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SEISMIC CAPACITY OF REINFORCED CONCRETE BUILDINGS WHICH SUFFERED 1985. 9. 19-20 MEXICO EARTHQUAKE

Tsuneo Okada[1)], Masaya Murakami[2)],
Tadao Minami[3)] and Yoshiaki Nakano[4)]

1) Professor, Institute of Industrial Science, University of Tokyo, 7-22-1, Roppongi, Minato-ku, Tokyo 106, Japan
2) Professor, Department of Architecture, Chiba University, 1-33, Yayoi-cho, Chiba City, Chiba 260, Japan
3) Professor, Earthquake Research Institute, University of Tokyo, 7-3-1, Yayoi, Bunkyo-ku, Tokyo 113, Japan
4) Graduate Student, Institute of Industrial Science, University of Tokyo, 7-22-1, Roppongi, Minato-ku, Tokyo 106, Japan

SUMMARY

Seismic capacity of twelve reinforced concrete buildings suffered 1985.9.19-20 Mexico Earthquake were estimated by the Japanese Standard for Evaluation of Seismic Capacity of Existing Reinforced Concrete Buildings, and correlation between the estimated capacity and the degree of damage were examined. An applicability of the Japanese Evaluation Standard to Mexican buildings was confirmed.

INTRODUCTION

An earthquake damage is a result of the real shaking table test on the structures. Therefore, the characteristics and performance of the structures suffered the earthquake should be precisely investigated to help mitigating the future earthquake damages. From this point of view, the seismic capacity of twelve reinforced concrete buildings in the Mexico City which suffered 1985.9.19-20 Mexico Earthquake were estimated by the "Japanese Standard for Evaluation of Seismic Capacity of Existing Reinforced Concrete Buildings(Ref. 1)" by the Technical Cooperative Mission sent to the Mexico City by the Japan International Cooperation Agency, Japanese Government(Ref. 2).

The purpose of this paper is to describe the estimated seismic capacity of twelve buildings and the correlation between the seismic capacity and the structural performance during the earthquake.

INVESTIGATED BUILDINGS

Twelve buildings investigated are listed in the Table 1. All are located at the down town of the Mexico City. Therefore, their soil conditions are quite bad. Building #1 is 12 storied office building with a basement which was severely damaged but avoided collapse probably due to the core wall located at the center part of the building from the basement through the top floor continuously. Slab system was flat slab called "Losa Plana" in Mexico.

Buildings #2 and #3 are 4 storied college buildings connected by an expansion joint each other. One had medium damage mostly on the columns and the other small structural damage. Non-structural elements such as exterior and interior hollow damaged.

Buildings #4 to #10 are typical structural types of apartment buildings in the Tlaltelolco Housing Complex, which had been constructed during the period of 1958 to 1964. There are 102 apartment buildings consisting of eight types; A, B, C, I, K, L, M, N. However, the structural systems are 7 types because the types M and N are identical.

Type A is 4 or 5 storied skip-floor system. Types B and I are 8 storied, Types C, K and L are 14 storied and Types M and N are 21 storied. Floor system of all types is flat slab. Wall framing system without column is used for Types M and N, while the other have open frame system with shear walls and/or bracing system. Floating foundation and friction piles are used for all types.

The most serious damage was observed in Type C. One of the Type C buildings (named Nuevo Leon) totally collapsed. No severe damage was observed in Type A buildings. Other features of the damage are described in the following chapter.

Buildings #11 and #12 are junior high school buildings which were designed according to the 1980 - 1982 CAPFCE standard (Ref. 3).

DEGREE OF DAMAGE

Damage classification is shown in the last column of Table 1. For the buildings #1, 2, 3, 11 and 12, the Japanese five level evaluation method for earthquake damage (Ref. 4) was used. For all buildings in Tlaltelolco Housing Complex, the evaluation by RIOBOO S.A. consisting of two level classification for structures and two level for non-structural elements was used.

Since the Japanese method was also applied to 14 buildings by the authors, both RIOBOO's classification and Japanese classification are compared in Fig.1. In comparing them, severe damage and medium damage in non-structural elements by RIOBOO's classification are corresponded to small damage and slight damage by Japanese classification, respectively. For the buildings damaged in non-structural elements, the RIOBOO's evaluation of damage is one rank higher than Japanese one. However, there is not so significant difference between both classifications. Therefore, the severe and medium damages in non-structural elements by RIOBOO's classification are allocated into small and slight damages by Japanese classification, respectively, in the damage analysis in this paper.

EVALUATION OF SEISMIC CAPACITY

The Japanese Standard for Evaluation of Seismic Capacity of Existing Reinforced Concrete Buildings (Ref. 1) was used. The standard evaluates the seismic capacity at each story and in each direction of the building by the following index;

$$Is = Eo \cdot G \cdot S_D \cdot T \qquad (1)$$

where, Eo = basic structural index calculated by ultimate horizontal strength, ductility, number of stories and story level considered.
G = local geological index to modify the Eo-index.
S_D = structural design index to modify the Eo-index due to the grade of the irregularity of the building shape and distribution of stiffness.
T = time index to modify the Eo-index due to the grade of the deterioration of strength and ductility.

The standard values of the G–, S_D– and T–indices are 1.0. The Eo index for the simple structural system can be expressed by the product of the ultimate horizontal strength index in terms of story shear coefficient (C), ductility index(F) and story index (Ø). Story index (Ø) at the first floor level is 1.0. Therefore, the Eo index at the first floor level of the simple structure can be defined as;

$$Eo = C \cdot F \quad \ldots\ldots (2)$$

The concept of Eo index corresponds to the seismic coefficient (a) in the Mexican seismic design codes shown in Eq.(3).

$$C = a / Q \quad \ldots\ldots (3)$$

where, C : design story shear coefficient.
a : seismic coefficient. For lake zone in Mexico City, (a) was 0.24 and raised to 0.40 by the Emergency Code 1985.10.
Q : ductility coefficient. For flat slab construction, Q was 4.0. Now, decreased to 2.0.

Dimensions of the structures, bar arrangement, and material properties defined in the design drawings, calculations and specifications were used in estimating the seismic capacity.

RELATIONSHIP BETWEEN ESTIMATED SEISMIC CAPACITY AND DEGREE OF DAMAGE

Relationship between the estimated seismic capacity and the degree of damage is illustrated in Fig. 2. The Is-index of the east-to-west direction is plotted in the abscissa and that of the north-to-south direction is in the ordinate for each building. The mark of ● indicates severe damage and the mark of o small or slight or no-damage. The size of the mark shows the number of buildings and shaded and hatched portions show the ratio of severe damage, and medium damage, respectively. According to decrease of the Is-indices, the number of damaged buildings increase and the Is-index of around 0.4 is a border between damage and no-damage.

Fig. 3 demonstrates the similar characteristics of Japanese buildings experienced 1968 Tokachi-Oki Earthquake, 1978 Izuoshima- Kinkai Earthquake and 1978 Miyagiken Earthquake. The border of the damage and no-damage is about 0.6 in Is-index.

CONCLUDING REMARKS

A good agreement between the seismic capacity of the structural system and the degree of damage of the buildings experienced 1985 Mexico Earthquake was obtained. A consideration of soil-structure interaction has been left for further study.

ACKNOLEDGEMENT

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*2 \ *1	No Damage	Slight Damage	Small Damage	Medium Damage	Collapse or Severe Damage
Structural Severe Damage				M	I, K
Structural Medium and Slight Damage		M	C		
Non-structural Severe Damage		B, C, L		I, K	
Non-structural Medium and Slight Damage			L		
Non-damaged	A, A	B			

*1 : damage evaluation by RIOBOO S.A. in Mexico.
*2 : damage evaluation by Japanese method on apartment buildings in Tlaltelolco Housing Complex

Fig.1 : Relationship Between Damage Evaluation by RIOBOO S.A. and Japanese Method (Alphabets Show The Type of Building)

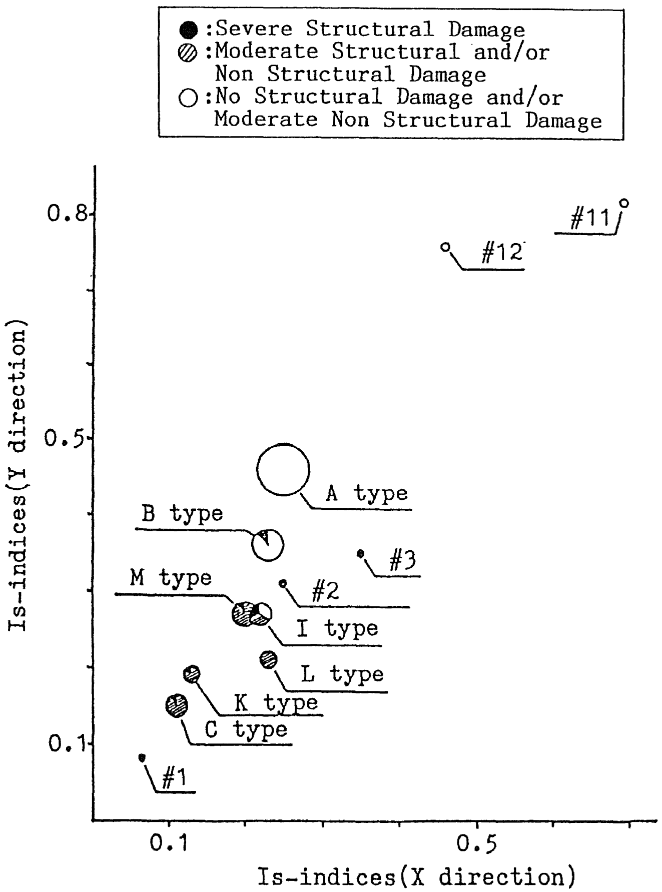

Fig.2 Is-indices by Second Level Screening Procedures vs. Earthquake damage in Mexico [Ref.(2)]

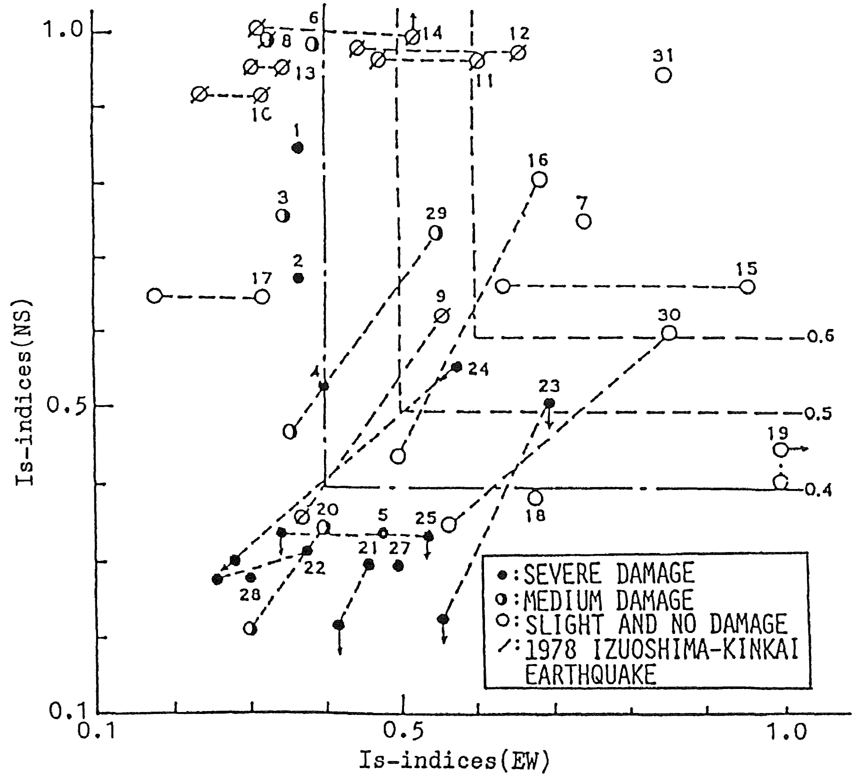

Fig.3 Is-indices by Second Level Screening Procedures vs. Earthquake damage in Japan [Ref.(5)]

Table 1 : Estimated Seïsmic Capacity and Degree of Damage

No.	Building	Year of Construction	Stories	Natural Periods *1 (sec.) 1st	2nd	2nd Level Screening Procedure: Is-Indices at 1st Floor *2 ΣC	Eo	Is	Minimum Is-Indices Eo	Is	(Floor)	Structural Damage *5 Severe	Medium	Non-Structural Damage *5 Severe	Medium	Sum of Buildings
1.	Office	1980-1982	12	2.3	0.56	0.04	0.06	0.06	<------		(1F)	(Severe) *4				
				1.7	0.44	0.05	0.06	0.06	<------		(1F)					1
2.	College	1982	4	0.7	----	0.25	0.25	0.25	<------		(1F)	(Medium) *4				
				0.98	----	0.31	0.31	0.31	<------		(1F)					1
3.	College	1983	4	0.65	----	0.29	0.26	0.26	<------		(1F)	(Slight) *4				
				0.96	----	0.35	0.35	0.35	<------		(1F)					1
4.	TLALTELOLCO Type I	1958-1964	8	1.0	----	0.28	0.25	0.22	<------		(1F)					
				1.25	0.48	0.37	0.35	0.27	<------		(1F)	3	2	1	3	9
5.	TLALTELOLCO Type M		21	1.8	0.42	0.065 *3			----	----	(--)					
				2.2	0.58	0.089 *3			----	----	(--)	1	11	---	---	12
6.	TLALTELOLCO Type L		14	2.0	0.42	0.26	0.25	0.23	0.18	0.17	(7F,9F)					
				1.65	0.37	0.25	0.25	0.21	<------		(1F)	---	2	3	---	5
7.	TLALTELOLCO Type K		14	1.9	0.57	0.17	0.17	0.13	<------		(1F)					
				1.8	0.48	0.26	0.26	0.19	<------		(1F)	1	4	1	---	6
8.	TLALTELOLCO Type A		4	----	----	0.15	0.15	0.11	0.19	0.19	(2F,3F)					
			5	----	----	0.37	0.46	0.46	<------		(1F)	---	---	---	---	44
9.	TLALTELOLCO Type C		14	1.63	0.42	0.15	0.15	0.15	<------		(1F)					
				1.15	0.40	0.37	0.29	0.23	0.17	0.15	(4F)	1	5	4	---	10
10.	TLALTELOLCO Type B		8	0.63	----	0.26	0.25	0.23	<------		(1F)					
				0.53	----	0.39	0.40	0.36	<------		(1F)	---	---	2	14	16
11.	School (Standard Type)	1980	4	----	----	0.49	0.47	0.47	0.46	0.46	(2F)	(No Damage) *4				
				----	----	0.76	0.76	0.76	<------		(1F)					1
12.	School (Standard Type)		3	----	----	0.69	0.69	0.69	0.63	0.63	(2F)	(No Damage) *4				
				----	----	0.82	0.82	0.82	<------		(1F)					1

*1 : measured by microtremor.
*2 : upper row ; longitudinal direction, lower row ; transverse direction
*3 : by non-linear static loading analysis.
*4 : estimated by 5 level evaluation method for eqrthquake damage in Japan, i.e. collapse-severe, medium, small, slight, and no damage.
*5 :damage evaluation by RIOBOO S.A. in Mexico. numerals show number of building.