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Behaviour of concrete shear walls with BFRP reinforcement

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Abstract

Corrosion of steel reinforcement in concrete structures is one of the main challenges in construction industry. Fibre Reinforced Polymer (FRP) reinforcement could be used as alternative to steel reinforcement providing several advantages, such as high resistance to corrosion, high tensile strength and opportunity for developing of more ductile mode of destruction. The last characteristic is extremely beneficial in aspect of lateral load resisting systems including Reinforced Concrete (RC) shear walls.

The presented experimental results are part of bigger research project and consist of preparing and testing two medium-scale concrete shear wall samples reinforced with steel and basalt FRP bars. The samples are tested under displacement controlled cyclic lateral loading.

The promising results could provide a momentum toward construction of RC shear walls using FRP reinforcement with the aims of improving durability and energy dissipation.

Keywords: Shear walls, internal FRP reinforcement, cyclic loading, energy dissipation and seismic behaviour.

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1. Introduction

Presented research is about reinforced concrete shear walls with internal Fibre Reinforced Polymers (FRP) reinforcement.

Maleki et al., (2012), has investigated application of glass FRP (GFRP) for improving the seismic behavior of steel shear walls where medium scale specimens are tested under quasi-static loading per Applied Technology Council (ATC) 24 (1992) recommendations. It was found that the GFRP laminates cause more uniform distribution of tension field within the infill plate.

Petkune et al., (2012), has investigated the performance of the steel shear walls subjected to previous seismic loading. The specimens are strengthened glass FRP wrapping to improve stiffness and energy dissipation and then subjected to quasi-static lateral loading per ATC-24 recommendation. The results of the studies are conforming and the system show significant improvement in strength and energy dissipation capacities after GFRP wrapping.

Mohammed et al. (2013) studied strength reduction factor for GFRP reinforced shear walls and proposed design guidelines and estimation of the allowed displacement.

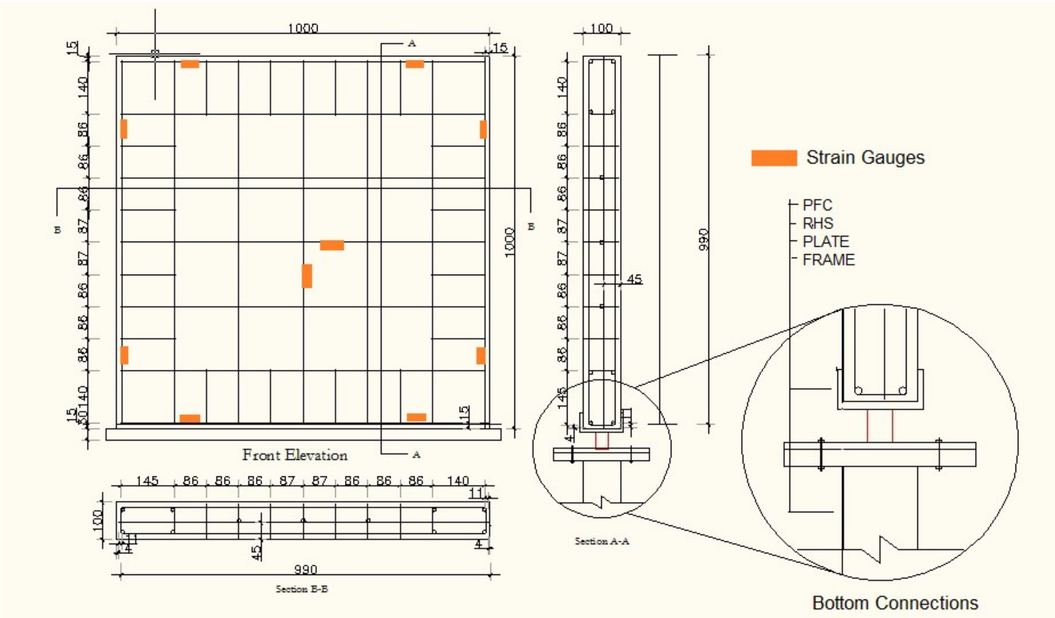


Figure 1: Reinforcement cage, bottom connection and strain gauges

The experimental programme presented in this research comprised of testing two 1000x1000x100mm reinforced concrete shear wall samples under quasi-static cyclic loading until failure. Reinforcement and general dimensions are indicated in Figure 1.

Concrete C30/37 was used for construction of all walls. The control specimen was reinforced with 6 mm high yield steel main bars and the basalt FRP (BFRP) reinforced specimen was with 6 mm bars as well. All stirrups were 6 mm mild steel. The properties of the steel and BFRP bars are indicated in Table 1, where d_b is the diameter, A_b is the cross sectional area of bars, $E_{f/s}$ is the modulus of elasticity and f_u is the ultimate tensile strength.

Table 1: Mechanical properties of steel and BFRP bars

Specimen	Bar	d_b (mm)	A_b (mm^2)	$E_{f/s}$ (GPa)	F_u (MPa)
RCBSW	BFRP	6	28.3	50	1000
RCSSW	Steel	6	28.3	210	460

The load cycles were applied using modified ATC 24 (1992) protocol assuming 1 cycle for each level of amplitude. Fourteen cycles of load were set up to be applied to the test specimen allowing for amplitudes from 0.2 mm to 40 mm as indicated in the Table-2 below. The loading was stopped when the shear wall could not sustain more loads and failed.

Table 2 - Load cycle – displacement amplitude table

Loading cycles	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Displacement Amplitude mm	0.2	0.4	0.8	1.2	2.5	3.5	5	10	15	20	25	30	35	40

2. Experimental results and Analysis

First cracks appeared at 0.9 mm for RCBSW (Reinforced Concrete Basalt Shear Wall) sample and at 1.1 mm for RCSSW sample (Figure 2a). At the amplitude of 10 mm internal reinforcement for RCSSW (Reinforced Concrete Steel Shear Wall) sample broke along the horizontal crack, mainly the vertical bars at the perimeter of the wall (Figure 2b). For RCBSW some of the bars along the internal reinforced part of the wall broke due to applied shear forces.

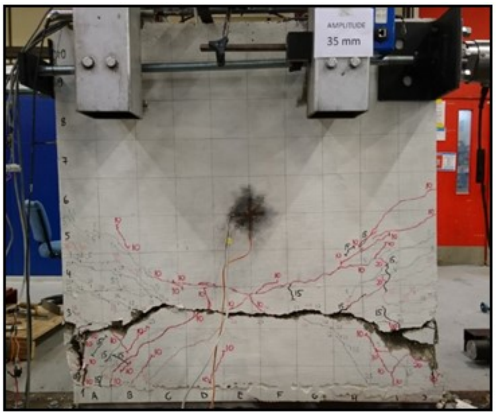


Figure 2a. RCSSW

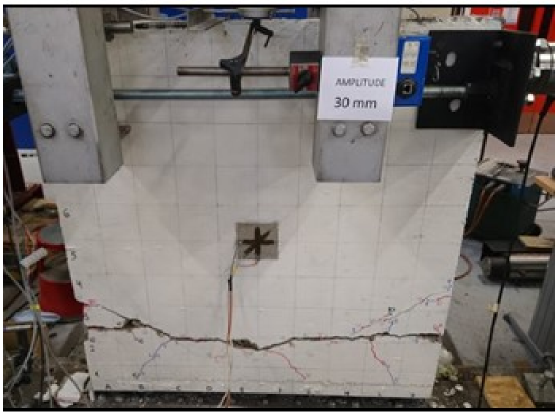
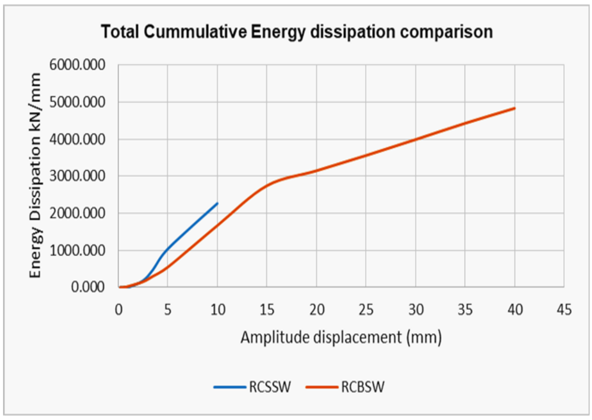


Figure 2b. RCBSW

At displacements above 10mm amplitude the corresponding force in RCBSW went down to 21 kN (approximately 20% of the ultimate load)and continued to stay on this level till max displacement of 40mm. This phenomenon could be explained with sliding of the remaining BFRP rebars inside concrete close to the periphery of the wall and corresponding friction which creates the residual force. RCSSW takes a bit higher loads in respectively smaller range of displacement amplitudes. The capacity increases to over 100 kN at about 2.5 mm displacement before it slightly fall at 3 mm and then sharply falls during an interval of 5 mm amplitude to 0 kN at close to 12 mm (Figure 3b).

The cumulative energy dissipation (ED) for displacements up to 40mm was much higher for the RCBSW testing sample than the RCSSW testing specimen. The RCSSW sample was destructed at 12mm displacement and energy dissipation contributions for this sample between 12mm and 40mm displacements were zero (Figure 3a).

RCSSW with the steel reinforcement has bigger energy dissipation at the smaller displacement amplitudes. Therefore, RCBSW shows much better results after reaching 13mm displacement amplitude. This indicates an important benefit of using BFRP instead of steel as reinforcement for shear walls under seismic loading.



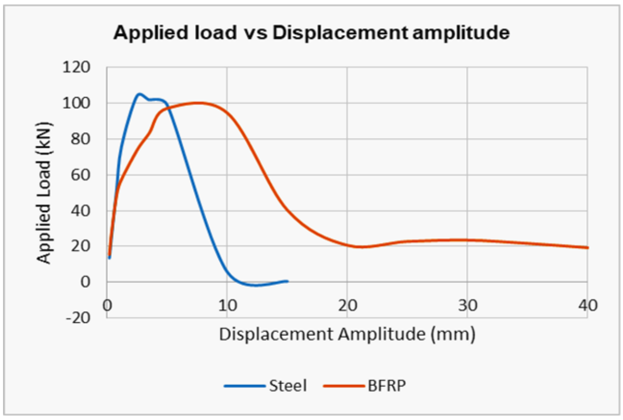


Figure 3a. Total Cummulative ED comparison Figure 3b: Load - Displacement curves

3. Conclusions

Because of higher deformability for the BFRP bars and more gradual destruction of the concrete in the walls there is a bigger cumulative energy dissipation for this type of shear walls.
RCBSW could keep up to 20% of the maximum load capacity at high level of amplitudes even after the internal reinforcement bars at the middle of the specimen were broken and the side ones were sliding out of the concrete.
RCSSW lost all the applied load capacity after the reinforcement bars were broken at 12mm displacement.

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