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SEISMIC STRENGTHENING OF AN EXISTING STEEL REINFORCED CONCRETE CITY OFFICE BUILDING IN SHIZUOKA PREFECTURE,JAPAN

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SUMMARY

About ten years have passed since a severe earthquake, so called Tokai Eearthquake, was predicted at the Suruga Bay by seismologists. The objective of this paper is to present an example of the evaluation of seismic performance and the seismic strengthening of the existing Numazu City Office Building in Shizuoka prefecture.

INTRODUCTION

The objective of this paper is to report an example of the seismic strengthening of the existing steel encased reinforced concrete building; Numazu City Office Building. This building is located at the north of Izu Peninsula near the Suruga Bay where Tokai Earthquake has been predicted(Fig.1). Almost all the strengthened buildings in Shizuoka Prefecture are lowrise reinforced concrete buildings, however, the building described here is 8 stories steel encased reinforced structure. Therefore, special consideration in evaluating the seismic capacity and in strengthening the structure were required.

OUTLINE OF BUILDING

This building was constructed in 1966. The building consists of two parts, i.e.,the main building of 8 stories steel encased reiforced concrete building with a basement and the assembly hall building of 2 stories reinforced concrete building with a basement(Fig.2). Main building has interior tall shear walls and exterior moment resisting frames. Assembly hall building has the moment resisting frames at 1st story and the frames with strong and stiff shear walls. The foundation is supported directly on the very solid gravel layer.

SEISMIC PERFORMANCE

<u>Procedure of Evaluation of Seismic Performance</u> Since two parts have different

types of structural system, different approachs to estimate the seismic performance are required. For the assembly hall building, the evaluation standard for reinforced concrete buildings (Ref. 1) was applied. For the main building, the evaluation standard for steel encased reinforced concrete buildings (Ref. 2) was applied. Both standards estimate the seismic performance of structure by an unified seismic performance index (I_s), accounting for the ultimate lateral strength and the ductility. In the estimation I_s-index of the main building, a non-linear member-to-member frame analysis, which is not required in the standard, was incorporated. The analytical model of a frame with shear wall in main building is illustrated in Fig. 4. In order to estimate the effect of the soil pressure at the basement to the lateral strength, three types of analysis in varing the degree of restraining the 1st story, i.e., soil pressure surrounding the basement are employed.

<u>Estimating of Seimic Index</u> The first story unified seismic performance indices of the main building are summarized in Table 1. The indicies in X(NS) direction are between 1.09 (Case ①) and 1.4 (Case②), and those in Y(EW) direction between 1.08 (Case ①) and 0.92 (Case ②). It is indicated that the lateral strength at the 1st story increases according as the increase of the restraint at the 1st floor level, however, the seismic index has the opposite tendency due to the decrease of the ductility. The seismic indicies of assembly hall building are shown in Table 2.

<u>Judgement of the Seismic Performance</u> The unified seismic performance index (I_s) should exceed the seismic judgement index (E_T) to resist to the predicted Tokai Earthquake in Shizuoka Prefecture (Ref. 3). As the Namazu City Office Building is located inside the seismic zone A in Fig. 1, seismic judgement index (E_T) is equal to 1.10 for main building (Table 1) and equal to 1.20 for assembly hall building (Table 2). Comparing the seismic indices of the main building with the seismic judgement index of 1.10, it was found that this building may have a fairly good performane, however, a certain amount of strengthening to Y(EW) direction may be needed. This index of the assembly hall building to Y(NS) direction and that to X(EW) directiun is 0.46 and 0.43, respectively. These values is remarkably lower than E_T index of 1.20. This building does not have a sufficient performance, especially, the lack of ductility of columns.

STRENGTHENING OF BUILDING

<u>Procedure of Strengthening</u> The following strengthening were proposed and the strengthening work started in 1985; (1) Several reinforced concrete shear walls should be added in EW-direction at the basement of the main building, (2) Exterior columns of main building should be covered by steel plate to improve ductility. (3) All columns of the first floor of the assembly hall should be covered by the steel plate to improve the ductility. (4) Additional steel frame to connect two buildings should be provided to avoid the progressive failure at the joint due to a local failure which may be caused by different vibration characteristics .

<u>Expected Seismic Performane After Strengthenig</u> The unified seismic performance indices (I_s) were again estimated accounting for the strengthening as shown in Table 1 and 2. Shear force and horizontal displacement relationships of the main building is shown in Fig. 5 and the failure mechanism of frame⑤ at yielding stage ② of Fig. 5 is illustrated in Fig. 6. From this figure, the dominant failure mechanism may become the rocking of shear wall at the base and the flexiual failure at the ends of beams. These values in both direction are larger than the judgement seismic index (E_T). The seismic performance of the assembly hall can be also improved by the strengthening mentioned previously.

Structural Detail of Strengthening Two types of strengthening method are employed at the basement of the main building. One is to add new reinforced concrete shear wall and another is steel encased reinforced concrete brace frames. The detail of an unit of steel encased reiforced concrete brace frame is illustraed in Fig.7(a) and the view after strengthening is shown in photo 1. The strengthening detail by increasing the ductiliy of 1st column of the assembly hall building is illustrated in Fig.7(b). Existing columns are covered by steel plates. The photo 2 shows the construction work of strengthening of the column.

ACKNOWLEDGEMENT

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2. Guideline for Evaluation of Seismic Capacity of Existing Steel Encased Reinforced Concrete Building (in Japanese), Japan Building Disaster Prevention Association, April, (1983).
3. Umemura, H, Okada, T. and Murakami, M., "Seismic Judgement Index Values for Evaluation of Seismic Capacity of R/C Building (in Japanese)", Annual Convention of A.I.J., (1980).

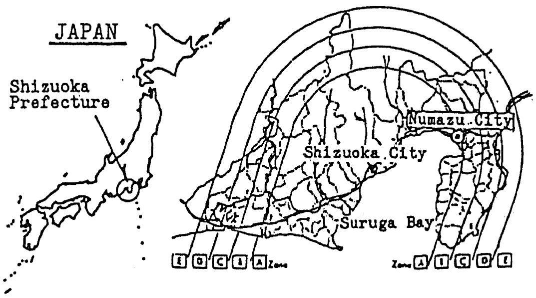


Fig.1 Location of Building

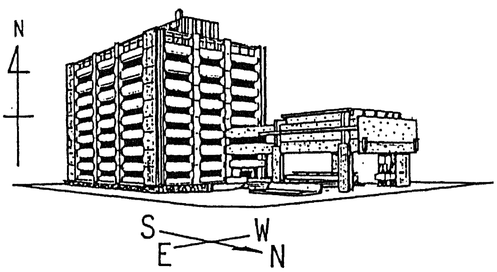


Fig.2 General View of Building

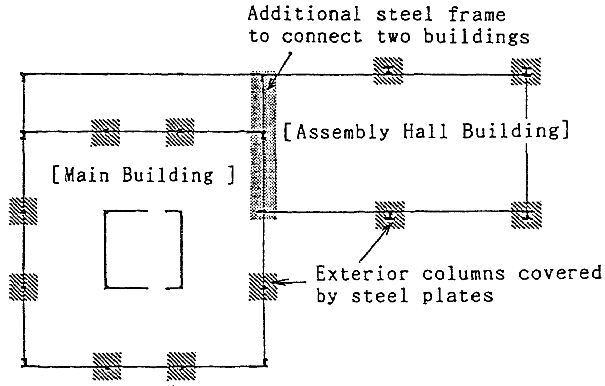
Table 1 Is and E_T indicies of Main Building (1st Story)

Directon	Is		E_T
	Before Strengthening	After Strengthening	
X (NS)	*1 *2 1.09～1.40	*1 *2 1.18～1.54	1.10
Y (EW)	*1 *2 1.08～0.92	*3 1.23	

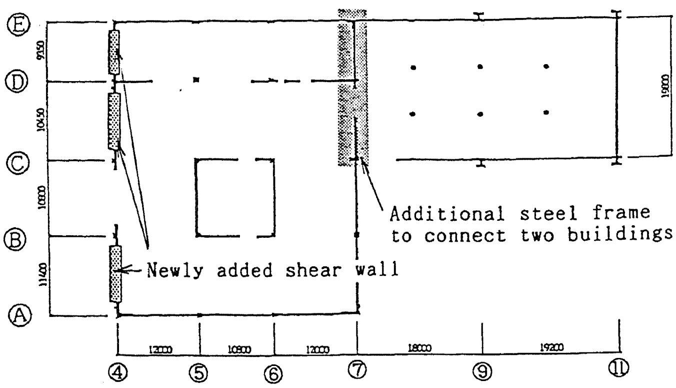
*1 CASE① (1st Story Floor is Fixed in Fig.4)
*2 CASE② (1st Story Floor is Free in Fig.4)
*3 CASE③ (Between CASE-① and CASE-② in Fig.4)

Table 2 Is and E_T Indicies of Assembly Hall Building (1st story)

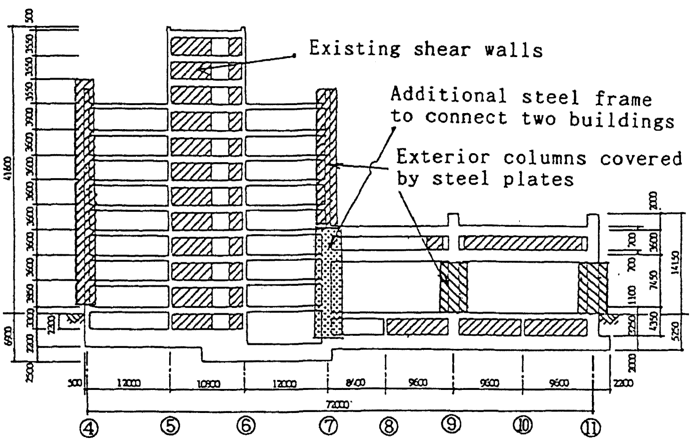
Direction	Is		E_T
	Before Strengthening	After Strengthening	
X (NS)	0.46	1.26	1.20
Y (EW)	0.43	1.20	



(a) 1st Floor Plan



(b) Basement Floor Plan



(c) Section of Frame c

Fig.3 Plan and Section of Building

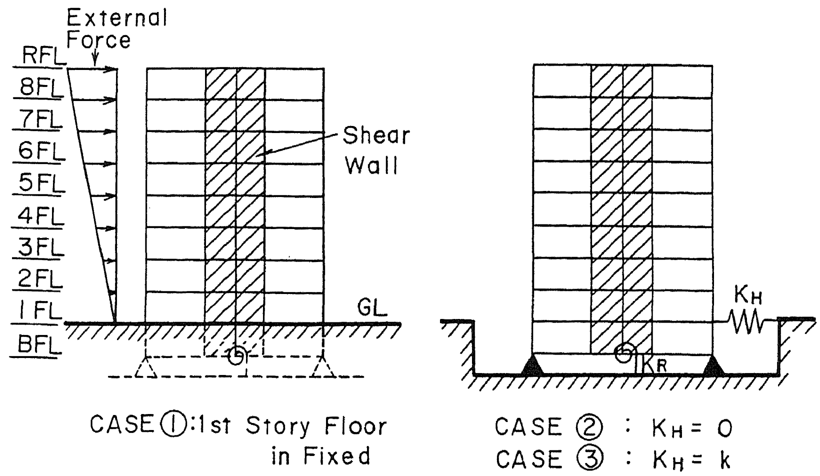


Fig.4 Analytical Model of Building

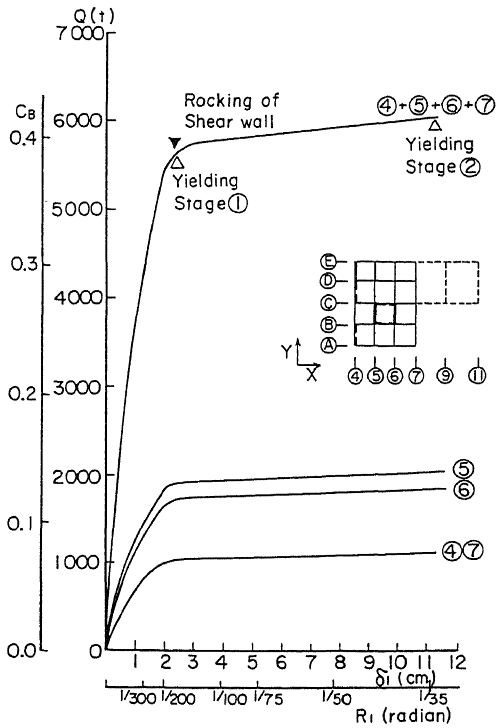


Fig.5 Shear Force-Displacement relationships (1st story,After Strengthening of Main Building)

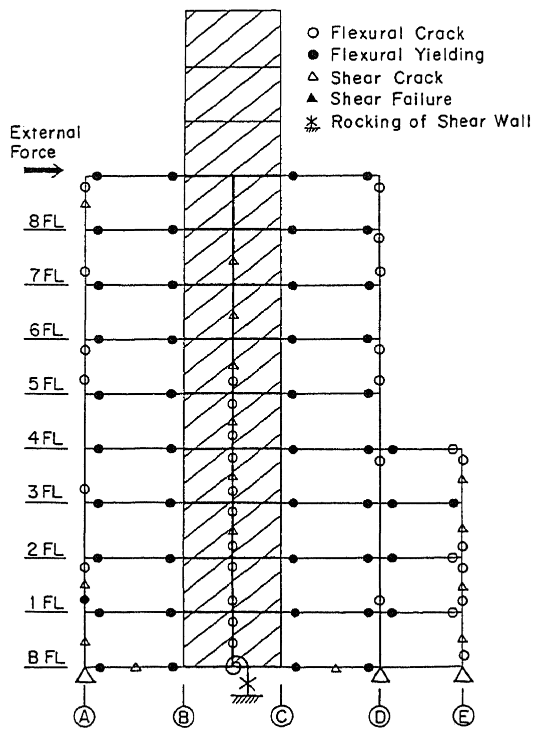
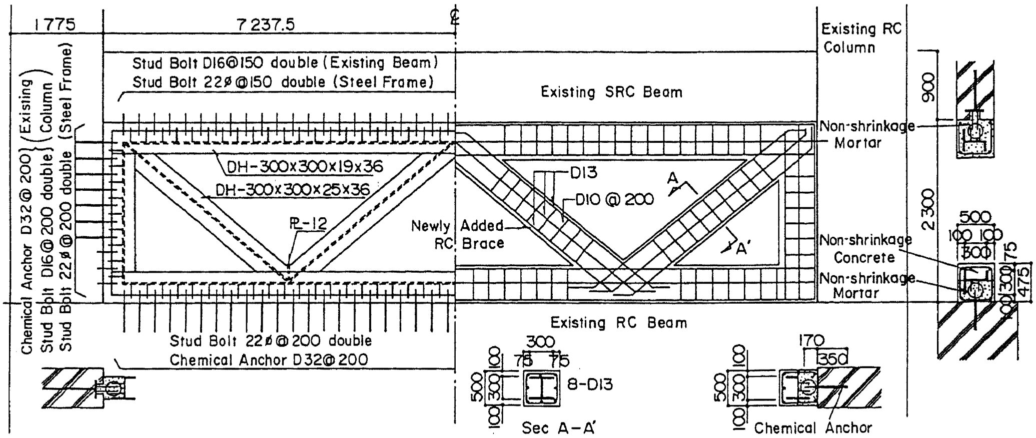
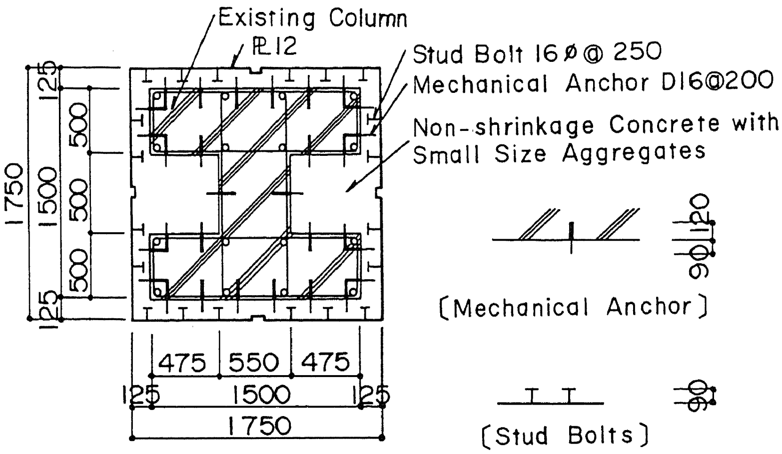


Fig.6 Failure Mechanism of Main Building (Frame 5 at Yielding Stage in Fig.4)



(a) Newly Added SRC Brace of Main Building
(Frame 4 Between Frame A and B)



(b) Exterior Columns Covered by Steel Plate of Assembly Hall Building

Fig.7 Detail of Strengthening

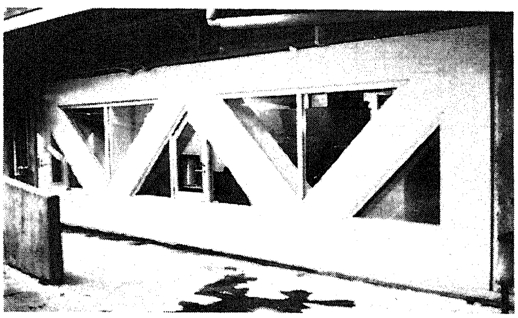


Photo 1 Newly Added SRC Brace of Main Building

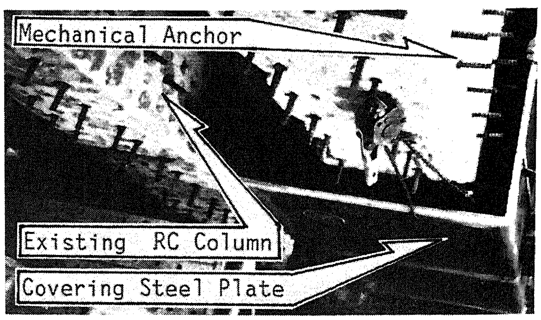


Photo 2 Exterior Column of Assembly Hall Building