Development of Low Cost Soil Stabilization Using Recycled Material

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Abstract. Recycled tyres have been used in many geotechnical engineering projects such as soil improvement, soil erosion and slope stability. Recycled tyres mainly in chip and shredded form are highly compressible under low and normal pressures. This characteristic would cause challenging problems in some applications of soil stabilization such as retaining wall and river bank projects. For high tensile stress and low tensile strain the use of fiberglass would be a good alternative for recycled tyre in some cases. To evaluate fiberglass as an alternative for recycled tyre, this paper focused on tests of tensile tests which have been carried out between fiberglass and recycled tyre strips. Fibreglass samples were produced from chopped strand fibre 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 x 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 tyre 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.

Keywords: Recycled tyre, fibreglass, tensile load, e modulus, stress-strain curve.

1. Introduction

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

Many others have performed studies on sand-tyre mixtures [9-11]. Some studies indicated that tyre chip-soil mixtures exhibit a significant initial plastic compression under loading and are highly compressible at normal low pressures [2,4]. Some other researches indicated that large strain ranged from 19.6% to 44 6% required to fully mobilizing the ultimate pull-out capacity [12].
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 recycled tyre. Then a comparison study carried out to show capability of fibreglass as an alternative to recycled tyre.

2. Experimental
To address the requirements of section 6 of ASTM D 4595 [13], 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. 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 fiberglass was chosen because of its low cost and properties which met all technical requirements (e.g. tensile stress and strain).

Figure 1. Instron 3690 series Actuator.  Figure 2. Chopped Strand Fibreglas.

Figure 3 shows fibreglass sample under tensile test, and The fibre strip were performed on developed fibreglass of 1, 2, 3 and 4 layers with 1 mm, 2 mm, 3 mm and 4 mm in thickness respectively. Tyre: For comparison purposes, strip samples of recycled tyre were also examined. Six samples of recycled tyre were cut into 100 mm width by 300 mm length from whole recycled tyres No.175/70R13 (Malaysian “Good Year” brand)( Fig 4).

Figure 3. Fiber glass sample under tensile test.  Figure 4. Tyre sample under tensile test.
3. Result And Discussion
The tensile tests were performed on strip samples where five parameters, maximum tensile load (MTL), elongation at break, maximum tensile (MTS) and tensile strain (TST) and Young's modulus (E) were measured. The results of tensile tests on fiberglass 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 fiberglass 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 recycled tyre strips [14]. A similar approach shows the mean value of TST at MIS 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 and as shown in Fig. 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 E (strain), linear regression analysis was performed and the best fitting lines were obtained by zero value of intercept. The values of the coefficient of determination (R2) greater than 96 indicate good linear relationship between σ and E. 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 where these can control the soft soil underneath.

| 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                   | 63.72   | 0.01            | 5249.67     |
| 2         | 1            | 3.3    | 2.0                    | 33      | 0.01            | 5410.85     |
| 3         | 1            | 5.95   | 1.53                   | 50.49   | 0.01            | 5884.75     |
| 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            | 5009.27     |
| 8         | 2            | 18.46  | 2.6                    | 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            | 4708.65     |
| 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 | 0.292 | 0.41 | 2.75 | 0.0 | 388.47 |
| 19        | 4            | 18.68  | 1.56                   | 46.71   | 0.01            | 3909.79     |
| 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            | 4673.59     |
| Mean      | 4            | 22.00  | 2.11                   | 55.03   | 0.01            | 4609.06     |
| Standard Deviation | 0.295 | 0.80 | 7.36 | 0.0 | 511.83 |
Conclusion

This study presents a new use development of fibreglass in geotechnical engineering. To determine the suitability of this material in this field, tensile tests were conducted on fibreglass strips. Since recycled tyres are a very useful material in geotechnical engineering field, a comparison analysis performed between tensile fibreglass and tyre samples. The results of this are as in Fig. 5. 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 as shown in Fig. 6. 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 tyre respectively. In contrast, the tyre 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 in solving soft soil problem. This was then developed into 8 Shape Mat to solve problem in geotechnical applications.

References
[1] Zorenberg J G, Christopher R B and LaRocquc C J, 2004 Application of Tyre Bale in Transportation Projects. J. Recycled Materials in Geotechnics 42-60.
[2] Bosscher P J, Edil T B and Kuraoka S, 1997 Design of Highway Embankments Using Tyre Chips. Journal of Geotechnical and Geoenvironmental Engineering 123(4) 295-304.
[3] Humphrey D N, 1999 Civil engineering application of tyre shreds, Proceedings of the Tyre Industry Conference, Clemson University, South Carolina, 3-5.
[4] Humphrey D N, and Manion W P, 1992 Properties of Tyre Chips for Lightweight Fill. Proceedings of Grouting, Soil Improvement and Geosynthetics, 1344-1355.
[5] Akbulut S, Arasan S and Kalka E, 2007 Modification of clayey soils using recycled tyre rubber and synthetic fibers. Applied Clay Sci, 38 23-32.
[6] Cetin H, Fener M and Gunaydin O, 2006 Geotechnical properties of tyre-cohesive clayey soil mixtures as a fill material. Engineering Geol, 88(1-2) 110-120.
[7] Dai J C, and Huang J T, 1999 Surface of clays and clay-rubber composite Sci, 15(1-2) 51-65.
[8] Marefat V and Soltani-Jiagheh H, 2011 Laboratory Behavior of Caly-Tyre Mixture. Worl Applied Sciences J, 13(5) 1035-1041.
[9] Christ M, and Park J B, 2010 Laboratory determination of strength properties of...
[10] Hataf N, and Rahimi M M, 2006 Experimental investigation of bearing capacity of sand reinforced with randomly distributed tyre shreds. Construction and Building Materials, 20(10) 910-916.
[11] Rao G V and Dutta R K, 2000 Compressibility and Strength Behaviour of Sand-tyre Chip Mixtures. J. Geotechnical and Geotechnical and Geological Engineering, 24(7) 11-724.
[12] O’Shaughnessy V and Garaga V K, 2000 Tyre-reinforced earthfill. Part 2: Pull-out behavior and reinforced slope design Canadian Geotechnical Journal, 37 97-116.
[13] ASTM, D4595-05. Standard Test Method for Tensile Properties of Geotextile by the Wide-Width Strip Method (2007)
[14] Huat B B K, Aziz A A and Chuan L W, 2008 Application of Scrap Tyres as Earth Reinforcement for Repair of Tropical Residual Soil Slope, Electronic J. Geotechnical Engineering, 13.