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Stabilization of Highway Embankment Using Stabilized Cohesive Frictional Soil with Shredded Scrap Tire

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ABSTRACT

Limitation of exceptional construction sites, particularly due to fast growing of human population and economic development is common nowadays in Malaysia. Utilization of waste materials, which are lightweight, was one of the possible solutions that can be used to solve bearing capacity and settlement problems of embankments on soft compressible soil. It has been found that the utilization of tire shreds in highway construction offers economic and environmental benefits. Research focused on the determination of physical and engineering properties of stabilized cohesive frictional soils using shredded scrap tires. Laboratory tests according to British Standard 1377 were performed on untreated cohesive frictional soil, 100% shredded tire and mixtures of the soil and shredded tire by ratios of 90%-10%, 70%-30%, 50%-50%, 30%-70% and 10%-90%. Results show that admixtures of soil and shredded tires by ratio of 70%-30% give highest improvement in term of shear strength parameters with 23% improvement of internal friction angle compared to the untreated cohesive frictional soil with 31º of internal friction angle. Mixtures of 50%-50% produced the best lightweight mixtures with internal friction angle value was 34º and the maximum dry density was 44% lower compared to the untreated soils respectively.

Keywords: *Stabilized soil, shredded scrap tires and shears strength.*

Introduction

Since the last decade, there has been considerable interest in the use of industrial waste as fills for engineering purpose. Reusing industrial waste instead of excavating and hauling natural soils and rocks is obviously beneficial to the aspect of cost and environment if necessary precautions are taken prior to its use. The properties of the waste material should be initially analysed, both originally and in state of mixture with soil for possibilities of better landfill material and soil or groundwater contamination. Examples of industrial by products that are currently being used for geotechnical purpose are foundry sands, paper mill sludge, plastics, fly ash and shredded tire.

Used tire is one of the most abundantly available waste materials nowadays due to the rapid development in automotive industry. Statistics for Malaysia indicated more than 100% increment in number of registered vehicles within ten years. Consequently, Malaysian Government has to deal with difficulties in managing huge amount of solid wastes produced by industries and domestic users. Malaysian industries produced 14,685,500 of pneumatic tires and 17,755,500 of inner tubes, while importing tires worth RM248.7 million in a sole year 2000. Of that, tire replacement market average is 1,257,000 pieces per month, with 35-40% goes to retread market and 65-70% for disposal dumping or other use (JPM, 2000). Discarded tires normally require almost hundred years to be completely decomposed. Thus, researchers were directed towards finding potential reuse of these materials. Several previous researchers indicated the potential of utilizing waste tires as construction materials (Edil and Benson, 1996; Chien-Jen and Shakoor, 1997; Vilupanandan and Basheer, 1998; Humphrey et al., 2000).

Although the use of shredded tires as lightweight fill is not very popular in Malaysia, it is indeed effectively used in other countries. In Minnesota, the shredded tires are used to build logging roads in order to overcome the problem of poor soils as depicted in the following figures. When used as road base, shredded tires significantly improve the drainage below the pavement and therefore extend the life of the roadway. Being elastic, shredded tires can also ease the constructions of the road and are beneficial for the roadway loads over unstable soils.

Research done by Chein-Jen (1998) show that the soil mixes with less than 30% of shredded tire material would meet the requirement for roadway embankment. Therefore, it will be suitable for the construction of roadway embankment. For example, in 1992, the Virginia Department of Transportation (VDOT) utilized more than 2 millions shredded tire in overpass embankment. The overpass project on State Route 199, near Interstate 64, used a mixture of shredded tires and soil to build 6 m highway embankments (Hughes, 1993).

Shredded scrap tires have many beneficial engineering properties such as lightweight, strong and durable. Shredded tires normally utilized as fill material for highway construction over soft ground. It's also improved the drainage below the pavement and therefore should extend the life of the roadway. The shredded tires also elastic and helps the constructions of the road. The lighter materials help in minimizing the foundation requirements, reduce land cutting for mountainous area, reduce settlements and prolong the life of landfill area (Ghani et. al, 2002). In the analysis of a retaining wall, mixture of 70% sand and 30% shredded tires contribute in reducing pressure on bearing capacity and total vertical pressure of approximately 29% and 21% respectively (Anas et. al., 2005). Figure 1 and 2 show the different 3 types of embankment configuration that has been used in construction (Vipulanandan & Basheer et al., 1998).

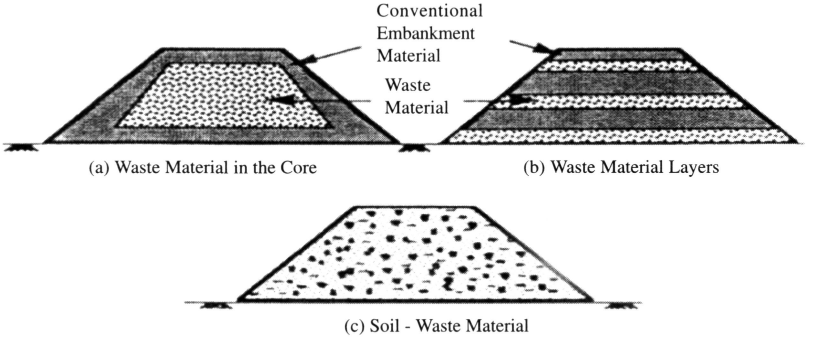

Figure 1: Different Embankment Configurations (Vipulanandan & Basheer, 1998)

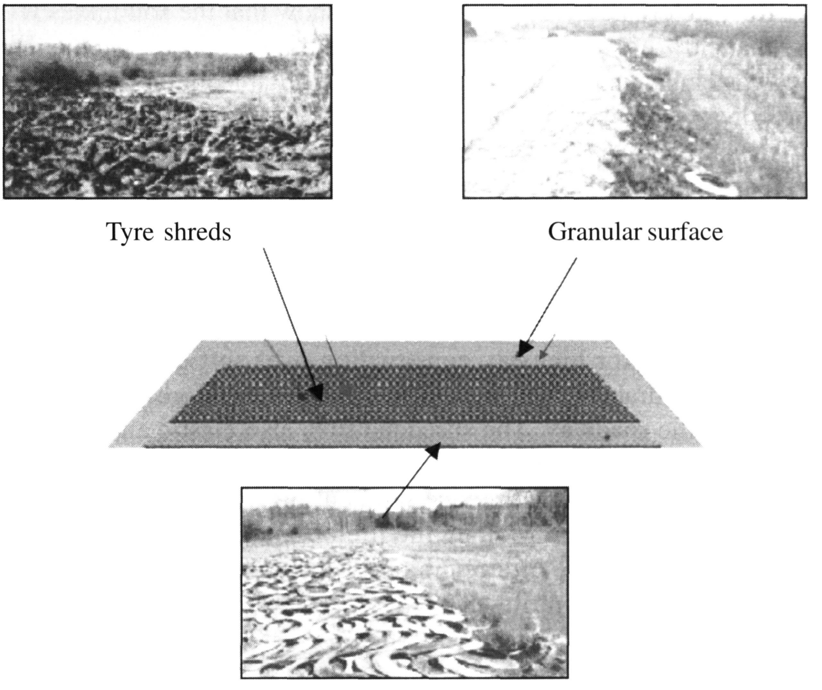

Figure 2: Construction of Road Base with Shredded Rubber Tires (Hughes, 1993)

Laboratory Procedures

Physical and Engineering Properties of Cohesive Frictional Soil

Cohesive frictional soil is defined as material containing more than 10% particles passing through B.S sieve with dimension of 63 μm and frictional angle, Φ of $\geq 20^{o}$ (DTp, 1987). In addition, cohesive frictional soil is also known as material having ≥ 52 μm dimension, liquid limit of $\leq 45\%$ and plasticity index of $\leq 20\%$. Moisture content of the soil in between 6 and 10% is acceptable, since it facilitates the construction works and structural stability. In United Kingdom, suitable fill materials should have the effective angle of internal friction of cohesionless soil, $\phi' \geq 25^{o}$ (Jones, C. J. F. P., 1996).

Tests were performed according to the British Standard, BS 1377 (1990) in order to determine the properties of cohesive frictional soils. The parameters that are related with basic physical and engineering characteristic of cohesive soils which is specific gravity, consistency limit, maximum dry density, optimum moisture content, particles size distribution, permeability and shear strength were obtained from the laboratory test. Results of untreated cohesive frictional soil are summarized as in Table 1 below:

Table 1: Properties of Cohesive Frictional Soils

Engineering properties	Cohesive frictional soil
Maximum dry density (Mg/m^3)	1.8
Optimum moisture content (%)	26.57
Internal frictional angle (^{o})	31
Liquid limit (%)	26.05
Plastic index (%)	<20
Coefficient of permeability (K) (mm/s)	0.242 x 10^{-5}
Specific gravity	2.64
Percentage of passing sieve (B.S 63 μm) (%)	61.00

Properties of Shredded Waste Tires

In this study, shredded tires without wire mesh or steel were used. Tires were shredded to sizes using tire shredder machine. Plate 1 below shows the shredded tires (7 mesh) and Figure 3 shows the particle size distribution of tires compared to the Public Work Department (PWD) grading limits of material for replacement of unsuitable material. From the graph of Figure 3, the (7 mesh) shredded tires were called uniformly graded materials with the coefficient of uniformity value was 1.90 < 4.0.

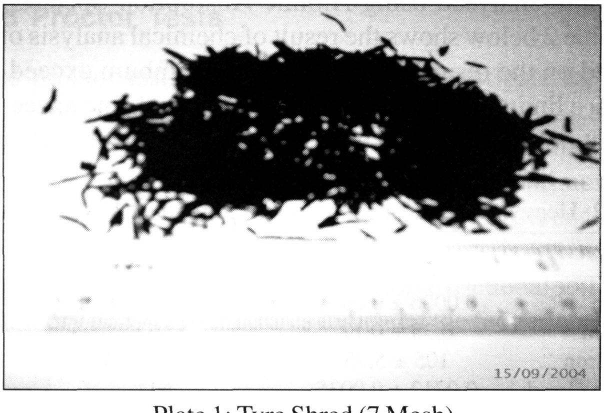

Plate 1: Tyre Shred (7 Mesh)

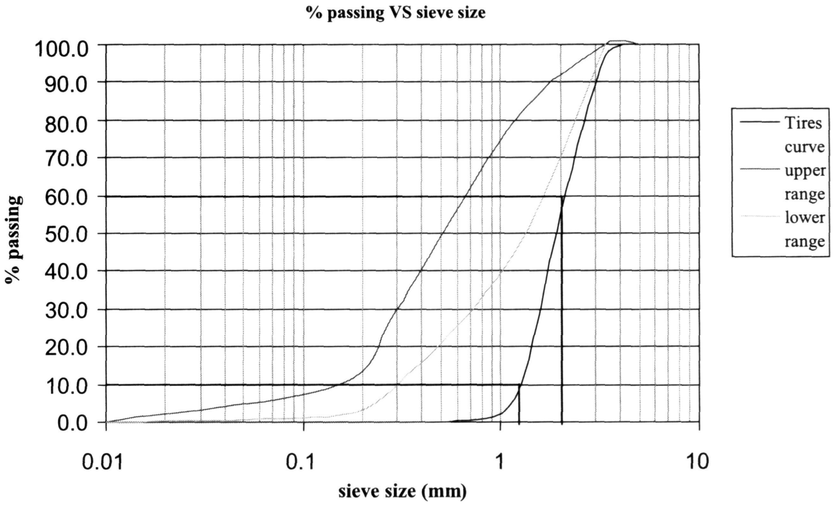

Figure 3: Particle Size Distribution Curve for 100% Tire Compared with PWD (JKR, 1988) Grading Limits of Material for Replacement of Unsuitable Materials

Chemical analysis was conducted on the shredded waste tire to investigate the concentration of heavy metals in shredded tyres and the leachates. Leachates are liquids produced by degradation process (anaerobic) and usually contained a very high pollution matters (Vesilind P. A. & Susan M.M., 2004). Tests were done purposely to investigate whether the concentration of heavy metals from shredded tyres exceed the tolerance limit as per Minnesota Pollution Control Agency (MPCA). Samples were analysed using Atomic Absorption Spectrophotometer (AAS). Table 2 below shows the result of chemical analysis on shredded tires. Based on the results from AAS test, plumbum exceed 40% from the tolerance limit, chromium exceeds 37.5%, and zinc exceeds 11772% and the rest of heavy metals substances were below the tolerance limit.

Table 2: Heavy Metals Concentration in Shredded Waste Tires ($\mu g/g$)

Element	Shredded tires	Leachate	MPCA
Cadmium	0.0006 ± 0.0001	0.0005 ± 0.0002	0.13
Chromium	0.33 ± 0.12	ND	0.24
Ferum / Iron	105 ± 5.75	79 ± 10.94	500
Plumbum / Lead	0.0712 ± 0.0035	ND	0.05
Zinc	2790 ± 658	0.08 ± 0.01	23.5

Results and Analysis

Classification of the Soils and Mixtures

The results of particle size distribution for all mixtures are shown in Table 3 and in Figure 4. According to the British Standard Soil Classification System, the soil is classified as well graded soil if the value of coefficient of uniformity greater than 3 (Whitlow, 2004). Otherwise the soil is considered as poorly graded or uniformly graded. Results show that the mixtures between 30% of soil and above were considered as well graded soils with the C_u values more than 3. However, mixtures of 10% soils + 90% shredded tires and 100% shredded tires were considered as uniformly graded soils.

Table 3: Grading Characteristics for Cohesive Frictional Soil, Shredded Tyre and Their Mixtures

Soil sample	Effective size, d_{10}	Effective size, d_{60}	Uniformity coefficient, $C_u = \frac{d_{60}}{d_{10}}$
100% soil	0.116	0.722	6.22
90% soil+10% tire	0.118	0.907	7.68
70% soil+30% tire	0.145	1.329	9.16
50% soil+50% tire	0.201	1.586	7.89
30% soil+70% tire	0.339	1.848	5.45
10% soil+90% tire	1.021	2.190	2.14
100% tire	1.343	2.552	1.90

Standard Proctor Tests

A standard proctor tests were performed to investigate the maximum dry density and the optimum water content of samples. Results show that the value of maximum dry density reduced when a portion of shredded tires amount were increased. However, the optimum moisture content of all mixtures didn't have a significant differences with the average value of all mixtures is 15.2%. The value is 8% less than the optimum moisture content of untreated cohesive frictional soil. Reduction of maximum dry density of mixtures indicated the reduction in weight of materials.

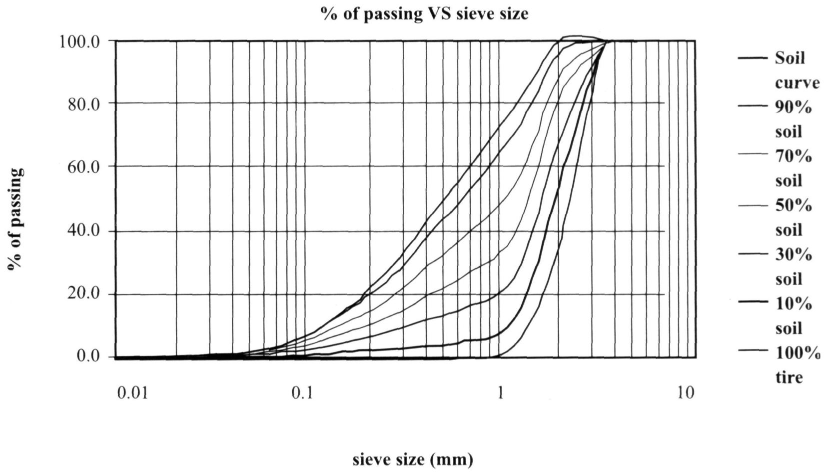

Figure 4: Comparison of Sieve Analysis for All Mixtures, Untreated Cohesive Frictional Soils and 100% Shredded Tires

Table 4: Maximum Dry Density and Optimum Moisture Content for Cohesive Frictional Soil and Shredded Tire

Soil sample	Maximum dry density (Mg/m^3)	Optimum moisture content (%)
100% soil	1.8	16.52
90% soil + 10% tire	1.6	14.60
70% soil + 30% tire	1.3	15.00
50% soil + 50% tire	1.0	15.50
30% soil + 70% tire	0.8	15.40
10% soil + 90% tire	0.6	15.50
100% tire	0.5	15.50

Shear Box Test

Shear box test were conducted according to BS 1377 (1990) to investigate the shear strength parameters of samples. According to the table 5 below, internal friction angle for mixtures of 90% soils, 70% and 50% soils increased compared to the untreated cohesive frictional soils. The highest improvement is around 23% increment for mixtures 70% soils + 30% shredded tires with 38° of internal friction angle. Shredded tires produced the lowest value of internal friction angle, which was 22°.

Table 5: Internal friction angle and cohesion value for the untreated cohesive frictional soils, mixtures and shredded scrap tire

Soil sample	Internal friction, ϕ angle (^{o})	Cohesion, c (kPa)
100% cohesive frictional soil	31°	9
90% soil + 10% tire	34°	18
70% soil + 30% tire	38°	14
50% soil + 50% tire	34°	17
30% soil + 70% tire	28°	10
10% soil + 90% tire	27°	11
100% shredded tire	22°	14

Discussions and Conclusion

Results from physical and engineering properties show the great potential of shredded scrap tires as replacement materials for backfills. Mixture of 70% soil + 30% shredded tires performed better compared to the untreated cohesive frictional soils. Replacement of 30% soils with shredded tires increased the shear strength value of untreated soil from 31° to 38° and the same time reduced the maximum dry density from 1.3 Mg/m^3 to 1.2 Mg/m^3. Results from sieve analysis also indicate that the mixture was well-graded materials with the C_u value greater than 3. The best mixtures to be considered was 50% soils + 50% shredded tires, where the value of maximum dry density was 1.0 Mg/m^3, C_u was 17 kPa and value of internal friction angle was 34°. This mixture allows the optimum utilization of shredded waste tires to produce lightweight backfills material without compromising the shear strength value.

In conclusion, the utilization of shredded scrap tires as replacement materials aids in decreasing lateral pressure, improving stability and thereby reducing settlement of retaining wall structure, while in the mean time contribute towards better solid waste management.

References

Anas, I., R. Hamir and S. Mohd (2005). *Pullout Test Study on Shredded Tires and Sand Mixture.* Proceeding of the International Symposium and Exhibition on Geoinformation (ISG2005), 27-29 September 2005. Penang.

BS 1377 (1990). *Soils for Civil Engineering Purpose*. British Standard Institution.

Chien Jen Chu (1998). "*A Geotechnical Investigation of the Potential Use of Shredded Scrap Tire in Soil Stabilization.*" Report, Kent States University.

Chien Jen Chu & Shakoor, A. (1997). *Use of Shredded Scrap Tires in Soil Stabilization*. Engineering Geology and the Environment. pp: 1687-1693.

Department of Transport (1987). *Reinforced Earth Retaining Wall for Embankment Including Abutments*. Tech. Mem. BE (Interim), Department of Environment, Highways Directorate.

Edil, T.B. & Benson, C.H. (1996). *Geotechnic of Industrial by-Products*. American Society of Civil Engineers.

Ghani, A.N.A., F. Ahmad & R. Hamir (2002). *Recycling Tire Wastes Into Lightweight Geomaterial for Civil Engineering Works*. Proceeding of the 20th CAFEO. 2-4 September 2002. Cambodia.

Hughes, C.S. (1993). "*Scrap Tire Utilization Technologies.*" National Asphalt Pavement Association, Lanham MD.

Humphrey, D.N., Whetten, N., Weaver, J., Recker, K. & Cosgrove, T.A. (1998). *Tire Shreds as Lightweight Fill for Embankments and Retaining Walls*. American Society of Civil Engineers. pp: 51-65.

Jabatan Kerja Raya (JKR) Malaysia (1988). *Standard Specification for Road Works.*

Jones, C. J. F. P. (1996). *Earth Reinforced and Soil Structures*. Thomas Telford Publishing. London.

Vilupanandan & M. Basheer (1998). *Recycle Material for Embankment Construction*. Proceeding of Sessions of Geo-Congress 98. Boston, Massachusetts. Pp: 100-114.

Whitlow R. (2004). *Basic Soil Mechanics*, Fourth Edition, Prentice Hall, Singapore.

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