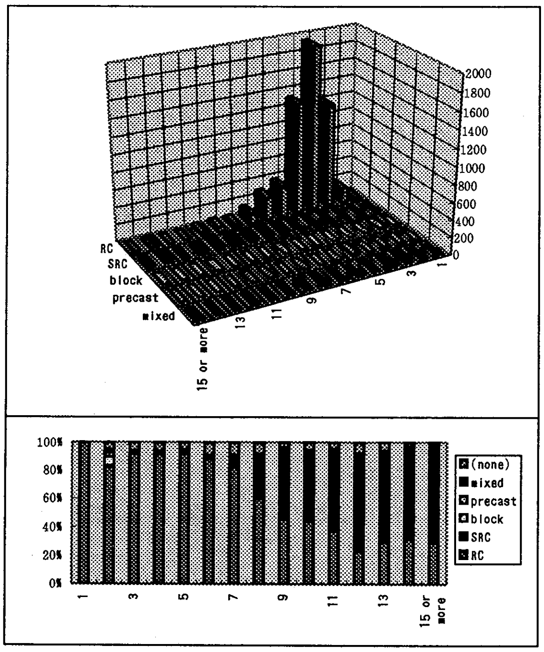


Fig. 2.2.3.22 type and story (Kobe city: RC)

	form of structure					
story	Rahmen	wall	mixed	other	(none)	total
1	5	1	1	0	0	7
2	51	142	1	1	19	214
3	748	455	13	0	112	1328
4	1414	492	13	0	184	2103
5	1008	264	10	0	141	1423
6	328	27	1	0	53	409
7	278	5	1	1	48	333
8	160	4	2	0	36	202
9	73	3	0	0	24	100
10	92	3	0	1	24	120
11	85	1	0	0	17	103
12	16	0	0	0	10	26
13	10	0	0	0	7	17
14	28	0	0	0	6	34
15 or more	21	0	0	0	0	16
other	1	1	0	0	1	3
(none)	199	118	5	0	98	420
total	4516	1516	47	3	781	6863

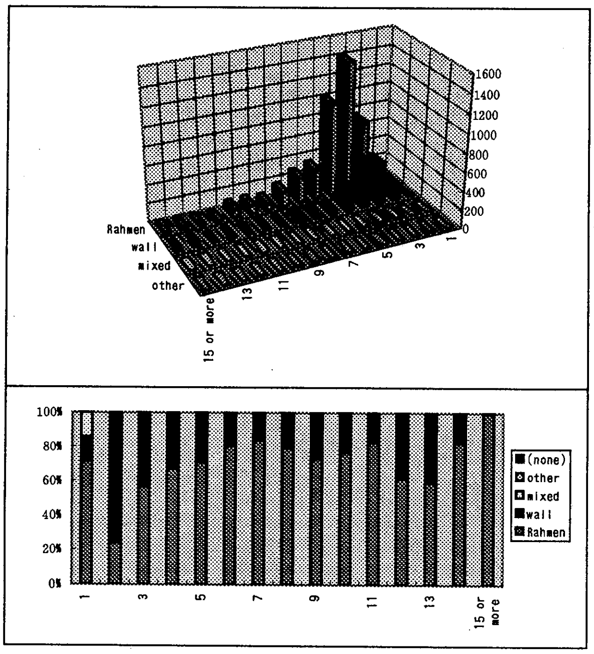


Fig. 2.2.3.23 system and story (Kobe city: RC)

c) Damage of the Steel Buildings

Table 2.2.3.5 totalization of each item (Kobe city: S)

area

ward	number
Tarumi	286 (11.7)
Suma	198 (8.1)
Nagata	277 (11.3)
Hyogo	361 (14.7)
Chuo	434 (17.7)
Nada	445 (18.1)
Higashi-nada	**451 (18.4)**
total	2452 (100.0)

usage

usage	number
house	**1093 (44.6)**
condominium	628 (25.6)
store	6 (0.2)
mixed	639 (26.1)
other	34 (1.4)
(none)	52 (2.1)
total	2452 (100.0)

number of stories

stories	number
1	13 (0.5)
2	764 (31.2)
3	**947 (38.6)**
4	425 (17.3)
5	151 (6.2)
6	29 (1.2)
7	17 (0.7)
8	16 (0.7)
9	10 (0.4)
10or more	10 (0.4)
other	70 (2.9)
total	2452 (100.0)

system of structure

system	number
Rahmen	**1678 (68.4)**
brace	395 (16.1)
mixed	134 (5.5)
(none)	245 (10.0)
total	2452 (100.0)

assessment result

assessment	number
Fatal	394 (16.1)
Damaged	497 (20.3)
Safe	**1547 (63.1)**
X	14 (0.6)
total	2452 (100.0)

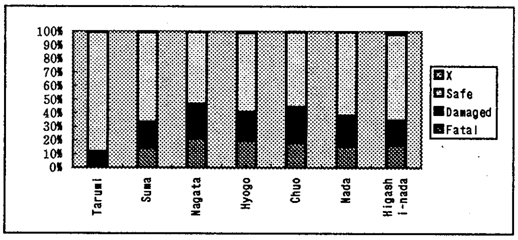
The R_s of S structure in Kobe city is 36.3% and higher than 27.6% for the whole area.

cross totalization (Kobe city: S)

The risk assessment result of each ward (Fig. 2.2.3.24) shows that the ratio of ''Fatal'' structure is high in Nagata. The R_s is around 40% excluding Tarumi where the number of ''Fatal'' and ''Damaged'' buildings are especially little.

Distribution of the risk assessment of each stories has two peaks at story 3 and 7 (excluding story 1 because of few samples). The ratio of ''Damaged'' structure changes at story 6 (Fig. 2.2.3.25) . The largest content of stories among each system of structure is 3 about Rahmen (44.9%), 2 about brace (78.7%) and 3 about mixed structure (41.0%). Most of the buildings more than 3 stories are the Rahmen structure. (Fig. 2.2.3.26)

ward	assessment result Fatal	Damaged	Safe	X	total
Tarumi	6	27	252	1	286
Suma	29	36	132	1	198
Nagata	60	69	148	0	277
Hyogo	73	73	212	3	361
Chuo	79	114	241	0	434
Nada	72	97	276	0	445
Higashi-nada	75	81	286	9	451
total	394	497	1547	14	2452



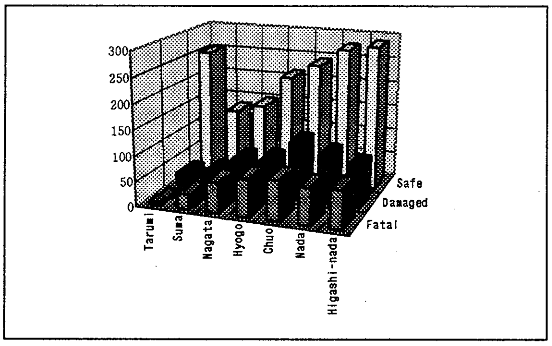
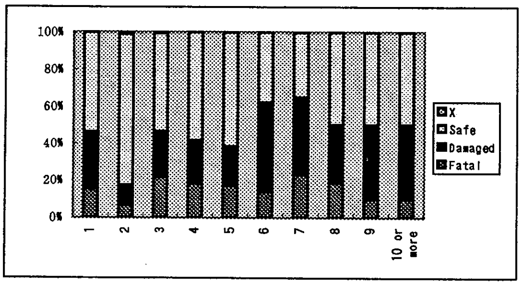


Fig. 2.2.3.24 ward and assessment (Kobe city: S)

story	assessment result Fatal	Damaged	Safe	X	total
1	2	4	7	0	13
2	50	81	625	8	764
3	206	232	503	6	947
4	78	99	248	0	425
5	26	32	93	0	151
6	4	14	11	0	29
7	4	7	6	0	17
8	3	5	8	0	16
9	1	4	5	0	10
10 or more	1	4	5	0	10
(none)	19	15	36	0	70
total	394	497	1547	14	2452



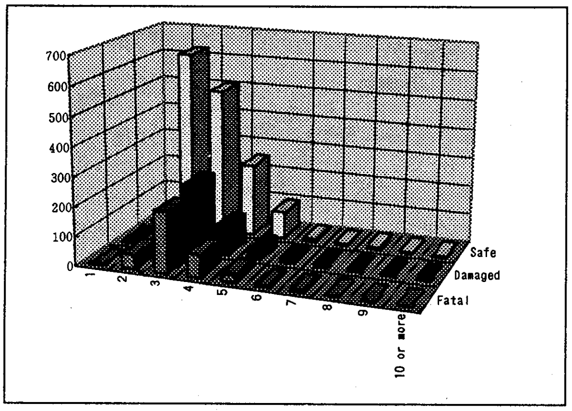
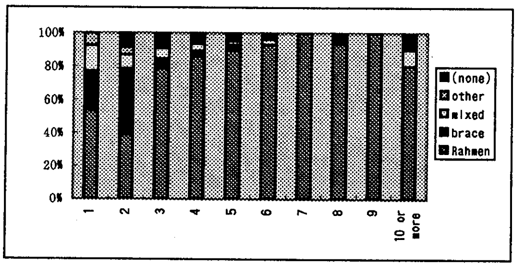


Fig. 2.2.3.25 story and assessment (Kobe city: S)

	form of structure					
story	Rahmen	brace	mixed	other	(none)	total
1	7	3	2	1	0	13
2	297	301	66	34	66	764
3	745	53	64	8	77	947
4	366	12	19	0	28	425
5	135	5	4	0	7	151
6	27	0	1	0	1	29
7	17	0	0	0	0	17
8	15	0	0	0	1	16
9	10	0	0	0	0	10
10 or more	8	0	1	0	1	10
(none)	35	9	5	3	18	70
total	1662	383	162	46	199	2452



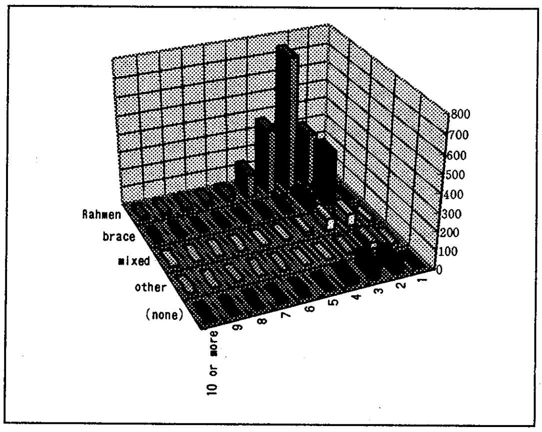


Fig. 2.2.3.26 system and story (Kobe city: S)

d) Damage of the Wood Buildings

Table 2.2.3.6 totalization of each item (Kobe city: wood)

area

ward	number
Tarumi	899 (11.4)
Suma	1024 (12.9)
Nagata	**1758 (22.2)**
Hyogo	1116 (14.1)
Chuo	1152 (14.5)
Nada	1199 (15.1)
Higashi-nada	768 (9.7)
(null)	3 (0.0)
total	7919 (100.0)

usage

usage	number
house	856 (10.8)
apartment	**5785 (73.1)**
office	1 (0.0)
store	8 (0.1)
store + house	77 (1.0)
factory	1 (0.0)
combined	583 (7.4)
other	394 (5.0)
(none)	214 (2.7)
total	7919 (100.0)

number of stories

number of stories	number
one-story	321 (4.1)
two-story	**6965 (88.0)**
mixed	14 (0.2)
other	27 (0.3)
(none)	592 (7.5)
total	7919 (100.0)

assessment result

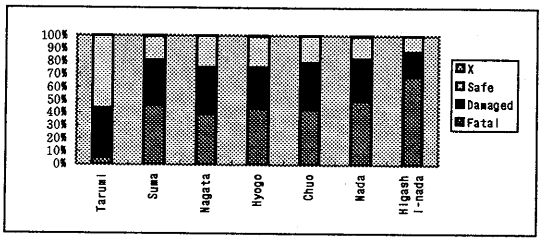
assessment	number
Fatal	**3312 (41.8)**
Damaged	2624 (33.1)
Safe	1973 (24.9)
X	10 (0.1)
total	7919 (100.0)

The R_s of wood buildings in Kobe city rises 74.9% more than 70.1% for the whole area.

cross totalization (Kobe city: wood)

In Fig. 2.2.3.27 the R_s of each ward increases from Nagata to Higashi-nada according to the distance from the epicenter (excluding Tarumi) contrary to the result of RC and S building. It is interesting that the ratio of ''Fatal'' building increases especially. The R_s of each scale of building (Fig. 2.2.3.28), R_s lowers in order of one-story, two-story, and the mixed building.

ward	assessment result				total
	Fatal	Damaged	Safe	X	
Tarumi	45	344	510	0	899
Suma	472	354	196	2	1024
Nagata	686	636	435	1	1758
Hyogo	487	354	273	2	1116
Chuo	495	411	245	1	1152
Nada	600	378	217	4	1199
Higashi-nada	525	146	97	0	768
(none)	2	1	0	0	3
total	3312	2624	1973	10	7919



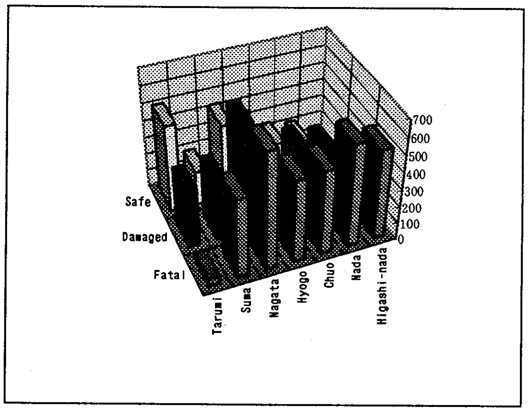
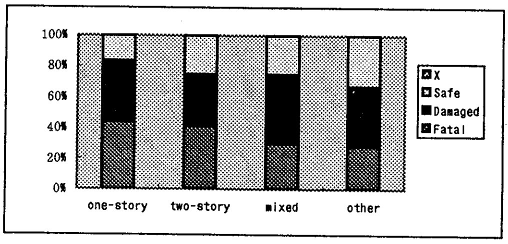


Fig. 2.2.3.27 ward and assessment (Kobe city: wood)

story	assessment result				total
	Fatal	Damaged	Safe	X	
one-story	138	124	52	0	314
two-story	2857	2270	1774	2	6903
mixed	25	37	21	0	83
other	21	29	25	0	75
(none)	271	164	101	8	544
total	3312	2624	1973	10	7919



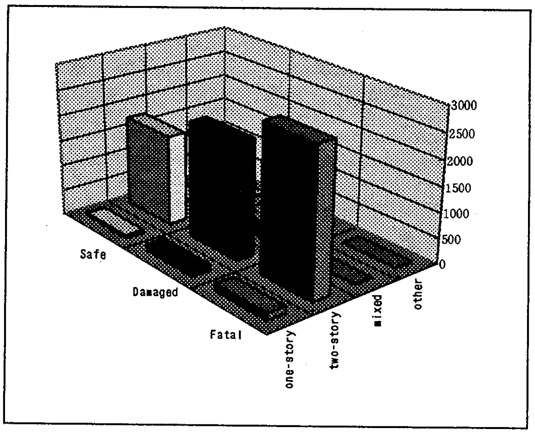


Fig. 2.2.3.28 story and assessment (Kobe city: wood)