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Experimental study of low-rise wall under fast loading rate.

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ABSTRACT

Experiment were conducted to investigate the flexural yielding and shear behavior of low-rise at high loading rate. The effects of loading rate was confirmed comparing the specimens with the same reinforcing bar detail which were applied two different loading rates, 1mm/sec for static and 100mm/sec for dynamic. The results of experiment shows that the flexural yielding strength at high loading rate is 10% higher than low loading rate. The maximum shear strength is 10% higher at high loading rate than low one. The effects of loading rate on rebar ratio is confirmed by flexural yielding design specimen with maximum rebar ratios.

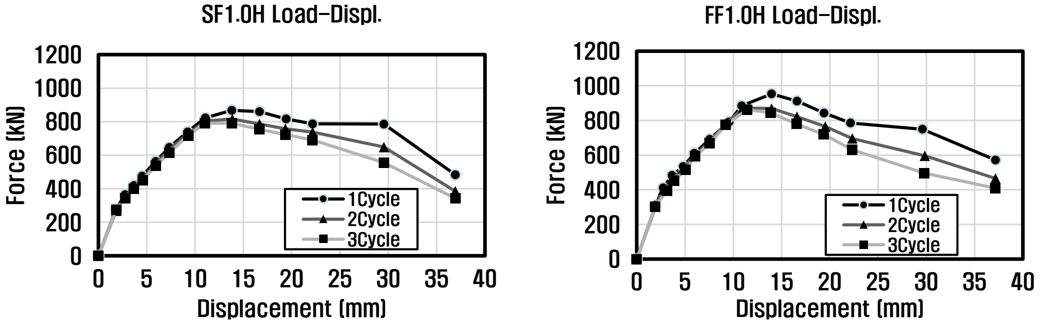

Fig. 1 Flexural Specimen Load-Displacement curve (Left: Static, Right: Dynamic)

1. INTRODUCTION

Due to the Gyeong-Ju earthquake, the characteristics of the Korean earthquakes appeared and the concerns about safety of domestic nuclear power plants has increased. KEPCO (Korea Electric Power Cooperation) and KAERI (Korea Atomic Energy Research Institute) have previously performed seismic performance evaluations. The exact extreme strength is needed for accurate seismic performance

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evaluations. A structure quakes very fast when an earthquake occurs. However many tests for seismic capacity were conducted on slow loading rate that is exclude the effects of loading rate. In the present study, the effect of loading rate on the low-rise wall subjected to cyclic loading was studied. The test parameters were the loading rate, design failure mode and reinforcing ratio.

2. TEST PLAN

2.1 Major test parameters and specimens

Three wall specimens with aspect ratio of 1.0 for flexural yielding failure and two for shear failure. The wall test program is summarized in Table1. The main test parameters was loading rate. Other test parameters were the design failure mode and shear reinforcement ratio. The first letters, F and S, refer to the loading rates: F is fast and S is slow. The fast loading rate is 100mm/s and slow one is 1mm/s. The second letters refer to the design failure modes: F is flexure yielding failure and S is shear failure. The failure mode was controlled by vertical reinforcing bar ratio in the wall flange area. The last word H and M refer to shear reinforcing bar ratio: 0.5% and 0.9%

Specimen	Aspect ratio h_w/l_w	Failure mode	Wall Concrete		Horizontal Bar			Vertical Bar				Loading rate, (mm/sec)
			f_c' (MPa)	P (kN)	Number and type	ρ_h (%)	$\rho_h f_{yh}$ MPa	ρ_{web} (%)	ρ_{flange} (%)	ρ_v (%)	$\rho_v f_{yv}$ MPa	
SFH	1.0	Flexure failure	36	0	6 - D13	0.51	2.55	0.47	4.05	1.66	7.92	1
FFH	1.0	Flexure failure	36	0	6 - D13	0.51	2.55	0.47	4.05	1.66	7.92	100
FFM	1.0	Flexure failure	36	0	7 - D16	0.92	4.31	1.19	5.75	2.71	13.05	100
SSH	1.0	Shear failure	35	0	6 - D13	0.51	2.55	0.47	1.94	0.96	4.68	1
FSH	1.0	Shear failure	36	0	6 - D13	0.51	2.55	0.47	1.94	0.96	4.68	100

Table. 1 Test plan

For instance SFH indicates that a flexural mode specimen with 0.5% of shear reinforcing bar and slow loading rate. Two pair of Specimens that one is SFH and FFH and the other is SSH and FSH. FFM was prepared for comparing with FFH as for effect of reinforcing bar ratio on flexural yielding failure.

The dimension of the walls were 1500mm (length) x 1500mm (height) x 200mm (thickness). In all specimens, Grade 420 MPa reinforcing bars were used.

2.2 Test instrumentation and procedure

Supports were installed back and forth of specimens to prevent slip between the specimen and the laboratory during experiments. 12 of pre-stressing steel bar were used to strongly compress the wall base and the laboratory floor. Auxiliary structures was installed to prevent eccentricity at specimen head. The experiments were performed with displacement control, and the values controlled using actuator stroke. The actuator stroke cannot accurately represent the displacement of specimen, but the actuator stroke was used because it is impossible to check the displacement in real time during the high loading rate experiment and reflect it on the actuator.

3. TEST RESULT

3.1 Crack patterns and failure modes

The two specimens SFH and FFH has the same reinforcing details and designed for flexural yielding failure. There were several differences when comparing two results. First, small and thick cracks were shown on fast loading rate. Secondly, the direction of the crack draw more gradual on fast loading rate specimen. As a result, the cracks were concentrated on the bottom of the specimens. The failure shapes of the SFH and FFH were fractured due to the concrete compression at the bottom of the flange of the specimens. The diagonal shear cracks appeared on the other two pair of specimens SSH and FSH.

3.2 SFH and FFH

Figure 2, left graph shows the envelop curve of load-displacement curves for the flexural yield failure specimens, SFH and FFH. The graph consisting of dotted lines and triangle markers is representing FFH and the other graph consisting of black lines and circular markers is representing SFH. The design flexural yielding strength is 823kN that based on sectional analysis. The maximum strength of FFH was 953kN and 867kN at the slow loading rate (SFH). Both experiments were larger than the design strength and maximum strength occurred in the same step. Two specimens showed typical flexural yielding failure behavior with the ductility ability after the maximum strength. The flexural strength of specimen at fast loading rate was 10% higher comparing with at that of slow loading rate.

3.3 FFM

The flexural strength of FFM which had maximum shear reinforcing bar ratio was 1415kN. The flexural yielding design strength was 1288kN. The test strength was 10% higher than design strength when the actuator pushes the specimen. Compared with FFH and SFH, higher ductility was shown. The ratio that maximum test value divide by design strength is 10% which is lower than FFH (16%).

3.4 SSH and FSH

Figure 2, right graph shows the envelop curve of the lateral load-displacement relationships of the two shear design specimens, SSH and FSH. The graph consists of dotted line indicating FSH and black bold line for SSH. The design shear strength is calculate following ACI 318 and ACI 349 and the value is 836kN. The maximum strength of FSH was 1605kN when the actuator pushes specimens and 1530kN when the actuator pulls. The extreme strength of SSH was 1544kN and 1302kN. Both specimens show much larger strength than design strength which is 86% on fast loading rate and 70% on slow loading rate. Two specimens showed typical diagonal shear failure with 45-degree shear cracks. The shear strength of FSH which was tested on fast loading rate was 10% higher than SSH which was tested on slow loading rate.

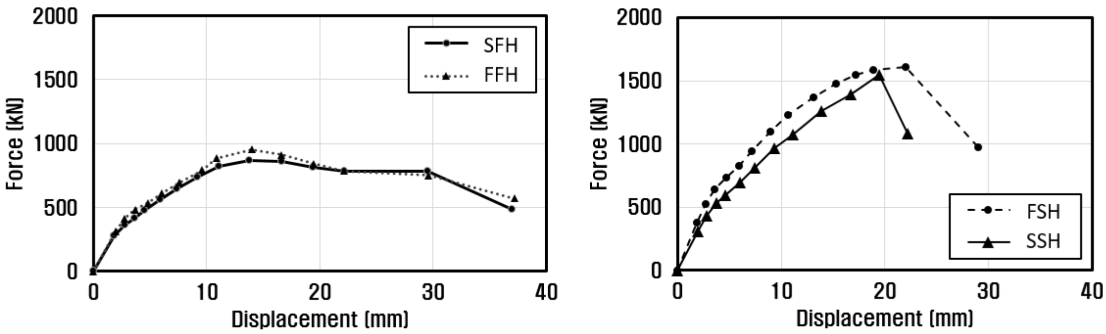

Fig. 2 Envelop of load-displacement (Left: SFH and FFH, Right: SSH and FSH)

4. CONSLUSIONS

To investigate the effect of loading rate on low-rise wall were tested under cyclic lateral loading with two type of loading rate. Test result summarized on table 2. Three specimens under fast loading rate had higher capacity than slow loading rate and design strength. The major findings of the present study are summarized as follows: 1. Thick and few cracks appears on fast loading test. This is because the tensile strength of concrete is higher on fast loading rate. 2. The effect of loading rate is higher under low reinforcing bar ratio. Compare FFM and FFH, the ratio test strength divided by design strength is higher on the half of reinforcing bar ratio model (FFH) than maximum reinforcing bar ratio. 3. Shear strength can evaluate 70% higher than ACI design strength. In addition, considering effect of loading rate, the extreme shear strength can estimate 10% higher.

Specimen	Aspect ratio	ρ_h (%)	Loading rate (mm/s)	V_d (kN)	V_{test} (kN)			V_f/V_{test} (kN)		
					(+)	(-)	Aver.	(+)	(-)	Aver.
SFH	1.0	0.51	1	823	867	716	792	1.05	0.87	0.96
FFH	1.0	0.51	100	823	953	803	878	1.16	0.98	1.06
FFM	1.0	0.92	100	1288	1415	1187	1301	1.10	0.91	1.01
SSM	1.0	0.51	1	836	1544	1302	1423	1.85	1.56	1.70
FSM	1.0	0.51	100	836	1605	1530	1568	1.92	1.83	1.86

Table. 2 Summary of Test result

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