DAMAGE TO A REINFORCED CONCRETE HOTEL BUILDING DUE TO THE OHITA EARTHQUAKE OF APRIL 21, 1975

by

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SYNOPSIS

Information about the damage to the K. L. Hotel building, damaged beyond repair during the 1975 Ohita earthquake, is given and the principal cause of the damage is presented.

INTRODUCTION

On April 21, 1975, an earthquake of an intensity in magnitude, M=6.4, affected the middle provinces of Ohita prefecture, which is located in southern part of Japan. Because the hypocenter of the main shock was only 9.3 kirometers deep, damage of the structures, especially dwelling damage, concentrated into a relatively small area (20 km × 8 km).

The K. L. Hotel located only at 2.3 kirometers northwest of the epicenter suffered great damage. Because the hotel was a relatively new reinforced concrete building built in 1964~1965, its damage attracted the attention of many structural engineers in Japan. In order to investigate the damage and its cause, a research committee[III] was organized immediately in Architectural Institute of Japan (AIJ), and the committee report was published in July 1976 [(1)]. The main purpose of this paper is to introduce the essentials of the report.

GENERAL DESCRIPTION OF THE K. L. HOTEL BUILDING

The K. L. Hotel building is a four-story reinforced concrete building containing about 70 bed rooms plus necessary support units (Fig.1). The building was designed in accordance with the provisions of the 1962 AIJ Standard for Structural Calculation of Reinforced Concrete Structures. The basement and the first story extend in plan beyond the upper three stories which have plan dimensions of about 16.8 × 61.2 meters (3 × 12 bays) and its longitudinal axis extends approximately in an east-west direction. The whole building is supported by a mat foundation which is on the three layers of soil concrete (Fig.2). Although this mat foundation is continuous all over the basement floor area, the longitudinal framing system for the basement and upper four stories is divided into three sections, the west, center and east sections, separated from each other by inserted wood panel moulds (Figs.3 and 4). The earthquake resisting system consists of reinforced concrete shear walls and moment-resisting frames.

From the laboratory tests on the materials used in the construction after the earthquake, all the main mechanical characteristics of steel bars and concretes were higher than the specified values of Japanese Industrial Standard (JIS).

EARTHQUAKE DAMAGE

Damage to the building caused by the earthquake was massive (Fig.5 and 6), however most of the severe structural damage was concentrated in the

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first story. Brief description of the significant damage to each section is as follows:

East Section (Figs.7~11): Figs.7 and 8 show the structural damage to Sections B-B and C-C, respectively. Numbers in the figures represent the crack width in mm. It is seen from these figures that the most severe damage occurred in the first story, where columns and shear walls completely collapsed and some interior columns punched through the slabs (Figs.9 and 10). Damage to the upper three stories and basement in this section was moderate but they were damaged beyond repair except for the basement.

Center Section: Damage to this section, which was the core area, was slight because of there being many walls throughout the stories.

West Section (Figs.12~14): Fig.12 shows the typical structural damage to the west section. This section suffered moderate damage to the first story columns and shear walls above the basement, and as the result of this, the upper three stories leaned slightly to the northwest. Figs.13 and 14 show the detail of typical damage to the top of the interior column and shear wall of the first story.

PRINCIPAL CAUSE OF THE DAMAGE

Seismic Force: The ground motion was severe, while the seismic design load corresponding to legal coefficient 0.16 of horizontal force specified by the Japanese Building Standard Law were considerably low. Although the ground motion at the site where this hotel was located was not recorded, it is reported by S. Omote that the peak acceleration at this site was about 420 gal [2]. Furthermore, linear elastic analyses on this hotel building indicated that a value of the first story shear force coefficient to which this building was subjected was greater than 0.35 [1]

Selection of Structural System: On the first story, though the uncracked framed shear walls carried 90 per cent of the storied shear forces, the ratios of $W / \Sigma A_w$ in N-S direction of the east and west sections were fairly greater than the ratios in other stories, especially the ratio of the east section was remarkably large (see Figs.15(a) and 15(b)). This fact shows that large stresses are induced in the shear walls during earthquakes. Moreover, there were many short columns whose shear forces were large on the first story of the east section. Such discontinuities in stiffness and strength were one of the reasons for the damage of this building.

Proportioning and Detailing of Members: The shear-force reinforcement for columns and shear walls, although permitted by the 1962 AIJ Standard, was inadequate. Such lack of adequate shear resistance capacity and ductility in shear walls and columns was one of the main factors in the severe structural damage (Figs.11 and 14).

Supervision of Works: Stirrup-ties could not be seen at the top of interior long-columns which suffered severe damage (Fig.13). The main cause of the damage that occurred in the long-columns of the first story was the lack of these stirrup-ties at the top of the interior columns.

REFERENCES

(1) Architectural Institute of Japan (AIJ), "Report on the Damage to a Reinforced Concrete Buildings due to the Ohita Earthquake of April 21, 1975," July, 1976, in Japanese.

(2) S. Omote and A. Miyake, "Maximum Ground Acceleration Estimated in the Epicentral Areas of the Ohita Earthquake Occurred in Kyushu, Japan, on April 21, 1975," 6WCEE, New Delhi, Jan., 1977.

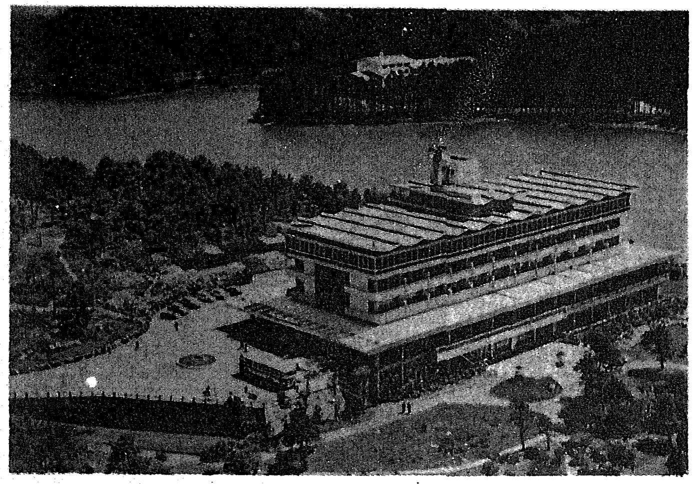

Fig.1 - East and North Elevation of the K. L. Hotel Building before the Earthquake

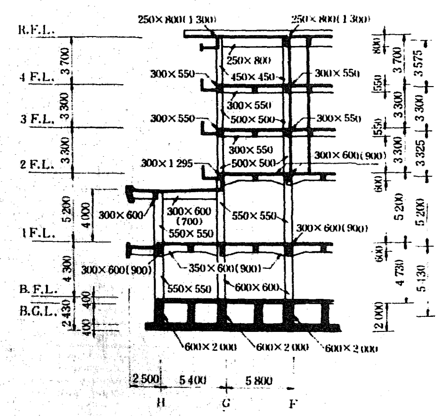

Fig.2 - Section A-A (West Elevation)

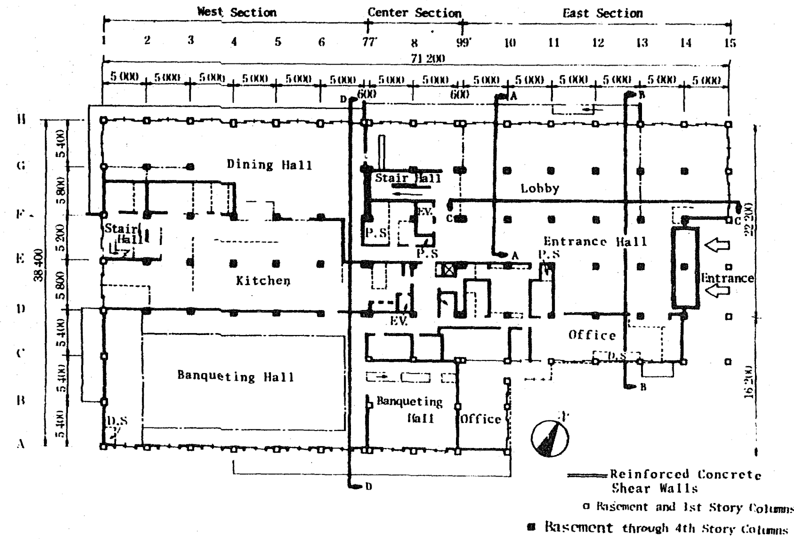

Fig.3 - Schematic First Floor Plan

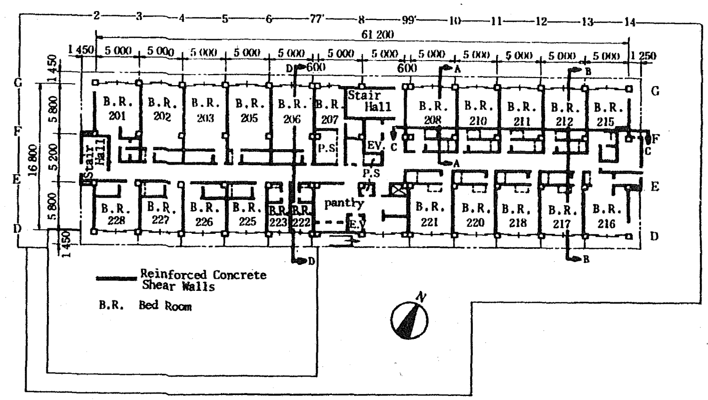

Fig.4 - Schematic Second Floor Plan

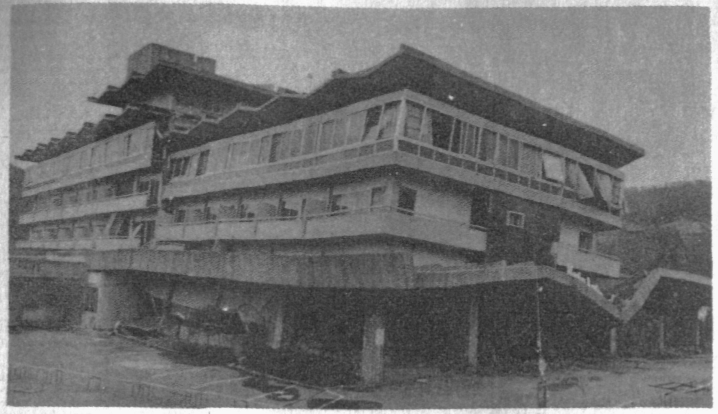

Fig.5 - South and East Sides of the K. L. Hotel after the Earthquake

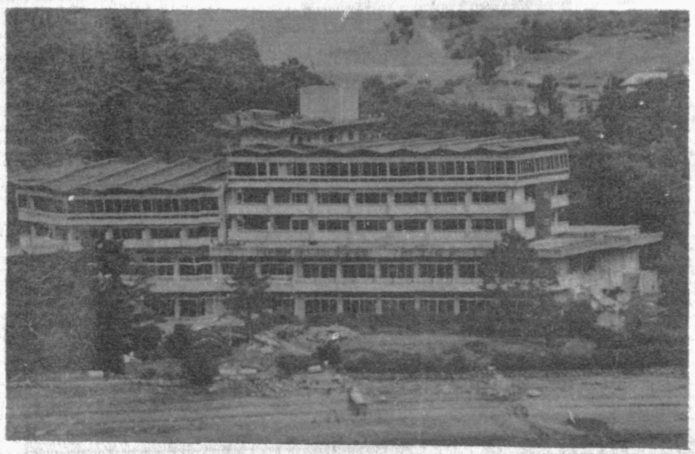

Fig.6 - North Side of the K. L. Hotel after the Earthquake

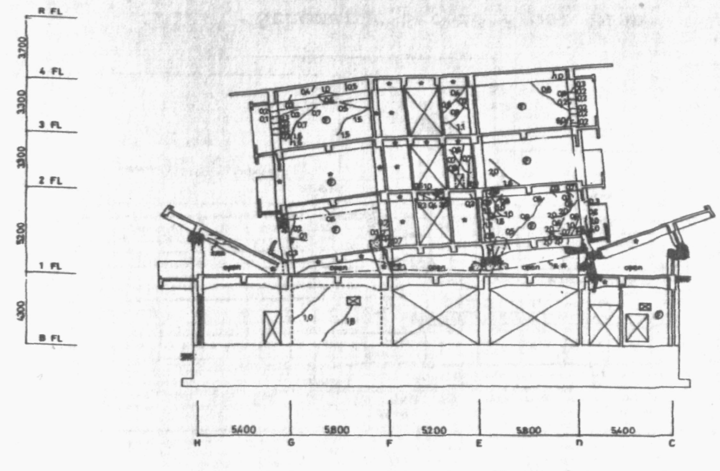

Fig.7 - Structural Damage to Section B-B (West Elevation)

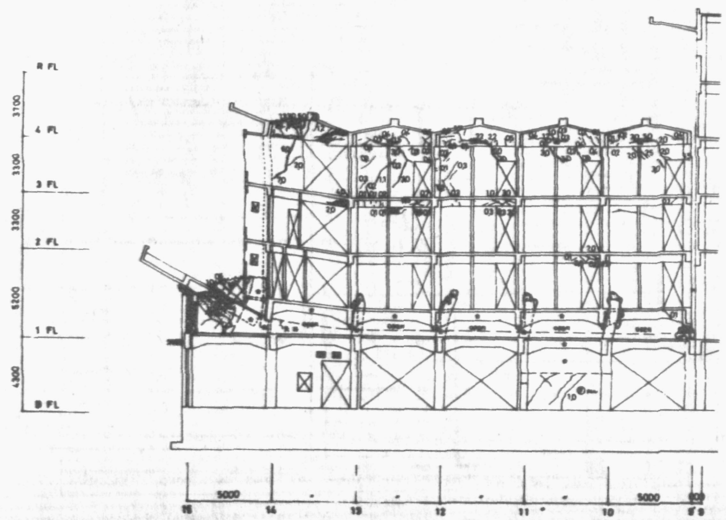

Fig.8 - Structural Damage to Section C-C (North Elevation)

Fig.9 - Detail of damage to the interior long-column at coordinates F-12 in Fig.8. Note that top of the column punched through the second floor slab.

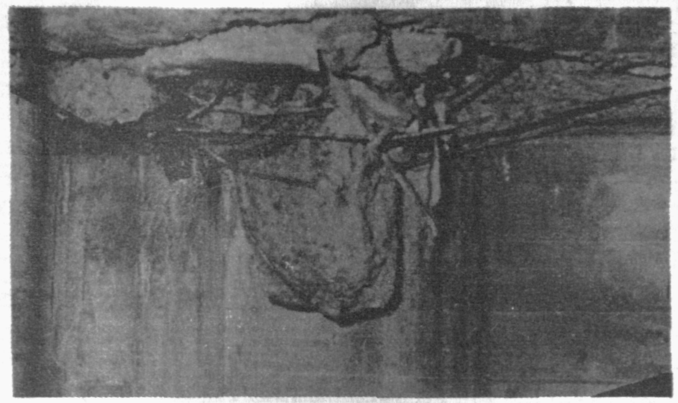

Fig.10 - Damage to the first story interior long-column at coordinates D-11. Bottom of the column punched through the first-story slab.

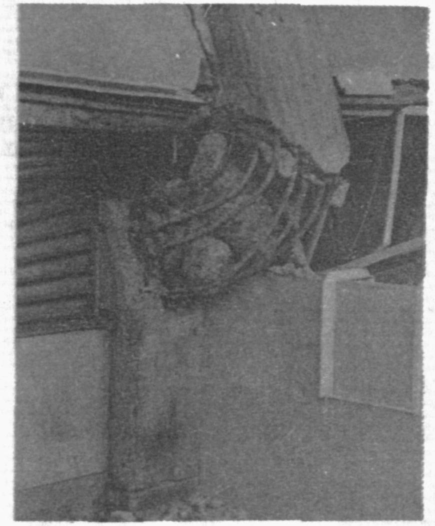

Fig.11 - Detail of damage to the exterior short-column at coordinates C-13 in Fig.8

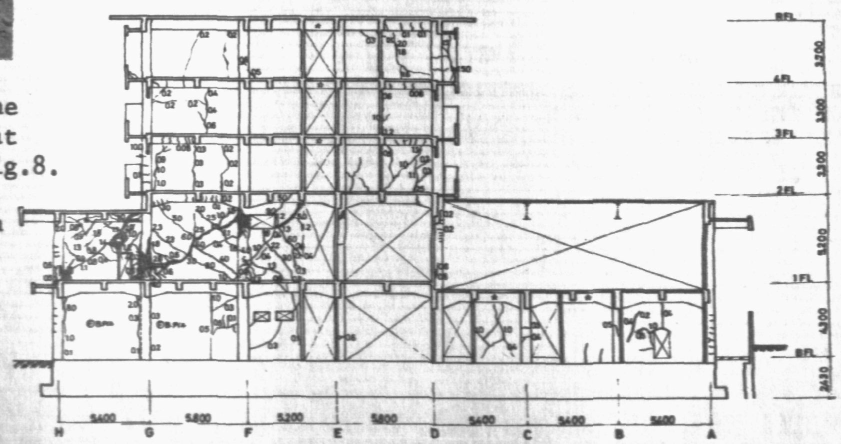

Fig.12 - Structural Damage to Section D-D (West Elevation)

Fig.13 - Detail of damage to the top of the interior long-column of the first story at co-ordinates F-3.
Note that few ties can be seen.

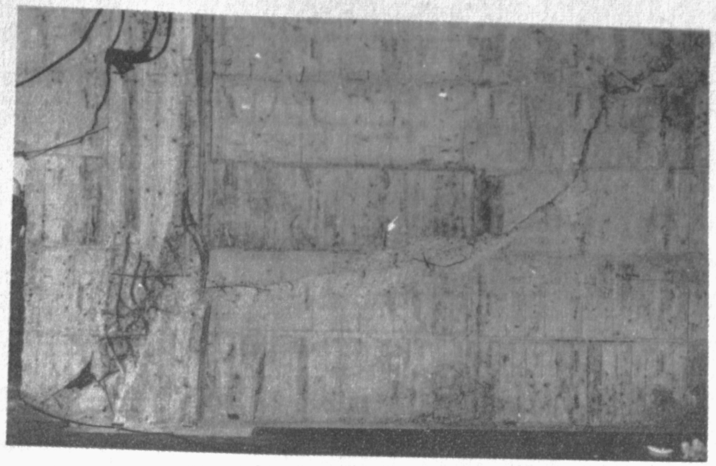

Fig.14 - Cracked shear wall

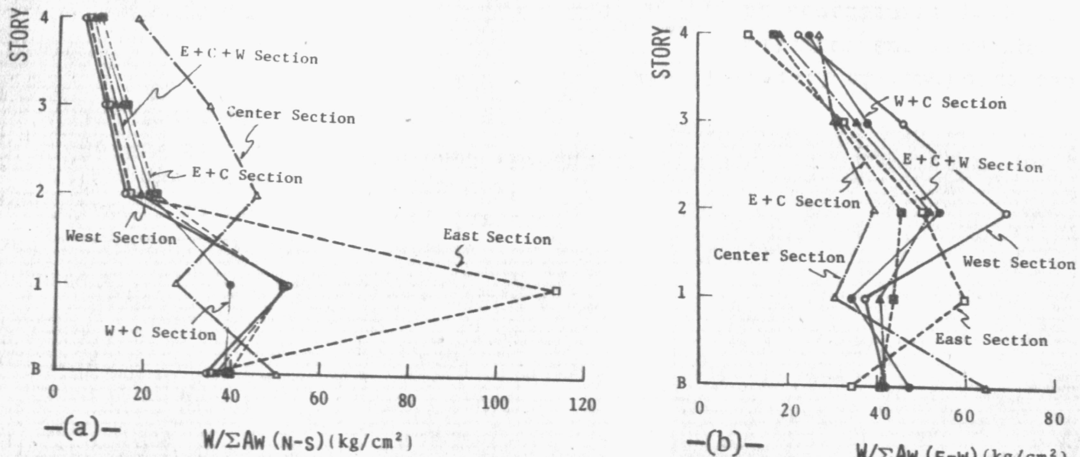

Fig.15 - The ratios of $W/\Sigma A_W$ for each section. W denotes the total of dead plus live loads of the upper stories and ΣA_W denotes the lateral cross-sectional area of the framed shear walls in the direction under consideration.