29 GFRC Production with AR-Mat Glass Fibre

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ABSTRACT

This paper presented a method for producing GRC panels using AR-Mat glass fibre. The GRC panels with low to high contents of AR-Mat glass fibre were prepared by pouring layers of mortar and placing layers of AR-Mat glass fibre one after the other until the required thickness is obtained. In this study, various parameters such as different patterns of placing AR-Mat glass fibre and different fibre contents were investigated by studying the physical and mechanical properties of GRC panels. The BS EN 1170-5: 1998 Standard tests were used to study physical and flexural properties of these GRC panels. It was observed from this production that very high content up to about 9% could be achieved with ease, and the preliminary test results showed that an increase in fibre content of AR-Mat glass fibre led to an increase in modulus of rupture (MOR). It was also seen that the panels with very high content of AR-Mat glass fibre exhibited about 65% higher MOR than those panels prepared by external spray-mix method.

Keywords: Bending, Glass Fibre Reinforced Concrete, AR-MAT Glass Fibre

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INTRODUCTION

Fibre reinforced concrete (FRC) can be simply defined as cement based matrices containing fibre (Naaman. 2003). The main purpose of using fibre in cementitious matrix (mortar or concrete) is to enhance tensile and flexural properties of the matrix, such as to increase tensile strength, modulus of rupture, and energy absorption and ductility of the matrix. Fibre used in FRC can be natural fibre or synthetic fibre. Alkaline resistant glass fibre (AR glass fibre) is a type of synthetic fibre, when use with mortar, it forms glass fibre reinforced concrete (GRC). GRC are mainly used in exterior building façade panel and as architectural precast concrete. Various production process of GRC have been developed that enable to make simple and complex shaped components, and the enhancement of tensile strength and toughness of material itself enables the transportation, handing and erection of GRC panels. The major disadvantage of GRC is that it will be suffer a loss in tensile strength (flexural) and toughness when it is exposed to out-door weathering, especially in humid environments (ACI committee 544). As a result, the application of this composite is restricted to non-structural or semi-structural components. This reduction of GRC properties with age is the result of two main mechanisms: (1) alkali attack on the glass fibre by hydroxyl ion from the hydration of cement matrix; (2) change in fibre-matrix interfacial bond due to deposition of $Ca(OH)_2$ product within the filaments of glass fibre (Leonard 1984, Marikunte et al. 1997). The last phenomenon leads to the improvement in bond of the individual filament. The failure mode of the glass fibre due to aging changes from pullout of fibre to the tensile fracture of fibre, which leads to embrittlement of the composites.

Currently, most of GRC products are produced via pre-mix or external spray-mix methods. Pre-mix method has the limitation of glass fibre content ceiling at about 3%, and the products are affected by the orientation of the glass fibre. While the products using external-spray mix method have a much higher ratio of two dimensional distribution of glass fibre and be able to use as much as 6% of glass fibre content. A 5% of glass fibre content is usually expected in most production with external-spray mix method; however, the actual amount of glass fibre and its distribution is difficult to control. This uneven distribution of glass fibre will lead to variation in strength of GRC panel and thus having weak point in the GRC panel or product. To overcome this, another method of production is needed. This paper presented a method for producing GRC panels using AR-Mat glass fibre, and high accuracy of glass to cement ratio can be achieve with ease. The GRC panels with low to high content of AR-Mat glass fibre were prepared by pouring layers of mortar and placing layers of AR-Mat glass fibre one after the other until the required thickness is obtained.

The objective of this research was to this study the physical and mechanical properties of GRC panels using AR-Mat glass fibre. The BS EN 1170-5: 1998 Standard tests were used to study the physical and flexural properties of these GRC panels. Various parameters such as different patterns of placing AR-Mat glass fibre, different fibre contents and ages of panels were investigated. This paper will present the flexural results of GRC panels using AR-Mat glass fibre such as flexural response and stress/strain at LOP and MOR, and also compared the results with those panels prepared by external spray-mix method.

EXPERIMENTAL PROGRAM

Materials

Materials used in this research consisted of ASTM Type I Portland cement, AR-Mat glass fibre, Cem-FIL AR glass fibre, river sand, water, and super-plasticizer (ViscoCrete-20HE). AR-Mat glass fibre used in this study has the weight of 150 g/m^2.

Mix Proportion, Preparation of Specimens, and Testing

The mix proportions of mortar used in this study were as follows. Cement binder to sand ratio was equal to 1:1. Water to cement binder ratio was kept as close to 0.35 as possible for both AR-Mat fibre production and external spray-mix production of GRC panels. The workability of mortar was adjusted by adding super-plasticizer which was dependent on the viscosity of mortar.

For AR-Mat glass fibre panels, the test specimens were prepared by pouring layers of mortar and placing layers of AR-Mat glass fibers one after the other until the required thickness is obtained. The illustration of investigated GRC panels with 2, 4, 6 and 12 layers of AR-Mat glass fibre is shown in Figures 1 and 2. The fiber contents of GRC panels with 2, 4, 6 and 12 layers of AR-Mat glass fibre are equivalent to 1.5%, 3.0%, 4.5%, and 9.0% by weight of composites. It is noted that there are two different patterns of placing AR-Mat glass fibre when 4 and 6 layers of glass fibre are used. The first pattern (Pattern A) is that the fiber mats are tried to place at the top and bottom surface of thickness of specimen, while the second pattern (Pattern B) is that the fiber mats are placed uniformly distributed throughout the thickness of specimens. For control GRC panels, the specimens were prepared by concentrical external-spray-mix machine. 35 mm chopped fibers encircled by spray mortar simultaneously dispense onto a flat mold surface. The fresh mortar/glass mix was then pressed with roller and trowel to reduce air entrapment.

All test specimens have the thickness of about 10 mm. The test panels had no skim coat and were cut to 50x300 mm according to BS-EN 1170-5 standard. Eight specimens were prepared for a series of tests according to BS-EN 1170-5 standard. After 24 hours of spraying, the panels were de-mould and immersed in water at room temperature waiting to be tested at 7 days. All GRC specimens were tested for water absorption and bending. For water absorption tests of GRC panels, the percentage of water absorption is obtained from the different weight of specimens before and after drying specimens for 24 hours in oven. For flexural tests of GRC panels, four-points bending tests with a span length of 250 mm were used according to BS EN 1170-5 standard. The main result from the tests is the relationship between applied load and the deflection at the middle of span length. Then, the flexural properties of GRC panels were obtained from this relationship, such as flexural strength at limit of proportionality (LOP), modulus of rupture (MOR), strain at LOP, and strain at MOR as shown in the following expression.

$$\sigma_{LOP} = \frac{F_{LOP} \times L}{b \times d^2} \quad (1)$$

$$\sigma_{MOR} = \frac{F_{MOR} \times L}{b \times d^2} \quad (2)$$

$$\varepsilon_{LOP} = \frac{108}{23} \times \frac{\Delta_{LOP} \times d}{L^2} \quad (3)$$

$$\varepsilon_{MOP} = \frac{108}{23} \times \frac{\Delta_{MOP} \times d}{L^2} \tag{4}$$

where σ_{MOR} is stress at failure (MPa), σ_{LOP} is stress at limit of proportionality (MPa), ε_{MOR} is strain at failure, ε_{LOP} is strain at limit of proportionality, F_{MOR} is failure load (N), F_{LOP} is load at limit proportionality (N), *L* is span length (mm), *b* is width of test piece (mm), *d* is depth of test piece (mm).

RESULTS AND DISCUSSION

Effect of Number of Layers of AR-Mat Glass Fibre

Figure 3 shows the flexural response of GRC panels with different numbers of layers of AR-Mat glass fibre. It is observed that an increase in numbers of layers leads to an enhancement in the flexural response in general, because the fibre content increases with an increase in numbers of layers of AR-Mat glass fiber. It is seen in Table 1 and Figure 5 that an increase in number of layers of AR-Mat glass fibre increases the strength of composite at LOP and MOR and also the strain of composite at LOP. However, the strain of composite at MOR tends to increase gradually with number of layers of AR-Mat glass fibre, until the 12 layers of AR-Mat glass fibre is used in the panels (Figure 6). The strain at MOR of this panel is lower than those panels with 4 and 6 layers of AR-Mat glass fibre.

Effect of Pattern of Placing AR-Mat Glass Fibre

Two different patterns (A and B) of placing AR-Mat glass fibre are investigated on the panels with 4 and 6 layers of glass fibre, and the test results are compared in Figure 4. As expected, it is observed that the pattern A presents the higher flexural response than the pattern B for both 4 and 6 layers of glass fibre due to the higher in moment arm between the top and bottom fibres. It is also seen in Table 1 and Figure 5 that the panels with pattern A present higher the strength at LOP and MOR and the strain at LOP than the panels with pattern B. However, the strain of panels at MOR tends to decrease slightly when pattern A of AR-Mat glass fibre is used in panels (Figure 6).

Comparison of AR-Mat Glass Fibre Panels and Spray-Mix Glass Fibre Panels

The comparison of the results from AR-Mat glass fibre panels and spray-mix glass fibre panels (control GRC) are shown in Figures 5 and 6 and Table 1. It is observed that with the same fibre content the panels with AR-Mat glass fibre exhibit the better flexural properties than those with spray-mix glass fibre. When the panels with 6 layers (4.5% fibre) and pattern A is compared to the control GRC (5.0% fibre), it is seen that the AR-Mat glass fibre panels are about 15% higher in stress at MOR than spray-mix glass fibre panels. Moreover, when the panels with 12 layers (9.0% fibre) is compared to the control GRC (5.0% fibre), it is seen that the AR-Mat glass fibre panels are about 65% higher in stress at MOR than spray-mix glass fibre panels.

CONCLUSIONS

This paper presents the flexural response and some mechanical properties of GRC panels using AR-Mat glass fibre, and it can be concluded from the investigation as follows:

1. An increase in number of layers of AR-Mat glass fibre leads to an enhancement in the flexural response in general, and specially increases the strength of panels at LOP and MOR and also the strain of composite at LOP.
2. An appropriate pattern of placing AR-Mat glass fibre leads to an optimum in flexural response and mechanical properties. The placing of AR-Mat glass fibre on the top and bottom of the specimen thickness (pattern A) presents an improvement in flexural response and some mechanical properties.
3. With the same fibre content, the panels with AR-Mat glass fibre could exhibit the better flexural properties than those with spray-mix glass fibre.
4. The panels with very high content of AR-Mat glass fibre could be achieved up to 9.0% by weight of composites with ease. This panel exhibits about 65% higher MOR than panels prepared by external spray-mix method.

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Table 1. Details of Investigated Specimens and Test Results of Stress and Strain at LOP and MOR

Sample ID	No. of Layers	% Glass Fibre	Stress at LOP	Strain at LOP	Stress at MOR	Strain at MOR
GMRC-2L-A	2	1.5	7.29	0.000230	8.94	0.004262
GMRC-4L=A	4	3	7.96	0.000397	16.12	0.007841
GMRC-4L-B	4	3	7.92	0.000322	14.91	0.008618
GMRC-6L-A	6	4.5	10.94	0.000492	23.89	0.009165
GMRC-6L-B	6	4.5	7.71	0.000587	21.78	0.009709
GMRC-12L	12	9	12.13	0.000714	35.59	0.006729
Control GRC	Random	5	10.38	0.000445	20.91	0.006349

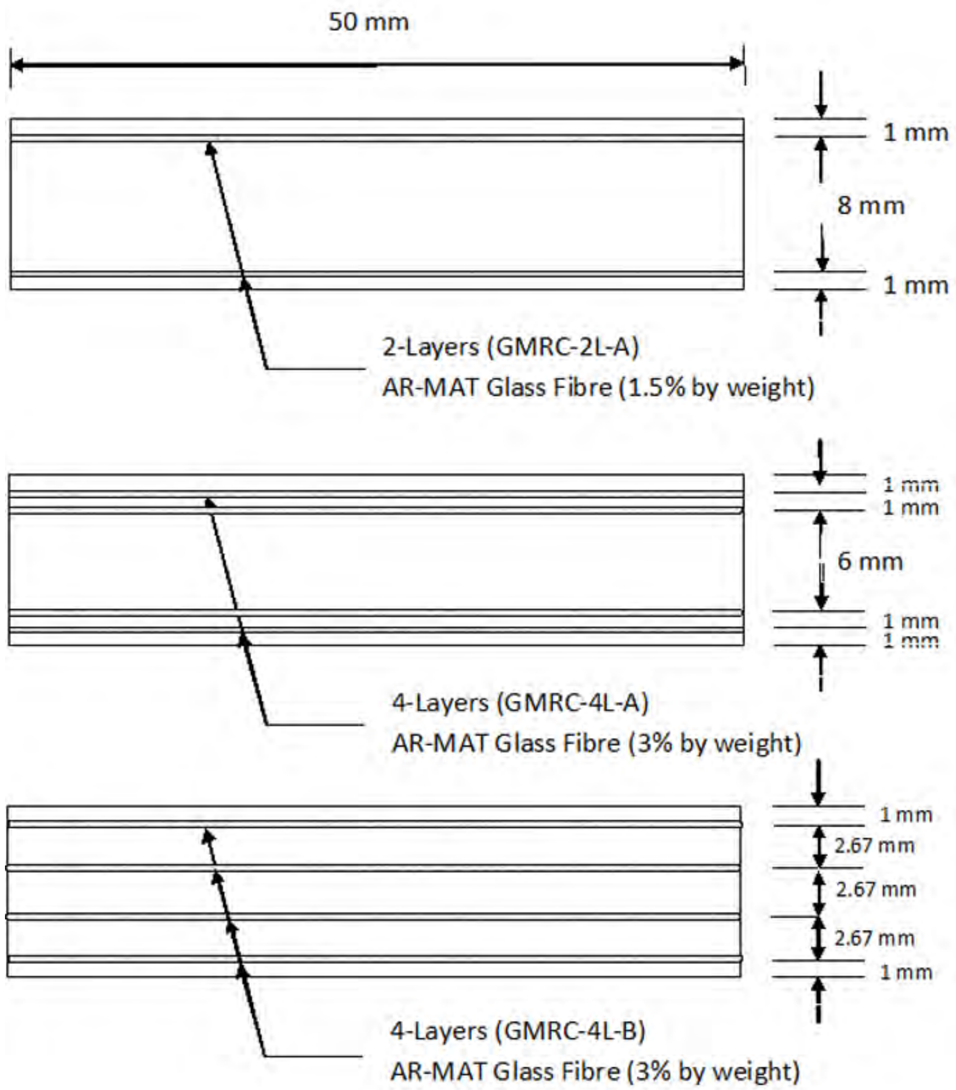

Figure 1. Illustration of Investigated GRC Panels using 2-Layers and 4-Layers AR-Mat Glass Fibre

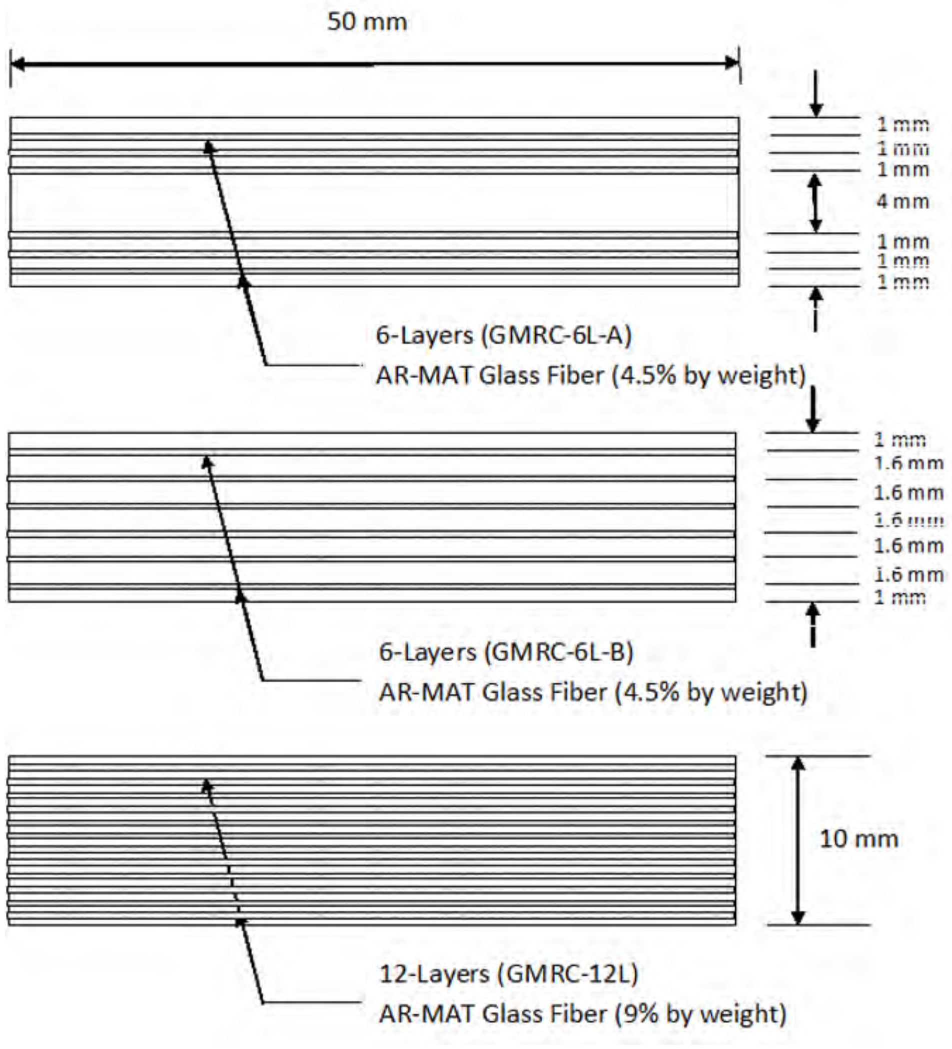

Figure 2. Illustration of Investigated GRC Panels using 6-Layers and 12-Layers AR-Mat Glass Fibre

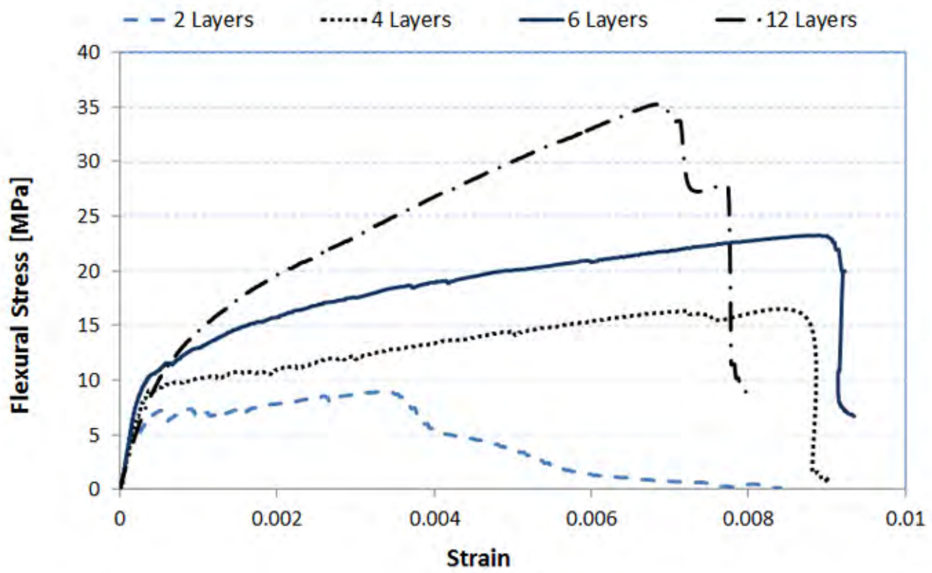

Figure 3. Flexural Response of GRC Panels with Different Numbers of Layers of AR-Mat Glass Fibre

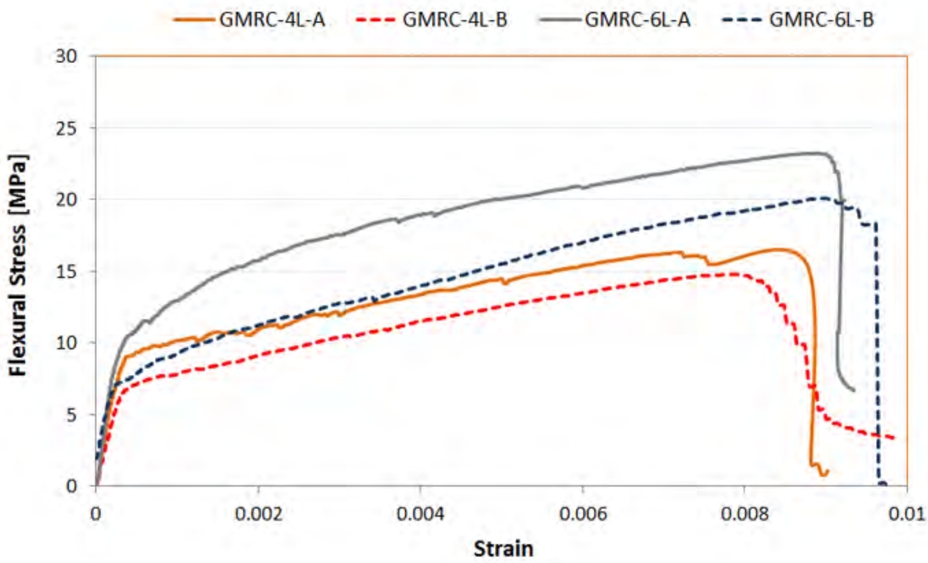

Figure 4. Flexural Response of GRC Panels with Different Patterns of Placing AR-Mat Glass Fibre

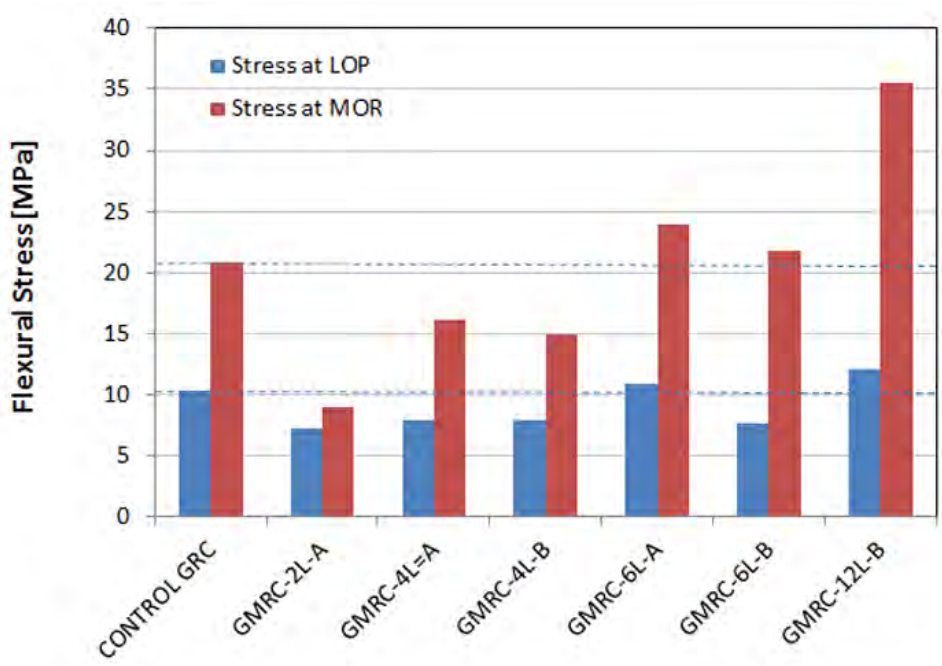

Figure 5. Flexural Stress at LOP and MOR of GRC Panels Using Different Amount of AR=Mat Glass Fibre Compared with Control GRC Panels

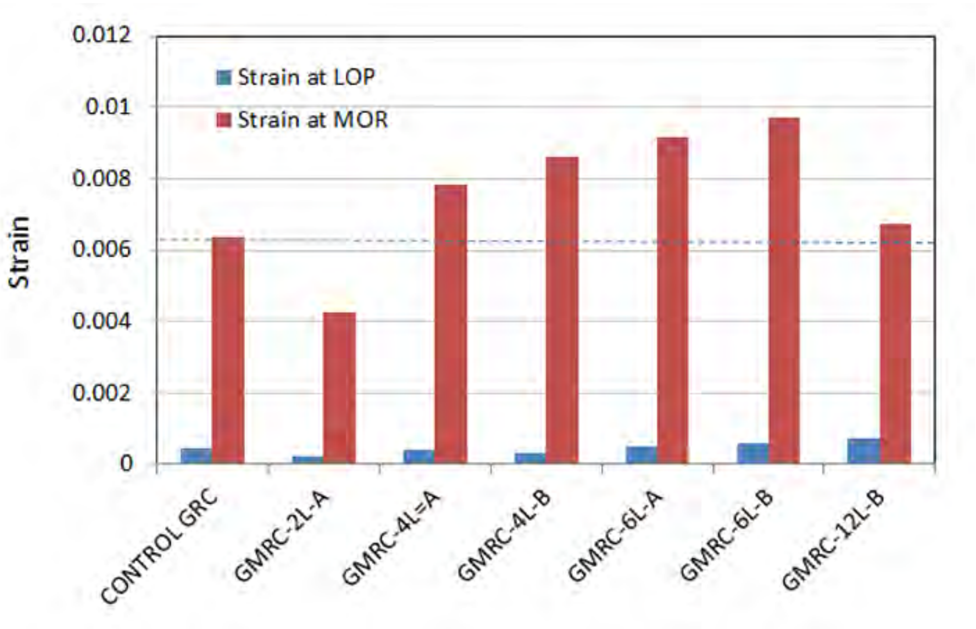

Figure 6. Flexural Strain at LOP and MOR of GRC Panels Using Different Amount of AR=Mat Glass Fibre Compared with Control GRC Panels