Study and analysis of the bond strength of metakaolin geopolymer with e-waste plastic at room and elevated temperature

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Abstract- Ordinary Portland cement (OPC) is generally accepted as a functional bond in the manufacture of concrete and cementitious mortars. Three MGP pastes were smooth (no fiber) and the remaining three were made by mixing EWP plastic beads. The MGP compound is made by differentiating sand, MK and sodium silicate content in NaOH proportions, resulting in different molar ratios. The specimens were subjected to room temperature and high temperatures of 80°C and 120°C for 6 h before the pullout test. The mortar reinforced with common MGP and EWP was cured at room temperature. Test results show that MGP mortars are a better alternative to cement-based repair mortars. The bond strength between the MGP repair material and the concrete surface was significantly reduced at 80 °C.

Keywords: Ambient curing; Metakaolin; Heat evolution; strengths

1 INTRODUCTION

Alkali-based fly ash (AAFA) is usually dissolved at high temperatures. It can be improved by mixing different cements. This study investigates for different uses of additive energies such as waste; methakaolin and silica fume in the different properties of the AAFA mixture under curing conditions. The effect of chemical differences and alkaline solution sequences on mechanical properties and permeability characteristics of AAFA and different cement additives (Hani Alanazi*et al.*2019) was also studied. The addition of fibers to the stabilizing GP concrete mixes increases the adhesion force to the event and connects it to 200 °C (Abdulrahman Albidah*et.al* 2020). The thermal conductivity of synthetic geopolymers is determined in terms of evolutionary compressive strength by exposure to 100, 200, 400, 600, 800 and 1000 °C. They showed that ceramic tiles can have satisfactory properties for thermal toxicity. A new waste product was created to discuss the possibility of generating geopolymer synthesis. The focus will be on the synthesis process to select the solution that works best. Excellent geopolymer products will be selected for high temperature testing in terms of the compressive strength, after a temperature range 100, 200, 400, 600, 800 and 1000 °C (ZengqingSun*et al.* 2013).

It was found that heat release accumulation increased and increased alkali and residual emissions were observed for both fly ash and metakaolin based geopolymers. Increased heat treatment increases heat flux and heat dissipation during geopolymerization. Chemical behavior of the geopolymers and various heat treatments were also investigated (JingmingCai*et al.*2019). The air temperature of methakalin-based geopolymers mixed with rice husk ash with 5-20% MK migration and weight was investigated. The aqueous component of the mixture was sodium hydroxide (NaOH) 8 molar and sodium silicate (Na_2SiO_3) contained 8.2% Na2O, 26.0% SiO2 and 56.6% H_2O. The alkaline activator solution was pre-mixed and allowed to rest for 24 h at a moderate temperature before treatment (Xinhao Liu*et.al* 2020).

A significant increase in pressure was observed at 10% to replace the metakaolin. SEM (EDS) analyzes of geopolymer starch containing fly ash were also observed. To provide cement, and finally, where possible, metakaolin compounds containing geopolymers are mixed with other pozzolanic materials such as fly ash and silica powder to increase strength and efficiency. Fifteen compounds were made. The manufactures of brick parts can be expensive (Osama.A*et al.* 2020).There are mechanical forms of methakaolin-based geopolymers using intermediate composition design. The items examined were NaOH inmates, the Na_2SiO_3 / NaOH weight scale, and the solid / liquid size ratio. The results of the experimental study showed that they were more suitable for samples that showed the formation of aluminosilicate gels, which increased the compressive strength. This method is divided into design test and quantitative analysis (BadrAouan*et al.* 2021).

Geopolymers are emitting building materials with low carbon footprint compared to conventional cement materials. For this purpose, after 14 days of incorporation, the hydrate samples were cut to an estimated size (1 x 1 x 1) cm^3. Measurements were taken in the pressure range between 0.034 ATM to 2041 atm. Another measure was taken as a model type (Jing Li*et al.* 2021).The molarity of potassium hydroxide was used as 8 m, 10 m and 12 m molarity at different treatment temperatures such as 60 °C, 70 °C and 80 °C (Pawan Anand Khanna et al. 2017).

The production of cement uses a lot of energy and involves a lot of carbon dioxide. Another option for making concrete friendly is to improve geopolymers. The current measurement is (a) FA-based geopolymer concrete design, (b) mechanical and physical structures to test, and (c) comparisons with conventional concrete. The ultimate goal of the search program is to concrete technology is not a mineral supplement, but as a valuable binder (instead of cement) within the geopolymer concrete (GC) segment has different FA silicate inner layers of 15%, 22.5% and 30% with a prepared volume. The best technical buildings are designed for comparison purposes. The measured parameters of GC and CC are stable, air volume, density, ultrasonic pulse velocity. Pressure force modulus of elasticity Poisson ratio and strong force by splitting and bending test (Nikolaos Nikoloutsopoulos*et al.*2021). Excellent geopolymers are made for foaming with hydrogen peroxide. The strength of the anonymous geopolymers was reduced to 5 MPa by raising the temperature to 800°C. Dumb geopolymers behave differently at depths of up to 3 MPa at 400 °C and rise to 14 MPa at 800 °C, up to 800 °C of the crystalline layer at higher levels. Non-respiratory geopolymers have been observed to reduce their strength, but to increase the strength of non-respiratory geopolymers in comparison, Geopolymer foam has better heat dissipation than irregular geopolymer (Heah Cheng-Yong et al. 2017).

Geopolymers prepared from mineral or industrial waste treated with alkaline solution. It is widely used as a new and durable building material. The thermal and electric properties of geopolymers at high temperatures have attracted. Thus, the number of systematic studies in these two areas is small. Therefore, this study examines the nature of heat. It was described the thermal properties of geopolymers. the mechanisms of residual pressure forces and the stress-related relationship between grasses geopolymers and metacaoli geopolymers were examined (Rui He *et al.*2020). The combination of GGBFS and Class F flying ashes provides dynamic moments and compelling power equal to the typical Portland cement (OPC). These procedures can be followed in the laboratory with a small section of clear bullets Thus, finding a large amount of sand SSD conditions is difficult. In this case, the internal fluid of the water activator can be adjusted to check the true internal moisture (Pradip Nath*et al.* 2014).

The addition of only 5% OPC to full bandwidth reduced the treatment time to the selected rent (Pradip Nath*et al.* 2014). This research studies the effect of calcium-rich compounds on the time and energy of the development of alkaline fly ash (FA). The three compounds rich in calcium are Portland cement (HK). Sodium hydroxide and sodium silicate solutions were used as stimulants in all mixtures alkaline activators for water / solid bonds (FA and calcium rich calculations) at an alkaline level of 0.60, sodium silicate in relation to sodium hydroxide and air temperature (25 °C) were used. The combination of the three calcium supplements led to a faster deployment time. Use of high calcium FA pressed by alkali. Therefore, it is important to clean up production, especially in the construction sector. The use of high-calcium FA with incubated ash suspension at room temperature describes the possibility of using three types of calcium rich as an additive in the formulation process. The results of this study should provide a basis for future use of a modified gastric high-calcium FA binder as a safe treatment (Prinya Chindaprasirt *et al.* 2018).The studies have shown that mosquitoes or slags can be used as concrete for concrete and forced into the stomach through the process of modification. Therefore, the main problem was that the heating system has strong properties. The conventional treatment used for OPC concrete can then be applied to alkaline active substances (Arie Wardhono *et al.* 2015).

The results should contribute to the understanding of the nature of the mechanics and to future improvements and performance of fly ash geopolymers (Kiatsuda Somna et al. 2011). The optimal heat for the FA-GPC is provided in a 75 °C oven at 18-24 hours. FA-GPC porosity and magic coefficient, good heat treatment increases the compressive strength and electrical instability of the FA-GPC. These included three treatments at 60, 75 and 90 °C and 4 treatment modes at 8, 12, 18 and 24 hours, plus those models were given cycle treatments. Internal components such as compression force, elastic module ultrasound pump speed. Distribution and reuse of pores with Portland Cement Concrete (OPC), the amount of drinking license tested (Amin Noushini*et al.* 2016).

2 EXPERIMENTAL PROGRAM

2.1 Control repair mortars

The cementitious cubes were used to evaluate the performance of the MGP repair mortars. It is prepared in cement and sand available locally in a ratio of 1: 2 with water / cement ratio of 0.5. Cement mortar is not a standard that enforces the strength of a mixture of geopolymer and cement. Also, the performance of cement mortar mixtures and polymer composites was investigated with different geopolymer mixtures at different temperatures.

Prepare nine cylinders 150 mm in diameter and 300 mm in height (3 samples from each temperature test) to determine the compressive strength of each mixture. The cylinder is poured in three steps and shaken with the help of a vibration table. The cement cubes used were cured under water for 28 days before the test.

2.2 Geopolymer repair mortars, Preparation of specimens and Curing method

In this study, three light weight plain MGP and three fiber-reinforced MGP fixtures were used. The purpose of using fiber reinforced MGP repair mortars is to assess the improvement in repair of mine structures due to the presence of fiber. In a recent study, tools used in the production of GP include MK, fine aggregate and alkaline activators. Locally available and commonly used sand with a fineness modulus of 2.64 was used as a fine aggregate. The MK-EWP used in the study was obtained by kaolin calcinations for 6 hours at 120°C. A 150 × 150 × 700 mm concrete prism was used as a concrete substrate to test the performance of the repair mortars. The compressive strength of the above concrete surface is 51 MPa (based on cylinder size 150 × 300 mm), which is much higher than the strength of the repair mortars. One of the prism's largest surfaces (150 × 300 mm) is designed to be used in application of repair mortar. The preparation included metal scrubbing, and cleaning acetone for manufacturing that is unstable and dust-free prior to repair mortar application. The ideal healing regime in terms of time and temperature plays an important role in the development of strength and behavior of the geopolymer concrete; thus, many trials have been done with the hardening process to produce an MK-EWP with a high compressive strength using a sustainable healing method. In the present experimental study, immediately after casting, the molds were covered with plastic to prevent water loss due to evaporation and to remain in the environment for 24 hours.

2.3 Mixing proportions

In this study, many test mixtures were prepared to determine the highest compressive strength for MK-GPC, which was selected as the reference mixture. For all mixtures, the ratio of alkaline activator solution to binder was 0.68, while the percentage of extra water was set at 2 and 10% by weight of binder, respectively. To understand the effect of the use of waste plastics in MK-GC, four mixtures with waste plastic contents of 0, 10, 20 and 30% were produced as partial volumetric replacement for the natural coarse aggregate and indicated as 0% EWP, 10% EWP, 20% EWP and 30% EWP respectively. Table 1 shown the physical properties of e-waste plastic (EWP), Table 2 summarizes the mixing ratios of different mixtures.

Table 1 Physical Properties of e-waste plastic (EWP)

Sl No.	Physical Properties	Results
1	Bulk Density (ASTM C29-09)	455Kg/M^3
2	Water Absorption (24 Hours)	0.00%
3	Thickness	Maximum 3mm

Table 2 Mix Proportions for all mixtures

Sl No.	Material (Kg/m^3)	Mixtures			
		0% EWP	10% EWP	20% EWP	30% EWP
1	Metakaolin	415	415	415	415
2	Course Aggregate	1241	1118	995	865
3	Fine Aggregate	470	470	470	470
4	E-Waste Plastic Aggregate	0	35.235	72.478	105.53
5	Alkaline Solution ($1NaOH/2NA_2SiO_3$)	265	265	265	265
6	Extra Water	7.3	7.3	7.3	7.3

2.4 Mixing and casting procedure

The procedure for producing the geopolymer is very important; the mixing, casting and curing processes were thus kept constant for all mixtures. All aggregates are prepared to be in a saturated, dry state (SSD). First, the course, fine and EWP aggregates are mixed with the metakaolin (MK) for 3 minutes in an electric rotary tilt mixer. Thereafter, half of the amount of alkali solution is gradually added to the dry mixture to mix together for 4-5 minutes, while the remaining alkaline solution and extra water are mixed by hand for about 1 minute and poured into the mixer. The mixing process takes 9-10 minutes, including 1 minute of rest to clean the blades. The homogeneous fresh MK-EWP was left out of the mixer and cast in layers in the required cast iron molds. Each layer is fastened 30 times with a standard steel bar and then on the vibrating table for 30 seconds.

3 TEST RESULTS AND DISCUSSION

Table 3 to 6 and Figures 1 to 4 show the compressive strength results of cement repair mortars after exposure to different temperatures, ambient conditions, temperature of 80 °C, temperature of 120 °C, respectively. Table 7 and Figure 5 show the results of the loss of compressive strength of repair mortars after exposure to different temperatures. Tables 8 to 11 and Figures 6 to 9 show the results of the effect of high temperature on the bond strength of different cement repair mortars and, GP1 and GP1F mortars, GP2 and GP2F mortars, GP3 and GP3F mortars respectively. Table 12 and Figure 10 show the results of the loss of pullout strength of repair mortars after exposure to different temperatures. Tables 13 to 16 and Figures 11 to 14 show the results of the effect of high temperature on the normalized bond strength of different cement repair mortars and, GP1 and GP1F mortars, GP2 and GP2F mortars, GP3 and GP3F mortars, respectively.

Table 3 Results of compressive strength of repair mortars of cement

Sl. No	Exposure temperatures (°C)	Cement Mortar (N/mm^2)
1	Ambient	42.2
2	80	27.2
3	120	26.3

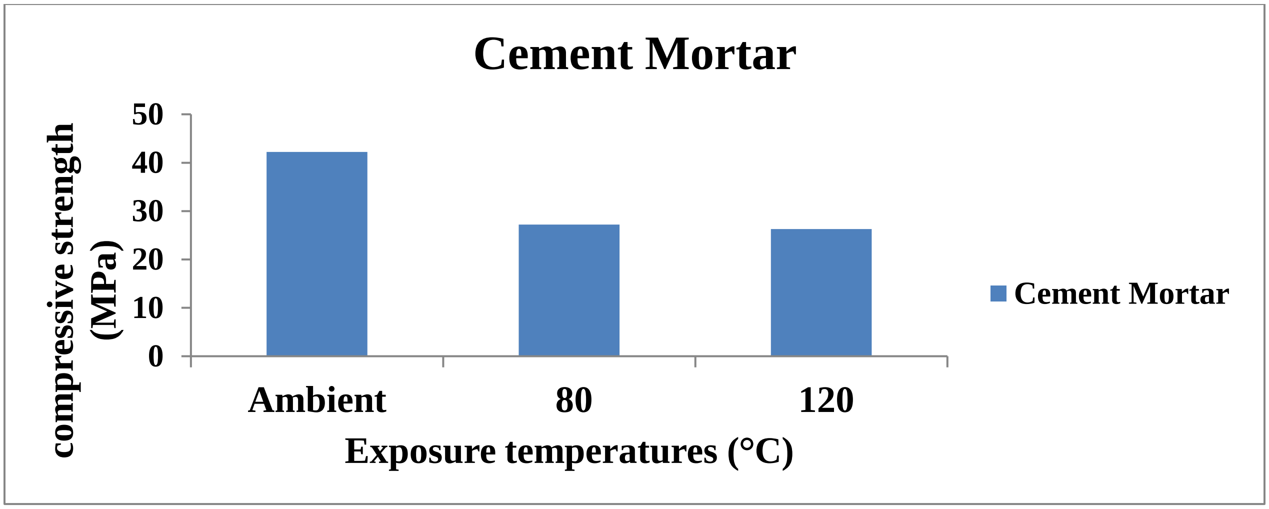

Figure 1Results of compressive strength of repair mortars of cement

Table 4 Results of compressive strength of GP mortars at ambient condition

Sl. No	GP mixes at ambient condition	Plain GP (N/mm^2)	Fiber reinforced (N/mm^2)
1	GP1/GP1F	28.2	40.8
2	GP2/GP2F	29.6	48.7
3	GP3/GP3F	28.7	15.4

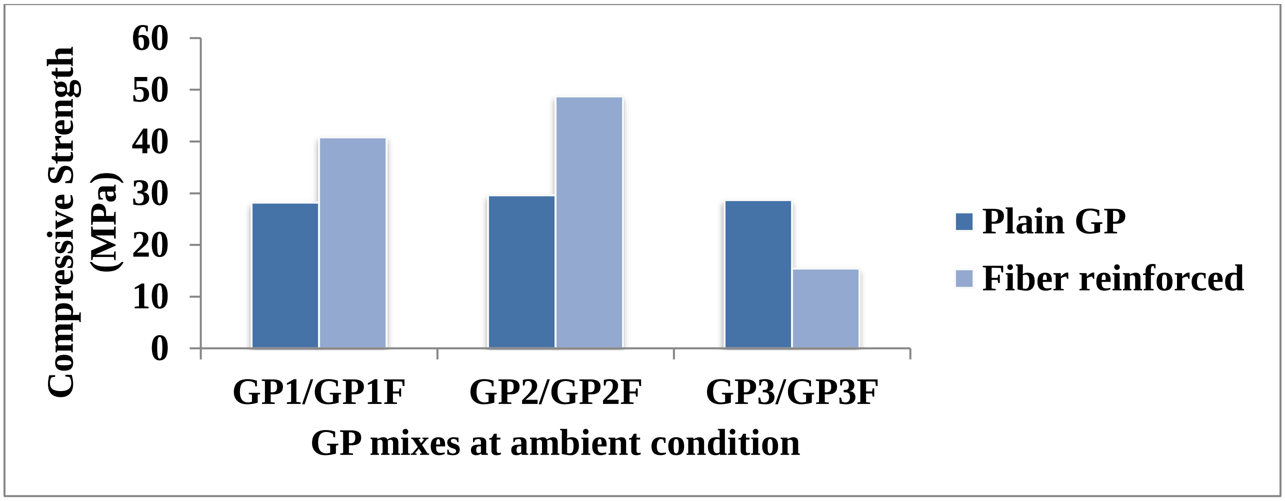

Figure 2 Results of compressive strength of GP mortars at ambient condition

Table 5 Results of compressive strength of GP mortars at temperature of 80 °C

Sl. No	GP mixes at temperature of 80 °C	Plain GP (N/mm^2)	Fiber reinforced (N/mm^2)
1	GP1/GP1F	25.4	39.5
2	GP2/GP2F	28.7	45.6
3	GP3/GP3F	25.4	11.2

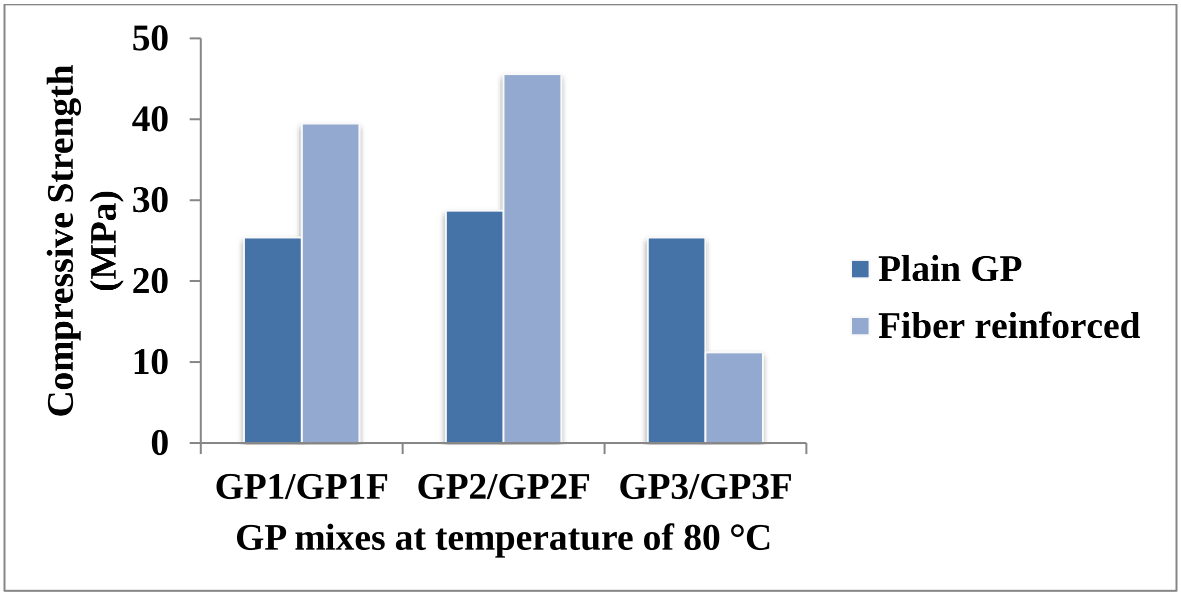

Figure 3 Results of compressive strength of GP mortars at temperature of 80 °C

Table 6 Results of compressive strength of GP mortars at temperature of 120 °C

Sl. No	GP mixes at temperature of 120°C	Plain GP (N/mm^2)	Fiber reinforced (N/mm^2)
1	GP1/GP1F	18.5	24.8
2	GP2/GP2F	21.3	29.5
3	GP3/GP3F	15.8	4.2

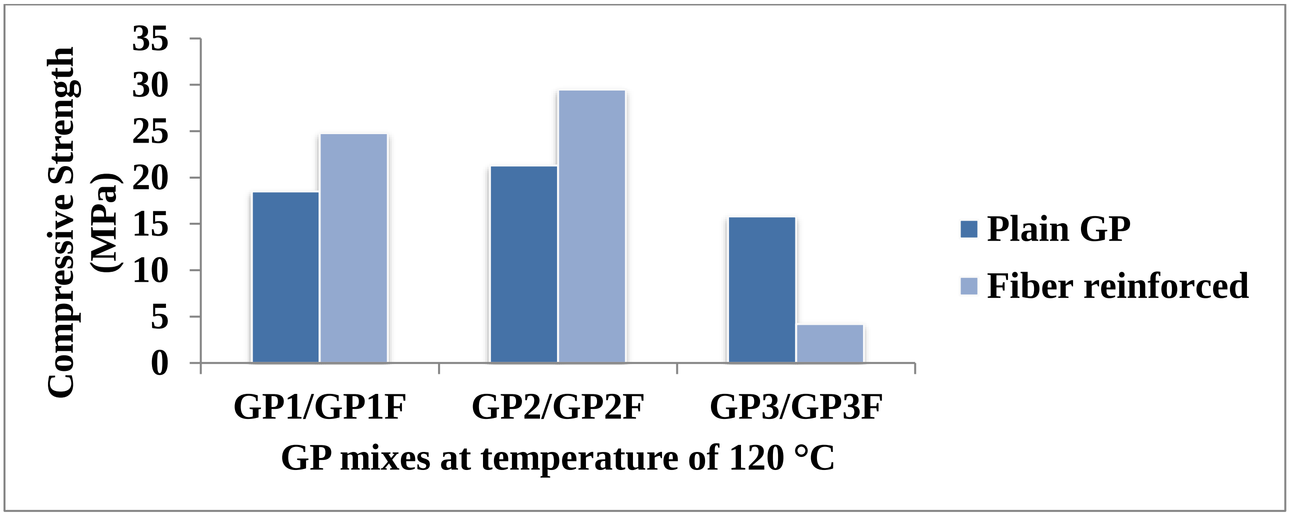

Figure 4 Results of compressive strength of GP mortars at temperature of 120 °C

Table 7 Results of loss in compressive strength of repair mortars after exposure to different temperatures

Sl. No	Mortars mixes at different temperatures	Loss in compressive strength (%) at temperature of 80 °C	Loss in compressive strength (%) at temperature of 120 °C
1	Cement mortar	37.5	39.6
2	GP1	9.2	37.5
3	GP2	6.5	28.7
4	GP3	13.2	45.3
5	GP1F	3.1	42.1
6	GP2F	5.9	42.6
7	GP3F	23.5	74.8

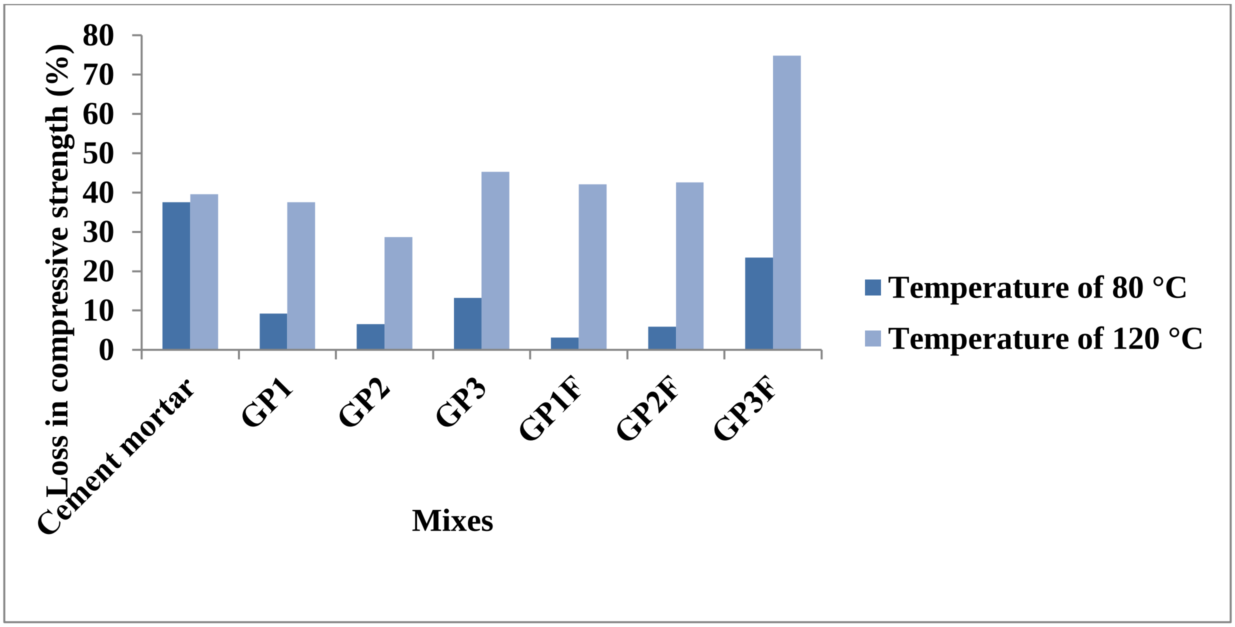

Figure 5 Results of loss in compressive strength of repair mortars after exposure to different temperatures

Table 8 Results of effect of elevated temperature on bond strength of different repair mortars of cement

Sl. No	Exposure temperatures (°C)	Bond strength in N/mm^2 of cement mortar
1	Ambient	2.11
2	80	1.20
3	120	0.96

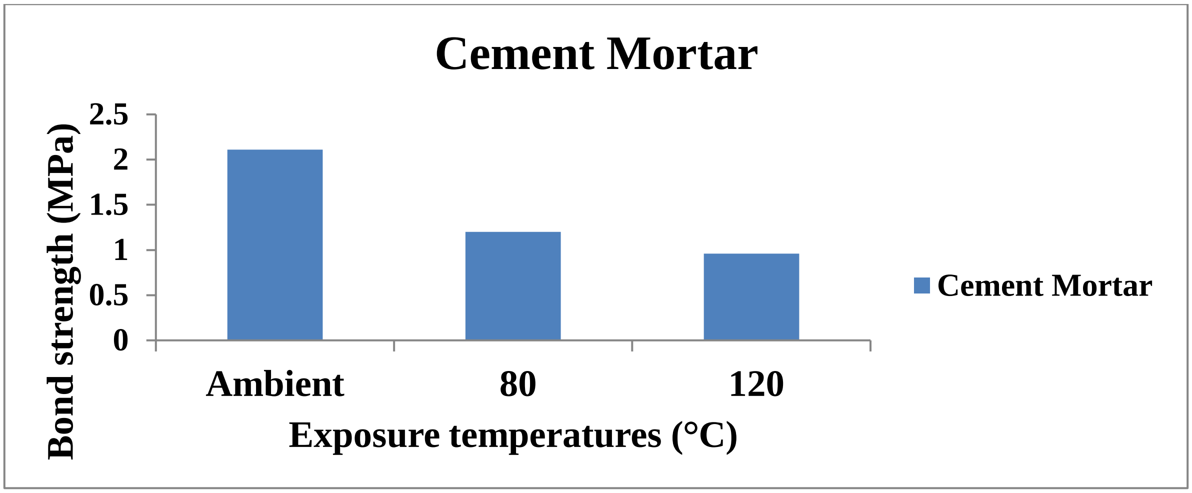

Figure 6 Results of effect of elevated temperature on bond strength of different repair mortars of cement

Table 9 Results of effect of elevated temperature on bond strength of different repair mortars of GP1 and GP1F mortars

Sl. No	Exposure temperatures (°C)	Bond strength in N/mm^2 of GP1 mortar	Bond strength N/mm^2 of GP1F mortar
1	Ambient	1.55	2.88
2	80	1.28	1.63
3	120	1.02	0.11

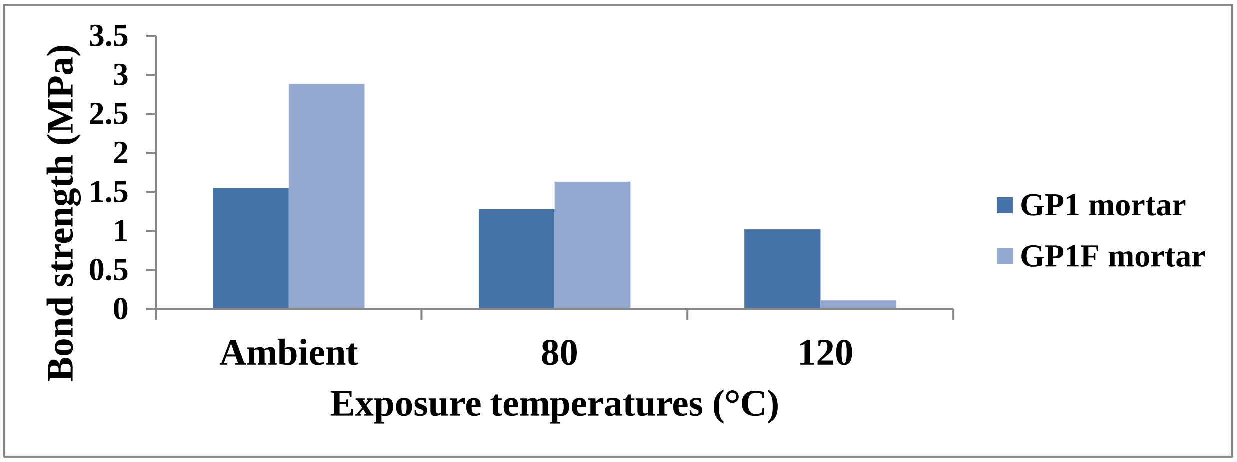

Figure 7 Results of effect of elevated temperature on bond strength of different repair mortars of GP1 and GP1F mortars

Table 10 Results of effect of elevated temperature on bond strength of different repair mortars of GP2 and GP2F mortars

Sl. No	Exposure temperatures (°C)	Bond strength in N/mm^2 of GP2 mortar	Bond strength N/mm^2 of GP2F mortar

1	Ambient	1.92	2.42
2	80	1.12	1.35
3	120	0.00	1.35

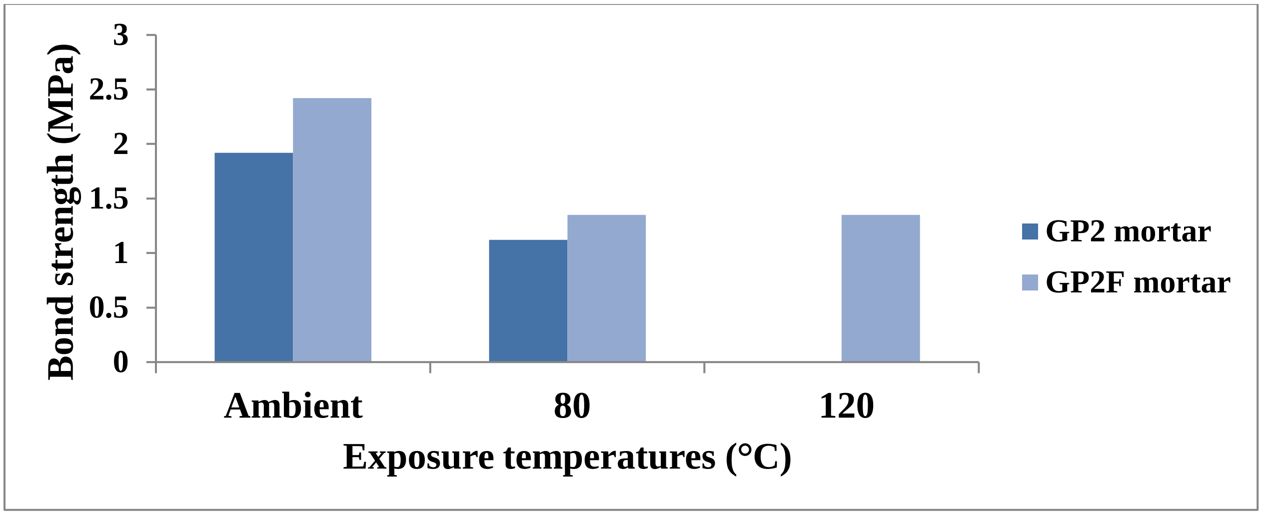

Figure 8 Results of effect of elevated temperature on bond strength of different repair mortars of GP2 and GP2F mortars

Table 11 Results of effect of elevated temperature on bond strength of different repair mortars of GP3 and GP3F mortars

Sl. No	Exposure temperatures (°C)	Bond strength in N/mm^2 of GP3 mortar	Bond strength N/mm^2 of GP3F mortar
1	Ambient	1.19	2.15
2	80	0.94	0.24
3	120	0.07	0.24

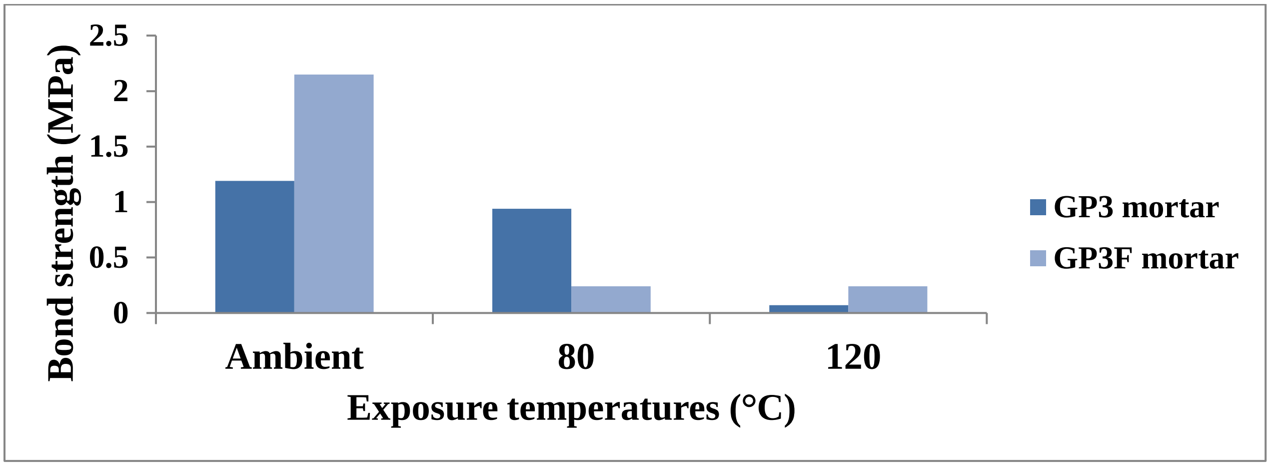

Figure 9 Results of effect of elevated temperature on bond strength of different repair mortars of GP3 and GP3F mortars

Table 12 Results of loss in pull-off strength of repair mortars after exposure to different temperatures

Sl. No	Mortars mixes at different temperatures	Loss in bond strength (%) at temperature of 80 °C	Loss in bond strength (%) at temperature of 120 °C
1	Cement mortar	43.2	51.2
2	GP1	17.6	35.6
3	GP2	40.3	100.0
4	GP3	25.6	95.4
5	GP1F	26.3	98.5

6	GP2F	43.2	43.8
7	GP3F	90.4	90.2

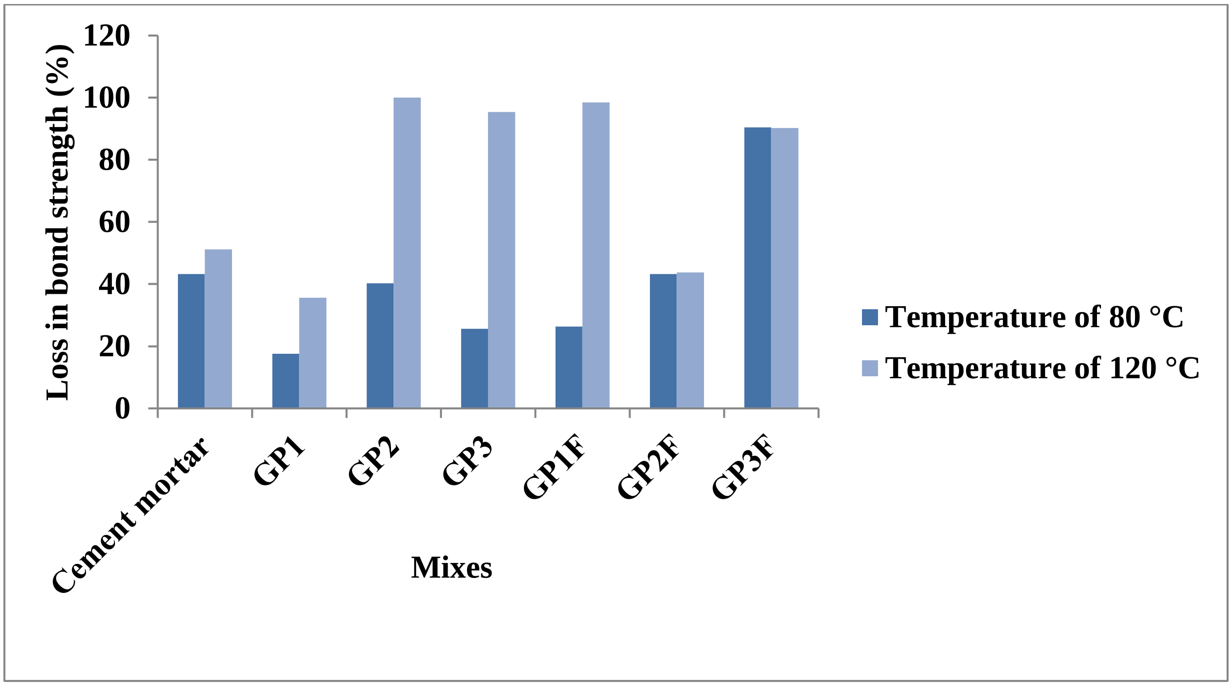

Figure 10 Results of loss in pull-off strength of repair mortars after exposure to different temperatures

Table 13 Results of effect of elevated temperature on normalized bond strength of different repair mortars of cement

Sl. No	Exposure temperatures (°C)	Normal bond strength in N/mm^2 of cement mortar
1	Ambient	0.31
2	80	0.18
3	120	0.16

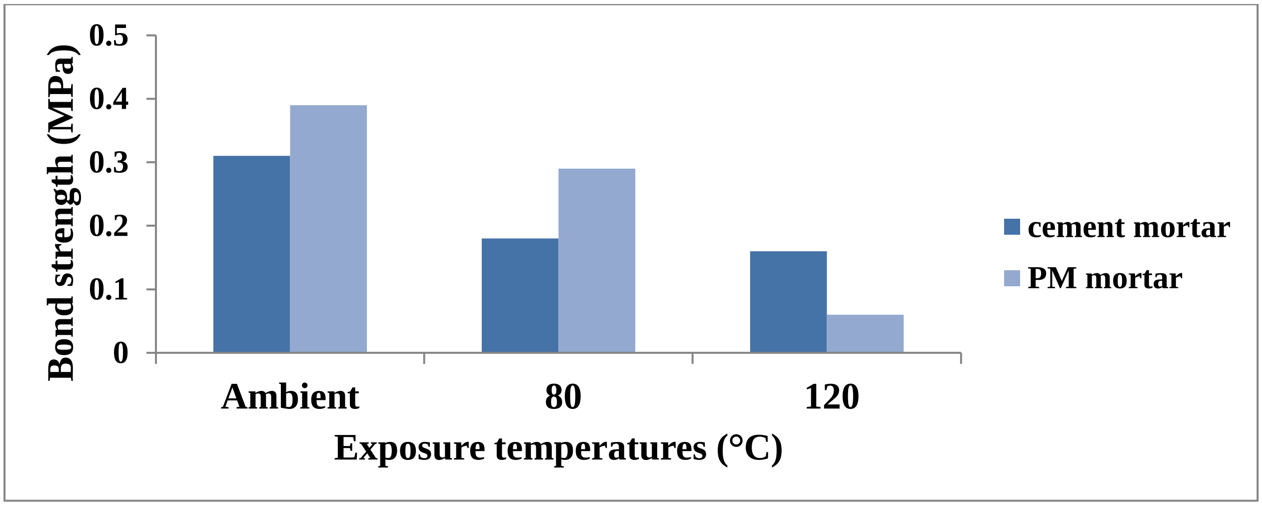

Figure 11Results of effect of elevated temperature on normalized bond strength of different repair mortars of cement

Table 14 Results of effect of elevated temperature on normalized bond strength of different repair mortars of GP1 and GP1F mortars

Sl. No	Exposure temperatures (°C)	Normal bond strength in N/mm^2 of GP1 mortar	Normal bond strength N/mm^2 of GP1F mortar
1	Ambient	0.29	0.44
2	80	0.24	0.26
3	120	0.19	0.03

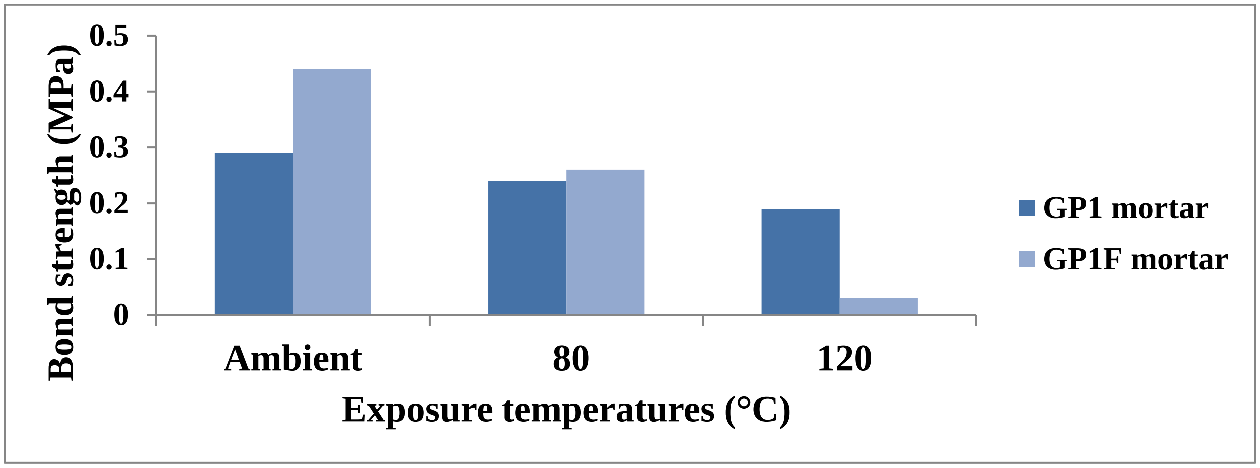

Figure 12 Results of effect of elevated temperature on normalized bond strength of different repair mortars of GP1 and GP1F mortars

Table 15 Results of effect of elevated temperature on normalized bond strength of different repair mortars of GP2 and GP2F mortars

Sl. No	Exposure temperatures (°C)	Normal bond strength in N/mm^2 of GP2 mortar	Normal bond strength N/mm^2 of GP2F mortar
1	Ambient	0.36	0.32
2	80	0.23	0.19
3	120	0.00	0.19

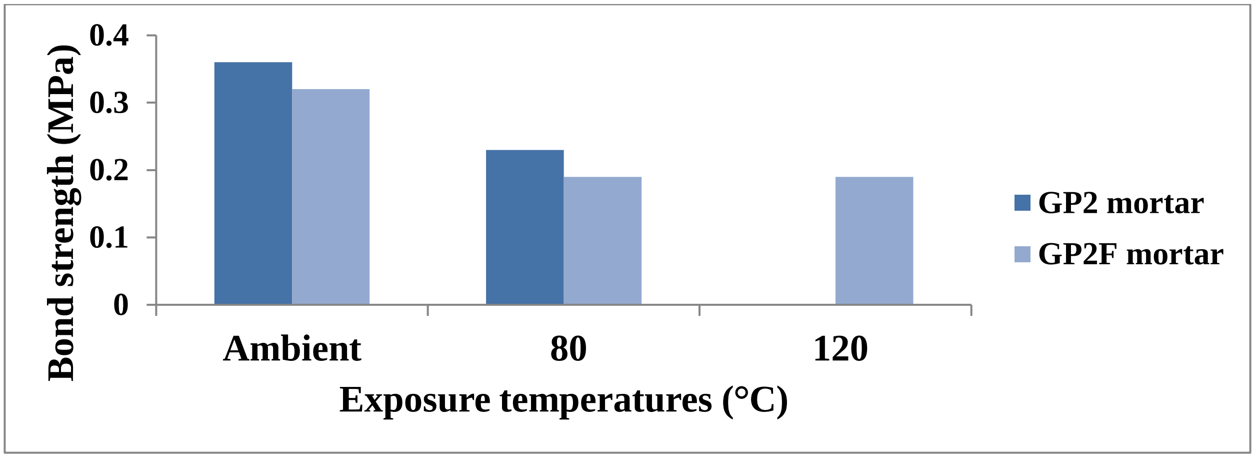

Figure 13 Results of effect of elevated temperature on normalized bond strength of different repair mortars of GP2 and GP2F mortars

Table 16 Results of effect of elevated temperature on normalized bond strength of different repair mortars of GP3 and GP3F mortars

Sl. No	Exposure temperatures (°C)	Normal bond strength in N/mm^2 of GP3 mortar	Normal bond strength N/mm^2 of GP3F mortar
1	Ambient	0.23	0.58

2	80	0.17	0.007
3	120	0.002	0.007

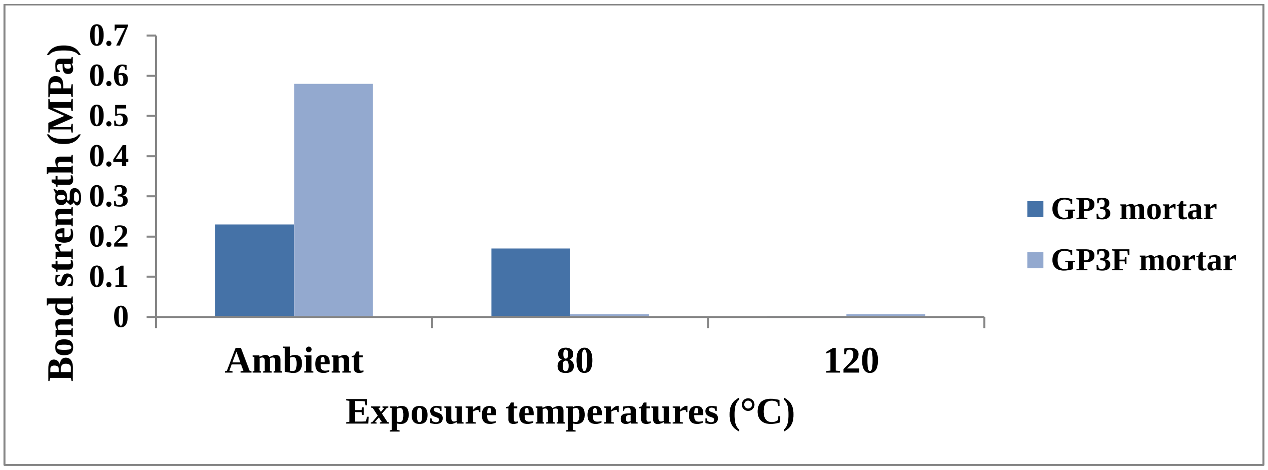

Figure 14 Results of effect of elevated temperature on normalized bond strength of different repair mortars of GP3 and GP3F mortars

4 CONCLUSIONS

Simple and reinforced MGP mortars, cured at room temperature, have excellent repairability and retrofit in terms of adherence and resistance to compression. Test results suggest that MGP mortars are promising alternatives to cementitious repair mortars. There was a significant drop in bond strength between the MGP repair material and the concrete substrate at a temperature of 80°C.

1. The incorporation of EWP fibers into the GP mortar increased its pullout resistance both at room temperature and at an elevated temperature of 80°C.
2. The results of this study provide guidance for the practical application of MGP mortar as a repair material under conditions of prolonged exposure to high temperatures.
3. Care must be taken when using MGP repair mortar where the exposure temperature must exceed 80°C.
4. The adhesion of MGP mortars must be confirmed by pulling tests before using them in risky temperature conditions.

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