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Recent Activities on Earthquake Preparedness in Japan

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Abstract

This is a summary of the keynote lecture delivered at the CTBUH2004. First, the lessons on building performance from the Great Hanshin-Awaji Earthquake Disaster caused by the 1995 Hyogo-ken Nanbu Earthquake are reviewed and then, some of the activities of earthquake preparedness mostly on buildings taken after the disaster are mentioned. A recent promotion of earthquake research is also introduced.

Keywords: earthquake preparedness, building, seismic evaluation, Hanshin-Awaji Earthquake Disaster, active fault

1. Introduction

The 1995 Hyogo-ken Nanbu Earthquake hit the Hanshin-Awaji area including a populated city of Kobe, therefore it is called Kobe Earthquake for short, and caused a serious disaster called as the Great Hanshin-Awaji Earthquake Disaster in Japan. More than six thousands people were killed and the amount of the damage was estimated to be more than ten trillions Japanese Yen (approximately one hundred billions U.S. Dollars).

The objective of this keynote lecture is to review the lessons from the earthquake disaster due to the 1995 Hyogo-ken Nanbu Earthquake, and to introduce the earthquake disaster mitigation programs mostly on buildings and houses carried out after the disaster in Japan.

2. Damage to Buildings/Houses and Lessons from Hyogo-Ken Nanbu Earthquake

One of the major features of the disaster was the collapse of structures such as buildings, houses highway bridges, railways, harbor structures, etc. Among them, the collapse of wooden houses caused to kill many people because the earthquake occurred in very early morning while most people were in beds. A damage statistics of buildings and houses is shown in Table 1 (Ministry of Construction 1995). About ten percents of wooden houses and about six percents of reinforced concrete, steel, and steel encased reinforced concrete buildings took heavily damages. Older buildings and houses took more damage, and less damage to new buildings and houses. As an example of relationship between grades of damage and construction years, a statistics for reinforced concrete school buildings is shown in Table 2 (Okada, T. et al 2000).

It is clear that most of seriously damaged buildings were constructed before 1981 when the Japanese seismic design code was revised and the required seismic level was drastically upgraded. Therefore, the importance of the upgrade of seismic safety of existing buildings and houses constructed before the year of 1981 has been strongly recognized as a lesson.

Another feature of the event was the earthquake fault that had not been moved for last one thousand years or more and caused strong ground shaking. A big discussion arose about the possibility of other existing active fault systems similar to those moved this time. Responding to this discussion, a special governmental organization named the Headquarters for Earthquake Research Promotion was established in 1995 and the comprehensive investigation of active fault systems has been launched by the initiation of the Government.

In the keynote lecture, the emphasis is laid upon to introduce the activities to upgrade the seismic safety of buildings and houses, and to investigate earthquake fault systems for future consideration in earthquake preparedness including seismic design and evaluation of buildings and houses.

3. Seismic Design Code for Buildings Revised in 2000

Seismic design code for buildings in Japan was first adopted in 1924, and revised in 1950, 1971, and 1981 before 1995 and the seismic performance of buildings and houses has been improved in each revision. This was one of the reasons why most buildings constructed according to 1981 seismic design code survived even to such severe ground motions in 1995 Hyogo-ken Nanbu Earthquake. However, the problem was that 1) their damage grades were scattered from no damage to severe damage, and 2) many of severe damaged buildings constructed after 1981 were

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demolished, even if they could prevent collapse. In order to be able to consider not only to prevent collapse but also to reuse without heavy repairing works, the Building Standard Law in Japan was revised in 1998 and enforced in 2000.

The main points of the revision are to leave the seismic design code 1981 with minor modifications as a minimum requirement to prevent collapse and to add a new method to be able to control damage grades based upon the required performance to buildings as an option for buildings of which height are less than 60 meters. For high-rise buildings of which height exceed 60 meters, a time history analysis should be used as 1981 codes. The optional method is to estimate a nonlinear response displacement of the building to the ground motion defined by design spectra, based upon an equivalent linear stiffness and an equivalent viscous damping. Exactly speaking, this method is not a design method but an estimation method of the response displacement of the buildings being designed. However, the adoption of this method will allow structural engineers not to follow some of the specifications for structural requirements such as dimensions of members, structural detailing etc. Therefore, the adoption of this method is considered to be a step toward a performance-based seismic design.

4. Promotion of Seismic Evaluation and Retrofit of Existing Buildings

Actions before 1995

The importance of the seismic evaluation and retrofit of existing buildings has been recognized since early 1970's. The Evaluation Standard and Guideline for Retrofit of Existing Reinforce Concrete Buildings was published in 1977 (JBDPA 1977, revised 1990 & 2001). Similar standards and guidelines were also published for steel buildings, steel encased reinforced concrete buildings and wooden houses. However, it had not been used widely but applied only to limited types of buildings such as reinforced concrete school buildings in limited regions such as Shizuoka Prefecture, where a possibility of an earthquake prediction is expected, and Kanto regions before 1995. A few buildings were evaluated and/or retrofitted in other regions including Hanshin-Awaji area.

Verification study

Studies to verify the applicability of the evaluation standard were carried out on reinforced concrete school buildings suffered from the Hyogo-ken Nanbu Earthquake. Fig.1 is a relationship between construction years and seismic performance indices estimated by the evaluation standard (JBDPA 1990) with degrees of damage of 104 reinforced concrete school buildings suffered from the 1995 Hyogo-ken Nanbu Earthquake (Okada, T. et al 2000). The evaluation standard assigns higher Is indices for buildings with higher seismic performance. It is indicated that 1) the seismic performance have been improved according to construction ages and 2) damages of buildings with lower Is indices are severer than those with higher Is indices.

In order to investigate the relationship between the grades of damages and Is indices, the distribution of Is indices of reinforced concrete school buildings was examined. The distributions of Is indices of several groups of reinforced concrete school buildings are shown in Fig.2 (Okada, T. et al 1989 and 1999). The curve 1 indicates the probabilistic density function of about two thousands school buildings in Shizuoka Prefecture approximated by lognormal function and the curve 2 indicates the probabilistic density function of the severely or moderately damaged buildings due to 1968 Tokachi-oki and 1978 Miyagiken-oki earthquakes. Since the damage ratios of both earthquakes were about 10 %, the density function (values of the vertical axis) of the curve 2 is reduced by a factor of 0.1. The curve 3 is showing the extrapolated probabilistic density function of damaged buildings when the ground intensity becomes 1.5 times of past two earthquakes mentioned above (Okada, T. et al 1989).

In order to compare the performance of buildings suffered from 1995 Hyogo-ken Nanbu Earthquake with those of buildings shown by the curves 1, 2 and 3, the Is indices of the school buildings that took severe or moderate damage shown in Fig.1 are plotted by hatched bars, where the frequency is adjusted so that the damage ratio becomes 30 % (Okada, T. et al 1999). The distribution of the hatched bars may be approximated by the curve 3. The result suggests that the input ground motion in 1995 Hyogo-ken Nanbu earthquake might be 1.5-2 times of those of the previous two earthquakes.

Actions after 1995

It has been strongly recognized after 1995 if we had retrofitted the buildings of lower seismic indices before the earthquake, we could have prevented such serious damages. Since about sixty percents of existing buildings and houses in Japan were constructed before 1981, the Law for Promotion of Seismic Retrofit was enforced in 1995 to promote the seismic evaluation and retrofit of such buildings and houses. The law places the owner of the building 1) which is constructed before 1981, 2) which is public and/or open to the public and 3) which has larger floor areas than 1,000 m^2 and multi-stories than two, under obligation to evaluate the seismic performance and to retrofit, if necessary. Owners of wooden houses are also recommended to take similar measures.

The training of engineers was also urgently needed. Therefore, the Network Committee for Seismic Evaluation and Retrofit of Existing Buildings was established in Japan Building Disaster Prevention Association in 1995, inviting the organizations related to building design and construction. Ninety-eight organizations such as regional associations for architects and building engineers have joined in the network committee, and have been carrying out the training of engineers and reviewing of the evaluation and retrofit projects for building officials.

Many public buildings such as school buildings, city halls, hospitals, etc. have been retrofitted by the financial support of the Government since 1995. However, the retrofit of wooden houses, which caused a great disaster in Hanshin-Awaji area, and private buildings have not been promoted much. Therefore, not only the Government but also many regional governments have launched recently the projects to support financially the evaluation and retrofit of private wooden houses.

5. Quick Inspection of Damaged Buildings

The quick inspection of damages is important to prevent secondary damage due to after shocks and to inform occupants of buildings and houses whether they can keep using their buildings and houses or not.

A project to make guideline for the quick inspection was launched in 1981 as a national project and the guideline to classify the damage into Unsafe (Red), Limited Entry (Yellow) or Inspected (Green) was published in 1990. Since then, it has been recommended the regional governments to take actions to train engineers and establish their own quick inspection system. However, the quick inspection system had been established only in several regional governments excluding the Hanshin-Awaji area until 1995. Therefore, the quick inspection of the grade of building damages was carried out by the initiation of the Government just after the Hyogo-ken Nanbu Earthquake. Quick inspection teams consisting of registered quick inspectors, engineers in the Government and regional governments, and volunteer engineers were organized by the initiation and support of the Government and non-profit organizations that took initiatives to establish the Network Committee for Seismic Evaluation and Retrofit of Existing Buildings later on. About 10,000(man/day) inspectors inspected about 40,000 buildings and 50,000 houses approximately in a month.

In view of the importance and effectiveness of the quick damage inspection, all regional governments have established the systems and the training of inspectors have been carrying out since 1995.

On October 6 in 2,000, an earthquake of M=7.3 on JMA scale attacked Tottori-ken, Shimane-ken and Okayama-ken located northwest of Kobe city. Fortunately, no death toll was reported, but 138 injured, 315 buildings and houses heavily damaged, 1,649 partially damaged and 7,318 slightly or less damaged. After the earthquake, regional governments initiated the quick inspection of damaged buildings and houses. More than 4,000 buildings and houses were inspected by 332 (man/day) registered inspectors in 2 weeks, and 443 buildings and houses were judged safe, 1,499 limited entry and 3,138 inspected.

Also in another earthquake in Miyagi-ken occurred on July 26, 2003, about 7,200 buildings and houses were inspected by about 740 (man/day) inspectors for 8 days (JBDPA home page). Currently total numbers of registered quick inspectors have exceeded a hundred thousands in Japan.

6. Promotion of Earthquake Research

As mentioned before, to promote earthquake research for improving disaster prevention measures by uniting various organizations, the Headquarters for Earthquake Research Promotion attached to the Prime Minister's office (now belongs to the Ministry of Education, Culture, Sports, Science and Technology: MEXT) was established in accordance with the Special Measure Law on Earthquake Disaster Prevention enacted in July 1995.

According to the policy of the headquarters, the comprehensive survey and observation of earthquakes to evaluate the kinds of earthquakes that occur in different regions of Japan and the comprehensive evaluation of seismic activity have been executing.

As for the evaluation of seismic activity, the Earthquake Research Committee in the Headquarters is evaluating intervals of activity and the potential for the next occurrence by location and scale (magnitude) of major active faults (98 main fault zones) and earthquakes along the trough (nine sectors). Fig.3 is showing the examples of probabilities of large-scale earthquakes due to active faults over the next thirty years. The evaluation is scheduled to be completed within the fiscal year of 2004. Based upon such evaluation, probabilistic seismic hazard maps will be also prepared. How to utilize these results into earthquake disaster mitigation programs including seismic design, seismic retrofit is a future task.

7. Concluding Remarks

Some activities on Earthquake Preparedness after 1995 event in Japan are quickly reviewed. The author does hope the keynote lecture may contribute to upgrade the earthquake preparedness in the future.

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Table 1. Damage Statistics of Buildings and Houses suffered from 1995 Hyogo-ken Nanbu Earthquake [Ministry of Construction 1995]

	Collapse and Severe Damage	Moderate Damage	Minor Damage or Less & Others	Total
1-2 Storied	46,022	42,208	401,046	489,276
(wooden houses)	(9.4 %)	(8.6 %)	(82.0 %)	(100 %)
More than 3 Storied	3,081	3,273	42,165	48,519
	(6.4 %)	(6.7 %)	(86.9 %)	(100 %)

Table 2. Damage Statistics of Reinforced Concrete School Buildings suffered from 1995 Hyogo-ken Nanbu Earthquake [Okada.T et. al. 2000]

	Pre-1971	1971-1981	Post-1981	Total
Collapse	18 (5%)	2 (1%)	0	20 (3%)
Severe Damage	24 (7%)	9 (5%)	0	33 (5%)
Moderate Damage	90 (27%)	39 (24%)	11 (8%)	140 (22%)
Minor Damage	41 (12%)	21 (13%)	7 (5%)	69 (11%)
Slight or no Damage	159 (48%)	95 (57%)	115 (87%)	369 (59%)
Total	332 (100%)	166 (100%)	133 (100%)	631 (100%)

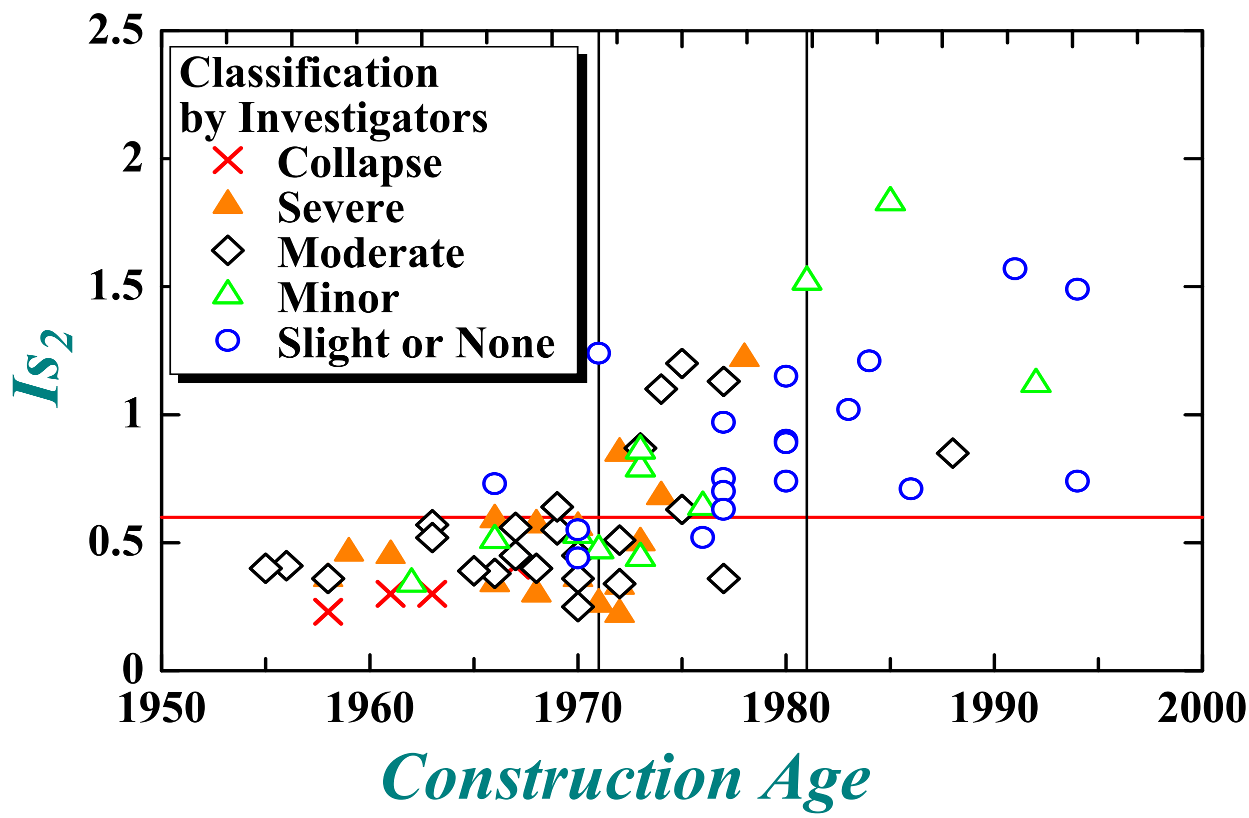

Fig.1 Seismic Indices vs. Construction Years of Reinforced Concrete School Buildings suffered from 1995 Hyogo-ken Nanbu Earthquake [Okada, T. et al 2000]

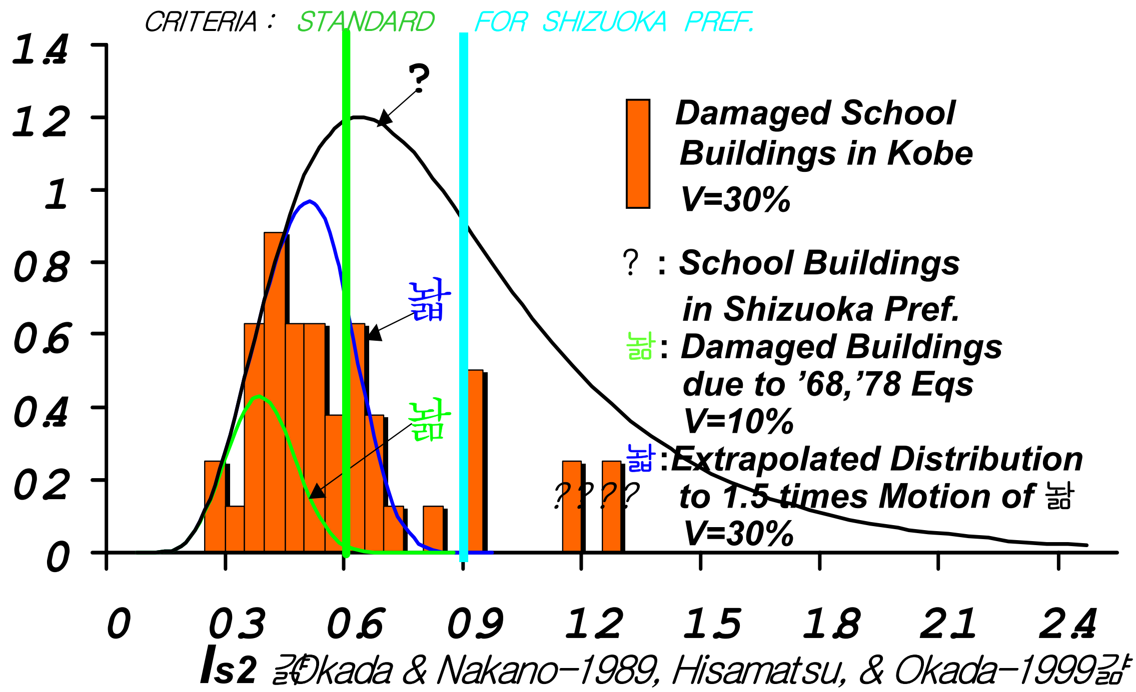

Fig.2 Distribution of Seismic Indices of Reinforced Concrete School Buildings [Okada, T. et al 1989, 1999]

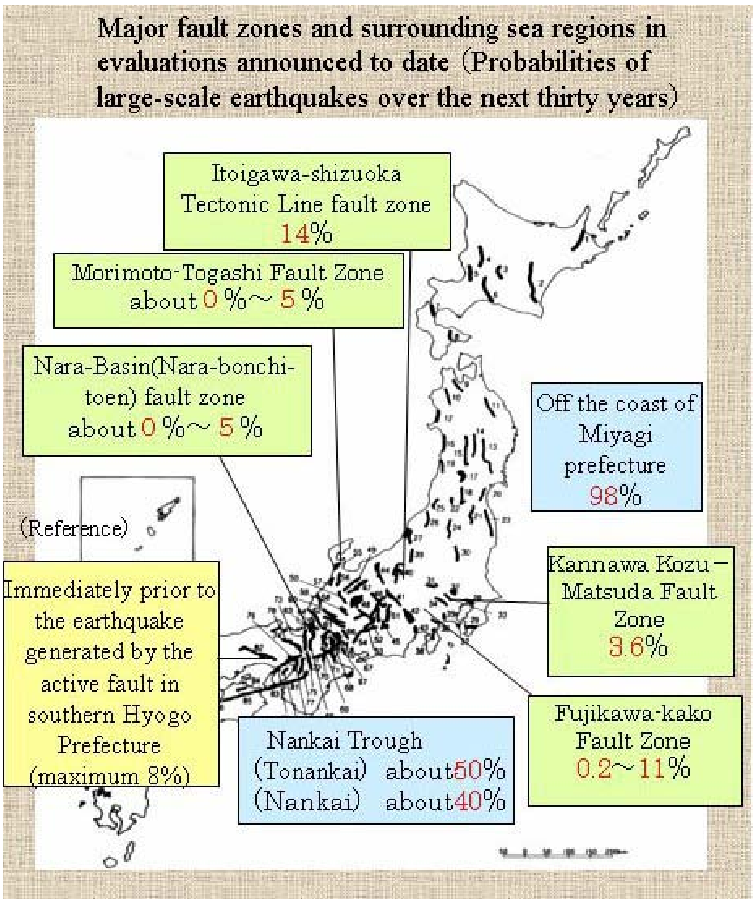

Fig.3 Examples of Probabilities of Large-scale Earthquakes over the Next Thirty Years [MEXT 2004]