Further Investigations into Premix GRC

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Abstract

The introduction of Self Compacting additives and the trend to move away from vibration has changed the nature of Premix GRC.

The mix is now far more fluid, but has this change affected the mechanical properties?

This paper will investigate this with reference to fibre type, fibre content, fibre length, water/cement ratio, and workability.

The influence of the position of the individual test coupon on the test board will be considered, together with the ratio of strengths of the mould and trowel faces.
It will conclude by suggesting certain rules to comply with the GRCA Specification.

INTRODUCTION

There are numerous parameters which affect the material properties of Premix GRC, and the AR glass fibre content has always been considered to be the most important. This will be investigated, together with the effect of the fibre length. It is also important that the water/cement ratio should be considered, along with the effect of differing workability.

Two different cement types were tested. In total over 600 individual flexural tests were carried out. With this wealth of data it was possible to compare the 14 and 28 day results, and also check if the position on the sample board where the individual coupon came from was important.

MIX DESIGNS

When comparing different mix designs, it is critical that only one parameter is changed at a time, so that the test results relate solely to that parameter.

This is not always easy, when you vary the fibre content or the fibre length, you change the workability, and then you have to consider if the change in workability is significant. If you make the workability the same, then you must either change the water or additive content.

This need for consistency was at the forefront when the various mix designs and procedures were decided.

PREPARATION OF SAMPLES

Five identical rubber sample board moulds, 600mm x 600mm were used.

Mixing initially took place in a GRC 125 Combination Mixer with batch sizes based on a 25kg bag of cement. In most of the trials this mix was then split into 5 parts, and the varying quantities or types of fibre etc were then added.

After casting, the moulds were stacked and covered with polythene, prior to de-moulding the next day. They were then cured under polythene for 6 days prior to marking and cutting. Flexural testing using a Testometric Micro 350 CT Universal Test machine was carried out at 14 and 28 Days. 14 days was selected because of the number of tests involved it was not possible to complete the necessary curing marking and cutting exactly by the whereas this was easily completed by Day 14.

It was found however that there was so little difference between the 14 and 28 day results that all 16 individual results from a test board were averaged and were considered as one result in this paper.

All the boards were marked in an identical manner and the coupons tested at 14 and 28 days were identical for every test.

POSITION OF INDIVIDUAL TEST COUPONS

Coupons T1-4 and L1-4 were tested after 14 days. Coupons T5-8 and L5-8 were tested after 28 days. The position of the coupons is shown in Figure 1.

Odd numbered coupons were tested with the mould face in tension. Even numbered coupons were tested with the trowel face in tension.

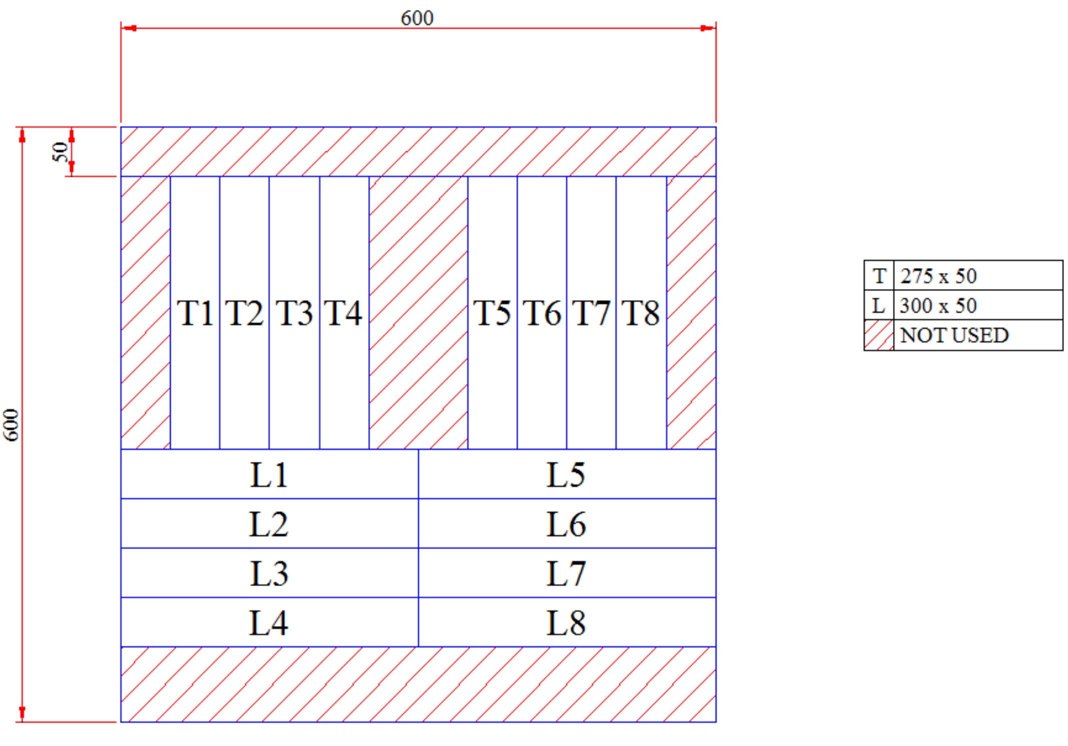


Figure 1. *Position of the coupons*

CEMENT TYPE

The cement available from Builders merchants in the UK is normally general purpose cement suitable for bricklaying. It contains pozzolans, fillers, and often air entraining agents. This grade is Cem II 32.50R, whereas for GRC or precast concrete production CEM I 52,5R is preferred.

The two types of cement were compared using the mix design Table 1.

Table 1. *Mix design*

Material	Weight (kg)
Cement 32.5R or 52.5R	25.0
Silica Sand	25.0
Water	8.50
Flowaid SCC	0.25
AR Glass Fibre 13mm ACS13H530X	3% of total mix weight

The results of 14 and 28 day testing are shown in Figure 2.

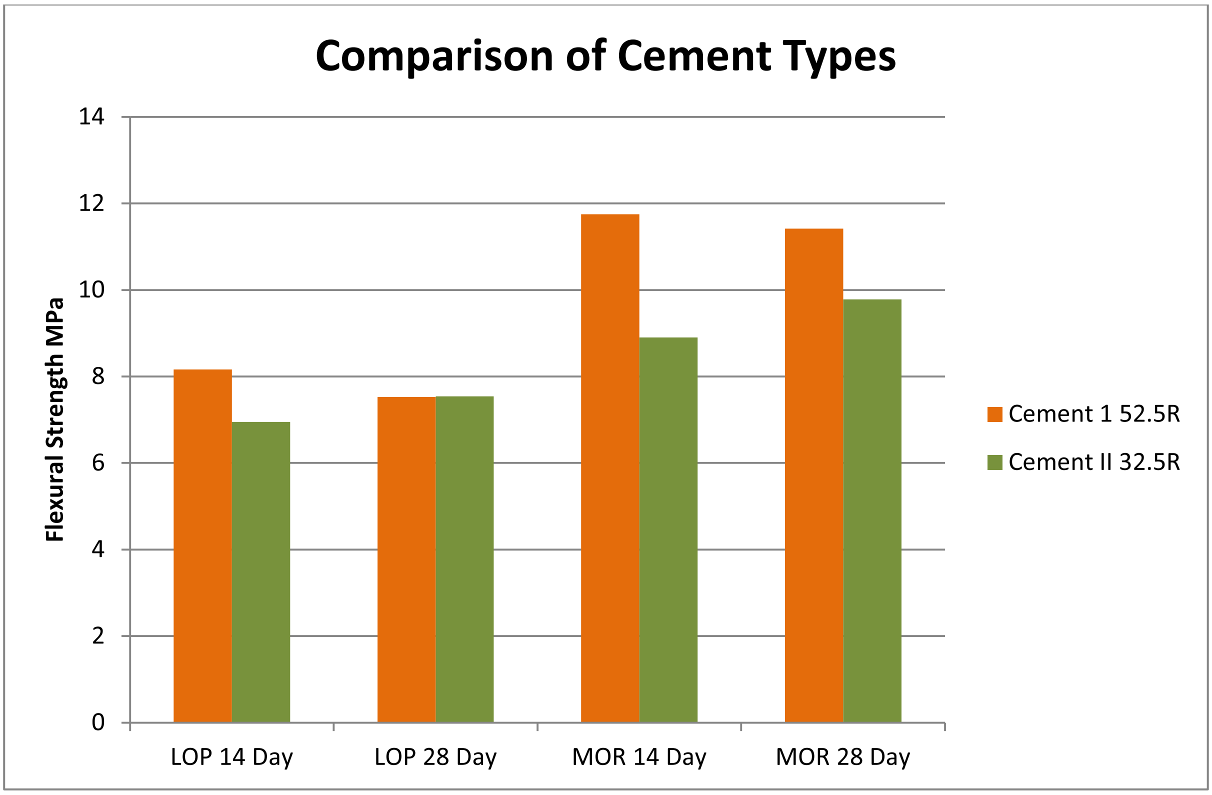


Figure 2. *Comparison of cement types*

These two initial tests were sufficient to show the difference between the two cements and all further tests were carried out using 52.50R cement from the same supplier.

WATER/CEMENT RATIO

It is commonly accepted concrete practice that the water/cement ratio should be as low as possible and this practice has been followed by the GRC Industry.

However to prove it is not so simple, as when the water/cement ratio is increased, the fluidity also increases - does this change also affect the mechanical properties?

The test devised varied the water/cement ratio, but kept the workability the same. This was achieved by varying the additive content from 0-1%. The water/cement ratio refers to the total water, including the water contents of the additives.

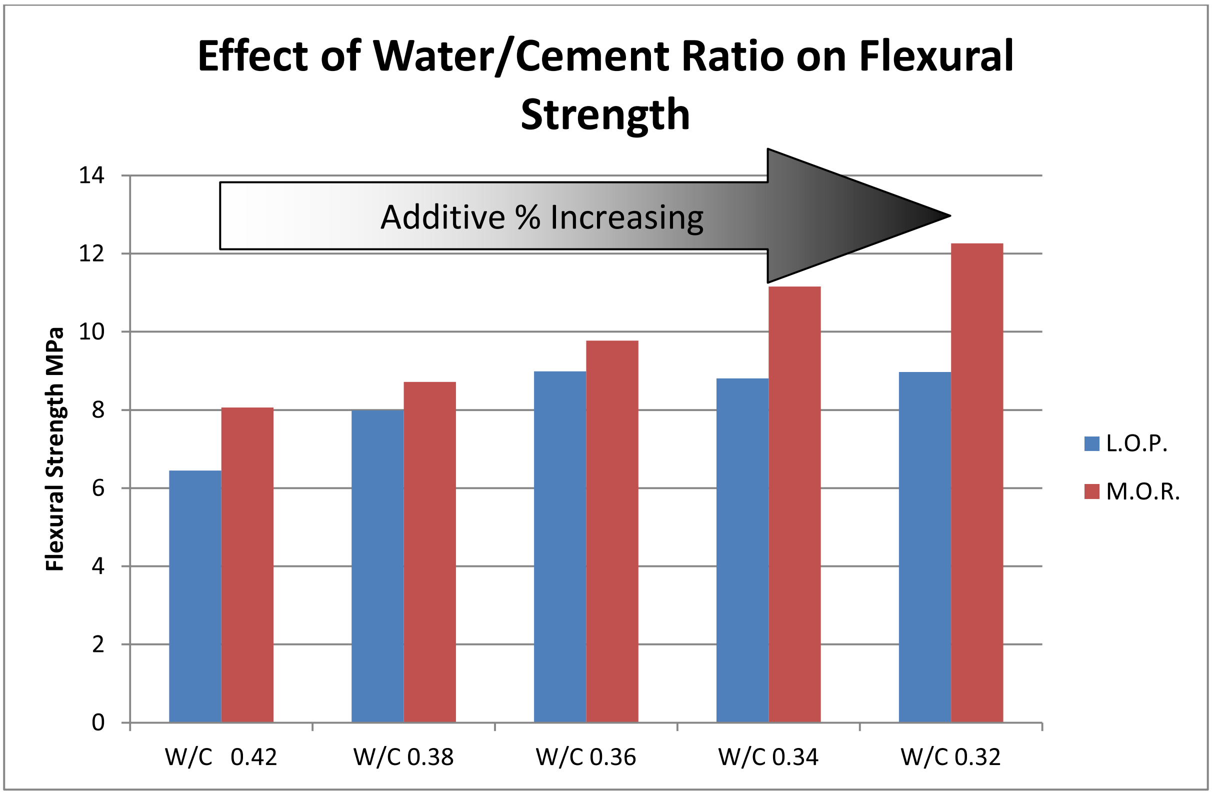


***Figure 3**. Effect of water/cement ratio on flexural strength*

The MOR results are completely as expected, with the increase in strength being proportional to the reduction in the water cement ratio. The LOP values which are supposed to relate to the matrix strength did not behave as expected. However as anyone who carries out regular testing will know, the LOP is very difficult to calculate. One manufacturer of flexural and tensile testing equipment said “The LOP is difficult to precisely determine with most materials, but GRC is the most difficult material we have ever encountered”.

The measurement of the LOP is worthy of a complete paper on its own, but for this exercise the MOR will be considered the more important parameter as its measurement is not subjective.

EFFECT OF WORKABILITY

There is anecdotal evidence that highly fluid mixes lead to lower strengths than "stiff", less fluid mixes, but is this the case? Again, the difficulty is changing the workability without changing anything else. Obviously something must be changed; it was decided to change the plasticizer (Flowaid SCC) content and to ensure that all other mix components remained the same. The mix was based on 25kg of cement, 25kg of sand, with a w/c ratio of 0.36 and 3% ACS13H530X fibre (by total weight).

It was felt that the standard slump test was unsuitable, as mixes with a suitable flow would all show the maximum number of rings. We therefore used a flow test previously developed, which has proven to be very accurate and to give reproducible results. A stainless steel funnel with a 19mm spout was used. The funnel was held vertically in a frame and filled with the test mix. The time taken for the mix to completely empty was recorded. When the time exceeded 80 seconds the time was recorded as 80 seconds+. The test apparatus is shown in Figure 4.

Figure 4. *Test apparatus*

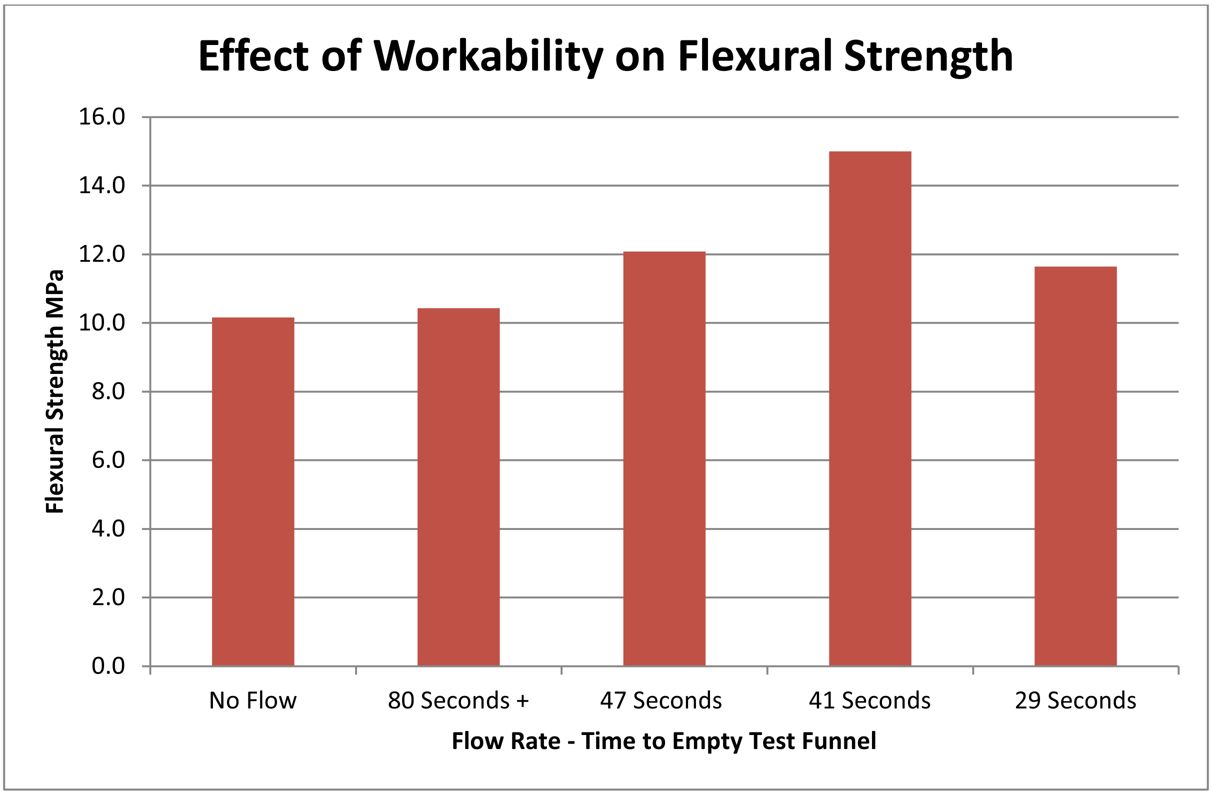


Figure 5. *Effect of workability on flexural strength*

The results were not as expected, as up to a point the flexural strength actually increased with increased fluidity. This is a very interesting finding, and like much else in this paper, it is worthy of further investigation.

EFFECT OF FIBRE CONTENT – PREVIOUS WORK

This repeated work that was carried out in 1995 and presented at the GRCA Congress in Strasbourg in October 1995.

The results from this paper are reproduced in Figures 6-8.

Briefly, the report showed that there was an optimum fibre content, or range of contents, for each fibre type. Above this optimum range, no benefit was obtained from increasing the fibre content.

This work was carried out over 20 years ago, since that time a whole new generation of super-plasticizers has been developed and the AR Glass Fibres have been improved.

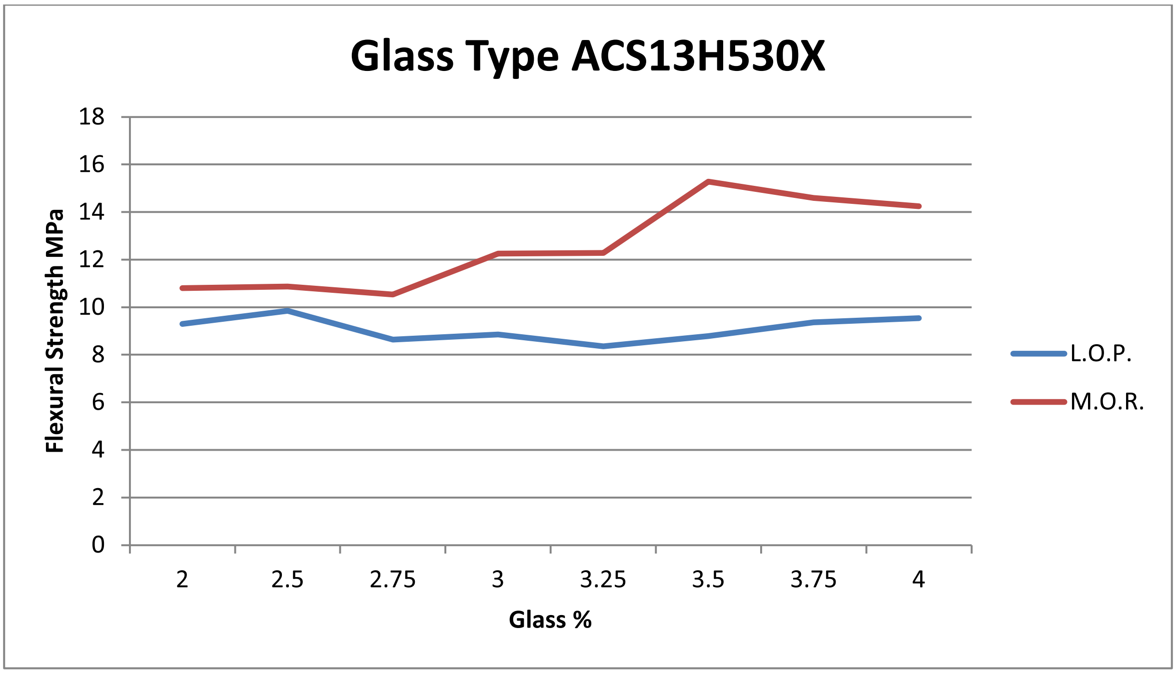


Figure 6. *Glass Type ACS13H530X*

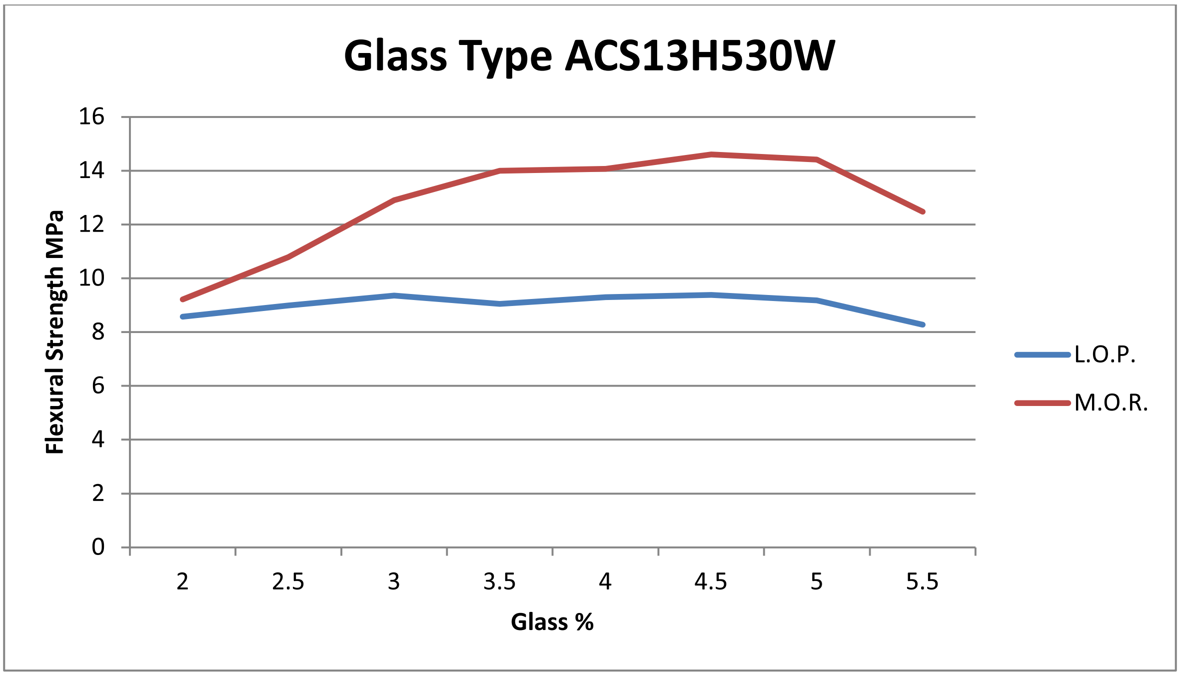


Figure 7. *Glass Type ACS13H530W*

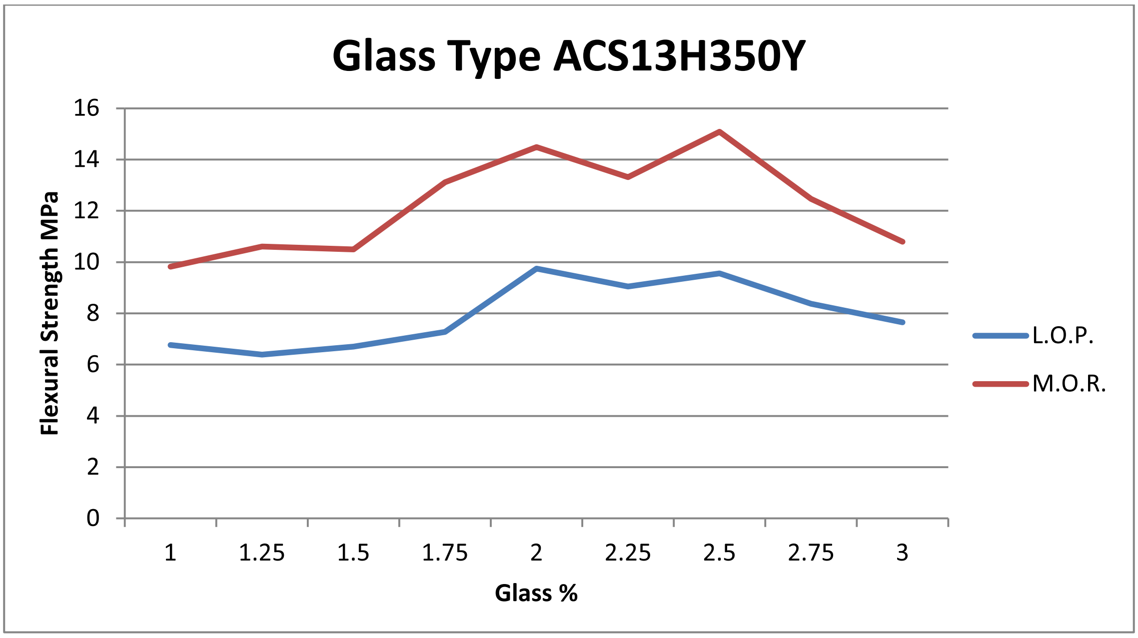


***Figure 8**. Glass Type ACS13H530Y*

EFFECT OF FIBRE CONTENT

A slurry mix for each fibre type was produced. This mix was based on 25kg of cement, 25kg of sand, with a w/c ratio of 0.36 and a 1% by cement weight addition of a self-compacting additive - Flowaid SCC.

The mix was split into 5 smaller mixes, and varying amounts of glass fibre were added. The resulting premix was poured into samples boards and levelled with a float. No vibration was used.

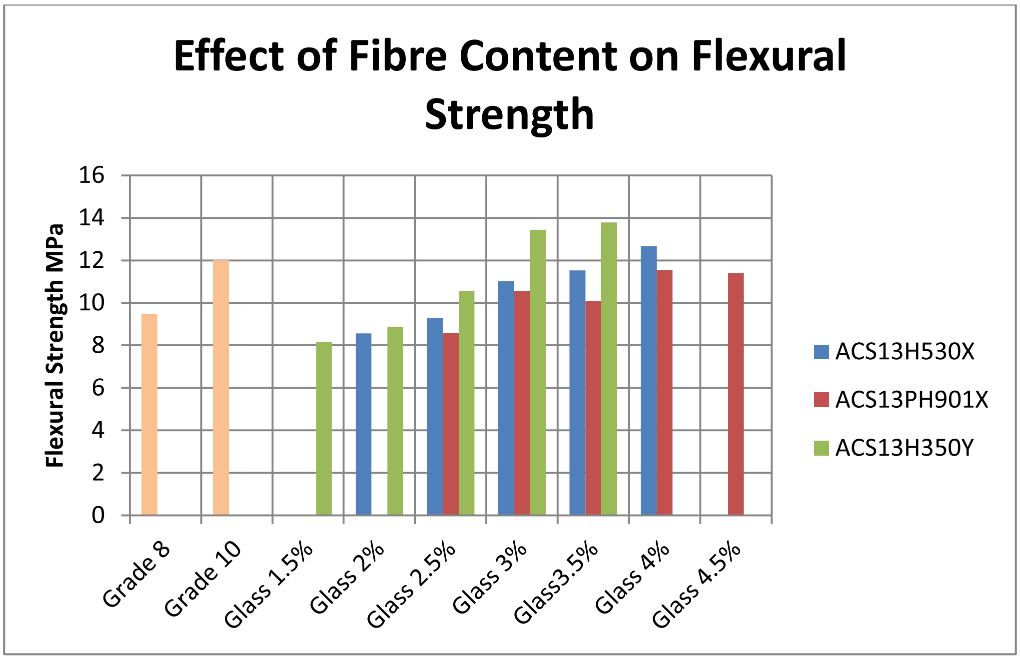


***Figure 9** Effect of fibre content on flexural strength*

The results are shown in Figure 9 and are compared to the requirements of GRCA Grades 8 and 10.

Unlike the previous work, there is no evidence of a tail off in strength, and the increase in strength is generally proportional to the increase in fibre content.

Grade 8 is achieved by ACS13H350Y at 2.5% and all fibres by 3%. Grade 10 is achieved by ACS13H350Y at 3.0% and ACS13H530X at 4.0%.

EFFECT OF FIBRE LENGTH

Results

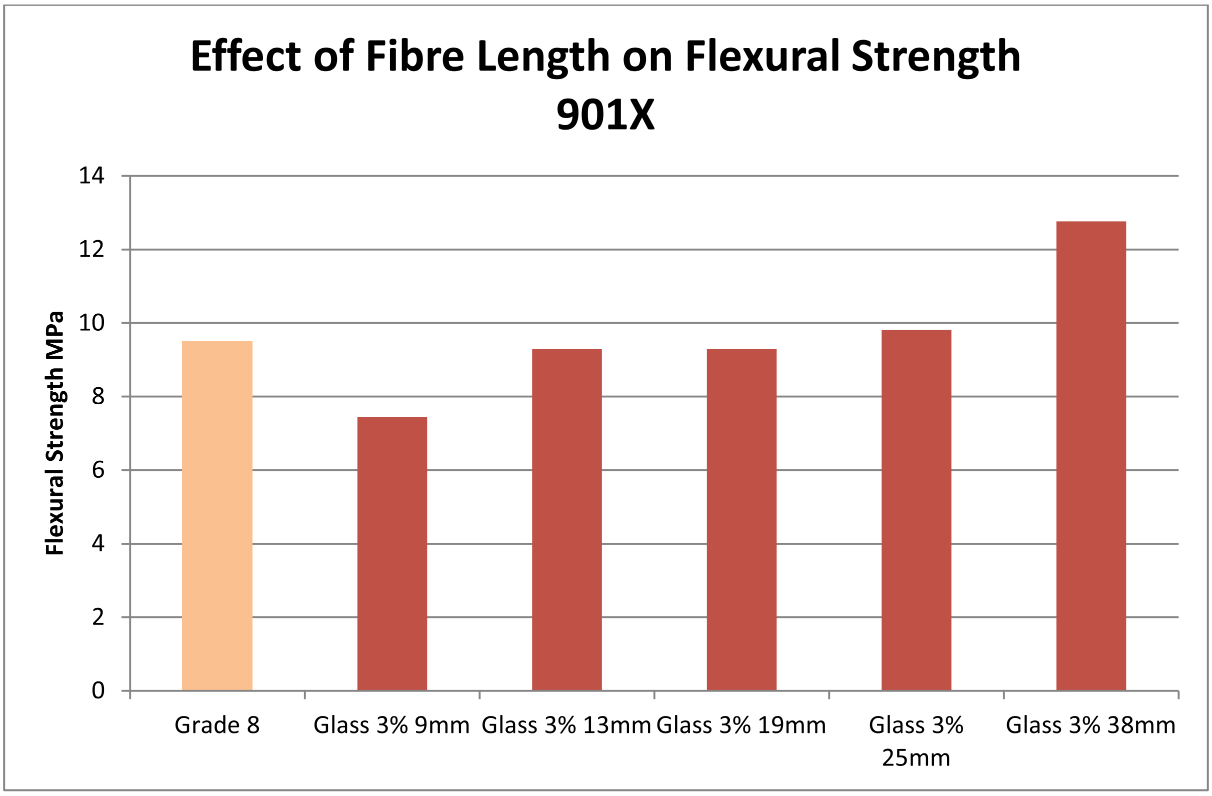


Figure 10 *Results ACS....PH901X: Effect of fibre length on flexural strength 901X*

Grade 8 GRC was achieved with 13mm fibres and longer, Grade 10 with 38mm fibres, although the practicality of using this length of fibre is questionable. There was little difference between 13, 19 and 25mm and as it is more practical to use 13mm, this length is preferred. The 9mm fibres gave low results and probably should not be used when strength is a requirement.

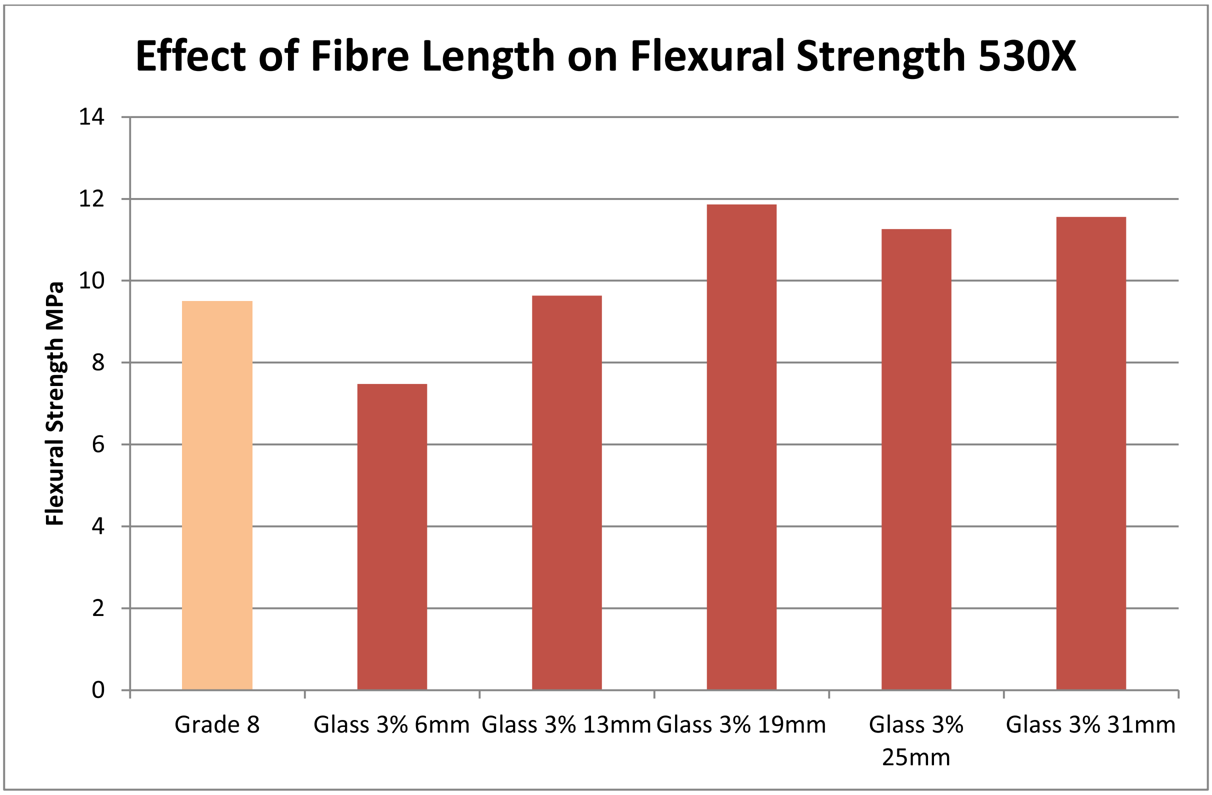


Figure 11. *Results ACS...H530X (Cut from Roving AR5000H530X):Effect of fibre length on flexural strength 530X*

Grade 8 GRC was again achieved with fibre lengths of 13mm and above. Again, the shorter fibres, in this case 6mm, gave lower strengths and probably should not be used where strength is a consideration.

This turned out to be the most interesting part of the project. It was felt that there were sufficient results to be statistically significant.

Initially, the 14 day results were compared to the 28 day, and coupons tested with the mould face in tension were compared to those tested with the trowel face in tension.

14 days	10.02	Face	10.11
28 Day	10.11	Back	10.02

These clearly showed that there is no increase in strength between 14 and 28 days and also that the mould/trowel strength ratio was virtually 1.

Analysis of first 512 individual coupon results are shown in Table 2a and b.

Table 2a. *512 individual coupon results*

T1	T2	T3	T4	T5	T6	T7	T8
10.83	10.83	8.52	8.52	11.15	7.76	11.01	10.98
8.99	9.98	9.52	8.09	8.13	8.77	8.6	10.01
10.88	9.43	11.15	9.62	10.56	12.68	15.79	11.82
10.55	11.31	12.73	10.3	10.03	9.4	11.44	12.52
12.79	13.74	13.35	11.18	11.57	9.48	9.48	17.27
12.14	12.23	10.8	9.45	14.38	17.18	9.23	18.8
8.35	10.8	9.51	7.99	11.46	7.94	8.58	8.5
10.82	9.4	9.56	7.75	12.47	9.34	7.7	9.89
12.4	8.13	10.18	10.68	7.67	7.87	8.95	10.35
9.19	7.46	8.61	7.54	8.17	8.11	7.65	9.56
8.16	7.27	7.72	6.28	7.06	6.30	6.95	6.08
7.62	6.68	8.48	7.79	10.84	12.44	8.97	14.15
13.87	9.59	11.13	19.86	8.31	8.35	18.93	13.92
15.35	19.31	16.77	14.40	17.4	13.22	9.55	10.21
15.07	15.25	18.5	16.36	11.17	11.24	11.67	11.48
8.18	6.90	7.94	7.15	8.65	8.68	7.83	11.47
10.51	8.97	8.38	7.02	8.19	7.70	10.06	9.11
12.59	11.67	12.19	9.02	11.63	14.09	8.67	13.06
8.92	9.78	15.52	12.80	12.89	10.76	8.35	13.07
14.49	15.41	8.51	15.95	14.08	11.15	9.77	12.35
8.59	7.06	7.12	6.36	9.81	8.71	6.86	8.24
12.66	6.31	6.95	11.13	9.18	8.46	11.98	10.43
11.25	5.62	6.99	7.31	13.24	9.12	11.02	12.91
13.52	11.37	9.23	5.83	12.65	11.99	11.89	14.93
14.31	16.75	10.15	6.24	8.58	7.48	12.49	9.31
8.75	10.11	9.17	7.71	8.27	8.70	10.67	11.78
12.34	9.82	7.93	8.02	12.21	8.76	12.04	9.13
16.21	9.72	9.84	9.84	11.54	9.05	13.28	10.81
16.34	15.71	15.94	8.21	15.48	15.74	19.05	15.97
16.3	12.71	10.66	10.01	10.72	8.28	11.42	8.90
11.00	9.98	9.78	9.01	10.23	9.34	10.00	10.84
+9.0%	-1.0%	-3.0%	-11.0%	+2.0%	-7.0%	-1.0%	+8.0%

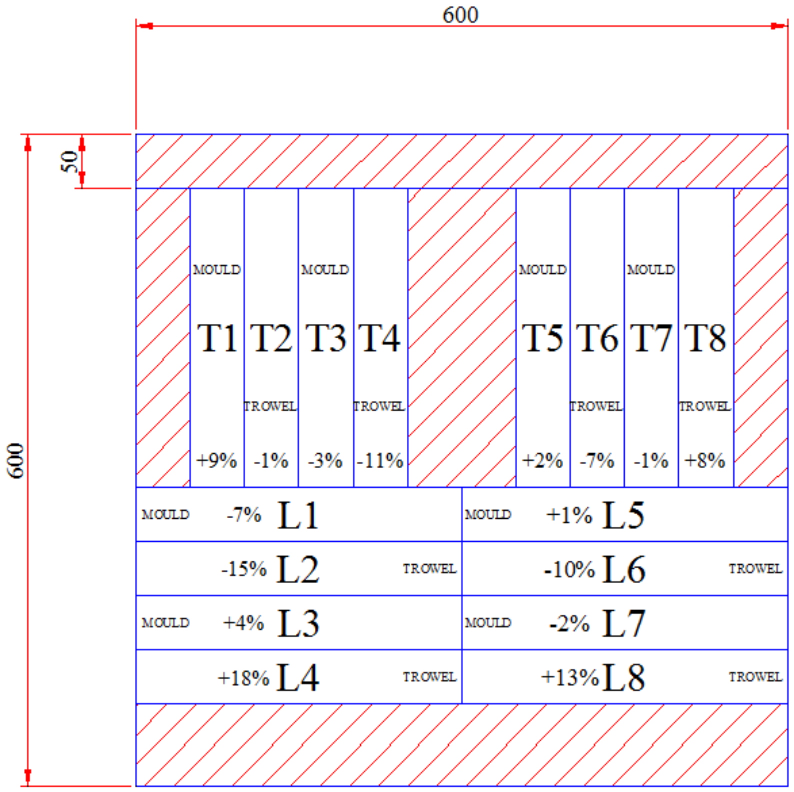
All values shown are the M.O.R. in MPa

Table 2b. *512 individual coupon results*

L1	L2	L3	L4	L5	L6	L7	L8
7.7	6.35	8.58	8.6	9.5	9.26	8.15	11.58
8.38	7.22	9.19	9.19	11.15	12.28	11.01	10.59
9.23	8.03	10.61	9.16	9.63	8.66	14.35	14.34
11.04	9.51	8.79	15.04	13.92	11.23	11.36	12.85
9.44	9.57	14.11	13.9	9.66	11.26	11.05	13.49
11.77	10.26	12.12	19.13	14.59	9.02	9.14	13.9
11.2	7.64	9.49	12.74	8.8	11.98	9.17	12.64
8.09	6.91	10.5	9.09	9.85	7.55	7.55	12.07
7.79	6.9	10.73	10.38	8	8.33	11.6	11.6
6.18	5.34	6.64	7.88	8.81	7.34	7.81	8.56
8.59	8.00	7.86	11.95	9.83	7.20	12.4	9.09
6.63	6.14	6.15	9.12	9.99	7.73	10.2	9.22
7.6	5.80	9.89	11.90	12.22	7.70	7.85	10.82
13.79	12.16	17.52	14.89	11.39	11.34	8.76	9.01
9.92	12.35	16.18	15.54	14.38	14.10	10.1	17.21
8.01	7.10	7.83	7.70	9.39	9.63	8.72	10.43
9.56	9.78	8.74	10.50	9.96	13.38	8.07	13.91
9.49	8.79	11.84	11.79	10.07	9.02	9.54	12.61
10.65	11.14	12.62	13.36	9.6	10.44	13.29	11.35
13.96	12.84	11.76	12.70	13.72	8.94	10.89	16.08
8.9	11.77	8.34	11.85	8.06	7.48	9.3	9.22
10.9	8.72	10.65	16.20	10.4	8.42	12.09	14.64
10.5	10.03	10.71	9.41	9.18	8.10	11.91	14.00
9.25	7.74	13.99	18.31	12.24	8.56	11.05	12.13
8.04	11.86	15.99	14.39	12.98	11.98	9.24	12.83
9.56	8.95	11.8	18.41	7.79	9.49	10.05	8.81
13.63	9.58	8.9	9.35	12.93	9.17	10.3	12.64
14.26	13.02	14.76	12.46	11.76	11.20	13.22	12.15
16.25	12.99	17.23	19.88	14.28	9.59	13.43	13.97
11.11	8.94	11.98	17.00	11.85	10.39	13.3	12.72
9.42	8.61	10.48	11.93	10.19	9.09	9.84	11.39
-7.0%	-15.0%	+4.0%	+18.0%	+1.0%	-10.0%	-2.0%	+13.0%

All values shown are the M.O.R. in MPa

However, further analysis revealed large variations from coupons taken from different parts of the board, these differences are shown in Figure 12.



T	275 x 50
L	300 x 50
	NOT USED

***Figure 12** Variations from coupons taken from different parts of the board*

In effect, coupons taken from the edge of the board can be seen to have a higher strength than those from the middle. This can have significant implications, both for daily quality control testing and for comparing various mix designs. It is essential that when carrying out any testing, the position of the coupon is known, and when making comparisons, coupons are cut from the same part of the board.

The reasons for these large variations are thought to be due to the position and orientation of the fibre. Previous work has tested the fibre content from various levels in the mixing bucket and also from different areas of the sample board, and has found these to be relatively consistent. The method of producing the sample boards has been to pour the mix into the centre of the mould and let it flow to the edges, moving it with a trowel for lower workability mixes. In effect by the time the GRC has reached the edge of the board there has been time for the fibres to move from a three dimensional array to being aligned parallel to the plane of the mould. The fibres in the middle of the board have not moved far and tend to be randomly orientated. The planar fibres contribute considerably more to bending than the fibres which are randomly orientated.

This is an area which requires more investigation, not only for the way that sample boards are produced, but also for products where these variations could be detrimental.

CONCLUSIONS

1. Grade 8 is relatively easy to achieve with a range of mix designs, provided a fibre content of 2.5% or more is used.
2. Use Cement 52.50.
3. A range of water/cement ratios can be used but 0.36 or below is recommended.
4. For strength do not use 6mm or 9mm fibre.
5. Satisfactory strengths can be achieved with a range of workability.
6. Tests can be carried out at 14 days waiting till 28 days is unnecessary.
7. There is very little difference between coupons tested with the mould face in tension and those with the trowel face in tension. It must be noted that this result is for Premix GRC and it cannot be assumed that the same results will be obtainable with sprayed GRC
8. Particular attention must be paid to the filling of the sample boards, and the position on the sample board where the individual coupons are cut from.