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# SEISMIC STRENGTHENING OF EXISTING REINFORCED CONCRETE BUILDINGS IN SHIZUOKA PREFECTURE, JAPAN

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## SUMMARY

The Shizuoka Prefectural Government established the earthquake counter section in 1977 to mitigate earthquake disaster due to a predicted earthquake Tokai Earthquake. About eleven years have passed since the earthquake counter section started the projects on the counterplans of disaster prevention (Refs. 1, 2). The objective of this paper is to present the outline and an example of strengthening of existing reinforced concrete building as one of the earthquake countermeasures in Shizuoka prefecture.

## INTRODUCTION

As one of the earthquake countermeasures to a predicted "Tokai Earthquake" (Fig.1), the prefectural government examined seismic performance of 1896 reinforced concrete buildings which were important as public facilities in view of earthquake emergency from 1977 to 1986 (Table 1). In this result, we have done strengthening work of the buildings which were judged "need urgent reinforcement" and also designated as the main facilities of disaster prevention or refuge just after the earthquake since 1980. Until 1987, 465 buildings were strengthened (Fig. 2). Among them, 441 buildings were strengthened by reinforced concrete shear walls, and 24 buildings were strengthened by steel braced frames or steel shear panels.

## METHODS OF SEISMIC STRENGTHENING

The strengthening to improve the seismic performance of existing reinforced concrete buildings are ;

(1) Increase of the story shear strength by adding new shear walls, and /or
(2) Increase of the story ductile capacity by improving the member ductility.

The Shizuoka prefectural government has employed mainly the above (1) method by the consideration of construction term, functional aspects and economical condition. There are two types of the adding new shear walls. One is by the reinforced concrete wall which has been commonly used, the other is by steel braced frames or steel shear panels. The latter, which is newly developed by the S.P.R.C. committee (Chairman; Professor H. Umemura) in Japan Building Disaster Prevention Association, is useful in the case that foundation capacity is not sufficient to support the building weight increased by adding new shear walls. Building safety after the strengthening is usually evaluated by;

$$Is \geq E_T \cdots\cdots (1)$$

where, Is = The unified second level seismic performance index of structure in the guideline, Japan Building Disaster Prevention Association.

$E_T$ = The unified seismic judgement index of structure in Shizuoka Prefecture (Ref.4)

When the detail investigation is required, the third level seismic screening in the guideline and/or a precise earthquake response analysis should be done. The steel frame with steel brace or steel panel is installed connected to existing frame by stud connectors and chemical anchors. Chemical anchors are driven into the existing frame (Fig. 3), stud connectors are welded to the steel frame, and cement type high strength mortar is injected into the circumference of the steel frame. The merits of this method as compared with reinforced concrete shear wall are as follows; (1) Load to foundation does not increase much, (2) Construction term can be shortened, (3) Construction work is easy and (4) Large openings can be provided. Strengthening design using steel structure has been done based on "Guideline for Evaluation of Seismic Capacity of Existing R/C Buildings (Ref. 3)" and "Guideline for Seismic Improvement of Existing R/C Buildings (Ref. 5)" which are supervised by Ministry of Construction, and " Report on the Experiment and the Investigation on the Seismic Improvement of Existing R/C Buildings" published by Japan Building Disaster Prevention Association sponsored by the Shizuoka Prefectural Government.

## SEISMIC PERFORMANCE OF AN EXAMPLE BUILDING

Outline of the Building Shimizu-Nishi High School building is chosen as an example (Fig.4). This building is three-storied reinforced concrete school-house structure constructed in 1960 having a total floor area approximately $3{,}200m^2$ (Figs. 5 and 6).

Seismic Performance Is-indices estimated by the guideline are shown in Table 2. In the second procedure, Is-indices of both transverse and longitudinal directions were less than the judgement indices ($E_T$) of Shizuoka Prefecture (Table 2, Ref. 4). Since this school building was located near the epicenter of predicted Tokai Earthquake as shown in Fig. 4, high judgement indices ($E_T$ = 0.95) was required. Furthermore, it was revealed that some columns in the north side were extremely brittle columns. It was presumed that in the longitudinal direction, the building would be damaged seriously, since the frame consisted mainly of shear failure columns and extremely brittle columns existed in every stories, and the ultimate strength was considerably insufficient. Though the frame consisted of mainly shear failure walls and flexural failure columns, and it had comparatively large ultimate strength in the transverse direction, the building was also required seismic strengthening so as to be satisfied with the Seismic Judgement Index of Shizuoka Prefecture.

## SEISMIC STRENGTHENING OF AN EXAMPLE BUILDING

Method of Seismic Strengthening The method of seismic strengthening of the above mentioned building are as follows;

(1) Making the target Unified Seismic Performance Index of Structure (Is) for strengthening more than 1.0.

(2) Changing the failure mechanism of extremely brittle columns by adding new shear walls, or making slits between columns and spandrel walls.

(3) Using the steel braced frames to longitudinal direction in order to minimize the incremental dead load, since the bearing capacity of the foundation was not sufficient.

(4) Using reinforced concrete shear walls to transverse direction.

Construction Techniques and Strengthening Works  The overall view of the building before- and after-strengthening are shown in Photo. 1. The term of strengthening works was about five months from June 1985 to September 1985. Total cost of construction was ¥136,000,000 Japanese yens. Removing spandrel walls in the existing frame, chemical anchors were driven, and the steel braced frame to which stud connectors were welded was installed with 200mm clearance. The spiral reinforcement were arranged in the clearance to avoid splitting failure of concrete, and the steel frame was connected with the existing frame, casting cement type high strength mortar (Fig. 7). For an architectural purpose, tile and wood were used in the circumference of the window, to soften the feeling from the different appearance between the new and existing parts (Photo. 2). Together with the seismic strengthening, coping of canopy was replaced from terrazzo to aluminum, and mortar finishment on the external wall were repaired by epoxy injection to prevent falling down during an earthquake.


## ACKNOWLEDGEMENTS

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## REFERENCES


1. Kawabata, S., Kamiya, Y. and Matsui, H., "Earthquake Countermeasures of Shizuoka Prefecture -Primarily about Building-," proceedings of the 7th WCEE, Istanbul, Turkey, September, (1980).
2. Kawabata, S., Kamiya, Y., Hamazaki, T. and Nagata, K., "A Case Study of Seismic Strengthening of Existing Reinforced Concrete Building in Shizuoka Prefecture Japan," proceedings of the 8th WCEE, San Francisco, U.S.A., (1984).
3. Guideline for Evaluation of Seismic Capacity of Existing R/C Building (in Japanese), Japan, Disaster Prevention Association, April, (1977).
4. Umemura, H., Okada, T. and Murakami M., "Seismic Judgement Index Values for Evaluation of Seismic Capacity of R/C Buildings (in Japanese)," Annual Convention of A.I.J., (1980).
5. Guideline for Seismic Improvement of Existing R/C Building (in Japanese), Japan Building Disaster Prevention Association, April, (1977).

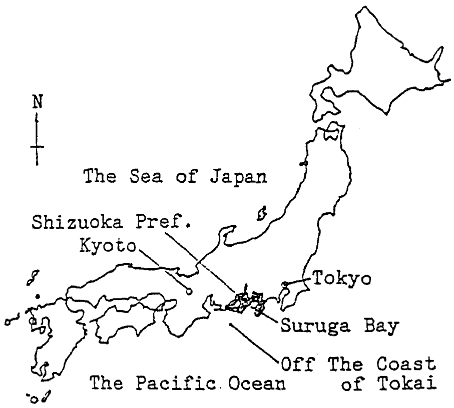



Fig.1 Location of Shizuoka Prefecture in Japan

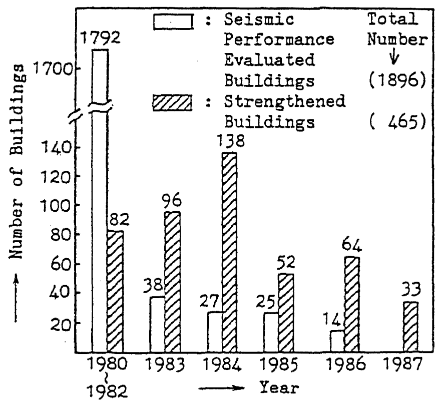



Fig.2 Number of Seismic Performance Evaluated and Strengthened Public Building

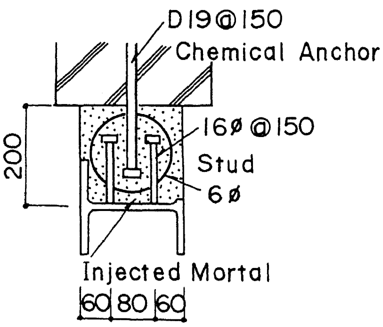



Fig.3 Detail of Connection

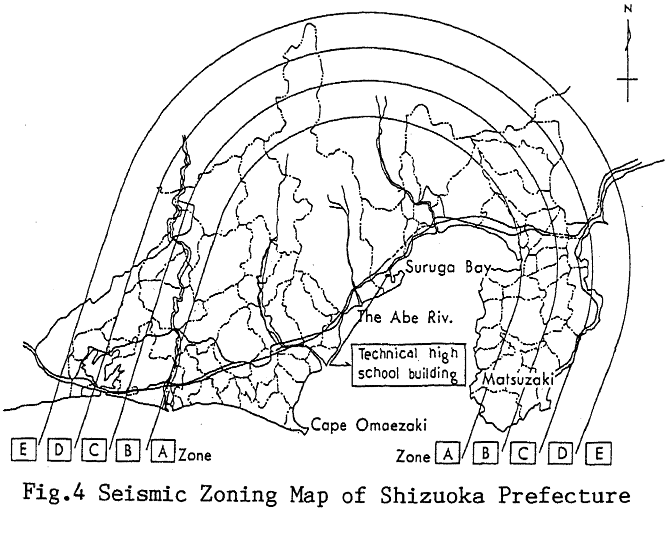
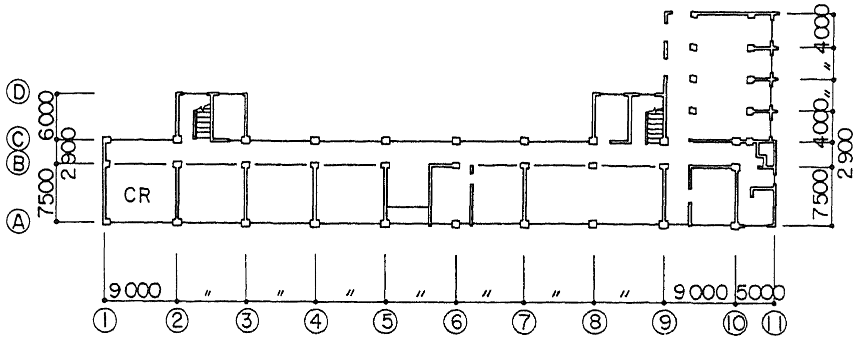
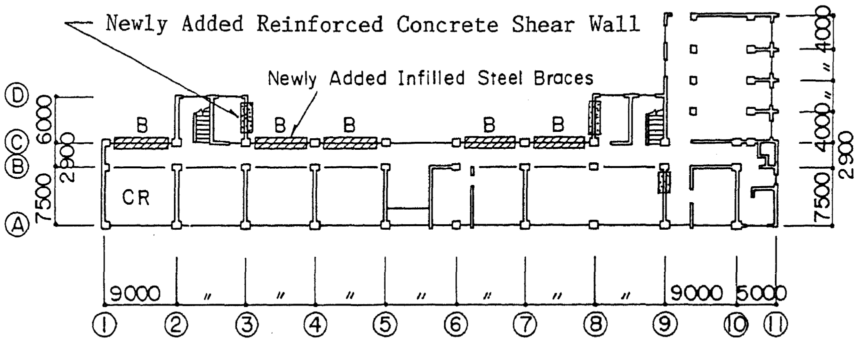



Fig.4 Seismic Zoning Map of Shizuoka Prefecture

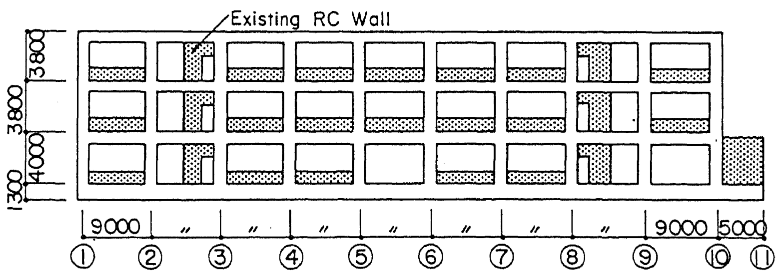



(a) Before Strengthening

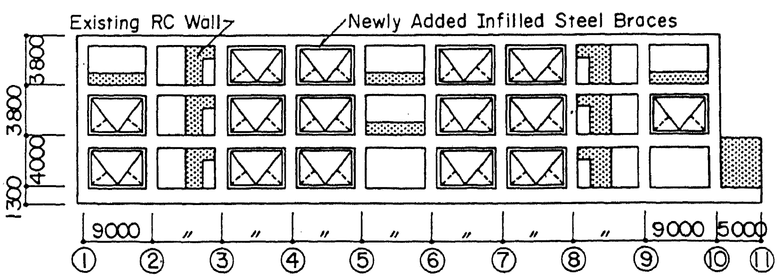



(b) After Strengthening

Fig.5 1st Story Plan of Building




(a) Before Strengthening




(b) After Strengthening

Fig.6 Evaluation of Building

Table 1 Is and $E_T$ Indicies of the Shizuoka Prefectural buildings

| Levels | Judgement | Factors( $E_T$=Es) | Number of buildings | Percentages |
|---|---|---|---|---|
| A | enongh resistance | Is ≧ $E_T$ | 266 | 14 % |
| B | need a check-up in detail | Is ≧0.7 $E_T$ | 379 | 20 % |
| C | need reinforcement | 0.3$E_T$<Is<0.7$E_T$ | 758 | 40 % |
| D | need urgent reinforcement | | 398 | 21 % |
| E | need rebuilding | 0.3$E_T$ ≧Is | 95 | 5 % |
| Total | —— | —— | 1.896 | 100 % |

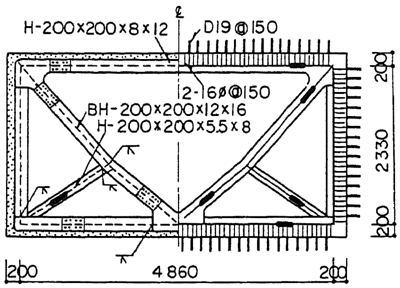
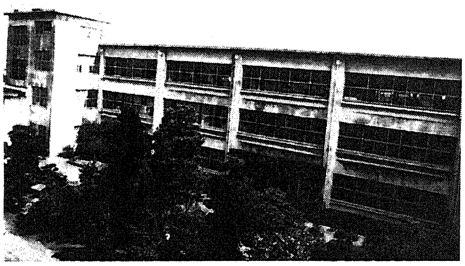



Fig.7 Detail of a Unit of Steel Brace

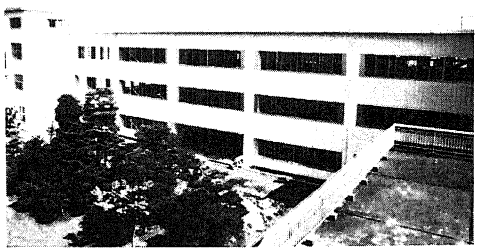
Table 2 Is and $\bar{E}_T$ Indicies of 1st Story (2nd Procedure)

| Direction | Is | | $E_T$ |
|---|---|---|---|
| | Before Strengthening | After Strengthening | |
| Transverse | 0.68 | 1.19 | 1.00 |
| Longitudinal | 0.35 (0.27) | 1.04 (0.60) | |

( ) : considering the extremely brittle colomns



(a) Before Strengthening



(b) After Strengthening

Photo 1 North Side View of Building

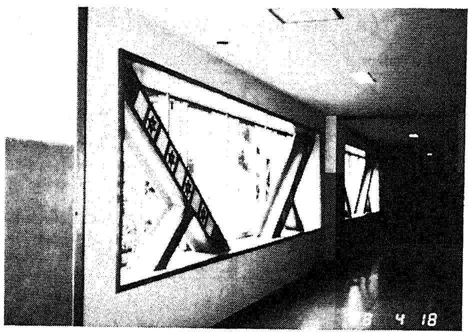


Photo 2 Typical Inside View Strengthened by Steel Braces