Mechanical properties of fly ash geopolymer mortar reinforced with polypropylene fibers

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Abstract

Geopolymers are new ceramic substances with the possibility to supplant Portland concrete in a wide scope of uses, from immobilization of substantial metals to concerts for structural designing. They rely on the alkaline activation of aluminosilicates, for example, blast furnace slag, pulverized fly ash, and metakaolin. Notwithstanding their high mechanical strength what's more, chemical durability, geopolymer concretes are in as a rule set apart with high permeability and porosity, which could contrarily influence the long-term durability or performance of concretes. This paper utilizes polypropylene fibers to enhance the geopolymer mechanical properties. Four percentage of polypropylene fibers where utilized which were 0.2, 0.5, 1 and 1.5% by weight of fly ash. The impact of these percentage on flow, dry density, mechanical strength, in expansion to flexural strength, were resolved. Results have demonstrated that the addition of polypropylene fibers lead very slightly decreased in the dry density, and decreased the flow, while it lead to enhance the flexural and compressive strength. The best percentage that give higher compressive and flexural strength was the one with a 0.5% addition by weight of fly ash.

Key word: Geopolymer, polypropylene fibers, fly ash, board, alkaline activator.

الخلاصه

الجيوبوليمرية من المواد السيراميكية الجديدة الممكن استخدامها بدلا من السمنت البورتلاندي في مجالات كثيرة و واسعة في الهندسة المدنية. وهي بالاساس تعتمد على التفاعل الكيميائي الحاصل بين السائل القلوي و المواد الومينوسيليكة من امثلتها الرماد المتطاير و مخلفات افران الاحتراق و الميتاكاؤولين. خواصها الميكانيكية جيدة بل و تتفوق في بعض الخواص على الخرسانة الاعتيادية كالديمومة و كونها صديقة للبيئة. في هذا البحث استخدمت الياف البوليبروبيلين لتحسين الخواص الميكانيكية للعجينة الجيوبوليمرية المصنوعة من الرماد المتطاير. حيث استخدمت اربع نسب وزنية من الالياف البوليبروبيلين و كانت 0.2% و0.5% و 1% و 1.5% من وزن الرماد المتطاير. تم التركيز في الدراسة على تأثير هذه الالياف المضافة بهذه النسب على التشغيلية و الكثافة الجافة و مقاومة الانضغاط و مقاومة الانثناء. النتائج بينت ان اضافة الالياف البوليبروبيلين ادت الى تقليل الكثافة بصورة قليلة جدا كذلك قللت التشغيلية، بينما الاضافة ادت الى تحسين مقاومة الانثناء و مقاومة الانضغاط. النسبة المثلى التي اعطت اعلى قيمة لمقاومة الانضغاط و الانثناء كانت 0.5% من وزن الرماد المتطاير.

الكلمات المفتاحية: الجيوبوليمر ، الياف البوليبروبيلين ، الرماد المتطاير ، الواح ، المحلول القلوي.

Introduction

At exhibit, geopolymer is getting more attention as an option binder to normal cement binders for applications in concrete industry (Hu *et.al.*, 2008; Pacheco *et.al.*, 2008). It is produced utilizing rich alumina and silica source materials, for example, calcined kaolin, fly ash, and blast furnace slag. Fly ash remains is utilized for the most part as supplementary cementitious substances to supplant of Portland cement in development industry. Numerous researchers have demonstrated that it can likewise be utilized as starting material for making good geopolymer (Chindaprasirt *et.al.*, 2007; Pangdaeng *et.al.*, 2012).

Geopolymeric reaction relies upon the enactment with alkali solutions and temperature curing at 40–75 ˚C (Chindaprasirt *et.al.*, 2007; Sinsiri *et.al.*, 2014). The acquired geopolymer paste possesses similarly strength and appearance to normal Portland cement paste. Regardless, when fly ash geopolymer material is cured at ambient temperature of around 25 ˚C, the strength improvement is rather slow and low strength is obtained (Guo *et.al.*, 2010). Numerous researchers have tried to improve the strength improvement of fly ash geopolymers (Palomo *et.al.,* 2007; Phoo *et.al.,* 2013). (Khater *et.al.,* 2013; Riahi and Nazari, 2012) revealed that the compressive strength of geopolymer relies upon the kind of beginning material and its fineness. The fine particles induce higher leaching of alumina and silica in the alkali environment and prompts a higher strength geopolymer (Chindaprasirt *et.al.,* 2007).

As of late, nanoparticle is getting more attention as an alternative binder used for the change of nanostructure of building materials). (Khater *et.al.,* 2013). Nano-SiO2 and nano-Al2O3 are most commonly utilized (Stefanidou *et.al.,* 2012) to enhance compressive and tensile strengths of concrete by additional pozzolanic and filler effects (Li, 2004). The nano-SiO2 particle belongs to highly pozzolanic materials since it comprises basically of SiO2 in amorphous form with a high specific surface, therefore, exhibits great pozzolanic activity (Qing *et.al.,* 2007). The objective of this study is to assess the effects of using PF at different weight fractions in a mix of (FGM) and study some mechanical properties of this mortar.

Materials and methods

2.1. Materials

Geopolymer pastes were orchestrated utilizing a fly ash from Turkish hard coal from power station Iskenderun (ASTM class F fly ash) as it shown in Fig. 1, with a chemical composition determined as shown in Table 1. and Fig. 2 shows the particle size range determined by laser diffraction according to the standard test method ASTM D422 (ASTM Committee, 2007).

The alkaline activators were blends of commercial soluble sodium silicate

(SiO2 = 27.75wt.%, Na2O = 15.25wt.% and H2O = 57 wt.%) in addition to sodium hydroxide pellets as it shown in Fig. 3. Decontaminated water was utilized to break up the sodium hydroxide pellets to 8 molarity. A natural sand was utilized, with particle size lower than 4.75 mm, specific gravity of 2.60 g/cm3 was utilized to get ready mortars, and a high range water reducer superplasticizer of modified polycarboxylate was used. In addition to the polypropylene fibers with 12 mm length used Table 2. shows the properties of the polypropylene fibers see Fig. 4.

Figure 1 Fly Ash.

Table 1 Fly Ash Chemical Composition.

component	SiO_2	$Fe2O_3$	Al_2O_3	L O I	CaO	MgO	SO_3	Na_2O	K_2O
Mass %	65.65	5.98	17.69	3.1	0.98	0.72	0.19	1.35	2.99

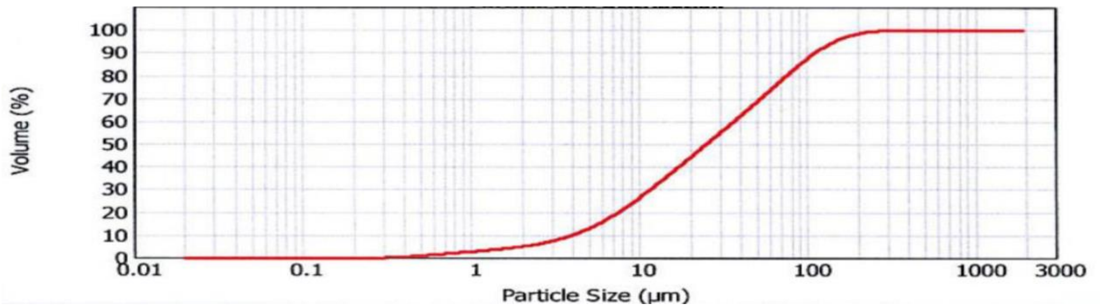

Figure 2 Fly Ash particle size distribution.

Figure 3 Soluble sodium silicate and sodium hydroxide pellets.

Table 2 Mechanical properties of polypropylene fiber.

Property	Carbon fiber
Specific gravity (g/cm^3)	0.91
Diameter (µm)	8-16
Tensile strength (MPa)	165
Alkali resistance	Excellent resistance
Melting point (°C)	160
Length (mm)	12

Figure 4 Polypropylene fiber.

2.2. Sample synthesis and tests conducted

In view of the substance piece of the fly ash (the reactive fraction), geopolymeric mortars with an aggregate: binder weight ratio of 1.5:1 were explained, the details are given in Table 3. The alkaline solutions were explained in the suitable extents and after that blended with the fly ash powders for 3 min in a planetary mixer to obtain overall (activator + fly ash) sodium hydroxide to sodium silicate weight ratio of 0.5. The sand, beforehand soaked with 4.0 wt% of water was at that point added to the geopolymeric blends and blended for about 3 min. The mortars were thrown into cubic molds of 5 cm per side and vibrated for 120 sec. The specimens were secured with plastic film and cured at 70 ˚C in electrical oven up to 24 hr.

For each mix, the compressive strength was resolved utilizing a programmed hydraulic press as indicated by the standard procedure ASTM C109 (ASTM Committee, 2011) after 3, 7 and 28 days; the data were accounted for as the average from three tested cubes randomly taken from the group, the testing machine which shown in Fig. 5.

Also prisms with dimensions of (305*152*12) mm prepared for flexural strength test after 7 and 28 days age as indicated by the standard procedure ASTM 1185-12 (ASTM Committee, 2012) see Fig. 6, in addition to flow table test subjected before preparing the flexural and compressive strength for all blends.

For dry density, cubes samples of 5 cm per side like that used in compressive strength were used at age 28 days.

Table 3 mix content.

Material	Quantity (kg/m3)
Fly ash	900
Sand	1350
Sodium silicate solution	247
Sodium hydroxide solutions (8 M)	174
Superplasticizer	19

Results and Discussion

1- Flow table

The impact of fibers on the flow of the four mortar blends is highlighted in Table 4 and Fig. 7. It is anything but difficult to take note of polypropylene fibers in fly ash geopolymer mortar reduces the flowing capacity. Then again; a higher amount of polypropylene fibers makes misfortune flow ability. In rundown, the impact of polypropylene fibers on either the flowing or working capacity is much less than the control fly ash geopolymer mortar. Results are in good agreement with previous finding (Hardjito *et.al.*, 2009).

Figure 5 The compressive machine.

Figure 6 Tester device for flexural testing.

Table 4 Workability estimations of all blends.

Fiber type	Fiber by weight (%)	Flow (%)
None	0	34
Polypropylene	0.2	32.5
Polypropylene	0.5	30.25
Polypropylene	1	26.5
Polypropylene	1.5	23

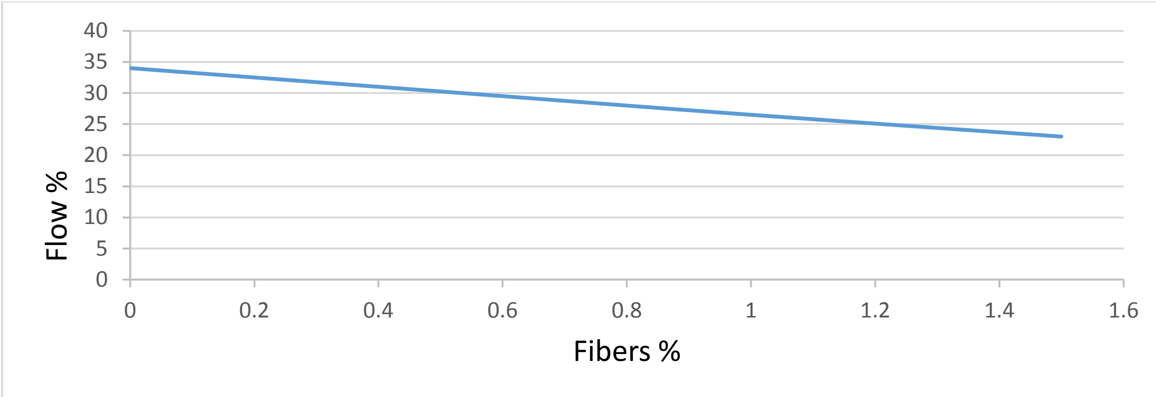

Figure 7 Flow of geopolymer mortar reinforced with polypropylene fibers.

2- Compressive strength

Table 5 and Fig. 8 demonstrates the average compressive strength of specimens from all blends at various ages. The early-age (up to three days) results generally indicate that the compressive strength of the fly ash geopolymer mortar was mostly gained, also mortars extraordinarily enhanced with the addition of polypropylene fibers, as all values were above 16 MPa. For instance, contrasted with the control specimens without polypropylene fibers, the compressive strength of the fly ash geopolymer mortar reinforced with polypropylene fibers increased by up to 124.5%, 128.8% and 106.6% at three days for mixtures with 0.2, 0.5 and 1% by weight fibers, respectively, while there was very slight decreased for blend with 1.5% by weight fibers. Moreover, the results of the fly ash geopolymer mortars at 7 and 28 days indicated that also there was more improvement in strength. For instance, contrasted with the control specimens without polypropylene fibers, the compressive strength of the fly ash geopolymer mortar reinforced with polypropylene fibers increased by up to 107.3%, 114.5% and 103.8% at 28 days for mixtures with 0.2, 0.5 and 1% by weight fibers, respectively, while there was very slight decreased for blend with 1.5% by weight fibers.

As it is known, fibers are added to mortar/concrete blends essentially to enhance flexural toughness, with a normal minor commitment to compressive strength, also as it is known increased addition of fibers lead to diminish the strength because of high air content and vast volume of voids present in the mixes, and consequently weakness of the composite matrix (Söylev *et.al.*, 2014). In this investigation, the results about for the most part demonstrated that the fly ash geopolymer mortar with polypropylene fibers gained relatively compressive strength at early and later ages more than without polypropylene fibers.

Table 5 Compressive strength of tested specimens.

Fiber type	Fiber by weight (%)	Compression strength (age 3 days) Mpa	Compression strength (age 7 days) Mpa	Compression strength (age 28 days) Mpa
None	0%	16.23	24.33	26.2
Polypropylene	0.2%	20.2	26.1	28.1
Polypropylene	0.5%	20.9	27.6	30
Polypropylene	1%	17.3	25.2	27.2
Polypropylene	1.5%	16	22.8	24

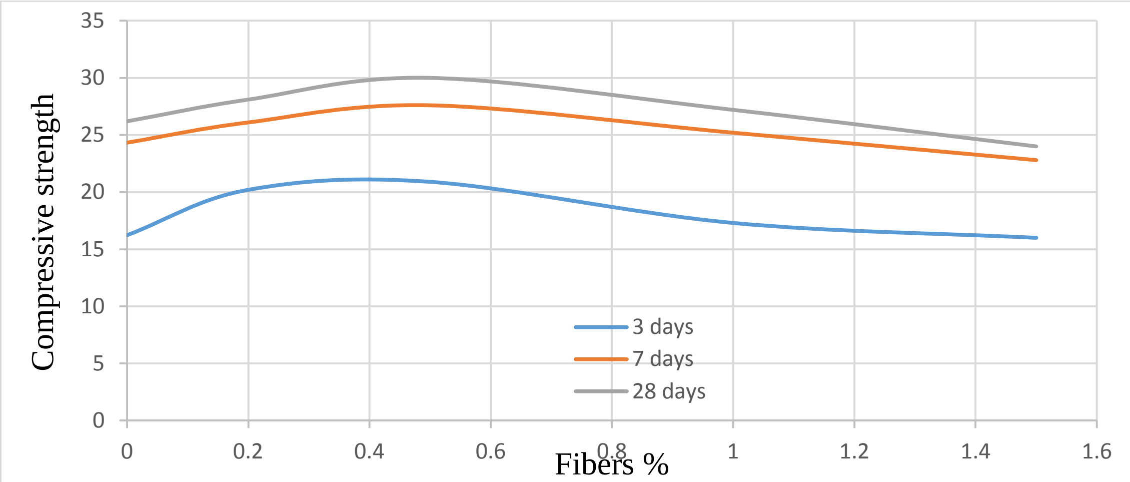

Figure 8 Compressive strength results for fly ash based geopolymer mortar reinforced with polypropylene fibers at 3, 7 and 28 days age.

3- Flexural strength

From Table 6 and Fig. 9 it is observed that with the increasing in the ratio of polypropylene fibers, the flexural strength increase. The outcomes demonstrate that ideal dose for flexure is 0.5% of polypropylene fibers by weight. The above outcomes demonstrate that flexural strength increments with increment in fibers weight fraction; this is because of the extra load taken by the fiber introduce in the matrix. In any case, subsequent to expanding the weight percentage of polypropylene fibers past the ideal esteem (0.5%) disgraceful blending of fibers with the matrix happens because of balling impact of fibers, this builds the measure of vibrations required to expel air voids from the blend which thusly causes the issue of draining and reductions flexural strength of the blend. The failure pattern of plain and fibrous mortar in flexural strength test shows that fibrous mortar are more malleable as thought about to plain mortar. This is on the grounds that when the matrix cracked, the load was exchanged from the composite to the fibers at the crack surfaces, which keeps the brittle failure of the composite, also as it is happened in compressive strength increased addition of fibers lead to diminish the strength because of high air content and vast volume of voids present in the mixes, and consequently weakness of the composite matrix. A similar effect of fibers in the concrete have been observed in other studies (Söylev *et.al.*, 2014).

Table 6 Flexural strength of tested specimens.

Fiber type	Fiber by weight (%)	Flexural strength (age 7 days) Mpa	Flexural strength (age 28 days) Mpa
None	0%	2.919	3.296
Polypropylene	0.2%	3.263	3.66
Polypropylene	0.5%	3.588	3.9
Polypropylene	1%	3.654	3.83
Polypropylene	1.5%	3.237	3.4

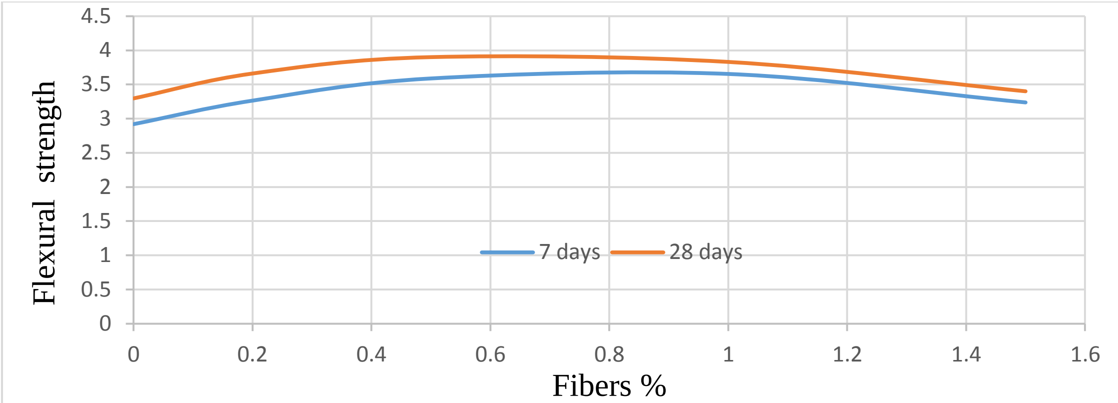

Figure 9 Flexural strength results for fly ash based geopolymer mortar reinforced with polypropylene fibers at 7 and 28 days age.

4- Density

Table 7 demonstrates the outcomes of the dry density for all blends, and from the outcomes, it can be seen that the incorporation of polypropylene fibers in the mortar blends diminishes the hardened density with slightly amount, and this can be credited to the gravity of fibers which specific gravity of fiber which reduce the general density of mortar as appeared in Fig. 10 It agree with the study (Dawood *et.al.*, 2014).

Table 7 Density of tested specimens

Fiber type	Fiber by weight (%)	Density (age 28 days) Kg/m^3
None	0%	2175
Polypropylene	0.2%	2171
Polypropylene	0.5%	2166
Polypropylene	1%	2158
Polypropylene	1.5%	2146

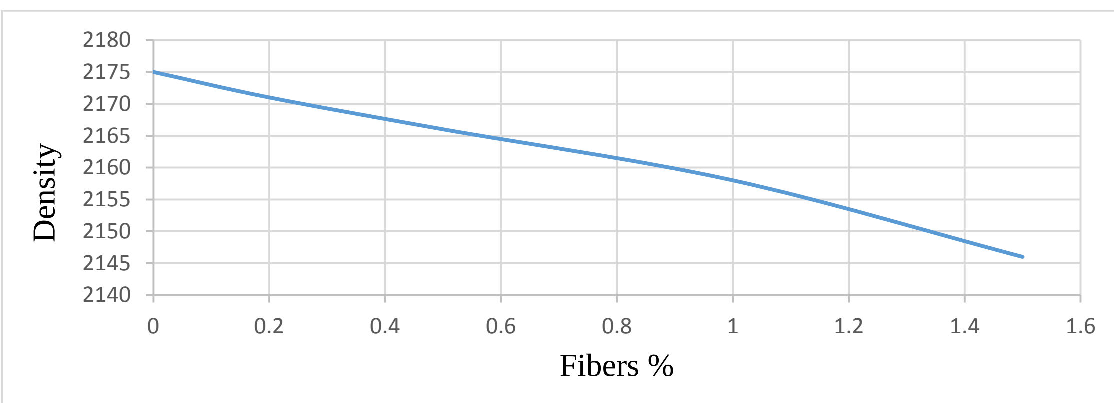

Figure 10 Density results for fly ash based geopolymer mortar reinforced with polypropylene fibers at 28 days age.

Conclusions

Some conclusions from this study can be uncovered as takes after.

1. The utilization of polypropylene fibers has clear effects on the properties of fly ash geopolymer mortar lead to produced boards with exceptionally worthy properties.

2. The flowability of the mortar is influenced marginally by the incorporation of the polypropylene fibers in the mixes, and this may help to utilize this fiber in the field of flowable mortar uses.
3. The use of polypropylene fibers slightly reduces the density.
4. The compressive strength results show that the use of 0.5% of the polypropylene fiber as weight fraction builds the strength by about 14.5%, yet past this rate there is an unmistakable decline in compressive reaches about 8.4% using 1.5% of fiber by weight fraction.
5. The flexural strength outcomes demonstrate that the utilization of 0.5% of the palm fiber as weight fraction expands the strength by about 18.3%.

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