Performance of polymer modified GRC compared to GRC produced with plasticizer only

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Abstract

Many studies have been conducted in the past confirming the benefits of using Forton polymer GRC over GRC produced without the use of polymer. In those studies, water to cement ratios were adjusted higher in the non-polymer mixes in order to maintain consistent flow properties resulting in potentially unfair comparisons. This paper details the comparison of the properties of GRC having a w/c ratio of 0.32 and made with/without 6% Forton polymers

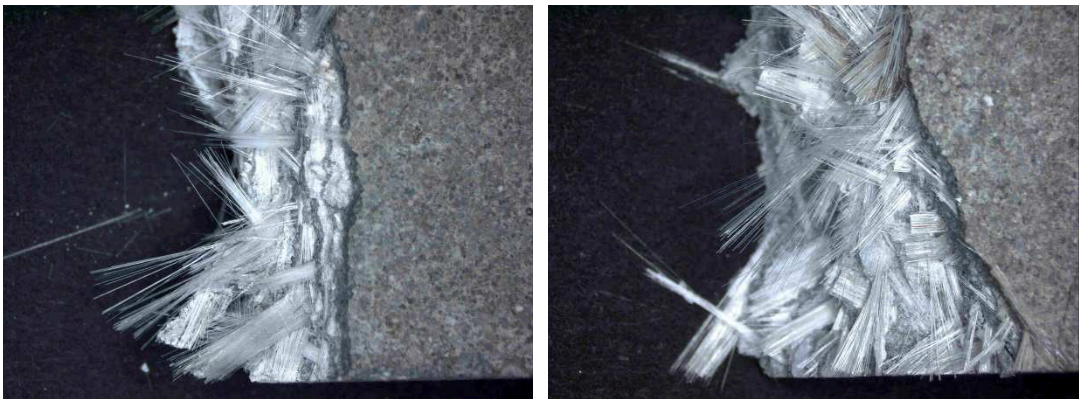
Keywords
Glass fiber reinforced concrete, glassfibre reinforced concrete, GFRC, GRC, polymer modified, air curing, long term durability, face cracking,

INTRODUCTION

The use of Forton polymer in glass fiber reinforced concrete (GRC) is one of the most studied and documented curing agents in GRC (Ref 1-23). It has been in commercial use for almost 40 years. During this time, extensive testing has been performed to demonstrate its utility in GRC. The primary utility is the ability to eliminate the required 7 day wet cure to achieve adequate 28 day strengths. However, in addition to eliminating the 7 day wet cure requirement, Forton has been shown to impart a number of other benefits to GRC including significantly improved long-term durability. This improvement in long-term durability has been demonstrated using panels that have been aged in a natural environment and monitored over the course of up to 20 years.

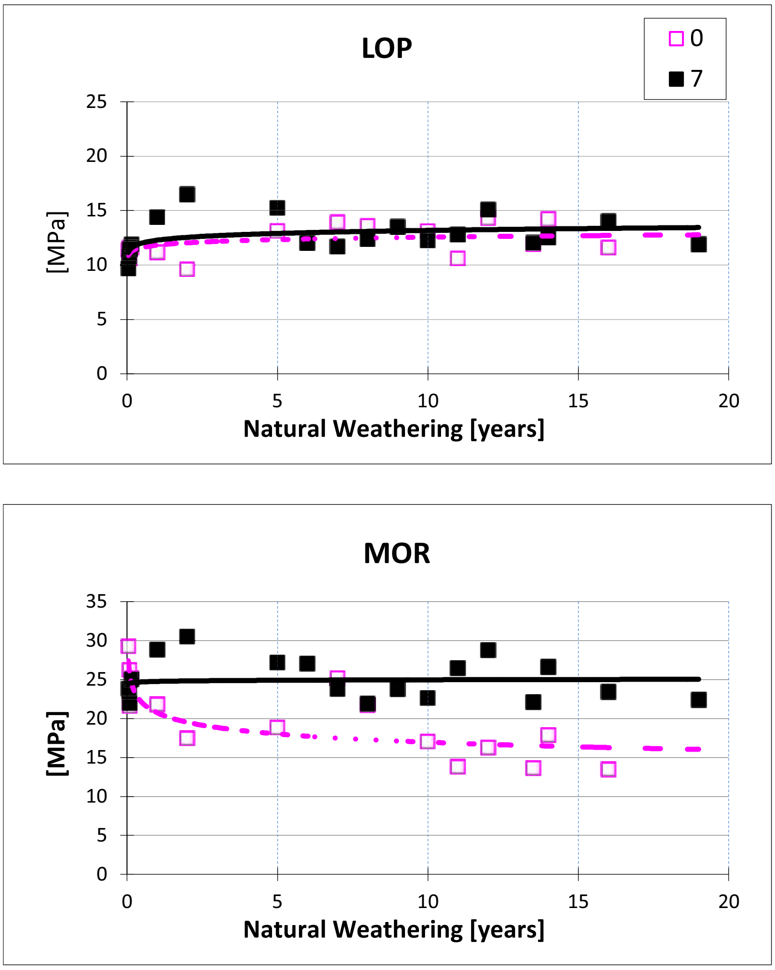
Results of these studies were presented by Hiram Ball at the GRCA conference in 2011. A brief summary of data and conclusions is shown below.

1. A sand and cement mixture, with the addition of at least 6 to 7% polymer solids to the weight of cement of Forton polymer, and reinforced with alkali resistant glass fiber, results in a composite that maintains its strength and ductility in a natural weathering environment. This is evidenced by a stabile LOP, a high MOR and high stable flexural strain to failure shown in Figure 1 and the ductile fracture shown in Figure 2.
2. The MOR of similar aged composites containing no Forton polymer is lower than that of Forton containing composites. Additionally, significant reductions in the strain to failure of aged composites containing no Forton polymer show that these materials become brittle over time in the same environments. Refer again to Figures 1 and 2.



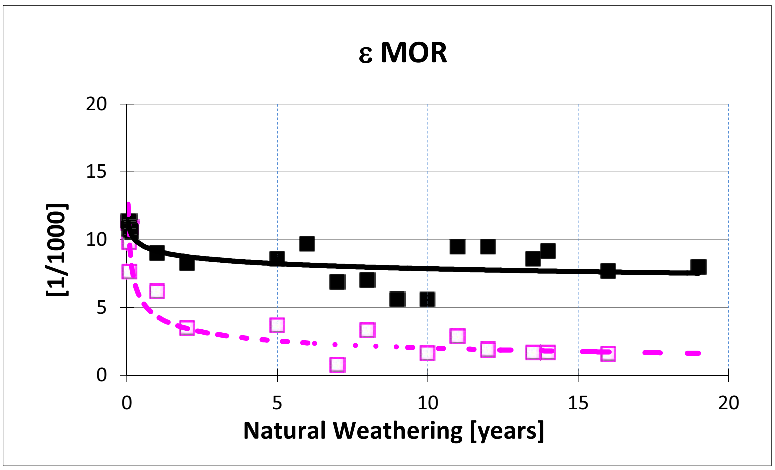
(A) (B)

Figure 1. *Photographs of the fractured region of 13 year old, naturally aged GRC containing no polymer (A), and 7.1% Forton polymer solids (B) based on weight of cement. Used with permission from Ref 21.*



(A)

(B)



(C)

Figure 2. *Plots showing the LOP, MOR, and e MOR as a function of time for GRC containing no polymer (pink open squares) and modified with at least 6% Forton polymer on weight of cement (black filled squares) for previous studies over the course of 19 years. Used by permission from Ref 21.*

Over the years we've received a number of complaints claiming that GRC reportedly produced with Forton was failing in one way or another. In each of these cases further investigation revealed that either Forton was not used in sufficient quantities to achieve the desired benefits or it was not used at all.

In speaking with many producers, we've found that despite these and other studies proving the benefits of acrylic polymer modification on GRC many producers continue to make GRC without either the required acrylic polymer curing agent or the alternative 7 day wet cure. GRC can be made today at very low water to cement ratios using superplasticizers which weren't available when the aforementioned tests were started. In these tests GRC made without acrylic polymer modification had lower water to cement ratios than those made with Forton in order to maintain consistent flow properties thus resulting in less dense, less strong concrete and potentially unfair comparisons. (See Table 1) In order to test the influence of water to cement ratio on the initial and long term properties of GRC made with and without polymer we began the following research.

Table 1. *Average water to cement and polymer to cement ratios for data presented in 2011 GRCA paper.*

	Prior Work	
	Forton	Control
w/c	0.31	0.37
p/c	6.80%	--

PRODUCTION AND CURING OF TEST BOARDS

Mix compositions for the current work are shown in Table 2.

Table 2. *Matrix compositions by weight (weight is in pounds unless otherwise specified)*

	Forton	Control
Cement	94	94
Sand	100	100
Water	25	30
Forton (51% solids)	11	0
Superplasticizer (oz)	4	5
w/c	0.32	0.32
p/c	6.0%	--

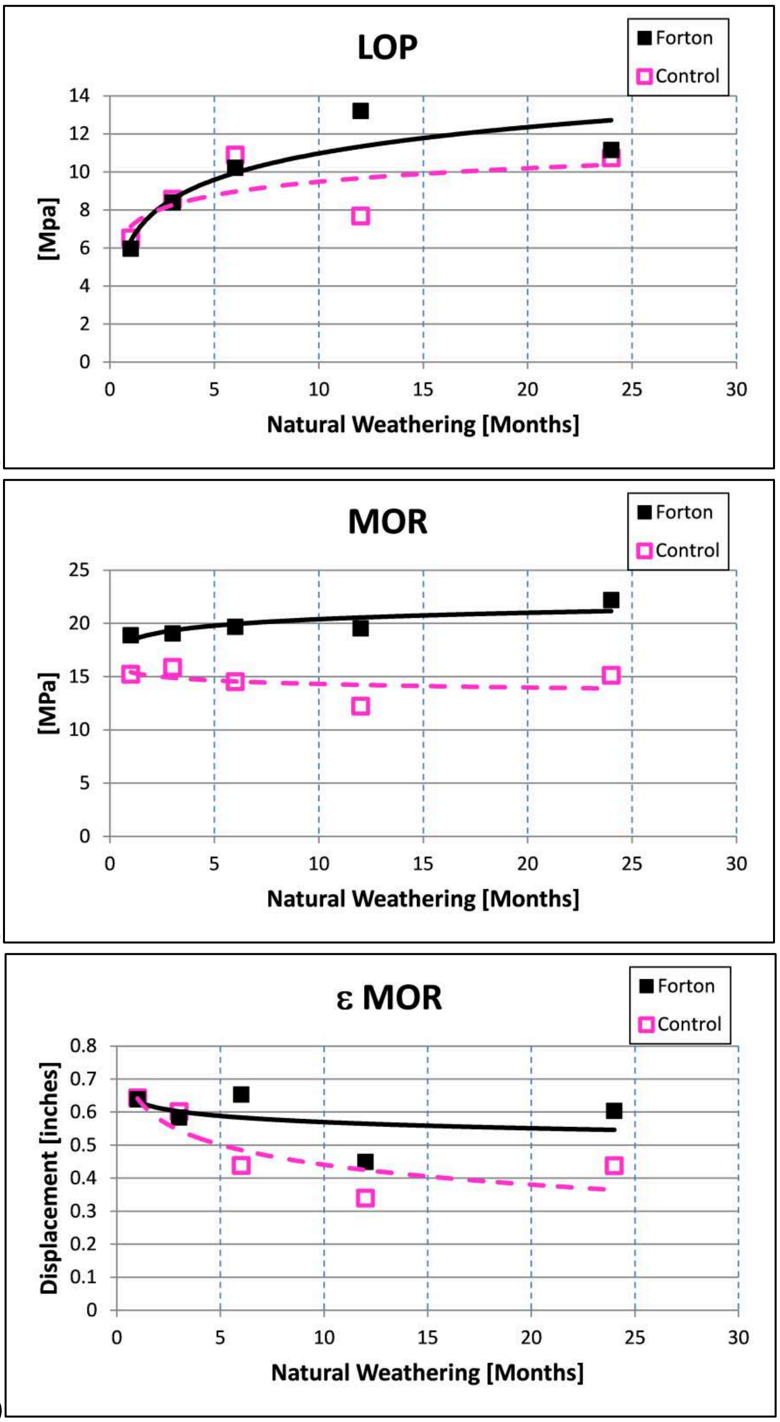
Table 3. *Processing conditions and material properties*

Measured Values	Glass	Fiber length	Slump	Slurry Unit Weight	Slurry temp	Air temp
(Units)	*%*	*Inches*	*Rings*	*pcf*	*°C*	*°C*
Forton	4.4	1.25	3	135.3	18	14
Control	4	1.25	3.5	138.4	18	16

Test panels were produced according to PCI MNL-130 5.6 with optimal dimensions of 48” x 18” x 0.5”. The targeted fiber content was 5% using 1.25” AR glass fibers. After the slurry and glass fiber calibration tests were done, test boards were sprayed using the two mixes listed in Table 2 and compacted using typical GRC compaction rollers. The material was then troweled smooth and covered with plastic overnight. Test boards were demolded the following day and stored under ambient conditions for 27 days before testing. The day before testing panels were cut into 2” x 12” coupons and soaked in tap water for 24 hours prior to testing.

28 DAY TO 2 YEAR RESULTS OF CURRENT STUDY

The LOP, MOR, and MOR for panels made with and without Forton are shown in Figure 3. The 28 day LOP for both systems are essentially the same at about 6 MPa. Over the course of two years both systems behave similarly and increase to around 11MPa. This is similar to results obtained in the previous study where the LOP remained stable, raising only a few MPa over the course of 19 years, primarily in the first few years.



(A)
(B)
(C)

Figure 3. *Plots showing the LOP (A), MOR (B), and ☐ MOR (C) as a function of time for GRC containing no polymer (pink open squares) and modified with 6% Forton polymer on weight of cement (black filled squares) for the current study over the course of 2 years.*

The MOR for the sample containing Forton starts at 19 MPa and increases gradually to 22 MPa. The 28 day and 2 year MOR for the Control sample are both 15 MPa, however, the general trend appears to be decreasing over time. Again, this reflects the results of the aforementioned study.

Finally, MOR at 28 days for both materials begins at 0.64". MOR for both samples decreased over the two years. While it is still too early to accurately predict what will happen over the next 20 years, it appears that, in this aspect as well, the samples are behaving similar to those in previous studies. The MOR of the control sample is decreasing more quickly than the sample containing Forton.

FACE CRACKING INVESTIGATION

In addition to strength and ductility we investigated the influence of polymer and surface curvature on face cracking. Surface curvature was investigated by comparing panels made in a flat mold with those made in a mold with significant curvature. The surface profile of the curved samples can be seen in Figure 4.

Figure 4. *Pictures of GRC panels produced with textured molds and made without polymer modification (4A) and with 6% Forton polymer solids (4B). Surfaces were treated with a red dye solution to highlight any face cracking.*

Panels were prepared using the recipe in Table 4.

Table 4. *Mix designs for materials used in face cracking investigation*

	Face mix		Backer Mix	
	Forton	Control	Forton	Control
Cement	30	30	50	50
Sand	15	15	25	25
Water	7.9	9.6	13.1	16
Forton (51% solids)	3.5	0	5.9	0
Superplasticizer (oz)	0.36	1.7	0.57	2.9
3/4" AR glass fiber	0	0	2.8	2.75
w/c	0.32	0.32	0.32	0.32
p/c	6.0%	0.0%	6.0%	0.0%

Panels were prepared by spraying and brushing face mix into molds measuring 24" x 48" (textured) and 18" x 48" (flat) then backed with premixed GRC and covered with plastic for 16 hours for initial cure. After the initial cure panels were placed outside in both horizontal and on 45° south facing positions and monitored. All panels containing no Forton exhibited cracking within two weeks of production. Panels containing 6% Forton remained free from any face cracks for the entire duration of the experiment, 2 years. Figure 4 shows pictures of panels produced with textured molds and made without polymer modification (Figure 4A) and with 6% Forton polymer solids (Figure 4B). In order to highlight the cracking a red dye solution was made and applied to the dry panels. Since the solution absorbed more quickly into the cracks these areas stand out relative to the uncracked areas.

CONCLUSIONS

A review of the data in this paper leads to the following conclusions:

- Addition of at least 6% Forton polymer to GRC has proven measurable benefits in long term durability
- Initial results from the current study indicate that composites produced with 6% Forton polymer and a water to cement ratio of 0.32 maintain their strength and ductility over time whereas those produced using the same processing protocol with the same water to cement ratio but without Forton polymer show measurable degradation in properties in as little as 6 months.
- Incorporation of 6% Forton polymer solids into GRC reduces the appearance of face cracking in panels compared to those produced without polymer under identical conditions and with the same mix design.

Design engineers, GFRC producers and building owners should seriously consider this information when evaluating production protocol. For, while it is possible to produce GRC that passes the require 28 day strength quality control tests using only water reducers or plasticizers, longer term performance of materials produced without following the proper protocol is questionable.

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