# IMPROVEMENT OF SEISMIC PERFORMANCE OF REINFORCED CONCRETE SCHOOL BUILDINGS IN JAPAN -PART2 SYSTEMATIC PROJECT FOR RETROFIT AND QUICK RESPONSE AGAINST FUTURE EARTHQUAKES

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## SUMMARY

This paper is to describe the measures of the Ministry of Education in cooperation with the Architectural Institute of Japan on the improvement of existing reinforced concrete school buildings. Based on the survey and analysis of the damaged buildings during 1995 Hyogo-ken Nanbu Earthquake, the Ministry of Education, Japanese Government, requested to the AIJ to develop the design manuals for retrofitting school buildings. The Task Committee of AIJ recommended the promotion of the seismic capacity evaluation to find out vulnerable school buildings and drafted the manuals for retrofitting existing school buildings, which are outlined in this paper. The Ministry of Education accepted the recommendations of the Task Committee and has been taking various measures to retrofit existing school buildings including financial support to local school districts. Statistical data on past retrofit design of school buildings were evaluated in technical and economical viewpoints. A new committee in AIJ follows the activities with special emphasis on quick recovery of school buildings after a major earthquake. A sophisticated and quick procedure including damage evaluation, temporary recovery and strengthening in consideration of permanent retrofit, and permission on use, is being developed and described as a guidelines for administrators and engineers.


## INTRODUCTION

The Hyogo-ken Nanbu Earthquake which occurred on January 17,1995 damaged a large number of buildings, including educational buildings in Japan. The fact that school buildings, occupied most parts of educational buildings, were damaged by this earthquake was a great shock to us, because those buildings are functioned not only as learning and living space for children, but also as refuges for community people. So the Ministry of Education fully recognized how important it was to improve seismic performance of school buildings.

In the meantime, public school buildings in Japan were constructed at a high pace in the past several decades to cope with the increase in school enrollments. And now most of those obsolete buildings must be reconstructed or reinforced. We are now in face of a difficult problem to improve seismic performance of school buildings efficiently and quickly so as to secure not only children but also community people.

Therefore the Ministry of Education requested to the Architectural Institute of Japan（AIJ）to study the extent of damage of reinforced concrete school buildings, the seismic capacity evaluation of them and the way of reinforcing them. This abstract describes that the Ministry of Education indicates guidelines for local governments, which establish and administer public school buildings in response to the AIJ reports.

## 2. IMPROVEMENT OF PUBLIC SCHOOL BUILDINGS IN JAPAN

The total floor space of the public elementary and lower secondary school buildings（except for wooden）is about 160 million square meters. The following is the outline of their completion year with social backgrounds.


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### 2.1 Mid-1960s（1956-1965）

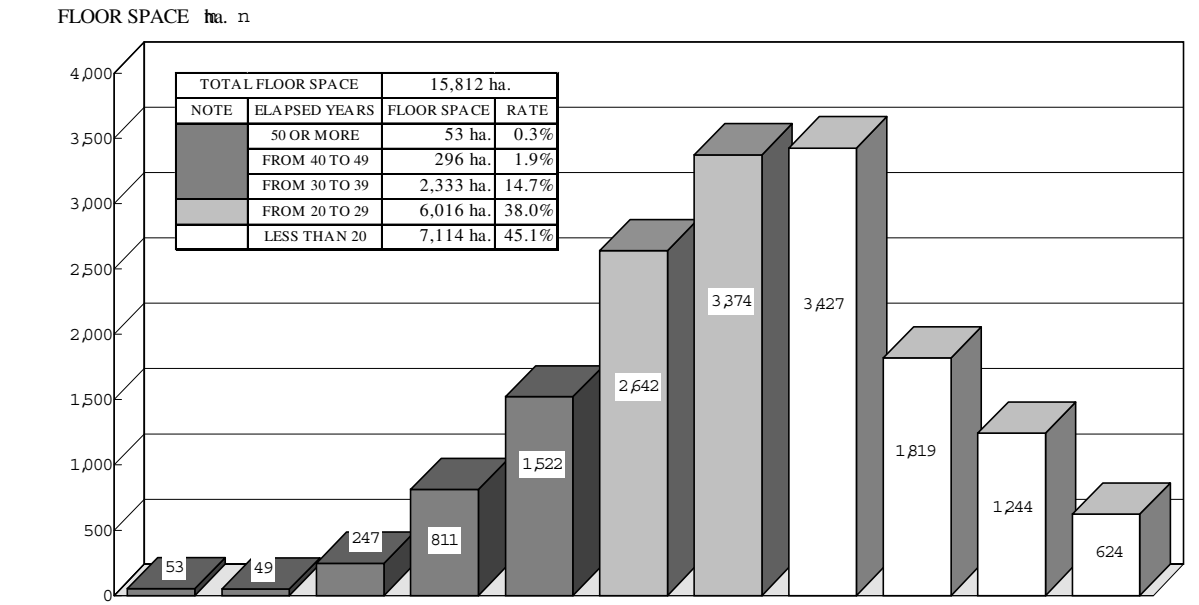
In this period, the National subsidies for public school buildings were established to cope with the first baby boom after the second World War in Japan, and many school buildings ware constructed according to the five-year-plans on the purpose of solving the acute shortage of them. At the same time reinforce concrete became into wide use to construct buildings including school buildings. But now the most of them were already reconstructed and the percentage of the floor spaces of public school buildings constructed in this period is under 10%（about 15 million square meters）.

### 2.2 Mid-1970s（1966-1975）

In this period, the economic growth in Japan shifted at the high rate, and the gross floor spaces of public school buildings increased accompanied with it. The percentage of the floor spaces of public school buildings constructed in this period is about 31%（about 49 million square meters）.

### 2.3 Mid-1980s（1976-1985）

In this period, a large amount of public school buildings were constructed to cope with a rapid increase of children caused by the second baby boom. As for the trends in the government budgets in this period, the government appropriated a huge amount of money for the nation wide construction of public school buildings every year. The percentage of the floor spaces of public school buildings constructed in this period is about 40%（about 64 million square meters）.




| ELAPSED YEARS | ~ 50 YEARS | 45 ~ 49 | 40 ~ 44 | 35 ~ 39 | 30 ~ 34 | 25 ~ 29 | 20 ~ 24 | 15 ~ 19 | 10 ~ 14 | 5 ~ 9 | 1 ~ 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| COMPLETION YEAR | BEFORE 1948 | 1949 ~ 1953 | 1954 ~ 1958 | 1959 ~ 1963 | 1964 ~ 1968 | 1969 ~ 1973 | 1974 ~ 1978 | 1979 ~ 1983 | 1984 ~ 1988 | 1989 ~ 1993 | 1994 ~ 1997 |
| RATE(%) | 0.3 | 0.3 | 1.6 | 5.1 | 9.6 | 16.7 | 21.3 | 21.7 | 11.5 | 7.9 | 4.0 |

**Figure 1:The floor spaces of public elementary and lower secondary school buildings（except for wooden）as of May 1, 1998.**

## 3. THE AMENDMENT OF ASEISMIC STRUCTURAL PLANNING AND THE CONSTRUCTION OF PUBLIC SCHOOL BUILDINGS

In Japan, aseismatic structural planning was amended twice after the Second World War, based on the amendments of Building Standard Law Enforcement Ordinance. The first amendment was in 1971, and the second one was in 1981, both of them were based on damages brought by earthquakes in 1968 and 1978. These

amendments are closely relevant to improvement of seismic performance of public school buildings. Because, as I previously stated, a large amount of public school buildings were constructed round about the time of two amendments. The percentage of the floor spaces of which were constructed before old planning (before 1971) is about 20%, and the percentage of the floor spaces constructed before new planning and after old planning (from 1971 to 1981) is about 50%. The most of these public school buildings are now required to be retrofitted or to be reconstructed from the point of view of improving seismic performance.

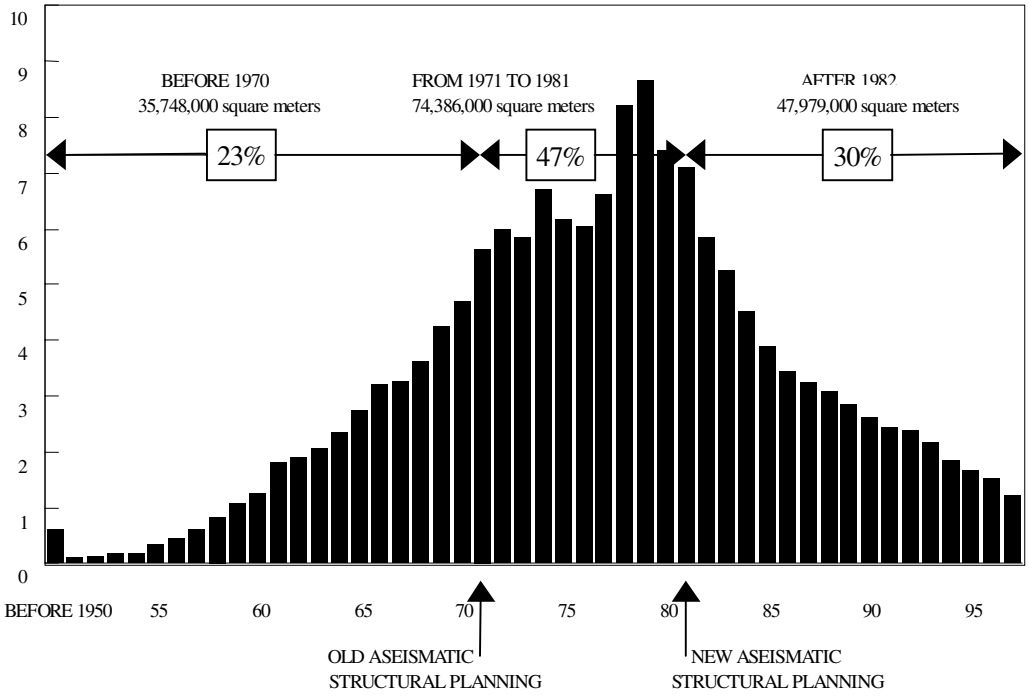



**Figure 2:The relation between amendment of aseismatic structural planning and the floor spaces of public elementary and lower secondary school buildings (except for wooden) as of May 1, 1998.**

## 4. DAMAGES OF EDUCATIONAL BUILDINGS CAUSED BY 1995 HYOGO-KEN NANBU EARTHQUAKE

### 4.1 1995 Hyogo-ken Nanbu Earthquake and Damages

The occurrence of the big earthquake in the early morning January 17 1995 caused great damages to Kinki district.

Major kinds of damages were the collapse of structures, the crack of walls and columns, the fall of interior materials, the damage of windows and so on, and about 4,500 educational buildings were damaged by the earthquake. The Japanese government appropriated 94 billion to recover damaged educational buildings in fiscal 1994 and 1995.

As for public school buildings, the government to be recovered subsidized 1,126 buildings, and 54 school buildings were reconstructed out of them.

In Japan the government subsidies the expense for recovering public school buildings (from kindergarten to university) according to the Law Concerning the National Treasury's Share of Reconstruction of Natural Calamity-damaged Public School. The government subsidy two thirds of the expense to recover the damaged school buildings.

### 4.2 The relation between the completion year and the extent of damage

According to the research which the Ministry of Education requested to the Architectural Institute of Japan (AIJ) to investigate seismic performance of educational buildings struck by the earthquake, most of 272 relatively damaged buildings were constructed before new aseismatic structural planning (June 1 1981). And buildings, which were constructed before old aseismatic structural planning (January 1 1971) were especially

damaged by the earthquake. On the contrary buildings constructed after new planning were comparatively less damaged by the earthquake.

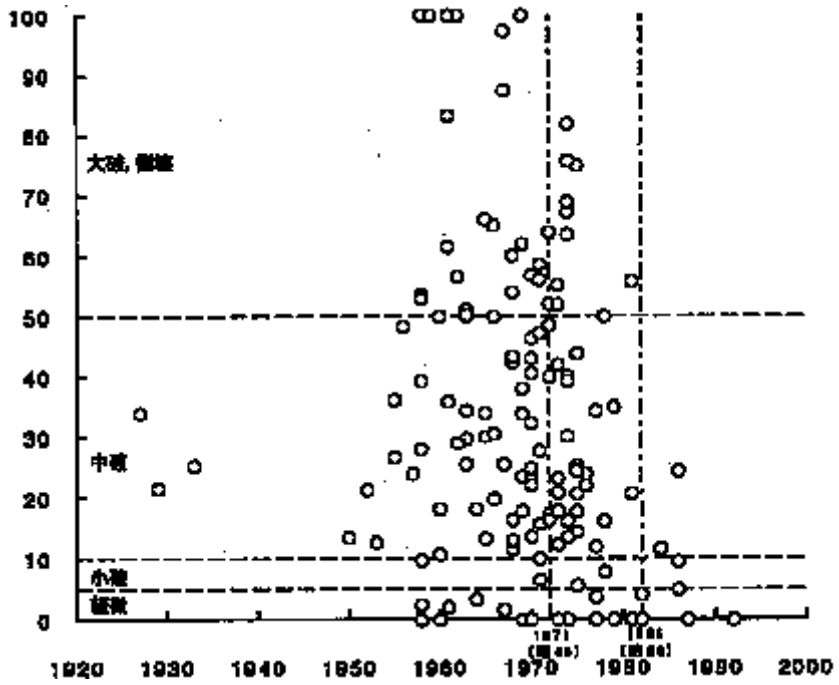



**Figure 3:The relation between the completion year and the extent of damage**

## 5. THE RELATION BETWEEN SEISMIC INDEX OF STRUCTURE（Is index） AND THE DAMAGES

### 5.1 Reinforced concrete school buildings

AIJ calculated the Seismic Index of Structure（Is index） of reinforced concrete school buildings including various kind of damages which are located in the center of a quake. 102 buildings were calculated by the primary method of checking for seismic safety and 70 buildings were calculated by the secondary method.

At first the result of analysis by the primary method is the following.

**Table 1: The relation between the Is index calculated by the primary method of checking and the degree of damage of public school buildings**

| Is index | The degree of damage |
|---|---|
| 0.2 < Is < 0.4 | Damages were from extreme to slight |
| 0.4 < Is < 0.8 | Damages were under medium |
| 0.8 < Is | No damage or slight damages |

Generally buildings whose Is index are over 0.5 are less damaged.

Next the result of analysis by the secondary method is the following.

Buildings collapsed or extremely damaged although their Is index were comparatively high were mostly four-storied toughness but inferior in strength, they were not collapsed but were judged to extremely damaged because of the residual deformation.

### 5.2 Steel school buildings

AIJ also calculated the Is index of steel school buildings 18 of them were comparatively damaged and 7 of them were less damaged. The following is the result of the analysis.

Most of the damaged buildings were constructed before new aseismatic structural planning (June 1 1981) and the their Is index were almost within limits of 0.3 to 0.6.

Some buildings that were calculated to high point even if they were constructed before new planning were less damaged.

Buildings after new planning were less damaged, though the amount of them calculated were not enough to conclude.

The reasons why buildings were damaged even if the Is index of them were calculated too high point are considered that they were constructed on the soft ground or on the hill, or the margin of the strength of joints were insufficient.

## 6. GENERAL MEASURES FOR ALL BUILDINGS TAKEN BY THE GOVERNMENT AFTER 1995 HYOGO-KEN NANBU EARTHQUAKE

### 6.1 Decision of the five-year-plan to provide against a big earthquake

Before the occurrence of 1995 Hyogo-ken Nanbu Earthquake, the government has taken some measures to cope with the prospect for the earthquake in Tokai district according to the Law Governing Special Measures for the Earthquake. One of the major measures is to subsidize the expense for reinforcement works of public buildings and other facilities in particular area (including 170 cities) to provide against a big earthquake. As for public elementary and lower secondary school buildings in this area, a half of the expense for reinforcement or reconstruction of them are also subsidized according to the law.

After 1995 Hyogo-ken Nanbu Earthquake, Congress enacted the Law Governing Special Measures for the Earthquake Disaster Prevention to improve nationwide seismic performance of buildings and other facilities. The five-year-plan (from 1996 to 2000) was drawn up to prevent the earthquake disaster according to this, and the major undertakings were the reinforcement and reconstruction of public facilities including public school buildings. The undertakings incorporated in the plan are given priority for subsidizing and the subsidy rates of some undertakings are increased. The competent minister notified the standards of the undertakings for the plan.

### 6.2 Amendment and enactment of new standards

In 1996 the Constructional Council submitted a report concerning the performance of the earthquake disaster prevention of the government and the public office. This report said, "in case of constructing a government or public office, a certain seismic performance of structures, materials and equipment's should be settled and secured in response to its importance, considering its meaning in the area which stands."

The Ministry of Construction amended the structural standard of the government and public office according to this report. By this standard, school buildings were provided to be constructed one-and-a-quarter times as horizontal strength as the ordinary buildings in order not only to secure the safety but also to function as refuges for community people after a big earthquake.

Moreover, Congress enacted the Law Promoting the Reinforcing Buildings to promote checking for seismic safety and reinforcement of public buildings. According to this law, some of public school buildings, which are above three-story and 10,000 square meters and are open to the general public must be checked for seismic safety and reinforced according to the result of checking. The standards provided by this law are the following.

**Table 3:The evaluation standard of seismic performance based on the Is and the q index**

| Is and q index | Seismic performance |
|---|---|
| $Is < 0.4$ or $q < 0.5$ | The risk of collapsing by the shock of earthquake is high |
| $Is < 0.6$ or $q < 1.0$ | There is a risk of collapsing by the shock of earthquake |
| $0.6 < Is$ or $1.0 < q$ | The risk of collapsing by the shock of earthquake is low |

## 7. MEASURES TAKEN BY THE MINISTRY OF EDUCATION

### 7.1 Measures as for standards of the improvement in seismic performance

According to the AIJ report considering seismic performance of educational buildings, the Ministry of Education sent the notice "Promotion of the Improvement of Educational Buildings in Seismic Performance" to prefectural boards of education on May 19, 1995. By this notice, the Ministry of Education showed the present consideration matter about the improvement of educational buildings in seismic performance. The outline is as follows.

1. As for existing buildings constructed before new aseismatic structural planning, the seismic capacity evaluation needs to be carried out and earthquake proof reinforcement needs to be performed if needed. In that case, the rigid distribution by non-earthquake proof wall, irregular plane form, etc. take into consideration pertinently the influence which it has on earthquake proof ability.
2. As for constructing new buildings, the structure plan which arranges a pillar and an earthquake proof wall pertinently, and a generous structure design are performed, suitable construction supervision is regarded. Especially as for a school building, the power poor of the beam going direction is fully secured.

Furthermore the Ministry of Education sent of a same name to prefecural boards of education on September 30, 1996. By this notice, the Ministry of Education showed them consideration matters, such as the consideration on the design in a new building, and the target at the time of reinforcement of the existing building. The outline is as follows.

1. As for constructing new buildings
   (1) Also as for buildings based on new aseismatic structural planning, since a part of them suffered damage, a generous design should be made.
   (2) As for making an educational building as a refuge of the community at the time of disaster prevention, it is appropriate to be designed with its earthquake load is added.
2. As for existing buildings
   Existing buildings need to be checked for seismic safety and reinforced according to the result of checking based on the Law Promoting the Reinforcing Buildings, and it needs to be designed in consideration of the role in the local society of educational buildings.

### 7.2 Measures about educational buildings according to the Law Governing Special Measures for the Earthquake Disaster Prevention

Also about educational buildings, some of them are incorporated in a five-year-plan according to the Law Governing Special Measures for the Earthquake Disaster Prevention.

1. Public elementary and lower secondary school buildings which require reconstruction or reinforcement on earthquake disaster prevention
2. Public special education school buildings which require reconstruction or reinforcement on earthquake disaster prevention
3. The pools with purification equipment required in order to secure drink water at the time of earthquake disaster

Among these, when carrying out reinforcement about 1(public elementary and lower secondary school buildings), the rate of national treasury subsidy is pulled up from 1/3 to 1/2. The standards of whether it is appropriated for a five-year-plan were shown by the notification of the Ministry of Education on August 24, 1995 as follows.

1. The building below the mark, which the Minister of Education defined about the degree of strength of a building
2. The building below the mark, which the Minister of Education defined about the degree of seismic performance of a building

About 2(the degree of seismic performance), the Minister of Education defined the standard as follows on March 22, 1996, according to standard of the Ministry of Construction and the research of AIJ that school buildings must be constructed one-and-a-quarter times as horizontal strength as the ordinary buildings.

**Table 4:The standard of the way of improving seismic performance of existing educational buildings based on the Is and the q index**

| Is and q index | Way of improving existing educational building |
|---|---|
| Is < 0.4 or q < 0.5 | Reconstruction |
| Is < 0.7 or q < 1.0 | Reinforcement (Reconstruction if needed) |
| Is < 1.0 | Reinforcement if needed |

### 7.3 Foundation of the system of an emergency danger judging of educational building

At the time of a large calamity, it is required to judge the dangerous state of buildings quickly so as to prevent the second calamity. Especially as for an educational building, it is required to be judged as soon as possible after a calamity whether it is dangerous to use because of its function as a refuge in the community. Also after 1995 Hyogo-ken Nanbu Earthquake, the Ministry of Education investigated by sending 60 persons' group which consists of technical officials in the Ministry of Education, National Universities and prefectural boards of education to cope with administrators' requests. Based on this, the Ministry of Education founded the system of an emergency danger judging of educational buildings and sent the notice shown about the enforcement method of the system. Outlines of the system are, to Take a short-term course by assembling technical officials in National Universities and prefectural boards of education, who have the qualification of the first class architect, to Make a list of members who take a short-time course, and to Request sending of them at the time of a large calamity

### 7.4 National subsidies for improvement of seismic performance of public school buildings

Suffering the damage of 1995 Hyogo-ken Nanbu Earthquake, The Ministry of Education founded new national subsidies and expanded existing them. The types of national subsidies for improvement of seismic performance of public school buildings are as follows.

**Table 5:The types and the rate of national subsidies**

| Construction Type | The Rate of Subsidy |
|---|---|
| Reconstruction | 1/3 |
| Reinforcement | 1/2 (partly 1/3) |
| Large Scale Alteration Accompanied by the Reinforcement | 1/3 |
| Recovery | 2/3 |

### 7.5 Other National subsidies about educational Buildings

The following subsidy systems were founded in the purpose, which improves the disaster prevention space for community people in addition to the system to school buildings.

1. Construction of the stockpile warehouse into a school site

2. Construction of the disaster prevention open space or green tract with sprinklers and fire prevention tank into a school site

3. Construction of the pool with purification equipment

4. Reinforcement of school lunch facility for food supply in case of disaster

And systems of national subsidy or low-interest loan for private school were founded. The subsidy system almost same (the standard of subsidy is same and the rate of subsidy is less than 1/3) also reinforcement of a

private school below a high school as a public school was founded. Moreover the system of low-interest loan is applied to reconstruction of all private school buildings which passed after construction for 30 years or more.

### 7.6 Draft of manuals to retrofit existing school buildings and to recover after a major earthquake quickly

In 1998, the Ministry of Education drafted manuals for administrators and engineers for the purpose of retrofitting existing school buildings and recovering after a major earthquake quickly. It shows above-mentioned technical standards, national subsidies and the procedure after a major earthquake.

## CONCLUSIONS

The major findings are:

1) Cost performance to increase seismic performance index were analyzed,
2) Retrofit program in practice was introduced with reliable technical backgrounds are economical efficiency,
3) A quick and systematic response procedure for school buildings after a major earthquake is proposed.

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