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A Comparison Study on the Tensile Strength of Fibreglass and Scrap Tire Strips

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Abstract: Scrap tires have been used in many geotechnical engineering projects such as soil improvement, soil erosion and slope stability. Scrap tires mainly in chip and shredded form are highly compressible under low and normal pressures. This characteristic would cause challenging problems in some applications such as retaining wall and river bank projects. Regards to the high tensile stress and low tensile strain of fibreglass, it would be a good alternative for scrap tire in some cases. To evaluate fibreglass as an alternative for scrap tire, this paper focused on two series of tensile tests which have been carried out on fibreglass and scrap tire strips. Fibreglass samples were produced from Chopped Strand fibber mat, a very low-cost type of fibreglass, which is cured by resin and hardener. Fibreglass samples in the thickness of 1 mm, 2 mm, 3 mm and 4 mm were developed 100 mm × 300 mm pieces. It was found that 3 mm fibreglass exhibited the maximum tensile load (MTL) and maximum tensile stress (MTS) greater than other samples. Statistical analysis on 3 mm fibreglass indicated that in the approximately equal MTL fibreglass samples experienced 2% while tire samples experienced 33.9% ultimate tensile strain (UTST) respectively. The results also showed an approximately linear relationship between stress and strain for fibreglass samples and Young's modulus (E), ranging from 3581 MPa to 4728 MPa.

Key words: Fibreglass · Scrap tire · Tensile Load · E modulus · Stress-strain curve

INTRODUCTION

Many countries are confronting the environmental problems posed by scrap tires and are seeking to identify useful economic techniques for managing these tires. Use of waste tires as a construction material would be a desirable solution to avoid the technical, economical and environmental issues of discarding them. According to many studies which address the civil engineering applications of scrap tires, these materials are normally grouped into three general categories: shredded, whole and bale tires [1]. Many studies reported good results when using shredded tire as construction material. A study to develop design procedures reported for using shredded scrap tires as a light-weight fill material in highway construction [2]. Another study presented some examples of projects in which tire shreds were used as light-weight fill for highway embankment construction, bridge abutment backfill, thermal insulation and drainage layers in landfills [3]. As for tire shredded as light weight material, a full-scale project carried out using tire shreds to reduce horizontal pressure in retaining walls [4]. Other researchers have focused on modifying clay soil with chip tires and ascertaining the engineering properties of the clay-tire composite [5-8]. Many others have performed studies on sand-tire mixtures [9-11].

Using whole tires is preferable to processing tires because less energy is required and less waste generated. In addition, construction could be performed using conventional techniques. Some case studies reported using whole tires in several projects focused on the role of negative wall friction in increasing the active thrust when the retaining wall becomes more compressible than the backfill [12]. Tensile strength of whole tires as a constructional material was subjected to the other study [13, 3] and finally, the results of chamber tests using whole tire as reinforcement in geotechnical engineering project was subjected to other study [14].

The use of tire bales is more suitable from the economical point of view as well as for using significant volume of scrap tires. A few studies have been presented on application of scrap bale tires in transportation projects and construction of road foundation on soft ground [15, 1].

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A review of literature indicated that the main concert of using scrap tires as soil reinforcement and slop stability element would be their high deformation characteristic. In some geotechnical engineering project such as retaining walls where limited amount of strain is required, this high deformation characteristic would a point of concern. Some studies indicated that tire chip–soil mixtures exhibit a significant initial plastic compression under loading and are highly compressible at normal low pressures [2,16,4]. Some other researches indicated that large strain ranged from 19.6% to 44 6% required to fully mobilizing the ultimate pull-out capacity [12].

Resolving the concern of utilizing scrap tire could be performed by employing a new material. Composite materials have been used for more than 50 years. Throughout the years, these materials have demonstrated superior properties to traditional materials and have been implemented in different domains [17]. A variety of composite materials have been examined, but polymeric matrix reinforced with fibbers is most commonly used for engineering structures. Glass fibbers are the most common choice of reinforcement and have been the object of many researches over the past 40 years [18-21]. A few studies have addressed applications of fibreglass in the field of geotechnical engineering. A new calculation procedure presented for the analysis of face reinforcement with fibreglass dowels in shallow tunnels. The main result of the calculation concerns the safety factor of the excavation face with dowel reinforcement. Based on this safety factor, it is possible to identify the appropriate length and number of dowels. The procedure has been applied to two real cases and satisfactory results have been obtained [22]. Significant of fibreglass pipe in soft native soil presented, in a case study, focusing on interaction between fibreglass and surrounding soil embedment [15]. Furthermore, the study of lateral behaviour of composite tapered piles in dense sand has been reported from the results of an experimental study [23]. However, to date there is no report on field application of fibreglass for soil improvement, soil erosion and slope stability. The unique properties of fibreglass including its affordability and cost effectiveness, strength, durability and light weight, make it suitable and desirable alternative for these purposes.

Since reinforcement elements must provide additional stability for the soil mass, its tensile strength is a key parameter that needs to be measured. This paper describes an experimental investigation of the tensile properties of strip samples of fibreglass and scrap tire. Then a comparison study carried out to show capability of fibreglass as an alternative to scrap tire.

Fig. 1: Instron 3690 series Actuator

Experimental Program

Tensile Test Machine: To address the requirements of section 6 of ASTM D 4595 [24], the Instron 3690 series Actuator with 250 kN loading capacity was used for performing tensile tests on fibreglass samples. This machine is a double acting, equal area hydraulic piston which can exert a tensile and compressive force. This machine is able to apply load on the sample with the speed of 0.5 mm/min-500 mm/min. Figure 1 is a photo of the Instron 3690.

Sample Preparation

Fibreglass: In this experimental investigation, tensile tests were performed on 1, 2, 3 and 4 layers fibreglass samples, with 1 mm, 2 mm, 3 mm and 4 mm thickness respectively. The samples were produced from Chopped Strand fibre mats (Figure 2) cured by resin and hardener. This type of fibreglass was chosen because of its low cost and properties which met all technical requirements (e.g. tensile stress and strain).

To develop fibreglass samples, the first step is to make a suitable mould. The mould can be made from variety of materials. These materials include wood, plaster, polyester resin, fibreglass, etc. In this study, we selected plywood 100 mm×300 mm as a mould. It should be noted that the finishing surface of mould must be very smooth. This will provide a smooth surface for final products. Meanwhile, this will help to release mould easily. The next stage is to apply Mould Release Wax, 3IlGMIRROR GLAZE WAX used in this study. This wax is in a paste form and has high carnauba content. Three thin coats of

Fig. 2: Chopped Strand Fibreglass

Fig. 3: Fiber glass sample under tensile test

Fig. 4: Tire sample under tensile test

wax were applied using a clean, lint free cloth by hand. It should be applied using an overlapping; circular motion to make sure wax covers all areas. Each layer of wax needs 30-40 min to dry. In the next step, resin (ISO PIITHALIC2834) and 1 %-2 % of hardener (MEKP LUPEROX DDM (F) - IIARDSI'CR) were mixed properly. Resin and hardener applied with a brush or a roller, full, even coverage. If it is not put on evenly, cure problems and premature release from the mould may result. Depending on the percentage of hardener and temperature, the mixture should be applied in at least 20 minutes. Once the mould was sufficiently covered with resin, the first layer of fibreglass was laid on and wet out with more resin. The next layers were added immediately on the previous wet layer. After all layers added on mould, it would be left alone for 30 minutes for partially cured, but still enough soft to be trimmed. After trimming, it was left for 24 hours before removing the mould from sample. Figure 3 shows fibreglass sample under tensile test.

Tensile tests were performed on developed 1, 2, 3 and 4 layers fibreglass samples, with 1 mm, 2 mm, 3 mm and 4 mm in thickness respectively

Tire: For comparison purposes, strip samples of scrap tire were also examined. Six samples of scrap tire were cut into 100 mm width× 300 mm length from whole scrap tires No.175/70R13 (Malaysian "Good Year" brand)(Figure 4).

The tests were carried out on both samples according to the ASTM D4595 [24]. The rate of strain was set to 10% per min according to section 10.3 of the standard. Furthermore, it should be noted that the ASTM D4595 standard was originally developed for tensile properties of geotextile with wide width strip, but the standard can be used for most geotextile, layered fibre, knit fibre, felts and scrap tire which are used in geotextile applications [24, 13].

Testing Program: Two series of tensile tests were carried out on the strip samples of fibreglass and tire as described in the standard and some required parameters were recorded automatically during the test and plotted in graph.

RESULT AND DISCUSSION

The tensile tests were performed on strip samples as described in Section 3.2. Five parameters, maximum tensile load (MTL), elongation at break, maximum tensile stress (MTS) and tensile strain (TST) and Young's modulus (E) were measured. The results of tensile tests on fibreglass are shown in Table 1.

According to Table 1, the MTL increases as thickness increases, for all thicknesses except 4 mm. The maximum MTL value, 27.65 kN, was obtained with a thickness of 3 mm. Increasing the thickness from 1 mm to 2 mm and from 2 mm to 3 mm results in MTL increase of 276% and 146.7% respectively. Thus, increasing rate of MTL decreases with thickness. It should be noted that in the following of this study thickness of 3 mm of fibreglass samples as optimum thickness have been subjected to further study.

The mean MTL for 3 mm samples is 23.1 kN, with standard deviation 2.92 kN. Statistical probability analysis carried out on the results shows that the probability of MTL greater than 15.34 kN is 99.7% and greater than 19.53 is 88.88%. The same method carried out in a study showed the same results on scrap tire strips [13].

A similar approach shows the mean value of TST at MTS is 0.02 mm/mm with 0 mm/mm standard deviation. This indicates that the probability of TST=0.02 mm/mm is 100%.

The stress-strain curves of samples numbers 13–18 from Table 1, shown in Figure 5, indicate that the relationship between stress and strain is approximately linear and Hook's law is valid for this material. Thus, to find the best relationship between σ (stress) and ε (strain), linear regression analysis was performed and the results are summarized in Table 2. The best fitting lines were obtained by zero value of intercept. The values of the coefficient of determination (R^2), greater than 96 indicate good linear relationship between σ and ϵ.

Table 1: The results of tensile test on the strip samples of fibreglass

Sample No	Thickness mm	MTL kN	Elongation at Break mm	MTS MPa	TST at MTS mm/mm	E modulus MPa
1	1	6.17	1.67	61.72	0.01	5249.67
2	1	3.3	2.6	33	0.01	5410.85
3	1	5.95	1.53	59.49	0.01	5834.75
4	1	5.66	1.45	56.57	0.01	5223.33
5	1	7.46	2.46	74.64	0.02	4783.91
6	1	5.7	1.47	57	0.01	5300.31
Mean	1	5.7	1.86	57.07	0.01	5300.5
Standard deviation	--	1.35	0.52	13.53	0.004	338.52
7	2	15.07	2.3	75.33	0.02	5069.27
8	2	18.46	2	92.3	0.02	6296.84
9	2	15.53	2.49	77.66	0.02	4759.39
10	2	17.14	2.63	85.68	0.02	5204.81
11	2	11.96	2.06	59.81	0.01	4687.17
12	2	16.3	2.52	81.5	0.02	5203.17
Mean	2	15.74	2.33	78.71	0.02	5203.4
Standard deviation		2.21	0.26	11.05	0.004	579.18
13	3	24.97	2.34	83.25	0.02	4768.65
14	3	23.31	1.52	77.7	0.02	-
15	3	20.86	2.28	69.52	0.02	4218.8
16	3	27.65	2.73	92.18	0.02	4438.63
17	3	19.53	2.44	65.09	0.02	3701.6
18	3	22.23	2.48	74.1	0.02	4324.12
Mean	3	23.1	2.30	77.0	0.02	4290.36
Standard deviation	0	2.92	0.41	2.75	0	388.47
19	4	18.68	1.56	46.71	0.01	3969.79
20	4	21.7	1.61	54.26	0.01	4139.66
21	4	18.57	3.7	46.43	0.01	4505.15
22	4	24.08	1.81	60.21	0.01	5241.41
23	4	25.88	2.01	64.7	0.01	5124.82
24	4	23.1	1.95	57.75	0.01	4673.50
Mean	4	22.00	2.11	55.01	0.01	4609.06
Standard deviation	0	2.95	0.80	7.36	0	511.83

Table 2: The relationship between σ and ε

Sample No	Equation	R^2(%)
13	σ=4728ε	98.9
14	σ=39648ε	99.1
15	σ=4106ε	98.9
16	σ=4453ε	96.7
17	σ=3642ε	98.2
18	σ=3581ε	97.4

Table 3: The results of tensile test on the strip samples of tire

Sample No	Thickness (cm)	MTL kN	Elongation at Break mm	MTS MPa	TST at MTS mm/mm	E-modulus MPa
1	10.88	19.49	38.04	17.91	0.09	174.65
2	11.20	21.33	36.53	19.04	0.10	170.53
3	10.47	20.66	45.1	19.73	0.11	168.34
4	10.34	20.47	43.5	19.8	0.12	158.17
5	11.23	24.67	37.75	21.96	0.13	155.39
6	11.24	19.82	45.89	17.63	0.10	168.72
Average	10.89	21.07	41.13	19.04	0.108	165.96
Standard deviation	0.40	1.87	4.15	2.01	0.014	7.5

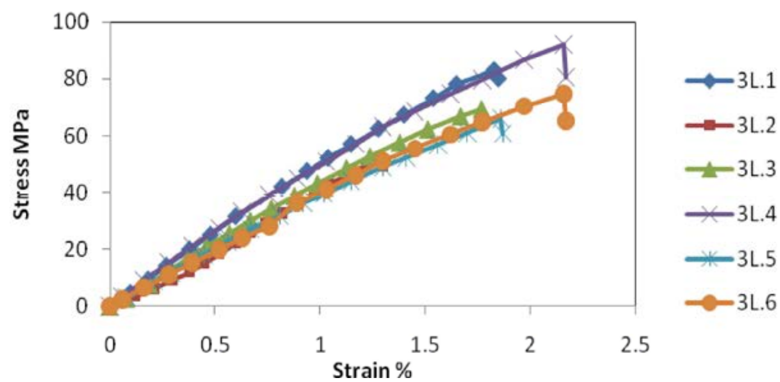

Fig. 5: Stress- strain cure for fibreglass strip

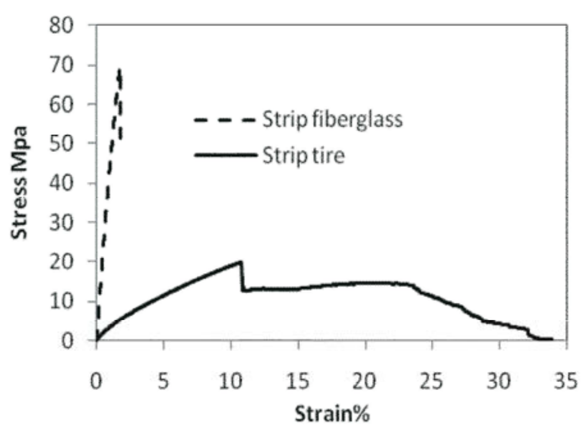

Fig. 6: The stress-strain curve for fibreglass sample No.15 and tire sample No. 3

The slope of equations in Table 2 shows the E-modulus of fibreglass samples, which ranges from 3581 MPa to 4728 MPa. These values are similar to those reported in Table 1.

The tensile test results for strip tire are shown in Table 3. The mean value of MTL and its standard deviation are 21.07 kN and 1.87 kN respectively. The statistical analysis indicates that the probability of MTL greater than 19.2 kN is 99.7 % and greater than 18.79 is 88.88 %. A Reported result showed that the probability of tensile strength greater than 20 kN was 88.88% [13]. The difference in the results could be due to the effect of scrap tire condition, which was used in two studies. The probability of TST at MTS greater than 0.094 mm/mm is 99.7 %.

The stress- strain curve is plotted for fibreglass sample No.15 (Table 1) and tire sample No. 3 (Table 3) in Figure 6. These two samples have approximately equal MTL, while the MTS is 68.4 MPa and 17.92 MPa for fibreglass and tire, respectively. On the other hand, the MTS in fibreglass is 3.82 times greater than tires. The tire sample experienced a very high strain at the ultimate point, 33.9%, which is 16.94 times greater than fibreglass. This high deformation capacity may cause many problems in geotechnical engineering projects. It should be noted that the compressibility may be more critical particularly when higher value of shredded and chipped tires subjected to low normal pressure [25, 11]. Thus, the high tensile stress capacity in addition to low tensile strain characteristic of fibreglass could be a key parameter to control deformation in some geotechnical projects such as retaining-wall and riverbank projects.

CONCLUSION

This study presents a new use of fibreglass in geotechnical engineering. To determine the suitability of this material in this field, tensile tests were conducted on fibreglass strips. Since scrap tires are a very useful material in geotechnical engineering field, a comparison analysis performed between tensile properties of the fibreglass and tire samples. The results of this study are summarized as follows:

- By increasing the thickness from 1 mm to 2 mm and from 2 mm to 3 mm, MTL increases 276% and 146.7%, respectively. Thus, the increasing rate of MTL decreases with thickness.
- The maximum value of MTL is 27.65 kN, obtained with a thickness of 3 mm.
- The MTL of fibreglass is 15.34 kN with 99.7 % probability. Its TST at MTS is 0.02 mm/mm.
- The stress-strain relationship is approximately linear and the Young's modulus of fibreglass samples (3 mm thickness) ranges from 3581 MPa to 4728 MPa.
- The MTS is 68.4 MPa and 17.92 MPa for fibreglass and tire, respectively. In contrast, tire sample has experienced a very high value of strain, 33.9%.
- The high tensile stress capacity and low tensile strain characteristic of fibreglass will make it very suitable material to control deformation in geotechnical engineering projects such as retaining-wall and riverbank projects

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