ON STRESS OF SURROUNDING FRAME OF REINFORCED CONCRETE WALLS AFTER CRACKING

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This paper concerns the stresses of surrounding frame of reinforced concrete walls ("wall" refers to the wall confined in unit rectangular reinforced concrete rigid frame) after cracking in wall panel under shear force. Experiment of reinforced mortar walls is carried out under shear force. Based on the results of this experiment, the elastic-plastic analysis of the frame with compressive and tensile bracings is proposed to evaluate the stresses of surrounding frame of reinforced concrete shear walls after cracking. The evaluated results coincide fairly well with the tested results and may be used as design guide of reinforced concrete shear walls for engineers.

INTRODUCTION

It has been shown from numerous past experiments that reinforced concrete shear walls are efficient in resisting against lateral forces and that the behaviors of walls after cracking depend upon mainly the restrictive effect of surrounding frame. However there have been few studies on surrounding frame of walls after cracking, except for analytical studies by Imai[1], Tomii and Hiraishi[2]. The objective of this paper is to make clear the stresses of surrounding frame of walls after cracking. Experiment is carried out to clarify the effects of wall panel reinforcing on the restrictive characteristics of surrounding frame. The new loading method by the author is adopted to apply uniform shear force to sides of wall panel. To follow the tested results and to evaluates the stresses of surrounding frame, analytical research is performed. The evaluated stresses of surrounding frame are compared with the tested results.

EXPERIMENTAL RESEARCH

Test Procedure

The experiments are performed on six reinforced mortar shear walls of which aspect and reinforcing are same, except that they have three kind of reinforcing ratio of wall panel, that is 0.35, 0.70 and 1.05 percent. The geometric aspect and the reinforcing of specimens are shown in Fig. 1. The head and last number of the name of specimens indicate the percent of reinforcing ratio of wall panel and the order of performance of test. As shown in Fig. 1, the compressive loading by hydraulic jack is split into diagonal tension and compression by a pair of L-shaped pieces. The diagonal tension is distributed indirectly into shear force along sides of wall panel by the bond between concrete and steel plates burried in surrounding frame and the diagonal compression, directly through roller at loading point of surrounding frame. The deformations of walls are meassured by the combination of lengthening and shortening of a pair of diagonals of walls by dial-indicators, as shown in Fig. 1.

Test Results

The values of tested results, that is, the shear stress of wall τ and

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the story displacement angle R at various cracking and maximum capacity and the mode of failure are summarized in Table 1. The relationships between the load P and the story displacement angle R are shown in Fig. 4. In Table 1 and Fig. 4, IC indicates the initial cracking in wall panel, FF and FS, the initial flexural and shear cracking of surrounding frame, SD, the shear failure, and MAX, the maximum capacity.

ANALYTICAL RESEARCH

Analysis

The wall panel after cracking of shear walls is replaced with tensile steel bracings and compressive concrete bracings which are parallel to diagonal direction and deform only axially. Two analytical methods are used to tensile steel bracing. In analysis-1, the reinforcing bars of wall panel are replaced with the equivalent tensile forces in diagonal direction to the yield stress of them. In analysis-2, they are replaced with the equivalent tensile bracing in diagonal direction to them. The models of two analyses are shown in Fig. 2 in which full lines indicates compressive bracings and dotted lines, tensile. The load-displacement relationship of axial, bending and shear forces of frame elements are determined independently. The patterns of the load-displacement relationship of them are shown in Fig. 3. The calculated values of the strength at cracking and ultimate capacity and the coefficient of the rigidity after cracking, that is, the ratio of the rigidity after cracking to the initial rigidity of the frame elements under axial, bending and shear forces are summarized in Table 2. The analyses are performed by stiffness method.

Analysis Results and Discussion

The relationship between the load and the story displacement angle are shown in Fig. 4. As seen from the comparison of the analysis curves with the tested curves, it may be suggested that the curve of analysis-1 follows well the curve of specimens of 0.35-W and 0.70-W, while the curve of analysis-2, that of specimen of 1.05-W. The evaluated values of the load and the story displacement angle at IC, FF, FS and SD corresponding to maximum capacity in test are plotted in Fig. 4 and tabulated in Table 1. It may be suggested that the evaluated values coincide fairly well with the tested values except for the story displacement angle at the shear failure of specimen of 1.05-W. From the above coincidence, it may be concluded that analysis-1 correspond to the specimens of 0.35-W and 0.70-W, while analysis-2, to the specimen of 1.05-W.

The shear force and the bending moment of the surrounding frame of walls after cracking evaluated by analysis-1 for the specimens of 0.35-W and 0.70-W and by analysis-2 for the specimen of 1.05-W are shown in Fig. 5. As expected from the tested results, the shear force develops in only the range of beam and column near the loading point of compression and decrease as the wall panel reinforcing increase. As seen from the bending moment diagrams, the moment of the beam is almost negative (such moment that outward external fiber of the surrounding frame is in tension and inward external fiber, in compression) except near the loading point of compression. And the moment of column is positive except the specimen of 0.70-W. The critical bending moment for the practical design is negative moment.

Therefore the bending reinforcing of the surrounding frame must be provided to the beam, especially at the center of the beam.

CONCLUSIONS

(a) The analysis method by the elastic-plastic analysis of the frame with compressive and tensile bracings may be used to get the behaviors of shear walls after cracking. (b) Analysis-1 is used to the wall having the lightly reinforcing in wall panel and analysis-2, to the wall having heavily reinforcing in wall panel. (c) The shear force of the surrounding frame develops in only the range of beam and column near the loading point of compression. (d) The bending moment at the center of beam is critical from the views of structural design of shear walls.

REFERENCES

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2) Tomii,M. and Hiraishi,H.; "Elastic Analysis of Framed Shear Walls by Assuming Their Infilled Panel Walls to be 45-Degree Orthotropic Plates, Part II --Numerical Examples--," Trans. of A.I.J., Oct., 1979, No.284, pp.51-58.

Table 1 Tested and Computed Results

	IC		FS & position			FF & position			MAX		Mode of failure
	$_w\tau_{cr}$	$_wR_{cr}$	$_f\tau_s$	$_fR_s$		$_f\tau_f$	$_fR_f$		τ_{max}	R_{max}	
0.35-W-1	20.7	0.59	37.8	3.03	C.E.*	28.8	2.08	B.CT.*	46.7	8.88	S.F.B.,S.F.C.*
0.35-W-2	19.8	0.64	39.6	2.85	B.E.	41.4	3.10	B.CT.	52.6	7.13	S.F.B.
ANALYSIS-1	21.6	0.90	39.6	3.20	B.E.	36.0	2.66	B.CT.	50.5	6.37	S.F.B.
ANALYSIS-2	21.6	1.16	36.0	3.03	B.E.	32.4	2.47	B.CT.	46.8	6.21	S.F.B.
0.70-W-1	25.2	0.53	45.0	2.64	C.E.	48.6	2.94	B.CT.	61.3	5.80	S.F.C.
0.70-W-2	21.7	0.32	54.1	3.81	C.E.	54.1	3.81	B.CT.	61.7	6.01	S.F.C.
ANALYSIS-1	21.6	0.34	46.8	2.87	C.E.	46.8	2.87	B.CT.	61.3	6.54	S.F.B.
ANALYSIS-2	21.6	0.93	43.2	3.00	B.E.	39.6	2.47	B.CT.	54.1	5.97	S.F.B.
1.05-W-1	22.5	0.50	45.0	2.42	C.E.	50.5	3.01	B.CT.	64.5	13.34	SL.F.
1.05-W-2	18.0	0.28	54.1	3.01	C.E.	54.1	3.01	B.CT.	68.8	9.82	S.F.C.,SL.F.
ANALYSIS-1	21.6	-0.17	61.3	5.20	B.C.E.	61.3	5.20	B.CT.	72.1	8.29	S.F.B.
ANALYSIS-2	21.6	0.82	50.5	3.29	B.E.	46.8	2.75	B.CT.	64.9	10.06	S.F.B.

* B.E.(C.E.) = Beam (Column) end B.C.E. = Beam and Column end
B.CT. = Beam center SL.F. = Slipping failure
S.F.B.(S.F.C.) = Shear failure of beam (of column)

$_w\tau_{cr}$ = shear stress of wall at cracking in wall panel, kg/cm^2
$_f\tau_s$ ($_f\tau_f$) = shear stress of wall at shear (flexural) cracking in surrounding frame, kg/cm^2
τ_{max} = shear stress of wall at maximum capacity, kg/cm^2
$_fR_s$ ($_fR_f$) = story displacement angle of wall at shear (flexural) cracking in surrounding frame, ($\times 10^{-3}$)
R_{max} = maximum story displacement angle, ($\times 10^{-3}$)

Table 2 Strengths and Coefficients of Rigidity

	axial force	bending moment	shear force
cracking strength	N_{cr} = 953kg	M_{cr} =1,365kg·cm	Q_{cr} = 773kg
ultimate strength	N_u =4,226kg	M_u =9,746kg·cm	Q_u =1,092kg
coefficients of rigidity after cracking	α_n = 0.31	α_m = 0.27	α_q = 0.10

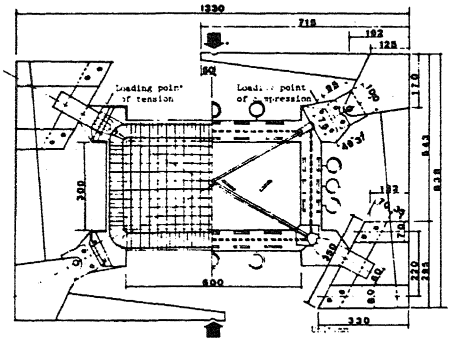

Fig. 1 Specimen and Loading Method

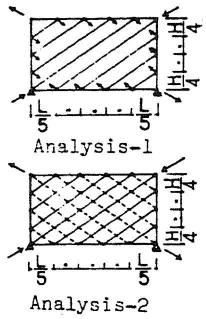

Fig. 2 Analysis Models

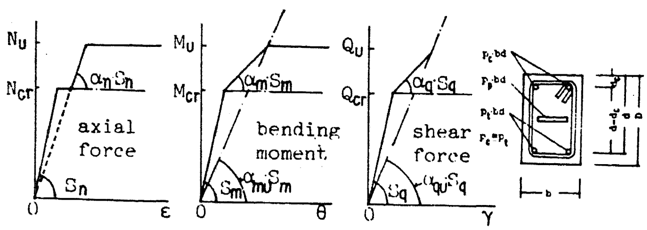

Fig. 3 Patterns of Load-Displacement Relationship

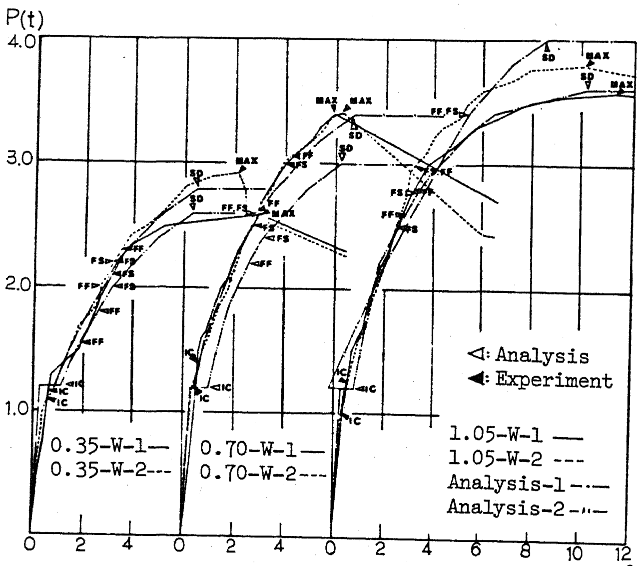

Fig. 4 Load-Story Displacement Angle Relationships

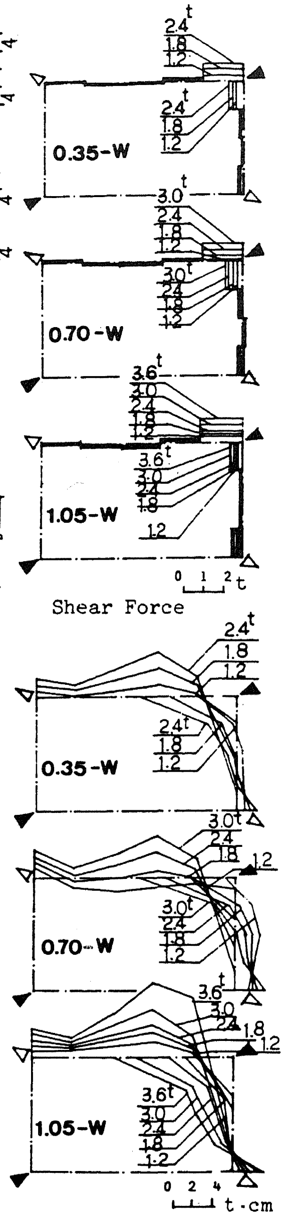

Fig. 5 Stresses of Surrounding Frame