Effect of Flanged Wall on Rigidity and Ultimate Strength of Reinforced Concrete Shear Wall

Kazuhide SATO, Takahito YANASE, Akira HIGASHIURA
Sato Kogyo Co., Ltd., Atsugi, Japan

1 INTRODUCTION

Major seismic components of a nuclear reactor building are a solid wall such as the box wall which consist of the web wall and the flanged wall. Recently, experimental studies have been carried out concerning the effect of these parameters such as the size of a wall, the reinforcement, the opening, etc. The effect of the flanged wall attached upon a solid wall, however, on the rigidity and the ultimate strength in its elasto-plastic region has not been sufficiently revealed.

In this study, the results of both the experiments and the elastic-plastic FEM analysis on the effect of a flanged wall of the rigidity and the ultimate strength in its elasto-plastic region are presented. The influence of the width of the flanged wall is discussed.

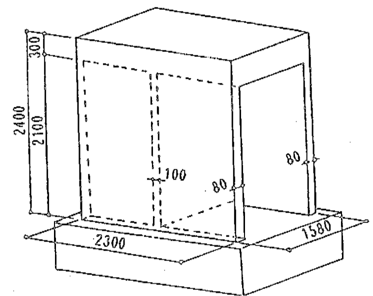
2 EXPERIMENTAL PROGRAM

2.1 Test specimen

The test specimen composed of the web wall and the flanged wall, which is a H section structure, is prepared in this study. The details and the properties of the test specimen are described Fig.1. The flanged walls 230cm in width are placed on both side of the web wall 150cm in length. The thickness of the web wall and the flanged wall are 8cm and 10cm, respectively. The height of the walls are 210cm. The resultant shear-span ratio is 1.5. The vertical and horizontal reinforcement ratio of the web wall is 0.43% and 1.00%, respectively. While that of the flanged wall are 0.27% and 0.67%, respectively. The maximum diameter of the coarse aggregate for the concrete is 10 mm, and the characteristics of concrete and the steel reinforcement are listed in Table 1.

2.2 Loading procedure

The test set-up is illustrated in Fig.2. Horizontal force is applied to the stub at the top of the structure. A constant normal stress of 12 kg/cm^2 is applied uniformly over the cross-section area of these walls. In the



(unit:mm)

Fig.1 Dimension of the test specimen

Table 1 Characteristics of materials

Concrete

Compression Strength (kgf/cm^2)	Young's Modulus ($x10^5kgf/cm^2$)	Poison's Ratio
376	1.97	0.165

Steel Reinforcement

Yield Strength (kgf/cm^2)	Tensile Strength (kgf/cm^2)	Young's Modulus ($x10^6kgf/cm^2$)
4347	5479	1.82

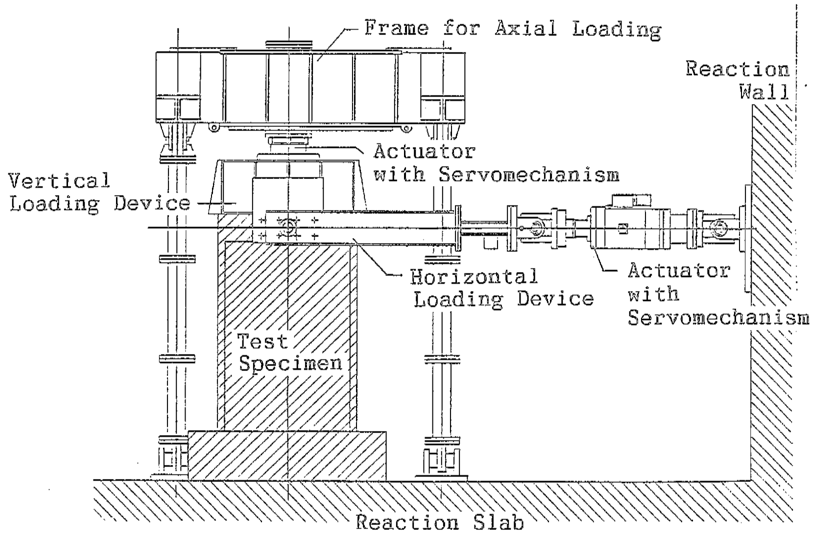


Fig. 2 Test set-up

experiment, computer-controlled actuator with servomechanism are utilized to apply lateral loads automatically prescribed at every controlled the displacement stage. Two time of cyclic loading are repeated. Deflections and deformations of the specimen, the strain of the reinforcing bars, and the strain of concrete on the surface are obtained.

3 ANALYTICAL PROGRAM

3.1 Analytical model

For an analytical study, the FEM analysis is employed. In the analysis, the panel of those wall are represented by a set of four nodes layered shell elements. Analytical model for FEM analysis is shown in Fig.3. The shell element is divided into layers, as shown in Fig.4. Each layer may have different material properties. The constitutive law for the concrete proposed by Dawin and Pecknold was used. A small modification is made so that the compressive strength parallel to the cracks is taken smaller value as proposed by Collins. The stress-strain relationship of the reinforcing bar is determined by perfect elasto-plastic well.

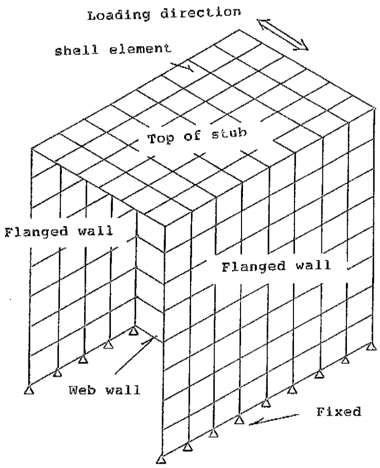


Fig.3 Analytical model for FEM

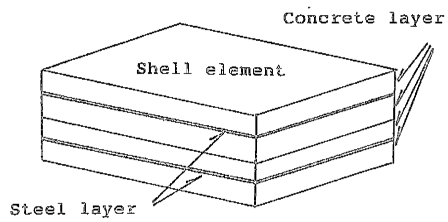


Fig.4 The layered shell element

3.2 Analytical parameters

The following three parameters are taken into consideration in this analytical study. Table 2 indicates the correlation among these parameters. These parameters are taken to be close correlated with the rigidity of a solid wall.

1.Width of a flanged wall
2.Height of a solid wall
3.Thickness of a top stub

Table 2 parameters of analysis

Height of solid wall (cm)	Width of flanged wall (cm)	Thickness of top stub 30cm	10cm
112.5	130	EL-33	ELT-33
	230	EL-31	ELT-33
	130	EL-13	ELT-13
225	230	EL-11	ELT-11
	450	EL-12	ELT-12
	130	EL-21	ELT-21
450	230	EL-22	ELT-22
	450	EL-23	ELT-23

4 RESULTS AND DISCUSSION

4.1 Experimental results

The relation of load-deflection and the crack distribution pattern of the test specimen at the end of loading are shown in Figs.5 and 6, respectively. The process of failures of the test specimen are as follows. As the first stage of yielding, bending cracks occurred to the flanged wall at the deflection angle of 1.11rad. An initial diagonal shear cracks is observed at the shear force of 32.8tonf on the web wall. At this stage the specimen could keep rigidity still. Finally, the compressive flexure failure with bending at the bottom portion of the flanged wall is happens as in shown Fig.5 and loading capacity is lost. The maximum shear strength applied to the test specimen is 55.3tonf and which is yielded at a deflection angle $13.5\mathrm{x}10^{-5}$rad.

The distributions of curvature of the specimen in elevation at the each deflection angle is shown in Fig.7. A tendency that the larger the deformation is, the larger the curvature value is. When the deformation of the specimen exceeds deflection angle of 10.0rad., the curvature of the bottom portion of the specimen takes a larger value to that for the other portion.

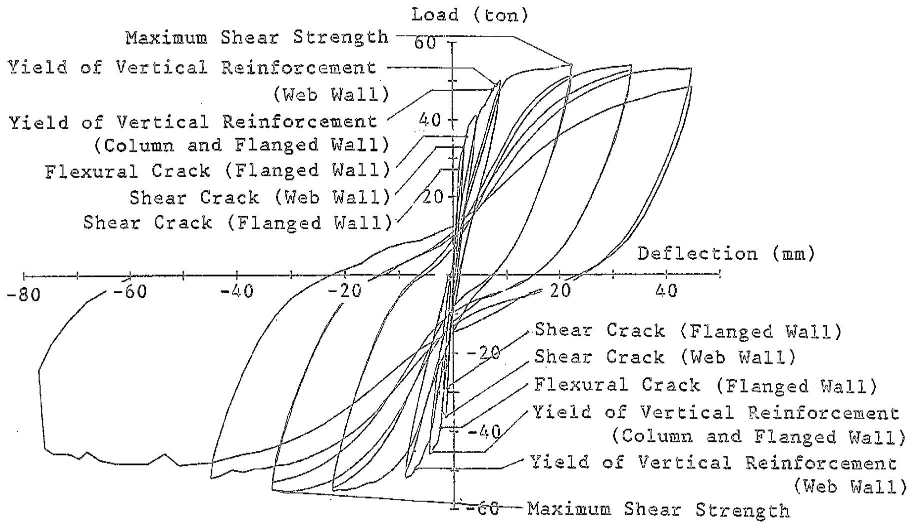


Fig.5 Relation of Load-deflection

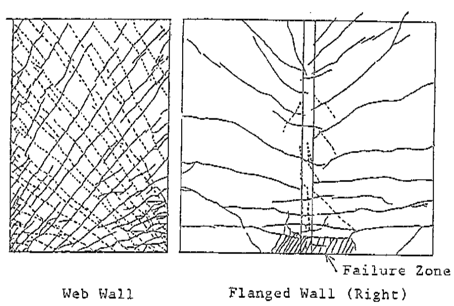


Fig.6 Crack distribution

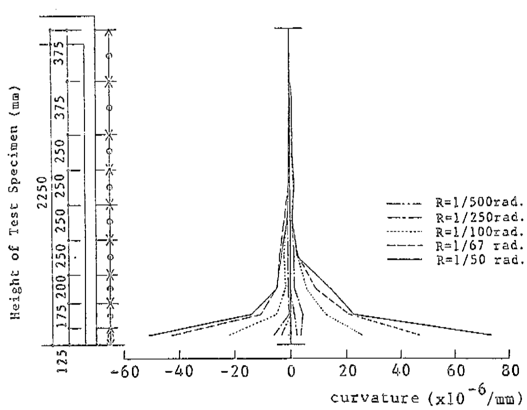


Fig.7 Distributions of curvature

4.2 Analytical results

The analytical results obtained from the FEM analysis for the solid wall models with various width of a flanged wall, height of a model and a thickness of a top stub are compared with those obtained from the flexural beam equation. The analytical results of the FEM and the flexural beam equation are shown in Fig. 8. The x-axis denotes the value of width of flanged wall, and the y-axis designates the values of Ki obtained from those analysis. The value of Ki increases in the enlarge of flanged wall. Mostly the value of Ki from the flexural beam theory is larger than the FEM analysis. When the height of the solid wall model exceeds 450cm, the Ki from the FEM analysis takes a larger value to that for obtained from the flexural beam theory. All the values of Ki from the FEM analysis with 30cm in thickness of a top stub are larger than the thickness of 10cm of that.

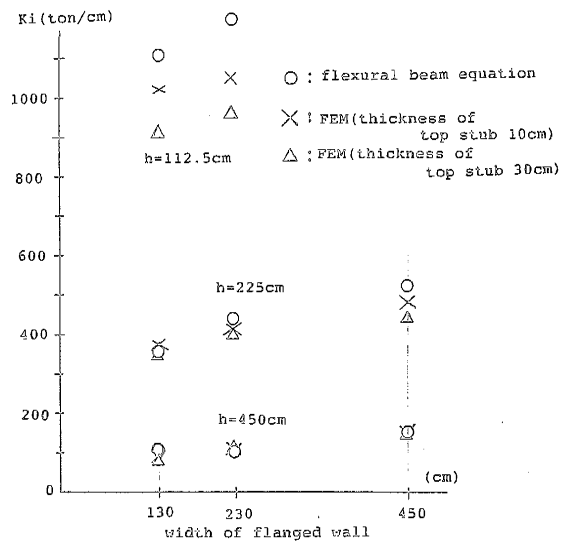


Fig.8 Relationship between Ki and width of flanged wall

4.3 Effect of flanged wall on initial rigidity

The formulas introduced up to the present such as that proposed in the Japanese calculation standard for reinforced concrete structures to evaluate the initial rigidity of a single-bay wall. They, however, do not take the flanged wall into account in evaluation of the rigidity of a solid wall.

The influence by the various width of a flanged wall into evaluation of the initial rigidity(K) is proposed in this study as follows:
The initial rigidity, as obtained from FEM analysis(Km), combine with a shear stiffness(Ks) and a flexural stiffness(Kb). The shear stiffness of a solid wall carry by a web wall only. The flexural stiffness of a solid wall obtain from not only a web wall but also flanged wall. The flexural stiffness of a solid wall, therefor, is expressed by the effect of a width of a flanged wall. The stiffness consideration for the effect of width of flanged wall(Ke) take from Km and Ks. So the effective width of flanged wall(We), as shown in Fig.9, which is calculated from Ke/Kbt. Where Kbt is computed by the full width of flange wall(Wt). Ke/Kbt is equal to We/Wt.

The correlation between We/Wt and Wt/h is described in Fig.10. The value of We/Wt is expressed by the equation of '1.21-0.85Wt/h' as shown in Fig.10, in which Wt/h is between 0.25 and 1.25. In the case of Wt/h less than 0.25, We/Wt is given by the constant value as 1.0. When Wt/h larger than 1.25, We/Wt is obtained by the constant value as 0.15.

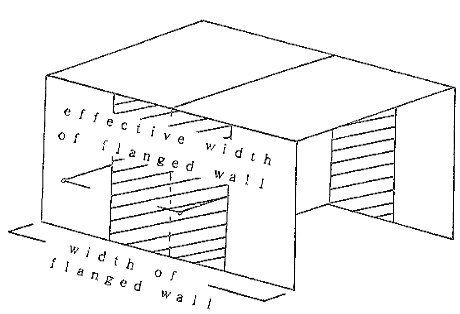


Fig.9 Effective width of flanged wall

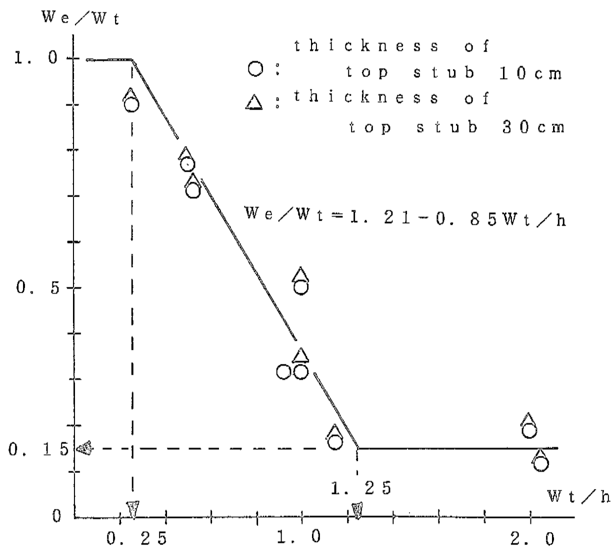


Fig.10 Relation of We/Wt and Wt/h

5 CONCLUSIONS

Based on the experimental and analytical study, the rigidity of the solid wall are evaluated in connection with the flanged wall in the breadth and the elastic performance. The flexure stiffness concerning the effect of a width of flanged walls is introduced.