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Properties of Geopolymer Rubberized Concrete

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الملخص العربى :

هذه الورقة هي منهج علمي لتقييم أداء دراسات القوة مثل مقاومة الانضغاط وقوة الانثناء وقوة الشد الغير مباشر ومعامل معاملات المرونة ومقارنة النتائج وتم اجراء الاختبارت لعده عوامل مختلفه مثل نسبة خلط المحلول القلوي والمولارية و نسبة المحلول إلى نسبة الرماد المتطاير للوصول إلى أفضل نتيجة والمقارنة بين النسب المتغيرة باستخدام استبدال ألياف الإطارات المطاطية في الخرسانة. واحدة من أهم النتائج هي أنه مع زيادة نسبة الاستبدال ، زادت نسبة قوة الشد الغير مباشر وقوة الانحناء.

الخلاصة :

يمكن أخذ الاستنتاجات التالية من نتائج هذا البحث:

1-مع زيادة نسبة المطاط ، تقل قابلية تشغيل الخرسانة

2-في جميع الأعمار تنخفض مقاومة الانضغاط مع زيادة نسبة نفايات ألياف المطاط.

3-نسبة سيليكات الصوديوم (Na2SiO3) إلى هيدروكسيد الصوديوم (NaOH) كمنشط مختلط ، وله تأثير كبير على مقاومة الانضغاط.

4-نظرا للارتباط الممتاز بين عجينة الجيوبوليمر والركام ، فإن مطاط التدرج الخرساني الجيوبوليمر له قوة شد أكبر من المطاط المتدرج الفردي.

5-مع زيادة نسبة المطاط ، تتحسن خصائص التوتر للخرسانة الجيوبوليمرية المطاطية ، مثل قوة الانثناء والشد. عندما تم استبدال 20٪ من الرمل بالمطاط ، تم العثور على أعلى مقاومة للثني. ويرجع ذلك إلى المطاط الذي يعمل كجسر أفضل بين الشقوق المنتشرة.

Abstract:

The need for cementitious materials has skyrocketed in recent years. Unfortunately, the current technique of producing Ordinary Portland Cement (OPC) has been linked to negative environmental consequences due to massive CO_2 emissions - a key Green House Gas (GHG). This has prompted concrete scientists and the building industry to look for innovative, long-lasting, user-friendly, eco-friendly, and, of course, cost-effective alternatives to present binders and construction materials. geopolymer binders made from a synthesis of silica and alumina rich pozzolanic precursors – such as fly ash – with alkali solution as an activator via the geopolymerization process have lately emerged as a luminously promising alternative to traditional cement. This research looks into not just the development of rubberized geopolymer concrete. furthermore, natural sand is currently over-exploited for construction and industry, resulting in a scarcity, which has led in a rapid increase in its cost. waste rubber tire fibres are used as a partial substitute for fine aggregates in this study. The study indicates that using scrap rubber tire fiber as a replacement for sand is not only cost-effective, but also user- and eco-friendly for creating rubberized geopolymer concrete without jeopardizing its long-term viability. This paper is a scientific approach for evaluating the performance of strength studies such as compressive strength, flexural strength, split tensile strength, and modulus of elasticity parameters and comparing the results with various content such as the ratio of mixing the alkaline solution, molarity, and the ratio of the solution to the ratio of fly ash to reach the best result and the comparison between variable ratios by use replacement waste rubber tire fibers in concrete. one of the most important results is that with the increase in the substitution ratio, the percentage of split Tensile strength and flexural strength increased.

Keywords- Geopolymer ; Geopolymer concrete; Properties; Fly ash; Rubber; Compressive strength ; Split tensile strength ; Flexural strength ; Modulus of elasticity

I. INTRODUCTION

Portland cement (PC)is used as a component of concrete which is used in various construction applications. Production of portland cement (PC) has environmental concerns in terms of the energy consumption and the emission of Carbon Dioxide (CO_2) [1].There is a diversity in the amount of electricity used in the production of cement such as 100 kW/h in India, Spain, Thailand and Italy and in Canada reaches to160 kW/h. [2]. For the energy saving and reduction emission of CO_2 ,The research is directed for more environmentally viable alternatives, hence the engineers began to develop environmental friendly concrete such as geopolymer concerte. Geopolymers are category of inorganic polymer aluminosilicate materials. Geopolymers are able to give proportionate performance with the conventional cementitious in a wide range of uses[3] and it also has additional benefit of expressively decreased Greenhouse emissions[4]. Geopolymer concrete has good properties for example, it has compressive strength reaches to more than 100 mega Pascal. It also has brilliant prospective for alkali and silica reaction, fire protection and resistance of acid[5]. Davidovits et al. [6] recommended that liquid of alkaline are able to act in response with aluminum and the silicon in an origin substance of geological source otherwise via produce items for example rice husk and fly ash in order to create grouts. For the reason that the chemical response which occurs on this wise is a process of a polymerization procedure, researchers named this expression "Geopolymer" towards signify these grouts. Even though various source materials are able to be utilized to present geopolymer grouts. Fly ash become the material that offers the excessive chance for profit-making exploitation and takes the prospective in order to decrease CO_2 emission and employ some recycled materials. One of these recycled materials is the rubber which is produced from waste car's tires around the world. Owing to the massive increase within the number of cars worldwide, the accumulation of waste tyres has become a serious waste management problem. A large amount of waste rubber tyres accumulates in the world every year, so there is a need to recycle this tyers or finding a use for it [7]. Researches directed to use rubber in their experiments in order to illustrate its benefits with geopolymer. Luhar et al.[8] studied rubber strength and rubber criteria of durability. They noticed that use of waste rubber fibre tire as a substitute for sand can be considered as a user and environment friendly and cost-effective. They focused on the performance of experiments that depend on strength for example, split tensile strength ,compressive strength, elasticity of modulus, strength of flexural, pull off strength ,resistance of fly ash on geopolymer with rubber concrete and finally compared their result with ordinary Portland cement concrete. Moghaddam et al. [9] employed a procedure for geopolymer concrete using fly ash exchanged with cement up to 20% and they also used crumb rubber equivalent to 10% of the dimensions of fine grains. Steel fiber were prepared besides the process of cured at temperature of 60 °C in dry situations. The second phase of work was after 28 days, in this step mechanical properties were calculated with sulfuric acid in the environment. The outcomes illustrated that compressive and tensile strengths gave the highest value which equal to 49 Mega Pascal (Mpa) and 4.7 (Mpa) correspondingly. Pham et al.[10], reconnoitered with experiments the influence of diverse percentages for crumb rubber partial substitution for fine aggregates and coarse to detect dynamic features of geopolymer concrete. The compressive dynamic assets including geopolymer concrete combined with crumb rubber has calculate using Split Hopkinson Pressure Bar tests (SHPB) [6]. Finally, results illustrated that rubberized geopolymer concrete constantly displayed improvement in impact resistance with the comparsion with normal geopolymer concrete. From the previous researches, it is noticed that using material such as rubber gives a good properities for geopolymer. In this paper, the direction of this work focus on physical and mechanical properties of geopolymer rubberized concrete. From experiments, when the rubber increases ,the compressive strength decreases. The target of this work is to choosing the suitable waste rubber for the application with geopolymer concrete and finding the fresh properties of rubberized geopolymer mixtures. Section II discusses the proposed experimental work and material and the details of each test. Finally, Section III concludes the experimental work, summarize the whole tests and give a future work vision for the paper .

2. Experimental program

2.1. Materials

the source materials (sodium hydroxide, sodium Silicate, Fine Aggregate, Coarse Aggregate , and fly ash) are the most important components of geopolymer. Geopolymer fly ash was made from class F fly ash. Chemical compositions of fly ash were determined using

X-ray fluorescence (XRF), as shown in Table 1. River sand was used as fine aggregate to prepare fly ash based rubberized geopolymer concrete. The fineness modulus, specific gravity and water absorption were of 2.56, 2.6 and 0.5%, respectively. The river sand complies zone-II as per M.Q.M:11.9 [11] specifications.

Rubber tyre fibres acquired from the mechanical grinding unit of rubber tyre waste were employed as partly replacement of the fine aggregates, as illustrated in Fig. 1. Looking to the physical attributes, rubber tyre fibres taken in use were roughly width is 0.5-2 mm ,specific gravity 1.15 . The rubber tyre fibres have substituted the fine aggregate in proportion of 5%,10%, 15% and 20% by volum. The particle size of the rubber tyre fibres is within Zone II, as per M.Q.M:11.9 [11], as demonstrated in Fig. 3. Chemical composition of rubber tyre fibres are also displayed in Fig. 2. [12]

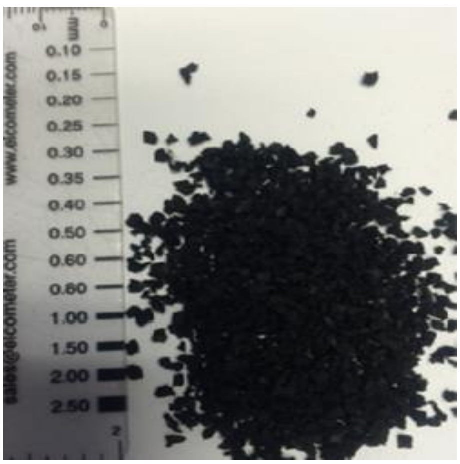

Fig. 1 Rubber tyre fibres

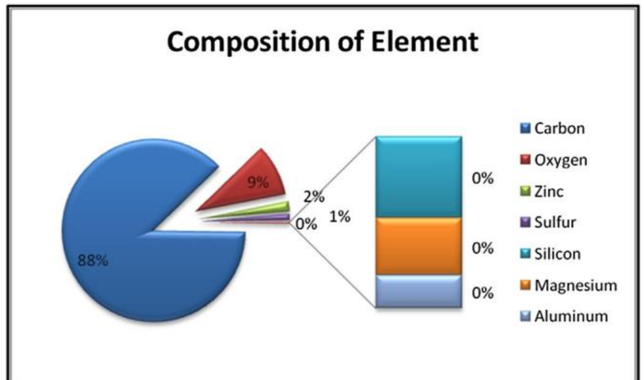

Fig 2 Rubber fibre chemical composition [6]

Table 1 Chemical Composition of fly ash by XRF (mass %)

Parameters	fly ash
Silicon Dioxide (SiO2)	54.70%
Aluminum Oxide (Al2O3)	29.00%
Iron Oxide (Fe2O3)	6.74%
Magnesium Oxide (MgO	0.80%
Sulfur Trioxide (SO3)	0.10%
Available Alkalis as Na2O	1.88%
Calcium Oxide (CaO)	1.29%
Loss on Ignition	2.72%

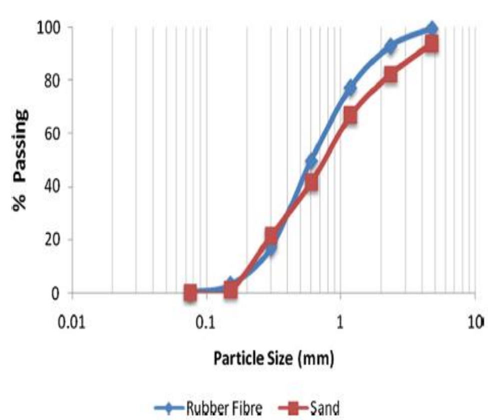

Fig 3 Sand and rubber fibre particle size analysis [6]

2.2. Process for manufacturing of geopolymer

The activator was a mixture of sodium hydroxide and sodium silicate solutions (the alkaline liquid). the sodium hydroxide flakes (NaOH with 98 percent purity) and sodium silicate solution (NA_2O = 10.6%, SiO_2 = 26.5 percent, and density = 1.46 g/ml at 25 C). Sodium hydroxide flakes, depending on the concentration, are used to make the sodium hydroxide solution. molarity, were weighed and then dissolved in a litre of distilled water. The molarity of a solution is defined as the number of moles of solute per litre. 40 g of NaOH flakes (molecular weight of NaOH = 40) were dissolved in one litre of water to make the 1 M solution. to allow the hydroxide solution to dissolve, it was left for about24 hours.The following day.To make the alkaline solution, the sodium silicate solution was mixed with the required amount of hydroxide solution it was left for about10 minet to allow the solution To cool Because this reaction is exothermic and it was left To cool to room temperature. In the concrete mixer, fine aggregate and fly ash were mixed for about 1 minute After that, the coarse aggregate was thinned and mixed for about 1 minute in the concrete mixer. The solution mixture was properly shaken before being poured into the mixer and mixed for 4–5 minutes and the Water is added gradually during mixing.

2.3. Design proportioning and testing parameters

One of the mixers was taken , whereThe proportions for the geopolymer concrete mix were calculated based on E.C.B 203-2018 [13]. the mix was modified to get the best mix see Table 2 and 3.

Table 2 :Proportions of mix designs for Mortar (per m3).

Mix	% Replacement by volume	Fly ash	Na2SiO3	NaOH	Weight of sand	Weight of replaced rubber	SN/NA	water	Molarity
		(Kg)	(Kg)	(Kg)	(Kg)	(Kg)		(Kg)	
RO_1	0	654	174	87	1307	0	2	-	M16
$R5_1$	5%	654	174	87	1241	29.2	2	-	M16
$R10_1$	10%	654	174	87	1176	58	2	-	M16
$R15_1$	15%	654	174	87	1111	86.8	2	-	M16
$R20_1$	20%	654	174	87	1046	115.5	2	-	M16
m1	0	654	87	174	1307	0	0.5	-	M(16)
m2	0	654	174	87	1307	0	2	-	M(16)
m3	0	654	186.4	74.6	1307	0	2.5	-	M(16)
RO_2	0	400	114.3	45.7	1781.54	0	2.5	-	M(10-12-14-16)
$R5_2$	5%	400	114.3	45.7	1692.46	39.4	2.5	20	M(12)
$R10_2$	10%	400	114.3	45.7	1603.38	78.8	2.5	20	M(12)
$R20_2$	20%	400	114.3	45.7	1425.23	157.6	2.5	20	M(12)

Whereas RO_1 is the control mixture,$R5_1$ is a mixture with a replacement ratio of 5%, $R10_1$ is a mixture with a replacement rate of 10%, $R15_1$ is a mixture with a replacement ratio of 15%, and $R20_1$is a mixture with a replacement rate of 20% And that m1, m2, m3 are mixtures with different mixing ratios of sodium hydroxide, sodium silicate, where m1 is a mixture of 0.5:1, m2 is a mixture of 2:1 and m3 mixture is a mixture of 2.5:1. After comparison, It found that m3 mixture is the best. RO_2 is the control mixture,$R5_2$ is a mixture with a replacement ratio of 5%, $R10_2$ is a mixture with a replacement rate of 10%, $R20_2$is a mixture with a replacement rate of 20%.

Table 3 : Proportions of mix designs concrete

Mix	% solution to the Fly ash	Fly ash	Na2SiO3	NaOH	Fine aggregate	Coarse aggregate	SN/NA	Weight of replaced rubber	water	Molarity
		(Kg)	(Kg)	(Kg)	(Kg)	(Kg)		(Kg)	(Kg)	
M1	0.4	400	114.3	45.7	552.8	1228.64	2.5	-	20	M(12)
M2	0.5	400	142.86	57.14	529.3	1176.18	2.5	-	20	M(12)
M3	0.6	400	171.93	68.57	505.4	1123.11	2.5	-	20	M(12)
$R5_3$	0.5	400	142.86	57.14	502.8	1175.84	2.5	11.72	20	M(12)
$R10_3$	0.5	400	142.86	57.14	486.3	1166.18	2.5	23.41	20	M(12)
$R20_3$	0.5	400	142.86	57.14	445.4	1152.11	2.5	46.82	20	M(12)

where that M1, M2, M3 are mixtures with different mixing ratios of the ratio of the solution to the ratio of fly ash(0.4-0.5-0.6) Respectively . $R5_2$ is a mixture with a replacement ratio of 5%, $R10_3$ is a mixture with a replacement rate of 10%, $R20_3$is a mixture with a replacement rate of 20%.

2.4. Test methods

2.4.1. Strength properties

After heat curing of the geopolymer specimen, strength propertieswere appraised. details of the testing program are described below.

2.4.1.1. Mortar

Table 4: Type of test for Mortar

Properties	Test	Testing Age (days)	Size of test specimen
Strength Properties	Compressive Strength	7, 28,	50*50*50 mm size cubes
	Compressive Strength	7, 28,	40 _ 40 _ 160 mm size Prism
	Split Tensile Strength	7, 28,	50 mm diameter and 100 mm height
	Flexural strength	28	40 _ 40 _ 160 mm beams
	Modulus of Elasticity	28	50 mm diameter and 100 mm height

2.4.1.1.1.Compressive strength test:-

For compressive strength tests, cube specimens of area of Prism (40×40×160) were cast mortar .After casting, all test specimens were finished with a steel trowel. after casting, the sample was left for 24 hours before being placed in the incubator for two days of treatment before the test. After 7, and 28 days, compression strength tests were performed. All specimens were tested using an automated compression testing machine (CTM), as shown in Fig. 4. The load was applied gradually at a rate of 140 kg/cm2/min on smooth surfaces to the specimens in the CTM until the ultimate load resistance was reached. The compressive strength was determined by taking the average of three specimen values.

Compressive Strength (N/mm^2) = $\frac{p}{A}$

where
P = Failure load of cube (kN)
A = Area of cube (mm^2)
A = Area of Published (40×40×160) (mm^2)

Fig. 4. Compression testing for morter

2.4.1.1.2.Split tensile strength test:-

The tensile strength of geopolymer concrete was determined with this method.The specimens were tested for strength 28 days later.were poured out 50 mm in diameter cylindrical specimens.The test was done at a height of 100 mm. The examination took place.by horizontally placing a cylindrical specimen between load surfaces CTM. On the longer side, a gradual load was applied.as shown in Fig. 5, until the specimen is ready to be used failed. The split tensile was calculated using an average of three tests.The split tensile strength was determined as follows:

Split Tensile Strength(N/mm^2)= $\frac{2P}{p\times L\times D}$

where
_ P = Failure load of cylinder (kN)
_ L = Height of Specimen (100 mm)
_ d = Diameter of Specimen (50 mm)

Fig. 5. Split tensile strength test

2.4.1.1.3.Flexural strength test

The flexural strength tests were carried out . The three-point loading method was used, in which the bearing surfaces of the supporting and loading rollers were loaded simultaneously.were thoroughly cleaned, and any loose sand or other debris was removed derived from the specimen's surface Specimens of various sizes. The test specimen beam was positioned in this manner.the manner in which the load was applied to the topmost surface of the specimen's axis is was parallel to the loading device's axis. a gradually increasing load Until the specimen failed, a rate of 180 kg/cm2/min was applied[15].

Flexural Strength(N/mm2)= $\frac{P \times L}{B \times D2}$

where,

_ P = Failure Load of Beam

_ L = Span of Beam (160 mm)

_ b = Width of Beam (40 mm)

_ d = Depth of Specimen (40 mm)

Fig. 6. Flexural strength test

2.4.1.1.4. Modulus of elasticity test

The modulus of elasticity is the slope of the stress-strain curve with a proportional limit of the material. The tests were carried out at CTAE, Udaipur, specifications[15]. For this test, cylindrical specimens with a diameter of 50 mm and a height of 100 mm were used. As shown in Fig. 7, a cylindrical specimen was placed vertically between two frames of a compressometer. To keep the frames in the right place, spacers were used. The compressometer had a dial gauge attached to it to show the change in length of the specimen when it was compressed. Over three minutes, a compressive load of 140 kg/cm^2/min was gradually applied to the test specimen loadingunloading \scycles. The modulus of elasticity was calculated using an average of three cycles.

Fig. 7. Modulus of elasticity test

2.4.1.2.concrete

Table 5:Type of test for concrete

Properties	Test	Testing Age (days)	Size of test specimen
Strength Properties	Compressive Strength	7, 28,	100 _ 100 _ 100 mm size cubes
	Split Tensile Strength	7, 28,	150 mm diameter and 300 mm height
	Flexural strength	28	100 _ 100 _ 500 mm beams
	Modulus of Elasticity	28	150 mm diameter and 300 mm height

2.4.1.2.1 Compressive strength test

For compressive strength tests, cube specimens of size 100 mm were cast according to M.Q.M:1658 [15]. After casting, all test specimens were finished with a steel trowel. After casting, the sample was left for 24 hours before being placed in the incubator for two days of treatment before the test.

After 7, 14, and 28 days, compression strength tests were performed. All specimens were tested using an automated compression testing machine (CTM), as shown in Fig. 8. The load was applied gradually at a rate of 140 kg/cm2/min on smooth surfaces to the specimens in the CTM until the ultimate load resistance was reached. The compressive strength was determined by taking the average of three specimen values.

$$\text{Compressive Strength } (\text{N/mm}^2) = \frac{\text{p}}{\text{A}}$$

where

P = Failure load of cube (kN)

A = Area of cube (100 ×100) (mm^2)

Fig. 8. Compression testing

2.4.1.2.2. Split tensile strength test

In 1943, Brazil was the first to develop this test. to M.Q.M:1658 [15] was used to determine split tensile strength. The tensile strength of geopolymer concrete was determined with this method.The specimens were tested for strength 28 days later.were poured out 150 mm in diameter cylindrical specimensThe test was done at a height of 300 mm. The examination took place.by horizontally placing a cylindrical specimen between load surfaces CTM. On the longer side, a gradual load was applied. as shown in Fig. 9 , until the specimen is ready to be used failed. The split tensile was calculated using an average of three tests.The split tensile strength was determined as follows:

Split Tensile Strength(N/mm^2)= $\frac{2P}{p\times L\times D}$

where

P = Failure load of cylinder (kN)

L = Height of Specimen (300 mm)

d = Diameter of Specimen (150 mm)

Fig. 9 Testing of split tensile strength

2.4.1.2.3 Flexural strength test

The flexural strength tests were carried out in accordance with M.Q.M:1658 [15] standards. The three-point loading approach was used, which involved cleaning the bearing surfaces of the supporting and loading rollers and removing loose sand or other debris from the specimen's surface. The specimens utilized in this test were 100 ×100 ×500 mm in size, as specified by M.Q.M:1658 [15] The load was applied to the topmost surface of the test specimen beam along two lines 13.3 cm apart on the uppermost surface of the beam. The specimen's axis was aligned with the loading device's axis. The specimen was subjected to a progressive load of 180 kg/cm2/min until it failed. The flexural strength of specific concrete type was calculated using the average of three specimens. Fig. 9 ,depicts the test setup utilized for this test. The beam specimens' flexural strength was estimated as follows:

Flexural Strength(N/mm^2)= $\frac{P \times L}{B \times D2}$

where,

_ P = Failure Load of Beam

_ L = Span of Beam (400 mm)

_ b = Width of Beam (100 mm)

_ d = Depth of Specimen (100 mm)

Fig. 9 . Flexural strength test

2.4.1.2.4 Modulus of elasticity test

The modulus of elasticity is the slope of the stress-strain curve with a proportional limit of the material. The tests were carried out at CTAE, Udaipur, in accordance with M.Q.M:1658 [15] specifications. For this test, cylindrical specimens with a diameter of 150 mm and a height of 300 mm were used. As shown in Fig. 10, a cylindrical specimen was placed vertically between two frames of a compressometer. To keep the frames in the right place, spacers were used. The compressometer had a dial gauge attached to it to show the change in length of the specimen when it was compressed. Over three minutes, a compressive load of 140 kg/cm2/min was gradually applied to the test specimen loadingunloading \scycles. The modulus of elasticity was calculated using an average of three cycles and the formula below.

Fig. 10 Modulus of elasticity test

2.5. Results and discussion

2.5.1.Mortar

2.5.1.1 Compressive strength test

Figure 11 depicts the compressive strength of geopolymer concrete after 7, and 28 days. It is clear that when the proportion of waste rubber tyres grows from 0 to 20 With the increase in the proportion of rubber, the compressive strength diminishes at all ages. Compressive strength is decreasing. The alternate material's strength is attributed to its lower rigidity.in comparison to the fine aggregate close to it The rubber fibers, in fact,Due to a lack of bonding, voids are created when the contents rise. having a greater concentration of rubber fiber particles, resulting in Compressive strength is decreased. From the same sources, similar outcomes were shown. Also see [16,17,18,19] for previous research. A chemical interaction between the alkaline solution and the source material causes a rapid geopolymerization process in geopolymer concrete, resulting in a 95 percent compressive strength improvement in only 7 days [20,21,22]. The compressive strength of geopolymer concrete ranges between 30.38 and 32.6 MPa after 28 days, depending on the rubber fibre content. The geopolymeric determines the compressive strength. Factors like NaOH concentration, alkaline liquid ratio, curing temperature, and aggregate content all affect the compressive strength of geopolymer concrete. According to previous research, raising each of these variables increases the compressive strength of geopol. [24,25,26].

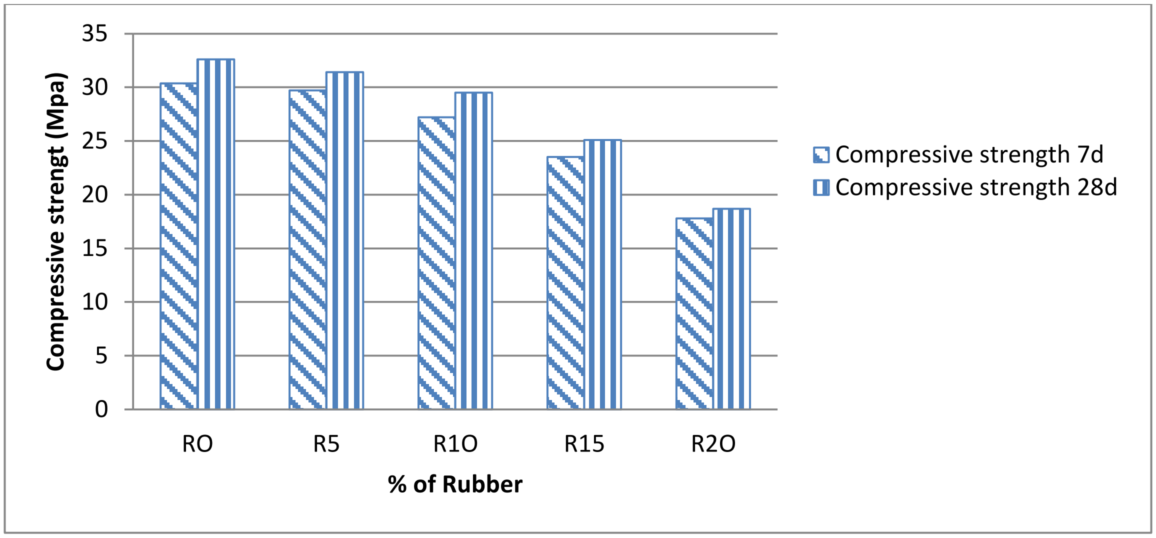

Fig. 11. Compressive strength of geopolymer mortar effected by Rubber percentage

Then a comparison was made between the ratio between the solution (0.5 / 2 / 2.5). It was noted that the ratio (2.5) is the highest in terms of resistance, as shown in Fig 12, and accordingly it was installed. then a comparison was made between MOLARITY(10-12-14-16)

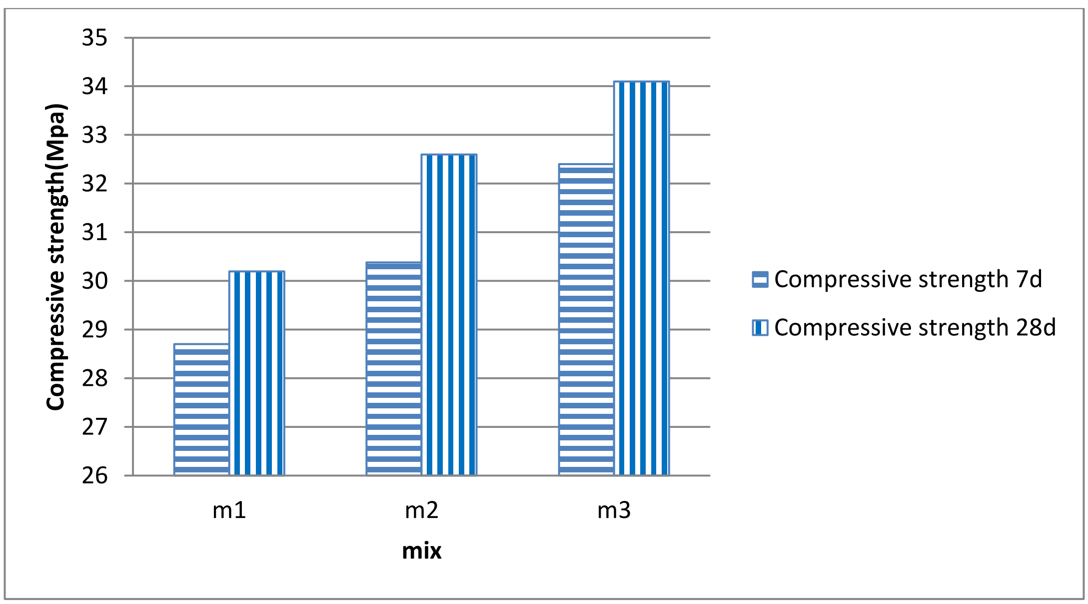

Fig 12 Compressive strength of geopolymer mortar effected by SN/NA

And as shown in the fig (Fig. 13), the ratio of molarity (12) is the best in terms of compressive strength, and accordingly it was selected. After that, tests were done on the new mixture on the Published and cylinder Samples

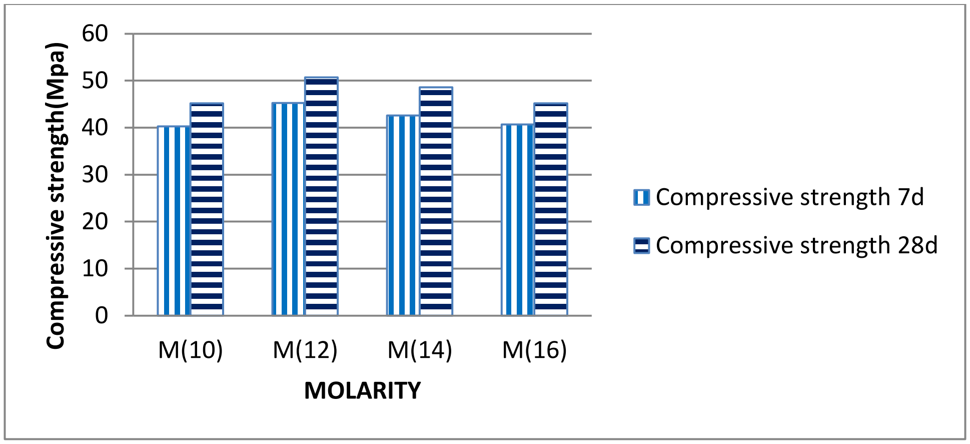

Fig 13 Compressive strength of geopolymer mortar effected by molarity

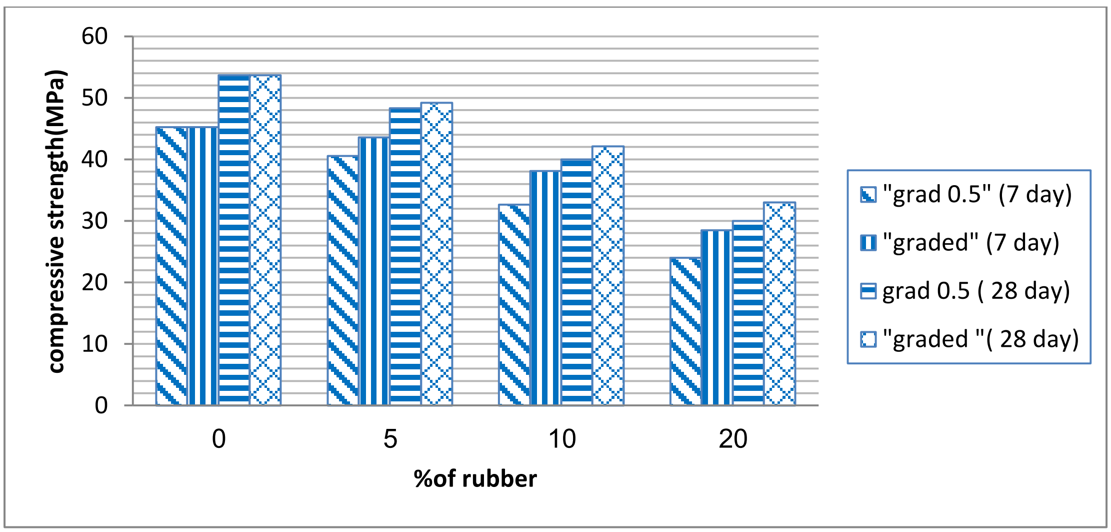

Fig 14 Compressive strength of geopolymer mortar effected by Rubber percentage and sizes

2.5.1.2 moduls of elastsicity

After 28 days, the average modulus of elasticity of the geopolymer was measured. The elasticity modulus of the geopolymer concrete ranged from 3100.5 to 2000 MPa (see Fig. 15). It can be observed that when the rubber fibre content rises, the modulus of elasticity falls in all of the combinations.The modulus of elasticity of geopolymer concrete is determined by the microstructure of the geopolymer and is unaffected by the aggregate. as well as materials for research. The homogeneity of the geopolymer diminishes as the rubber fibre concentration increases, resulting in a reduction in the modulus of elasticity. The results show that rubberized concrete has less stiffness than control concrete, therefore the modulus of elasticity of concrete decreases as the quantity of rubber fiber increases.Previous research [27] has made similar observations.As the rubber fibre concentration increases from 0 to 30%, the modulus of elasticity of geopolymer concrete.

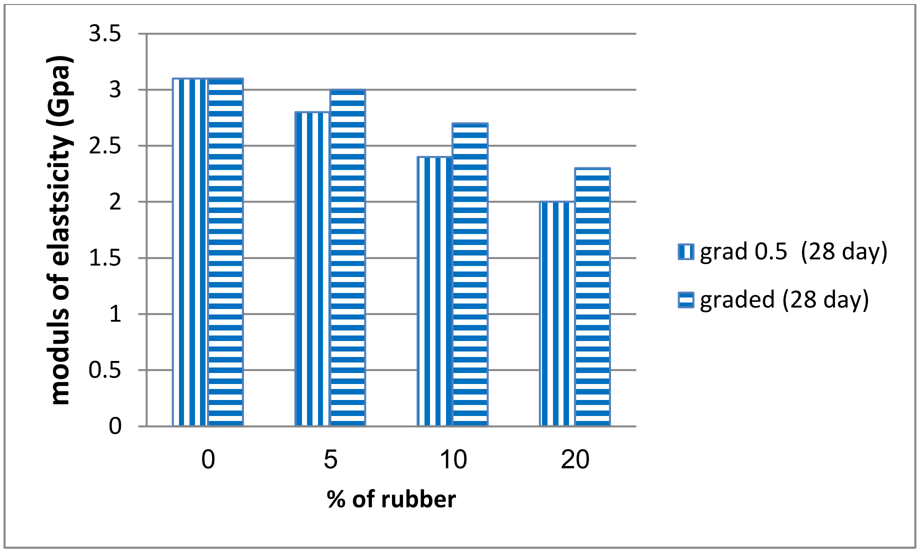

Fig 15 Modulus of elasticity geopolymer concrete mortar effected by Rubber percentage and sizes

2.5.1.3 flexural strength

Figures 15 depict the geopolymer concrete's average flexural strength After 7, and 28 days. The geopolymer concrete's flexural strength ranges between 4 and 4.32 MPa. In all combinations, the flexural strength grows with age. Previous studies [28,29] found similar evidence. Geopolymer concrete's tensile characteristics (0.5,1.2) Because of the stronger connection between the geopolymeric paste and aggregate, properties such as flexural and tensile strength are superior than those (0.5)mix. Flexural strength rises as the proportion of rubber fibres rises.The addition of discarded rubber tires in rubberized geopolymer concrete affects its flexural strength. Fibres create a better bridge across propagating fractures, resulting in an improvement in flexural strength. Similar observations were made in the preceding article.

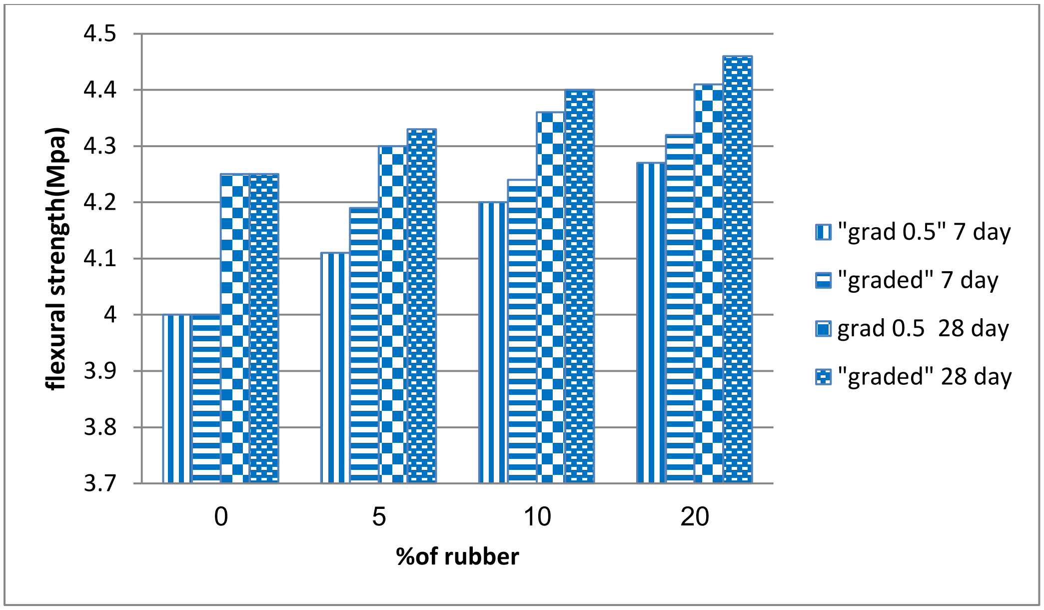

Fig 16 Flexural strength of geopolymer mortar effected by Rubber percentage and sizes

2.5.1.4 Split tensile strength test

Figs. 16 depicts the geopolymer's split tensile strength After 7, and 28 days, the concrete will be poured. Tensile strength is divided into two parts.All mixtures have a strength of 5.34 to 5.56 MPa after mixing.There are 28 days left in the month. The tensile strength of geopolymer concrete is superior.as a result of the strong ties that exist between the two aggregates and geopolymer paste There have been other similar observations.Previous research [31,32,33] has confirmed this. The tensile strength of the highest splitAfter 28 days, the 20% rubber(0.5-1-2) fibre blend had gained strength. After 7 days, the controlgeopolymer concrete had the lowest tensile strength. As the rubber fibre percentage grows from 0 to 20%, the split tensile strength gradually increases. In a prior research [34,35], similar findings were observed. Because there is a high level of geopolymeric bonding between the geopolymer paste and aggregate in geopolymer concrete, none of the aggregate was taken out during testing when the cylinder was split in half. The chemical connection between the alkaline liquid and aggregate causes this [36,37].

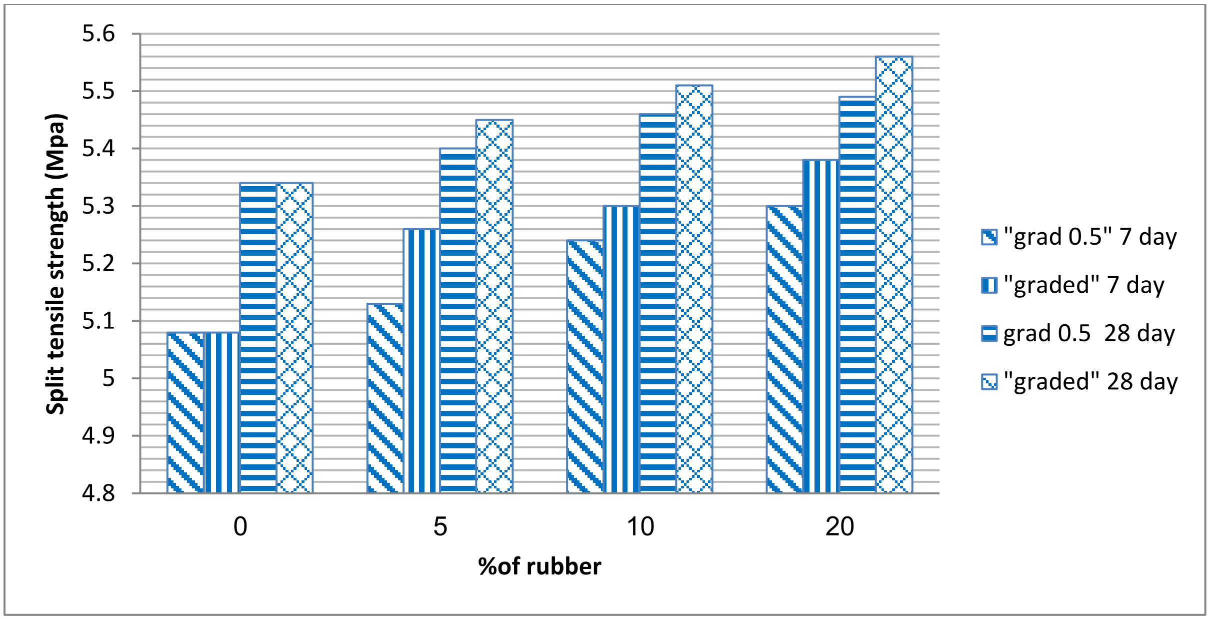

Fig 17 Split tensile strength of geopolymer mortar effected by Rubber percentage and sizes

2.5. 2.Concrete

In the beginning, a comparison was made between the percentage of the solution TO fly ash. As shown in the figure (17), a ratio of 0.4 is the best result, and a ratio of 0.6 is the weakest result, and this is due to an increase in the percentage of the solution in the mix.

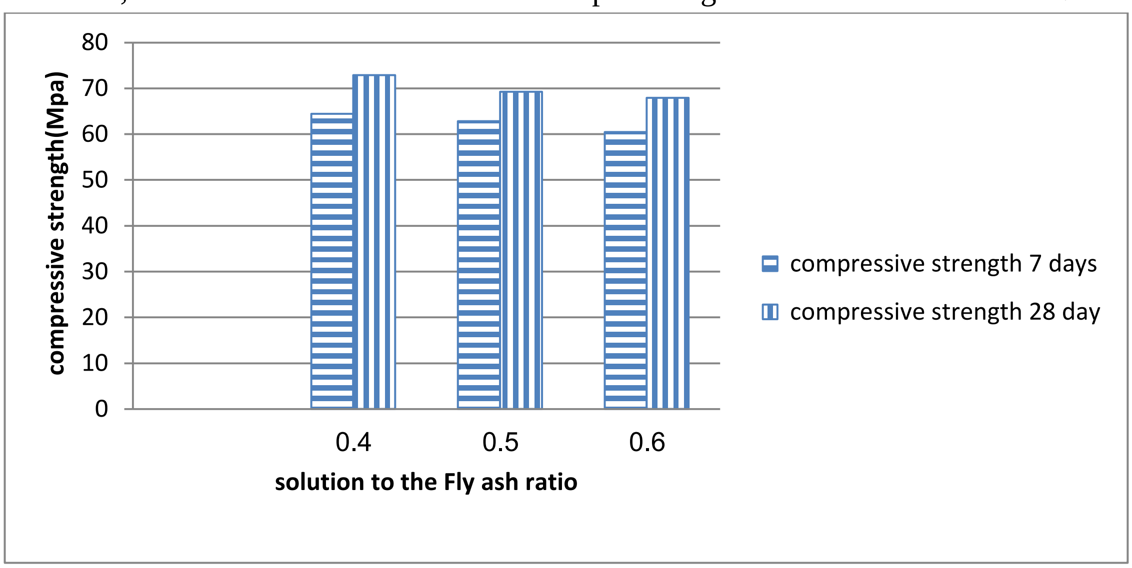

Fig 18 Compressive strength of geopolymer concrete effected by solution to the Fly ash ratio

As shown in the Fig (19), a ratio of 0.4 is the best result, and a ratio of 0.6 is the weakest result, and this is due to an increase in the percentage of the solution in the mix.

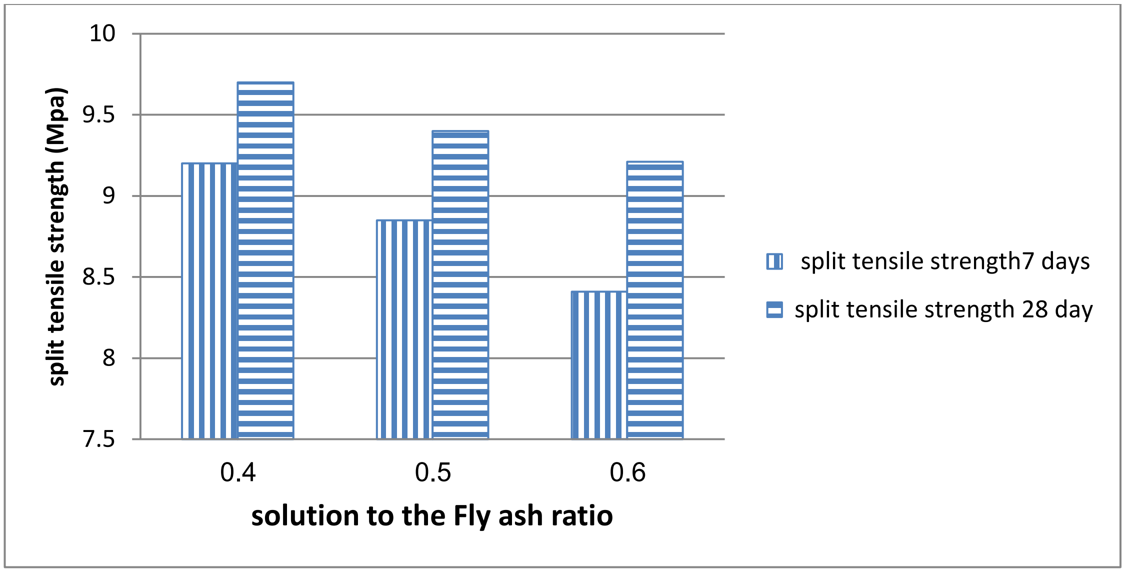

Fig 19 Split tensile strength of geopolymer concrete effected by solution to the Fly ash ratio

As shown in the Fig (20), a ratio of 0.4 is the best result, and a ratio of 0.6 is the weakest result, and this is due to an increase in the percentage of the solution in the mix.

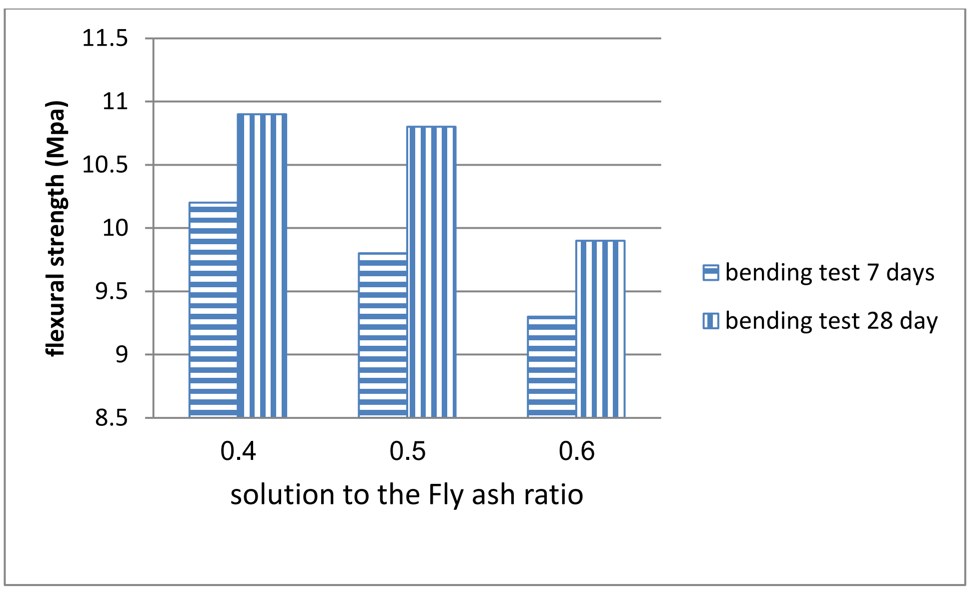

Fig. 20. Flexural strength of geopolymer concrete effected by solution to the Fly ash ratio

As shown in the Fig 21, a ratio of 0.4 is the best result, and a ratio of 0.6 is the weakest result, and this is due to an increase in the percentage of the solution in the mix. It was noticed during the work of the Flow Test that 0.4 is the lowest value in terms of operability and that 0.6 is the highest value for operability, and accordingly, a percentage of 0.5 was chosen

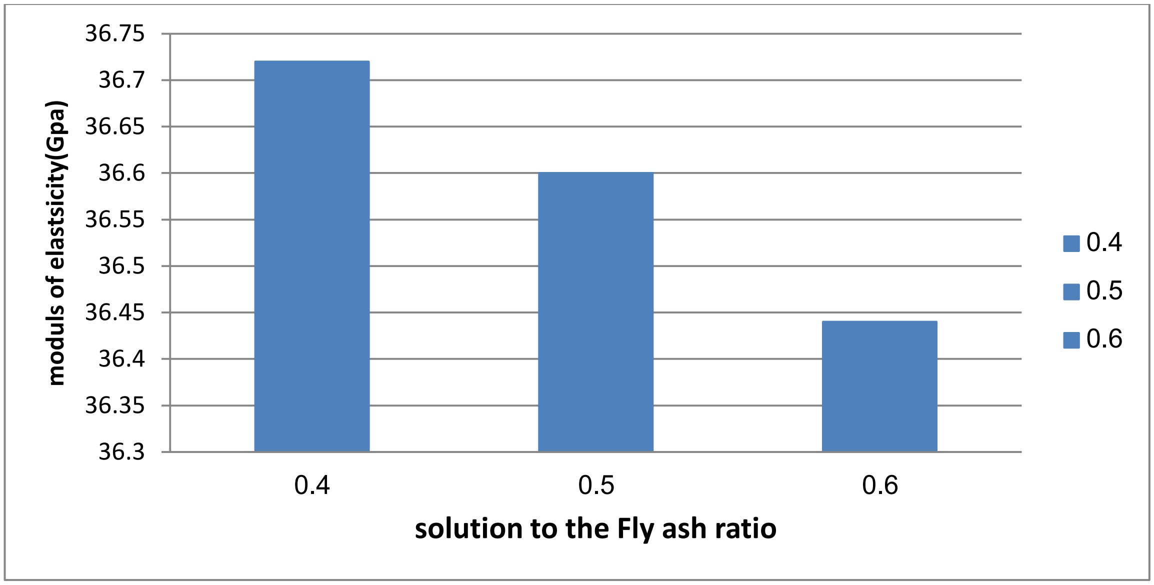

Fig 21 Modulus of elasticity for geopolymer concrete effected by solution to the Fly ash ratio

As shown in Fig 22, with the increase in the percentage of rubber, the resistance decreases and that the gradient mix of rubber is better than the mix with one gradation

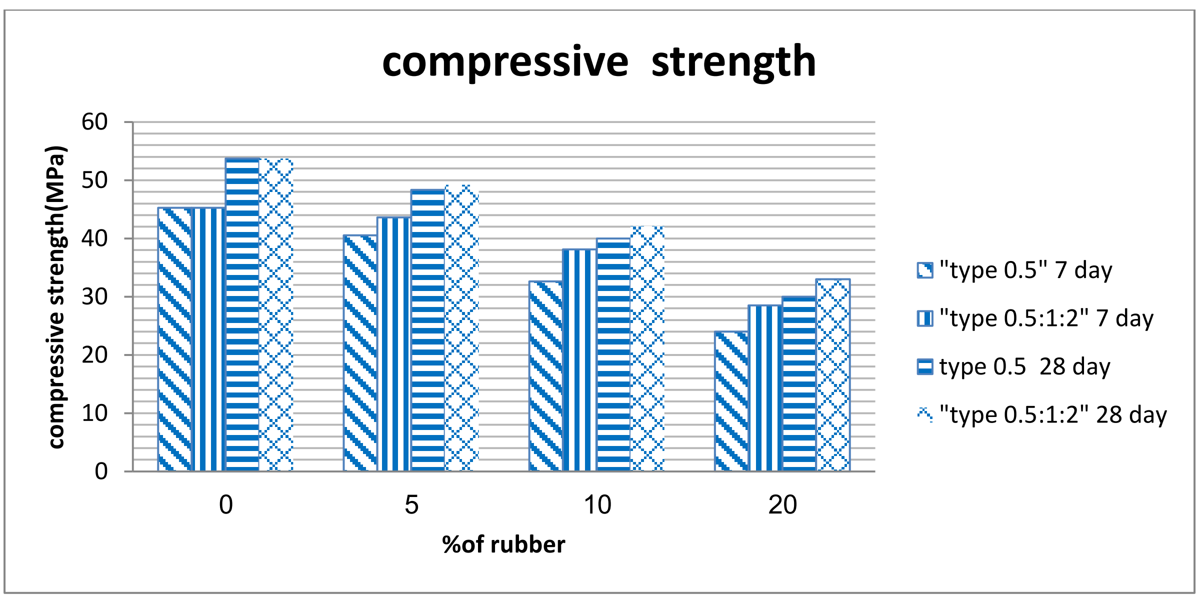

Fig 22 Compressive strength of geopolymer concrete effected by Rubber percentage and sizes

As shown in Fig 23, with the increase in the percentage of rubber, the bending resistance increases

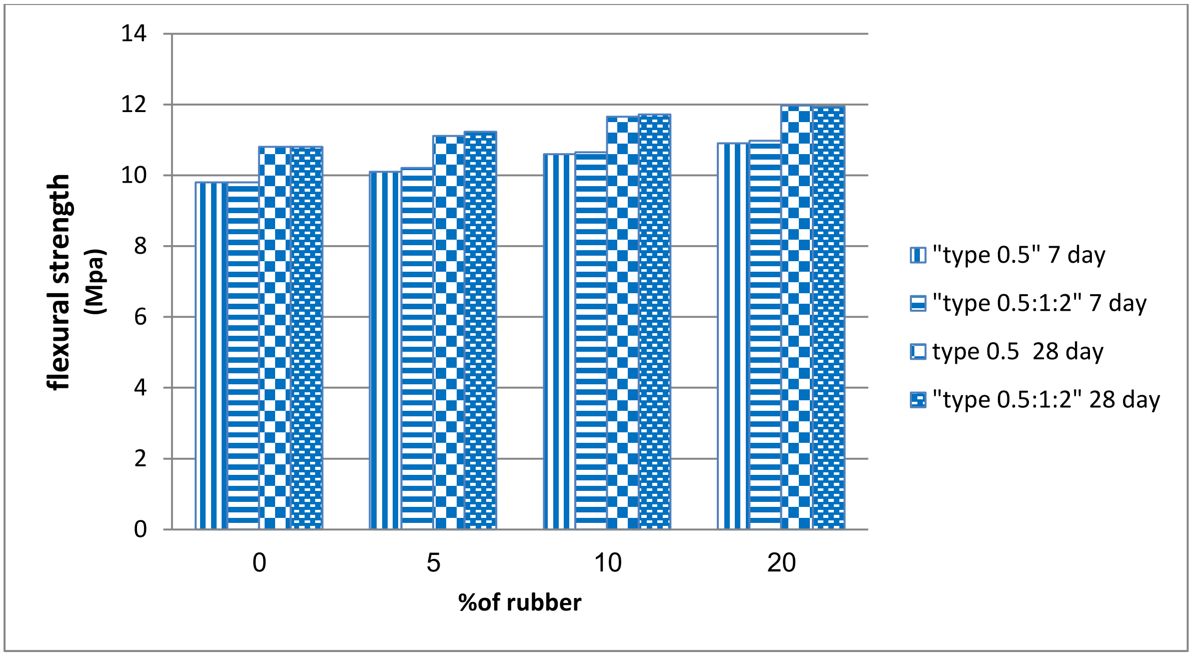

Fig. 23. Flexural strength of geopolymer concrete effected by Rubber percentage and sizes

shown in Fig 24, with the increase in the percentage of rubber, the Split tensile strength increases

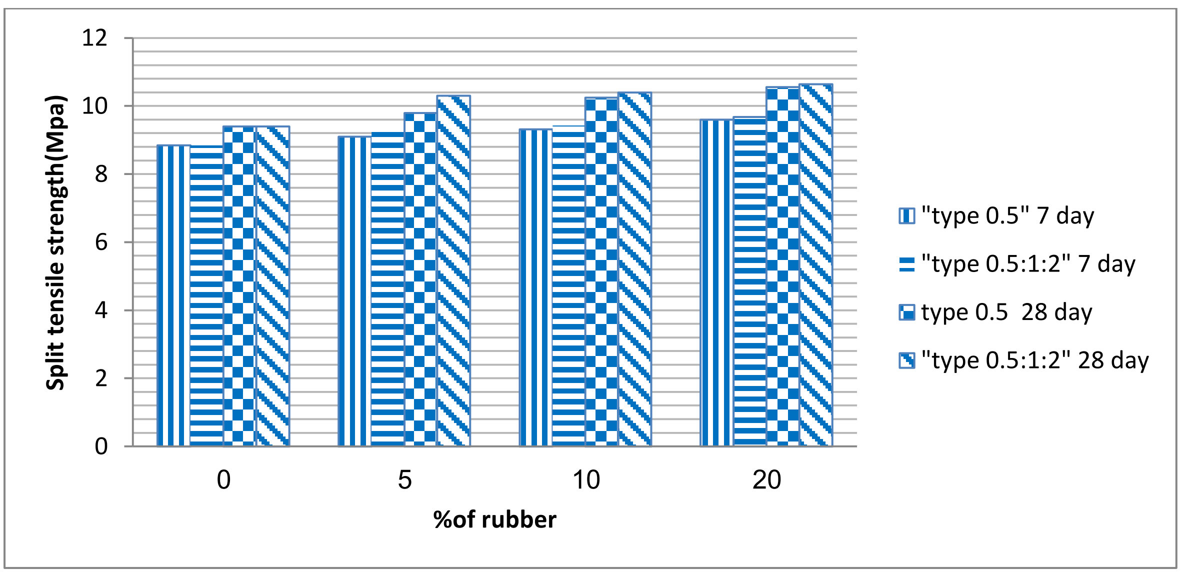

Fig 24. Split tensile strength of geopolymer concrete effected by Rubber percentage and sizes

as shown in figure 25, with the increase in the percentage of rubber, the Modulus of elasticity decreases

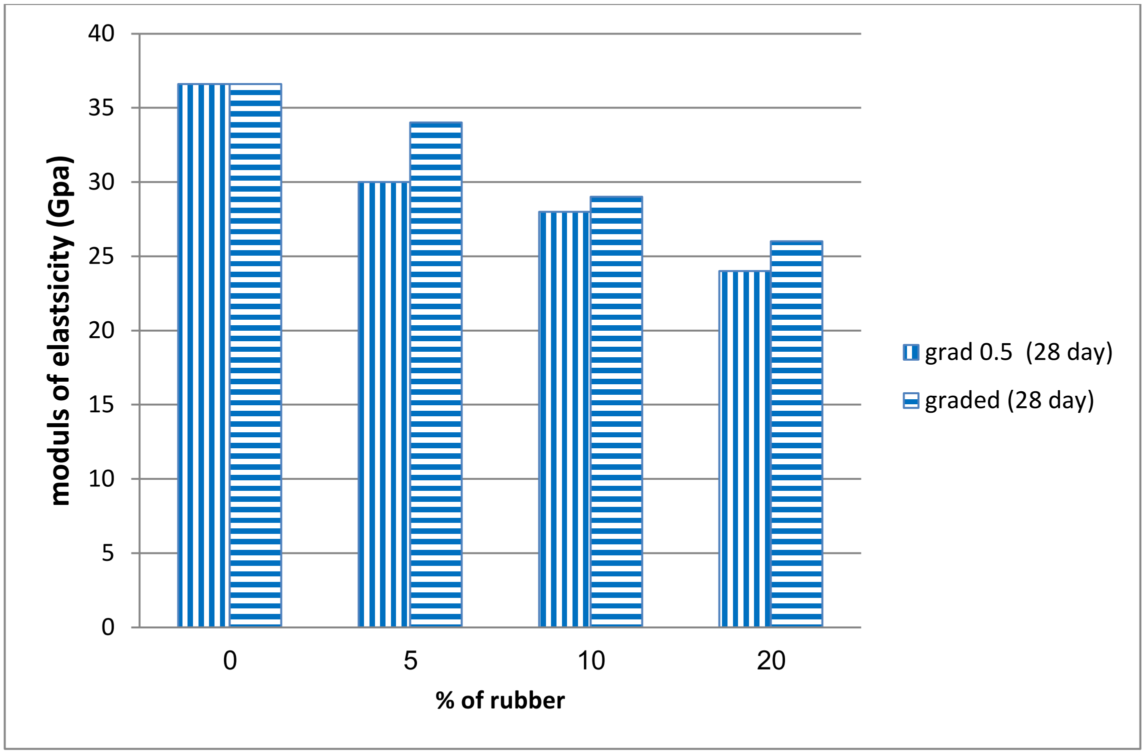

Fig. 25. Modulus of elasticity of geopolymer concrete effected by Rubber percentage and sizes

3.Conclusion

The following conclusions may be taken from the findings of this research:

1- With the increase in the percentage of rubber, the workability of concrete decreases

2- At all ages, the compressive strength falls as the proportion of waste rubber fibres increases.

3- the ratio of sodium silicate ($Na2SiO3$) to sodium hydroxide (NaOH), as the mixed activator, It has a great effect on of compressive strength.

4- Due to the excellent connection between the geopolymer paste and aggregate, the geopolymer concrete gradient rubber has a greater tensile strength than single gradient rubber.

5- As the proportion of rubber increases, the tension characteristics of rubberized geopolymer concrete, such as flexural and tensile strength, improve. When 20% of the sand was replaced with rubber, the highest flexural strength was found. This is due to the rubber, which act as a better bridge between cracks that have spread.

References:

[1] Habert, G. (2013). Environmental impact of Portland cement production. In Eco-efficient concrete (pp. 3-25). Woodhead Publishing.

[2] Taylor, M., Tam, C., & Gielen, D. (2006). Energy efficiency and CO2 emissions from the global cement industry. Korea, 50(2.2), 61-7.

[3] Singh, B., Ishwarya, G., Gupta, M., & Bhattacharyya, S. K. (2015). Geopolymer concrete: A review of some recent developments. Construction and building materials, 85, 78-90.

[4] Teh, S. H., Wiedmann, T., Castel, A., & de Burgh, J. (2017). Hybrid life cycle assessment of greenhouse gas emissions from cement, concrete and geopolymer concrete in Australia. Journal of Cleaner Production, 152, 312-320.

[5] Amran, Y. M., Alyousef, R., Alabduljabbar, H., & El-Zeadani, M. (2020). Clean production and properties of geopolymer concrete; A review. journal of cleaner production, 251, 119679.

[6] Nawy, E. G. (2008). Concrete construction engineering handbook. CRC press.

[7] Aly, A. M., El-Feky, M. S., Kohail, M., & Nasr, E. S. A. (2019). Performance of geopolymer concrete containing recycled rubber. Construction and Building Materials, 207, 136-144.

[8] Luhar, S., Chaudhary, S., & Luhar, I. (2019). Development of rubberized geopolymer concrete: Strength and durability studies. Construction and Building Materials, 204, 740-753.

[9] Moghaddam, S. C., Madandoust, R., Jamshidi, M., & Nikbin, I. M. (2021). Mechanical properties of fly ash-based geopolymer concrete with crumb rubber and steel fiber under ambient and sulfuric acid conditions. Construction and Building Materials, 281, 122571.

[10] Pham, T. M., Liu, J., Tran, P., Pang, V. L., Shi, F., Chen, W., ... & Tran, T. M. (2020). Dynamic compressive properties of lightweight rubberized geopolymer concrete. Construction and Building Materials, 265, 120753.

[11] M.Q.M:11.9, Specification for Coarse and Fine Aggregate from Natural Sources for Concrete, Egypt code 2018

[12] Luhar, S., Chaudhary, U. D., Dave, U. V., & Khandelwal, U. (2015, November). A brief review on geopolymer concrete. In 5th Nirma University International Conference on Engineering, Ahmedabad.

[13] E.C.B 203-2018 ", Concrete Mix Proportioning Guidelines." Egypt code. (2018).

[14] Luhar, S., & Khandelwal, U. (2015). Durability studies of flyash based geopolymer concrete. Int. J. Eng. Res. Appl, 5(8), 17-32.

[15] M.Q.M:1658, Methods of Tests for Strength of Concrete, Egypt code. (2018).

[16] Mohammed, B. S., Liew, M. S., Alaloul, W. S., Al-Fakih, A., Ibrahim, W., & Adamu, M. (2018). Development of rubberized geopolymer interlocking bricks. Case studies in construction materials, 8, 401-408.

[17] Wongsa, A., Sata, V., Nematollahi, B., Sanjayan, J., & Chindaprasirt, P. (2018). Mechanical and thermal properties of lightweight geopolymer mortar incorporating crumb rubber. Journal of Cleaner Production, 195, 1069-1080.

[18] Yahya, Z., Abdullah, M. M. A. B., Ramli, S. N. H., Minciuna, M. G., & Abd Razak, R. (2018, June). Durability of fly ash based geopolymer concrete infilled with rubber crumb in seawater exposure. In IOP Conference Series: Materials Science and Engineering (Vol. 374, No. 1, p. 012069). IOP Publishing.

[19] Park, Y., Abolmaali, A., Kim, Y. H., & Ghahremannejad, M. (2016). Compressive strength of fly ash-based geopolymer concrete with crumb rubber partially replacing sand. Construction and Building Materials, 118, 43-51.

[20] Sofi, A. (2018). Effect of waste tyre rubber on mechanical and durability properties of concrete–A review. Ain Shams Engineering Journal, 9(4), 2691-2700.

[21] Luhar, S., Chaudhary, S., & Luhar, I. (2019). Development of rubberized geopolymer concrete: Strength and durability studies. Construction and Building Materials, 204, 740-753.

[22] Standard, Indian. "IS 10262: 2009, Concrete Mix Proportioning Guidelines." Bureau of Indian Standards (2009).

[23] Patankar, Subhash V., Yuwaraj M. Ghugal, and Sanjay S. Jamkar. "Mix design of fly ash based geopolymer concrete." Advances in structural engineering. Springer, New Delhi, 2015. 1619-1634.

[24] Provis, John L., and Jan Stephanus Jakob Van Deventer, eds. Geopolymers: structures, processing, properties and industrial applications. Elsevier, 2009.

[25] Fernandez-Jimenez, Ana M., Angel Palomo, and Cecilio Lopez-Hombrados. "Engineering properties of alkali-activated fly ash concrete." ACI Materials Journal 103.2 (2006): 106.

[26] Benazzouk, A., Douzane, O., Langlet, T., Mezreb, K., Roucoult, J. M., & Quéneudec, M. (2007). Physico-mechanical properties and water absorption of cement composite containing shredded rubber wastes. Cement and Concrete Composites, 29(10), 732-740.

[27] Aamr-Daya, E., Langlet, T., Benazzouk, A., & Quéneudec, M. (2008). Feasibility study of lightweight cement composite containing flax by-product particles: Physico-mechanical properties. Cement and Concrete Composites, 30(10), 957-963.

[28] Hardjito, D., Wallah, S. E., Sumajouw, D. M. J., & Rangan, B. V. (2005, August). Introducing fly ash-based geopolymer concrete: manufacture and engineering properties. In 30th conference on our world in concrete & structures (Vol. 24).

[29] Olivia, M. (2011). Durability related properties of low calcium fly ash based geopolymer concrete (Doctoral dissertation, Curtin University).

[30] B.V. Rangan, Mix design and production of fly ash based geopolymer concrete, Indian Concr. J. (2008) 7–15

[31] Shetty, M. S., and A. K. Jain. Concrete Technology (Theory and Practice), 8e. S. Chand Publishing, 2019.

[32] Güneyisi, Erhan, Mehmet Gesoğlu, and Turan Özturan. "Properties of rubberized concretes containing silica fume." Cement and concrete research 34.12 (2004): 2309-2317.

[33] Khaloo, Ali R., M. Dehestani, and P. Rahmatabadi. "Mechanical properties of concrete containing a high volume of tire–rubber particles." Waste management 28.12 (2008): 2472-2482.

[34] Ganjian, Eshmaiel, Morteza Khorami, and Ali Akbar Maghsoudi. "Scrap-tyre-rubber replacement for aggregate and filler in concrete." Construction and building materials 23.5 (2009): 1828-1836.

[35] Reda Taha, Mahmoud M., et al. "Mechanical, fracture, and microstructural investigations of rubber concrete." Journal of materials in civil engineering 20.10 (2008): 640-649.

[36] Oikonomou, Nikolaos, and S. Mavridou. "Improvement of chloride ion penetration resistance in cement mortars modified with rubber from worn automobile tires." Cement and Concrete Composites 31.6 (2009): 403-407.

[37] Ozbay, Erdogan, Mohamed Lachemi, and Umur Korkut Sevim. "Compressive strength, abrasion resistance and energy absorption capacity of rubberized concretes with and without slag." Materials and structures 44.7 (2011): 1297-1307.