BUILDING CODES AND TRADEOFFS FOR EARTHQUAKE RISK REDUCTION:DISASTER MANAGEMENT FOR HOUSING

Norio MAKI[1] And Haruo HAYASHI[2]

SUMMARY

This paper addresses disaster management for housing. The countermeasures against housing damage after the Hanshin-Awaji Earthquake Disaster were first classified to Response, Recovery, Preparedness and Mitigation. This paper focuses on Mitigation, which is essential countermeasure among these four countermeasures. The success and limitations of building codes as mitigation countermeasure is clarified by case study of Nishinomiya City. The variables of measurement for mitigation are also examined. The following facts were acquired in this paper: (1) The building codes are effective to reduce the risk of the damage. (2) In engineered structure, the amendment in 1970 was effective to reduce the rate of the totally collapse and the amendment in 1980 to reduce the rate of the half collapse. (3) There are many problems about management of the building codes in Japan. (4) There are 1,420 buildings that do not conform to present building codes. (5) Nonconformity to the zoning codes, not only the structural and safety codes, becomes the problem in disaster management for housing, especially in Recovery. (6) The retrofit of the building is conducted mainly for the public building. (7) Not only the building codes but also the defect liability and insurance is effective for mitigation countermeasure.

INTRODUCTION

Housing was the most severe issue in disaster management of the Hanshin-Awaji Earthquake Disaster. The earthquake destroyed about 250, 000 residential buildings (total or half collapse) and killed 6, 430 people. Human casualties were mainly caused by the collapse of wooden housing. (e.g., Yamazaki,1999) In Hyogo and Osaka Prefectures, 49, 681 public temporary houses were supplied for 5 years. The three-year reconstruction plan of 125, 000 units of housing was established including 38,600 public housing units. The Building Standard Law was amended in 1998 following the lessons learned from the Hanshin-Awaji Earthquake Disaster.

There are two objectives for disaster management. One is the prevention of damage and the other is the reduction of damage; the former is termed risk management and the latter, crisis management. From the viewpoint of the time period, there are two phases, post and pre-disaster. Combining objectives and phases, disaster management consists of Mitigation, Preparedness, Response and Recovery. (Hayashi, 1995) The disaster management circle is shown in **Figure 1**.

This paper addresses disaster management of housing. The countermeasures against housing damage after the Hanshin-Awaji Earthquake Disaster were first classified according to the above mentioned four countermeasures. Among these four countermeasures Mitigation is essential countermeasure. If housing had not collapsed, 6,430 persons would have been killed, and the Response and Recovery would have been easier. The building codes are

essential measurement for Mitigation. The success and limitations of building codes are clarified by the case study of Nishinomiya City and the variables of measurement for Mitigation are also examined.

[1] *The Institute of Physical and Chemical Research (RIKEN), Japan E-mail: maki@miki.riken.go.jp*
[2] *DPRI, Kyoto University and Disaster Mitigation Research Center, Japan E-mail: hayashi@drs.dpri.ac.jp*

DISATER MANAGEMENT FOR HOUSING

Response

Response is defined to the countermeasure for ensuring the life and the safety of residents. (Hayashi, 1999) Regarding housing, the following countermeasures were conducted after the Hanshin-Awaji Earthquake Disaster; 1) Building Damage Assessment and 2) Emergency Shelter Supply. Building damage assessment consists of three parts in a series. 1) Initial Damage Estimation, 2) Building Safety Evaluation and 3) Damage Assessment.

Initial Damage Estimation is the damage assessment for applying the Disaster Relief Law (Saigai Kyujyo Hou). This assessment’s objectives are determined whether this event is a disaster or not. According to this judgement, the disaster response is carried out. The lesson learned from the Hanshin-Awaji Earthquake Disaster in Early Damage Estimation is that there were no effective systems in both management and information. Hyogo Prefecture Government has since developed the “Prefecture Hyogo Overall Emergency management Network for disaster Information eXchange, PHENIX”, which will be used in non-disaster times for exchanging information with residents, and in the event of a disaster, will support prompt and exact emergency countermeasures. In addition to Hyogo prefecture, Kobe and Yokohama Cities have set up an early damage estimation system for quick response.

Building Safety Evaluation is the damage assessment for checking the safety of buildings. It judges whether housing is habitable or not. This assessment was conducted in two phases after the Hanshin-Awaji Earthquake Disaster. The first phase was from 18th to 22nd Jan. 1995 and the notices declaring the building `unusable` were placed on obviously unsafe buildings. The second phase was from 23rd Jan. to 9th Feb.1995, and one of three notices, Green (Safe), Yellow (Limited Use) or Red (Unsafe), was placed on each apartment house. There are two lessons; one is that the residents did not understand the purpose of this assessment. The result of this assessment was misunderstood, in that it was thought to be showing the possibility of repair for each building. Second is that this assessment was conducted too late. According to results of a questionnaire regarding the post-disaster resettlement, the victims needed the information about their housing within one week of the earthquake. (Tatsuki, 1999)

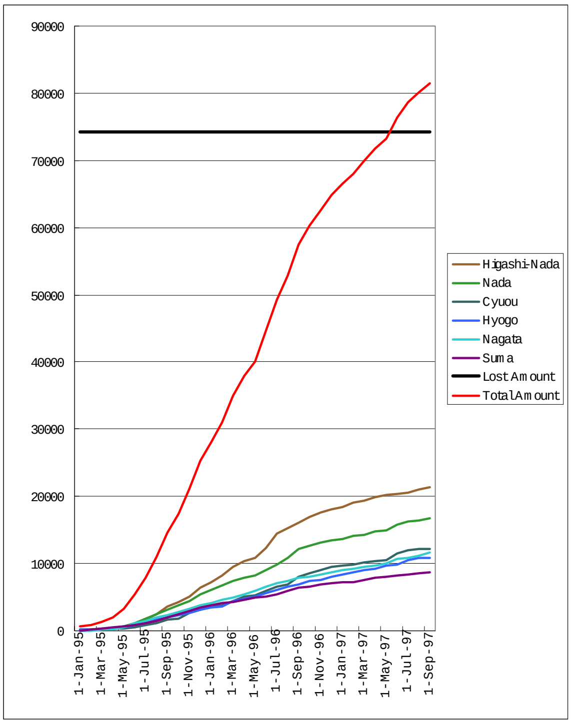
Damage Assessment is the assessment for issuing the Victims Certification, Total Collapse, Half Collapse, Slight Damage and No Damage. Almost all countermeasures concerned with the relief and recovery of normal life were carried out according to this Certification; distribution of donated money, availability of public temporary housing, resettlement to permanent restoration public housing and loans for the restoration of housing, normal life or business. The Victims Individual Recovery Support Law was passed after the Hanshin-Awaji Earthquake, which is the law that allows the payment of one million yen maximum to the victims of a natural disaster. This law states that money will be paid according to the degree of damage to housing, which will be determined by Damage Assessment. The lesson from the Hanshin-Awaji Earthquake Disaster is that this assessment was a key factor in the recovery of normal life and the recovery of housing.

Fig.1 Disaster Management of Housing

Recovery

After the Hanshin-Awaji Earthquake, 49, 861 public temporary housing units were supplied. (Maki, 1996) For the permanent housing, Hyogo Prefecture Government established The Hyogo Prefecture Three-Year Housing Reconstruction Plan in August 1995. This plan made provision for 125, 000 housing units, including 46, 000 private sector housing, 64, 000 public sector housing. **Figure 2** shows the housing supply after the Hanshin-Awaji Earthquake Disaster in Kobe City. It was found that Kobe City lost 74,234 housing units in the affected area, judging from the property tax records. Figure 2 shows that the lost amount of housing units has been recovered in two years. The lessons from the Hanshin-Awaji Earthquake Disaster are that the reconstruction plan underestimated the housing supply offered by the private sector.

Fig.2 Recovery of Housing Units in Kobe City



Preparedness

The Fundamental Disaster Management Law, the basic law for Japanese disaster management enacted in 1961, states that each local government must be equipped with a disaster management manual. This manual is called the Regional Disaster Management Manual (Chiiki Bousai Keikaku). However, this manual mainly deals with Response; the sections on Recovery and Reconstruction are only two or three pages among some hundreds of pages. The lessons from the Hanshin-Awaji Earthquake Disaster are that the recovery and reconstruction measures were or are the most serious issues among the post-event countermeasures. The Tokyo Metropolitan Government established the Pre-event Reconstruction Plan; it consists of two volumes: one is the pre-event reconstruction urban planning and the other is the pre-event life reconstruction plan. The pre-event housing reconstruction plan is included in the pre-event life reconstruction plan, which reflects all the lessons from the Hanshin-Awaji Earthquake Disaster and shows the present attainment in post-earthquake housing management.

Mitigation

Disaster management in Japan had mainly conducted by mitigation countermeasures until the Hanshin-Awaji Earthquake Disaster. The Building Standard Law was the only mitigation countermeasure for housing. The first uniform building code in Japan was established in 1919 and called the Urban Building Law (Shigaich Kenchiku Butsu Hou). In 1923, The Great Kanto Earthquake struck the Kanto area and caused severe damage. This first Japanese building codes was revised in 1924 following the Great Kanto Earthquake. Since the Great Kanto Earthquake, two major earthquakes have affected rural areas but the building codes were not revised. This is because the Urban Building Law was applied only to urban areas; at first, applied only to the six major cities in Japan. The present Building Standard Law was established in 1950. The relation between the major earthquakes and building codes amendments is shown in **Table 1**. Both building codes before WW2 and the present have been revised after almost every major earthquake.

Wooden structure housing killed many people in the Hanshin-Awaji Earthquake Disaster. However, it is during WW2 that building codes were first applied to wooden housing. The application of Urban Building Law was limited to only large-scale structures. The reason why the building codes were applied to wooden housing during WW2 was that the Wartime Wooden Building Regulation was established in 1939 to regulate new construction for shortage of building material during wartime. In 1950, the Building Standard Law was established. In this law, the building codes were officially applied to wooden structure housing.

DOES THE BUILDING STANDARD LAW SUCCEED IN REDUCING DAMAGE

Engineered Structures

Figure 3 shows the damage rate of the steel structures in Nishinomiya City. Gradient is calculated according to

the following formula. (Damage percentage –damage percentage of previous year)^2*SIGN (damage percentage–damage percentage of previous year).
This data was calculated from the property tax records. Registration to the property tax records is conducted at January 1st after building completion. The building codes are applied when an application for the Building Confirmation is submitted. It takes about one year to complete construction after submitting. 1960, 1972 and 1982 should be the year which each amendment becomes effective. The rate of total collapse dramatically changed in 1961, 1963, 1964 and 1970. The year of change does not match the year that the amendment becomes effective. However, the rate both half and total collapse has been becoming significantly lower since 1974 compared from the rate until 1973. It must be the effectiveness of the amendment in 1970. Though the building codes were also amended in 1980, there was no apparent effect from the macroscopic view.

Figure 4 shows the damage rate of the reinforced concrete structures in Nishinomiya City. The rate of total collapse changes in 1962, 1963, 1968, 1969, 1970, 1972, 1973 and 1974. This frequent change is because of the data limitation; the data is consisted from each apartment complex. There is a case in which one apartment complex has 800 buildings. Therefore, one apartment complex can affect the percentage dramatically. The year of change does not match the year that the amendment becomes effective. However, the rate of total collapse has been becoming significantly lower since 1974 compared from the rate until 1973. It must be the effect of the amendment in 1970. Though the building codes were also amended in 1980, there was no apparent effect from the macroscopic view.

Non-Engineered Structure

Figure 5 shows the damage rate of wooden structure in Nishinomiya City. The rate of total collapse changes in 1962, 1970 and 1980. The year of change does not match the year that the amendment becomes effective. However, the rate of total collapse has been becoming significantly lower in 1973 and 1980 compared from the rate of previous years. The change since 1973 must be the effect of the amendment in 1970 and the change since 1980 the effect of the amendment in 1980.

Table 1 Transition of Japanese Building Codes (Created from Ohashi (1993))

Pre-WW2			Establishment of the Urban Building Law	1919
	The Greta Kanto Earthquake	1923		
			Amendment of the Urban Building Law	1924
	Kita Tanba Earthquake	1925		
	Kita Tango Earthquake	1927		
War Time			The Wartime Wooden Building Regulation	1939
	Tottori Earthquake	1943		
			The Wartime Building Standard	1944
	Higashi Nankai Earthquake	1944		
	Mikawa Earthquake	1945		
	Nankai Earthquake	1946		
			The Japanese Building Standard	1947
	Fukui Earthquake	1948		
Post-WW2			The Building Standard Law	1950
			Amendment of the Regulation about Building Standard Law and defection of the structural calculation methods of the Urban Building Law	1959 (enacted from Dec.23, 1959)
	Niigata Earthquake	1964		
	Tokachi-oki Earthquake	1968		
			Amendment of the Regulation about Building Standard Law and RC Structural Calculation Standard of AIJ	1970 (enacted from Jan.1, 1971)
	Izu Ohsima Kinkai Earthquake	1978		
	Miyagi-ken-oki Earthquake	1978		
	Nihonkai Cyubu Earthquake	1983		
			Amendment of the Regulation about Building Standard Law	1980 (enacted from July.1, 1981)
	Kushiro-oki Earthquake	1993		
	Hokkai-do Nansei-oki Earthquake	1993		
	Hyogo-ken Nanbu Earthquake	1995		
			Amendment of the Building Standard Law	1998 (enacted from July.12, 1998)

Fig. 3 Steel Structure

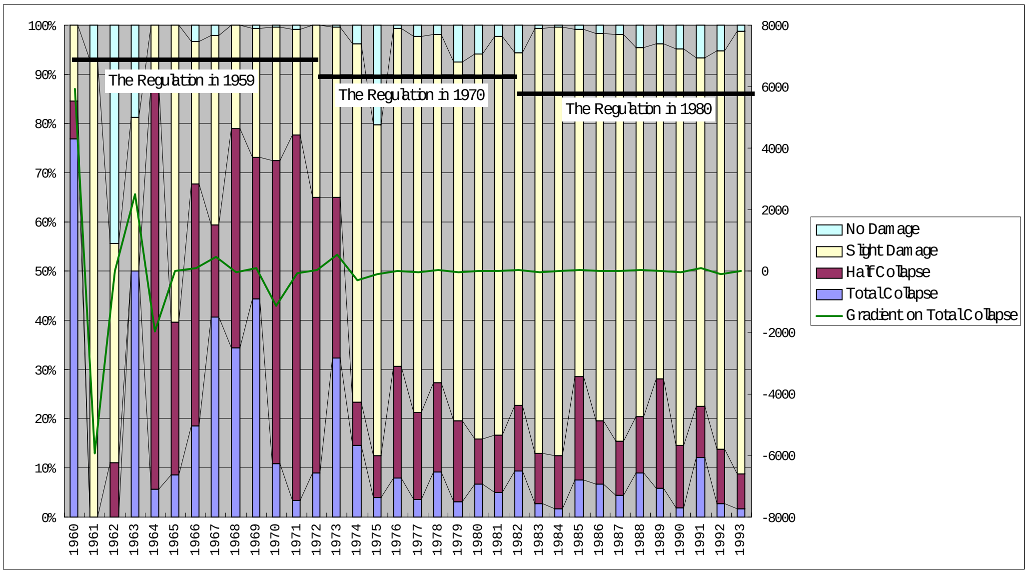


Fig.4 Reinforced Concrete Structure

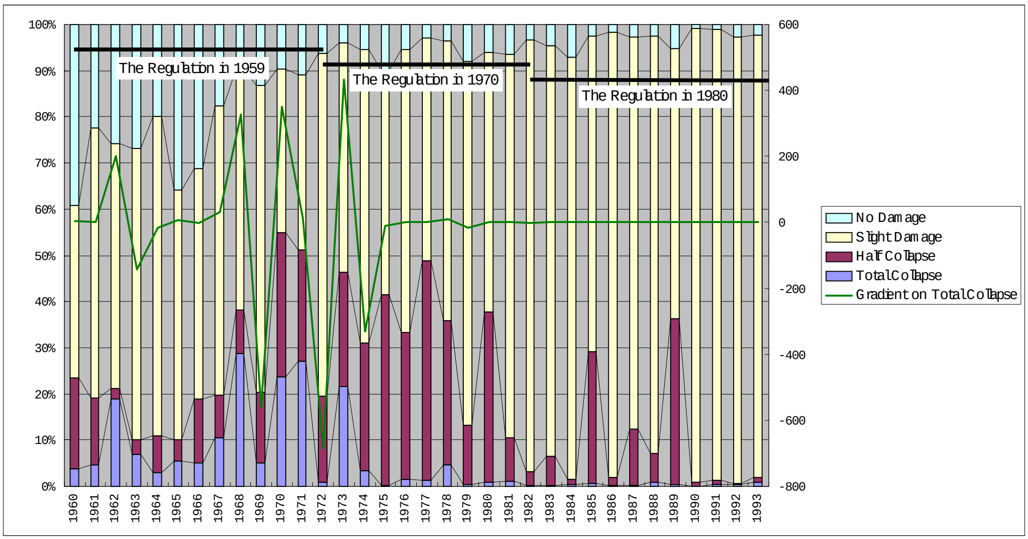
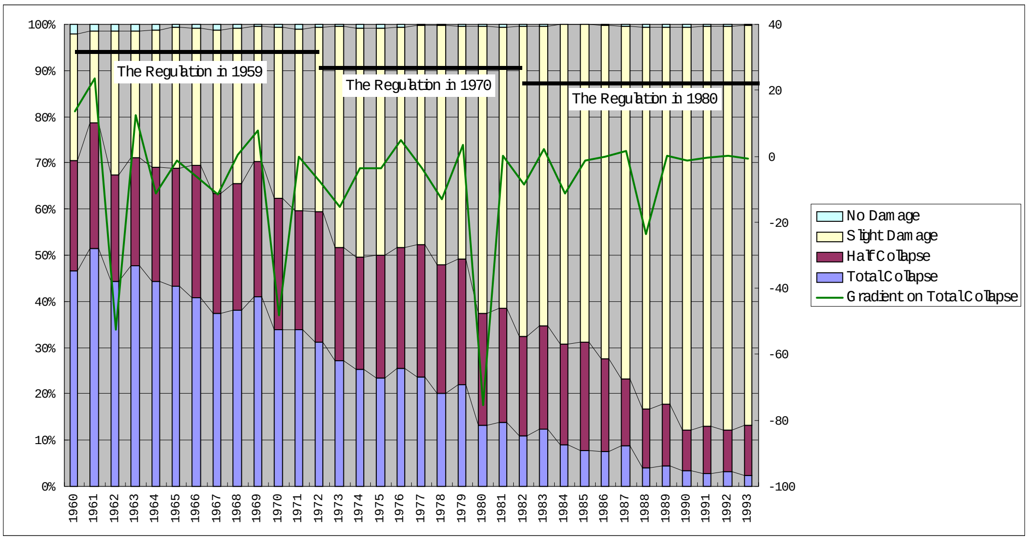


Fig. 5 Wooden Structure



The effectiveness of the Building Standard Law of Japan
Three things can be pointed out from the analysis of this chapter: (1) Amendment of the building codes is effective to reduce the damage. (2) Damage rate of the old building is high. (3) Sensitivity to the amendment is not good. (1) appear to have relation to the structural performance regulated by the building codes, and (2) and (3) to the management system of the building codes.

The structural performance of each amendment is effective. According to the amendment, the damage rate of the building has been reduced without fail. The relation between the building codes amendments and the rate of damage of engineered structure is shown in **Table 2**. The amendment in 1959 appears to weaken the structure of engineered buildings. This is because the calculation method in the Urban Building Law was designed using 1/2 of elastic limit, though the present building is designed using the elastic limit. The amendment in 1970 was effective to reduce the rate of the totally collapse. It can be said that it was effective to save the life of the residents or occupants. The amendment in 1980 was effective to reduce the rate of the half collapse. It can be said that it was effective to save the functions of the building. It is shown in the analysis of this chapter.

The relation between the building codes amendments and the rate of damage of non-engineered structure is shown in **Table 3**. The each amendment can be effect to reduce the damage rate both in half and total collapse. The amendment in 1980 was effect to reduce the rate of the total collapse, effective to save the life of residents.

On the hand, there are many problems about management of the building codes in Japan. The following chapters will deals with the management issues.

WHY THE COLLAPSE RATE OF OLD BUILDING IS HIGH?

The Building Standard Law
Aging is essential answer to above question. In addition to aging, there are two other causes by management system of the building codes in Japan: (1) The Building Standard Law does not be applied retroactively. (2) The Building Standard Law does not applied in rebuilding on housing.

There are 1,420 million buildings that do not conform to present Building Standard Law. Of 1,420 million buildings, 220 million are commercial and 1,200 million are residential (Of these, 1,100 million are wooden structures). There are three issues involved in nonconformity; 1) structure codes, 2) safety codes and 3) zoning codes. Nonconformity to structure and safety codes is directly related to the reduction of risk.

A characteristic of the Japanese Building Standard Law is that it contains both building and zoning codes. Nonconformity to zoning codes caused problems during recovery from the Hanshin-Awaji Earthquake Disaster. For example, if a condominium is damaged, but does not conform to the present zoning code of the present Building Standard Law and the Urban Planning Law, especially in the ratio of building volume to property area, it cannot be reconstruct to same scale. For affected housing, contact with a road at least 4 m wide is a serious problem for reconstruction.

Table 2 Damage rate of engineered structure (Steel and RC)

	-1959	1960-1971	1972-1981	1982-93
Totally Collapse	3%	18%	5%	1%
Half Collapse	12%	22%	27%	9%
Slight Damage	46%	46%	62%	86%
No Damage	39%	13%	5%	3%

Table 3 Damage rate of non-engineered structure

	-1959	1960-1971	1972-1981	1982-93
Totally Collapse	53%	41%	23%	7%
Half Collapse	20%	26%	26%	16%
Slight Damage	22%	31%	50%	77%
No Damage	5%	1%	0%	0%

In new construction, the following 4 types of building must apply for and receive a building permit from building officials: (1) a movie theater, hospital or department store, etc. and the floor area exceeds 100 square meters. (2) Large scale wooden structure, (3) non-wooden structure, (4) building within city planning area. (The Building Center of Japan, 1995) However, in the rebuilding of a major structure, (4) need not apply for and receive a building permit, though (1), (2) and (3) must do it.

Current Approach to Innovation

The evaluation of a structure's seismic capacity of engineered structure has become to be conducted all over Japan. Buildings, which have been evaluated, are mainly Government own buildings. Aichi Prefecture submitted 1083 buildings for evaluation during FY1995-97. The main target of the evaluation was schools (48%) and the main structure type was RC (77%). Though 1083 buildings in total were evaluated, the number of evaluations conducted during HY1996-1998 for the retrofit plan was only 115 cases. (Aichi Prefecture Building and Housing Center et.al., 1999) The central government established a law for the promotion of the retrofit for the seismic safety in 1995. A building that is retrofitted for seismic safety can receive subsidization from the government. However, this law only promotes a desirable objectives, the number of retrofits accomplished using this subsidization is few, especially private sector building.

For housing or the non-engineered structure, the low interest loan to retrofit for seismic safety was prepared by the Housing Loan Corporation, public sector for housing loan according to the a law for the promotion of the retrofit for the seismic safety in 1995. However, the person who uses this loan is very few. The housing supply in the 1990s is 120-150 million units and the life span of Japanese housing (total number of housing stock / housing supply per year) is 26 years which is shorter than that in western countries. (Cf.. 75 years in the U.K., 44 years in the U.S.) This short life span may be key factor why the house owners hesitate to retrofit their housing.

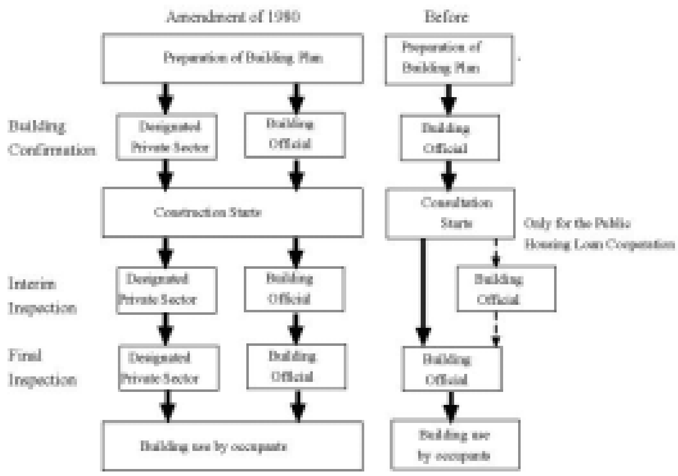
WHY THE SENSITIVITY TO THE AMENDMENT IS NOT GOOD?

Inspection System

The answer to the above question is that the inspection system in the Building Standard Law does not function well. For example, the rate of completing the final inspections in 1996 was only 43.4% in Hyogo Prefecture. It ranges from 25.6% - 48.2% in affected area by the Hanshin-Awaji Earthquake Disaster and never exceeds 50%. This fact also shows that the poor construction and non-conformity to the building codes cannot be checked. It appears to be resulted to the low sensitivity to the amendment.

There is a penalty about violation to the Building Standard Law. However, it is few cases that the violation was found and punished. This is because building officials is not afford to clamp down the non-conformity of the buildings, for the amount of new construction is huge in Japan. In Hyogo Prefecture, 34, 468 new buildings were constructed in 1998. Compared with such an amount of buildings, the number of building officials is limited. For example in Kobe City, 26 building officials dealt with 7, 915 new buildings in 1998; those officials include a management and the electrical and mechanical officials. After the Hanshin-Awaji Earthquake, the management system of the Building Standard Law was amended as shown in **Figure 6**. The interim inspection was introduced and designated Private Sector was authorized to arrange their own inspections.

Fig. 6 Inspection System of Japan (The Building Center of Japan, 1998)



Current Approach to Innovation

A law for the promotion of a high quality of housing was established in 1999. This law consists of three parts, 1) the housing performance indication, 2) a system of setting disputes and 3) defect liability for ten years. The establishment of this law has no direct relation to the Hanshin-Awaji Earthquake Disaster. However, construction defects were found in buildings damaged by the Hanshin-Awaji Earthquake. This law will work as a deterrent force for building contractor to conform the building codes.

“Insurance itself is not considered a mitigation measure because it redistributes rather than reduces losses, but a carefully designed insurance program can encourage the adoption of loss reduction measures by putting a price tag on the risk and creating financial incentives through rate discounts, lower deductibles, and higher coverage limits.” (Mileti, 1999) The Japanese earthquake insurance cannot be described well designed. There are differences of insurance expenses depending on the seismisity of each region, but no account is taken of the housing condition. However, for the defect liability, the contractors need to be insured. This insurance will function as the mitigation force.

CONCLUSION

1) The building codes are effective to reduce the risk of the damage.
2) In engineered structure, the amendment in 1970 was effective to reduce the rate of the totally collapse and the amendment in 1980 to reduce the rate of the half collapse.
3) There are many problems about management of the building codes in Japan.
4) There are 1,420 buildings that do not conform to present building codes.
5) Nonconformity to the zoning codes, not only the structural and safety codes, becomes the problem in disaster management for housing, especially in Recovery.
6) The retrofit of the building is conducted mainly for the public building.
7) Not only the building codes but also the defect liability and insurance is effective for mitigation countermeasure.

REFERENCE

Aichi Prefecture Building and Housing Center and JSCA (1999). *The outline of the evaluation of seismic capacity: the analysis of the seismic capability evaluation by the Aichi Prefecture Building and Housing Center.* (in Japanese)

The Building Center of Japan (1995). *Introduction to the Building Standard Law.*

The Building Center of Japan (1998). *Law for Amendment of the Building Standard Law 98.*

Hayashi, Haruo (1995). Social Scientific Issues Revealed in the Kobe Earthquake of 1995, *The Japanese Journal of Experimental Social Psychology*, Vol.35, No.2, pp194 – 206. (in Japanese)

Hayashi, Haruo et.al. (1998). Activities and Findings of Emergency Response Sub-committee, *Lessons from the Hanshin-Awaji Greta Earthquake Disaster*. (in Japanese)

Maki, Norio et.al. (1996). NATURAL DISASTER AND RESTORATION HOUSING IN ASIAN COUNTRIES, *Proc.11 WCEE*

Mileti , Dennis S. (1999). *Disaster by Design*, p172.

Ohashi, Yuji (1993). *The History of Structural Codes of Buildings in Japan*. (in Japanese)

Tatsuki, Shigeo and HAYASHI, Haruo (1999). Determinants of the changes of residence and life reconstruction among the 1995 Kobe earthquake victims, 24th Annual Hazards Research and Applications Workshop

Yamazaki, Fumio (1996). ESTIMATION OF HUMAN CASUALITIES DUE TO URBAN EATRTHQUAKE, *Proc.11 WCEE*