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Cyclic test for effects of loading rate on flexural yielding capacity of wall

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1. Introduction

In the event of an earthquake, structures vibrate at high speed. However, most of seismic design code reflect the result of experiments at static loading rate. The behavior of the wall in the event of earthquake is considered to be different. In the research, the effects of loading rate on the row-rise wall were investigated. That carried out to find the maximum load and realistic behavior of the wall on fast loading rate.

2. Experiment models and variables

Nuclear power plants structures require high seismic performance. Accordingly that requirement, reinforcement bar ratio should be close to the maximum rebar ratio by ACI 349 and structures are mainly consisted of maximum shear reinforcement ratio. Nuclear power plant structures are mostly wall structures and the walls are very low aspect ratios of 0.5~1.0.

2.1 Experiment Model

Nuclear power plants wall use the maximum rebar ratio. However the rebar ratio is reduced by half of maximum reinforcement bar ratio according to the performance of the dynamic actuator. The specimen size was 1500mm (length) and 200mm (thickness). The concrete design compressive strength was 42 MPa and the rebar was used KS D 3504 SD400 that nominal yielding strength is 420 MPa. In order to prevent unintended failure, specimens' base and head were designed very high reinforcement bar ratio

2.2 Experiment variables

In this experiment, a test was conducted to evaluate the flexural yielding strength of low-rise wall by loading rate. Table I is a description of the specimens. All specimens was designed to flexural yielding failure. The specimen 1.0FHF was used as reference specimens that reinforcement bar ratio was 0.5 and aspect ratio was 1.0. 1.0FHS which was same detail with 1.0FHF was made for the purpose of direct comparison depending on loading rate. The fast loading rate was 100mm/sec and the slower one is 1mm/sec. The other specimens 1.0FMF and 0.5FHF were designed to investigate the reinforcement bar ratio and the aspect ratio at each through comparison with 1.0FHF.

2.3 Test setup

Jigs was installed back and forth of specimens to prevent slip between the specimen and the laboratory during experiments. 12 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. Experiment Result

There was higher reaction when the actuator pushed the specimen. This is because a loss of tension between the steel rod and nut that is connecting the laboratory, the actuator and the specimens, for that reason the small strength was obtained when the tensile force acts on the actuator.

3.1 1.0FHF and 1.0FHS

Figure 1 shows the load-displacement curves for the flexural yield failure specimens, 1.0FHF and 1.0FHS. A graph consisting of dotted lines and triangle markers is representing 1.0FHF and the other graph consisting of black lines and circular markers is representing 1.0FHS. The design flexural yielding strength that based on sectional analysis is indicated by a red dotted line and the estimation of shear-friction strength which was based on ACI-349 is marked by a blue dotted line. The maximum strength was 953kN at the fast loading rate

Table I. Experiment specimen design values.

Name	**Aspect ratio**	**Failure Mode**	**Concrete compressive strength F_{ck} (MPa)**	**Horizontal Bar**		**Vertical Bar**	**Loading rate (mm/sec)**
				ρ_h (%)	$\rho_h f_{yh}$ MPa	***Bar Number and Type***	
1.0FHF	1.0	Flexure	35.8	0.51	2.44	6 – D10 / 4 – D13 / 8 – D25	100
1.0FHS	1.0	Flexure	35.8	0.51	2.44	6 – D10 / 4 – D13 / 8 – D25	1
1.0FMF	1.0	Flexure	35	0.92	4.36	12 – D16 / 4 – D29 / 8 – D32	100
0.5FHF	0.5	Flexure	41	0.51	2.44	6 – D10 / 4 – D13 / 4 - D16 / 4 – D19	100

and 867kN at the slow loading rate. Both experiments were larger than the design strength of 823kN 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 at slow loading rate was 110% comparing with at that of fast loading rate.

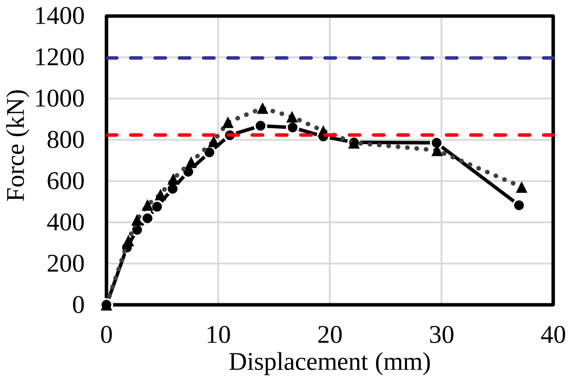

Fig I. Load-Displacement curves of 1.0FHF and 1.0FHS

3.2 1.0FMF

The flexural yielding strength of the specimens with maximum reinforcement bar ratio, 1.0FMF, was 1415kN that was 10% higher than the design flexural yielding strength. Compared with 1.0FHF, higher ductility was shown, and the step when maximum strength occurred appeared after one step after that of 1.0FHF.

3.3 0.5FHF

This specimen was specimen to investigate the effect of aspect ratio. The flexural strength of the specimen was 976kN. That is 17% higher than the design strength 832kN. The flexural yielding strength increment ratio was similar to the specimen that aspect ratio 1.0. The relation between the effect of loading rate and the aspect ratio is small is small until 1.0 aspect ratio.

4. Conclusion

Table II summarizes the experimental results. The maximum strength was higher than the design strength at all specimens. The results of experiments 1.0FHF and 1.0FHS, which were experimented with the same detail but different loading rate, the strength is higher on fast loading rate. Compared 1.0FHF and 1.0FMF, the effect of loading rate was higher in wall with low reinforcement bar ratio. These results can be used in various seismic performance evaluation.

Table II. Summary of experimental results.

Name	Aspect ratio	ρ_h (%)	V_f (kN)	V_{test}		V_f/V_{test}	
				(+)	(-)	(+)	(-)
1.0FHF	1.0	0.51	823	867	716	1.05	0.87
1.0FHS	1.0	0.51	823	953	803	1.16	0.98
1.0FMF	1.0	0.92	1288	1415	1187	1.10	0.91
0.5FHF	0.5	0.51	832	976	747	1.17	0.76

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