

# ASEISMIC ANALYSIS OF THE TALL BUILDING STRUCTURE WITH COUPLED SHEAR WALL

by

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## SYNOPSIS

In this paper, an aseismic design method for tall building structure with coupled shear wall is described. Namely the procedure of the aseismic design and the aseismic safety based on dynamic analysis for the structure are described. This method is applied to an actual structure. In addition, the adequacy to the method is lateral load test with test models.

## INTRODUCTION

Shear wall is efficient structural elements designed to resist lateral force in buildings. However shear walls with openings are commonly designed. Such shear walls are defined as so called "coupled shear wall". The analysis of the coupled shear wall has been executed by many researchers and structural engineers(1). Almost of these studies is based on a conception of static analysis. The typical method in these studies is Laminae approach(2,3). Tso et al.(4) have determined the fundamental frequency of coupled shear wall using this method. But usually shear walls are not satisfy uniformity of dimesion, opening location and structural properties throughout the height. Furthermore the shear walls are continuum mechanics in nature, the analysis as continuum should be executed to idealize as closely actual structure possible. Therefore the technique known as finite element analysis considers the structure to be divided into a mesh of two or three dimensional elements is better.

In this paper, the stiffness of coupled shear wall is estimated using finite element method(called FEM from following). The earthquake responses are calculated by means of idealized lumped mass models from actual structure. The iteration of this procedure is performed. Finally a office building is presented as design example. In addition, the lateral load test is executed by model to improve this aseismic design method.

## PRINCIPLE OF ASEISMIC DESIGN

The aseismic design based on dynamic analysis should be intended to give the resonable dynamic characteristic for building structures so that the earthquake responses of them may safely occur within allowable values against the prescribed group of destructive earthquake excitation. The frame systems may be a factor which vary such dynamic characteristics. The coupled shear wall consists of shear wall and connecting beams. Since the stiffness of shear wall is usually larger than connecting beam, the excessive stresses are distributed on the connecting beams subjected to

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ground motions, and early yielding results for connecting beams. Furthermore since the lateral loads derived from dynamic analysis are usually reversal force, the connecting beam are repeatedly loaded with large stress. In order to secure large ductility as overall, structural material should be endowed with large energy absorption capacity. In the concrete, steel reinforced concrete members are useful for coupled shear walls. The examination of the aseismic safety is executed by earthquake response of values of structural model. Each response values of relative angle, shear, overturning moment, shear stress and normal stress are used as this measure of aseismic safety.

As previously mentioned, Laminae, Frame and Element approach have been proposed for method of analysis. However analysis by FEM may be best because of following four factor, 1) analysis method for continuum 2) no regularity of structural properties throughout the height of shear wall 3) considering of orthogonal side wall 4) considering of elastic-plastic state of structural element. Therefore the horizontal stiffness of coupled shear wall is estimated using FEM and earthquake responses of structural models which are idealized from actual building structure are calculated, the appropriate members are given for actual structure. This procedure is repeated.

#### PROCEDURE OF ASEISMIC DESIGN

Because of limited available aseismic data and the short period due to the scale and configuration of earthquake resisting element, the structural design of concrete only are carried out after determining design constants derived from the preliminary earthquake response analysis. The shear response is calculated for this concrete model and the steel sections of shear walls or connecting beams are designed by the static stress analysis for the lateral external force calculated as earthquake response values. The horizontal stiffness of designed coupled shear walls is estimated by FEM, and again earthquake response analysis is carried out for the steel reinforced concrete coupled shear walls and each responses of relative angle, shear, overturning moment, shear stress and normal stress are calculated. Using these response values the examination of the aseismic safety is performed for the structural models and if it is not within allowable values, the correction of the structural members is carried out. After repeatation of this procedure, practically structural members are determined.

Although the stiffness and the strength of connecting beams are small values compared with the overall stiffness and strength, if the designer expect efficient coupling effect, at the least the strong beams may be required on the top and base, it is desired that such structure design is performed. In this case the ultimate strength should be considered one story-one bay frame.

#### EXAMPLE

The designed building structure with steel reinforced concrete coupled shear wall is shown in Figs.-1,2. This structure presented here is 15 stories above ground, 3 stories below ground, 68.0m heigh and the coupled shear wall is situated in the center of the building.

The twenty-three degree-of-freedom of idealized lumped mass model is used to dynamic analysis. In this case, the interaction effect between the soil and the structure is taken into account. The fundamental period of the structure is 1.1 sec., the wall thickness of the designed shear wall vary from 1.25m at the base to 0.6m at the top and the centrifugal casting steel pipes erected at the four corners of the shear wall vary from thickness 67mm, diameter 750mm at the base to 21mm, 300mm at the top. Final earthquake responses are shown in Fig.-3~Fig.-5.

#### EXPERIMENTAL RESULTS

The test model is shown in Fig.-6. This test model is made of reinforced mortar, the scale is one-twentieth of actual structure. The distribution of lateral load is derived from the earthquake response values of structural model. The results are shown in Fig.-7~Fig.-9.

#### CONCLUDING REMARKS

An aseismic design method of the building structure with coupled shear wall is presented herein.

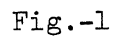
The design force which is used to the aseismic design of the building structure is dynamic phenomenon in nature. Therefore the shear responses derived from dynamic analysis should be used to structural design.

The shear walls and the connecting beams are important structural properties of the coupled shear wall, in these design energy absorption capacity is required. Specially the connecting beams are designed steel only, the strength of concrete is ignored. But the ultimate strength of overall system should be secured by the shear walls, for that reason the steel reinforced concrete is adopted in the design of top beams and shear walls.

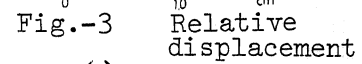
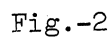
This design procedure for this project indicates a philosophy for the future design of the structure of this type to earthquake ground motion.

#### REFERENCE

- (1) Reported by ACI Committee 442 "Response of Buildings to Lateral Forces" ACI Journal Feb. 1971, pp.81-106.
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- (3) Rosman, R., "Approximate Analysis of Shear Walls Subject to Lateral Loads" ACI Journal June. 1964, pp.717-732.
- (4) Tso, Wai K., and Chan, Ho-Bong, "Dynamic Analysis of Plane Coupled Shear Walls" ASCE Vol 97 EM 1, Feb. 1971, pp.33-48



### Example structure



Relative displacement

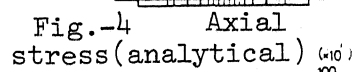


Fig.-4 Axial  
stress(analytical) ( $\times 10^4$ )

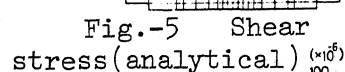


Fig.-5 Shear stress(analytical) ( $\times 10^5$ )

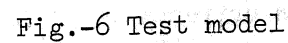


Fig.-6 Test model

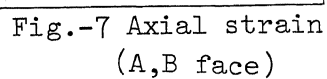


Fig.-7 Axial strain  
(A,B face)

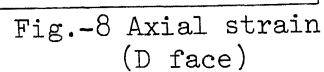


Fig.-8 Axial strain  
(D face)

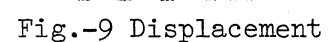


Fig.-9 Displacement