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Behavior of Tensile Strength for Fibrous for Fibrous Geopolymer Concrete

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الملخص العربى :

الهدف من هذة الدراسة هو تحقيق الأستفادة الكاملة من المخلفات الصناعية المتوفرة محلياً في مصر وإعادة تدويرها بدلا من التخلص منها واستخدامها في إنتاج الخرسانة الجيوبوليمرية بدلا من الأسمنت وتتدعيمها بألياف الصلب المصنوعة من الفيبر ، بالاضافة الى دراسة الخواص الميكانيكية للخرسانة الجيوبوليمرية المقواه بألياف الحديد المصنوعة من الفيبر . من خلال برنامج عملى يشتمل على مرحلتين. المرحلة الاولى هى دراسة وإختبار الخواص الميكانيكية للمواد والخامات المستخدمة وصب الخرسانة العادية المحتوية على الأسمنت البورتلاندي ، المرحلة الثانية عمل و صب 9 خلطات بكميات مختلفة (kg/m^3 400-300-200) من الخرسانة الجيوبوليمرية فقط والجيوبوليمرية الممزوجة والمقواة بألياف الحديد المصنوعة من الفيبر بنسب مختلفة (1%-2 %) وعمل اختبارات الهبوط إختبارات (مقاومة الضغط - الإنحناء - الشد الغير مباشر - معاير المرونة وأختبار البنية الدقيقة) عند عمر 28 يوم لكل الخلطات تم مناقشة وتحليل النتائج مع إجراء مقارنة بين النتائج المعملية التي تم الحصول عليها للخرسانة العادية و الجيوبوليمرية المدعمة بألياف الفيبر .

ABSTRACT:

The aim of this study is to achieve benefit from industrial waste locally in Egypt to produce Geopolymer concrete (GPC) reinforced by steel fiber. Experimental program focused on the tensile behavior of GPC. The first stage is the study and testing of the mechanical properties of the materials used and casting conventual concrete with Portland cement, The second stage is the work and pouring of 9 mixtures of different quantities (200-300-400 kg/m^3) of geopolymer concrete only and mixed, reinforced with steel fiber with different ratio (1% - 2%).making (slump, compressive, flexure, splitting strength, modules of elasticity and micro structure test) at the age of 27 days on the all mixes, the results were analyzed and compared with ordinary concrete and geopolymer reinforced by steel fiber.

KEYWORDS: Geopolymer concrete (GPC), Steel Fiber (S.F), Fly ash (F.A).

1. INTRODUCTION

The National Ready Mixed Concrete Association [1] proved that producing 1 ton of Portland cement generates approximately 1 ton of CO_2 and that the cement industry accounts for about 5% of global greenhouse gas emissions. Therefore, new techniques to produce concrete with reduced greenhouse gas emissions are needed. As the demand for concrete as a construction material increases, so also the demand for Portland cement. It is estimated that the production of cement will increase from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010 [2]. On the other hand, the climate change due to global warming has become a major concern. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2), to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming [3]. The cement industry is held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere [3, 4].

Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, granulated blast furnace slag, rice-husk ash and metakaolin, and the development of alternative binders to Portland cement. Concrete structures were designed to withstand various types of environmental conditions categorized as from mild to very severe conditions. Fire represents one of the most severe environmental conditions to which concrete structures may be subjected to such as close conduit structure like tunnel [3, 4]. Geopolymer concrete (GPC) is an alternative for cement with waste materials such as fly ash and GGBFS, Geopolymer concrete has been used to produce precast products such as, railway sleepers, sewer pipes, and pre-stressed concrete building components. The tests performed on these products have shown acceptable results of geopolymer concrete reinforced by steel fiber compared to conventional concrete, steel fiber are part of the concrete matrix, its increasing its overall ductility, durability and load bearing capacity. In addition, other research works were carried out to investigate the durability of geopolymer concrete reinforced by steel fiber under different environmental conditions. The results indicated that, the geopolymer concrete showed good resistance to many environmental conditions.

2. EXPERIMENTAL PROGRAM

The experimental program was divided into two phases. The first phase determines mechanical properties of used materials, cast control concrete mixture and the Geopolymer concrete without steel fiber. The second phase includes cast Geopolymer concrete reinforced by steel fiber with different ratio (1% - 2). Standard cylinders (150mm in diameter and 300mm in height) were tested after twenty-eight days to determinate indirect tensile strength. These samples were steam cured and the others cured in ambient temperature.

3. MATERIALS

In this research, the natural sand which is composed of siliceous materials was prepared as fine aggregate, and the natural crushed stone was prepared as coarse aggregate. The experimental tests are including fine aggregate and coarse aggregate; a suitable quantity of aggregate was taken to perform sieve analysis test. The properties of the fine and coarse aggregate were calculated from experimental tests, and they were tabulated as provided in

Table (1) and (2). The sieve analysis test was conducted using a group of vertically stacked sieves. The percentage of aggregate passage from each sieve was determined with the size of the sieve aperture and it was compared with the minimum and maximum aggregate passage from the sieve's sizes Table (3) and (4) show the test results for coarse and fine aggregate, respectively. Also, Figure (1) and (2) show the grading curve for coarse and fine aggregate, respectively.

Table (1): Physical properties of the fine aggregate

Property	Results
Specific weight	2.64
Bulk Density (t/m^3)	1.76

Table (2): Physical properties of the coarse aggregates

Property	Results
Specific Weight	2.57
Bulk Density (t/m^3)	1.59

Table (3): Passing Percentage of Coarse Aggregate to Sieve Size

Sieve size (*mm*	20	12.5	9.5	4.75
Passing %	100	95.5	67	0
Limits of passir	100	90 - 100	40 - 70	0 - 15

Table (4): Passing Percentage of Fine Aggregate to Sieve Size

Sieve size (*mm*)	4.75	2.36	1.18	0.60	0.30	0.15
Passing %	99.5	93.4	86.7	68.5	13.3	2.1
Limits of passing %	90 - 100	85 - 100	75 - 100	60 - 79	12 - 40	0 - 10

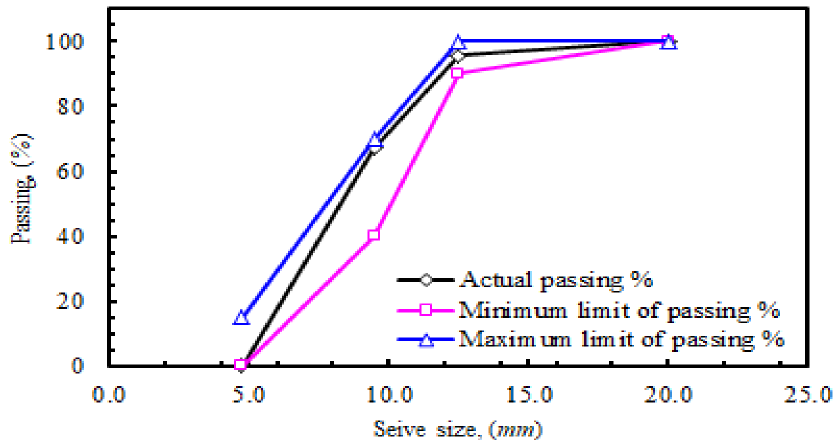

Figure (1): Grading curve for coarse aggregate

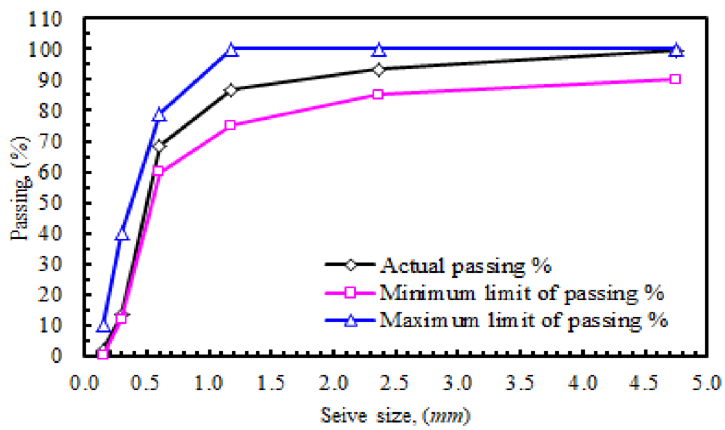

Figure (2): Grading curve for fine aggregate

The used of fly ash (FA) is by-product material rich in silicon and aluminum, such as low-calcium fly ash according to the ASTM C 618 Class F. In the present experimental work, low-calcium (Class F). The chemical composition of the fly ash, as determined by x-ray fluorescence (XRF) analysis is given in Table (5).

Table (5): XRF analysis for the used fly ash

Oxide	Content %	Limitation %
SiO2	61.3	Min. 70%
AL2O3	29.4	
Fe2o3	3.27	
CaO	1.21	--------
MgO	0.75	--------
K2O	1.2	--------
SO3	0.003	Max. 3%
TiO2	0.01	--------
Na2O	0.73	Max. 1.5%
CL	0.04	Max. 0.05%

Corrugated steel fibers are made from cold drawn low carbon steel wires. It’s 30mm length and 0.38mm diameter, 2300MPa tensile strength, 78.9 aspect ratio, therefore it has a high corrosion resistance and high durability. Figure (3) shows the used steel fibers.

Figure (3): Egyptian European Steel Fiber

4. Geopolymer Concrete Mixtures

Table (6-1): Design of control mix .

Mix No.	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)	slump
1	400	00	1200	180	9.22

Table (6-2): Design of Mixes 300 (kg/m3) .

Mix No.	Alumina Silicate Source (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	STEEL FIBER	NaOH Solution (kg/m^3)	Na_2Sio_3 Solution (kg/m^3)	Extra Water (kg/m^3)	Slump (cm)
1	200 (Fly ash Only)	600	1200	-------	25.7 (7.71 S-17.79 W)	64.3	38.5	8.84
2	200 (Fly ash + 1% SF)	600	1200	8	25.7 (7.71 S-17.79 W)	64.3	40.3	7.51
3	200 (Fly ash+2% SF)	600	1200	16	25.7 (7.71 S-17.79 W)	64.3	43.8	6.22

Table (6-3): Design of Mixes 300 (kg/m^3) .

Mix No.	Alumina Silicate Source (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	STEEL FIBER	NaOH Solution (kg/m^3)	Na_2Sio_3 Solution (kg/m^3)	Extra Water (kg/m^3)	Slump (cm)
1	300 (Fly ash Only)	600	1200	-------	38.5 11.63 S-26.87 W)	96.5	38.92	8.43
2	300 (Fly ash + 1% SF)	600	1200	8	38.5 11.63 S-26.87 W	96.5	41.83	6.90
3	300 (Fly ash+2% SF)	600	1200	16	38.5 11.63 S-26.87 W	96.5	44.52	6.13

Table (6-4): Design of Mixes 400 (kg/m3) .

Mix No.	Alumina Silicate Source (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	STEEL FIBER	NaOH Solution (kg/m^3)	Na_2Sio_3 Solution (kg/m^3)	Extra Water (kg/m^3)	Slump (cm)
1	400 (Fly ash Only)	600	1200	-------	51.5 15.57 S-35.93 W)	128.5	39.45	8.17
2	400 (Fly ash + 1% SF)	600	1200	8	51.5 15.57 S-35.93 W	128.5	42.22	6.32
3	400 (Fly ash +2% SF)	600	1200	16	51.5 15.57 S-35.93 W	128.5	45.11	5.98

5. MANUFACTURING OF GEOPOLYMER CONCRETE

The method of manufacturing of Geopolymer concrete as the same conventional techniques as Portland cement concrete as following: Firstly, fly ash, fine aggregate, coarse aggregate and steel fiber were mixed together in the dry condition in the pan mixer for three minutes and the coarse aggregate should be in saturated-surface-dry (SSD) condition. Secondly, the liquid solution which was consisted of Hydroxide Sodium (NaOH) and Silicate Sodium (Na_2SiO_3) was prepared. sodium hydroxide solution should be prepared 24 hours before casting. The solution was mixed with extra water and super plasticizer if mixture need that. Thirdly, the liquid solution was added with the dry mixture and mixed for another four minutes as shown in figure (4). Finally, the fresh concrete shall be filled into the standard cylinders in three layers. The casting procedure was carried out by commonly used methods.

6. SPECIMENTS CURING

After casting, samples were left to harden for 72 hours, then samples removed from molds. Finally, they are transferred to the steam curing tank and left for three days. Curing process was indicated as shown in Figure (4).

igure (4): Steam curing tank

6. SAMPLES TEST

The tensile strength was applied after twenty-eight days and indirectly measured through the splitting tensile strength test of ASTM C496 (ASTM, 2011) [6]. The line load was applied with loading rate of 1 kN/s across the entire length of the specimen as shown in Figure (5)

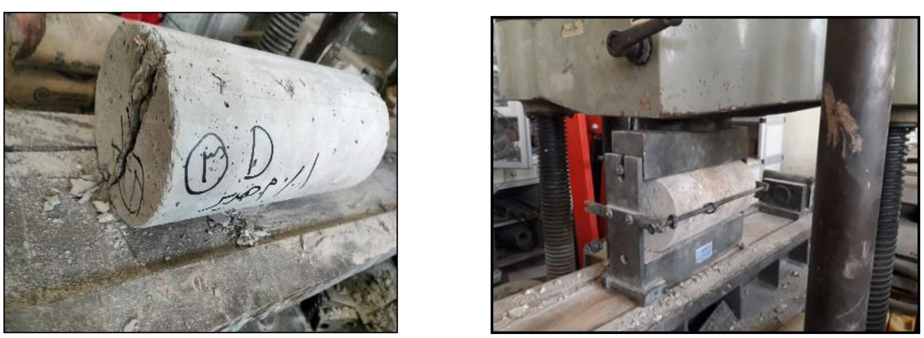

Figure (5): Splitting Tensile Test

7. RESULTS AND CONCLUSION

Figure (6) shows the effect different ratio of steel fiber on mixes (200 F.A only ,200 F.A+1% S.F, 200 F.A +2% S.F, 300 F.A only ,300 F.A+1% S.F,300 F.A +2% S.F,400 F.A only ,400 F.A+1% S.F,400 F.A +2% S.F) as an addition fly ash. Basically, Geopolymer concrete manufactured with (200 F.A +2% S.F) showed the lowest indirect tensile strength compared to the indirect tensile strength of the traditional concrete. It was observed that the comparison between all mixes with control: tensile strength of Mix200 F.A only was higher than 10.83 % , b1 Mix 200 F.A+1% higher than 18.3% , 200 F.A+2% lower than 17 %, Mix300 F.A only was higher than 3.6 %, 300 F.A+1% higher tha20.83 %, 300 F.A+2% higher than 14.7 %, Mix 400 F.A only was higher than 17.3 %, 400 F.A+1% higher than 34.7 % ,300 F.A+2% higher than 26.4 %On the other hand, Mix D (400 kg/m3 F.A+1% S.F) was 34.7 % higher than that for Mix A (traditional concrete) at 28 days. From the obtained results, it can be concluded that Geopolymer concrete manufactured with 400kg/m3 F.A with addition 1% S.F showed the the highest and best splitting tensile strength among all mixes. Geopolymer concrete manufactured with 200kg/m^3 F.A with addition 2% S.F showed the lowest splitting tensile strength. It is clear that the adverse impact of NA replacement by F.A on the splitting tensile strength could not only be reversed by SF addition but could also exceed that of the control. This is primarily owed to the steel fibers' ability to bridge the micro cracks and increase the energy requirements for crack propagation. The higher splitting tensile strength is assumed from the improved bonding at the interface of Geopolymer paste and aggregate, Hardjito and Rangan, (2005) [7], Rangan (2008) [8], explained that this phenomenon was caused by a chemical interaction between the aggregate and alkaline solution.

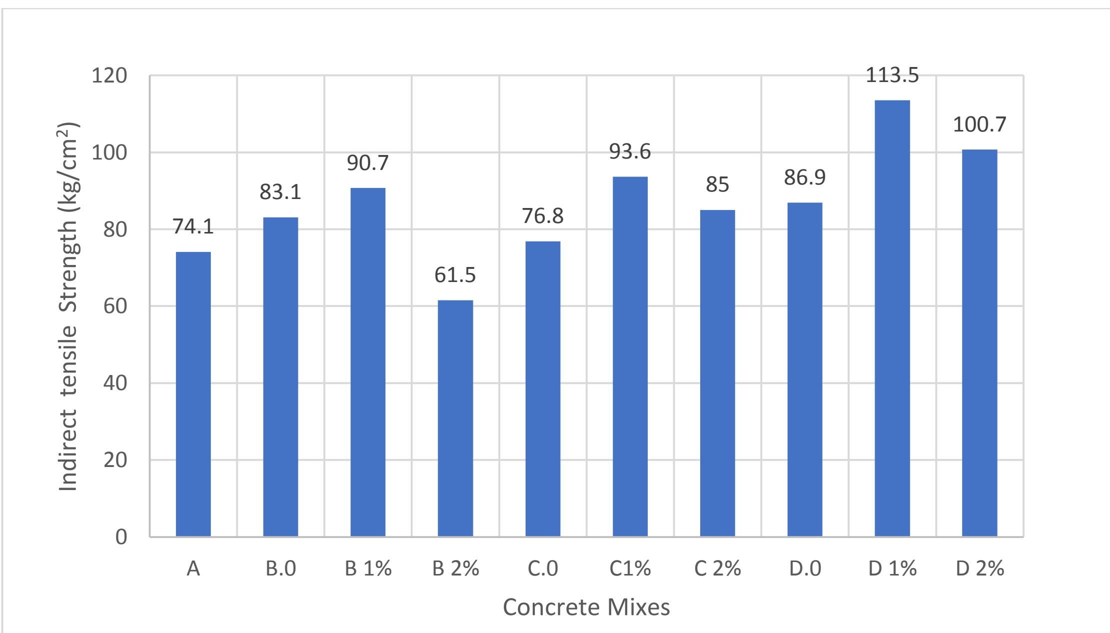

Figure (6): The Relationship between in direct Tensile Strength and Age 28 days for All Mixes at molarity (12M)

8. CONCLUSIONS

From the test results obtained from this research, the following conclusions can be drawn:

- Geopolymer concrete can be used for concreting works in a similar way to traditional concrete with slight change in the mixing procedure. i.e. preparation of alkaline solution needs preparation 24hr prior to mixing. Also, a great care is required while the used activators.
- The splitting tensile strength of Geopolymer concrete manufactured with 400kg/m^3 F.A with addition 1% S.F showed the highest and best splitting tensile strength among all mixes while, Geopolymer concrete manufactured with 200kg/m^3 F.A with addition 2% S.F showed the lowest splitting tensile strength.
- Using addition steel fiber with ratio 1% gives the optimum strength and more economic than addition 2% steel fiber.

9. REFERENCES

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