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DAMAGE ASSESMENT OF LOW-RISE R.C. SHEARWALLS WITHOUT BOUNDARY ELEMENTS

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SUMMARY

This paper tries to establish the damage assessment criteria for low-rise R.C. shearwalls after repeated or reversed cyclic horizontal loads. Two different groups of shearwall, both without boundary element nor axial forces, were tested. The first group of shearwall was with vertical slits all way down from top to bottom of wall. The second group of shearwall was without any slit. There were 9 specimens in each group of shearwall. The dimensions of the specimens were either 100cm x 50cm x 10cm or 100cm x 75cm x 10cm. Loading histories were monotonic, repeated cyclic in one direction and reversed cyclic in two directions. Cracks propagation and cracking patterns were examed carefully in each loading stage. The damage assessment of wall was introduced by the visible cracking patterns, by accumulated plastic deformation and by the damage index equation:

$$D = \frac{\alpha\delta_m}{\delta_f} + \frac{\beta\int dE}{P_u\delta_f} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

which was modified from Prof. Ang's equation (Ref.1). Where δ_f is the deflection of wall at failure; δ_m is max. response of wall; P_u is the ultimate load; $\int dE$ is the energy dissipation; α and β are correlation factors.

INTRODUCTION

Low-rise shearwalls without vertical slits are sometimes used in building structures as well as auxiliary rooms of nuclear power plants. The theoretical and empirical analyses of such shearwalls under monotonic loading were published in Ref.2, 3 and 4. While the rules for stiffness change were studied in Ref.5.

The slitted walls tested in this paper are different from those of Kajima's Lab, Japan (Ref.6). Kajima's walls are precasted and infilled to steel frame. For easy erection of the walls, the length of slits are about one half of the wall height to keep the integration of wall. The slitted walls discussed in this paper is developed for cast-in-place with R.C. frame. There is no worry for erection trouble. So slits are all the way down from top to bottom of wall to increase the ductility of shearwalls. The yield load P_y ultimate load P_u and rules for stiffness change were discussed in Ref. 4 and 7.

This paper discusses the damage conditions of these two groups of R. C. shearwalls under cyclic loads completely from experimental results. The criteria for damage assessment could be apply to either post-earthquake or pre-earthquake suppose the crack patterns are visible on the wall or the hysteresis of wall can be predicted, for example by Ref.5 and 7.

EXPERIMENTAL TEST

The parameters for tested shearwalls are amount of reinforcement, strength of concrete and loading history as listed in TABLE 1(a) and 1(b). The height of slitted walls is 50 cm; while the height of non-slitted walls is either 50 cm or 75 cm.

The experimental instrumentation is shown in Fig.1. The specimen is loaded horizontally through five high tension bolts at the loading beam by hydraulic jacks. The total lateral deflection of the specimen is measured by linear potentiometers placed on slide faces. Fig.2 shows the typical comparison of load-deflection curves of slitted and non-slitted walls. The vertical axis is the horizontal load; the horizontal axis is the lateral deflection measured at top of wall.

TYPICAL CRACKING PATTERNS

Let's define slight damage stage for $P_c < P < P_y$; moderate damage stage for $P_y < P < P_u$; severe damage stage for $P > P_u$. Fig.3 shows the typical cracking patterns of walls at slight damage, moderate damage and severe damage stages. For instance, for non-slitted shearwalls, the incline angle of diagonal cracks is about 40 degrees at slight damage stage; about 45 degrees at moderate damage stage and about 55 degrees at severe damage stage. For slitted shearwalls, flexural horizontal crack appear at both ends of slits at slight damage stage; diagonal cracks appear in some single wall columns at moderate damage stage; diagonal cracks across two or three wall columns at severe damage stage. The visible crack patterns provide good references for damage assessment of walls post-earthquake.

ACCUMULATED PLASTIC DEFORMATION

The accumulated plastic deformation is a good damage index for reinforcing bars subjected to reversed cyclic loadings (Ref. 8). Applying the same technical process to shearwalls subjected to cyclic loadings, the accumulated plastic deformations are shown in Fig. 4. Fig. 4 implies that if the accumulated plastic deformation under cyclic loads is about 1/3 of the failure deformation under monotonic load, the wall is moderate damaged. And if the accumulated plastic deformation is about 2/3 of failure deformation under monotonic load, the wall is severe damaged. So the accumulated plastic deformation is one of damage index supposed the hysteretic loops of R.C. walls are predictable.

DAMAGE INDEX EQUATION

Equation (1) is an empirical formula to calculate the damage assessment of R.C. members. In general, $\alpha = 1.0$ and $\beta = 0.2$ (Ref. 1). For low-rise R.C. shearwalls tested in this paper, whether slitted or not, the most stable correlation factors are $\alpha = 1.0$ and $\beta = 0.1$. TABLE 2 shows the D values corresponding to damage conditions and possible peak loads.

CONCLUSION

This paper presents three damage assessment methods for R.C. shearwalls, completely through experimental test, as follows:

1). by cracking patterns as shown in Fig.3.

2). by accumulated plastic deformations. Let's divide this deformation by the failure deflection δ_f under monotonic load. If the quotient is in between 0.33 and 0.67, it is moderate damaged. If the quotient is more than 0.67, it is severe damaged.

3). by damage index D as shown in TABLE 2.

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TABLE 1(a) DATA OF SLITTED WALLS

Speci. No.	WxHxt cmxcmxcm	Vertical Rebars		Horizontal Rebars		f'_c kg/cm²	No.of Slit	Slit Infill	Loading History
		Rebar	f_y kg/cm²	Rebar	f_y kg/cm²				
SSW21	100x50x10	8-D10	4770	4-D10	4770	272	3	None	Monotonic
SSW22	100x50x10	8-D10	4770	4-D10	4770	275	3		Rept.Cycl.
SSW23	100x50x10	8-D10	4770	4-D10	4770	280	3		Rept.Cycl.
SSW24	100x50x10	8-D10	4770	4-D10	4770	285	3	1 Asbes sheet	Monotonic
SSW25	100x50x18	8-D10	4770	4-D10	4770	270	3		Rept.Cycl.
SSW26	100x50x18	8-D10	4770	4-D10	4770	275	3		Rever.Cycl.
SSW27	100x50x10	8-D10	4770	4-D10	4770	275	3	2 Asbes sheets	Monotonic
SSW28	100x50x18	8-D10	4770	4-D10	4770	270	3		Rept.Cycl.
SSW29	100x50x18	8-D10	4770	4-D10	4770	288	3		Rever.Cycl.

TABLE 1(b) DATA OF NON-SLITTED WALLS

Speci. No.	W x H x t cmxcmxcm	Vertical Rebars		Horizontal Rebars		f'_c kg/cm²	Loading History
		Rebar	f_y kg/cm²	Rebar	f_y kg/cm²		
SW9	100x50x10	2-D19 3-D10	4265 4770	4-D10	4770	266	Monotonic
SW1A	100x50x10	6-D13	4770	4-D10	4770	275	Rept. Cycl.
SW11	100x50x10	2-D19 3-D10	4265 4770	4-D10	4770	266	Rever. Cycl.
SW13	100x50x10	6-D13	4930	0		330	Monotonic
SW2	100x50x10	6-D13	4770	4-D10	4770	265	Rever. Cycl.
SW15	100x75x10	2-D19 3-D10	4265 4770	6-D10	4770	265	Monotonic
SW16	100x75x10	6-D13	4770	6-D10	4770	270	Monotonic
SW17	100x75x10	2-D19 3-D10	4265 4770	6-D10	4770	265	Rever. Cycl.
SW19	100x75x10	6-D13	4770	0	-	250	Monotonic

TABLE 2 DAMAGE ASSESSMENT BY D VALUES

Damage Conditions	Possible Peak Loads	Damage Index D
Slight Damage	$P_c < P < P_y$	$a < D < b$
Moderate Damage	$P_y < P < P_u$	$b < D < c$
Sever Damage	P overs P_u	$D > c$

1). For slitted shearwalls:
for repeated loads, $a = 0.2$ $b = 0.6$ $c = 1.0$
for reversed loads, $a = 0.2$ $b = 1.2$ $c = 2.0$
2). For non-slitted shearwalls:
for repeated loads, $a = 0.2$ $b = 0.4$ $c = 0.8$
for reversed loads, $a = 0.2$ $b = 0.8$ $c = 1.6$

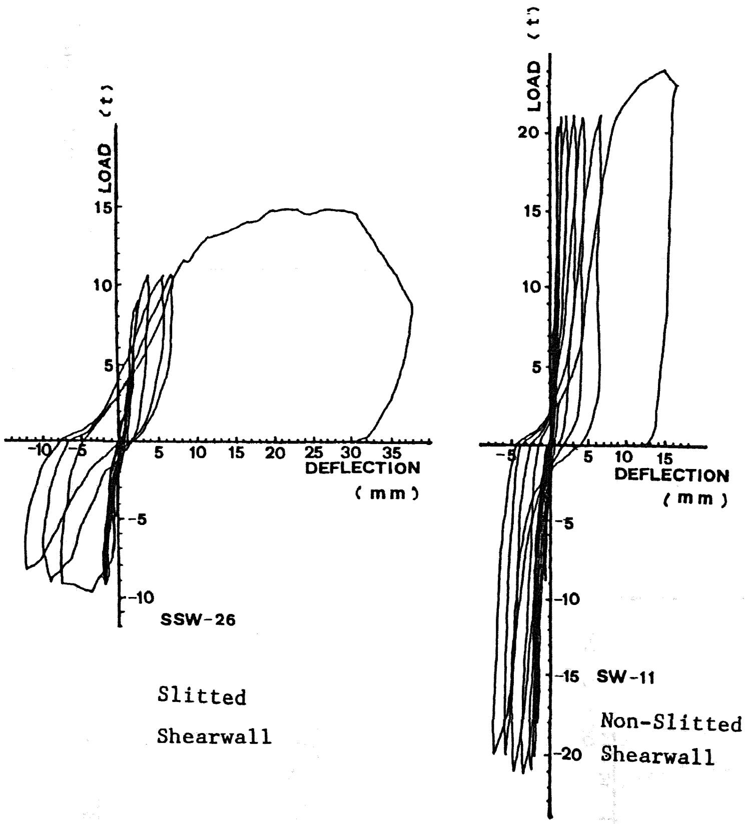


FIG.2 COMPARISON OF LOAD-DEFLECTION CURVES FOR SLITTED AND NON-SLITTED WALLS

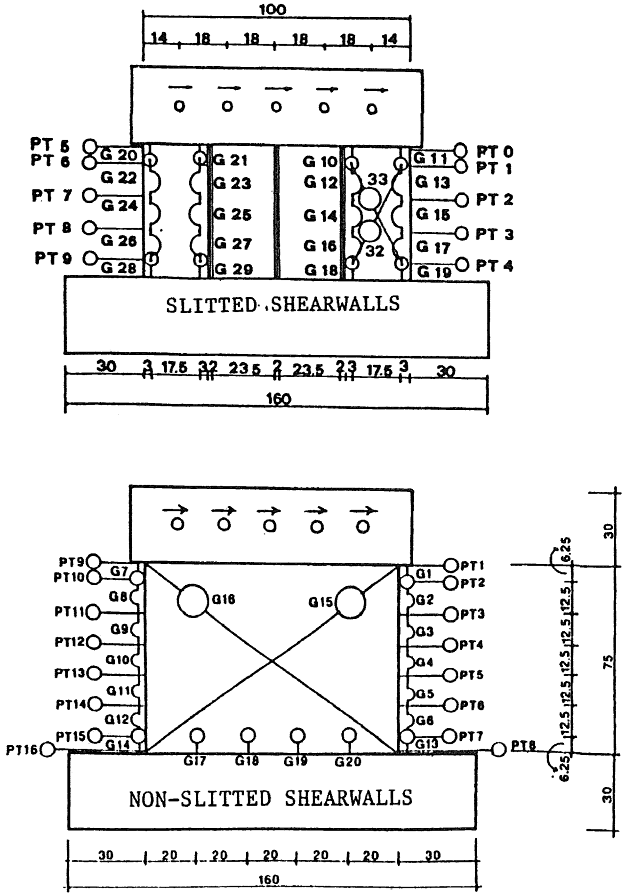
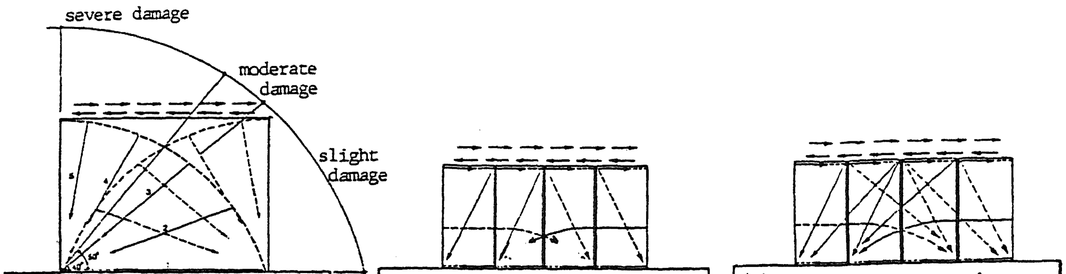


FIG.1 EXPREIMENTAL INSTRUMENTATION



(a) cracking at different stages for walls without slit

(b) cracking at moderate damage for slitted walls

(c) cracking at severe damage for slitted walls

FIG.3 TYPICAL CRACKING PATTERNS

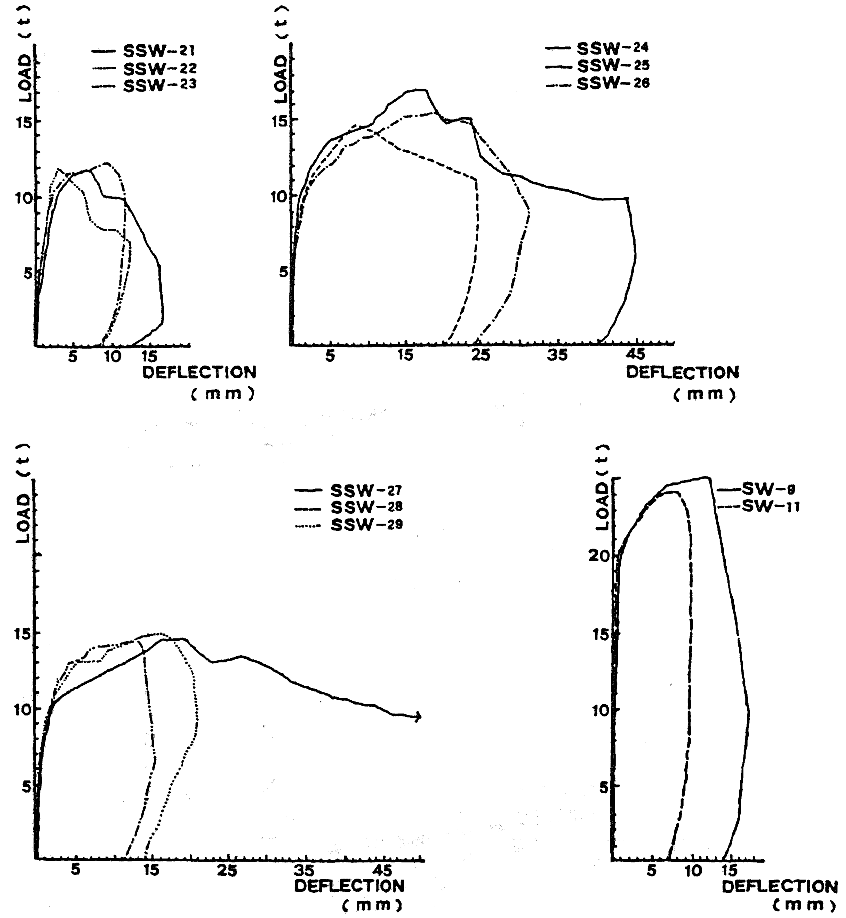


FIG.4 COMPARISON OF ACCUMULATED PLASTIC DEFORMATION AND MONOTONIC DEFORMATION