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DURABILITY OF LOW-MEDIUM STRENGTH GGBS CONCRETE AND ASSESSMENT SUPERFLUOUS POLYPROPYLENE FIBER

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ABSTRACT

Wastes from industrial and agricultural processes can cause disposal and management issues, posing a significant challenge for environmental work. Many PP fiber and GGBS remain in the environment as waste, so it is imperative to use these building materials making a step towards sustainability and green building. This article describes the possibility of using waste in concrete production as a partial replacement of cement with GGBS and the addition of polypropylene fibers. Compared with the single cement concrete, the M20 mixture is replaced by GGBS, the cement weight is 30-40% by weight, and the polypropylene fiber addition is 1.5, 2.0, and 2.5% by weight of the binder. The compressive and tensile strengths were tested. Compared with traditional concrete mixtures, partial replacement of cement with GGBS and polypropylene fibers can help improve the strength of cemented concrete materials. The results show that the composite cement containing 2% polypropylene fiber and 30% GGBS has the highest compressive strength and split tensile strength. This paper investigates the effect of 0.9 kg/m3 of polypropylene fiber additives used in concrete on the strength values of two concretes and the freeze-thaw resistance of the composite structure. Low- and medium-strength concrete is made of polypropylene fiber, and polypropylene fiber may not be used. The concrete undergoes a freeze-thaw cycle from 6°C to -20°C; when the impregnated concrete cube reaches a 5% weight loss, samples are taken from the test program, which is limited to 50 cycles. The concrete cube whose weight is reduced by 5% due to the freeze/thaw effect is a single CEM1, a single GGBS concrete cube. All fiber cubes are kept within the specified 5% weight loss standard. The use of polypropylene fibers as freeze/thaw protection in concrete is relatively new. This study expands the knowledge about the performance of different strength concretes and GGBS as partial cement substitutes. Use slag sand as fine aggregate to check the freeze-thaw behaviour of concrete. According to the slow freeze-thaw test method, the deterioration of the mechanical properties of GBS concrete is manifested by two W/B ratios and three GGBS substitution ratios. The microscopic morphology of GGBS concrete was tested and analyzed. The results show that the dynamic relative elastic modulus and mass loss ECC of the sodium chloride solution during the freeze-thaw cycle is greater than that of the tap water during the freeze-thaw cycle. Elastic modulus and ECC mass loss caused by freeze-thaw cycles increases with the increase of FA content.

Keywords: polypropylene fiber, compressive strength, monofilament fiber, freeze-thaw cycles, compressive strength, and weight loss.

1. INTRODUCTION

Concrete is the most widely distributed building material globally, second only to water, and it is the most widely distributed material on earth. It is obtained by mixing binders, water, and aggregates, and sometimes additives in the required proportions. However, due to its low elongation, bending, impact resistance and crack resistance, it is very brittle [5] [7]. One way to improve the brittleness of concrete is to add fine fibers to the concrete randomly. It is called Fiber Concrete (FRC). The main reason for adding fibers to the cement matrix is to improve the tensile strength, energy absorption capacity, toughness, and flexural strength of the concrete and improve the concrete's deformation performance when it is cracked [8] [9].

Today many by-products in the form of industrial waste are used, such as blast furnace slag (GGBS), fly ash, quartz powder, etc. Adding additional binders can improve the mechanical properties of concrete and reduce cement consumption by replacing some cement with these pozzolanic materials. This experimental study aims to partially study the mechanical properties of concrete using different proportions of GGBS to replace conventional Portland cement. Fibers are also used with different percentages of binder content. They have been extensively studied, and this test examines the freeze-thaw effects of incompletely hardened concrete [1].

In India, freezing/thawing exposure occurs after chloride-induced corrosion. When salt is used due to thermal shock and a decrease in concrete surface temperature, use frozen/coarse aggregate particles that may tend to thaw thus resulting in leakage [10]. Frost/thaw protection in concrete is usually provided by a combination of air-entraining agents. Clogging the pores of GGBS leads to poor permeability [3]. So, careful control of the moisture-cement ratio to ensure low value, high strength, and correct design to avoid damage to the area is needed. The practical application of this research is to find an alternative aerated method to protect bare concrete from frost/thaw protection. Extensive research has been conducted on the strength of the fiber compared to concrete containing PP fiber. However, there are limited studies to test the strength of concrete containing GGBS and PP fiber under mixed concrete, frost/pigeon conditions. What has not been thoroughly studied is the freeze-thaw cycle performance of concrete in the early stages of its development [2] [4].

2. METHODOLOGY

2.1 Material and Mixture preparation

Pozzolana Portland Cement (PPC) by Ambuja was used in this research. The fibers used in this concrete test are classified as Coordinated System [HS], code 39021000 is type 1 (monofilament diameter <0.3 mm) and its characteristics: length 19 mm Flexibility, diameter 22 microns, flow rate 0.9 kg/m3, Moisture absorption 0.6% and melting point 175◦C [11]. Fibers were brought from Alwar Rajasthan and used in the study.

2.2 Experimental Work

Several concrete mixes have been made. The control mixture (CM) GP00 consists of 100% PPC. In mixtures GP30 and GP40, cement was partially replaced by 30% by weight and 40% by weight of GGBS. In the mixtures GP31, GP32 and GP33, the cement part is replaced by 30% GGBS, and the fiber is added 1.5%, 2.0% and 2.5%, respectively; similarly in the mixtures, GP41, GP42 and GP43, the cement is replaced by 40% GGBS and 1.5%, 2.0% and 2.5% fiber is added, respectively [6].

Table 1: Materials fraction

Materials Kg/m^3	*Cement (kg)*	*CA (kg)*	*FA (kg)*	*GGBS*
GP00	358.1	1171.1	717.8	0
GP30	250.72	1171.1	717.8	107.45
GP31	214.90	1171.1	717.8	107.45
GP32	250.72	1171.1	717.8	107.45
GP33	250.72	1171.1	717.8	107.45
GP40	250.72	1171.1	717.8	143.27
GP41	214.90	1171.1	717.8	143.27
GP42	214.90	1171.1	717.8	143.27
GP43	214.90	1171.1	717.8	143.27

The content of fine aggregate and coarse aggregate in all mixtures remains unchanged [15] [16]. The standard Indian method was used in the hybrid design process and the nominal slump was 135-155 mm [19]. The mixing ratio and the w/c ratio used are

1: 2: 3.3 and 0.45 respectively [13] [14]. See Table 1 indicates the material quantities of each concrete mix ratio.

2.3 Casting and curing

Figure 1: Cubes casting and curing

Six cylindrical test pieces with 150 mm x 150 mm x 150 mm and a 150 mm x 300 mm diameter were cast for each mixture as shown in Figure 1. After 24 hours, the samples were moulded and cured in water at room temperature. M20 mixtures LS, LF, LG, and LC indicate Low strength mix, Low strength mix with fibers, Low strength mix with 30% GGBS cement replacement, and Low strength mix with 30% GGBS cement replacement and fibers respectively. Similarly, M30 mixtures MS, MF, MG, and MC indicate Medium strength mix, Medium strength mix with fibers, Medium strength mix with 30% GGBS cement replacement, and Medium strength mix with 30% GGBS cement replacement and fibers respectively. For each test mix type, 3 test cubes were prepared.

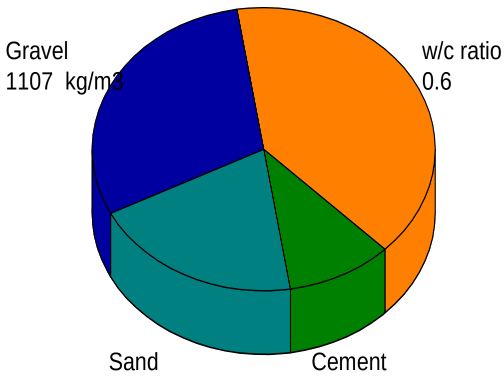
The significance of the two calculated strength mixtures is that in low-strength mixtures, the cement content is less than the recommended minimum value of 300 kg/m3 for freezing/thawing resistance, and in mixtures with average strength higher than this value. Therefore, a significant difference in freezing/thawing performance should be provided. Another parameter is the water-cement ratio. Design of low-strength concretes deviates from the recommended water/cement ratio of 0.4-0.5, within which it is considered impermeable, and adopt 0.6 as the same. Medium-strength concrete is at the upper limit where water tightness can occur, water/cement ratio is taken as 0.4, although this is unlikely due to the short curing time.

ASTM 666 is used for the freeze/thaw method, and Method B is used for thawing frozen cubes in water. According to IS:516-1959, four batches of 8, 100mm cubes are put into the drum mixer, the batch is divided into two equal parts, mixed again to add fibers and distribute them evenly. This procedure ensures that all concretes have the same mixing time. is used to determine consistency. Let the test cubes solidify in a tank filled with 20°C water for four days, and then undergo a freeze/thaw cycle. Save it as a control and test at the end of the freeze/thaw procedure. Before the freeze-thaw cycle begins, the tested concrete cannot develop any significant strength. This situation will cause the most severe hydrostatic pressure on the weaker concrete inside the cube. This allowed for a short test procedure to obtain significant results [12].

A pilot study was conducted to determine the optimal thawing time for cubes using water as the thawing medium. The cube is thawed at room temperature (20°C±3) for 2 hours, after which the temperature of the cube is 5°. This allows two cycles per day during the five-week trial period. 40 and 50 freeze/thaw cycles on the cubes were performed. Weigh every 10 cycles and observe the changes in surface finish. If there is a 5% weight loss before the 50th cycle, remove the cube from the test program because the compressive strength test at the extraction point or 50 cycles is used to compare the main strength of different batches. Finally, each batch has a control cube that has not undergone a freeze/thaw cycle and is allowed to solidify for 28 days and compared with cubes that have undergone a freeze/thaw cycle. All test cubes are measured at room temperature (20°C ± 3°C, weighed when thawed), and fully saturated with water.

Table 2: Composition of the mixture

S. No.	*Strength Mix (kg/ m$^{3)}$*	
	Low	*Medium*
Cement	240	370
Sand	731	675
Gravel	1107	1008



(a)

(b)

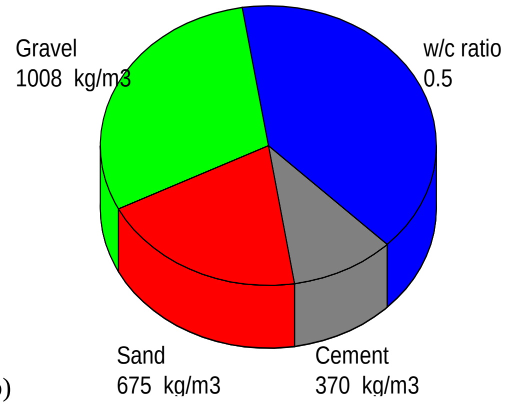


Figure 2: Freezing/thawing mixture composition (a) Low (b) Medium Strength

3. RESULT AND DISCUSSIONS

3.1 Cement

According to the FESEM analysis shown in Figure 3, the cement particles exhibit uneven shapes.

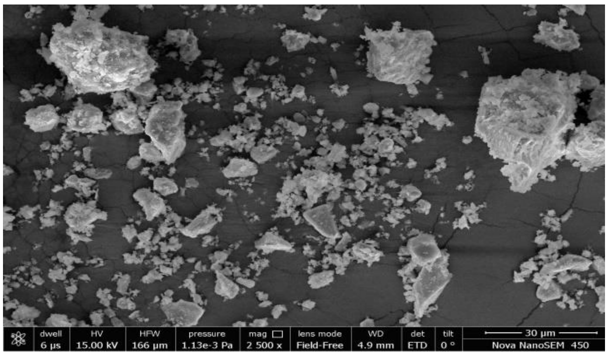


Figure 3: FESEM image – Cement

3.2 GGBS

1. Under various magnifications, the GGBS particles, on the other hand, are angular, as shown in Figure 4.

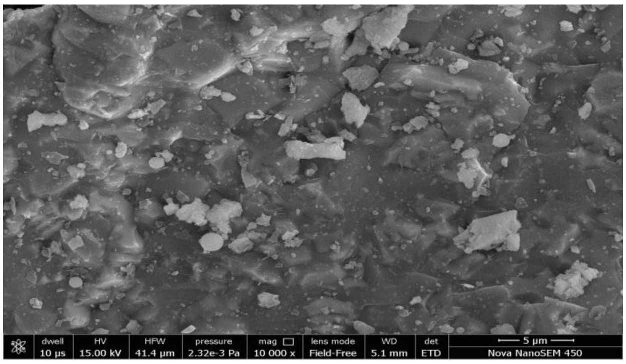


Figure 4: FESEM image - GGBS

3.3 Fine aggregate

The smooth texture and uneven form of fine aggregate are illustrated in the FESEM analysis of fine aggregate (Figure 5).

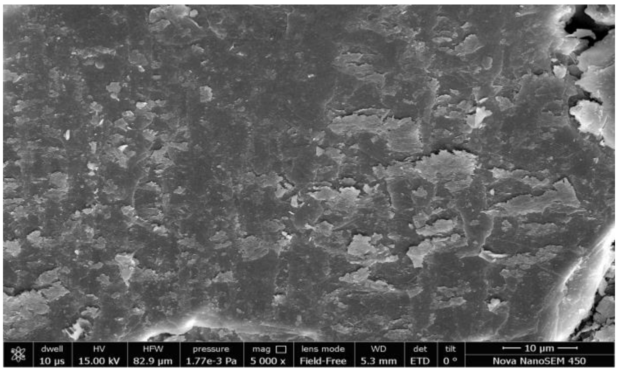


Figure 5: FESEM image – Natural Sand

3.4 Compressive & Tensile Strength

The compressive strength of three test cubes with dimensions of 100 mm x 100 mm x 100 mm is determined according to IS 516: 1959 [17]. The shelf life of the test samples is 28 days. Test the sample by applying an increased pressure load. Figure 6 and Table 3 show the compressive strength comparison of different proportions of GGBS without polypropylene fiber after 7 days and 28 days. For 28 days, the compressive strength of concrete increased as the GGBS content increased to 30% (GP30) by 8.27% but decreased by 5.1% for 40% GGBS (GP40) substitution when compared with the conventional mixture.

Figure 7 and Table 4 show the compressive strength comparison of different proportions of

GGBS and polypropylene after 7 days and 28 days. Figure 7 shows that concrete sample GP32 has the highest compressive strength (29.80 N/mm^2), but after 7 days, the compressive strength of concrete GP33 (2.5% polypropylene + 30% GGBS) is the highest (19.95 N/mm^2). Compared with the control sample, the percentage increase is about 1.20%.

The tensile strength of three cylinders with a diameter of 150 mm and a length of 300 mm is determined according to IS 516: 1959. Test hardened concrete: the tensile strength of the sample after 28 days of hardening [18] [20].

Table 3: Compressive strength comparison regular concrete and GGBS concrete without fiber

Mix Nomination	*Compressive Strength (N/mm^2)*	
	7 days	*28 days*
GP00	19.7	28.4
GP30	19.9	30.75
GP40	20.84	26.95

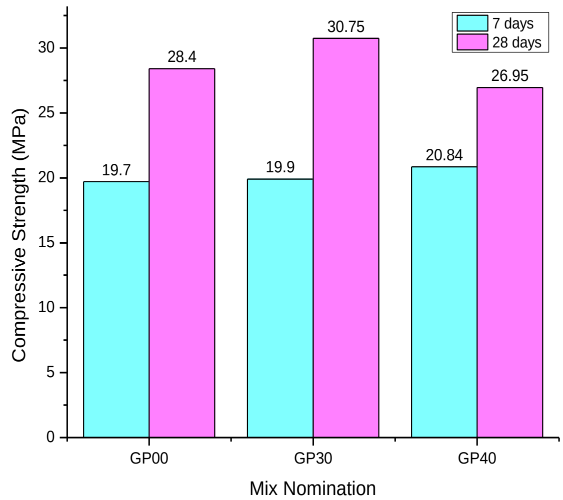


Figure 6: Compressive strength comparison without fiber

Table 4: Compressive strength comparison of standard concrete and GGBS concrete with fiber

Mix Nomination	*Compressive Strength (N/mm^2)*	
	7 days	*28 days*
GP00	19.7	28.4
GP31	15.55	26.43
GP32	19.73	29.80
GP33	19.95	24.50
GP41	17.24	24.50
GP42	15.51	22.70
GP43	13.99	19.8

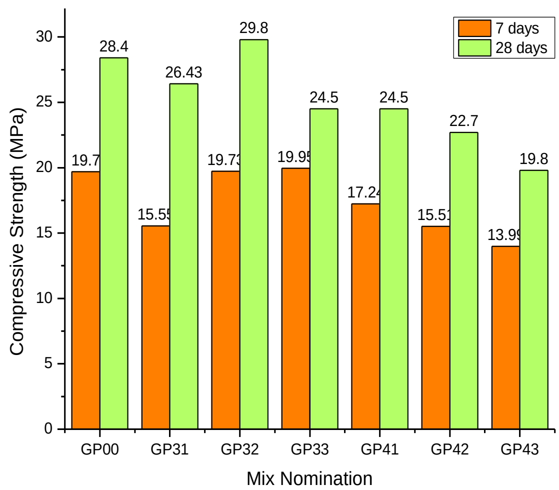


Figure 7: Compressive strength comparison with fiber

Table 5: Tensile strength comparison of standard concrete and GGBS concrete without fiber

Mix Nomination	*Tensile Strength (N/mm^2)*	
	7 days	*28 days*
GP00	1.70	2.50
GP30	2.00	2.90
GP40	1.40	2.10

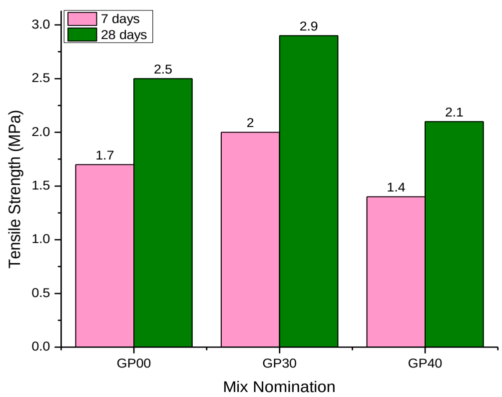


Figure 8: Tensile strength comparison without fiber

Table 6: Split tensile strength comparison of standard concrete and GGBS concrete with fiber

Mix Nomination	*Tensile Strength (N/mm^2)*

	7 days	*28 days*
GP00	1.70	2.50
GP31	1.60	2.69
GP32	1.80	2.90
GP33	1.71	2.80
GP41	1.50	2.40
GP42	1.60	2.57
GP43	1.26	2.01

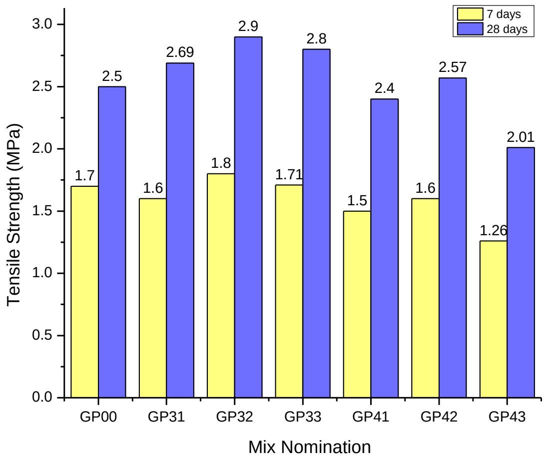


Figure 9: Split tensile strength comparison with fiber

Compared to the M20 mixture with 2% polypropylene fiber, the best substitution percentage of 30% GGBS for cement quality gave better results than the control mixture. The fracture strength results are shown in Figure 7 and 9. Compared with the control concrete, the breaking strength recorded for all mixtures of GGBS (30%) and fiber showed higher resistance. This can be seen from the compressive strength and flexural strength.

It can be said that the compressive strength of the GGBS is increased by 8.27% for 28 days and the tensile strength is also increased by 16% when the fiber is not added. After adding 2% fiber the compressive and tensile strength of the GGBS is increased by 4.93% and 16% for 28 days respectively. It was found that the increase in the 7 days old compressive and tensile strength was as high as 0.15% and 5.88% of the control mixture respectively. It is easy to see that sample GP32 (30% GGBS + 2% polypropylene) has the highest tensile strength among all tested samples.

Medium-strength concrete is generally more durable than low-strength concrete, but only concrete fiber samples MF and MC are intact and will not lose more than 5% of their quality. The residual compressive strength is measured when the program is cancelled or 50 freeze/thaw cycles, as shown in Figure 9 and 10. If these cubes are tested for up to 50 cycles, the final compressive strength result for 40 cycles will be zero.

When fibers are included in the mixture, the control cubes show reduced compressive strength. Compared with all ordinary concrete cubes, low-strength concrete has undergone 40-50 cycles, and the compressive strength of LF and LC with significant weight loss was tested at 40 cycles. Due to the low ratio of water to cement, the compressive strength is high. Medium-strength concrete begins to fail between 40 and 50 cycles, and five of the six simple concrete cubes exhibit a weight loss of 25% to 35%. Table 7 and Figure 9 (a) and 9 (b) show the individual freeze/thaw test cubes' performance in terms of progressive weight loss compared to their original weight compared to the 5% weight loss criteria. Compressive strength results are shown in Table 8 and Figure 10.

Table 7: Freeze/thaw cube weights for 0, 40, and 50 cycles

Mix	*Cycles: Cube weights (grams)*		
	0	*40*	*50*
LS	2438	2421	2412
LF	2442	2430	2421
LG	2429	2426	2424
LC	2433	2431	2429
MS	2475	2371	1948
MF	2478	2475	2474
MG	2472	2395	2391
MC	2474	2472	2470

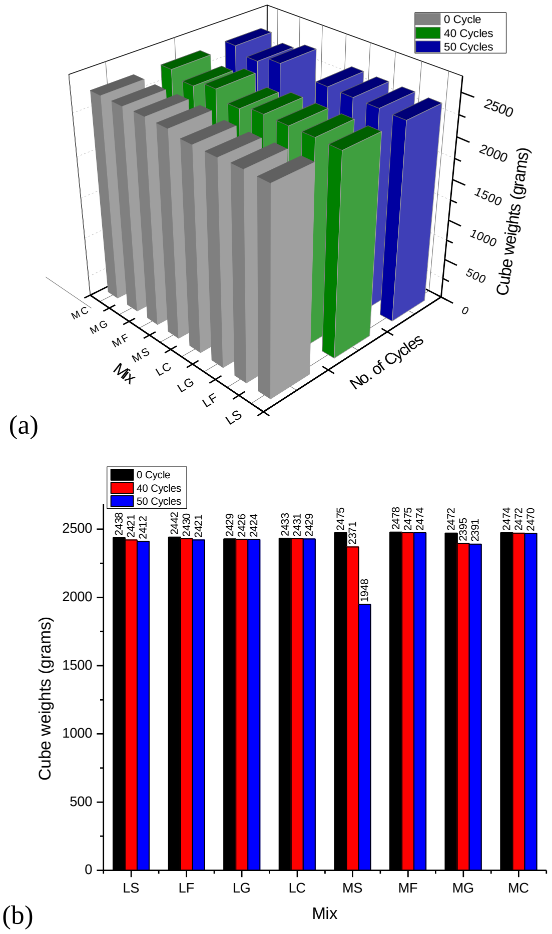


Figure 9: Low and medium strength concrete freeze/thaw cube weights

Table 8: Table of results for compressive strength (mean values used)

Blend	*Freeze/thaw test cubes Compressive Strength (MPa) for No. of cycles*		
	0	*40*	*50*
LS	19.9	1.2	-
LF	18.5	-	6.3
LG	18	2.4	-
LC	16.4	-	4.4
MS	34.5	1.6	1.6
MF	30.7	-	10.1
MG	32.9	2.5	2.5
MC	30.15	-	8.3

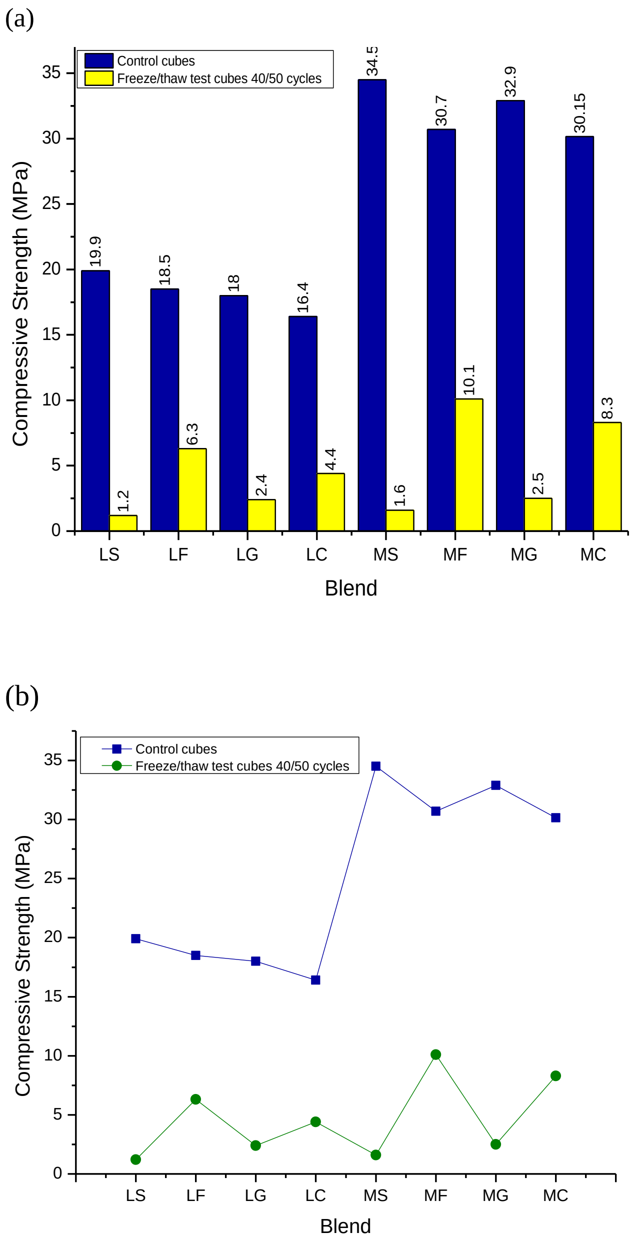


Figure 10: Mean compressive strength of different batches of concrete – after freeze/thaw cycles (a) bar chart (b) line diagram

4. CONCLUSIONS

Based on a limited study of the performance of polypropylene fiber concrete and GGBS concrete compared to conventional concrete with design strength of M20, the following conclusions are drawn:

Compared with conventional concrete, 30% GGBS has a higher compressive strength than 40% GGBS. Compared with all variants (including the fiber-free control concrete), the concrete mixture containing 30% GGBS and 2% polypropylene fiber has the highest compressive and tensile strength and is suitable for all ages. The compressive strength and tensile strength of concrete GP32, when poured are about 3% and 6% higher than traditional concrete.

The results show that GGBS has a slower strength development than conventional PPC concrete and is more susceptible to damage from this performance. Compared with traditional concrete, polypropylene monofilament improves the freeze-thaw strength performance of concrete in weight loss and compressive strength. When using different adhesives and using different compressive strengths, different types of concrete can produce this effect. Compared with conventional concrete with and without GGBS, the improved freezing/thawing behaviour is remarkable.

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