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OPTIMUM MOMENT DISTRIBUTION BETWEEN SHEAR WALLS AND BOUNDARY BEAMS OF COUPLED SHEAR WALL WITH FLANGE WALLS

MAKOTO KATO and KEN-ICHI SUGAYA and NORIKAZU NAGATSUKA

Structural Engineering Department, Building Research Institute, Ministry of Construction,
1 Tatehara, Tsukuba City, Ibaraki, 305 Japan

ABSTRACT

The center-core type coupled shear walls that have flange walls, and are connected by coupling beams, have a merit in planning to take a wide space around them. As the main seismic structural members of the building are the coupled shear walls, the performance of this shear walls dominate the seismic capacity of the building. And it is necessary to establish the design methodology of this shear walls. This paper introduces the analytical and experimental research on the optimum moment distribution between the shear walls and coupling beams. The results show the optimum moment carrying ratio and the required base shear coefficient so as to satisfy the preliminary seismic design criteria.

KEYWORDS

Base shear coefficient ; center-core ; coupled shear walls ; coupling beam ; optimum moment distribution.

INTRODUCTION

In the US-Japan Cooperative Structural Research Project on Composite and Hybrid Structure, a building with center-core type shear walls and exterior steel frame is selected as a prototype building for research. Figure 1 shows a plan of prototype building. The center-core type shear walls have flange walls, and are connected by coupling beams together. That is so-called a coupled shear walls. This type of building has a merit in planning to take a wide space around them. As the center-core shear walls and the exterior steel frame are not connected rigidly, the main seismic structural members of the prototype building are the coupled shear walls. Therefore the performance of this coupled shear walls dominate the seismic capacity of the building, and it is necessary to establish the design methodology of these shear walls.

This paper is the analytical research on the optimum moment distribution between the shear walls and coupling beams. The optimum moment carrying ratio and the required base shear coefficient are discussed in order to satisfy the preliminary seismic design criteria that are the drift limit of coupling beams of 2%, and no allowance of flexural yield of coupled shear walls. The result of this analytical research is reflected in design methodology of the test specimen. The experiment will be conducted in February 1996. The experiment will show the results that shear force distribution among walls in the tension and in the compression sides respectively, and the restoring force characteristics of shear walls.

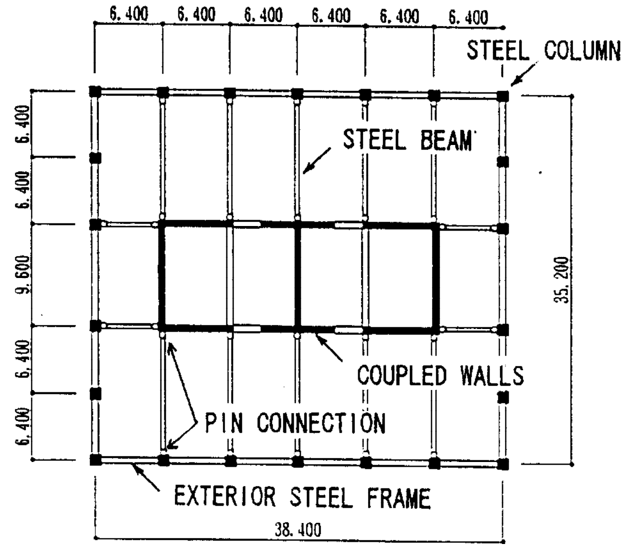


Fig.1 The plan of prototype building with center-core type shear walls and exterior steel frame

TARGET BUILDING

The twelve stories building is selected among several prototype buildings. Coupled shear walls in the twelve stories building is under severe design condition for the shear force and for the drift control comparing with the lower or the higher building. The lower building could be designed by the strength resisting concept. And the higher building is necessary to provide some seismic elements, that is hat truss or belt truss which reduces the drift and the over-turning moment of walls. Figure 2 shows the conceptual drawing of these structural system.

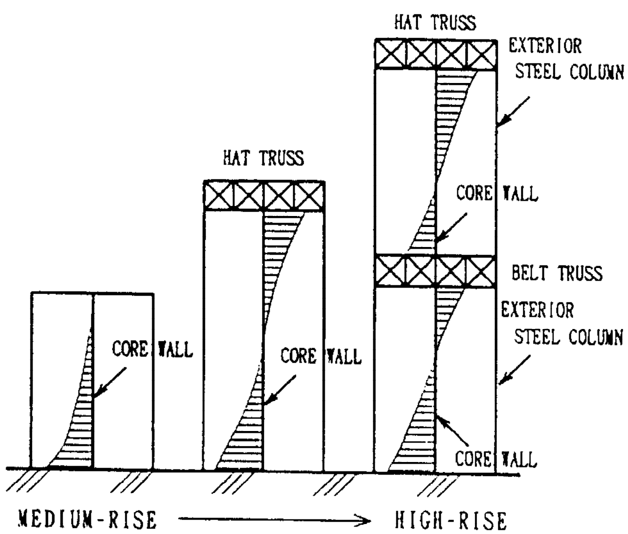


Fig.2 The conceptual drawing of structural system

Test specimen is the model of the part cut from center-core wall portion as shown in Fig.3. In order to focus on the shear force distribution carried by walls in both the tension and the compression sides, H-shape wall located at the center of wall group is omitted in this test. And also the exterior C-shape walls, half of these walls are modeled to T-shape walls. The test specimen is consist of two T-shape walls connected with twelve coupling beams, and load transducer put at the center of each coupling beam. Number of story of the test specimen is twelve, and scale is about one-third.

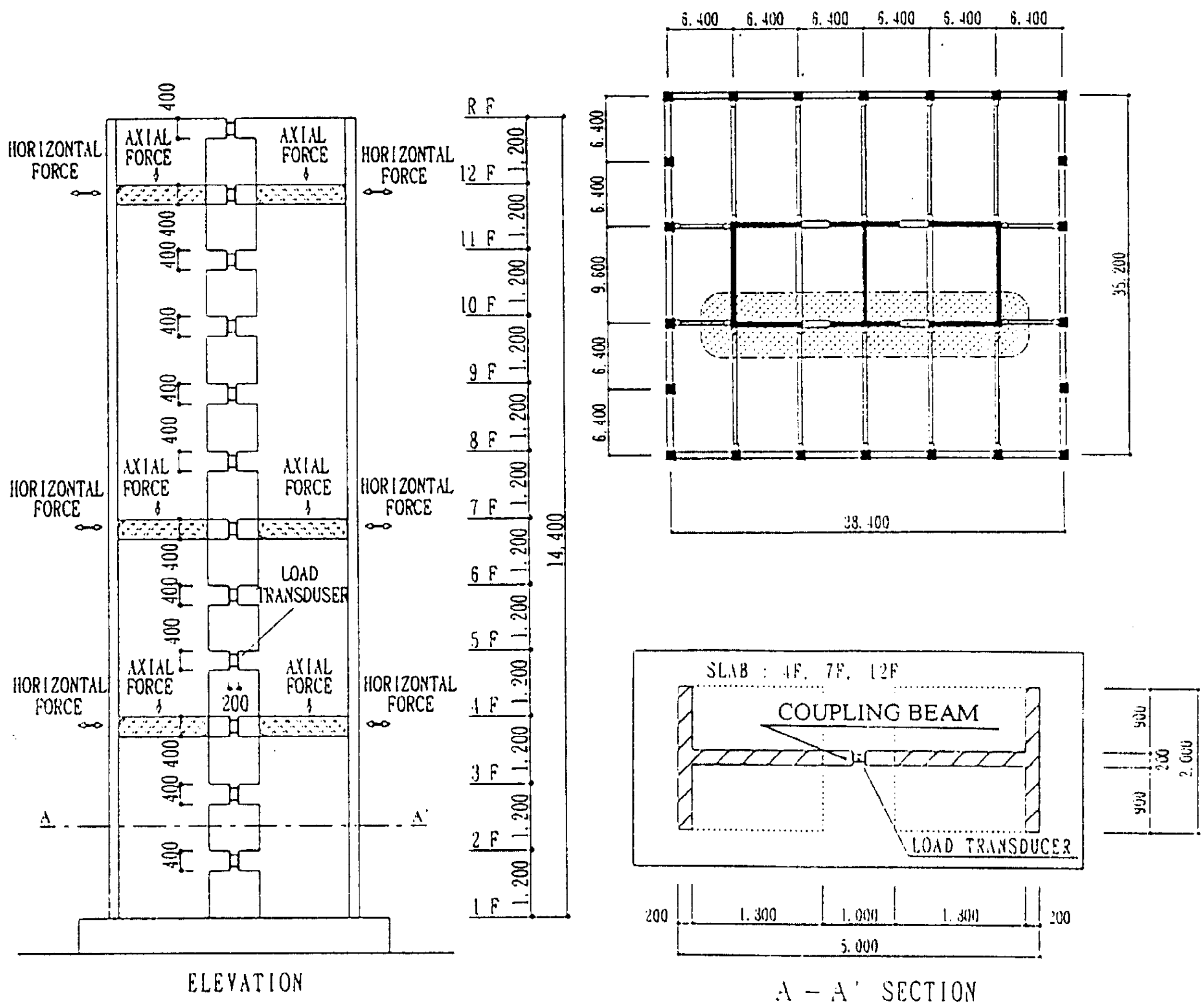


Fig.3 The plan and elevation of the test specimen modeled to T-shape walls

ANALYSIS

Analytical Model

The target building is modeled into a simple frame as shown in Fig.4. Column represents the all shear walls, and coupling beams also do all coupling beams existing in the prototype building. The lateral shear carried by steel frame against the total shear is small enough to neglect the effect of steel frame. Lateral load capacity of this prototype building is about 0.39 in terms of base shear coefficient.

Restoring force characteristics of wall used in this analysis is illustrated in Fig.5. Origin oriented model up to yield point, and after that degrading trilinear model are applied to. Yield point is determined by the pre-analysis of section under uniform moment distribution condition along the member axis. Degrading trilinear model is applied to the restoring force characteristics model for coupling beam. Yield point and other parameters for model are determined based on the test result of coupling beam. The seismic test of coupling beam were conducted to know the typical seismic behavior of its. Damping coefficient to a tangent stiffness is assumed to be 3%.

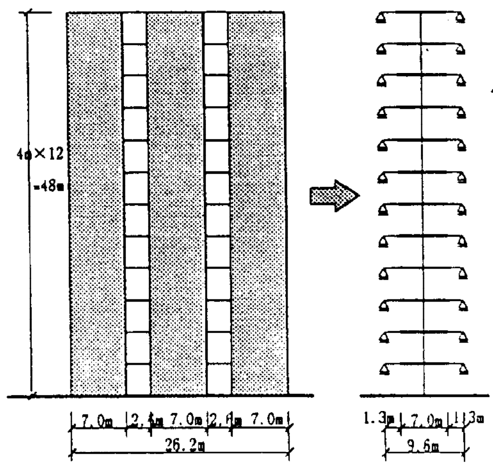


Fig.4 Analytical model of the prototype building modeled into a simple frame

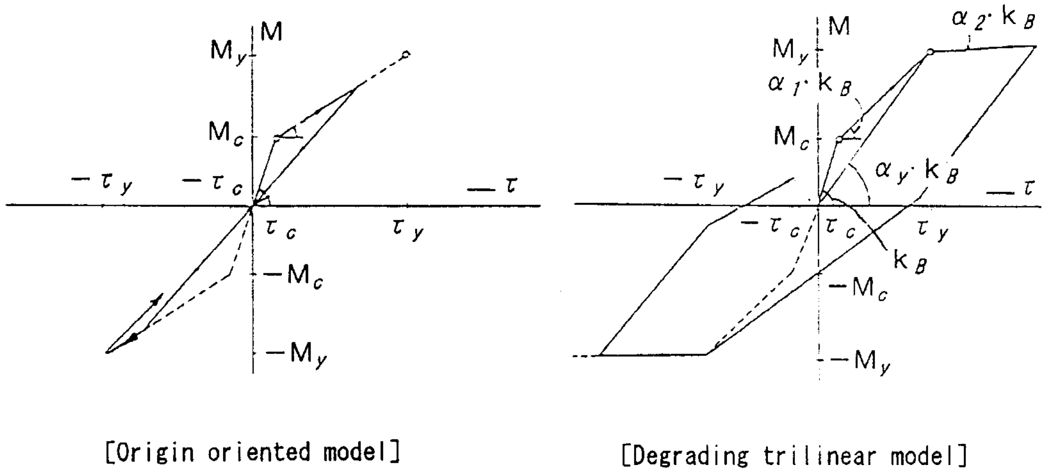


Fig.5 Restoring force characteristics of wall

Variables

Variables are the over-turning moment carrying ratio of coupling beams to the total over-turning moment; those are 4 cases from 20% to 80%. Cases of analysis conducted in this paper are listed in Table 1. Lateral load capacity of analytical model is about 0.39 in terms of base shear coefficient,

Table 1 Cases of analysis

Cases of analysis	The over-turning moment carrying ratio of coupling beams and coupled shear walls to the total over-turning moment	
	Coupling beams	Coupled shear walls
B20:W80	20%	80%
B40:W60	40%	60%
B60:W40	60%	40%
B80:W20	80%	20%

Static Analysis

Static load incremental non-linear analysis are conducted against analytical model. Lateral load distribution along the height is specified by Japanese Building Code as shown in Fig.6. Figure 7 shows the shear of the 1st. story and the displacement of the top floor relationship. In case that over-turning moment carrying ratio of beam is smaller, beams yield prior to wall; cases of B20:W80, B40:W60, and B60:W40. And flexural yielding of beams and wall is almost same in case that over-turning moment carrying ratio of beam is greater; case of B80:W20.

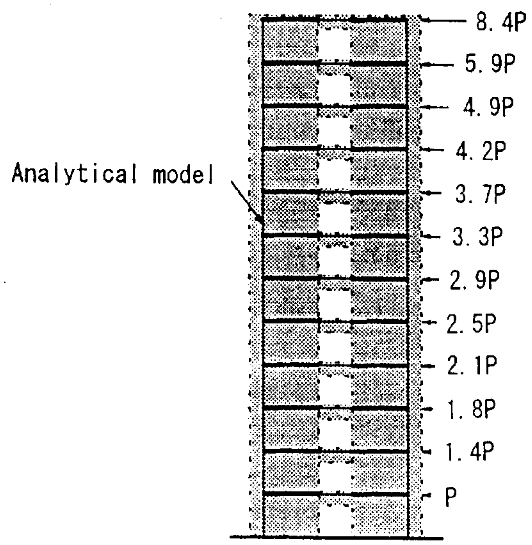


Fig. 6 Lateral load distribution along the height

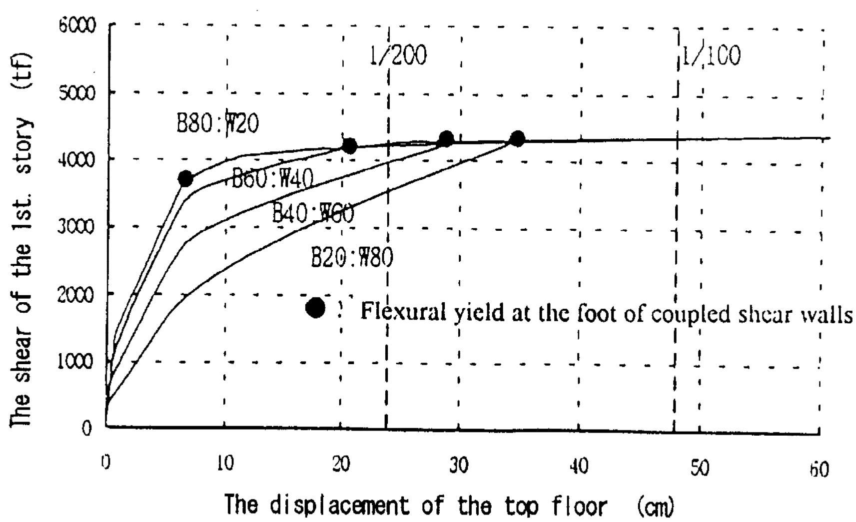


Fig. 7 The shear of the 1st. story and the displacement of the top floor relationship

Dynamic Analysis

Input ground motion used in the dynamic analysis is an artificial earthquake wave whose response spectrum covers several type of typical recorded earthquake responses, and its intensity is the largest expected at a construction site. In dynamic analysis, intensity of this earthquake is changed from 100 to 500 gal by every 100 gal. Figure 8 shows response spectrum of its.

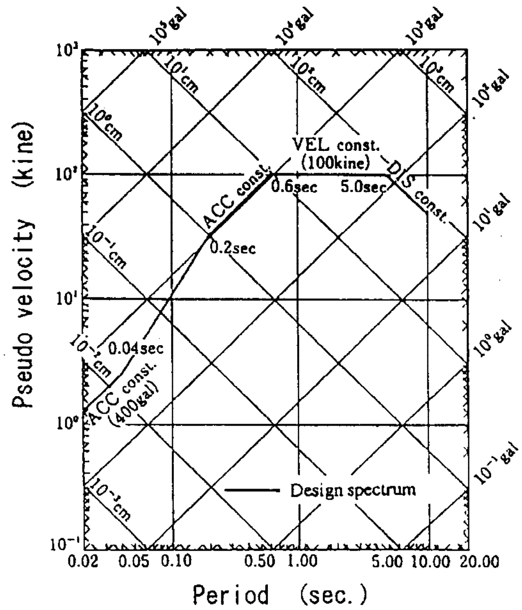


Fig.8 Response spectrum of input ground motion

RESULTS

The Story Drift and the Deformation of Coupling Beam

Figure 9 shows maximum responses on the deformation of the upper story. The story drift and the deformation of coupling beam of the upper story become larger in proportion that the moment carrying ratio of coupling beams is smaller. And when intensity of input ground motion is larger, response of those become larger.

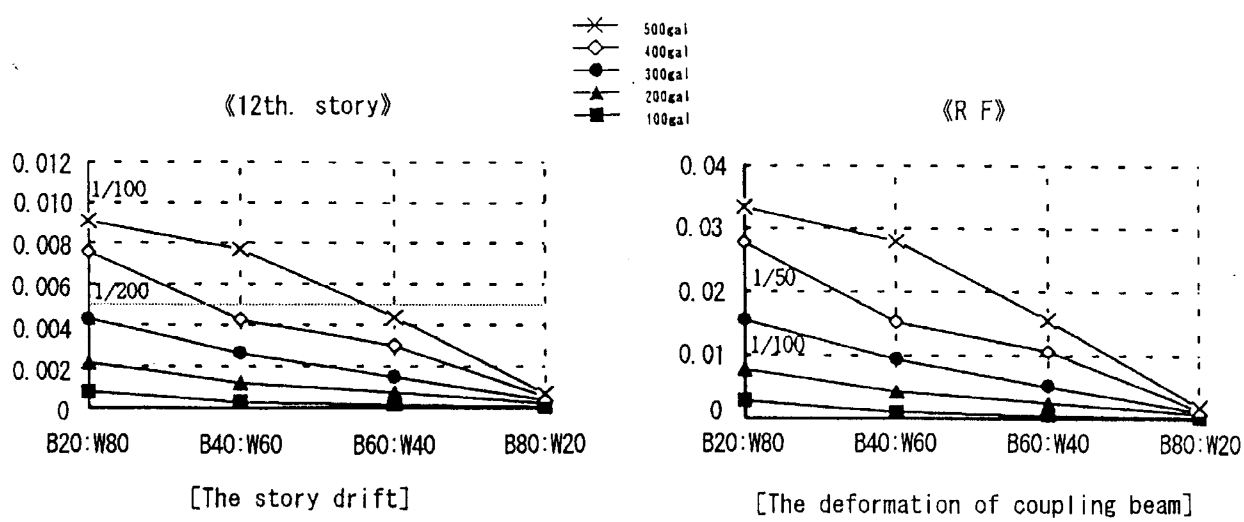
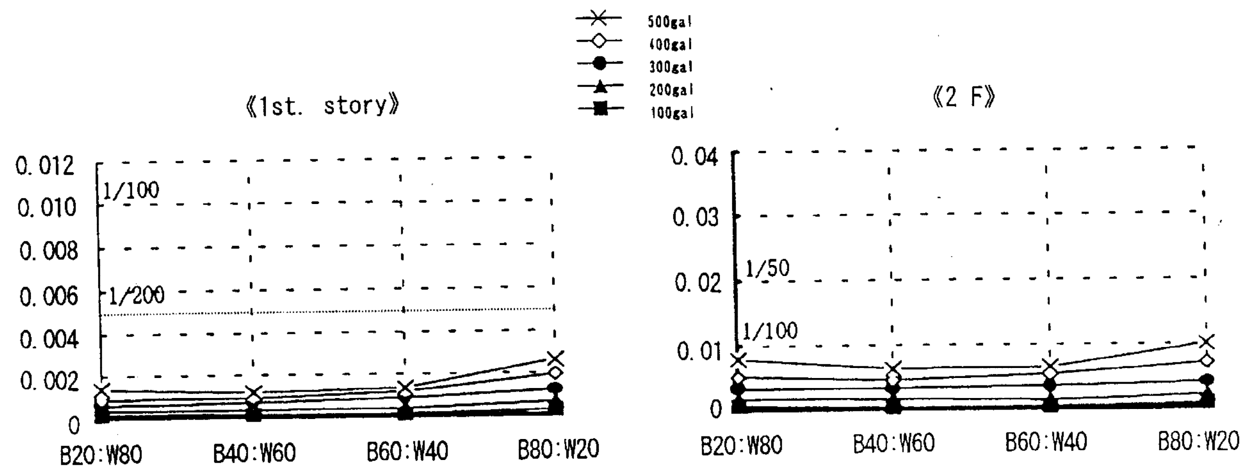


Fig.9 Maximum responses on the deformation of the upper story

On the other hand, when the moment carrying ratio of coupling beams becomes larger, or intensity of ground motion is larger, the foot of shear wall becomes easily to yield in flexure, then the story drift of the 1st. becomes larger. Maximum responses on the deformation of the lower story is shown in Fig.10.

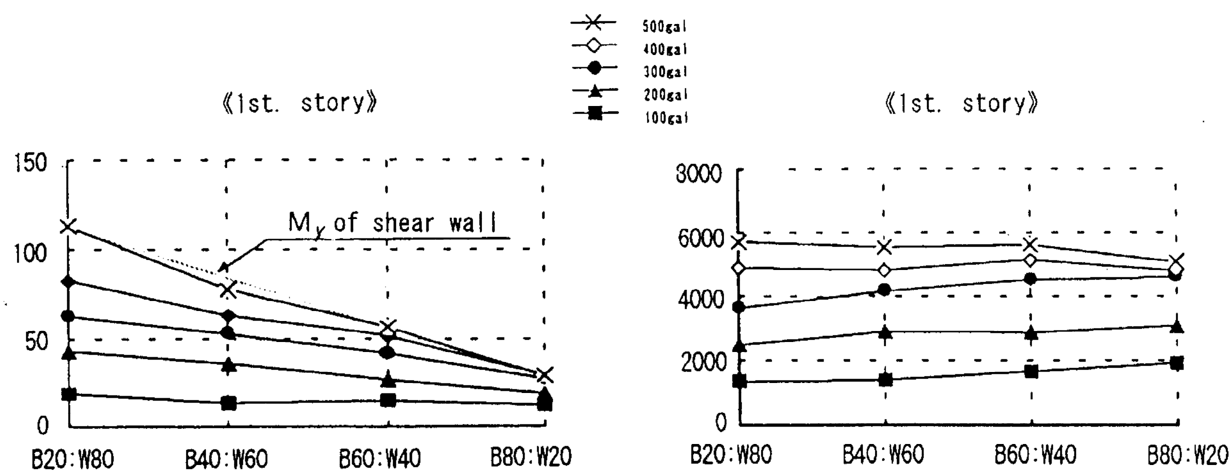


[The story drift] [The deformation of coupling beam]

Fig.10 Maximum responses on the deformation of the lower story

The Bending Moment and the Shear Force

Figure 11 shows the bending moment and the shear force of the 1st. story. The bending moment at the foot of coupled shear walls decreases in inverse proportion to the moment carrying ratio of coupling beams. However, the shear force of the 1st. story of the coupled shear walls increases in proportion to that.



[The bending moment ($\times 10^3$ tf·m)] [The shear force (tf)]

Fig.11 The bending moment and the shear force of the 1st. story

CONCLUSION

The moment carrying ratio of coupling beams to the total moment has influence on flexural yielding at the foot of coupled shear walls and the required ductility of coupling beam. In order to satisfy the preliminary seismic design criteria that are the drift limit of coupling beams of 2%, and no allowance of flexural yield of coupled shear walls, the optimum moment carrying ratio of coupling beams is 40% to 60%. In this connection, the moment carrying ratio of coupling beams of test specimen is 40%, lateral load capacity of its aims at 0.35 in terms of base shear coefficient..

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REFERENCES

Aktan, A.E. and V.V. Bertero(1981). Earthquake Engineering Research Center,The SeismicResistantDesign of R/C Coupled Structural Walls, *UCB/EERC-81/07*.

Aktan, A.E. and V.V. Bertero(1982). Earthquake Engineering Research Center, States of The Art and Practice in The Optimum Seismic Design and Analytical Response Prediction of R/C Frame-Wall Structures, *UCB/EERC-82/06*.

Aktan, A.E. and V.V. Bertero, and M. Piazza(1982). Earthquake Engineering Research Center, Prediction of The Seismic Responses of R/C Frame-Coupled Wall Structures, *UCB/EERC-82/12*.

Nagatsuka, N. *et al.* (1995). U.S.-Japan Cooperative Structural Research Project on Composite and Hybrid Structure (HWS-3) (Analytical Study on Strength Ratio of Beams to Walls in Coupled Wall System)Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan, *Structures I B-1*, 827-828.

Okada, T. *et al.* (1993). Outlines of New RC Structural Design Guidelines (Design concept and criteria). Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan, *Structures II*, 331-332.

Sugaya, K. *et al.* (1995). U.S.-Japan Cooperative Structural Research Project on Composite and Hybrid Structure (HWS-2) (Seismic Properties of Boundary Link Beam and Performance of Load Transducer). Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan, *Structures I B-1*, 825-826.

Teshigawara, M. *et al.* (1995). U.S.-Japan Cooperative Structural Research Project on Composite and Hybrid Structure (HWS-1) (An Outline of Coupled Structural Wall Test Plan). Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan, *Structures I B-1*, 823-824.