2008
Prague

New range of AR glassfibres for better control of cement paste rheology

G. TARDY AND J.C. ROMERO
OCV Reinforcements

New Cem-FIL® products technology

Continuous contact with our customers worldwide helps us to understand their needs and problems. One of these is the increase of viscosity due to fibre addition. Indeed, the viability of some glassfibre-reinforced concrete (GRC) premix projects, using complicated shapes or thin layers, is highly dependent on mix viscosity. Moreover, the glassfibre content is limited by the paste workability and flowability. For this reason we have developed a complete range of new hydrophobic products, which permit working with a more fluid material, lower water/cement (w/c) ratios or higher glassfibre content. This is the result of combining chemistry R&D and new production technology.

The importance of sizing

Sizing is a combination of different organic components that coat the fibre and give it different characteristics, such as flexibility and abrasion resistance. When the fibres are added, the slurry viscosity tends to increase as a result of the fibres' demand for water. This is a capillary effect related to the fibres' surface tension. In this respect, the amount of water demanded by the fibres is a function of the specific surface tension and the total surface to be moistened around the fibres, and between filaments if there is any significant porosity.

It is clear that the total surface of the fibre is related to the amount of fibre used, but the situation is actually more complex. In fact, during the mixing process, the fibre can be damaged, broken and opened in the longitudinal axis. This can multiply significantly the free surface to be wetted.

Fluid-meter				
	Premix products		Spray products	
% fibre	**Cem-FIL 60/2**	**Cem-FIL 60/3**	**Cem-FIL 54/76**	**Cem-FIL61/2**
1%			1	
2%	1.55		3.09	1.13
3%	5.6	0.83	11.06	3.31
4%	20.81	1.87		18.14
5%		4.78		
6%		9.26		
Shoking table				
	Premix products		**Spray products**	
% fibre	**Cem-FIL 60/2**	**Cem-FIL 60/3**	**Cem-FIL 54/76**	**Cem-FIL61/2**
1%			230	235
2%	187	235	160	197
3%	150	196	127	157
4%	127	172		130
5%		155		
6%		146		

Water/cement ratio	Shoking table
0.28	120
0.29	165
0.30	185
0.32	205
0.34	235

Figure 1: Increase of fibre surface

Furthermore, depending on the hydrophilic or hydrophobic properties of the fibre's surface, water demand can vary from 40% to 75% of the fibre weight. The consequence is then in effect a reduction of the w/c ratio of up to 10% for the worst-case scenario.

In terms of chemistry, when the fibre is added to the slurry, the thin layer of sizing is hydrated by water and becomes partially soluble. Organic components released in the media and fixed at the surface, but directly in contact with cement particles, have an influence on viscosity and setting times. In effect, this is the same as the action of a viscosity modifier or a superplasticiser.

The water solubility of different strands is represented in Figure 2. Generally speaking, the 'new generation' strands exhibit a lower solubility of sizing.

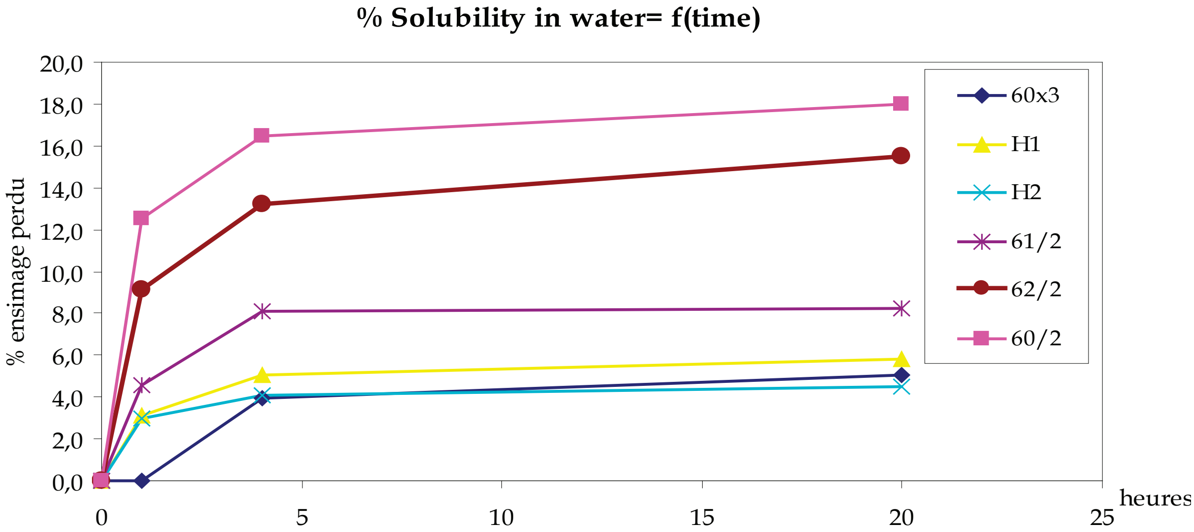

Figure 2: Sizing solubility in water = f (time)

The final solubility is achieved after 4 hours at room temperature, and very often a major part is already achieved after 1 hour. It is important to consider this range of time, because hydration of cement (especially C3A cement) begins very quickly, and most of the C3S hydration takes place after 3 to 4 hours.

With this in mind, it has been a double challenge to create a new fibre with lower specific surface tension, higher abrasion resistance and neutral or positive effect of the water-soluble element of sizing on cement paste, and ultimately on GRC composite properties.

A new process technology

As already explained, sizing is the 'personality' of the fibre. However, sizing performance is related not only to the type of organic raw material but also to the thermal treatment applied during the fibre production process.

The standard production process involves winding a cake and drying it for many hours at temperatures between 100 and 150ºC, before chopping it to the desired length. This lengthy and soft thermal treatment does not allow development of a new hydrophobic sizing formulation that would also give an additional abrasion resistance. This process also requires addition of sizing lubricants and other softeners to make winding and unwinding processes possible, and these products sometimes do not benefit the GRC rheology and/or mechanical properties.

Consequently a new process technology, known as the high division direct chopping process, was developed. It consists of a new system that can process several low tex strands directly under the bushing, and an oven capable of drying the processed fibre at high temperature, in less than 10 minutes. This allows a chemistry more focused on cement–fibre interaction to be designed.

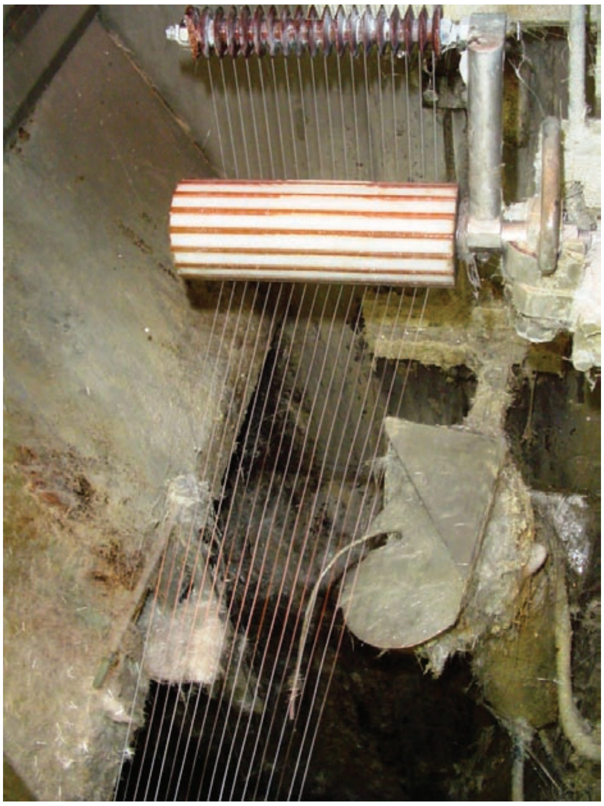

Figure 3: High division chopping process

Figure 4: High division chopping process

The other positive effect was a more compact strand, because filaments do not tend to move and create differential tension between each other during the winding operation, or to be damaged during unwinding of cakes for offline chopping. Following several months of investigation and hundreds of trials, fibres that are more resistant and hydrophobic have been developed

Cem-FIL® 62/3, Cem-FIL® 60/3 and Cem-FIL® 63/1 are the new generation of Cem-FIL® chopped strands. In fact, these fibres can resist long mixing periods into the most damaging matrices and also possess stable fibre quality. However, in this paper we are concerned only with their effect on paste viscosity.

Added improvements

Obviously, water demand is not limited to premix GRC manufacturing. The spray GRC method is also affected by fibre water demand. If water consumption is high, GRC can become difficult to work with. Compaction by rolling becomes hard and slow, and some air bubbles can be retained in the material, which can impede mechanical performance. Accordingly we have developed a new hydrophobic and more integral product in a roving format: Cem-FIL® 61/2.

Cem-FIL® 61/2 was developed on the basis of the same hydrophobic solution as the chopped strands; this included several years' investigation to obtain a stronger fibre but at the same time retaining 'standard' manufacturing process requirements. When the continuous strand is chopped by the spray gun, a weak fibre can be opened like a paintbrush. This again increases the surface area (see Figure 1) but Cem-FIL® 61/2 is less affected by this due to its integrity.

With hydrophobicity and high integrity, GRC manufactured by the spray method with Cem-FIL® 61/2 demonstrates very good workability, easy compaction and better time efficiency. Moreover, it permits a lower w/c ratio or reduced amount of superplasticiser. Due to its integrity and abrasion resistance, Cem-FIL® 61/2 is the first roving that can be used in both the premix and spray GRC manufacturing process.

Results and discussion

In order to measure the viscosity of premix GRC, two methods were used: (1) the shaker table method and (2) testing by fluid-meter. These are now discussed in turn.

Shaker table

A cylindrical mould, placed in the middle of a round table (see Figures 5 to 8), is filled with the paste to be investigated. This mould ensures that the same volume of slurry is used. After removing the mould, the table containing the paste is shocked 15 times by a manual mechanism. For each shock, the paste flows and increases in diameter. The result of this test is the final diameter. Obviously, the higher the paste viscosity the smaller the final diameter.

Figure 5

Figure 6

Figure 7

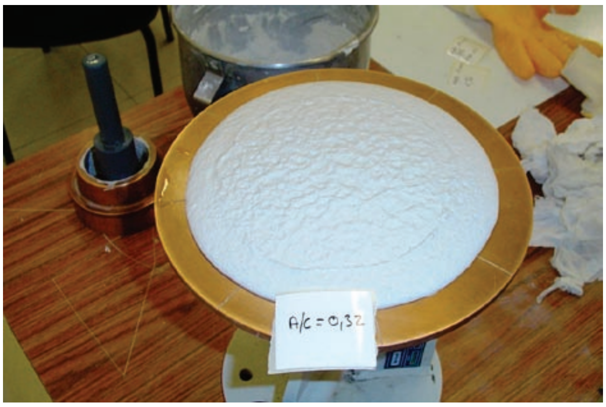

Figure 8

First, we studied the viscosity of the plain slurry, varying only the w/c ratio by decreasing the amount of water. The ratio between cement and the other mortar components remained the same.

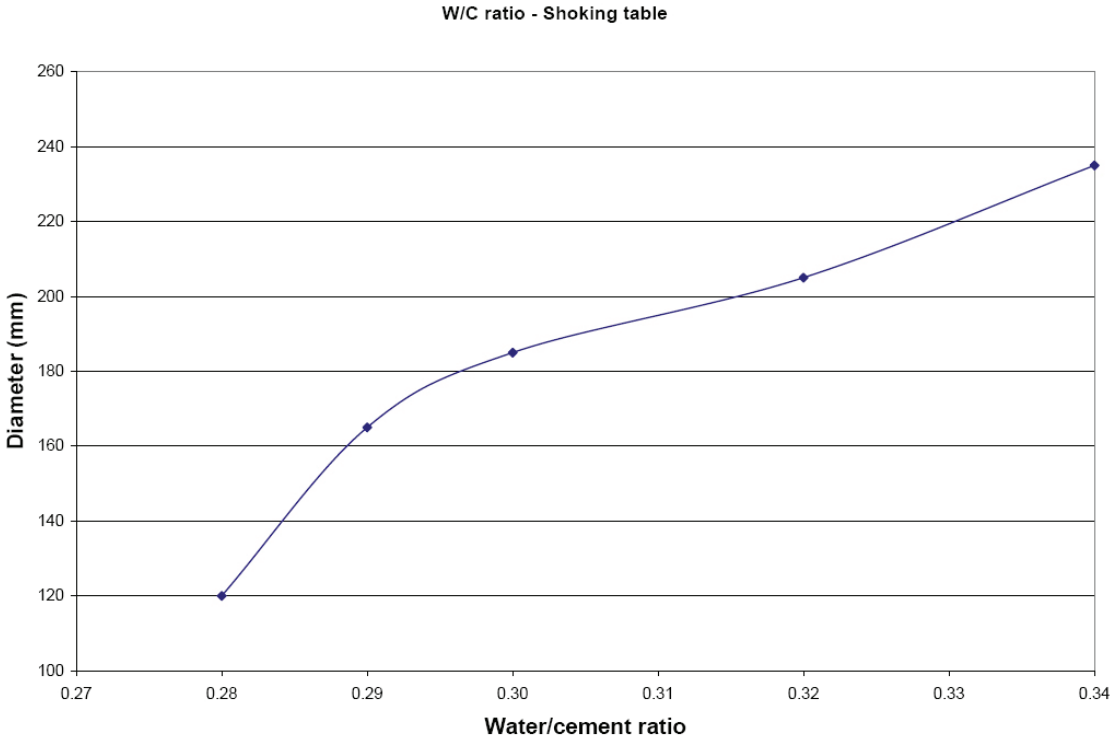

Figure 9: Shaker table. Paste viscosity vs w/c ratio

Using these results, the effect of the fibre could be related to a decrease in w/c ratio. This means that we can calculate the water demand of the fibre in an approximate way.

Second, different kinds of products (for premix and spray methods) were compared by mixing a 0.36 w/c ratio mortar with different percentages of fibre. The blue lines in Figures 10 and 11 represent the historical Cem-FIL® products and the pink lines represent the new Cem-FIL® fibres.

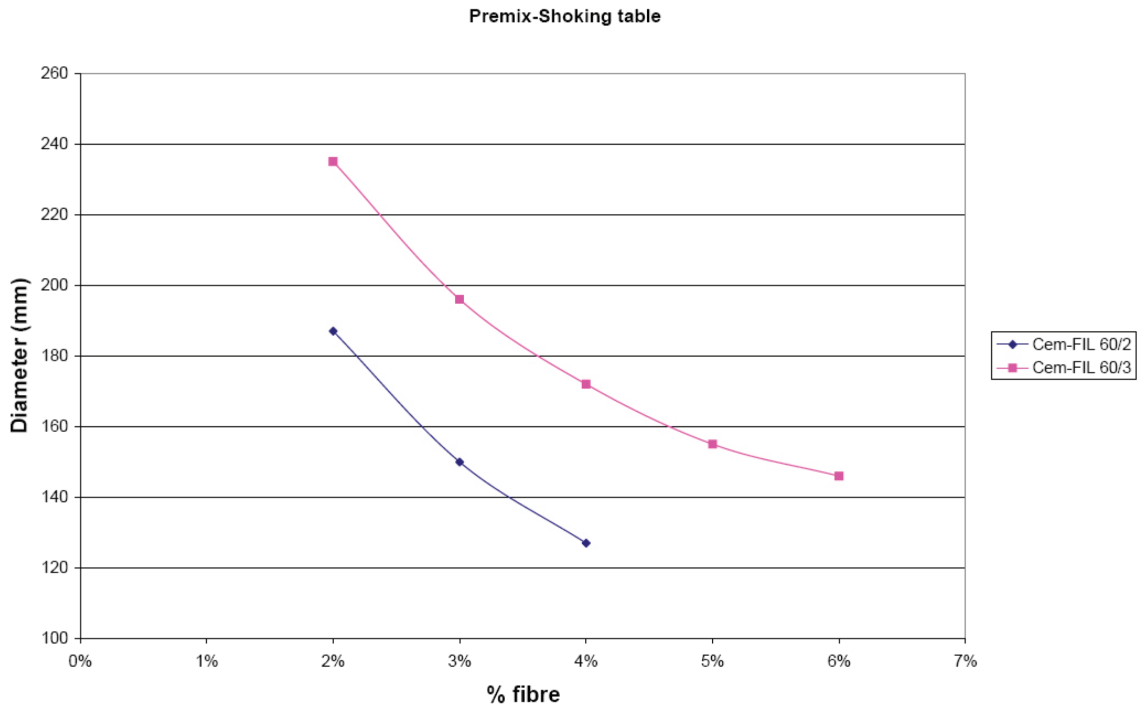

Figure 10: Shaker table. Premix product's viscosity vs percentage of fibre content

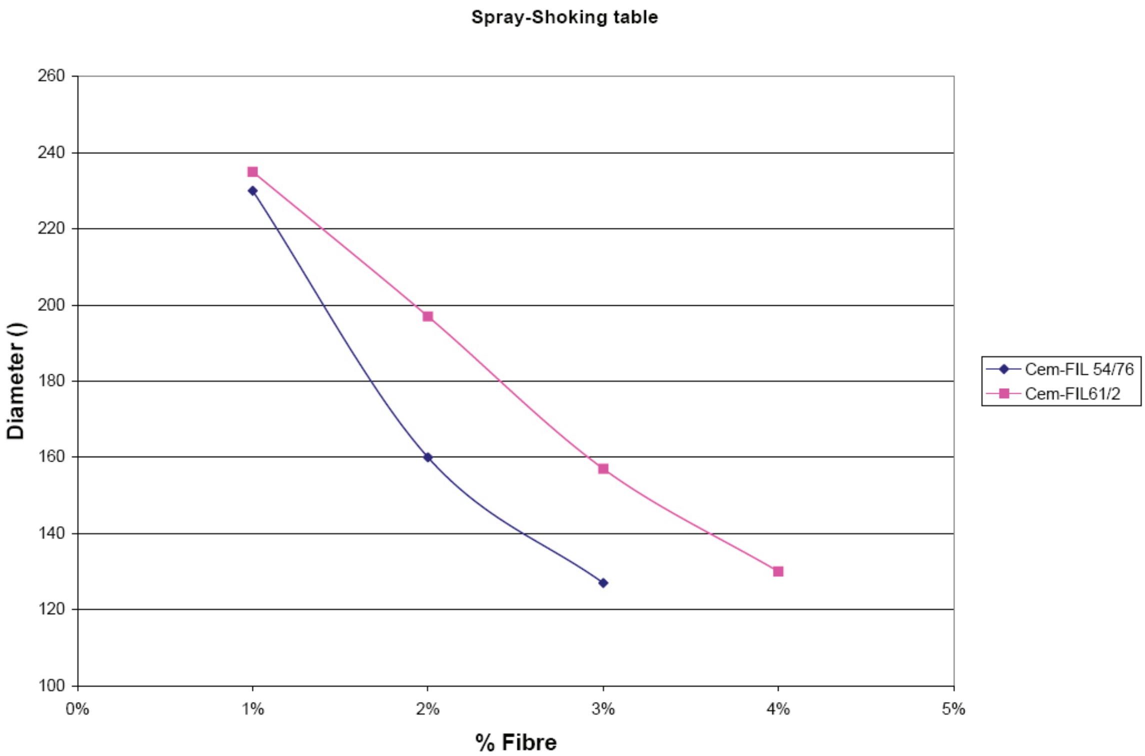

Figure 11: Shaker table. Spray product's viscosity vs percentage of fibre content

In both cases, the new fibres rendered the slurry less viscous. In the case of Premix products, the workability limit of GRC is around 150 mm for the shaker table result. Less than 150 mm represents a level of viscosity that does not permit air removal, and therefore a porous, weak GRC is obtained. Looking at Figure 10, it can be seen that 4% of Cem-FIL® 60/2 is too much for this matrix formulation and the limit would be 3%. However, in the case of Cem-FIL® 60/3, 6% fibre content could be used. That means that premix GRC can be made with twice the amount of fibre or with a lower w/c ratio.

In the case of spray products, the difference is smaller, but is sufficient to render the wetting process easier and faster. The paste rheology evolves with time. One of the considerations in the use of a GRC mix is the workability time, before the viscosity becomes too low.

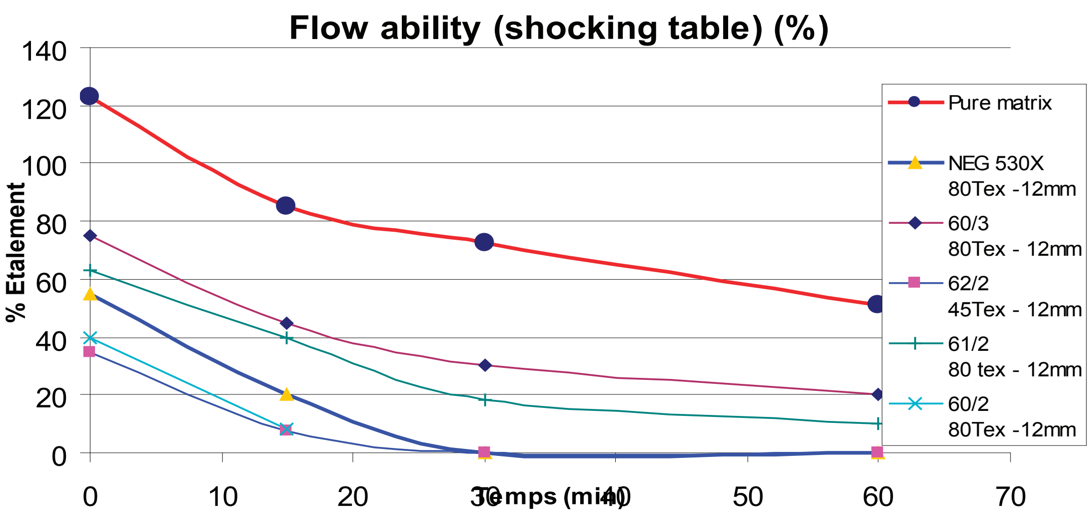

Figure 12: Viscosity = f (time) for different strands (w/c = 0.34; fibres = 3.5%)

Although GRC premix is always more viscous than a non-reinforced matrix, it can be seen that the trend of the most hydrophobic strand is flatter and allows a longer working time.

Fluid-meter

The second way to measure the mortar fluidity is by using a fluid-meter. A measured and defined amount of mortar is put into the back section of the fluid-meter (see Figure 15). When the floodgate is released the motor starts running, the device vibrates and the mortar starts to flow until it reaches the marked line. The result of the test is the time between floodgate release and mortar reaching the line.

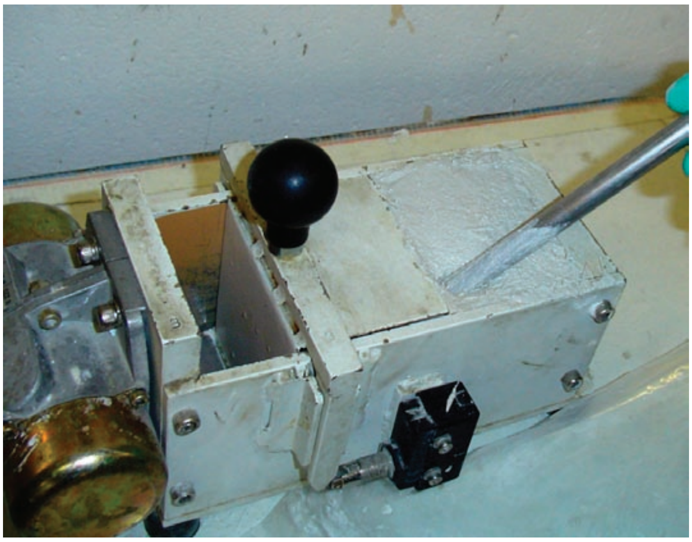

Figure 13: Filling the fluid-meter

Figure 14: End of the fluid-meter test

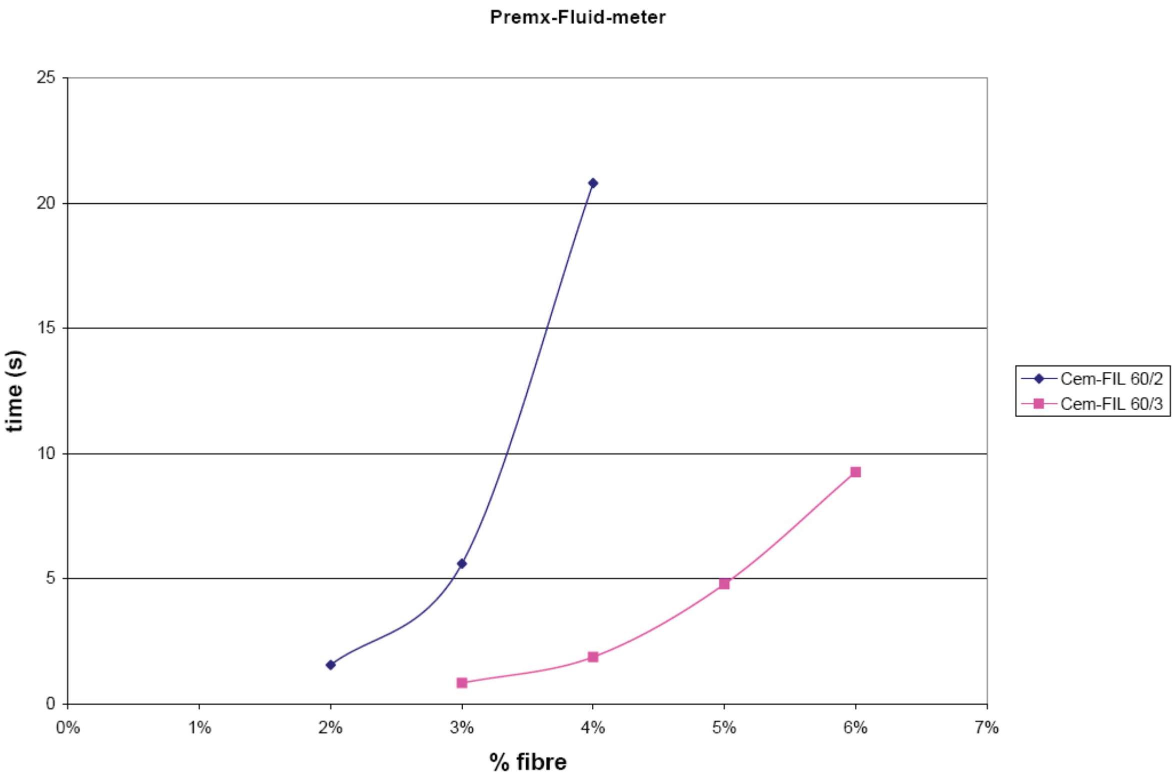

Figure 15: Fluid-meter. Premix product viscosity vs percentage fibre content

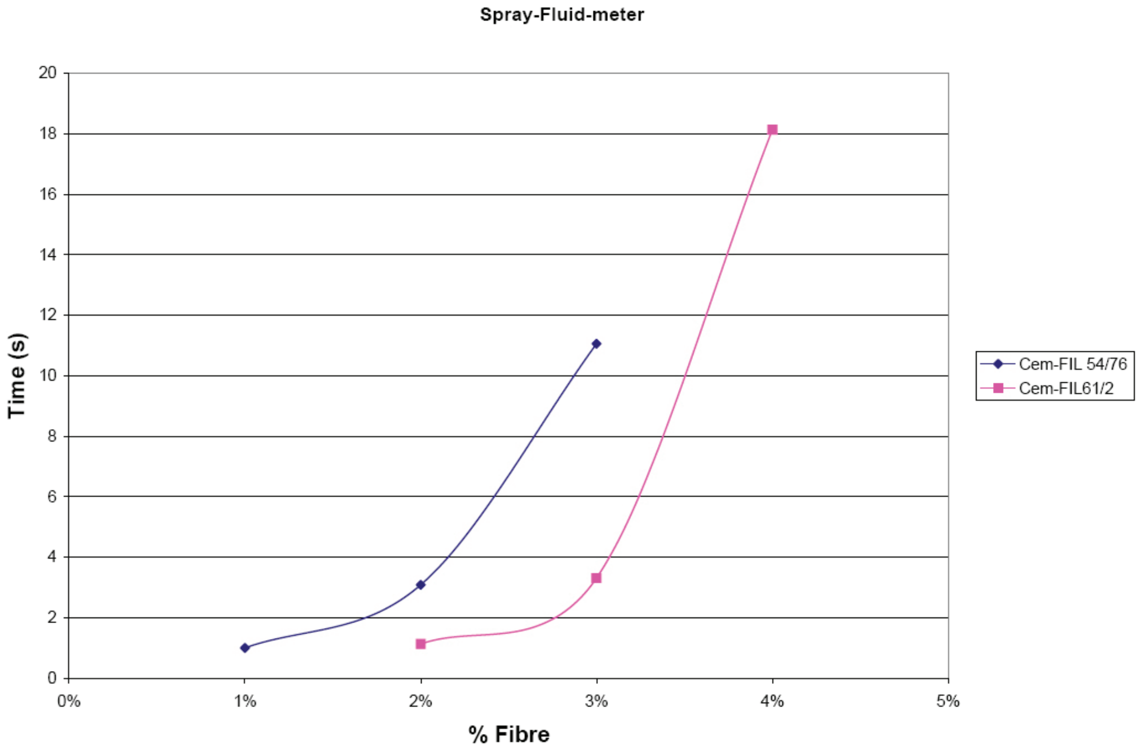

Figure 16: Fluid-meter. Spray product viscosity vs percentage fibre content

Figures 13 and 14 corroborate the results obtained using the shaker table.

Perspectives and conclusions

OCV Reinforcement's experience in both the glassfibre manufacturing process and sizing chemistry has been used to meet the requirements of our Cem-FIL GRC manufacturers, i.e. lower viscosity and a stable rheology for an extended time, while maintaining an excellent range of mechanical properties.

In the coming years, continuous contact with our customers and the continuing work of our chemists in researching sizing–cement hydration interactions will lead to further innovations in our fibre technology, thereby assisting the advancement of Cem-FIL clients.