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Cylindrical formwork from filament wound GRC

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Abstract

During the last years, the study of confined concrete has involved many scientists and technicians from universities and companies around the world. It has been demonstrated that to confine concrete in a closed jacket of high-strength material is a good solution for strengthening precast elements. The remaining problem to be solved is how to close this jacket in an effective and economical way. This paper describes a preliminary test used to qualify the performance of wound glassfibre-reinforced concrete (GRC) tubes as permanent formwork for columns and beams. Results show how these cylinders can increase the compression resistance of regular concrete by more than a factor of 2 with walls less than 10 mm thick. Different kinds of wound tubes have been tested and compared.

Initiating and developing the idea

For a number of years OCV has been working together with Composite Materials Technology on the improvement of winding glassfibre-reinforced concrete (GRC). Using alkali-resistant Cem-FIL direct roving and a special matrix formulation, cylindrical tubes of the highest-strength GRC are being produced in the USA. The resulting poles are the best solution for power distribution, in substitution of steel, concrete or wood, as the most resistant poles against natural catastrophes such as earthquakes or hurricanes. These tubes can be finished with many different designs, colours and materials.

Figure 1: Wound GRC tubes

Figure 2: Laboratory-manufactured tube

After demonstrating the flexural strength of these tubes, we started thinking about the possibility of using them as permanent formwork for columns.

1st layer	2nd layer	Max. force (kN)
15°	-	26.1
90°	15°	41.12
15°	90°	43.53

Table 1: Some flexural strength results

Winding GRC allowed us to produce almost any section size. Hollow tubes can be transported from the production plant to the jobsite without any danger, and can be painted or sprayed with mortar or any other finishing treatment. It was an attractive idea, but the performance had to be measured.

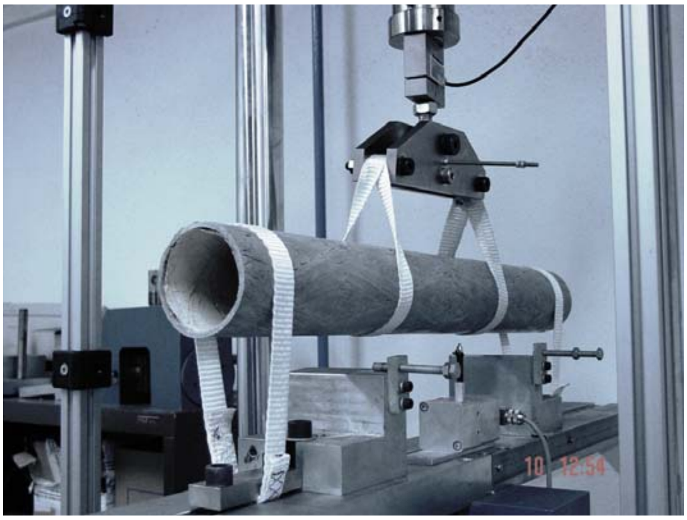

Figure 3: Flexion test

Figure 4: Sprayed mortar finishing

Different winding ratios were tested in order to achieve the best performance. The winding ratio is the ratio between the speed of the winder along the axis and the rotational speed of the pole. By varying this, different winding architectures are possible. When the travelling device which winds the fibre on the pole surface has a high axial speed compared with the tube's rotational speed, the fibre has a low angle with reference to the pole's longitudinal axis. Conversely, if the travelling device's speed were zero, this angle would be 90° and the new strand would be placed on top of last turn's strand. Generally speaking, we call 90° architecture those where the fibre is put closest to the last turn's strand (slightly less than 90°). Those used in this preliminary test were combinations of 15° and 90° layers.

Figure 5: A 15° winding ratio

Figure 6: A 90° winding ratio

To study the compression resistance, test method UNE-EN 12390-3 was used. For that purpose, tubes with a length of 2.12 m were tested. The internal diameter was 125 mm and the external diameter was 140 mm in the 15 + 90° and 90 + 15° cases and 142 for the 90 + 90° pole. This resulted in 7 mm of wall thickness for the two first tubes and 8 mm for the last one.

Seven days after the tube fabrication, they were cut to obtain 300 mm long specimens. This way, specimens of almost the same dimensions as the concrete cylinders specified in the norm were manufactured for every architectural combination. Only the final diameters were slightly different.

For each type of pole, three GRC cylinders were made and used as a mould to be filled with the same concrete formulation, in order to obtain the confined concrete specimens. With the same formulation, three further concrete specimens were made using steel moulds.

Figure 7: Specimen to be filled with concrete

Component	Weight (grams)
Cement CEM II/A-P 42,5	11.5
Water	3.94
Stone	37.61
Sand	25.07
Superplastizicer Sikament FF	115
Water/cement ratio	0.6
Sand/cement ratio	2.18
Sand/stone ratio	1.5
Abrams' cone	6,5 cm

Table 2: Concrete formulation

Once both GRC tubes and cylindrical steel moulds were filled with concrete, they were cured for 28 days in a climate chamber at 95% relative humidity and 22°C. The compressive strength was then measured by using a hydraulic press type IBERTEST MEH-3000PT-W.

Figure 8: Hydraulic press

Results and conclusions

Trial	**Compresion strength (Mpa)**	**Average**	**Std deviation**	**% deviation**
15°+90°	46.7			
15°+90°	45.7			
15°+90°	46.04			
15°+90°	36.2			
15°+90°	44.08	43.7	4.3	9.9
Plain concrete	19.38			
Plain concrete	21.35			
Plain concrete	19.03			
Plain concrete	19.89			
Plain concrete	20.61	20.1		
Trial	**Compresion strength (Mpa)**			
90°+15°	42.23			
90°+15°	40.63			
90°+15°	42.8	41.9	1.1	2.7
Plain concrete	19.57			
Plain concrete	21.12			
Plain concrete	22.51	21.1		
Trial	**Compresion strength (Mpa)**			
90°+90°	58.53			
90°+90°	56.42			
90°+90°	56.02	57.0	1.3	2.4
Plain concrete	20.02			
Plain concrete	21.7			
Plain concrete	19.64	20.5		
	Total plain concrete	**20.4**	**1.1**	**5.4**

Table 3

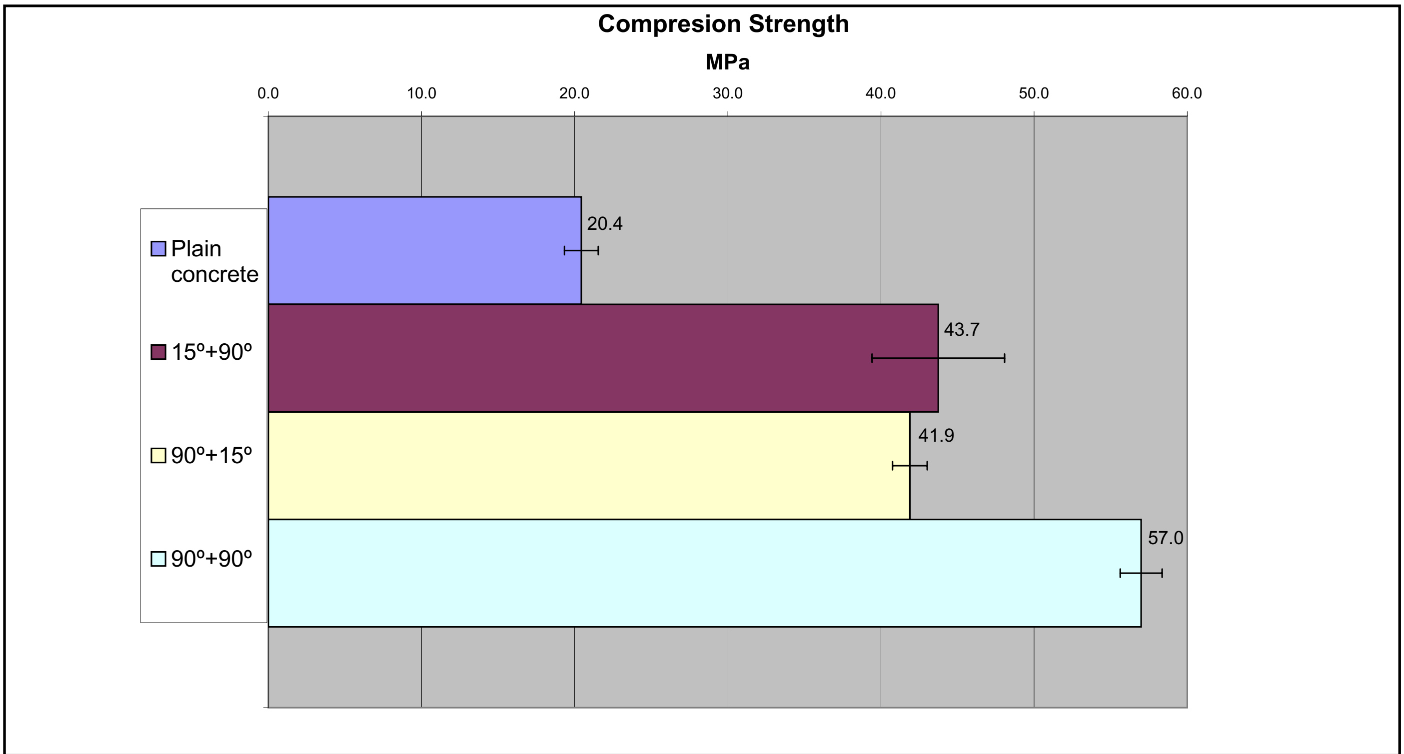

Figure 9

As the same concrete formulation was always used, the result of the concrete references was virtually the same, with only a 5% deviation. We can then use the average of all results as a reference for each trial, and compare the trial results with them without any correction.

We thought that a 90° layer would always be better than a 15° layer, so the test was planned using two layers. Thus 90° + 90° and a superposition of 90° and 15° were planned to get an idea about the performance of each layer alone. But the effect of the architecture had to be studied as well. It would not be expected to be the same to place a 15° layer on top of a 90° layer, or to do the opposite. So both architectures were studied: 90° + 15° means a 90° layer as the first layer and 15° layers as the external surface of the pole.

The difference between 15° + 90° and 90° + 15° is not significant, but as expected it is better to put the 90° as the external layer, because it can still bear some of the load when the internal 15° layer fails.

The best performances were obtained using two 90° layers (almost three times more resistant than plain concrete) as expected.

As a final conclusion based on these results, we can conclude that wound GRC tubes could be used as permanent formwork. An exhaustive study should be performed in order to learn more about this solution.