

JCI Activity on ISO Standard for Seismic Evaluation of Concrete Structures

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Synopsis: Diagnosis of the earthquake resistance of the buildings and conducting seismic strengthening have been promoted from 1970s in Japan. Seismic performance is evaluated by the seismic index of “ I_s ” that is the product of the strength and ductility index of the building. The seismic index of “ I_s ” corresponds to the input energy of the earthquake. In another word, the earthquake-resistant performance of the building is expressed as the intensity of the earthquake that the building can resist. In order to make use of this technique for improving the earthquake resistance of buildings at earthquake-prone area in the world, the standardization of evaluation of seismic performance and strengthening of buildings are tried in the ISO/TC71/SC7. The draft of this ISO standard provides the standard work items related to seismic assessment and retrofit, and standard procedures in each stage, and makes the contents and the scope of each duty clear.

Keywords: seismic retrofit; seismic assessment; ISO; The seismic index of “ I_s ”

INTRODUCTION

Earthquakes that cause damage to structures occur frequently in many areas of the world. Especially, heavy damage by earthquakes concentrates in vulnerable structures and vulnerable parts. As the result of the direct action of earthquakes, RC structures may collapse or overturn in earthquake prone areas. However, it is expected that through seismic assessment and retrofit of concrete structures, human life losses, economical losses, and structural collapses could be mitigated and/or prevented, and quick recovery could be attained. Japan has the Seismic Evaluation Standard and Rehab. Guidelines for RC buildings. The Standard and Guidelines have been applied to a lot of RC buildings since the 1970's in Japan. We hope that our technology helps to mitigate earthquake disasters in the world.

RESEARCH SIGNIFICANCE

The reduction of earthquake damage in earthquake prone areas including Japan is important. For this purpose, it is most important to improve earthquake resistance of buildings. The seismic diagnosis method in Japan has been applied to a lot of buildings and the efficiency is verified through many damaging earthquakes. Making use of this technique, evaluation of seismic performance and strengthening of buildings in the ISO/TC71/SC7 are attempted to be standardized for improving the earthquake resistance of buildings in earthquake-prone areas in the world.

JAPANESE STANDARD FOR SEISMIC EVALUATION AND GUIDELINES FOR REHABILITATION

The Standard and Guidelines were originally developed in 1977, but more than 20 years passed until they were widely applied throughout Japan. After the Kobe Earthquake in 1995, nationwide earthquake disaster mitigation programs were started. Major damaging earthquakes and related amendments of seismic provisions are listed in Table 1.

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Table 1. Major damaged earthquake and related amendment of seismic provisions

	EQ	M	Fatalities
	1968 Tokachi-oki	7.9	50
[1971 Revision of Seismic Code		
	1977 Seismic Evaluation Standard and Rehab. Guidelines (RC)		
	1978 Miyagiken-oki	7.4	28
[1981 Revision of Seismic Code		
	1995 Kobe	7.3	6432
	Law to promote Seismic Eval. and Rehab.		
	→ Nationwide EQ disaster mitigation programs started		

Typical earthquake damage is shown in Photos 1 to 6. Lack of strength, beam-column joint failure, shear failure, and short column shear failure, are all typical failure types of RC buildings in Japan. Seismic evaluation standards in Japan are provided based on these typical types of earthquake damage.



Photo 1. Unbalanced stiffness in plan



Photo 2. Beam-column joint failure



Photo 3. Shear failure

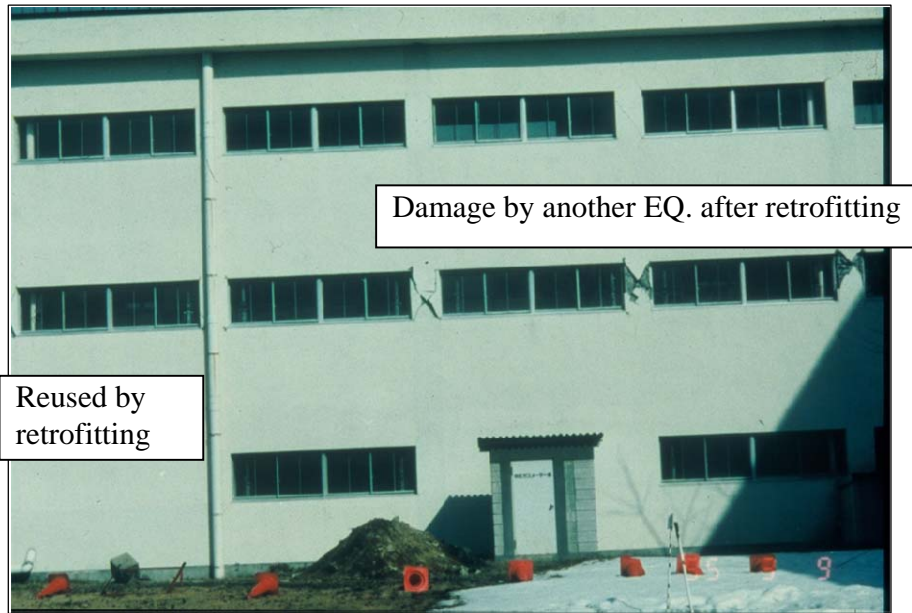


Photo 4. Short column shear failure



Photo 5. Failure of structural wall



Hyogo-ken Nambu EQ.

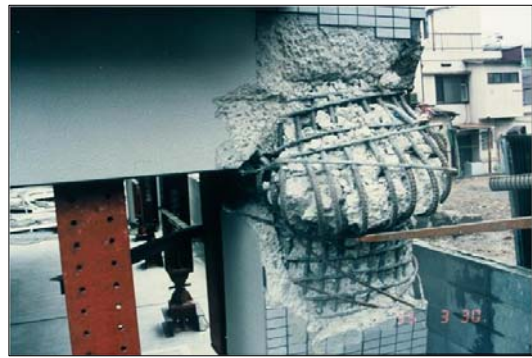


Photo 6. Soft first story

Outlines of Japanese Standard for Seismic Evaluation

Seismic capacity is numerically evaluated by the I_s -Index defined in the Standard. The I_s -Index is the product of E_0 , S_D , and T .

$$I_s = E_0 \times S_D \times T$$

where

E_0 is a basic structural seismic capacity index = C [Strength Index] \times F [Ductility Index]

S_D is a factor to modify the E_0 -Index due to structural irregularity (torsion, soft story mechanism, etc.)

T is a factor to allow for the deterioration of the original performance

A building with a higher value of I_s is expected to show better seismic performance. Figure 1 shows the load vs. displacement relationship of two different types of RC buildings. A is a RC building with high stiffness, high strength, and a high wall ratio; B is a RC moment resisting frame structure, for which strength is not high but ductility is high. The green circle denotes earthquake response, and the red cross shows the ultimate limit state of both RC buildings. Both buildings are just safe against the expected

earthquake motions, because the green circle is just to the left of the red cross on the load-displacement curves. That means that it is possible to evaluate the structural safety of both buildings using the same I_s -index. The required I_{s0} is the response due to the expected earthquake motions. It should be understood that the I_s -index is represented in the term of intensity of earthquake.

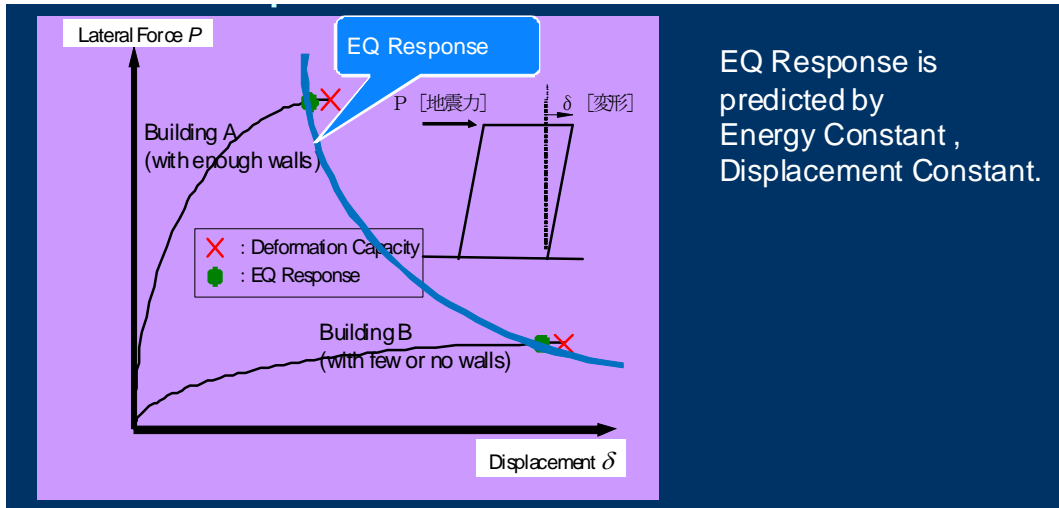


Figure 1. Load vs. displacement relationship of two different types of RC buildings

The flow of the seismic evaluation and rehabilitation process is as follows:

(1) Seismic Evaluation of the Building Concerned (I_s)

(2) Determine Required Seismic Capacity (I_{s0})

$I_s > I_{s0}$: OK -----> END

$I_s < I_{s0}$: and Rehabilitation Needed ---> GO TO (3)

I_s is the Seismic Capacity of the Building

I_{s0} is the Required Seismic Capacity

(3) Select Rehabilitation Scheme(s)

(4) Design Connection Details

(5) Re-evaluate Rehabilitated Structure

I_s (after rehabilitation) > I_{s0} : OK

I_s (Capacity) > I_{s0} (Required)

Here,

$$I_{s0} = E_s \times Z \times G \times U$$

where

E_s is the Required Basic Seismic Capacity Index = 0.6 (in standard areas)

Z is the Zone factor (seismicity, expected PGA etc.)

G is the Soil factor (amplification, topography etc.)

U is the Usage (Importance) factor

In Japan, I_{so} (or E_s) is determined from nonlinear response considering expected earthquake motions, and probabilistic studies on the I_s -index vs. observed damage in past earthquakes. Figure 2 shows the relationship of damage ratio to the I_s -index. In the figure 2, The blank bars express relative frequency distribution of I_s level of the buildings in Shizuoka Prefecture. This distribution can be similar to lognormality distribution like line 1. The hatch bars express the relative frequency of the building which suffered big damage by 1968 Tokachi-oki earthquake and 1978 Miyagi-ken-oki earthquake. This can be similar by lognormality distribution like line 3, too. It is found there is no buildings whose I_s is above 0.6 suffered big damage.

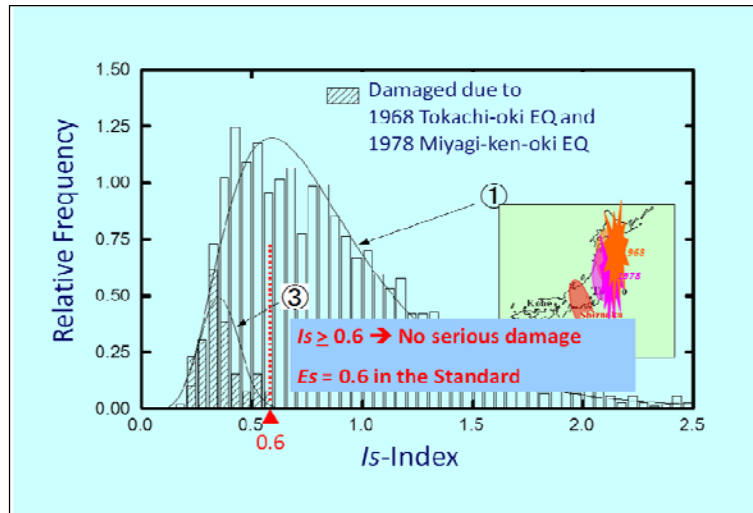


Figure 2. Relationship of damage ratio to I_s -index.

Rehabilitation Scheme

Increasing strength, ductility, and both are the Rehabilitation scheme for RC buildings (Figure 3). A typical method for increasing strength is adding a structural wall in the frame as shown in Photo 7. Photo 8 is an example of ductility rehabilitation. This method is effective for a structure that has a small number of non-ductile members that govern the ultimate limit state. Other rehabilitation methods include base-isolation, shown in Photo 9, and exterior frame rehabilitation shown in Photo 10.

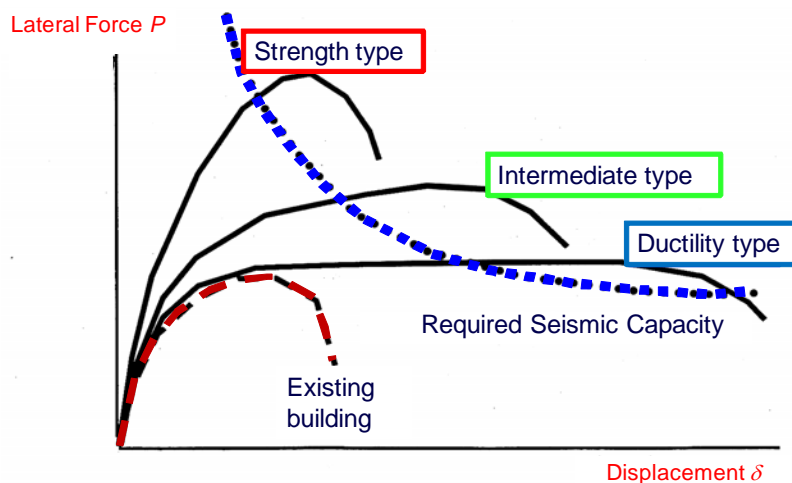


Figure 3. Rehabilitation scheme for RC buildings



Photo 7. Increasing strength by adding a structural wall



Photo 8. Ductility rehabilitation



Photo 9. Base-isolation

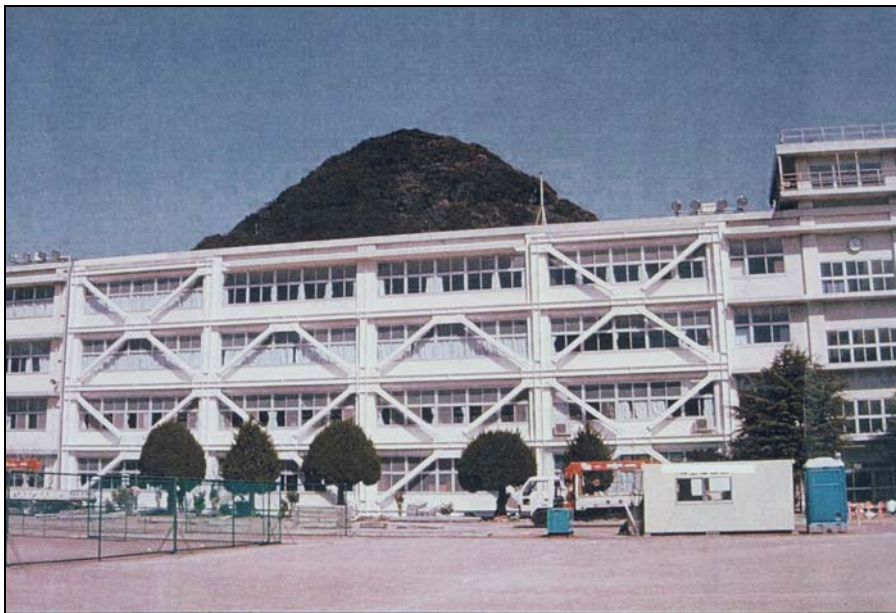


Photo 10. Exterior frame rehabilitation

ISO/CD 16711 SEISMIC ASSESMENT AND RETROFIT OF CONCRETE STRUCTURES

It is necessary to establish principles for seismic assessments, selection of the seismic retrofit scheme, the framework of the procedure for screening vulnerable structures, and the methods of executing seismic retrofits. This international standard provides the standard work items related to seismic assessment and retrofit, standard procedures in each stage, and it makes the contents and the scope of each duty clear. The scope of this international standard includes reinforced concrete structures and pre-stressed concrete structures which were designed based on the design standard established in an area or a specific country. This standard does not apply to unreinforced concrete and masonry structures.

In this international standard, the seismic performance of existing reinforced concrete structures is expressed in term of the intensity of earthquake motions that will lead the structures to the safety limit state. As a result, whether the existing RC structures fulfil the provisions of the design standard in the specific country or area does not matter. That is a key principle of this standard.

The retrofit can be also conducted based on seismic performance, not on whether the seismic retrofit meets an existing standard. Because this international standard sets the rational performance requirement described above, the vulnerable parts of the structure that should be reinforced are clearly identified.

Detailed seismic assessment, retrofit design and the execution, construction management and the inspection should be conducted by competent persons with the appropriate qualifications required by their national body.

The ISO/CD 16711 standard for Seismic Assessment and Retrofit of Concrete Structures is discussed in ISO/TC 71/SC 7/WG 4. The Framework of Seismic Assessment and Retrofit is shown in Figure 8. In Chapter 3 preliminary assessment and investigation items are listed, and the targeted building is judged for whether or not it should go on for a detailed assessment. In Chapter 4 detailed seismic assessment, detailed investigation, and analysis are conducted according to the seismic performance objectives. In Chapter 5 the seismic retrofit plan, selection of performance objectives of the seismic retrofit, selection of basic strategy for seismic retrofit planning of retrofit seismic re-evaluation, and confirmation are provided. In chapter 6 seismic retrofit execution, detailed inspection for construction, planning of retrofit construction, and quality assurance are required. The procedure should be initiated in order, starting from the first phase, but the procedure may be finished at any stage according to the specific situation under consideration.

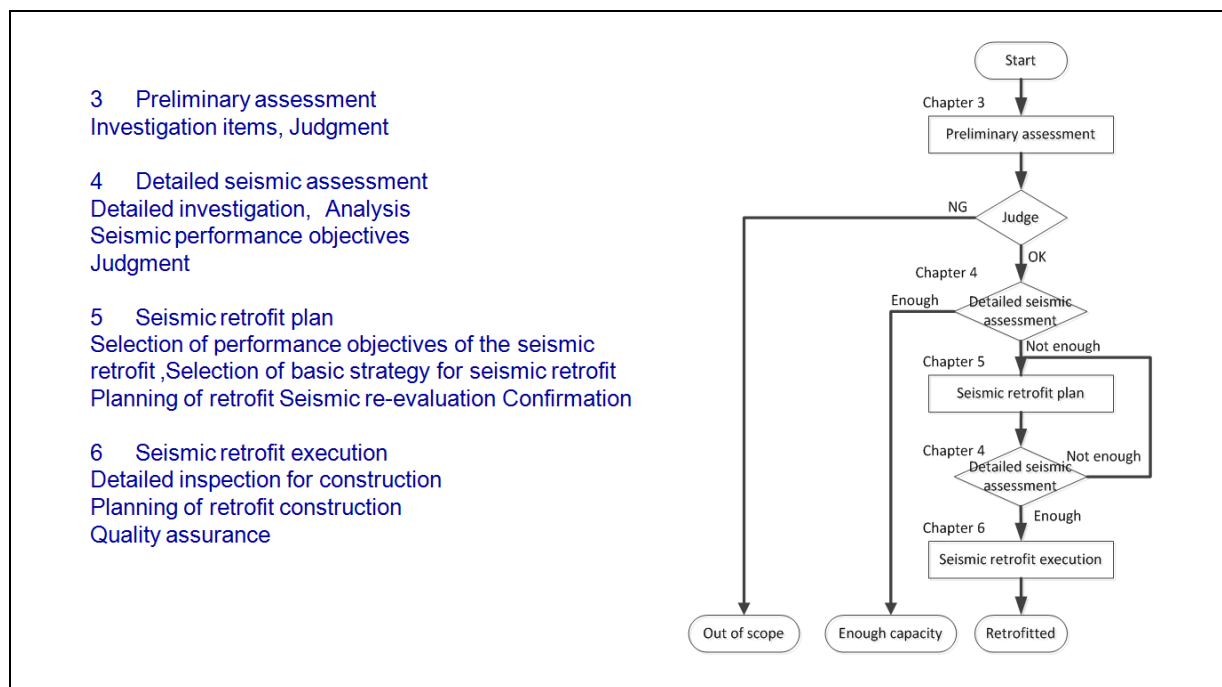


Figure 8. Framework of seismic assessment and retrofit

CONCLUSIONS

Japan has developed the Seismic Evaluation Standard and Rehabilitation Guidelines for RC buildings. The Standard has been applied in Japan to many RC buildings since the 1970's, and strengthening of many RC buildings has been completed. We hope that our technology will help to mitigate earthquake disasters around the world through the ISO Standard.

ACKNOWLEDGMENTS

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REFERENCES

1. Standard for Seismic Evaluation of Existing Reinforced Concrete Buildings, 2001, Guidelines for Seismic Retrofit of Existing Reinforced Concrete Buildings, 2001, and Technical Manual for Seismic Evaluation and Seismic Retrofit of Existing Reinforced Concrete Buildings, 2001, (Translated by Building Research Institute).