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Weathering effects on the manufacturing process of GRC material

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Materials

ABSTRACT

Purpose: Weathering effects on the weight and shrinkage strain of GFRC composite material are experimentally investigated in this paper. The five samples with different percents of glass fibers are chosen to test the effects of humidity on the deformation of GRC.
Design/methodology/approach: These samples are exposed to the environment with different humidity.
Findings: GRC was considered for the fabrication of 30m high telecommunication towers. Other structural such as pedestrian bridges, roof elements and floor slabs were also studied.
Practical implications: The experimental results show that the effect of weight change on strain at dry environment is more significant than wet environment, and GFRC with 5% of glass fiber obviously reduces the weight change and strain.
Originality/value: In this paper the variation of absorbing water rate, edabsorbing water rate, shrinkage strain, weight change, temperature, expansion strain and temperature change rate of GRC material with time was experimentally investigated.
Keywords: Composites; GRC; Humidity; Strain

1. Introduction

GRC (Glass-fiber reinforced concrete) has been used for many years in non-structural elements like façade panels and other products. GRC is composed of cement, sand, water and admixtures, in which short length glass fibers are dispersed, leading to an increase of the tension and impact strength of the material.

The applications of GRC material for structural elements were also developed and investigated in recent years. GRC was considered for the fabrication of 30m high telecommunication towers [1-3]. Other structural such as pedestrian bridges [4], roof elements and floor slabs [5] were also studied.

One of the most concerning problems was the durability of the glass fibers [6, 7]. In this paper the variation of absorbing water rate, edabsorbing water rate, shrinkage strain, weight change, temperature, expansion strain and temperature change rate of GRC material with time was experimentally investigated.

2. Experimental method

2.1. Parameters

The effect of temperature and humidity on GRC depends on fiber content, additive, exposed time, etc. In this study, the fiber contents with 0, 3 and 5 percent were used in the experiment, the additives were Cem-STAR Metakoalin and VF774, and the exposed time was changed to make relative comparisons.

2.2. Materials

Cement used in the experiment is OPC produced by Taiwan Cement Company. The content of silicon sand is between 96 and 98 percent of sand weight. Water content cannot be larger than 2 percent of sand weight. The glass fiber is Cem-FIL2 with the length from 35 to 37 millimeter, which is produced by CemFIL company. The additives of 5 percent of samples were Cem-STAR Metakoalin and VF774, which contents were, respectively, 12.5 and 7 percent of cement and sand weights. The additive of another 5 percent of samples was 12.5 percent of Cem-STAR Metakoalin.

2.3. Sample preparation

Samples were fabricated using hand spray-up method. As indicated in the schematic diagram of Fig. 1, the fabrication procedure of GRC sample was described as follows:

1. Cement and sand were mixed and stirred uniformly.
2. The uniformly stirred cement and sand were sent to the spray-gun by a compressor with constant pressure about 6kg/cm^2. The gun sprayed the uniformly stirred cement and sand on the mold which length, width and height were 1220mm, 1620mm, and 12.5 mm, respectively. In the meantime (at the same time) the CemFIL 2 was cut into length about 35mm by the rotary knife and mixed with the uniformly stirred cement and sand at the exit of the gun.
3. The thickness of each layer on which the gun sprayed the mixture was about 3mm. A roller was used to press the mixture to delete the bubbles and enhance the combination among fiber, cement and sand.
4. Steps 2 and 3 were repeated about 4 times to obtain the total thickness 12.5mm.
5. The samples were taken out after 24 hours and put into the saturated $CaCO_3$ solution.
6. After 28 days the samples were taken out from the saturated $CaCO_3$ solution and cut into the size 300mmx50mmx12.5mm according the standard of BS6432.
7. Then the samples were put in laboratory with relative humidity 60%~90% and after 365 days these samples were taken out to test in the experiment of this study.

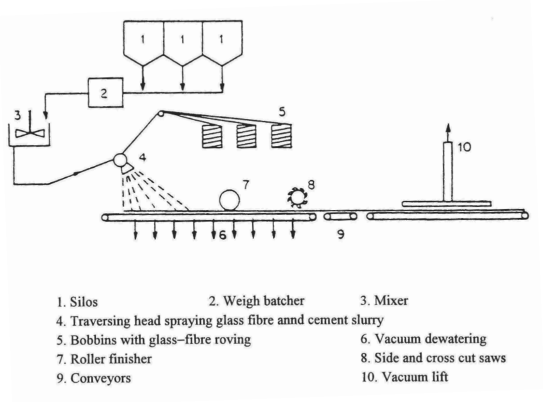

Fig. 1. Schematic diagram of fabrication for GRC sample

2.4. Density test of the sample

According to ASTM C948-81 the samples were put in 23°C distilled water. After 24 hours the samples were taken out and the weight W_0 of each sample was recorded. Then the water on the surface of each sample was deleted and the weight W_1 of each sample was recorded. Sequentially the samples were put in 105°C case with constant temperature and humidity. After 24 hours the samples were taken out and the weight W_2 of each sample was recorded.

2.5. Absorbing water rate

The waterproof material was smeared on the surface of the samples and the weight W_0 of each sample was recorded. Then the samples were put in 23°C distilled water. Every 30 minutes the samples were taken out, the water on the surface of each sample was deleted and the weight W_i of each sample was recorded.

The rate of absorbing water for the sample was defined as

$$Edabsorbing\ water\ rate \equiv \frac{W_i - W_0}{W_i} \times 100\ \%$$

2.6. Edabsorbing water rate

The waterproof material (paint, varnish) was smeared on the surface of the samples and then the samples were put in 23°C distilled water. After one week the samples were taken out, water on the surface of each sample was deleted and the weight W_0 of each sample was recorded. Sequentially the samples were set at the laboratory with temperature 23°C and relative humidity 80%. The weight W_i of each sample was recorded every ten minutes.
The rate of edabsorbing water for the sample was defined as

$$Edabsorbing\ water\ rate \equiv \frac{W_i - W_0}{W_i} \times 100\ \%$$

2.7. Shrinkage strain and weight change

The waterproof material (paint, varnish) was smeared on the surface of the samples. According to ASTM C342-84 using 200mm ELE Demec strain gauge measured the initial length L_0 and weight W_0 of the samples. Then the samples were dried at the laboratory with temperature 23°C and relative humidity 80%. The length L_0 and weight W_0 of the samples were recorded every day.

2.8. Expansion strain

Selecting two T6061 AL bar with the same size 300mmx25.4mmx12.5mm, 15mm strain gauge was attach to the geometry center of longitudinal axis of the 300mmx12.5mm plane for one AL bar and K type thermal couple was set at the geometry center of the other AL bar. Similarly taking two group samples, 60mm strain gauge was attach to the geometry center of longitudinal axis of the 300mmx50mm plane for one group of samples and K type thermal couple was set at the geometry center of the other group of samples. Then AL bars, samples and dummy strain gauge were together put in the case with constant temperature 23°C and relative humidity 80%. After 24 hours the AL bars, samples and dummy strain gauge were taken out to conduct the test of expansion.

2.9. Temperature effect

K type thermal couple was set at the geometry center of the samples with size 300mmx50mmx12.5mm. Then one group of samples were put in the case with constant relative humidity 80%. The samples in the case were cooled from 23°C to 15°C with cooling rate 2.67°C/hr and maintained 1 hour at 15°C. Sequentially the samples were heated from 15°C to 65°C with heating rate 3.33°C/hr and then were again cooled to 15°C with cooling rate 10°C/hr. In the process the data acquisition machine TDS-302 recorded the temperature of the geometry center of the samples every five minutes. The other group of samples was set outside the laboratory and the temperature of the geometry center of the samples and relative humidity of surroundings were also recorded using TDS-302 every five minutes.

3. Results and discussion

The effect of relative humidity on stress is shown in Fig. 2. MOR in this figure represents modulus of rupture. The stress increases with the exposed time for high relative humidity (for example, the cases of water and R.H. 100%). On the other hand the stress decreases with the exposed time for the case of R.H. 50%. The possible reason is because the dry contraction leads to crack in GRC composite material.

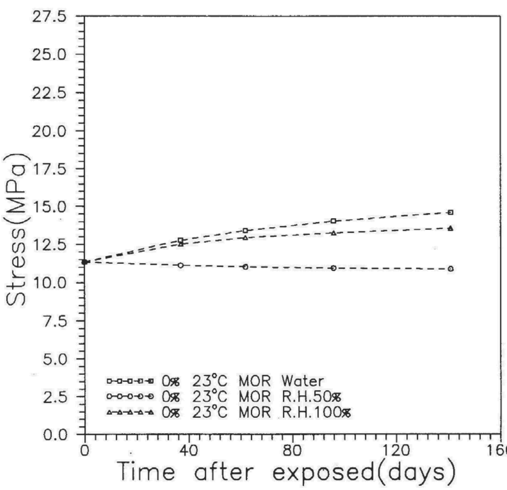

Fig. 2. Variation of stress with the exposed time for 0 of GRC at different relative humidities

For GRC composite material with 5°C of glass fibre, variation of stress with the exposed time is plotted in Fig. 3 for different relative humidity. In contrast to the case with 0% glass fibre in Fig. 2, the stress increases with the exposed time for all the cases of GRC composite material with 5% glass fibre. This attributes to the glass fibre in GRC composite material, which inhibits the dry contraction resulting in fracture.

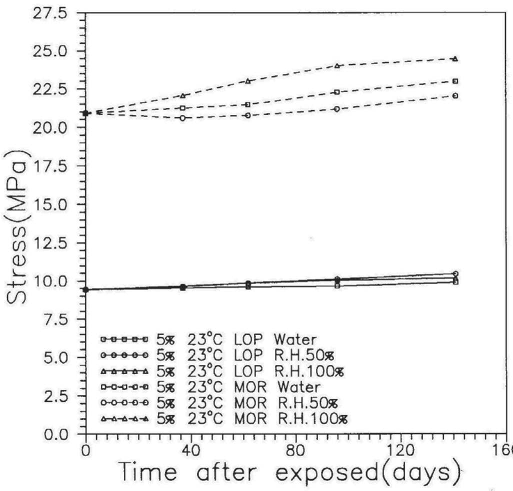

Fig. 3. Variation of stress with the exposed time for 5% of GRC at different relative humidities

Figure 4 showed the variation of absorbing water rate with time for different samples. The percent represents the content of glass fiber in the samples manufactured by Taiwan Cement Company. The samples C1 and C2 were made in other nation. The absorbing water rates of samples with 0%, 3% and 5% of glass fibers quickly increase at the beginning and approach to a steady value for long time. However the absorbing water rates of samples C1 and C2 slowly increase with time. The ratio of absorbing water is defined as the ratio of absorbing water rate of samples to sample with 0% of glass fibers. The ratio of absorbing water rate for the samples with 3% and 5% of glass fiber are greater than 1 and decreases with time. The samples with 3% and 5% of glass fiber quickly absorbed water in 30 minutes. On the other hand the ratio of absorbing water rate for the samples C1 and C2 increases with time. This is because the additivess VF774 and Cem-STAR Metakaolin in the samples C1 and C2 form the membrane between cement paste and glass fiber and reduce the apertures. Hence water penetrates into the membrane slowly. This results in the slow increase of absorbing water ratio with time for the samples C1 and C2.

The edabsorbing water rate ratio versus time was plotted in Fig. 5 for different samples. The ratio of edabsorbing water rate for the samples with 3% and 5% of glass fiber are also greater than 1 and smaller than the ratio of absorbing water rate. This means that the absorption of water for the samples with 3% and 5% of glass fiber is better than the edabsorption of water. However the ratio of edabsorbing water rate for the samples C1 and C2 are smaller than 1 and greater than the ratio of absorbing water rate.

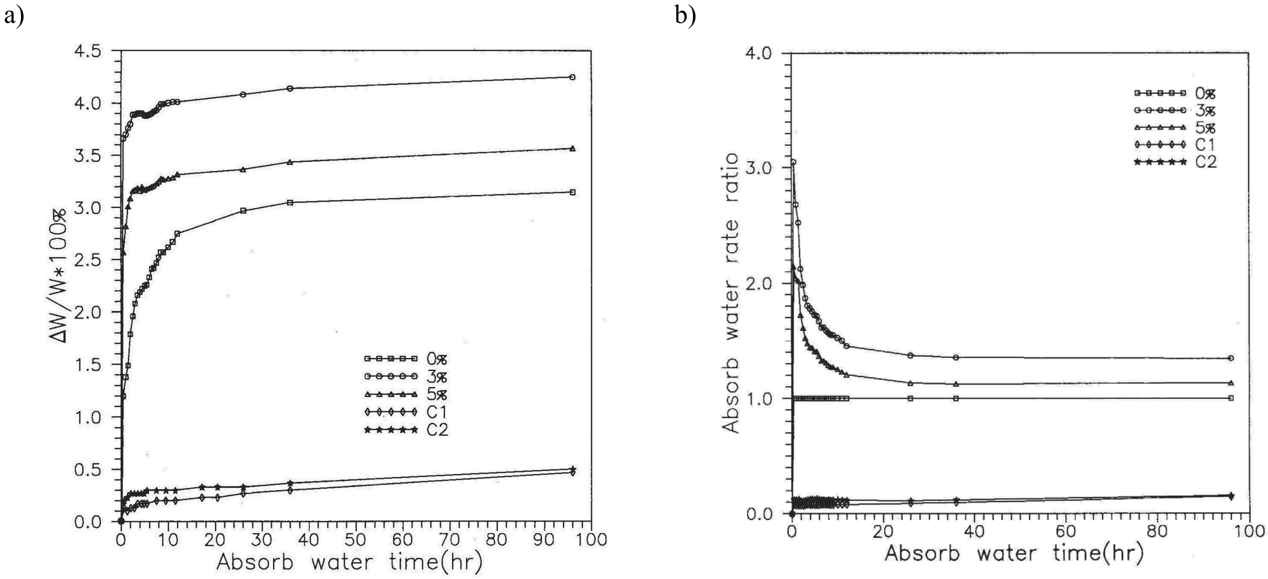

Fig. 4. Variation of absorbing water rate and absorbing water rate ratio with time for different samples

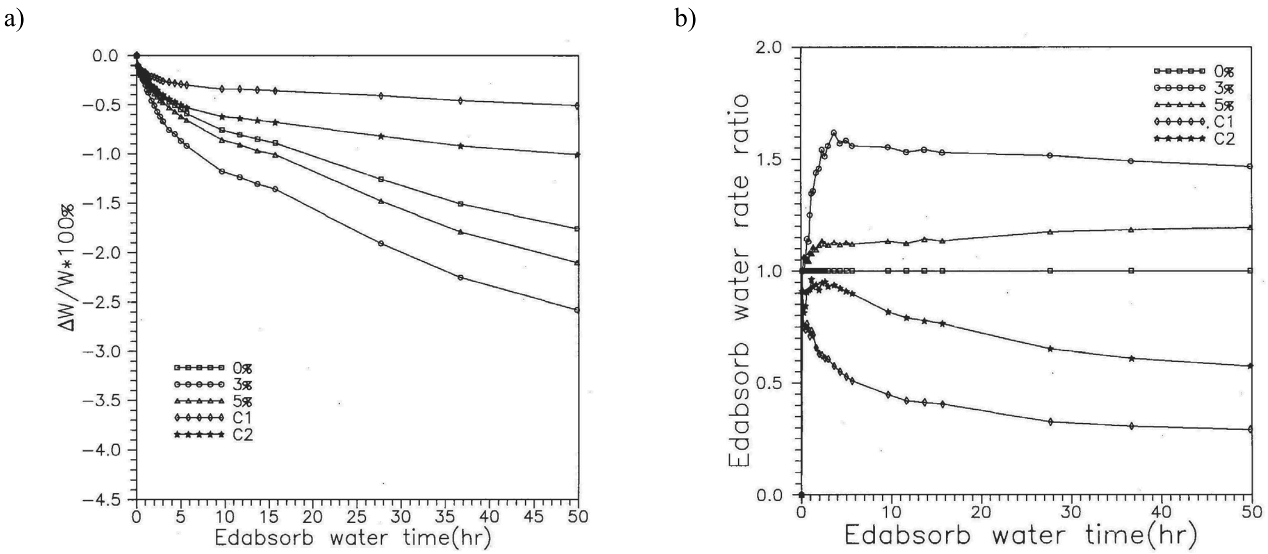

Fig. 5. Variation of edabsorbing water rate and edabsorbing water rate ratio with time for different samples

Figure 6 indicated how the shrinkage strain and weight change varied with time for different samples. The weight change of samples increases with time but the weight change is small at the beginning. After one day the weight change is large and the maximum occurs in the case of sample C2. This shows the sample C2 with the additive Cem-STAR Metakaolin releases much more water than other samples for long enough time. Among these samples the shrinkage strain is maximal for the sample with 3% of glass fiber and minimal for the case of sample C2. It should be noted that the shrinkage strain and weight change of sample C2 obviously increase for long exposure time.

The effect of temperature on expansion strain was plotted in Fig. 7. The temperature of sample C1 increases with time most slowly. Expansion strain of all samples increases with temperature. However the Expansion strain of samples C1 and C2 with the additive is smaller than the samples with 0%, 3% and 5% of glass fiber. The expansion strain of the sample with 5% of glass fiber is 11.2039×10^{-6}% at relative humidity 80% and temperature 65°C, which agrees with the experimental result of other author's study.

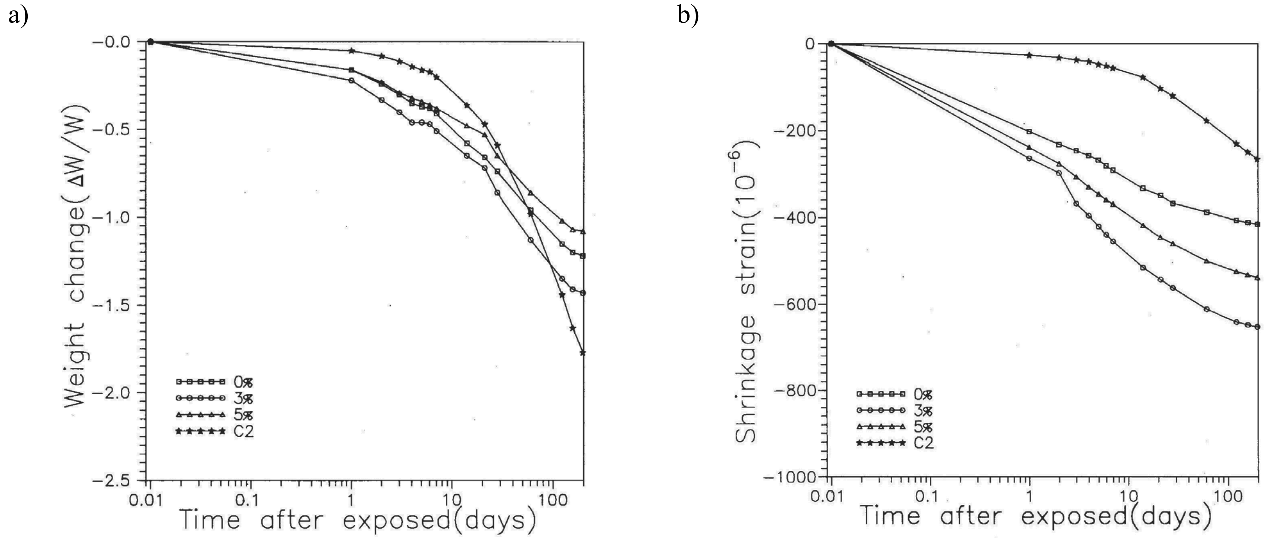

Fig. 6. Variation of shrinkage strain and weight change with time for different samples

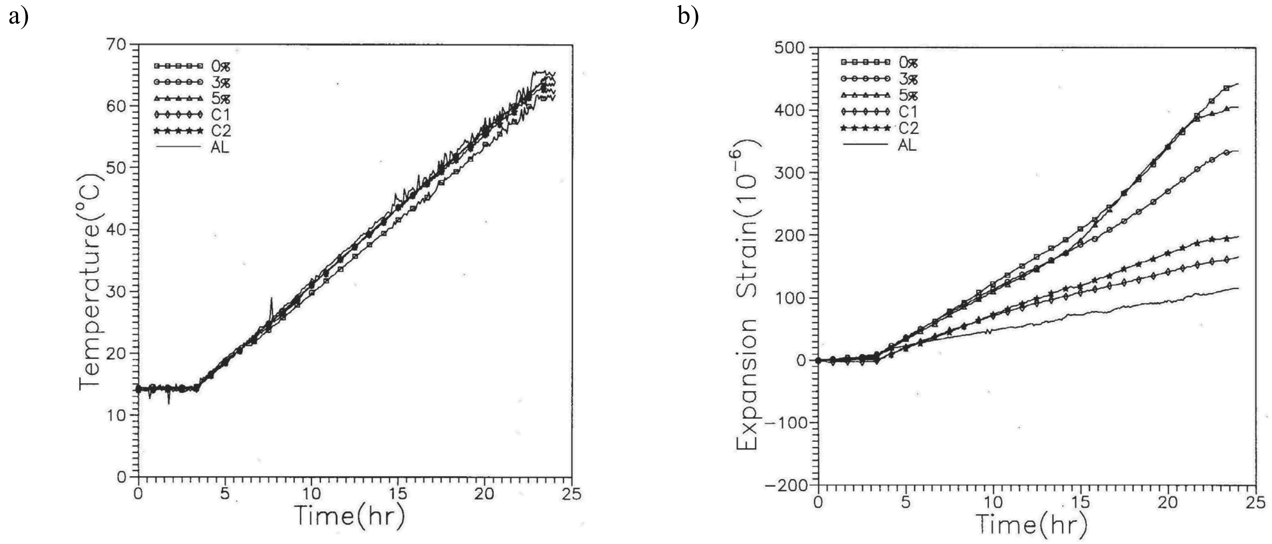

Fig. 7. Variation of temperature and expansion strain with time for different samples

4. Conclusions

The effect of relative humidity on stress of GRC material was tested in this work. The stress of GRC material with glass fibre increases with the exposed time because the glass fibre prevents the crack from dry contraction. The variation of absorbing water rate, edabsorbing water rate, shrinkage strain, weight change, temperature, and expansion strain of GRC material with time were also experimentally investigated in this paper. The absorbing water rates of samples with 0%, 3% and 5% of glass fibers quickly increase at the beginning and approach to a steady value for long time. However the absorbing water rates of samples C1 and C2 slowly increase with time. This is because the additivess VF774 and Cem-STAR Metakaolin in the samples C1 and C2 form the membrane between cement paste and glass fiber and reduce the apertures. Hence water penetrates into the membrane slowly. This leads to the slow increase of absorbing water ratio with time for the samples C1 and C2. The edabsorbing water rates of C1 and C2 samples are also lower than these of 0%, 3% and 5% samples. The edabsorbing water rates of samples increase the increasing water rate. The absorbing water rate of 0%, 3%, and 5% samples is greater than the edabsorbing water rate. On the contrary the absorbing water rates of C1 and C2 samples is smaller than the edabsorbing water rate. The weight change of all samples is small for short exposure time and is large for long enough time. The weight change of C2 sample is smallest among the samples at the beginning but biggest for long time. The shrinkage strain of C2 sample is smaller than that of 0%, 3% and 5% samples. However the shrinkage strain of C2 sample changes more quickly for long exposure time. The expansion strain of C1 and C2 samples is less than that of 0%, 3% and 5% samples. The expansion strain of 5% sample measured by this work agrees with the results of other author's studies.

References

[1] F. Branco, J. Ferreira, L. Calado, Structural Behaviour of Prestrssed GRC Towers, Proceedings of the 12th International Congress of the Internation Glassfibre Reinforced Concrete Association, Dulin, 2001, 13-23.

[2] F. Branco, J. Ferreira, J. Brito, J. Santos, Building Structures with GRC, Proceedings of the CIB Word Building Congress, Wellington, New Zealand, 2001.

[3] F. Branco, J. Ferreira, J. Brito, J. Santos, The Use of GRC as a Structural Material, Proceedings of the Symposium "Mechanics of Composite Materials and Structures", Coimbra, 1999.

[4] J. Viegas, Production Control of GRFC Structural Components in Portugal, Proceedings of the 12th International Congress of the Internation Glassfibre Reinforced Concrete Association, Dulin, 2001, 33-40.

[5] D. Cian, B. Della Bella, Structural Applications of GRC for Precast Floors, Proceedings of the 12th International Congress of the Internation Glassfibre Reinforced Concrete Association, Dulin, 2001, 41-52.

[6] Z. Guan, Y. Jiang, Y. Tanabasi, H. Huang, Reinforcement Mechanics of Passive Bolts in Conventional Tunnelling, International Journal of Rock Mechanics & Mining Science 44 (2007) 625-636.

[7] P. Purnell, J. Beddows, Durability and Simulated Ageing of New Matrix Glass Fibre Reinforced Concrete, Cement & Concrete Composites 27 (2005) 875-884.

[8] P. N. Balaguru, S. P. Shah, Fiber-Reinforced Cement Composites, McGraw-Hill, Inc., 1992.