Design Guidelines on Use of Scrap Tire Bales in Embankment Construction

A number of companies are involved in the business of making tire bales. A tire bale is a construction block produced by compressing whole tires and tying them using steel wires. Tire Bales are produced using a baler, which is a hydraulically operated whole tire compression and baling machine. The typical tire baler, shown in Figure 1 produces a tire with the size 50 in. x 60 in. x 30 in. and weighs approximately one ton. The 50 inch and 60 inch dimensions of the tire bale can be changed to produce bales of different sizes using the same baler. Even after compressing whole tires, the unit weight of a tire bale is typically between 35 and 45 lb/ft^3, which makes it ideal for lightweight fill applications. Tire bales have also been used to construct gabion baskets, erosion control walls and short retaining walls.

Tire bales are more appropriate for lightweight, non-structural fills. However, they may also be appropriate for structural fills provided that an adequately thick cover of soil is provided over the scrap tire bales.

(a)

(b)

Figure 1. (a) A Hydraulic Tire Baler, and (b) Placement of Tire Bales (Courtesy of New Mexico Environment Department)

Steel straps are used to wrap tire bales once the tires are compressed in the baler. However, these straps are used primarily for handling purposes. Even if these straps are cut or broken, the tires do not spring back. However, as a precaution, the steel straps shall be left with the bale in the embankment fill.

Encore Systems, Inc., one of the leading tire bale manufacturers, have tested tire bales by compressing them using a hydraulic ram and transmitting the load to the bale using a one-inch thick steel plate. The load was applied over an area of 50 inches by 60 inches. These tests included an ultimate compressive load test and a creep test at a load of 88,000 lbs. (compression stress of approximately 30 psi) conducted over a 72-hour duration. Some of the key data items from the test are given below:

Load at which bundle strap gave way	175,000 lb. (58.3 psi)
Ultimate load	339,000 lb. (112.8 psi)
(Rubber did not fail at this point, but loading was stopped)	
Deflection at 339,000 lb. load	11.45 inches
Creep deflection at a load of 88,000 lb.	8.1 inches
(over a test duration of 72 hours)[1]	

The tire bale, when tested in compression, displayed properties similar to rubber. The elastic modulus of synthetic rubber is in the range of 500 to 10,000 psi, and that of vulcanized rubber is approximately 500,000 psi. Using the test data provided by Encore Balers, Inc., the elastic modulus of the tire bale, when tested under unconfined compression, could be as low as 130 psi. Since rubber improves its compressive strength with increased loading, particularly under confined conditions, the anticipated primary failure mechanism of structural pavement embankments using tire bales is expected be fatigue cracking of the pavement. Preliminary calculations using layered elastic analysis of pavement structures have shown that several (at least 3 to 4) feet of soil cover is needed over the tire bale fill to reduce the stress level at the top of the tire bale to below 1 psi, which may limit the pavement surface deflection to manageable levels.

[1] A deflection of 5 inches out of the total creep deflection of 8.1 inches occurred during the first 5 minutes of loading.

Design Guidelines on Use of Scrap Tire Chips (or shreds) in Embankment Construction

1. Tire shreds have a compacted dry density that is one-third to one-half of that for a typical soil.

2. Thermal resistivity of tire chips is approximately eight times greater than for a typical granular soil.

3. Initial plastic compression of 100 percent tire chip fills may be as high as 40 percent. However, once compressed, the fill behaves like an elastic material.

4. Some Typical Geotechnical Properties of Tire Chips:

	Chip Size (inches)	Friction Angle (degrees)	Cohesion (psi)	Lateral Earth Pressure Coeff. at Rest (K_0)	Poisson's Ratio	Elastic Modulus (psi)
Source #1	2	21	1.12	0.41	0.28	164
Source #2	3	19	1.67	0.26	0.20	163
Source #3	2	25	1.25	0.47	0.32	112

5. Densification of tire chip fills is best achieved by applying weight.

6. Tire chip size is not very critical for the performance of the fill. However, construction is eased when smaller chip sizes are used. Commonly used tire chip sizes fall in the range of 3 to 12 inches. Larger shreds can also be used in certain situations provided all tires are shredded such that the largest shred is the lesser of one quarter circle in shape or 24 inches in length. In all cases, at least one side wall should be severed from the tread.

7. Tire chips may be used in combination with both sand and clay soils. However, sand makes construction easier and also provides higher elastic modulus values for the same soil:tire chip ratio.

6. There is no layer thickness requirement for this class of tire chip fills as long as the percentage of tire chips in the tire chip-soil blend is at least 30 percent.

7. Since rubber improves its compressive strength with increased loading, particularly under confined conditions, the anticipated primary failure mechanism of structural pavement embankments using tire chips would be fatigue cracking of the pavement. Preliminary calculations using layered elastic analysis of pavement structures have shown that several (at least 3 to 4) feet of soil cover is needed over the tire bale fill to reduce the stress level at the top of the tire bale to below 1 psi, which may limit the deflection in the tire bale to manageable levels. A minimum of 3 feet of soil cover is recommended if the tires are used in a pavement embankment.

8. Tire chips should not be used near groundwater that is acidic.

9. Additional information and guidance may be obtained from ASTM D 6270: *Standard Practice for Use of Scrap Tires in Civil Engineering Applications*.