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USE OF SCRAP TYRE AS LIGHTWEIGHT MATERIAL IN CIVIL ENGINEERING INFRASTRUCTURE WORKS

A. Naser Abdul Ghani, *PhD., P.Eng.*

Infrastructure Technology Research Unit
School of Housing, Building and Planning
Universiti Sains Malaysia
11800 Penang

Corresponding author: anaser@usm.my

Abstract

Load reduction effect of using lightweight material in new construction, expansion, rehabilitation or maintenance of infrastructure facilities provide advantages in term of reduction of total cost, construction time and maintenance work especially in soft ground areas. This paper describes the possible use of scrap tyres in civil engineering infrastructure construction works.

Keywords: scrap tyre, civil engineering infrastructure

Introduction

In civil engineering infrastructure works, lightweight materials are used mostly as filling materials for road construction purposes. The lighter materials minimize foundation requirements, reduce land cutting for mountainous area, prevent settlements and shorten construction times. In the case of retaining wall, lighter fill will reduce the lateral earth pressure thus reducing the structural requirements of the wall including the foundations.

The lightweight waste material currently in use includes the ultra lightweight EPS (Expanded Poly Styrene), air foam mortar, expanded beads mixed with soil with controllable density, whole tire, tire chips or shreds, coal ash, hollow structures, wood chips and shells. Table 1 indicates the type of domestic and industrial byproducts or modified products; and their respective densities as well as related geotechnical properties.

Table 1: Lightweight waste materials (adapted from [1])

Geomaterial	**Unit Wt. (kN/m3)**	**Related Properties**
EPS from waste packaging materials.	0.1-0.3	Very light – average 100 times lighter than soils
Beads in mix with soil	7 or more	Controllable densities
Whole Tires	NA	Used in Reinforced Soil
Tire Shreds/Chips	3-6	Free-draining
Tire shreds with soil	10-15	Controllable densities
Tire shreds/chips block	3-10	Properties can be engineered to requirements
Volcanic ash	12-15	Natural material
Hollow structures	Approx. 10	Pipes, culverts etc
Wood chips	7-10	To be used below ground water level
Rice Husks	1-3	To be used below ground water level
Shells	Approx. 1.1	Natural material
Coal ash	10-15	Granular material.

SCRAP TYRE

One of the problems associated with socio-economic development of a country is waste disposal. In the engineering and transportation sector, one category of the wastes generated is scrap tyre and it poses serious health and environmental problems. In 2005, the Ministry of Transport Malaysia's record indicated more than eleven million registered vehicles in Malaysia. Recent statistics for Malaysia indicated more than 100% increase in number of registered vehicles within ten years. Since 1987, an average total of more than 5 million scrap tires have been produced annually. At an average of 20kg for each tyre, this would come up to 100,000 tonnes a year. The trend is increasing because of increasing population and number of vehicles. Figure 1 shows the trend in motor vehicle registration at the Road and Transport Department, Ministry of Transport.

Most of these scrap tires end up in congested landfill such as in Figure 2, illegally dumped or burned. Very small portions are recycled into submerged artificial reefs in the fisheries industry. In major developed countries, disposal of scrap tires are being regulated. The banning of scrap tires disposal, which are generated at a rate of approximately 250 million per year in the United States, resulted in large stockpiles of scrap tires [2].

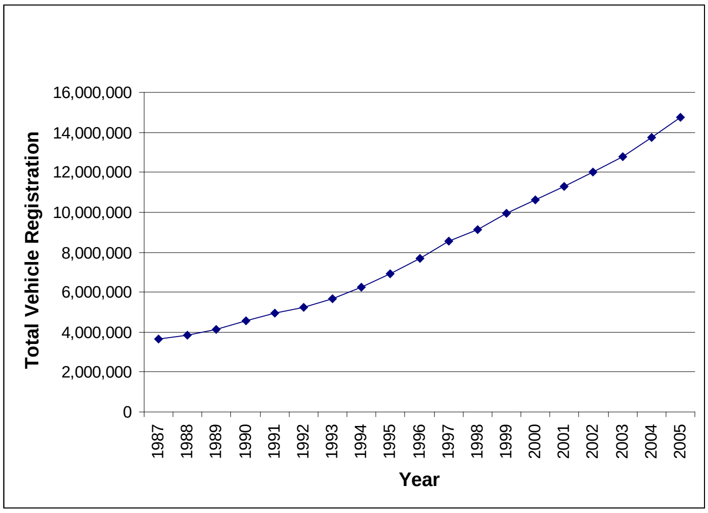


Figure 1: Trend in motor vehicle registration (based on data from [3])

Under the newly drafted Malaysian recycling law [4], it will be compulsory for certain solid wastes to be recycled or stockpiled. This may include scrap tires. However, when stockpiled, scrap tires provide an ideal breeding place for rats, mosquitoes, and other disease vectors. Stockpiling of tyres can also result in fire hazards. The best way to reduce environmental and health problems associated with scrap tires is to minimize, and eventually eliminate them by recycling.

Figure 2: Scrap tyres in dumped at a municipal sanitary landfill in Penang

LIGHTWEIGHT FILL AND EMBANKMENT

EPS (Expanded Polystyrene) was first used as road embankment on soft ground in Norway in 1972. Since then, the use of lightweight fill and embankment has been increasingly accepted for construction projects. In Japan, these load reducing techniques, has been expanded further by the usage of industrial waste as lightweight geomaterials [5]. The domestic and industrial waste has been recycled and used in construction works.

There are several techniques of using waste products as lightweight geomaterials. These techniques can be classified into three (3) categories:

1. The use of the wastes on its own (e.g. sawdusts, bark residue, tire shreds/chips, expanded glass). ([6], [7]).

2. The use of the wastes by mixing with soils(e.g. tire shreds, EPS beads, plastic, slag, waste glass). The material can be mix with soil at suitable proportion and compacted in the same manner as conventional material [8], [9], [10], [11].

3. The use of the wastes as a component in a geocomposite with additives (e.g. tire chips, fly ash). In this category, binder material is used to bind the material together for easy installation [12].

Table 2: Lightweight Fill and Embankment Applications

Application Category	Detail Applications	Descriptions
Soft Ground	Reducing Residual Settlement	Road built on soft ground are prone to settlement under repeated traffic loads. Lightweight fill reduce settlement by reducing the self weight of embankment.
	Preventing Differential Settlement between Approach Embankment and Structures.	Reducing cost of mitigation work arising from differential settlement.
	Reducing Construction Period	Lightweight embankment is particularly useful when construction period is limited. The foundation and soil improvements works can also be reduce substantially.
	Reducing Maintenance Works	The problem associated with settlement and deformations discussed above has made lightweight fill more advantageous in term of maintenance and road standards.
Mountainous Area	Minimizing topographic Changes	Reduce the conventional cut-and-embankment requirements by using lightweight embankment on the valley side of a hill.
	Solution to Landslide Prone Area	Lightweight material impose minimal load on slope prone to landslide. is more economical compared to conventional anti-landslide techniques. It will also be advantageous if construction time is critical.
Retaining Wall Backfill	Compressible Layers or Inclusion for Retaining Wall backfill	Inducing active conditions on retaining wall. Lighter material will also reduce lateral pressure on the wall. The decrease of vertical load reduce foundation requirements.

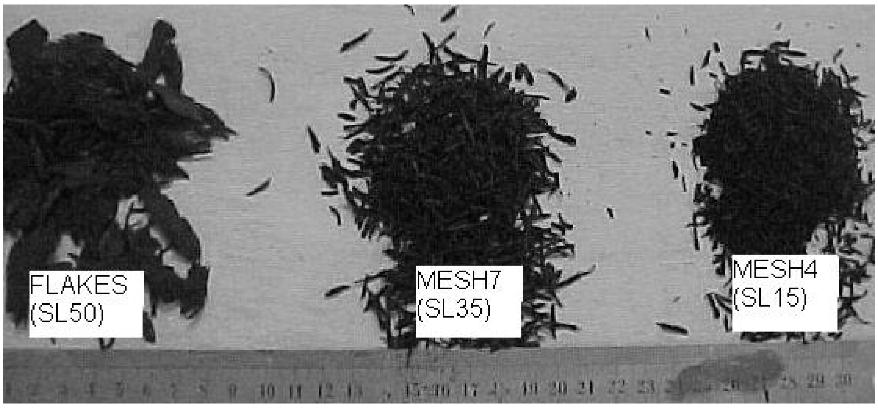
CHARACTERISTICS OF SCRAP TYRE BASED GEOMATERIAL

Tyre wastes can be used as lightweight geomaterial, as indicated earlier, either in the form of whole tires, shredded or chips, or in mix with soil. Studies regarding the use of scrap tyres, especially, as embankment materials in geotechnical applications have been carried out by many researchers. These studies include laboratory investigations, numerical and physical models and actual field investigations (Ahmed and Lovell [13]; Bernal [14]; Masad et. al [15]; Lee et. al [16];

Chu and Shakoor [17]; Tweedie et. al [18] [19], Bergado and Youwai [20]; Humphrey and Tweedie [21]; and Edil [22]). Tyre shred or chips or bits can be used on its own or in a soil mixture. Recent studies by Lee et. al [12] demonstrated that scrap tyre in pieces of uniform bits can be bound into blocks by using cementing material such as OPC (Ordinary Portland Cement). Key properties of various forms of tyre wastes based geomaterial are listed in Table 3.

Table 3: Key Properties of Tire Waste Based Geomaterials.

Category	**Density**	**Strength**	**Other Geotechnical Properties**
Whole Tire	NA	NA	Usually used in reinforced soil applications.
Tire Shreds/Chips	3 – 5.5 kN/m^3 with compaction 8 – 9 kN/m^3	Angle of repose range from 37-43 degree for loose and up to 85 when compacted.	Good draining properties of more than 1 cm/sec.
Tire Shreds/Chips in Mix with Soil	Up to 13 kN/m^3 for 50/50 soil-tire mixture	Compacted to requirements.	mixing of 38-40 % tire shreds/chips give the optimum economic and technical advantages.
Tire shreds/bits with binding additives	5 – 10 kN/m^3, but density and other properties can be engineered to requirements.	Compressive strength can be engineered to requirements.	Good draining properties. Placements by pumping or in blocks form.



note: SL50 = shred length 50mm

Figure 3: Raw Shredded Scrap Tires

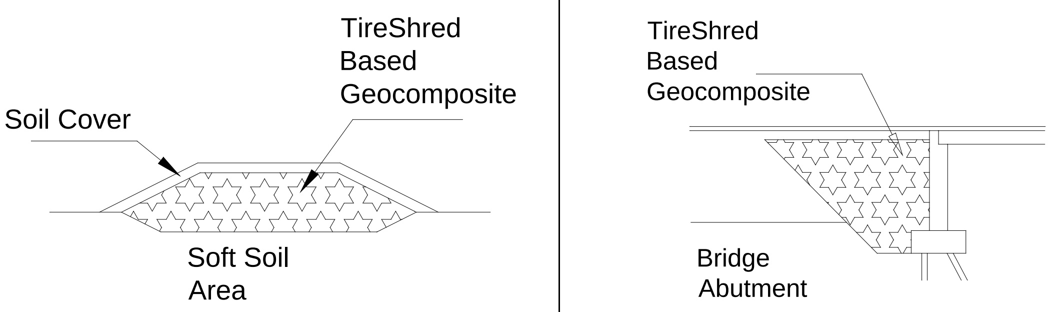
Scrap tyres	Shredded scrap tyre	Scrap tyre based geocomposite

Figure 4: From scrap tyre to block geocomposite geomaterial

APPLICATIONS

The concept of using recycle lightweight geomaterial for civil engineering construction is feasible not only because they are environmental friendly, but it can also reduce the total project costs in term of construction and maintenance especially in areas with poor soil conditions.

Figure 5a and 5b shows the conceptual application of scrap tyre based geomaterial in constructions of infrastructure facilities.



Reduce loading consequently settlement and avoiding potential sliding and soil treatment requirements.	Control differential settlement, eliminate sudden bump and maintenance, reduce lateral and vertical pressure, thus reduce foundation requirements

Figure 5a: Practical Applicability

As compressible layers to induce active conditions for retaining wall, at the same time reduce lateral and vertical pressure.	Minimizing earthwork operations on hill slopes and reducing load on ground and retaining systems.

Figure 5b: Practical Applicability

Scrap tyre can also be utilized as fill material especially as retaining wall backfill since it has low density and good draining properties. It should be utilized in the form that possesses predictable and controllable geotechnical properties. With predictable compression behavior under loading, this material can be further utilized as load reduction layer in the backfill.

Extensive literature search has revealed that only two types of construction material are actually used as wall load reduction layer and inclusion in the construction of earth retaining structures. They are Expanded Poly Styrene (EPS) block and shredded tires in loose form (Partos and Kazaniswky [23];Lareal et al. [24]; Karpurapu and Bathurst [25]; Ismail and Nor [26]; Murphy [27]; Aytekin [28]; Humphrey et al. [29]; Hazarika et al. [30]). An example applied to pressure reduction layer in earth retaining structure construction is illustrated in Figure 6.

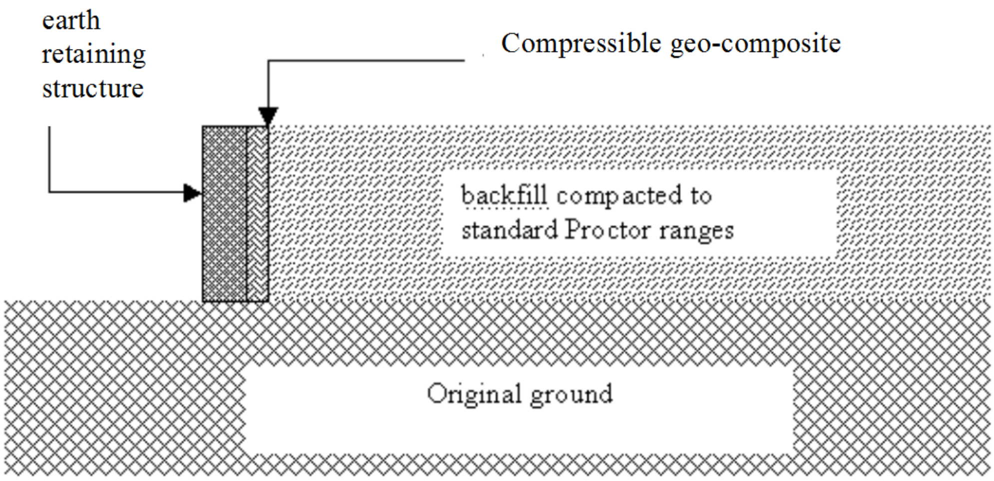


Figure 6: Pressure reduction layer in earth retaining structure

Scrap tyres are abundantly available and they do not easily decompose. These scrap tyres can be recycled into construction material to minimize the scrap tire problem. While EPS blocks possesses predictable properties, the use of shredded tyres as a load reducing layer is limited due to several difficulties: 1) Installation of loose shredded tyres in a vertical layer behind retaining wall is difficult. 2) The performance of shredded tyre in loose form depends on proper in-situ compaction. 3) In the case of shredded tire mixed with soil, vibration load and water table fluctuations or draining water could cause segregation. This may results in excessive deformation.

The mechanism of earth pressure reduction on it retaining systems can be best described by control yielding concept [20] shown in Figure 7. The deformation of compressible layer would allow soil to expand, thus reducing the horizontal stress when shearing resistance is mobilized. When a compressible material is compressed, the stress on the material increases, which in turn allows the soil backfill to shift from at rest state to an active state condition. Based on the known behavior of geomaterial, the level of shifting could be adjusted to match the active state condition.

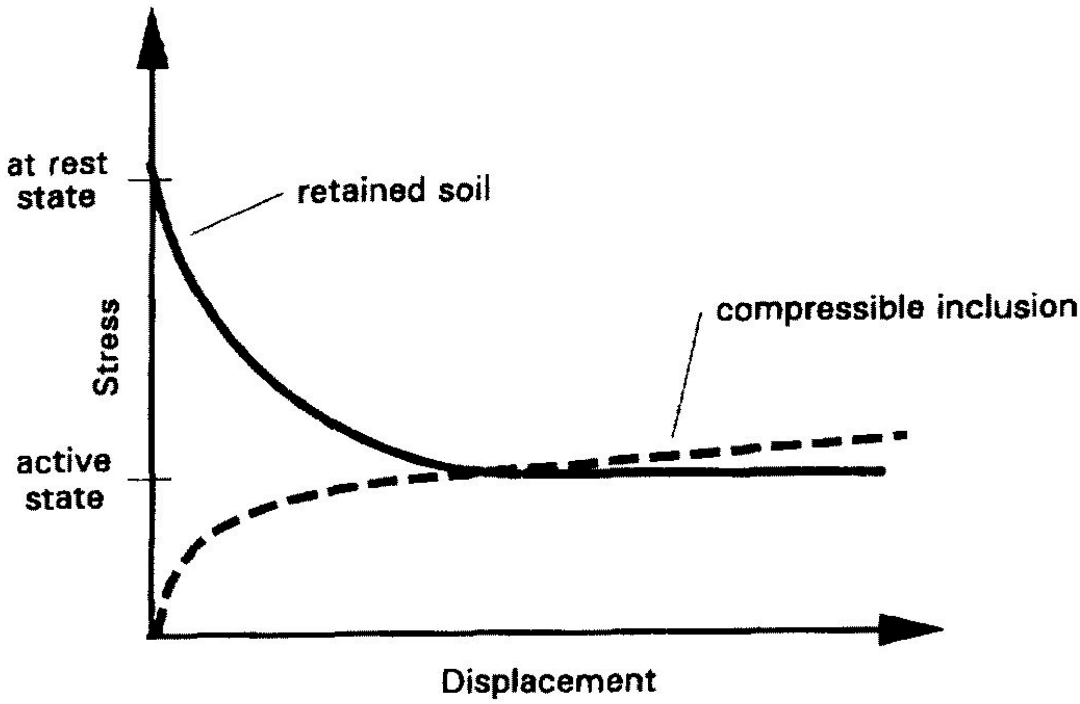


Figure 7: Control yielding concept [20]

CONCLUSION

The generation of industrial byproducts especially tyre wastes is growing Malaysia. Recycling these materials into lightweight geomaterial for civil engineering construction will not only reduce overall construction costs and time in the poor ground areas, but it will also contribute to the proper management of these wastes.

This paper has discussed key geotechnical properties of waste materials, especially waste tyres, that can be used as component in lightweight geomaterials. Also presented in this paper are some concepts of practical applications of tire wastes based composite geomaterials.

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