UNIVERSIDAD NACIONAL DE INGENIERIA
FACULTAD DE INGENIERIA CIVIL
CENTRO PERUANO JAPONES DE
INVESTIGACIONES SISMICAS Y
MITIGACION DE DESASTRES

(Texto de la Conferencia presentada en el Seminario Internacional de Planeamiento, Diseño, Reparación y Adminsitración de Hospitales en Zonas Sísmicas Realizado en Lima - Perú, del 20 de Agosto al 9 de Setiembre de 1989)

"THE OUTLINES OF THE GUIDELINES FOR POST-EARTHQUAKE DAMAGE INSPECTION AND RESTORATION OF R/C BUILDINGS"

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RESUMEN

Se describen las técnicas japonesas de inspección post-sismo y de rehabilitación de edificios diafragmados de concreto armado dañados por terremotos. Estas técnicas han sido desarrolladas por investigaciones conjuntas bajo la cooperación entre instituciones gubernamentales, universidades y empresas privadas, y sirven de directrices para la inspección y toma de decisiones que afectan a edificios construidos con anterioridad a la vigencia de las actuales normas de edificación.

ANEXO A "Identificación y evaluación de edificios sísmicamente vulnerables (con anotaciones relativas al caso de hospitales)". (Héctor Gallegos). ESTE DOCUMENTO ES LA PARTE PERTINENTE DEL TRABAJO PRESENTADO POR EL PROF. OHKUBO, EN LAS 5as. JORNADAS CHILENAS DE SISMOLOGIA E INGENIERIA ANTISISMICA, AGOSTO 1989.

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The guidelines was developed in 1985 as a part of "The Synthetic Research Projects for Development of Restoration Techniques to Earthquake Damaged Structures", and was published in 1989 as a popular edition (Ref. 6).

The guidelines consists of (1) the techniques for inspection and evaluation for the buildings damaged and (2) the techniques for restoration for them. The general flow from beginning inspection to completing restoration is illustrated in Figure-0.

The damage is generally inspected with several objectives. One of the objectives is to prepare statistical data of the disaster, and another is to use the inspected results for the emergency treatment immediately after an earthquake and for the permanent restoration planning. Therefore, we need to have different types of damage inspection methods for each inspection stage and each objective.

Emergency inspection and evaluation Emergency inspection and evaluation immediately after an earthquake has two important objectives. The first objectives is to inspect a risk of collapse of heavily damaged buildings against following aftershocks, and to suggest the prohibition of entrance to the building if dangerous. The second objective is to inspect the safety of non-damaged and slightly damaged public buildings and to determine the suitability of use, because a public building (in particular school buildings) has to serve the function as a shelter for evacuation at the time of disaster. Such inspection and evaluation should be made speedily in about half an hour for a building, using the prescribed manual (see Table-6). The inspection is done normally from outside of a building. However, the interior safety should be investigated in a public building. Persons in charge of the inspection may not be structural experts but ordinary building engineers of local government.

Inspection items in emergency inspection Followings is investigated ; 1) overall inclination of a building, 2) overall settlement of a building, 3) damages of structural members, 4) possible overturning of sub-structures such as the chimnies, exterior staircases, and others, 5) possible falling of exterior finishings, exterior curtain walls, signboards fixed on the exterior walls, and others.

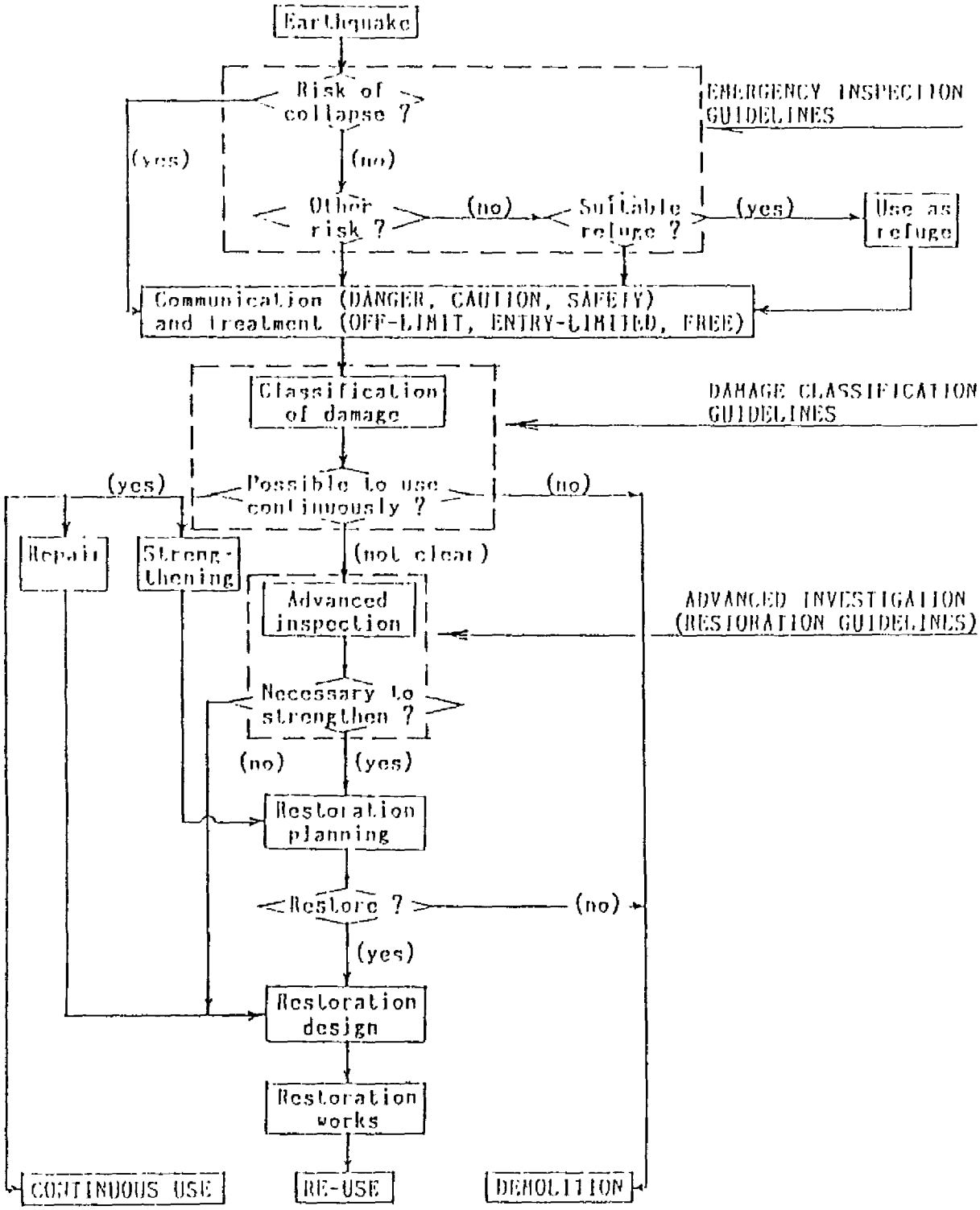

Figure-9 General Flow-Diagram for Post-Earthquake Inspection, Evaluation and Restoration

EMERGENCY INSPECTION FROM OF EARTHQUAKE DAMAGE
(FOR REINFORCED CONCRETE BUILDINGS)

TIME AND DATE OF INSPECTION
TIME : □a.m.□p.m._____ DAY _____ MON _____ YEAR _____
NAME OF INSPECTOR : _____
1. DESCRIPTION OF BUILDING INSPECTED
1.1 NAME : _____
1.2 LOCATION : _____
1.3 OWNER : _____ TEL _____
1.4 CONTACT PERSON : _____ TEL _____
1.5 USE :
□PRIVATE USE : □RESIDENCE □APARTMENT □OFFICE □STORE
□WAREHOUSE □FACTORY
□OTHER _____
□PUBLIC USE : □SCHOOL □NURSERY □CITY HALL □PUBLIC HALL
□POLICE ST □FIRE ST □HOSPITAL □GYMNASIUM
□ASSEMBLY HALL □BROADCAST ST
□OTHERS _____
1.6 NUMBER OF FLOORS : ABOVE THE GROUND _____
BASEMENT _____ PENT HOUSE _____
1.7 STRUCTURAL SYSTEM :□ MOMENT RESISTING FRAME □ FLAT SLAB
□ WALL (BOX) TYPE STRUCTURE
1.8 CLADDING : □ MORTAR □ TILE □ CURTAIN WALL □ BRICK
□ SHEET METAL □ NONE □ OTHERS _____
2. INSPECTION
2.1 INSPECTION FOR STRUCTURES

(EXTERIOR DAMAGE)	DAMAGE RANK (A)	(B)	(C)
* OVERALL INCLINATION (Deg)	□<1	□ 1 - 2	□>2
* OVERALL SETTLEMENT (m)	□<0.2	□ 0.2 - 1	□>1.0

* DAMAGE TO STRUCTURAL MEMBERS AT THE FLOOR NO. : _____
(a) IN CASE OF FRAME STRUCTURE / FLAT SLAB
TOTAL NUMBER OF EXTERIOR COLUMNS : _____
NUMBER / RATIO OF EXTERIOR COLUMNS TO DAMAGE RANK .
RANK-IV _____ / □<10 % □ 10 - 20 % □>20 %
RANK-V _____ / □<1 % □ 1 - 10 % □>10 %
(b) IN CASE OF WALL (BOX) TYPE STRUCTURES
TOTAL LENGTH OF EXTERIOR WALLS : _____(m)
LENGTH / RATIO OF EXTERIOR WALLS TO DAMAGE RANK :
RANK-IV _____m / □<10 % □ 10 - 20 % □>20 %
RANK-V _____m / □<1 % □ 1 - 10 % □>10 %

(INTERIOR DAMAGE)
(a) IN CASE OF FRAME STRUCTURE / FLAT SLAB
TOTAL NUMBER OF EXTERIOR COLUMNS : _____
NUMBER / RATIO OF EXTERIOR COLUMNS TO DAMAGE RANK :
RANK-IV _____ / □<10 % □ 10 - 20 % □>20 %
RANK-V _____ / □<1 % □ 1 - 10 % □>10 %
(b) IN CASE OF WALL (BOX) TYPE STRUCTURES
TOTAL LENGTH OF EXTERIOR WALLS : _____(m)
LENGTH / RATIO OF EXTERIOR WALLS TO DAMAGE RANK .
RANK-IV _____m / □<10 % □ 10 - 20 % □>20 %
RANK-V _____m / □<1 % □ 1 - 10 % □>10 %

2.2 POSSIBLE RISK OF OVERTURNING OR FALLING OBJECTS

(EXTERIOR)	RISK LEVEL (a) SAFETY	(b) CAUTION	(c) DANGER
* WINDOW GLASS	□	□	□
* SIGN-TOWER	□	□	□
* SIGNBOARD	□	□	□
* STAIRCASE	□	□	□
* CLADDING	□	□	□
* EAVES	□	□	□
* BALCONY	□	□	□
* PARAPET	□	□	□
* ELEVATED TANK	□	□	□
* COOLING TOWER	□	□	□
* CHIMNEY	□	□	□
* PENTHOUSE	□	□	□
* OTHERS : _____	□	□	□
(INTERIOR)			
* CEILING	□	□	□
* LIGHTING APPARATUS	□	□	□
*OTHERS : _____	□	□	□

3. RESULTS OF INSPECTION
* TOTAL NUMBER OF RISK LEVEL-(c) : _____
* TOTAL NUMBER OF RISK LEVEL-(b) : _____
4 DECISION AND SUGGESTION

	BUILDING	BUILDING-SURROUNDINGS
* SAFETY	□	□
* CAUTION (ENTRY LIMITED)	□	□
* DANGER (OFF LIMITS)	□	□

Table-6 Post-Earthquake Damage Inspection Form for R/C Buildings for Emergency Inspection, (Ref.6)

Emergency evaluation Damage ranks for the overall inclination and settlement of a building and for the structural members are classified from (A) to (C), as shown in Table-7. Damage rank (A) can be tolerable, whereas (C) is dangerous. However, damage ranks of possible overturning and falling objects may be determined using the practical experience of an investigator.

On the basis of evaluated damage, the risk level of the building against following aftershocks is determined as (1) DANGER, (2) CAUTION, or (3) SAFETY, by the following criteria ;

(1) DANGER : 1) more than one C-rank or two B-rank items exist in structural members, 2) a C-rank item exists in possible overturning or falling objects.
(2) CAUTION : more than one B-rank item exists in structural members.
(3) SAFETY : inapplicable to both "DANGER" AND "CAUTION".

Inspection Items	Damage Rank		
	Rank (A)	Rank (B)	Rank (C)
1. Overall inclination of a building, θ (deg.)	Less than 1	1 - 2	More than 2
2. Overall settlement of building, S (m)	Less than 0.2	0.2 - 1.0	More than 1.0
3. Damage of structure			
(a) Frame type structures			
* Ratio of exterior columns with "Damage Rank-IV", (%)	Less than 10	10 - 20	More than 20
* Ratio of exterior columns with "Damage Rank-V", (%)	Less than 1.0	1.0 - 10	More than 10
(b) Box type structures			
* Ratio of exterior wall-length with "Damage Rank-IV", (%)	Less than 10	10 - 20	More than 20
* Ratio of exterior wall-length with "Damage Rank-V", (%)	Less than 1.0	1.0 - 10	More than 10
Following items inspected from inside shall be added to ensure the safety			
(c) Frame type structures			
* Ratio of exterior columns with "Damage Rank-IV", (%)	Less than 10	10 - 20	More than 20
* Ratio of exterior columns with "Damage Rank-V", (%)	Less than 1.0	1.0 - 10	More than 10
(d) Box type structures			
* Ratio of exterior wall-length with "Damage Rank-IV", (%)	Less than 10	10 - 20	More than 20
* Ratio of exterior wall-length with "Damage Rank-V", (%)	Less than 1.0	1.0 - 10	More than 10

Table-7 Inspection Items and Damage Rank for Emergency Inspection, (Ref.6)

The buildings and the surrounding area determined as "DANGER" should be posted "DANGER", and the entrance should be generally prohibited. The buildings and the surrounding area determined as "CAUTION" should be posted "WARNING AGAINST ENTRANCE". The decision of "SAFETY" is applied only to public buildings. The public buildings determined as "SAFETY" may be used as a shelter for evacuation or as a place for medical treatment.

Damage evaluation for permanent use The Guidelines of Damage Classification is applied to the damaged buildings after several days of an earthquake in order to classify the damage degree of damaged buildings and to decide the treatment of damaged buildings, such as re-use without any structural repairs, re-use after repairing or strengthening, or demolition without restoration.

The damage evaluation in this stage is made primarily on the basis of potential seismic capacity of the structure after damage. However, the estimation of potential seismic capacity by the Guidelines of Damage Classification is rather approximate. Therefore, if the decision for the treatment is difficult, further advanced investigation shown in "The Guidelines for Restoration" may be applied to the building.

Inspection for damage classification The almost same inspection items as "Emergency Inspection" are investigated, but the more detailed inspection is required. The investigation is made by the structural engineers permitted by the governmental organizations.

Damage classification and permanent treatment The criteria for damage classification are shown in Table-8 to Table-10, respectively. The estimation of Σdi in Table-10 (damage classification against structures) is made using Table-11. The permanent treatment for damaged buildings is recommended as shown in Table-12, using the results from Table-8 to Table-10.

Overall Inclination Angle θ (rad)	θ < 1/100	1/100 - 3/100	3/100 - 6/100	θ > 6/100
Damage Class	Small or Slight	Moderate	Severe	Collapse (Overturned)

Table-8 Identification of Damage due to Overall Inclination of a Building for Damage Classification, (Ref.6)

Maximum Settlement S (m)	S < 0.2	0.2 - 1.0	S > 1.0
Damage Class	Slight	Moderate	Severe

Table-9 Identification of Damage due to Overall Settlement of a Building for Damage Classification, (Ref.6)

Maximum Damage Ratio Σdi (%)	Σdi < 5	5 - 10	10 - 50	Σdi > 50
Damage Class	Slight	Small	Moderate	Severe Collapse

Note : Building with the story where structural members of damage rank-V occupy more than 50 % shall be judged as collapse

Table-10 Identification due to Damage of Structures for Damage Classification, (Ref.6)

Rank	Damage state of structural members	Existing ratio of damaged members	Damage ratio di (%)
I	* Visible narrow crack on surface of concrete (crack width is less than 0.2 mm)	Less than 10%	0.5
		10 - 20 %	1
		20 - 30 %	2
		30 - 40 %	3
		40 - 50 %	4
		More than 50%	5
II	* Visible clear crack on surface of concrete (crack width is about 0.2 - 1.0 mm)	Less than 5 %	0.5
		5 - 10 %	1
		10 - 15 %	2
		15 - 20 %	4
		20 - 25 %	5
		25 - 30 %	6
		30 - 35 %	8
		35 - 40 %	9
		40 - 45 %	10
		45 - 50 %	11
		More than 50%	13
III	* Local crush of covered concrete * Considerably wide crack (crack width is about 1 - 2 mm)	Less than 3 %	2
		3 - 5 %	3
		5 - 10 %	5
		10 - 15 %	8
		15 - 20 %	10
		20 - 25 %	13
		25 - 30 %	15
		30 - 35 %	18
		35 - 40 %	20
		40 - 45 %	23
		45 - 50 %	25
		More than 50%	30
IV	* Remarkable crush of concrete with exposure of re-bars * Spalling of covered concrete	Less than 3 %	3
		3 - 5 %	5
		5 - 10 %	9
		10 - 15 %	14
		15 - 20 %	18
		20 - 25 %	23
		25 - 30 %	27
		30 - 35 %	32
		35 - 40 %	36
		40 - 45 %	41
		45 - 50 %	45
		More than 50%	50
V	* Bending of re-bars * Crush of core concrete * Visible vertical deformation of columns * Visible settlement and/or inclination of floor	Less than 3 %	4
		3 - 5	7
		5 - 10	11
		10 - 15	21
		15 - 20	27
		20 - 25	34
		25 - 30	40
		30 - 35	48
		More than 35%	50

Table-11 Damage Rank of Structural Members and Damage Ratio for Damage Classification, (Ref.6)

Seismic Intensity (JMA)	Identification of Damage and Permanent Treatment				
	Slight	Small	Moderate	Severe	Collapse
Less than or equal to "V"	—	—	Repairing or strengthening (to advanced investigation)	Strengthening or demolition	Strengthening or demolition
Greater than or equal to "VI"	Re-use	Re-use	Repairing	Repairing or strengthening (to advanced investigation)	Strengthening or demolition

Table-12 Recommended Permanent Treatment for Damaged Buildings for Damage Classification, (Ref.6)

Estimation of seismic capacity for damaged buildings The more advanced investigation in "The Guidelines for Restoration Techniques" is applied to the damaged buildings, whose damage level is not clear only by "The Guidelines of Damage Classification".

The estimation of seismic capacity for damaged buildings is also done on the basis of same concept as the evaluation of seismic capacity for existing buildings, usually applying the method of phase-2 or -3 screening. For the damaged buildings, the damage index ϕ, defined by Equation (11) as the ratio of the potential seismic capacity after damage to that before damage, is calculated, and Table-13 is applied to the building to decide that either strengthening should be required or should not be required.

$$\phi = (1 - (Is'/Is)) \times 100 \quad (\%) \qquad (11)$$

where, Is' : seismic structural index of the building after damage.
Is : seismic structural index of the building before damage.

Construction Year *1	Seismic Intensity by Japanese Meteorological Agency *2			
	Less than IV	Lower V	Upper V	Greater than IV
Before 1971	20%	30%	40%	50%
After 1971	30%	40%	50%	

Note) *1 : The building, whose hoop spacing is less than 10 cm, may be considering "after 1971", even if it was constructed before 1971.
*2 : In order to divide the seismic intensity "V" into "Lower V" and "Upper V", the ground acceleration of 150 gal may be used as boundary.

Table-13 Upper Limit Value of Earthquake Damage Index - Φ , (%) for Advanced Investigation, (Ref.6)

ACKNOWLEDGMENT

The works to revise each guidelines in this paper were done through the discussion in Sub-Committee on Reinforced Concrete Buildings chaired by Prof. Tsuneo Okada, promoted by The Japan Building Disaster Prevention Association. The members of the sub-committee are M. Hirosawa, M. Murakami, N. Iida, T. Kaminosono, W. Gojo, I. Matsuzaki, Y. Yamamoto, S. Sugano and author. The suggestions and cooperation for this paper by the members of the sub-committee are deeply acknowledged.

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