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Bond strength in PVA fibre reinforced fly ash-based geopolymer concrete

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Keywords: PVA fibre, geopolymer concrete, bond strength, pull-out test, fly ash, alkali solution, mechanical properties.

Abstract. This paper presents the effect of polyvinyl alcohol (PVA) fibre on the bond strength in geopolymer concrete. The main focus of the study is to investigate how bond performance is affected by varying the amount of PVA fibre content. The PVA fibre content of 0 %, 0.2 %, 0.4 %, 0.6 % and 0.8 % by volume of concrete were utilized. Alkali activated class F fly ash was used to prepare the concrete specimens. Moreover, the Ordinary Portland cement (OPC) specimen was also prepared to conduct the comparative study. The results showed that the application of PVA fibre improves the bond resistance between the pull-out bar and concrete matrix. It has been investigated that the utilization of PVA fibre in geopolymer concrete improves up to 25.9 % bond strength as compared with the concrete without PVA fibre. The addition of PVA fibre provides a more ductile mode of failure in both geopolymer and OPC concrete than to the concrete without PVA fibre. For the different percentages of PVA fibre used, the specimen with 0.6 % PVA fibre shows maximum compressive strength, splitting and bond strength. The comparative study reveals that the specimen with and without PVA fibre blended geopolymer concrete shows higher bond strength than OPC concrete.

1. Introduction

As the most widely used binder in concrete, the main problem behind the ordinary Portland cement (OPC) is it requires large burning fossil fuels. The production of OPC is currently exceeding 2.6 billion tons per year worldwide, and growing at 5 % annually affecting the total cement production accounts for roughly 5–8 % of the global carbon-di-oxide (CO2) [1–3]. Among the greenhouse gasses, carbon-di-oxide (CO2) contributes about 65 % of the global warming caused mainly by economic growth and human population [4]. As a result, it is necessary to search environmentally friendly binding agents for concrete.

Currently geopolymer concrete (GPC) is becoming a novel construction material, which significantly reduces the above stated problem. According to the previous researches, utilization of geopolymer concrete generates up to 60 % less CO2 than the OPC production [5–8]. In addition, the geopolymer concrete has better mechanical properties and higher resistance in aggressive environment, as compared to the conventional concrete [9–13]. The previous studies revealed that low calcium fly ash (class F) has been investigated as a suitable material for geopolymer concrete binder because of its wide availability, pertinent silica and alumina composition and less water demand. The low-calcium fly ash based GPC had shown excellent mechanical and durability properties at short and long term tests [14]. In addition, according to [15] fly ash-based geopolymer concrete provides an excellent sulfate resistance as compared to cement based concrete.

Several researches were conducted to understand the concrete-steel bond behavior in the OPC concrete by considering different parameters that affect the bond resistance. However, few studies were presented on the bond behavior of GPC. Some attempts were reported in the previous studies about the important property of the hardened GPC, which was its bond with reinforcing steel bars and concrete matrix [16–19]. To provide wide acceptance of the geopolymer concrete in the construction industry, different factors should be studied on the bond strength between the geopolymer concrete and the reinforcing bar.

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The bond between the reinforcing bar and concrete is an important factor, which allows durability for the reinforced concrete structures. If there is a better bond, cracks will be minimized and the rebar will be also being better protected from corrosion [20]. The previous study indicates that even partial replacement of fly ash to OPC concrete increases the bond performance of the concrete [21]. Previous studies shows that to enhance the mechanical bond between the concrete matrix and its reinforcement, the addition of glass fibre, steel fibres, glass, carbon, aramid and hybrid fibres are recommended [22–26]. The recent study showed that the concrete with polyvinyl alcohol (PVA) fibre and fly ash stabilized soil with polypropylene fibre has a better mechanical strength and changed the brittle behavior into a ductile one [18], [27], [28]. Furthermore, studies showed that the fibrous geopolymer concrete generally provide better bond strength than the OPC concrete [29], [30].

Due to high brittle property of geopolymer concrete, an intensive study needed to improve the ductile behavior of geopolymer concrete. Therefore, this paper mainly shows the effect of PVA fibre on the bond strength in geopolymer concrete. Apparently, other physical, chemical and mechanical properties of the material and test specimens are also presented. As a main study parameter, the PVA fibre content of 0 %, 0.2 %, 0.4 %, 0.6 % and 0.8 % by volume of concrete were utilized.

2. Materials and Methods

2.1. Materials

The materials used to prepare the pull-out specimens were fly ash, an alkali solution, aggregates, steel pull-out bar and PVA fibre. The fly ash class F was used as a binder material from PT. Petrokimia Gresik, Indonesia, with reference to the quality standard [31]. The fly ash has a specific gravity of 2.67. Its chemical properties are depicted in section 3.1. The locally available coarse and fine aggregates were used in this research from PT. Surya Beton, Indonesia. The coarse aggregates from the crushed stone with maximum size less than 12 mm, and fine aggregates from fine sand, which passes through 4.75 mm sieve, in surface saturated dry condition, were used to make GPC specimens.

The alkali solution, which is a mixture of NaOH and Na2SiO3, was used. The sodium silicate solution has a composition of Na2O, SiO2 and water content of 15 %, 30 % and 55 % by mass, respectively. The concentration of NaOH solution is eight moles. The sodium silicate was supplied by PT. Kasmaji Inti Utama, Indonesia. The PVA fibre is the main variable, which was used to study its effect on the bond strength. Table 1 shows the mechanical properties of the PVA fibre, which is obtained from manufacturer manual.

Table 1. Properties of PVA fibre.

Fibre type	Tensile strength (MPa)	Flexural strength (GPa)	Diameter (μm)	Length (mm)	Density (gr/cc)	Melting temperature (^{0}c)	Water absorption
RECS15	1600.00	40.00	38.00	8.00	1.30	225.00	< 1 %

The mix design was prepared for 35 MPa concrete strength, which can guarantee the satisfactory properties of concrete for a particular job. The mix proportions of materials were intended to obtain concrete specimen with the density of 2400 kg/m^3, as provided in Table 2. The GPC paste with an aggregate ratio of 1:3 by the mass was used. The quantity of fine to coarse aggregate by the mass ratio of 2:3 was mixed together with GPC paste and alkali solution. The alkali solution, which is a mixture of sodium silicate to sodium hydroxide, having a mix ratio of 2.5 by mass, was used to prepare the test specimen. The PVA fibre of 0 %, 0.2 %, 0.4 %, 0.6 % and 0.8 % by volume of concrete was utilized as the main parameter. The maximum amount of fibre was limited to 0.8 %, because of the workability issue of the GPC paste.

Table 2. Mix Design for the preparation of concrete specimens.

Material	Mass (Kg/m^3)						
	GPC					OPC	
	GPC-1 0% PVA	GPC-2 0.2% PVA	GPC-3 0.4% PVA	GPC-4 0.6% PVA	GPC-5 0.8% PVA	OPC-1 0% PVA	OPC-2 0.4% PVA
Coarse aggregate	1080	1080	1080	1080	1080	1012	1012
Fine aggregate	720	720	720	720	720	620	620
Fly ash	390	390	390	390	390	-	-
Na_2SiO_3	150	150	150	150	150	-	-
NaOH	60	60	60	60	60	-	-
PVA fibre	-	3	5	8	10	-	5
Cement	-	-	-	-	-	533	533
Water	-	-	-	-	-	237	237

To conduct the comparative pullout test study between the geopolymer and conventional OPC concrete, primarily OPC concrete specimens having close compressive strength with geopolymer concrete were prepared. Accordingly, an analysis was conducted by keeping the other parameters, such as the diameter of the bar, bond length, cover and PVA fibre content constant. The specimens with 0 % and 0.4 % PVA fibre content were used for comparison. Ribbed bar with a diameter of 16 mm was used to perform the pullout test. The average yield and ultimate tensile stress of the pull-out bar are 492.9 MPa and 622.6 MPa, respectively.

As shown in Figure 1 the alkali solution is prepared prior to mixing process. During the preparation of the solution there is high generation of heat. Thus, the solution has to cool down before mixing with other ingredients. The PVA fiber was added after the fresh geopolymer concrete was well mixed. Addition of PVA fibre at the same with aggregate and fly ash leads to formation of balling.

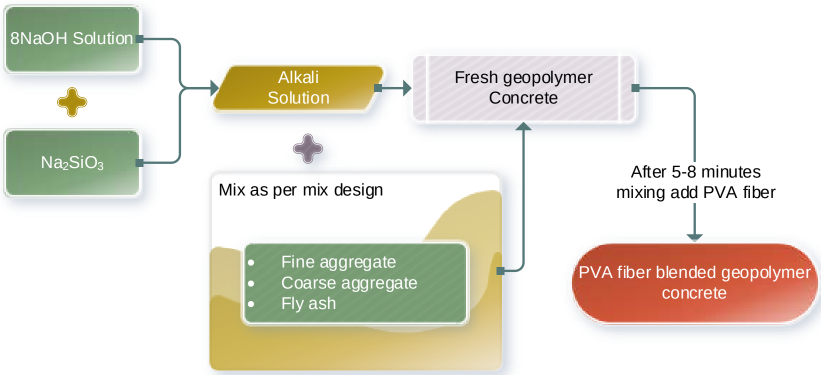
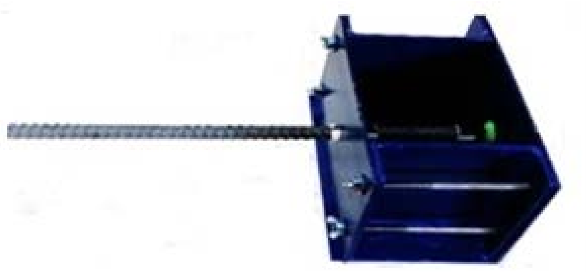


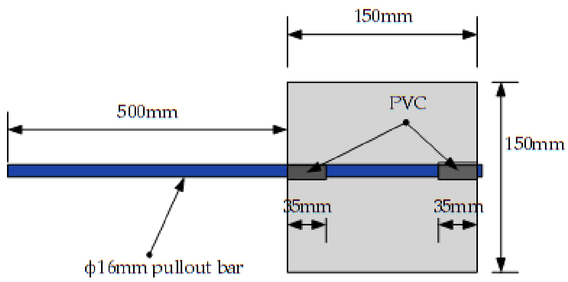
Figure 1. A schematic flow diagram for the preparation of PVA fibre blended GPC.

2.2. Test specimen preparation and curing

For each variation, three cubical lollipop specimens with the size of 150 mm were prepared. For the pullout load application, adequate length was provided based on the test machine. Accordingly, the steel cube mold with the interior dimension of 150 mm was used, as shown in Figure 2(a). To achieve the required bond length at the centre of the specimen, the PVC pipe was used. The PVC pipe was embedded such that, it neither restrains the slip of the bar nor affects the transfer of the bar forces to the concrete along the bond length. Figure 2(b) shows the arrangement for PVC pipe and the pullout bar in a concrete cube. The pullout deformed bar of diameter 16 mm, with 80 mm embedment length, was positioned horizontally at the middle of the specimens. One end of the pullout bar was projected out from the surface of concrete specimen about 500 mm, to grip the rebar to apply the pullout load. On the other free-load end, the rebar is projected at the surface of the specimen to set linear variable differential transformer (LVDT).



Pull-out bar arrangement



b) Pull-out test specimen

Figure 2. Mold setup and schematic for pull-out test specimen.

Before casting, molds were coated with the lubricant oil to make the demolding process easy. After that, fresh concrete was poured in three layers, and each layer was compacted by using a vibrator and compacting rod, with a special consideration of not disturbing the position of the pull-out. Even though all fresh concrete mixtures were poured in three layers, the compaction time varied. Especially for specimens containing 0.6 % and 0.8 % PVA fibre, the compaction time was longer as compared to the other mixes. This is related to the workability issue of the mixes. As the PVA fibre content increases, the workability of fresh concrete decreases drastically. After casting, specimens were kept at room temperature for one day. Then after one day, the concrete specimens were demolded and cured for 28 days in a moist condition. In addition to the pull-out specimens, the compressive and splitting test for the cylindrical specimens were prepared for each variation. For these specimens, the curing condition is the same as the pull-out specimens. After 28 days of curing, the compressive and splitting tests were conducted.

2.3. . Experimental setup for pullout test

To conduct the pull-out test, Universal Testing Machine having a model I/H-500KNI was used. A steel plate of size 200×200×13 mm, with a central opening of diameter 20 mm, was placed at the loaded surface of the concrete specimen. This plate was intended to make a smoother surface for the test specimen and to allow a free failure of concrete because of the pull-out load. The pull-out tests were conducted under controlled displacements according to [22]. Figure 3 shows pull-out setup for all specimens.

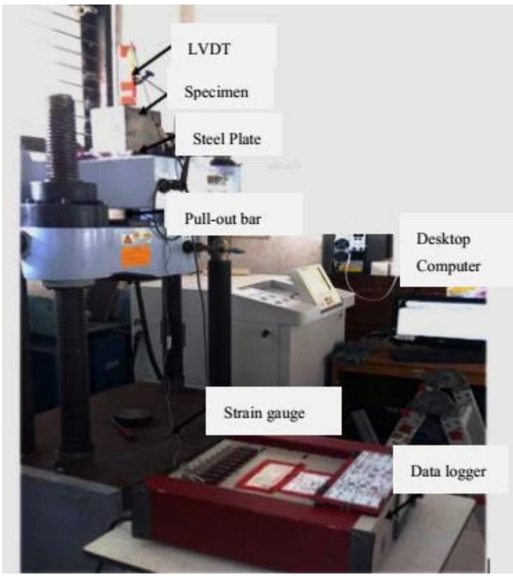


Figure 3. Experimental pull-out test setup.

During testing, at the unloaded end of the pull-out bar, one LVDT was mounted to measure the end displacement. The loading was recorded by using the mounted desktop computer with the test machine, which recorded the load and stroke at the same time. The load was applied to the pull-out bar at a rate of 1 mm/min.

3. Results and Discussions

3.1. Test results for Fly Ash

3.1.1. XRF and XRD Results

In order to determine the chemical composition of the fly ash, XRF test was conducted. The percentage composition of chemical and compound from this investigation are depicted in Table 3. such as silica, alumina, calcium and ferrite were determined with this testing. Additionally, the classification of fly ash as class F(low calcium) or C (high Calcium) referred to ASTM C618 [31] were evaluated. According to ASTM C618, if the percentage content sum of SiO2, Al2O3, and Fe2O3 is greater or equal to 70 %, the fly ash is classified as class F. Hence, for the test result it was concluded that the class of fly ash used in the mixture is class F.

Table 3. Chemical composition of the fly ash based on X-ray diffraction (XRF) analysis result.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	SO_3	TiO_2	Mn_2O_3	Na_2O	Cr_2O_3
Results (%)	48.47	26.05	12.54	5.18	2.77	1.66	1.05	0.92	0.19	0.47	0.02

Using composition of the alkali-fly ash mixture in the paste, the ratio of Si to Al by atom mass was fixed at 1.89 where from 48.47 % of silica content of fly ash, around 70 % is considered as a reactive silica. According to our previous results [14] this ratio was the most recommended for geopolymer concrete mixing.

Figure 4 shows the XRD pattern of fly ash-based geopolymer paste. The results show that the major peak of crystalline is quartz (SiO2) and albite (Na-Al-Si complex). In addition, as a raw material, the fly ash also contained magnetite (Fe3O4), which influenced the reddish color of both fly ash and the concrete [32].

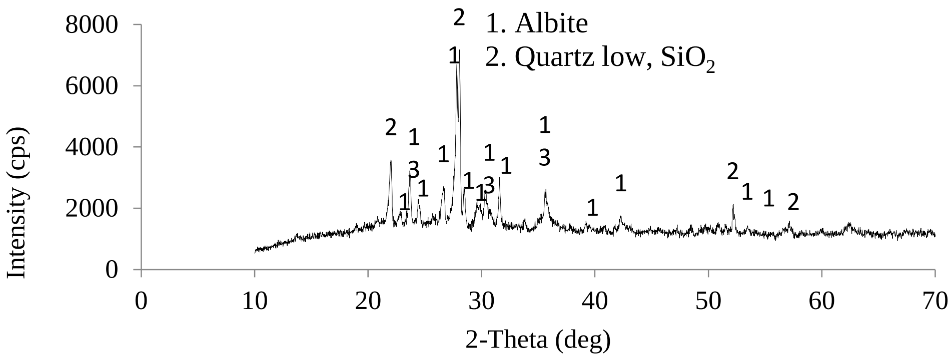
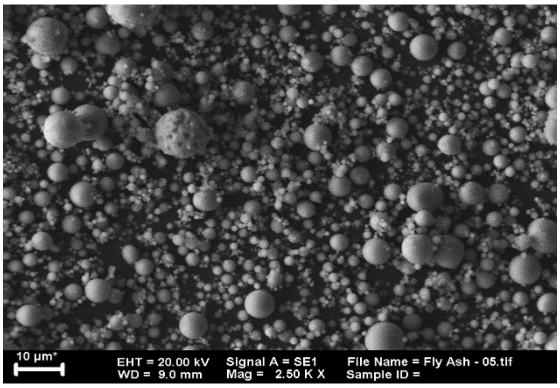
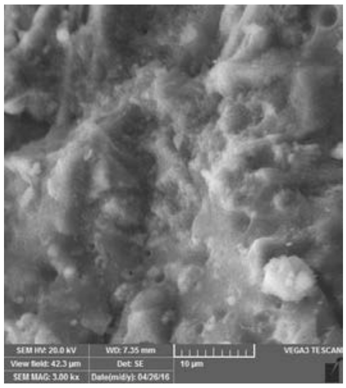


Figure 4. XRD result for geopolymer paste.

3.1.2. Scanning Electron Microscope (SEM)

The Scanning Electron Microscope (SEM) used in order to investigate the morphology of particles [32][33]. As stated in previous study, the morphology particle shape data can be also utilized to predict the mechanical and physical properties of material [34]. The SEM test result of fly ash is shown in Figure 5(a) and the concrete in Figure 5 (b). It is clearly shown that almost all fly ash particles dissolved in alkali-silica alumina system during geopolymerization process. This is also an indicator that the dense paste contributes to a high mechanical strength.



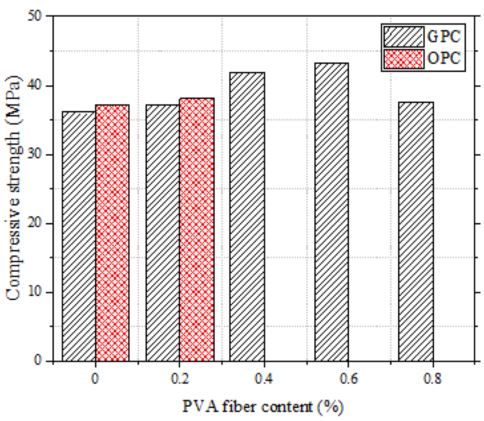


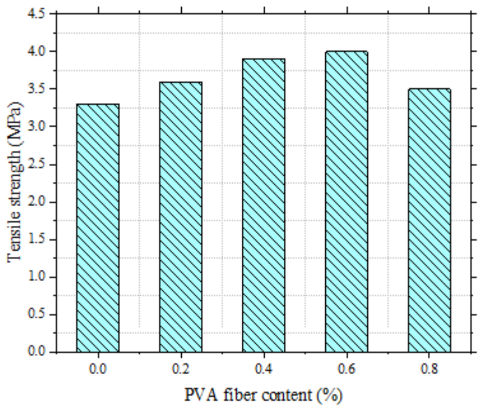
Fly ash particles **Geopolymer concrete**

Figure 5. SEM results for fly ash and geopolymer concrete.

3.2. Concrete compressive and split tensile test

Three cylindrical concrete specimens with a diameter of 10 cm and height of 20 cm were prepared for each variation, according to ASTM C39 [35]. The compressive strength for GPC and OPC specimens without fibre content was calculated as 36.08 MPa and 37.19 MPa, respectively. Once more, for each variation of the PVA fibre, three specimens were tested. It has been investigated that the addition of PVA fibre improves the compressive strength. Studies also reported that the application of fibre in geopolymer mixtures enhances the compressive strength; conversely, the high addition of fibre restrains free flow and dropped the slump significantly [26].





Compressive strength result **Splitting tensile strength result**

Figure 6. Experimental compressive and splitting tensile strength test results.

As depicted in Figure 6(a), the specimen with 0.6 % PVA fibre results in the maximum compressive strength, i.e. 43.16 MPa. For the specimen with 0.8 % PVA fibre, the compressive strength decreases, unlike the other specimens. This shows that the utilization of PVA fibre higher than 0.6 % has a tendency to decrease the strength of concrete significantly. It is an interesting fact to observe it experimentally, because it has a relation with the compacting problems during the casting. As shown in Figure 6(b), the split tensile test result also follows the same pattern as the compressive strength test. It proved that the fibre contributed lateral confinement to resist the uniaxial load. If the fibre mixes well with the geopolymer matrix, it also prevents the compressive load from opening more cracks during the splitting test. It is also an evidence that the crack opening is transferred from the matrix to the fibre before it gaps become wider and another crack starts to occur. When the fibres direction is perpendicular to the crack, they resist to the split of the matrix. This mechanism is recorded in Figure 7 by micro-camera with 750 x magnification. The fibres are very well bond with geopolymer matrix.

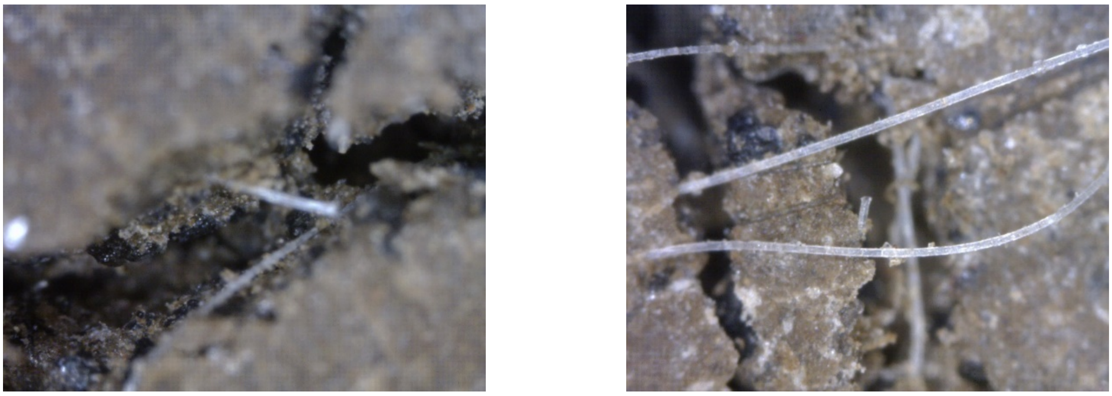


Figure 7. PVA fibre in the matrix and crack gap during splitting test.

The correlation of the experimental split tensile strength result, from the current study and the formerly predicted empirical relations between the compressive and splitting tensile strength by different sources, is depicted in Table 4. As shown in Table 4, the two empirical relations stated for GFRC and PFRC by [37] fairly estimated splitting tensile strength for PVA fibre reinforced concrete. Hence, the authors of this study also recommend these two equations for the prediction of splitting tensile strength from compressive strength of PVA fibre reinforced concrete.

Table 4. Study on the empirical relation between splitting tensile and compressive strength with current study.

Source	Relationship	Split tensile strength, f_{tsp} (MPa) for each PVA fibre variation				
		0%	0.2%	0.4 %	0.6%	0.8%
Current study	Experimental results	3.30	3.60	3.90	4.00	3.50
[38]	$f_{tsp} = 0.56 f_c^{0.5}$ for $f_c \le 83 MPa$	3.36	3.41	3.62	3.68	3.43
[39]	$f_{tsp} = 0.38 f_c^{0.63}$ for $f_c \le 120 MPa$	3.64	3.71	3.99	4.07	3.73
[37]	$f_{tsp} = 0.60 f_c^{0.5}$ for GFRC*	3.60	3.66	3.88	3.94	3.68
[37]	$f_{tsp} = 0.55 f_c^{0.5}$ for PFRC**	3.30	3.35	3.56	3.61	3.37
[40]	$f_{tsp} = 0.12 f_c^{0.92}$ for HSFRC***	3.25	3.34	3.72	3.83	3.38

Note:

- GFRC* is glass fibre reinforced concrete
- PFRC** is polypropylene fibre reinforced concrete
- HSFRC*** is High-strength steel fibre reinforce concrete
- f_c is Compressive strength (MPa) for each PVA fibre variation

3.3. Tensile test results for pull-out bar

Before conducting the effect of PVA fibre on the bond strength, determination of the mechanical properties of the pullout bars are a compulsory task. The tensile tests were conducted for all batch of pull-out bars to minimize possible errors during the pull-out test. In this regard, nine rebar samples—three samples from each three 12 m long ribbed bar—were used to check the consistency of the pull-out bars. This is conducted because the mechanical properties, such as the minimum upper yield strength and elongation values directly influence the pull-out test. The results obtained from the tensile test for nine samples are discussed in Table 5. Conventionally, steel bars are named by metric diameter. Therefore, diameter 16 mm was preferred for the designation. Hence, the metric diameter is used for the pull-out test result calculation. The test results in Table 5 shows that the steel bars used in this study are sufficient to achieve optimum performance for structural application.

Table 5. Tensile strength test result for pullout bar.

Batch No.	Length (mm)	Weight (Kg)	Nominal diameter (mm)	Metric diameter (mm)	Nominal area (mm^2)	Yield force (N)	Yield stress (N/mm^2)	Ultimate force (N)	Ultimate stress (N/mm^2)
1	500.00	0.76	15.70	16.00	193.76	99637.40	495.56	125138.00	622.39
	500.00	0.76	15.70	16.00	193.76	100498.00	499.84	125975.00	626.55
	500.00	0.76	15.70	16.00	193.76	96474.70	479.83	124955.00	621.48
2	500.00	0.76	15.70	16.00	193.76	99589.60	495.32	126126.00	627.30
	500.00	0.76	15.70	16.00	193.76	101414.00	504.39	125983.00	626.59
	500.00	0.76	15.70	16.00	193.76	99884.40	496.78	125871.00	626.03
3	500.00	0.76	15.70	16.00	193.76	98745.20	491.12	125035.00	621.87
	500.00	0.76	15.70	16.00	193.76	97335.10	484.11	123179.00	612.64
	500.00	0.76	15.70	16.00	193.76	98378.70	489.30	124381.00	618.62
Average						99106.34	492.91	125182.56	622.61

3.4. Pull-out test results

The average bond strength was calculated by dividing the applied load to the surface area of the embedded length of the pullout bar, as shown in Eq. (1) [41], [42]. The bond stress is calculated by assuming that a uniform stress will occur along the bond length. The maximum bond stress values for the pullout specimens with 0 %, 0.2 %, 0.4 %, 0.6 % and 0.8 % PVA fibre are 15.74 MPa, 20.24 MPa, 21.22 MPa, 21.23 MPa and 15.05 MPa, respectively. Accordingly, the specimen with 0.6 % PVA fibre shows the highest bond strength, which is similar case with the compressive strength, and it is similar to the specimen containing 0.4 % PVA fibre. Significantly, the bond strength increases with the compressive strength of the concrete. However, for 0.8 % PVA fibre, the bond strength decreases as compared with the other specimens. As presented in previous study by [43] the random orientation of fibers leads to anisotropic behavior and increasing voids, which directly decreases interfacial bonding. Figure 8 depicts the experimental results for the pullout tests.

As shown in Figure 8, the failure mode for each PVA fibre variation is slightly different. The GPC without fibre shows a brittle failure, which cannot totally resist any load after the ultimate bond load. During the experimental test, all GPCs without fibre failed by splitting. However, specimens with PVA fibre show slight ductile failure. The pull-out specimens with 0.2 % and 0.4 % PVA content show a very close failure mode, in which both specimens show a ductile failure. It was also investigated that the crack openings were significantly reduced by the PVA fibre addition. This phenomenon is related to the results of the splitting test.

$$\tau = \frac{P}{\pi * \varphi_b * l_b}, \tag{1}$$

where τ is Bond strength, MPa;

P is Pull-out load, N;

φ_b is Pull-out bar diameter, mm;

l_b is Bond length, mm.

However, the specimens with 0.6 % and 0.8 % PVA fibre content failed in more a ductile mode, as compared to other specimens. Wherever a given concrete becomes stiffer and less workable, it needs more time to be compacted. Nevertheless, because of the short setting time of GPC paste, spending more time on compacting was worth the task. Furthermore, the extended vibration disturbs the position of reinforcement bar and PVC pipe. The bond between the concrete matrix and the surface of reinforcement bar was also affected as a result of the high content fibre.

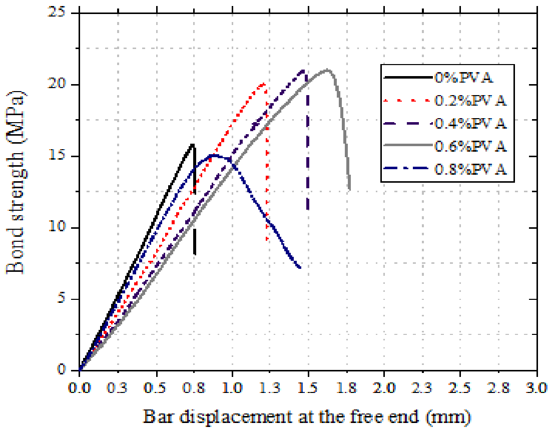


Figure 8. Pull-out test results for each PVA fibre variation.

3.5. Comparative Study

The comparative study was conducted for specimens without fibre and 0.4 % fibre contents. This study also depicted that higher potential in bond strength in GPC. However, the slump test result indicates that 0.4 % fibre addition shows better workability in OPC concrete, as compared to the GPC paste. The experimental results obtained for the comparative study for slump test is presented in Table 6.

Table 6. Results for slump test.

Paste type	PVA fibre content (%)	Slump test result (cm)
OPC	0.0	16.20
OPC	0.4	12.60
GPC	0.0	9.00
GPC	0.4	5.00

It can be clearly understood from Figure 9 that an addition of PVA fibre improves the bond strength in both the concrete types. Numerically, the specimen with 0.4 % PVA fibre content by volume in OPC concrete shows 12.4 % increase in bond strength from OPC concrete without fibre. As compared to the GPC, utilisation of fibre in OPC concrete shows less improvement in bond strength, which is almost the same as the GPC without fibre. Even though the compressive strength of OPC concrete, which is 37.19 MPa, is slightly higher than the GPC, the GPC matrix has better bond resistance.

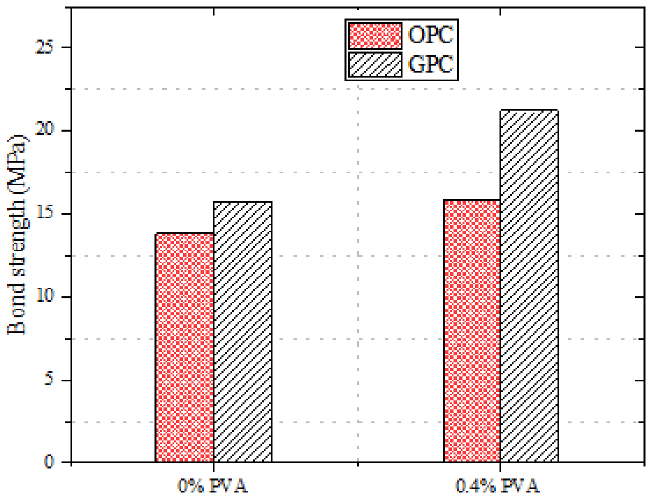


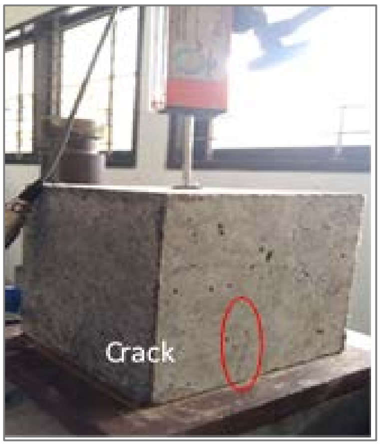
Figure 9. Comparative study between geopolymer and OPC concrete pull-out test.

As shown in Figure 10, the pull-out specimens fail by splitting; the same type of failure was stated in the previous studies by [22], [24]. However, the extent of cracking is different in both geopolymer and OPC concrete. The specimens without fibre fully separated by splitting crack. For the fibre reinforced concrete, the specimens show small cracks around the supported face of the concrete.

a. GPC specimen without PVA fibre

b. OPC specimen without PVA fibre

c. GPC specimen with 0.4% PVA fibre



d. OPC specimen with 0.4% PVA fibre

Figure 10.Comparative study for the splitting cracks failures.

It is clearly seen that the brittle failure in concrete specimens without PVA fibre is more substantial than the PVA fibre reinforced concrete in both cases. The patterns of cracks are also slightly similar, which occurs along the pull-out bar direction. The crack patterns in Figure 10(a) and Figure 10(b) shows that the GPC is more brittle than the OPC concrete. This phenomenon is insignificant in PVA fibre reinforced pullout specimens. As shown in Figure 10(c) and Figure 10(d), the crack opening is minimised by the addition of PVA fibre in both the specimens. Again, GPC shows a wider crack opening, as compared to OPC concrete, in 0.4 % PVA fibre reinforced specimens.

4. Conclusions

This paper focuses on the effect of PVA fibre on bond strength in geopolymer concrete, with the aim to contribute to the experimental database and provide comprehensive understanding on the role of PVA fibre. The PVA fibre variation of 0 %, 0.2 %, 0.4 %, 0.6 % and 0.8 % by volume of geopolymer concrete was used as the main study parameter. Hence, five mix designs that are one mix design without fibre and four mix designs with fibre were prepared for the experimental work. Prior to the pull-out test, a compressive test was conducted to investigate the effect of PVA fibre on the mechanical properties of geopolymer concrete. Afterwards, the direct pull-out test was conducted for each variation to analyse how the PVA fibre addition affects the bond resistance between the concrete matrix and pull-out bar. To this end, the ultimate bond load, crack patterns and failure mechanism was studied. In addition, the OPC concrete specimens, having close compressive strength with geopolymer concrete, were prepared to conduct the comparative study. Thus, the specimens with 0 % and 0.4 % PVA fibre content were used for a comparative study. The overall conclusions from this study are given as follows:

1. It has been investigated that the addition of PVA fibre improves both compressive and bond strength for the concrete mix. The experimental study reveals that the utilization of PVA fibre in geopolymer concrete shows about 19.62 % increase in the compressive strength.

2. The same trend as the compressive strength is also observed for the bond strength. The addition of PVA fibre improves the bond strength of concrete by about 25.9 % in geopolymer concrete.

3. The optimum amount of PVA fibre addition is 0.4 % by volume of the concrete. Even though the specimen with 0.6 % PVA fibre content has the highest bond strength, the workability of the mix is poor.

4. The utilization of PVA fibre for more than 0.6 % has shown a tendency to decrease the bond resistance. The specimen with 0.8 % PVA fibre content reveals this condition. As the PVA fibre content increases, the workability of the fresh concrete decreases.

5. A comparative study reveals that both the non-PVA and PVA fibre blended geopolymer concrete shows higher bond strength than the OPC concrete. The addition of PVA fibre provides a more ductile mode of failure in both geopolymer and OPC concrete, as compared to the concrete without PVA fibre.

6. The utilization of PVA fibre in OPC concrete results in the less increment in bond strength, as compared to the geopolymer concrete.

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