Lightweight Fill Materials for Road Construction

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A lightweight fill is any material used to replace a heavier in situ soil to reduce the load on subgrade soils. The use of lightweight fills is increasing in many areas of the United States. Various materials have been used; however, because of their experimental nature there are no formal design guidelines specific to each material. Additional research is required to determine more specific design guidelines for each available lightweight fill material. The selection of a lightweight fill is generally based on local knowledge of each fill material. For any construction project requiring a lightweight fill, there may be several alternative materials to consider. However, due to a limited knowledge or unfamiliarity with these materials, design engineers might not consider them as an alternative. This synthesis has been written to help determine what technology and materials are available for use in road construction in areas where a lightweight fill material may be appropriate. The fills investigated are sawdust and wood chips, expanded polystyrene, foamed concrete, and shredded tires.

Minnesota is known as the Land of 10,000 Lakes; however, there are just as many, if not more, swamps and bogs. Generally, the soils near the swamps and bogs restrict the type of road construction available. These construction restrictions can cause city, county, and state engineers a variety of design problems. Sometimes traversing these areas can be costly and time consuming. Consequently, new roads may not follow the most desirable routes, and existing routes may continue to have high maintenance costs.

The use of wetlands for construction purposes is regulated, making it difficult to obtain construction permits. These regulations complicate the use of wetlands beyond the scope of this report.

In Minnesota, soils of concern are generally organic or clay materials and involve a relatively high water table near the surface. When encountering areas of organic materials or other poor soils, the first alternative is to find an acceptable route around the area. In some instances, this may not be feasible and the poor soils must be traversed. When constructing on an area of poor soils, there are several alternatives:

1. The soils of concern can be removed to a depth where stronger soils are found and backfilled with a granular material;
2. A small amount of the poor soil may be removed and replaced with a lightweight material of lower density, thus creating a floating platform;
3. If the in situ soils are only a concern while saturated, the area may be permanently drained to a suitable depth;
4. Construction may be staged and the soils may be surcharged;
5. A geotextile may be placed over the existing vegetation and covered with a granular material; and
6. The area may be bridged by a suspended structure.

These options are all viable and should be evaluated individually to determine feasibility and cost-effectiveness. This report will focus on the second alternative—construction with lightweight materials.

Lightweight Fills

Various lightweight fill materials have been in use for many years throughout Minnesota. The materials most commonly used are sawdust and wood chips and chunks. These materials are light and inexpensive byproducts and are often readily available. Although many of their qualities are desirable for a fill material in road construction, wood products also possess some undesirable qualities. In many cases, wood products placed above the permanent water tables are highly biodegradable. Additionally, toxins may leach from the wood products and enter the groundwater system. A danger of fire with wood products also exists, more so during than after construction.

Shredded waste tires are another readily available and inexpensive product that may be used as a lightweight fill material. The use of tires below the water level causes concern for toxic leachates when exposed to certain chemicals. This is currently a concern of the Minnesota Pollution Control Agency (MPCA), and further independent research is welcome.

Expanded polystyrene (EPS) is a form of heavy-duty Styrofoam that has a density lower than any other lightweight fill currently in use. EPS is nonbiodegradable and is easily placed using little or no machinery. The deterrent of EPS is its high cost. Although widely used and relatively inexpensive in Norway, there is limited documented use in the United States. One documented use is in Pickford, Michigan, near a Dow Chemical plant. The costs of EPS in Pickford are unique in that the Dow plant had a stockpile of unused EPS at the time it was needed.

Bark and Sawdust

Bark and sawdust are lightweight fill materials that will greatly reduce the static load of a pavement structure. Wood products have been used for many years by the timber companies as a lightweight fill material for the reclamation of peat bogs and swamplands. Many county, state, and federal agencies have also used these products as lightweight fill material for swamps, as well as in areas where excessive soil loads could cause slope shear failures.

Cosmopolis, Washington (1)

The use of sawdust was researched by the FHWA in 1974 on a site near Cosmopolis, Washington, a site at which excessive rain fall led to a slope failure (*1*). Although these soils were *above the water table*, sawdust was selected as a lightweight fill. This created a problem in that when placed above the water table (an aerobic condition), sawdust is biodegradable and will decay and break down. To reduce the biodegradation process, an emulsified asphalt sealer was mixed with the sawdust on the slopes, creating an impermeable shell to help achieve a near-anaerobic condition. Three varieties of sawdust were used: hog fuel, planer chips, and bark chips. The uncompacted and compacted densities were 380 kg/m^3 (23.7 lb/ft^3) and 581 kg/m^3 (36.3 lb/ft^3), respectively. Traffic characteristics of this roadway are not reported; therefore, the effects of heavy loads cannot be determined. The FHWA report states the following conclusions:

1. Sawdust is a very workable and easily placed fill material;
2. Sawdust can reduce the driving weight of a potential slide area by as much as 71 percent, thereby reducing the chance of slope shear failure;
3. The fibrous intertwining of sawdust particles tends to create an interconnected web, thereby distributing the loads in a more lateral direction;
4. Sawdust does not require mechanical compaction —the compaction obtained from the construction equipment is adequate;
5. Indications are that sawdust fill materials can sustain roadway sections for 15 years or longer before the decomposition of the fill requires reconstruction; and
6. The use of sawdust material above the water table should be based on economics, availability, and environmental concerns.

Mt. Baker–Snoqualmie National Forest, Washington (2)

Sawdust and wood waste have been used within the Mt. Baker–Snoqualmie National Forest for varying purposes from fill over soft, compressible soils to backfill behind and on top of fabric-reinforced retaining structures. Multiple road structures have been built since 1975 using some type of wood waste product during construction. Many of these sites were located along steep slopes experiencing slope instability and slump. The existing soils were subcut to depths of up to 4.3 m (14 ft) and replaced with sawdust. The sawdust was placed in 0.3-m (1 ft) layers and compacted with hauling and spreading equipment. The surface of the sawdust was sometimes sprayed with emulsified asphalt to prevent ultraviolet degradation; however, many sawdust piles 20 years or more old showed little degradation, and therefore not all sawdust construction sites received asphalt protection.

The sites constructed within the Mt. Baker–Snoqualmie National Forest are performing well with little additional settlement. The method of using sawdust in areas of marginal stability has proven cost-effective and easy to construct. Additional construction sites have been planned and will be monitored.

The Minnesota Department of Transportation (DOT) does not have written design guidelines for the use of wood products in road construction. The Minnesota DOT Office of Materials and Research sponsored a research study in 1976 conducted by Lukanen (*3*). This project consisted of six methods of floating roadway widening sections over a peat swamp:

1. Corduroy—a method of placing tied logs perpendicular to the road to create a solid working platform for further construction;
2. Wood chip working platform—a modification of the corduroy method to create a working platform with 0.6 m (2 ft) of wood chips; the chips are then capped with a minimum of 15 cm (6 in.) of clay to reduce their exposure to air;
3. Wood chip embankment—used in areas of high fill to reduce the total fill weight and capped with 0.6 m (2 ft) of clay to reduce exposure to air;
4. Full-width fabric section—fabric is placed transversely across the road and into the ditches; it should limit horizontal movement and transfer some of the load of the widening to the existing roadbed;
5. Ditch fabric section—fabric is placed 5.2 m (17 ft) from centerline and extended into the ditch area, adding tensile strength and allowing a thinner layer of fill on which equipment can work; and
6. Weakened plane section—a 1.1-m-deep (3 ft), 15-cm-wide (6 in.) trench is dug 4.6 m (15 ft) from centerline, allowing the widened section to settle without causing distress within the original road section.

The construction and observation of these six methods yielded the following findings and conclusions.

> Wood chips provide a good working platform upon which fill can be placed and light machinery can operate. They did not displace in front of machinery or fill and had sufficient stability to withstand submersion in water. Running water, however, may easily displace wood chips. . . . Any kind of disturbance of the existing vegetation mat appears to cause problems. A drainage ditch was cut into the root mat and longitudinal cracking appeared in the lane adjacent to the ditch. A drainage ditch was cut adjacent to the widening over a shallow swamp, and longitudinal cracking appeared in the pavement for several hundred feet along the ditch. Later borings showed the fill to be setting on .9 to 1.5 meters (3-5 ft) of peat in this area. . . . The construction costs of floated widenings are much less than the keying method of sobcutting the sides to a stable subgrade and backfilling. Floating widenings are also much quicker to construct than keyed widenings. . . . Any drainage ditches that have to be constructed in conjunction with widening on future projects should be placed a sufficient distance away from the road to prevent transverse movement and the formation of longitudinal cracks in the pavement. (*3*)

When using sawmill residue or timber corduroy as a road embankment, the biodeterioration of the lignocellulosic material has to be controlled. Wood is made up of more than 50 percent cellulose and 10 percent to 35 percent lignin. Lignin is a more complex carbohydrate than cellulose; however, both will break down under aerobic conditions. Various methods to control biodeterioration exist:

- Ensure that the wood product remains below the groundwater table;
- Use chemical treatments such as an emulsified asphalt or other type of sealer, which may be expensive and difficult to distribute evenly;
- Use a geotextile fabric to restrict aeration to the sawmill residue (*4*); and
- Cap wood product with a layer of plastic soil to reduce exposure to air.

Polystyrene Foam

Expanded polystyrene has had limited use in the United States as a lightweight fill. (One documented case was in Pickford, Michigan.) However, Norway and Finland, with their numerous wetlands and peat bogs, have extensive experience with EPS as a lightweight fill. For many years, Norway has been using EPS as insulation boards for a frost protectant. In 1972, Norway began using polystyrene in greater thicknesses to reduce excessive settlements in areas where soils were unable to support the static load of a pavement structure.

The cost of EPS depends on the strength required, amount needed, and various other factors. For this reason, it is impossible to estimate product cost accurately. The unit cost of EPS may be high although an analysis of the cost of load reduction per square foot must be conducted for all alternatives under consideration. Total load reduction is the weight of the soil removed minus the weight of the fill used. The cost of load reduction takes into account the cost of the soil excavation plus the cost of the required fill material. Although a material of lower density may be more expensive, it may require less excavation, thereby decreasing the cost of excavation and the amount of fill material required.

Pickford, Michigan (5)

Engineers within the United States have done little experimentation with polystyrene as a lightweight fill. One application of EPS is located near Pickford, Michigan, on the Big Munuscong River. This is a case where the soft dense soils, approximately 2002 kg/m^3 (125 lb/ft^3), of a bridge approach were sliding toward the river, moving the piers and abutments. Since increasing the length of the bridge or completely removing the unstable soils were determined to be too costly, various lightweight fills were considered.

Lightweight expanded aggregate would have required excavation below the pier and river bottom. This option was eliminated because of instability problems and the transportation cost of hauling the aggregate (nearest source was 402 km (250 mi) away).

A seminested series of corrugated metal pipes in a sand fill was considered, which would have decreased the fill load by creating void areas within the pipes. This procedure would have required 4.9 m (16 ft) of excavation and 305 lineal m (1,000 ft) of various culvert sizes. Because of the cost of the corrugated pipe, this option was not chosen.

Another option, cedar logs, would have provided a load reduction of 1121 kg/m^2 for each 1 m of fill (70 lb/ft^2 for each 1 ft). Since this option would require 3823 m^3 (5,000 yd^3) of cedar logs, it was rejected because the logs could not be obtained within a reasonable time. Additionally, their long-term durability was questionable.

Polystyrene was examined and found to weigh much less than sand or very soft clay, 48 kg/m^3 versus 1922 kg/m^3 (3 lb/ft^3 vs. 120 lb/ft^3). The tremendous weight reduction per depth of excavation would be a great advantage, reducing the required excavation substantially. EPS has long-term durability and is only slightly affected by the surrounding moisture (5). Approximately 983 m^3 (1,285 yd^3) of EPS would be required.

The Michigan Department of State Highways and Transportation (DSHT) discovered that due to an ordering error Dow Chemical Company (Midland, Mich.) possessed a large amount of EPS from a previous order and provided the material at a lower than normal unit cost. To obtain a product cost for future projects, a producer would have to be contacted and given the amount and required strength of the needed EPS.

The unit cost of the EPS for this project is not a representative cost for future projects. Polystyrene fill was selected because of its low density, minimum required excavation, durability, ease of placement, immediate availability, and comparatively low cost. The foam came in 2.44-m × 0.61-m × 3.81-cm boards (8 ft × 2 ft × 1.5 in.). These boards were taped together in bundles of eight forming a billet 2.44 m × 0.61 m × 0.31 m (8 ft × 2 ft × 1 ft) weighing 22.7 kg (50 lb). The billets were placed, staggering joints, at a total thickness of 1.52 m (5 ft) near the bridge where the most load reduction was needed to one billet of 3.81 cm (1.5 in.), 45.7 m (150 ft) from the abutment. It was important to cover the polystyrene with enough fill material to resist the buoyant forces of the foam when the Big Munuscong River rises in the spring. Prior to covering with soil, the foam was covered with a 4-mil-thick polystyrene sheeting. This sheeting was placed to protect the foam from possible spillage of petroleum-based liquids that could seep through the granular cover and dissolve the polystyrene.

Norway

Numerous projects have been conducted throughout Norway using expanded polystyrene as a lightweight fill. Norway, like the northern United States, experiences numerous freeze-thaw periods and extended periods with temperatures below freezing. The United States may be able to benefit from some of Norway's experience with EPS.

In an issue of *Veglaboratoriet*, produced by the Norwegian Road Research Laboratory, the following experiences with expanded polystyrene as a lightweight fill are discussed (6).

Compressive Strength

The compressive strength of the EPS was tested at four construction sites using excavated samples. These construction sites in Solbotmoan, Flom, Langhus, and Lenken have been in place from 1 to 5 years. The study concluded that the compressive strength of the expanded polystyrene has not decreased measurably over time. In fact, in some cases the compressive strength had increased, possibly due to the increase of the moisture content of the fill material.

Moisture Resistance

In the most extreme case, a polystyrene fill was permanently submerged below the groundwater level for 9 years at Solbotmoan to evaluate EPS resistance to moisture. An increase of 9 percent absorption was observed. Above the groundwater level, the moisture content decreased to 1 percent by volume. In areas of periodic submersal, a moisture content of 4 percent was observed. Due to these moisture contents a density of 16.6 kg/m^3 (28 lb/yd^3) is recommended for dry conditions and 33.2 kg/m^3 (56 lb/yd^3) for submerged conditions.

Settlements

Only slight settlements have been noticed at a few sites throughout Norway. Most settlements can be attributed to slippage of the underlying embankment materials. Settlement within the polystyrene blocks can be expected to be between 0.5 percent and 2 percent of the thickness of the blocks.

Flammability

Similar to sawdust and bark chips, polystyrene is flammable. Two sites in Norway, a fill and a stockpile, accidently burned and were destroyed. The fill was a 1499-m^3 (1,960-yd^3) polystyrene embankment leading up to Knatten Bridge in the district of Akefhsus. The fire was caused by welding too close to the bridge abutment. It is recommended that extreme care be taken when conducting any high-temperature work near polystyrene.

A self-extinguishing polystyrene is available at a higher cost; however, statistics show it would be cheaper to use the standard polystyrene and accept the occasional loss.

Chemical Resistance

Petroleum-based products will react with and dissolve polystyrene foam. Therefore, it is necessary to cover the material with a concrete slab or a petroleum-resistant geotextile rather than an asphalt surface. In the event of an accident or spill, the chemical products would be prevented from reaching the EPS.

Pavement Bearing Capacity

Through analysis conducted at the Norwegian Road Research Laboratory, the stresses and strains in the pavement and subgrade were calculated using a modified Chevron program. The research concluded that varying the depth of the polystyrene fill had no significant influence on the pavement design.

A 10-cm (4-in.) concrete slab is recommended below the bituminous surface. If the concrete slab is omitted, the bituminous would need to be increased by 0.3 to 0.4 m (12 in. to 16 in.) to keep stresses and deflections at the same level. This is a substantial structure, and the increase cost would need to be considered in a cost comparison study.

Dynamic Loads

If the total dynamic and static loads are limited to 80 percent or less of the compressive strength of the polystyrene, EPS can theoretically service an unlimited number of loads. Therefore, for all practical purposes of a 20-year design period, dynamic loads do not affect an expanded polystyrene fill. It is likely the pavement surface will reach the end of its design life long before the EPS fill material. EPS is available in a wide range of compressive strengths; these strengths must be known for each loading condition.

Icing Problems

EPS has high insulative properties. During a frost cycle, a pavement structure with EPS does not experience the warming effects of the soil below causing differential icing with respect to the surrounding road surface. This may cause traffic hazards; therefore deicing procedures must be established.

Shredded Tires

Automotive tires are discarded at a rate of 3 million [84 106 m^3 of tires (110,000 yd^3)] annually in just the state of Minnesota (*7*). This large volume of waste has little applicable reuse. In 1985, a recycling firm and a logging contractor contacted the MPCA regarding the use of waste tires in constructing forest roads. In 1986, the Hedbom Forest Road in Floodwood, Minnesota, was constructed using waste tires. The tires were placed below the base material using nine different placement strategies (*7*). These placements ranged from whole tires tied together to spreading shredded tires as a base material. As of the last review in 1989, all of the test sections were performing exceptionally well. This study caused the MPCA to conduct testing to establish some guidelines for the use of waste tires as a fill material. These guidelines have led to some controversy. Many individuals wish to further investigate the use of waste tires as a lightweight fill as opposed to stockpiling, which may have equal or greater hazards.

MPCA Guidelines

The use of shredded tires as a lightweight fill may be efficient and effective, but there is an environmental concern. A study published by the Minnesota Pollution Control Agency discusses many of the possible negative aspects of the use of shredded tires as a fill material (*8*). Laboratory tests were conducted over a range of pH levels from 3.5 to 8 to simulate potential worst-case scenarios. These laboratory tests were extreme and may or may not represent actual field conditions. Soils in northeastern Minnesota tend to be acidic, while the soils in the southwest are primarily alkaline. Soil sampling was also conducted around two existing waste tire stockpiles. The laboratory tests conducted and soil samples tested yielded the following conclusions:

1. Toxic metals are leached, in the highest concentrations, from the tires under acidic conditions. The ma-

terials of concern are barium, cadmium, chromium, lead, selenium, and zinc.

2. Polynuclear aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons are leached from tire materials in the highest concentration under alkaline conditions.

3. Asphalt materials may leach higher concentrations of contaminants of concern than tire materials under some conditions.

4. Recommended allowable limits for drinking water set by the Minnesota Department of Health may be exceeded under "worst-case" conditions for arsenic, barium, cadmium, chromium, lead, selenium, and carcinogenic and noncarcinogenic PAHs. "Worst-case" conditions for metals appear to occur at low pH (acid) conditions. "Worst-case" conditions for organics appear to occur at high pH (basic) conditions.

5. A biological field survey did not identify significant differences between waste tire areas and control areas with respect to soil samples.

6. Potential environmental impacts from the use of waste tires can be minimized by placing tire materials only in the unsaturated zone (above the water table) of the roadway subgrade. This can be accomplished by placing alternative materials, such as wood chips or soil, below the water table.

7. The metals leached from waste tire stockpiles are similar in concentrations to those leached in areas where tires are used for fill.

From this study, the MPCA has set forth guidelines for using shredded tires as a lightweight fill material in construction. Although other states may vary, following are the Minnesota guidelines (9).

1. Road Repair and Construction:

- Shredded waste tires can be used in road construction or repair if the tire shreds will be above the water table and not in contact with groundwater. Tire shreds cannot be used below the water table.
- Roads and road slopes must be designed and constructed to reduce water infiltration and to promote surface water drainage away from the roadbed, to minimize the amount of surface water seeping through the shredded tires.

2. General Construction (applies to *all* shredded tire construction projects)

- A synthetic geotextile fabric is recommended above and below the areas where shredded waste tires are used. The fabric will prevent movement of soil into the tire shreds and will hold the tire shreds in place.
- Tire shreds must be covered by a low-permeability surface to reduce seepage of surface water.

If a proposed construction project meets these criteria, the MPCA should be contacted to determine what type of information or monitoring is required. If subsequent monitoring indicates unacceptable types and levels of leachates, it is likely the MPCA will require the removal of the fill material.

CSAH 21, Rice, Minnesota (10)

A portion of County State Aid Highway (CSAH) 21 in Benton County, north of Rice, Minnesota, crosses a swamp. A traffic count conducted in 1987 indicated the annual average daily traffic was approximately 500 vehicles. Increases in the level of the swamp caused the need to increase the roadway elevation. Conventional methods of additional granular fill were used to raise this roadway above the water level. During extended periods of dry conditions, the underlying peat material decreased in strength and failed. A decision was made to use a lightweight fill rather than remove the soft underlying soils. In an experiment to reduce a waste problem while solving a construction problem, shredded tires obtained from a tire landfill, which the MPCA had designated for early cleanup, were selected as a lightweight fill material.

The existing embankment was excavated to a level 15 cm (6 in.) above the surrounding marsh. A layer of shredded tires, approximately 1.2 m (4 ft) in depth, was sandwiched between a geotextile fabric and covered with 1.1 m (3.5 ft) of clean granular backfill. The geofabric was used to prevent the intrusion of soils into the tire fill. The section was paved with gravel base, subbase, and bituminous as normal and is performing well with no apparent visual problems.

Duluth and Tower Avenues, Prior Lake, Minnesota (11)

The intersection of Duluth Avenue and Tower Avenue in the city of Prior Lake required reconstruction in 1991. To obtain state funding, the city was required to change the alignment of the two roadways. The new alignment crossed a wetland with organic deposits approximately 9.1 m (30 ft) in depth.
Three options were considered:

1. Excavate to an adequate load bearing strata and refill with granular material,
2. Stage construction and surcharge to compress the underlying organics, and
3. Replace subgrade with a lightweight fill.

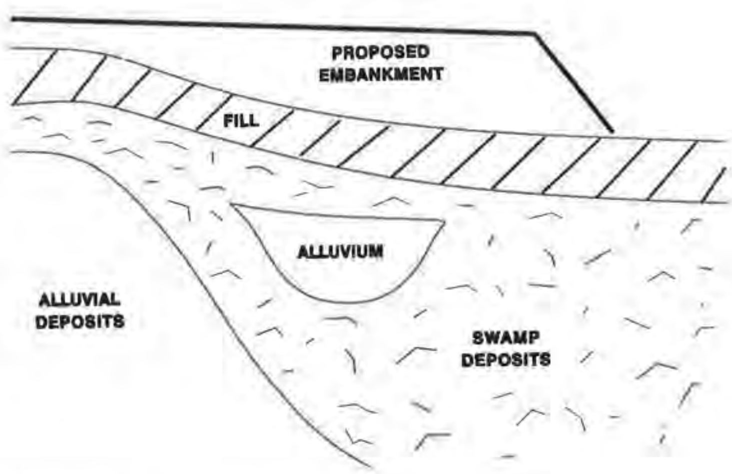

FIGURE 1 Soil cross section.

Because of the relatively higher costs and time constraints of Options 1 and 2, the city decided on Option 3, construction with a lightweight fill. Wood chips were placed to a depth of 0.3 m (1 ft) above the anticipated groundwater level on top of a Minnesota DOT Type 3 geotextile fabric. Wood chips were placed to conform with the MPCA regulation restricting the use of shredded tires below the groundwater level. To reduce the risk of biodegradation, wood chips were not used for the entire fill. Approximately 3 ft of shredded recycled tires were placed directly on the wood chips and covered with a Minnesota DOT Type 5 geotextile. A 15-cm (6-in.) sand layer and 61 cm (24 in.) of Class 5 were used to cover the entire section prior to paving. A cross section of the existing soils and the final design may be found in Figures 1 and 2.

During placement of the 0.76 m (2.5 ft) of sand and Class 5 materials, the tire shreds settled 15 cm (6 in.), resulting in the need for an additional 15 cm of granular base. Although this settlement was unexpected, the additional 15 cm of compaction increased the modulus of the tire shreds; however, the actual increase in modulus is unknown. Based on this project, it is the city engineers' opinion that pavement design using shredded tire subgrades should assume an R-value of 5 for the tire material (*11*).

This section was constructed in 1991, so it is too early to determine if any problems or irregularities will develop. The section appears to be in good condition and the city engineers expected it to perform adequately.

Interim Design Guidelines

This interim report was conducted to determine some of the characteristics of a shredded tire fill and was generated from data gathered from a private access road constructed with shredded tires at thicknesses of 0.9 m and 1.8 m (3 ft and 6 ft). Some of the conclusions found in this interim report are as follows:

1. The rate and effectiveness of compaction are similar to sawdust fills.
2. It appears all appreciable increase in bulk unit weight can be achieved with about 24 passes of a D7 Caterpillar.
3. The maximum bulk unit weight of tire shreds with an average particle area of 929 cm^2 (1 ft^2) is approximately 320 kg/m^3 to 368 kg/m^3 (20 lb/ft^3 to 23 lb/ft^3).

Currently, the primary cost of using waste tires is for the transportation and placement of the material. Many stockpilers are willing to shred and give the tires away to reduce their inventory. As the use of waste tires increases, the cost from the suppliers may increase; however, it will likely remain one of the least expensive materials.

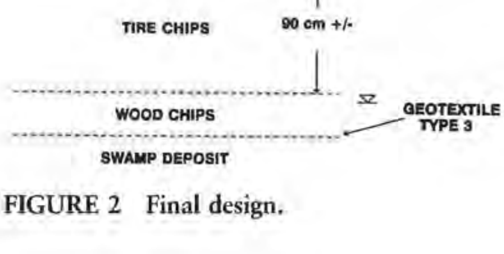

FIGURE 2 Final design.

Foamed Concrete

Lightweight foamed concrete has been widely used in building construction for floors, roof decks, and insulation. Recently, foamed concrete has been used as a lightweight fill in highway construction, primarily in the area of bridge abutments. These areas may contain poor soils and require a lightweight fill that does not exhibit horizontal pressures on the adjoining structure. Foamed concrete has been used for many roadway projects simply because a lightweight fill material with high strength is required.

Foamed concrete is generally mixed on site by the supplier with a portable mixing unit. The cost of this fill may be too costly—at \$30 to \$35/m^3 (\$40 to \$45/yd^3)—for small county and city projects in remote areas; although for special cases, such as bridge abutments, it may be an economical alternative.

The only foamed concrete considered to be a "lightweight" fill for this report is a product called Elastizell, produced and patented by the Elastizell Corporation of America, based in Ann Arbor, Michigan. The material mix plants are truck mounted and are therefore available in Minnesota. Various classes of the material are produced with different strengths and densities. The maximum cast densities can be found in Table 1.

7th and Lyndale, Minneapolis, Minnesota

A large project in Minneapolis, Minnesota—the intersection of Lyndale Avenue and 7th Street near I-94—was constructed using Elastizell. (A detailed report of this project is not available.) A new bridge over I-94 required high approach fills. Normally this would not have been a problem; however, the approach was located over poor soils and was to cross over the Basset Creek storm sewer tunnel. Future settlement of the high fill was a concern. A fill was needed that was light enough to minimize settlement and strong enough to support the high approach with minimal horizontal stress. Elastizell was selected and various classes with different compressive strengths were used. A cross section of the various materials is shown in Figure 3. This project has performed well for 10 years and no future problems are anticipated.

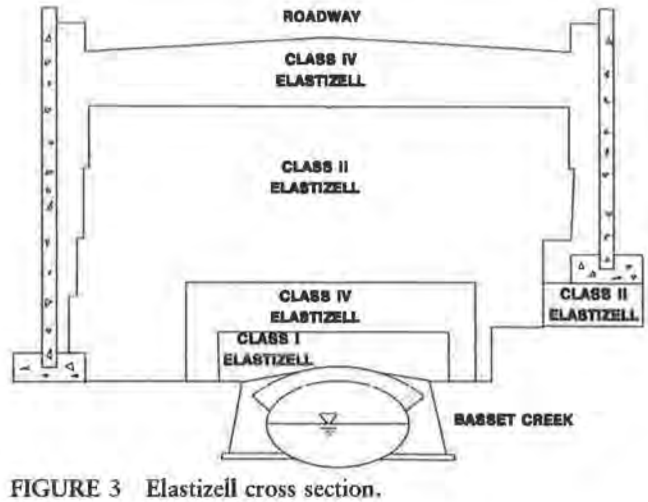

FIGURE 3 Elastizell cross section.

TABLE 1 Elastizell Specifications

CLASS	MAXIMUM CAST DENSITY (kg/m^3)	MINIMUM COMPRESSIVE STRENGTH (pa) x 1,000	ULTIMATE BEARING CAPACITY (kg/m^3) x 1,000
I	384	68.9	6.8
II	481	276	28.3
III	577	552	56.6
IV	673	827	83.9
V	801	1,103	112
VI	1,281	2,068	210

Waiska River, MI-28 Crossing (12)

During the replacement of the bridge superstructure crossing the Waiska River 9.6 km (6 mi) west of I-75 in Michigan (1976), it was discovered that the eastern approach had settled 0.46 m (1.5 ft) and would require replacement. Because of the soft alluvial clay subsoils, either the bridge structure would have to be lengthened or the soils in the "approach area" would have to be removed and replaced with a lightweight fill material. The relatively high cost of lengthening the bridge structure was prohibitive and a lightweight fill option was selected. Elastizell was used to keep horizontal stresses against the bridge abutment to a minimum. The Michigan Department of State Highways and Transportation covered the foamed concrete with approximately 1.2 m (4 ft) of sand subbase to reduce the number of freeze-thaw cycles to which the concrete might be exposed.

The construction report for this project concluded:

1. Placement of the foamed concrete by the producer and its equipment was easy with relatively few construction problems. Due to the low viscosity, it was recommended that any transverse slopes be step tapered using basic concrete forming procedures.

2. Specifications must be developed to enable acceptance on the basis of 2- or 3-day compressive strength and dry density.

3. Due to material property characteristics (cost, low compressive strength, nonhomogeneity, water sorption characteristics, and equilibrium wet density), Elastizell

concrete cannot be recommended for general use as a lightweight fill material without qualifications.

A follow-up study had not been conducted at the time this paper was written.

Pine River Bridge, St. Clair, Michigan (13)

Another construction site was the Pine River Bridge project in St. Clair, Michigan (1976). The original bridge had been rebuilt in 1933 but had become increasingly difficult and costly to maintain. The area consisted of deep, soft alluvial clays that resulted in extensive settlement that required structural repairs. A new bridge was designed that included a 1.1-m (3.5-ft) raise in grade.

Because of the soft clay subgrade, two design alternatives were considered to prevent future settlement: the construction of additional approach spans or the use of a lightweight fill material. It was estimated that the use of a lightweight fill material could save as much as $200,000 for this project.

The technical report for this project contains conclusions similar to the Waiska River project in that the Elastizell was easily placed, although specifications and qualifications must be further developed.

Performance of Foamed Concrete

In a later report concerning the two Michigan projects mentioned previously (*14*), the Michigan DSHT concluded:

1. In general, Elastizell concrete appears to be a satisfactory lightweight fill material. The material has adequate strength, remains lighter than the design unit weight and does not absorb water, and settlements are negligible.
2. Although structurally sound, the Elastizell fills contain a large number of soft, powdery areas that have little or no support value. To date, these areas have not appeared to be damaging, but they should certainly be eliminated or minimized by better batch-mixing control.
3. No conclusions concerning the long-term performance of Elastizell were made at this time. Sampling and testing of the fills continue to monitor any changes in settlement, in-place density, or moisture content that may take place with continued exposure.

FINDINGS

General

The current level of technology being applied to the design of roadways using lightweight fills is based on either experience or the adaptions of other design guidelines.

Although a material may have a high cost, an economic study should be conducted to determine the cost per kilogram load reduction per square meter to determine the total cost. A cost study may show that the more expensive material may require less excavation and therefore require less fill material compared to the less expensive lightweight fill material.

For example, a construction area located over soft alluvial clays requires a load reduction of the subgrade materials, 2440 kg/m^3 (500 lb/ft^2), to minimize future settlement. Assuming an in-place wet density of the surface materials to be 2002 kg/m^3 (125 lb/ft^3), the following excavations and fill depths would be required: shredded tires, 1.65 m; wood chips, 1.44 m; and polystyrene foam, 1.28 m.

A cost analysis would include the cost of the excavation, lightweight fill, and fill placement.

$(excavation) + $(fill material) + $(fill placement)

= comparable fill cost

Although shredded tires may be cheaper, polystyrene foam requires less excavation and is placed easily without the need of heavy equipment.

Sawdust, Wood Chips, and Corduroy

Wood material is viable as a lightweight fill; however, it is biodegradable. Design parameters are known and many agencies have experimented with wood materials. Some wood materials are considered a by-product and therefore are generally inexpensive.

Expanded Polystyrene

Although EPS has had limited use in Michigan and even less use in the rest of the United States, it has been used extensively in Norway and Finland where it is performing well. Further use of EPS in the United States may prove to be beneficial and cost-effective.

Waste Tires

Shredded tires are an effective lightweight material that may be used above the water table. They provide adequate strength and load transfer while reducing the static load on the underlying soils.

Currently the MPCA restricts the use of tires within a saturated zone. A composite alternative using waste tires has been to place wood chips to a depth of 0.3 m (1 ft) above the water table, taking care to prevent biodegradation, and continue the fill with waste tires. However, the use of one fill that is nonbiodegradable and inexpensive throughout all layers, in comparison to using numerous fills, could cut the cost of expanding our roads across load-restrictive soils.

Foamed Concrete

Foamed concrete is a high-strength, low-density material that would work well in many areas. The cost of foamed concrete is high; therefore, it may be justified only in special cases where high strength and limited horizontal forces are required.

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The opinions, findings, and conclusions in this paper are those of the authors and not necessarily those of the Transportation Research Board.