TIRE SHREDS FOR HIGHWAY CONSTRUCTION

DANA N. HUMPHREY, NATHAN WHETTEN, JAMES WEAVER, AND KENNETH RECKER

Dana Humphrey is Professor, Department of Civil and Environmental Engineering, University of Maine. Nathan Whetten is Senior Geotechnical Engineer, Haley & Aldrich, Hartford, Connecticut. James Weaver is Vice President and Kenneth Recker is Vice President, Haley & Aldrich, Portland, Maine.

Highway designers are increasingly turning to tire shreds as a source of lightweight fill for embankments constructed on weak foundation soils, for landslide stabilization, and for retaining wall backfill. Tire shreds are scrap tires that have been cut into pieces measuring from 75 to a maximum of 300 mm in any dimension. Their in-place density is less than half that of conventional soil fill. Moreover, tire shreds are generally less expensive than other lightweight fills.

Much has been learned since the first major tire shred fill was constructed by the Oregon Department of Transportation in 1990. Field trials have been performed to determine the effect of a tire shred layer on the performance of flexible pavement. Laboratory and field studies have shown that tire shreds have a negligible effect on groundwater quality. Progress has been steady, but there have been some stumbling blocks. In 1995 two tire shred fills in Washington State and one in Colorado experienced a serious self-heating reaction. However, guidelines to limit self-heating are now available (*1, 2*). An exciting new development is the recently released ASTM guideline specifications for use of scrap tires in civil engineering applications (*2*).

Highway applications of tire shreds are using millions of tires each year, but there is room for significant growth. In 1996, about 64 million scrap tires went unused. A recently completed survey is expected to show similar numbers. In some parts of the country, the demand for scrap tires is so low that tire shreds for highway projects can be had for the cost of delivery.

Special Properties of Tire Shreds

Tire shreds have several special properties that can help civil engineers solve difficult highway design problems. The most important of these properties is that tire shreds are lightweight. Their in-place density is between 0.7 and 0.9 Mg/m^3—even after they have been compressed under the weight of overlying fill. By comparison, soil fill typically weighs 2 Mg/m^3. Their low density makes tire shreds an excellent lightweight fill for improving the stability of embankments built on weak soils and helping to stabilize landslides.

Tire shreds also produce low horizontal stress, and they are compressible. Thus when they are used as fill behind walls and bridge abutments, they produce lower horizontal pressures than conventional soil backfill. This property allows for construction of thinner walls that are less expensive.

Tire shreds are very free draining as well. Even when they are compressed under the weight of overlying fill, they have a permeability of greater than 1 cm/sec. With such a high permeability, tire shreds can be used as drainage layers and edge drain backfill for roads.

Still another useful property of tire shreds is that they have a high insulating value. In fact, their insulating value is seven times better than that of soil. Together with their good drainage properties, this means tire shreds can be used to limit frost penetration beneath roads and to remove excess water during spring thaws. Moreover, edge drains constructed with tire shreds will not freeze up during the cold winter months.

Lightweight Fill

Tire shreds were used as lightweight fill in the construction of two 9.8-m-high highway embankments in Portland, Maine. These embankments were the approach fills to a new bridge over the Maine Turnpike. The bridge is part of a new interchange that will provide better access to the Portland Jetport and Congress Street. This site was underlain by about 12 m of weak marine clay. The designers found that embankments built of conventional soil were too heavy, which resulted in an unacceptably low factor of safety against slope instability. Several ways to strengthen the foundation soils were examined, but were found to be too costly. What was really needed was to make the embankment lighter.

The designers considered several types of lightweight fill, including tire shreds, expanded polystyrene insulation boards, and expanded shale. Tire shreds were chosen because they cost $300,000 less than the other alternatives. Moreover, the project put some 1.2 million tires to a beneficial end use. The tires came from an abandoned stockpile in Durham, Maine. Through an innovative agreement, the Maine Turnpike Authority paid the normal purchase price for tire shreds, and the Maine Department of Environmental Protection paid the additional cost associated with the requirement that the shreds come from the Durham stockpile.

The Portland Jetport Interchange was the first project built in full accordance with the guidelines to limit self-heating of thick tire shred fills (*1, 2*). The guidelines require that a tire shred layer be no thicker than 3 m, so two layers separated by 0.9 m of soil were used. Low-permeability soil with a minimum of 30 percent passing the No. 200 sieve was placed on the outside and top of the fill to control the inflow of air and water. The final precaution to limit heating was to use large shreds with less than 25 percent passing the 38-mm sieve and less than 1 percent passing the No. 4 (4.75-mm) sieve. Temperature measurements taken in the embankments during and after construction showed no evidence of self-heating.

The tire shreds were placed with conventional construction techniques. First, geotextile was placed on the prepared base to act as a separator between the tire shreds and the surrounding soil. Then the tire shreds were spread in 305-mm-thick lifts using a small bulldozer (see Figure 1). Experience has shown that tire shreds with a maximum size of up to 305 mm can be spread with conventional construction equipment. Each lift was compacted with six passes of a 9-metric-ton vibratory roller. After being placed, the shreds were covered with a geotextile separator. The embankment was topped with 1.2 m of granular soil plus 1.2 m of temporary surcharge. The purpose of the surcharge was to increase the rate of consolidation of the soft clay foundation soils and was unrelated to the tire shred fill.

Retaining Wall Backfill

There are many reasons to use tire shreds as backfill for retaining walls. As noted earlier, the shreds are lightweight, so they produce low horizontal pressure on the back side of the wall. Moreover, they are free draining, so there is no problem with water pressure building up behind the wall, and they are a good insulator, so they prevent difficulties due to frost action. Tire shreds were used for this application in a test wall constructed at the University of Maine and behind the north abutment of the Merrymeeting Bridge in Topsham, Maine. Another application involves using the compressibility of tire shreds to reduce the pressure on a rigid-frame bridge, an application employed for another project in Topsham.

FIGURE 1 Spreading tire shreds for Portland Jetport Interchange in Maine using a small bulldozer.

FIGURE 2 Completed rigid-frame bridge on Route 196, Topsham, Maine.

Most retaining walls and bridge abutments are designed to move outward as the backfill is placed. This small movement allows the soil backfill to develop its strength, thereby reducing the horizontal pressure on the wall. For rigid-frame bridges, however, the tops of the abutment walls are connected together with a concrete slab, so the walls cannot move away from the backfill. In addition, batter piles or a concrete base slab restricts the movement of the base of the abutment.

These were the challenges faced by the designers of a rigid-frame bridge that would carry Route 196 over an existing rail line in Topsham. The bridge spans a single-track railroad providing a 7.6-m-wide by 7.0-m-high opening for rail traffic. Approach fills were up to 11 m high. The road alignment intersects the railroad at an acute 24-degree angle, necessitating a bridge with a 93-m width. Overall, the bridge resembles a long tunnel.

The designers were faced with a choice. Since the abutment walls could not move away from the backfill, a conventional design would call for the walls to resist relatively high at-rest horizontal pressures. A less costly alternative would be to find a way to allow the soil backfill to move 25 mm or so toward the abutments. The solution was a 0.9-m-wide zone of tire shreds placed against each abutment wall. The tire shred zones would provide enough compressibility to allow the adjacent soil backfill to move toward the bridge, lowering the stress on the wall to "active" pressures. This approach allowed the designers to use abutment walls with less steel reinforcement and concrete.

The tire shreds for this project had a maximum size of 75 mm. This size was preferable since each lift of shreds would need to be hand leveled prior to compaction. Moreover, self-heating of a 0.9-m-wide zone was not a concern, so there was no reason to use larger shreds. Even though the tire shred zone was only 0.9 m wide, the project used some 100,000 tires—evidence of the potential for small projects to use large numbers of tires. The sources for the tire shreds were abandoned stockpiles and recently generated scrap tires.

Construction started with placement of a geotextile to act as a separator between the tire shreds and the adjacent soil. Tire shreds and adjacent granular borrow were raised in 0.2-m lifts. The shreds were placed with a front-end loader. Each lift was compacted by four passes of a walk-behind roller. In retrospect, it would have been acceptable, as well as easier for the contractor, to use 0.3-m-thick lifts.

The tire shred zone significantly reduced the horizontal pressure on the backs of the abutment walls. Pressure cells mounted in the concrete walls showed pressures of 10 to 18 kilopascals (kPa) with tire shreds, compared with about 45 kPa for areas backfilled with conventional granular fill. Moreover, compaction did not produce the high "locked-in" horizontal stresses that often occur with soil backfill. Thus dramatic benefits can be obtained by using tire shreds as backfill for rigid-frame bridges. Figure 2 shows the completed rigid-frame bridge in Topsham.

Water Quality Effects

Several studies have shown that tire shreds can be used in most applications with negligible effects on groundwater quality. In North Yarmouth, Maine, a test project was constructed to study the effect of tire

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