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Evaluation of Wall Performance with Aspect Ratio of 1.0 and 550MPa Bars

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1. Introduction

Massive numbers of steel bars are needed to construct structures meeting high standard of safety requirements such as structures used for nuclear power plant facilities. In order to achieve competitiveness in exporting nuclear power plants, high-strength bars are necessary to improve safety by way of using a reduced number of bars and optimized design. The yield strength of horizontal and vertical bars used for the wall of a nuclear power plant auxiliary building is limited to 60,000psi (420Mpa) by current KEPIC SNC code. ACI 349, the matrix of KEPIC SNC code, also limits the yield strength of the bars to 60,000psi (420Mpa). But raising the yield strength of flexural bars to 80,000psi (550MPa) is in progress. For the case of shear bar, however, yield strength of shear and torsion bar are limited to 60,000psi (420MPa) to restrain crack width against diagonal tension. According to recent domestic and foreign studies, high-strength bars are possible to use as shear reinforcement bars. The yield strength of shear bars in Korea and European countries is higher than the yield strength limited by KEPIC and ACI. To use shear bar (horizontal bar) having higher yield strength for the wall used in a nuclear power plant, experiments with Gr.80 bars were performed in this study to evaluate the wall performance and to verify applicability of high-strength bars (Gr.80) as shear bars.

2. Evaluation of Wall Performance

In a nuclear power plant structure, using shear wall systems is predominant to resist against seismic loads and lateral loads. Verification of shear performance with test specimens driven from shear failure of wall is required to make better use of high-strength bars as shear bars. Not only for the shear performance but also for the verification of shear performance after flexural failure through the test specimens driven from shear failure are needed for walls of nuclear power plant structure which require high seismic resistance performance.

2.1 Design of Test Specimen

All test specimens are rectangular and have cross-sectional dimensions of width 1500mm× height 1500mm× thickness 200mm. Failure mode of members was classified into two groups to run the test. Shear failure mode was planned to check resistance against horizontal load. (Refer to table 2.1, S1, S2: Shear failure modes.) Referring to the results of a previous study stating that the ductility of bar decreases as the yield strength of bar increases, flexure failure modes were designed to analyze ductility of targeted 550MPa bar (Refer to table 2.1, F1, F2: flexure failure modes). To raise the yield strength of horizontal rebar, two types of horizontal bar were used: one having yield strength of 420MPa (actual yield strength 470MPa) and the other having yield strength of 550MPa (actual yield strength 667MPa). Steel ratios of specimens using each type of the bar were 0.68% and 0.99%, respectively. In flexure failure modes, two types of the bar were used: one having yield strength of 420MPa and the other having yield strength of 550MPa while maintaining concrete strength constant at 46MPa.

Table 2.1 Variables of Wall Specimen

No.	Wall web region				Wall boundary region		
	Horizontal		Vertical		Confine ment rebars	Vertical	
	f_{yh} (MPa)	ρ_h (%)	f_{yv} (MPa)	ρ_v (%)		f_{yf} (MPa)	ρ_f (%)
S1	550 (667)	0.68	550 (653)	0.70	-	550 (617)	9.6
S2	420 (470)	0.99	420 (470)	1.10	-	550 (617)	9.6
F1	550 (667)	0.25	550 (653)	0.36	D13	550 (653)	2.0
F2	420 (470)	0.40	420 (470)	0.54	D13	420 (470)	2.65

2.2 Loading Plan

After installing test apparatus on each specimen as shown in Fig. 1, axial load and lateral load were applied to the specimen simultaneously. The constant axial load was applied to the specimen with 7% of concrete compression force on the cross section of wall. For the performance evaluation of wall based on yield strength of horizontal bar, cyclic loads in accordance with procedure specified in Acceptance Criteria for Special Precast Concrete Structural wall were applied as lateral loads.

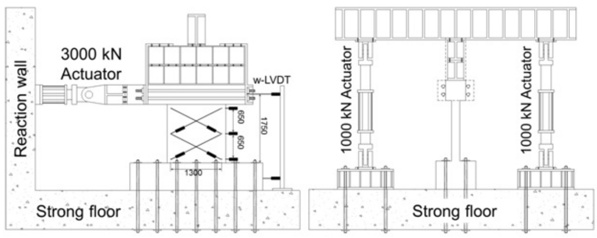


Fig. 1. Setup for Test Specimen

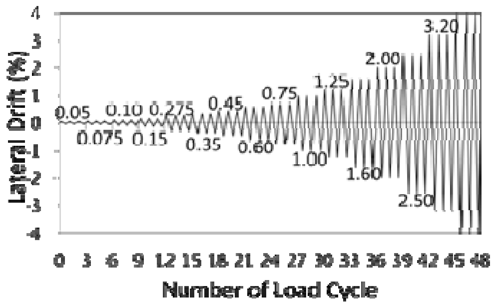
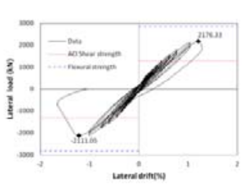


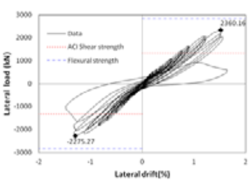
Fig. 2 Plan for Applying Loads

2.3 Test Results

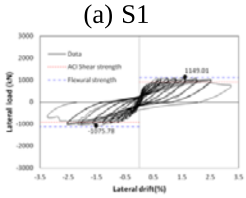
Fig. 3 shows the relationship between loads and displacements. In the figure, test values, expected value of ACI shear strength, and expected value of flexure strength are plotted. For test specimens of shear failure, failures are made within the range not exceeding the flexure strength. All shear failure test specimens are ruptured by crush of concrete at the web region after magnification of diagonal shear crack. In addition, horizontal bar in concrete web region are yielded. Maximum strength values of test specimen No. 1, which was prepared by using bar having yield strength of 667MPa with horizontal steel ratio of ρ_h =0.0068, were 2176kN(+) and 2111kN(-). On the other hand, maximum strength values of test specimen No. 2, which were prepared by using rebar having 470MPa with horizontal steel ratio ρ_h =0.0099, were 2360kN(+) and 2275(-). The strength of No. 2 specimen shows an average 8% higher than that of No. 1. It is revealed that the maximum strength value of test specimen are 1.67~1.79 times higher than the nominal shear strength suggested by the general provision of ACI 349.



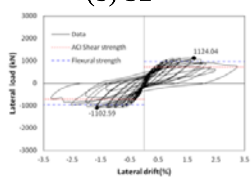
(a) S1



(b) S2



(c) F1



(d) F2

Fig. 3. Load-Displacement Relationship of Each Group of Test Specimen

Both flexure yield test specimen F1 and F2 were flexure yielded without showing early shear failure and showed higher load bearing capability than flexure strength. For the case of F1, maximum strengths were reached at 1149kN (+) and 1075kN (-) at 1.6% drift. On the other hand, maximum strength of F2 showed 1124kN (+) and 1102kN (-) at 1.7% drift.

3. Conclusions

To use 550MPa bars for the walls of a nuclear power plant structure, walls made by using 550MPa bars are compared and analyzed with walls made by using 420MPa bars as current code KEPIC SNC (ACI349) 420MPa is limited to. It is revealed that walls using 550MPa grade bar have 67% higher shear strength than walls using bars in accordance with current code. In addition, walls using bars having 550MPa strength show similar behavior to walls using bars having typical strength. However, maximum strength of walls using high strength bars showed 8% reduction in shear strength when compare with maximum strength of walls using bars having typical strength. We believe that the percentage of bars in concrete is reduced, and the reduction of percentage increases the diagonal crack width of concrete. Even though the maximum strength of the wall is reduced, the maximum strength is still higher than the strength suggested by the current code. Therefore, we believe that the reduced maximum strength may not cause a big issue. We also found that ductility capability of high-strength bar is not so very different from that of typical strength bar. This study is used as a reference material for the safe application of bars having higher maximum yield strength of shear bar, 550MPa, rather than bars having the maximum yield strength limited by current code, 420MPa.

ACKNOWLEDGMENT

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