International Journal of Emerging Engineering Research and Technology
Volume 2, Issue 4, July 2014, PP 264-272
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Use of Shredded Tyres in Embankment Construction – An Overview

Khushboo K. Soni[1], Samruddhi C. Sagane[2]

[1]Asst. Prof., Department of Civil Engineering,
Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati (M.S.), India,
ksonie.1@gmail.com
[2]Asst. Prof., Department of Civil Engineering,
Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati (M.S.), India,
samrudddhisagane@gmail.com

Abstract: *Today billions of waste tyres are reported to be stockpiled across the countries, and millions of waste tyres are generated annually. A significant number of them are disposed in landfills, left in empty yards and even dumped illegally. Tyres have characteristics that make them difficult to dispose off, and as they are potentially combustible thus constitute environmental and health hazards by producing air pollution from tyre stockpile fires and breeding grounds for potential disease carrying mosquitoes and vermin. In order to avoid even larger stockpiles across the country, alternate ways of using waste tyres must be implemented. The most desirable approach to reduce waste tyre stockpiles is to recover the resource by recycling and reusing. The study involves construction of test tyre shred, soil embankment as well as basic laboratory tests for material characteristics and instrumentation of embankment. The objective of this study is to evaluate the feasibility of using a mixture of tyre shreds and soil as fill material for embankments on the basis of field instrumentation and tests.*

Keywords: *Tyre shreds, embankment, stockpile, recover, reuse.*

1. Introduction

A tyre is a ring-shaped covering that fits around a wheel rim to protect it and enable better vehicle performance by providing a flexible cushion that absorbs shock while keeping the wheel in close contact with the ground. There are two main types of tyres, those made of metal and of rubber. The metal tyre is basically a flat hoop fitted tightly over the exterior of the wheel such as used in rail road cars for low rolling resistance. Free-moving vehicles such as automobiles, trucks, buses, bicycles, and airplanes use rubber tyres, which provide both high friction and some cushioning ability. Rubber tyres are of two types: (1) solid, or cushion, tyres, in which the rubber portion functions to carry the load, absorb shocks, and resist cutting and abrasion; and (2) pneumatic tyres, in which the load is carried and the shocks are absorbed mainly by the compressed air that fills the tyre.

Tyre shreds are waste tyres that have been cut into pieces that are generally 50 to 300 mm in size. Figure.1.1 shows the shredded tyres. In general, the material is very elastic, very porous, contains good vibration damping properties, and is easily compacted. They have been found substitute for sand, gravel, lightweight material. They offer the following advantages when used as a fill material: lightweight, low lateral pressure, low thermal conductivity, and free draining.

Figure 1.1 *Shredded Tyres*

Because of these advantages they have been used on more than 100 road construction projects. While the potential effect on groundwater quality is thought to be small when used for highway applications. There are many benefits of using shred tyres as lightweight fill in embankment or retaining wall since tyre shreds are non-biodegradable and thus more durable. Also, it is inexpensive compared to other lightweight material.

Currently, 2 to 4 billion tyres are stockpiled nationwide and approximately 40 to 50 million scrap tyres are stockpiled at numerous locations in world. These stockpiled tyres represent a public health hazard and an aesthetic nuisance. Numerous studies have been conducted to investigate and develop alternative methods to land filling and stockpiling, such as recycling the waste tyres (Figure 1.2)

Figure 1.2 *Large Stockpiles of Waste Tyres*

1.1. Materials

The composition of pneumatic tyres consist of following

1. Natural rubber or polyisoprene is the basic elastomer used in tyre making.
2. Styrene-butadiene co-polymer (SBR) is a synthetic rubber which is often substituted in part for natural rubber based on the comparative raw materials cost.
3. Polybutadiene is used in combination with other rubbers because of its low heat-buildup properties.
4. Halobutyl rubber is used for the tubeless inner liner compounds, because of its low air permeability.
5. The halogen atoms provide a bond with the carcass compounds which are mainly natural rubber.
6. Bromobutyl is superior to chlorobutyl, but is more expensive.
7. Carbon Black forms a high percentage of the rubber compound. This gives reinforcement and abrasion resistance.
8. Silica used together with carbon black in high performance tyres, as low heat buildup reinforcement.
9. Sulphur cross links the rubber molecules in the vulcanization process.
10. Vulcanizing Accelerators are complex organic compounds that speed up the vulcanization.
11. Activators assist the vulcanization. The main one is zinc oxide.
12. Antioxidants and antiozonants prevent sidewall cracking due to the action of sunlight and ozone.

1.2. Typical components of a tyre assembly

Inner liner- The inner liner is an extruded halobutyl rubber sheet compounded with additives that result in low air permeability.

Body ply- The body ply is a calendered sheet consisting of one layer of rubber, one layer of reinforcing fabric, and a second layer of rubber.

Sidewall- Sidewalls are non-reinforced extruded profiles with additives to give the sides of the tyre good abrasion resistance and environmental resistance.

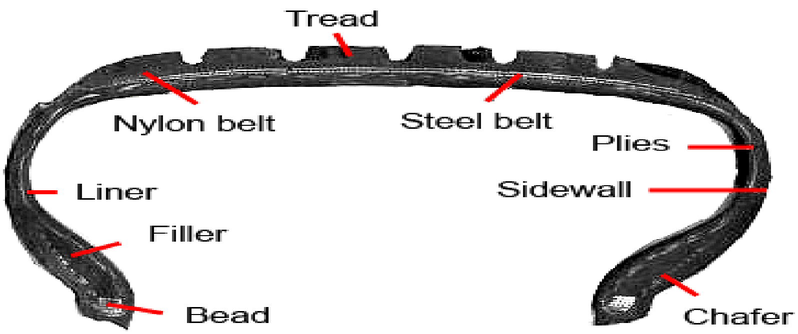

Figure 1.2.1 *Typical Components of Tyres*

Beads- Beads are bands of high tensile-strength steel wire encased in a rubber compound. Bead wire is coated with special alloys of bronze or brass. Coatings protect the steel from corrosion and provide the mechanical strength to fit the tyre to the wheel.

Belt package- Belts are calendered sheets consisting of a layer of rubber and a layer of closely spaced steel cords. Belts give the tyre strength and dent resistance.

Tread- The tread is a thick profile that surrounds the tyre carcass. Tread compounds include additives to impart wear resistance and traction in addition to environmental resistance.

Cushion gum- Many higher-performing tyres include an extruded component between the belt package and the tread to isolate the tread from mechanical wear from the steel belts.

2. ENGINEERING PROPERTIES OF TYRE SHREDS

Various engineering properties consist of unit weight, hydraulic conductivity, compressibility, shear strength, low earth pressure, good thermal insulation, good drainage, etc.

2.1. Unit Weight, Specific Gravity and Hydraulic Conductivity

The unit weight is the ratio of the weight of a substance to the volume of a substance, whereas specific gravity is the ratio of the unit weight of solids divided by the unit weight of water. Specific gravity of tyre shreds ranges from 1.02 to 1.36, depending on the amount of glass belting or steel wire in the tyre. The specific gravity of soils typically ranges from 2.6 to 2.8, which is more than twice that of tyre shreds. Following table 2.1.1 shows various unit weights of different types of compacted tyre shred. As shown in table 2.1.1, the unit weight of compacted tyre shred ranges from 2.4 kN/m^3 to 7.0 kN/m^3.

Table 2.1.1 *Dry Unit Weight of Different Types of Compacted Tyre Shreds*

Tyre Shred Size (cm)	Dry Unit Weight (kN/m3)	Compaction Type
1.3- 2.5	4.90	ASTM 4253
1.3	4.67	ASTM 4253
1.3 - 5.1	6.07	50% Standard
1.3 - 2.5	6.29	50% Standard
1.0 - 5.1	6.29	Standard
1.3 - 3.8	6.38	Standard
1.3 - 2.5	6.45	Standard
2.3	6.26	Standard
1.27 - 5.1	6.56	Modified
1.3 - 2.5	6.71	Modified
0.2 - 7.6	6.13	60% Standard
0.2 – 5.1	6.29	60% Standard
0.2 – 2.5	2.40	60% Standard
3.8	6.96	Full scale field test
7.6	6.78	Full scale field test

Hydraulic conductivity is defined as the rate of water flow under laminar flow conditions through a unit cross-sectional area of porous medium under unit hydraulic gradient and standard temperature conditions. Compacted tyre shred has hydraulic conductivity values equivalent to that of typical coarse gravel which ranges from 2.0 cm/s to 0.75 cm/s shown in table 2.1.2. The wide range of hydraulic conductivity values is attributed to the differences in shred size and composition, compaction level (initial density/void ratio), and normal stress.

Table 2.1.2 *Hydraulic Conductivity of Different Types of Tyre Shreds*

Tyre shred Size (cm)	Hydraulic Conductivity (cm/s)	Test Condition
1 - 5.1	7.7	Void ratio, e = 0.925
1 - 5.1	2.1	e = 0.488
1.9 – 7.6	15.4	e = 1.114
1.9 - 7.6	4.8	e = 0.583
1- 3.8	6.9	e = 0.833
1 - 3.8	1.5	e = 0.414
20.3 – 40.6	9.0	e = 2.77
20.3 – 40.6	3.2	e = 1.53
20.3 – 40.6	1.8	e = 0.78
1.3 – 3.8	7.6	e = 0.693
1.3 – 3.8	1.5	e = 0.328
1.3 – 7.6	16.3	e = 0.857
1.3 – 7.6	5.6	e = 0.546
2.5	1.8 x 10-3	Mix with Ottawa sand, 15.5% of tyre shred in weight
2.5	3.5 x 10-3	Mix with Ottawa sand, 30.1% of tyre shred in weight
2.5	8.7 x 10-3	Mix with Ottawa sand, 37.7% of tyre shred in weight
2.5	1.8 x 10-5	Mix with Crosby till, 14.8% of tyre shred in weight
2.5	2.1 x 10-3	Mix with Crosby till, 30.1% of tyre shred in weight
2.5	8.8 x 10-3	Mix with Crosby till, 40% of tyre shred in weight
1.3	9.7 x 10-3	Mix with Crosby till, 40% of tyre shred in weight

2.2. Compressibility, Shear Strength and Environmental Properties

The property of a material pertaining to its susceptibility to volume change due to changes in stress is called compressibility. Tyre shreds are highly compressible because of their high porosity and high rubber content. Tyre shreds compress when a load is applied primarily due to two mechanisms: (a) bending and orientation of the shreds into a more compact packing arrangement, and (b) the compression of individual tyre shreds under stress. The compressibility of tyre shreds is generally measured by placing the tyre shreds in containers that have diameters ranging from 6 to 29 inches, and then measuring the vertical compression caused by an increasing vertical stress. Table 2.2.1 shows the compressibility values of tyre shreds.

Table 2.2.1 *Compressibility of Different Types of Tyre Shreds*

Tyre Shred Size (inch)	**Compressibility (%)**	**Specific Test Conditions (Stress in psf)**
0.75 - 1.5	30	1440
0.08 - 2	33 - 37	4176 (compacted)
0.08 - 2	52	4176 (loose)
0.08 - 1	33 - 35	4176 (compacted)
0.08 - 1	45	4176 (loose)
0.08 - 3	38 - 41	4176 (compacted)
0.08 - 2	29 - 37	4176 (compacted)
0.5 - 1.5	27	-
1.18	25	104
	40	8532
2 - 3	37	14400
8 - 16	55	793
3	18 - 28	522

0.5 -5.5	31	665
0.5 - 5.5	50	3400
0.5 - 5.5	65	21000

Shear strength is one of the fundamental engineering properties that govern bearing capacity and slope stability. Table 2.2.2 shows shear strength values for different types of tyre shred. The ratio of tyre chip and sand at maximum shear strength is approximately 39% at low to medium confining stress. This is thought to be an optimum ratio for a tyre shred and sand mixture for light-weight fill.

Table 2.2.2 *Shear Strength of Different Types of Tyre Shreds*

Tyre Shred Size (cm)	C (kN/m2)	Φ (º)	Test Condition
1.3	35.8	20.5	Standard compaction & 20% strain as failure
2.5	39.2	24.6	Modified compaction & 20% strain as failure
2.5	33.2	25.3	Standard compaction & 20% strain as failure
2.5	37.3	22.6	50% standard compaction & 20% strain as failure
<3.8	8.6		Normal stress: 19.2 – 71.8 (kN/m2)
<5.1	4.3 - 7.7		
<7.6	11.5		
5.1	0	17 - 35	17 at 5% strain 35 to 20 strain
0.46	70.0	6	10% strain
	71.0	11	15% strain
	82.0	15	20% strain
<0.2	0	45	Triaxial tests under confining pressure of 34.5-55.0 (kN/m2)
<0.9	0	47 - 60	
<1.9	0	54	
<3.8	0	57	

Table 2.2.3 shows the principal chemical substances of tyres are natural and synthetic rubber that contains inorganic and organic components. Various studies from laboratory tests and field test embankments with tyre shred fill material indicate negligible effect on environmental problems such as groundwater quality.

Table 2.2.3 *Chemical Composition of Scrap Tyres*

Description	% by weight as received	% by weight, dry basis
Proximate analysis		
Moisture	0.62	-
Ash	4.78	4.81
Volatile Matter	66.64	67.06
Fixed Carbon	27.96	28.13
Total	100	100
Element mineral analysis (Oxide form)		
Zinc	1.52	1.53
Calcium	0.378	0.380
Iron	0.321	0.323
Chlorine	0.149	0.150
Chromium	0.0097	0.0098
Fluoride	0.0010	0.0010
Cadmium	0.0006	0.0006
Lead	0.0065	0.0065

3. CIVIL ENGINEERING APPLICATIONS OF TYRE SHREDS

The use of tyre shreds in civil engineering applications began in 1980’s. In almost all applications, scrap tyre material replaces some other material currently used in construction such as lightweight fill materials like expanded shale or polystyrene insulation blocks, drainage aggregate, or even soil or clean fill. Rough tyre shreds can be used as embankment fill and in landfill projects. Tyres can be used in number of ways in civil engineering including-

1. Lightweight fill
2. Backfill to structures
3. Drainage for roads
4. Landfill engineering

3.1. Sub grade Fill and Embankments

Tyre shreds can be used to construct embankments on weak, compressible foundation soils. Tyre shreds are viable in this application due to their light weight. For most projects, using tyre shreds as a lightweight fill material is significantly cheaper than alternatives. Figure.3.1.1 shows cross section through embankment. Figure.3.1.2 shows road embankment constructed with shredded tyres. They may also be used in landfill capping and closures, and as a material for daily cover. Figure.3.1.3 shows Caterpillar D-4 spreading tyre shreds for lightweight embankment fill.

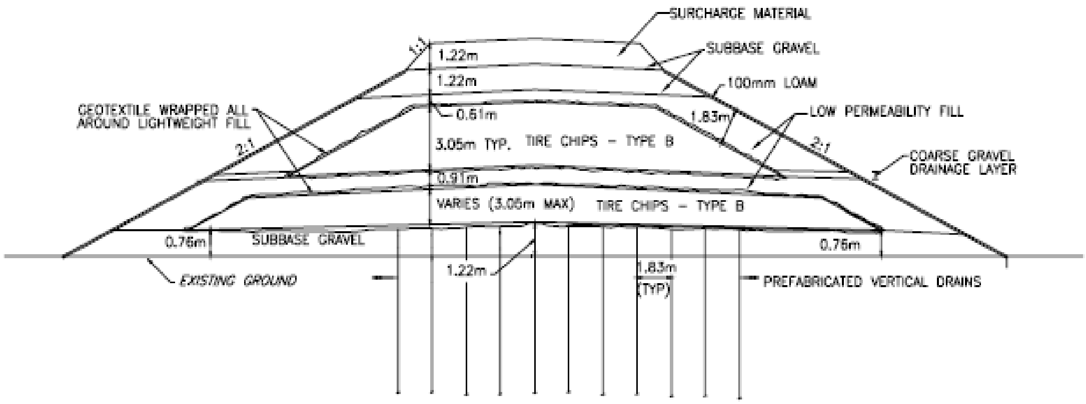

Figure 3.1.1*Cross Section through Embankment*

Figure 3.1.2 *Road Embankment constructed with Shredded Tyres*

Figure 3.1.3 *Caterpillar D-4 Spreading Tyre Shreds for Lightweight Embankment Fill*

3.2. Backfill for Walls and Bridge Abutments

Tyre shreds can be useful as backfill for walls and bridge abutments. The weight of the tyre shreds reduces horizontal pressures and allows for construction of thinner, less expensive walls. Tyre shreds can also reduce problems with water and frost build up behind walls because tyre shreds provide good thermal insulation. Figure.3.2.1 shows tyre shreds as compressible backfill for rigid frame bridge. Figure.3.2.2 shows the placement of tyre shreds using front end loader for rigid frame bridge.

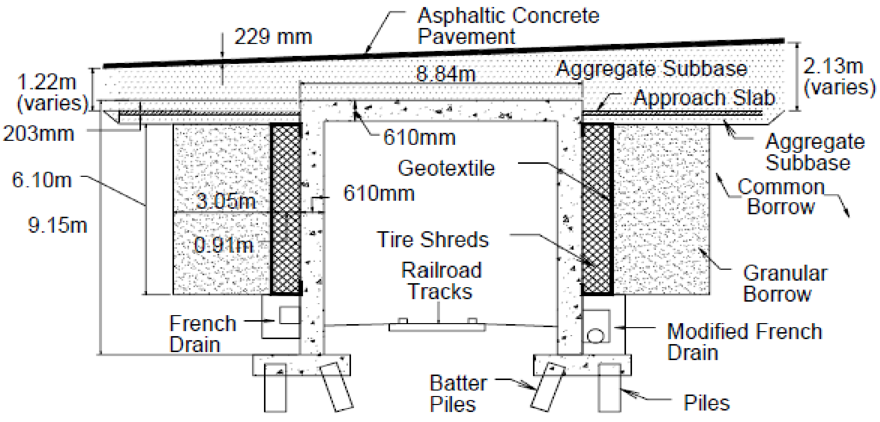

Figure 3.2.1 *Tyre Shreds as Compressible Backfill for Rigid Frame Bridge*

Figure 3.2.2 *Placing Tyre Shreds using Front End Loader for Rigid Frame Bridge*

3.3 Insulation to Limit Frost Penetration

Frost penetration beneath roads in northern climates can be very destructive. When silty soils are frozen, water is drawn up from the water table creating lenses of ice that can be more than an inch thick. This causes heave of the road that can produce an uneven driving surface and crack the pavement. In some cases, the total amount of heave can be greater than 5 inches. In the spring, the ice lenses melt, releasing their water to the road surface. This excess water weakens the road sub base leading to rutting of gravel surfaced roads and pavement cracking in paved roads. Over the long term, the damage caused by frost action greatly increases roadway maintenance costs. Tyre shreds are a seven - times better insulator and are more permeable than gravel. Figure.3.3.1 shows the typical cross section using tyre shreds for insulation and drainage. Figure.3.3.2 shows the placing and compaction of tyre shreds in edge drain.

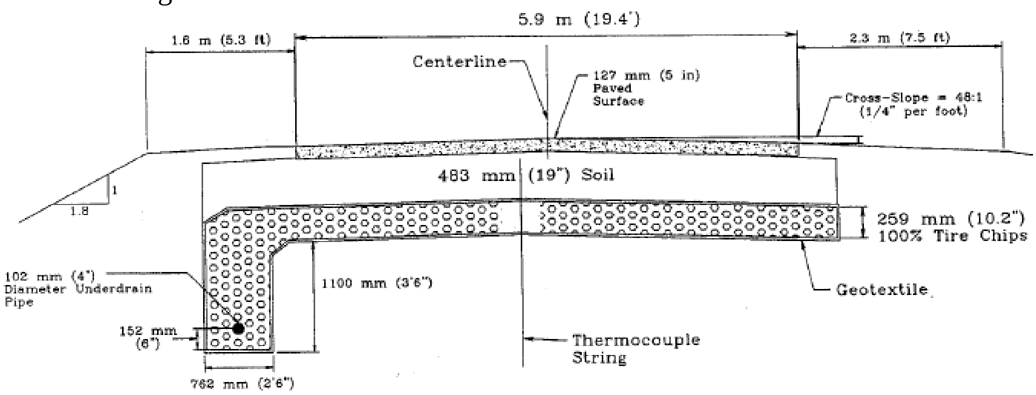

Figure 3.3.1 *Typical Cross Section Using Tyre Shreds for Insulation and Drainage*

Figure 3.3.2 *Placing and Compacting Tyre Shreds in Edge Drain*

4. CONCLUSION

As a large number of stockpiles of waste tyres have been found across the world, it is been concluded from the research which has been done until now and from the market that the world is moving toward disposing tyres by using them in various processed and unprocessed applications. They have been found substitute for gravel, sand, lightweight material, etc. They are cost effective. When used in civil engineering applications no significant environmental problems are found. On the other hand, they improve civil engineering performance. Full scale construction projects to monitor environmental and engineering performance are undertaken. Modifications in specifications are done. Thus, it is hoped that more researches, seminars, technological development will promote the adaption of this.

REFERENCES

[1] Bosscher, Peter J., Edil, Tuncer B., and Eldin, N. N., “Construction and Performance of a Shredded Waste Tyre Test Embankment.”, Presented at the 71stAnnual Meeting of the Transportation Research Board, Washington, DC. (1992).

[2] Humphery, D.N., and Sandford, T.C., Cribbs, M.M., and Manion, W.P. (1993), “Shear Strength and Compressibility of Tyre Chips for Use as Retaining Wall Backfill.”, Transportation Research Record 1422, Transportation Research Board, Washington, D.C.

[3] http://www.northerntyre.com/01%20The%20Use%20of%20Post Consumer%20Tyres%20in%20Civil%20Engineering.PDF, 15th Sept.,2011

[4] http://www.epa.gov/osw/conserve/rrr/imr/irc-meet/07-tires.pdf 15th Sept.,2011.

[5] http://en.wikipedia.org/wiki/Tire_manufacturing ,15th Sept.,2011

[6] Lawrence B.K., Chen, L.H., and Humphrey, D.N. (1998), “Use of Tyre Chip/Soil Mixtures to Limit Frost Heave and Pavement Damage of Paved Roads”, Department of Civil and Environmental Engineering, University of Maine, Orono, Maine.

[7] Masad, E., Taha, R., Ho, C., and Papagiannakis, T., , “Engineering Properties of Tyre/Soil Mixtures as a Lightweight Fill Material”, Geotechnical Testing Journal, Vol.19, No.3, pp. 297-304. (1996).

[8] Zimmerman, P.S., “Compressibility, Hydraulic Conductivity, and Soil Infiltration Testing of Tyre Shreds and Field Testing of a Shredded Tyre Horizontal Drain”, M.S. Thesis, Iowa State University, Ames, Iowa. (1997).

AUTHORS' BIOGRAPHY

Ms. K. K. Soni is Assistant Professor at Prof. Ram Meghe Institute of Technology & Research, Badnera with two years experience in teaching. She is also pursuing M.E. in Structural Engineering. She completed B.Tech. in Civil Engineering from Govt. College of Engineering Amravati, Maharashtra.

Ms. S. C. Sagane is Assistant Professor at Prof. Ram Meghe Institute of Technology & Research, Badnera with one year experience in teaching. She is also pursuing M.E. in Structural Engineering. She completed B.E. in Civil Engineering from P. R. Patil College of Engineering & Technology, Amravati, Maharashtra.