AGGREGATE AND SOIL SURFACES

UNBOUND AND MECHANICALLY STABILIZED SURFACINGS

CELLULAR CONFINEMENT

GENERAL INFORMATION

Generic Name(s): Cellular Confined Aggregate, Geocell, Cellular Confinement System

Trade Names: Geoweb, Hyson Cells

Product Description: Cellular confined aggregate, sometimes referred to as geocells, are constructed with a geosynthetic product that forms a honeycomb-like cellular structure that is infilled with aggregate to create a stabilized aggregate layer. Cellular confined aggregate improves the load distribution characteristics of the granular material due to the reinforcement provided by the geosynthetic, the passive resistance of material in adjoining cells, and the transfer of vertical stresses to adjoining cells. High friction values between the infill material and cell walls are developed by the use of geocells with textured or perforated walls. Perforated wall geocells have the added advantage of allowing lateral drainage through the granular layer, which is beneficial when the cellular confined aggregate is founded on low permeability, cohesive soil.

Product Suppliers: GeoProducts, LLC, 8615 Golden Spike Lane, Houston, TX 77086, (281) 820-5493, www.geoproducts.org; and

Presto Products Company, P.O. Box 2399, Appleton, WI 54912-2399, (800) 548-3424, www.prestogeo.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and geocell products are available.

APPLICATION

Typical Use: Soil reinforcement, road surfacing.

Traffic Range: As a reinforced base, cellular confined aggregate can be used for Very Low to High traffic volume applications. As a road surfacing, cellular confined aggregate can be used for Very Low to Medium traffic volume applications.

Restrictions:

Traffic: None.

Climate: None; however, use in wet and/or cold climates will lead to more frequent deterioration and more frequent maintenance.

Weather: None.

Terrain: None.

Soil Type: N/A

Other: None.

Other Comments: Cellular confined aggregate can be used to reduce the required granular layer thickness in a roadway design, allow the use of locally available marginal materials, or reduce the maintenance requirements of a gravel road over its design life. Depending on the infill material used, geocells can support grass growth where a more natural appearance is desired.

DESIGN

SLC: 0.35 (geocell with granular infill).

Other Design Values: None.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support. For low volume applications, geocells can be constructed directly on the subgrade unless heavy loads dictate the need for greater subbase/subgrade support. Subgrade and base materials should be compacted and graded to provide a uniform working platform prior to geocell placement. When built over fine-grained, cohesive soils, a nonwoven geotextile is placed on the subgrade surface as a separation layer to prevent the migration of fines into the cellular confined aggregate.

Other Comments: The road surface should be graded to promote surface drainage and prevent ponding on the road surface that can promote softening of the reinforced materials, although the infill materials are usually quite permeable. Cellular confined aggregate can be constructed with a thickness of 100 to 200 mm (4 to 8 in.). Lower quality granular materials can be used for applications where driving speeds are slow and ride quality is not critical. High quality granular materials should be used for roads that have higher driving speeds and ride quality is more important. Cellular confined aggregate is usually covered with a surface course. A minimum of 50 mm (2 in.) of dense graded crushed granular material that has good rut resistance is recommended as a surface course above the cellular confined aggregate. If a HACP layer is used for road surfacing, a minimum of 25 mm (1 in.) of cover aggregate over the geocells is recommended.

CONSTRUCTION

Availability of Experienced Personnel: Cellular confined aggregate is not a commonly used surfacing, but the installation is relatively simple. Qualified contractors are, in general, locally available in large urban areas and regionally available in remote areas.

Materials: The geocell geosynthetic product and aggregate are required for construction of cellular confined aggregate. Aggregate infill material should be granular with a maximum particle size of 50 mm (2 in.). The aggregate material should have less than 10% fines content and a plasticity index below 6.

Equipment: Equipment required for cellular confined aggregate construction includes: backhoe, excavator, or front-end loader, grading equipment, and compaction equipment. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: N/A

Placement Process: The geocell sections are placed on the prepared subgrade/base, stretched out to their design length, and staked to hold the sections in place. If the geocell sections are placed on a fine-grained material, a nonwoven geotextile should be placed prior to the geocell sections to act as a separation layer to prevent aggregate/subgrade mixing. Adjacent geocell sections are laid out and connected with adjoining sections. Once the geocell sections are in place, the geocells are infilled with aggregate. When infilling, the aggregate drop height should be less than 0.9 m (3 ft.). The geocell sections should be overfilled by 25 to 50 mm (1 to 2 in.) to allow for settling and compaction. The infill material is then compacted using tamping equipment. The cover aggregate can then be placed, compacted, and graded.

Weather Restrictions: Avoid construction during heavy rain or snow events and when the soil is frozen.

Construction Rate: Cellular confined aggregate construction rates are in the range of 200 to 400 m^2/day (240 to 480 yd^2/day).

Lane Closure Requirements: The roadway lane should be closed during construction, but can be opened to traffic once construction is complete.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: Cellular confined aggregate was developed by the U.S. Army Corps of Engineers in the late 1970s. Cellular confined aggregate has been used on a variety of projects, but it is not a commonly used surfacing material. Research, design and construction information, and project experience are available.

Life Expectancy: Life expectancy varies depending on traffic, subgrade support, and weather conditions. Cellular confined aggregate should not be used as a permanent surfacing material; some aggregate cover is required to protect the geocells from traffic abrasion. Typical life expectancy for cellular confined aggregate, assuming that an aggregate surface course is placed over the cellular confined aggregate, is expected to be 15 to 20 years. However, considerably longer lives are possible with regular maintenance.

Ride Quality: Cellular confined aggregate can provide fair to good ride quality if a thin aggregate surface course is placed over the geocells. Ride quality deteriorates over the serviceable life.

Main Distress / Failure Modes: Surface erosion, aggregate/subgrade mixing (that effectively reduces the aggregate thickness providing structural support), edge failures.

Preservation Needs: When covered with a surface course, the cellular confined aggregate layer generally does not require maintenance. The aggregate surface course will require periodic grading (typically every 6 months) and the periodic placement of additional aggregate (typically every 1 to 2 years).

SAFETY

Hazards: Loose aggregate can create a windshield hazard. Large quantities of fugitive dust, which reduces driver visibility, can be produced by untreated surfacings during dry weather conditions.

Skid Resistance: Unbound gravel/aggregate road surfacings can provide poor to good skid resistance, depending on the type of aggregate and gradation. Hard, durable crushed aggregates can provide good skid resistance. The wearing course must also be well graded and compacted to reduce the amount of loose particles on the surface that can reduce skid resistance.

Road Striping Possible?: No.

Other Comments: None.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Geocells are manufactured from polypropylene. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

Delivery and Haul Requirements: Geocells must be transported to the site from the distributor. Geocell sections collapse into a compact configuration to minimize the haul space required. Delivery distances may be significant for remote sites. If quality aggregates are not locally available, they must be transported to the site also.

Potential Short-Term Construction Impacts: Construction process can damage vegetation adjacent to the road.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: The amount of surface runoff will depend on the permeability of the surface material. Water infiltration into a dense, well-graded unbound wearing course that is adequately sloped will generally be small, with the majority of the water becoming surface runoff. However, if the surfacing is permeable, surface runoff will be reduced.

Erosion: Cellular confined aggregate helps to reduce erosion of poorly graded and compacted gravel/aggregate material. Dense, well-graded wearing course materials are generally less susceptible to erosion. Surface water control and management should be considered in the road design to minimize the potential for surface erosion.

Water quality: None. However, sediment loading from erosion of gravel/aggregate surfacings can possibly impact water quality. A buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles.

Aquatic species: None. However, sediment loading from erosion of gravel/aggregate surfacings can possibly impact aquatic species. A buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles.

Plant quality: None. However, dust generated from untreated gravel/aggregate surfacings can impact plant quality by covering the leaves and reducing the amount of sunlight received by the plant.

Air Quality: None. However, dust generated from untreated gravel/aggregate surfacings can have a long-term impact on air quality.

Other: None.

Ability to Recycle/Reuse: The aggregate infill can be reused as a construction material. Geocell geosynthetic material is not recyclable.

Other Environmental Considerations: Cellular confined aggregate is particularly useful on sections of gravel roads subject to periodic flooding or overtopping. The geocells help to retain the gravel infill from wash out.

AESTHETICS

Appearance: Cellular confined aggregate is typically covered with a wearing surface, so the geocell product does not alter the appearance of an aggregate material. The appearance will be of an aggregate surface with the overall color determined by the aggregate material type and source.

Appearance Degradation Over Time: Cellular confined aggregates do not experience appearance degradation over time. Without maintenance, unbound aggregate surfacings deteriorate over time in terms of surface uniformity.

COST

Supply Price: N/A

Supply+Install Price: \$36 to \$42/m^2 (\$30 to \$35/yd^2).

EXAMPLE PROJECTS

Overflow Parking Lot, Brazoria National Wildlife Refuge, Brazoria County, TX.
Stone Mountain Park, Stone Mountain, GA.

SELECT RESOURCES

Presto Products Company, www.prestogeo.com.

FIBER REINFORCEMENT

GENERAL INFORMATION

Generic Name(s): Fiber-Reinforced Soil, Fiber-Reinforced Sand

Trade Names: Geofibers

Product Description: Fiber reinforcement can be used to stabilize clays, sands, and sandy gravel soils. It can increase the shear strength, stiffness, and bearing capacity of the material being treated. Fibers can be natural or man made. Materials that have been used for fiber reinforcement include metallic, polypropylene, glass, wire, cellophane, straw, and hemp fibers. The fibers are mixed with the soil to create a uniformly reinforced soil mix with discrete, randomly oriented fibers. The soil is then placed and compacted. Typical fiber application rates are 0.1% to 0.5%, by weight. Fiber reinforcement improves the quality and suitability of soils as road making materials.

Product Suppliers: Fiber Reinforced Soil, LLC, P.O. Box 17455, Chattanooga, TN 37415, (423) 877-9550, www.fibersoils.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and fiber reinforcement products are available.

APPLICATION

Typical Use: Road surfacing, soil stabilizer.

Traffic Range: As a road surfacing, Very Low.

Restrictions:

Traffic: Fiber-reinforced soils should not be used as a surfacing for high speed traffic applications.

Climate: None; however, wet and/or cold climates will lead to more frequent deterioration and require more frequent maintenance.

Weather: Fiber-reinforced soils are very susceptible to adverse weather conditions. They will soften significantly in very wet weather and during periods of thaw.

Terrain: Fiber-reinforced soil surfaces should be limited to relatively flat terrains.

Soil Type: N/A

Other: Fiber-reinforced surfacings are highly susceptible to damage from snow plow operations.

Other Comments: None.

DESIGN

SLC: 0.05 to 0.20, Value will vary with soil type, fiber product, and application rate. Laboratory mixing should be performed to determine the strength of the stabilized material. Using laboratory strength testing results, an estimate of the SLC can be made using correlations or engineering judgment.

Other Design Values: Fiber reinforcement can increase the soil strength by 30% to 100% or more.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support.

Other Comments: The road surface should be graded to promote surface drainage and prevent ponding on the road surface that can promote softening of unbound materials.

The strength and durability of fiber-reinforced soils is affected by the fiber type, length, diameter, and application rate and depth of treatment. Fiber reinforcement is also influenced by the soil type, percent fines, moisture content, and percent compaction. Typically, fines contents of up to 10% are preferred for granular surfacings. Polypropylene fibers are currently the most commonly used fiber type. Studies have shown that for sand soils, the optimum fiber length and application rate are 50 mm (2 in.) and 1% by weight, respectively. At application rates below 0.6%, the sand acts as a strain softening material; at application rates above 0.6%, fiber-reinforced sands behave as a strain hardening material.

A persistent performance problem with unbound surfaces is the generation of dust as the surface dries. Several dust suppression and stabilization products have been developed to reduce the amount of fugitive dust originating from the unbound surface. Many of these products also improve the strength and durability of the surfacing and reduce surface erosion. Use of dust suppressants in conjunction with fiber-reinforced soil is recommended.

CONSTRUCTION

Availability of Experienced Personnel: Fiber-reinforced soil is not a common road surfacing, so the availability of experienced contractors may be limited. However, the construction process is relatively straightforward and experienced soil stabilization contractors should be able to successfully construct fiber-reinforced soil surfacings, with guidance from the supplier's technical representative.

Materials: Fibers are the only material required. Materials that have been used for fiber reinforcement include metallic, polypropylene, glass, wire, cellophane, straw, and hemp fibers. Polypropylene is currently the most commonly used fiber type.

Equipment: Equipment required for fiber reinforcement construction includes: rotary mixer, grading equipment (i.e. bulldozer or motor grader), and compactor. Equipment is widely available in most areas.

Manufacturing/Mixing Process: If the unbound surfacing material is not already in place, fibers can be mixed with the material prior to shipment to the site.

Placement Process: The fibers are spread and mixed in situ with the unbound material using several passes of a rotary mixer to obtain a uniform mixture. Uniform mixing of the fibers into the unbound material becomes more difficult as the application rate is increased. Once mixing is complete, the surface is compacted and graded. The compactive effort required for fiber-reinforced soil may be slightly greater than for unreinforced soil.

Weather Restrictions: Avoid construction during heavy rain or snow events and when the subgrade is saturated or frozen.

Construction Rate: Fiber reinforcement application rates are in the range of 2,000 to 4,000 m^2/day (2,400 to 4,800 yd^2/day).

Lane Closure Requirements: It is recommended that the roadway lane be closed during construction. The lane can be reopened once construction is completed.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: Fiber reinforcement for road surfacings is a fairly new concept that has developed within the past 20 years. Only a limited amount of information is available on design and construction and project experience.

Life Expectancy: Life expectancy varies depending on traffic, surfacing material characteristics, fiber type and application rate, and weather conditions. Fiber reinforced surfacings will lose material annually due to erosion, mixing with subgrade, dust, and shoving. Regular maintenance and periodic applications of additional material must be performed to maintain the structural integrity of the fiber-reinforced layer. Even with regular maintenance, many fiber-reinforced surfacings must be reconstructed after 4 to 6 years; however, some roads will last much longer with regular maintenance.

Ride Quality: Fair to good ride quality can be achieved with fiber-reinforced surfacings. Ride quality deteriorates with time if timely maintenance is not conducted.

Main Distress / Failure Modes: Aggregate loss, rutting, erosion, washboarding, washouts.

Preservation Needs: Regrading of the road surfacing is periodically required, depending on traffic conditions; a regrading frequency of 6 months to 1 year is typical. In addition, surfacing material has to be added to repair distressed areas and replace the aggregate lost due to mixing with underlying soils, erosion, and dust. Depending on the thickness of the reinforced surface layer, new material may have to be added to the surface every 2 to 4 years.

SAFETY

Hazards: Loose aggregate can create a windshield hazard; if sand is the surfacing material, the sand particles are usually too small to cause vehicle damage. Large quantities of fugitive dust, which reduces driver visibility, can be produced by untreated surfacings during dry weather conditions.

Skid Resistance: Fiber reinforced soils usually provide poor to good skid resistance, depending on the type of material stabilized. Coarse granular soils provide better skid resistance.

Road Striping Possible?: No.

Other Comments: None.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Fibers can be natural or man made. Materials that have been used for fiber reinforcement include metallic, polypropylene, glass, wire, cellophane, straw, and hemp fibers. Polypropylene fibers are the most commonly used and are manufactured materials.

Delivery and Haul Requirements: Fibers must be delivered to the site from the supplier. Delivery distances may be significant for remote sites.

Potential Short-Term Construction Impacts: Dust generated during fiber application can damage vegetation adjacent to the road.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: None. Permeable surfacing materials, such as gravels and sands, will allow for increased infiltration into the road structure and less surface runoff.

Erosion: Poorly graded and compacted unbound surfacings can be highly susceptible to erosion. Dense, well-graded materials are generally less susceptible to erosion, but erosion is still a primary concern for these materials as well. Fiber reinforcement can help reduce erosion susceptibility to a certain extent. Surface water control and management should be considered in the road design to minimize the potential for surface erosion.

Water quality: Fiber reinforcement will reduce, but not eliminate erosion of untreated surface soils. Sediment loading from erosion of unbound surfacings can possibly impact water quality. If the surrounding environment is sensitive to sediment loading, then a buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles.

Aquatic species: Fiber reinforcement will reduce, but not eliminate erosion of untreated surface soils. Sediment loading from erosion of unbound surface materials can possibly impact aquatic species. If the surrounding environment is sensitive to sediment loading, a buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles.

Plant quality: None. However, dust generated from untreated fiber reinforced surfacings can impact plant quality by covering the leaves and reducing the amount of sunlight received by the plant.

Air Quality: Dust generated from untreated fiber-reinforced soils can have a long-term impact on air quality. Dust suppression products can be used to reduce fugitive dust generation.

Other: None.

Ability to Recycle/Reuse: Fiber-reinforced materials can be reused as a construction material. However, it is not practical to remove fibers from a fiber-stabilized material for reuse.

Other Environmental Considerations: For fiber-reinforced soils, tire/road noise will depend on the material gradation and surface smoothness, but will generally be high.

AESTHETICS

Appearance: The appearance and color will mainly be influenced by the soil type and gradation. However, the color of the fiber reinforcement, typically black for polypropylene, will also influence the appearance, depending on the amount of fibers added. The fibers will be visible in the surfacing material, with strands of fiber protruding from the soil mixture.

Appearance Degradation Over Time: Fiber-reinforced surfacings can deteriorate over time, in terms of surface uniformity. Fiber-reinforced surfaces can experience appearance degradation over time due to surface distresses, such as rutting, shoving, and material loss.

COST

Supply Price: $4.40/kg ($2.00/lb) of fiber.

Supply+Install Price: $10.00 to $16.00/$m^2$ ($7.70 to $12.30/$yd^2$) for a 200 mm (8 in.) thick reinforced layer.

EXAMPLE PROJECTS

None.

SELECT RESOURCES

Santoni, R.L., Tingle, J.S., and Webster, S.L. (2001). "Engineering Properties of Sand-Fiber Mixtures for Road Construction," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 127, No. 3, pp. 258-268.

Santoni, R.L., and Webster, S.L. (2001). "Airfields and Roads Construction Using Fiber Stabilization of Sands," *Journal of Transportation Engineering*, ASCE, Vol. 127, No. 2, pp. 96-104.

Schaefer, V.R., Ed. (1997). "2.11- Fiber Reinforced Soils," *Ground Improvement, Ground Reinforcement, Ground Treatment: Developments 1987-1997*, Geotechnical Special Publication No. 69, ASCE, Reston, VA.

GEOTEXTILE / GEOGRID REINFORCEMENT

GENERAL INFORMATION

Generic Name(s): Geotextile, Geogrid, Geotextile/geogrid-supported aggregate

Trade Names: Numerous products available.

Product Description: A geotextile is a flexible porous fabric constructed of synthetic fibers and designed specifically for use in applications related to soil, rock, or any other earthen materials. The geotextile can be manufactured with standard weaving machinery (referred to as a woven geotextile) or by matting fibers together in a random fashion (referred to as a nonwoven geotextile). A geogrid is manufactured from a polymer into a "fabric" with an open, grid-like structure and designed specifically for use in applications related to soil, rock, or any other earthen material. Geogrids are generally stronger, stiffer, and tougher products than geotextiles. Geotextiles and geogrids both belong to a group of synthetic products collectively referred to as geosynthetics. Geosynthetic products can be used in a wide range of applications to reinforce soils and to act as filter or separation layers in pavement construction. Geosynthetics are also used in the construction of paved roads but this product sheet only deals with their use on unpaved roads.

Product Suppliers: Representative list of manufacturers, suppliers, and contractors can be obtained from: Geosynthetic Materials Association (GMA), (800) 225-4324, www.gmanow.com.

APPLICATION

Typical Use: Soil reinforcement, road surfacing (frequently on sites with poor strength subgrades or with shortage of quality aggregates).

Traffic Range: As a reinforced base, Very Low to High. As a road surfacing, Very Low to Low.

Restrictions:

Traffic: None.

Climate: None; however, wet and/or cold climates will lead to more frequent deterioration and more frequent maintenance.

Weather: Unbound road surfacings, including those reinforced with geotextiles/geogrids, are susceptible to adverse weather conditions. They will soften significantly in very wet weather and during periods of thaw.

Terrain: None.

Soil Type: Geotextile/geogrid-supported aggregates should have a maximum of 15% fines for use as a road surfacing and 10% for use as a base material.

Other: None.

Other Comments: Geosynthetics serve one of two primary functions when used with unbound aggregate layers in roadway applications: separation and/or reinforcement. Geotextiles are used primarily for separation and sometimes for reinforcement. Geogrids are used primarily for reinforcement and are more effective than geotextiles for that purpose. When used for separation, geotextiles are placed on top of a fine-grained subgrade prior to placing the aggregate layer. The purpose of the geotextile is to prevent (1) aggregate loss from the aggregate being pushed into the subgrade and (2) fines from the subgrade infiltrating into the aggregate layer and reducing the aggregate's structural and drainage properties.

For reinforcement purposes, the geotextile or geogrid is typically placed at or near the bottom of the aggregate base layer. The geosynthetic reinforces the base layer through shear interaction between the aggregate and geosynthetic, referred to as lateral base course restraint. Geogrids are considered to be better reinforcement materials than geotextiles because they are stiffer and more durable.

Geotextile separation layers have the potential to reduce aggregate requirements by 25%. Geotextiles and geogrids used together for reinforcement have the potential to reduce aggregate requirements by 50%. Therefore, geotextiles and/or geogrids can be used to reduce the thickness of aggregate layers required over soft soils or to reduce the amount of aggregate required in areas where aggregate is scarce. For the geotextile/geogrid to be beneficial as reinforcement, the geosynthetic must be stiffer than the underlying soil.

DESIGN

SLC: N/A; for low volume unpaved road design, geotextile and/or geogrid reinforcement is taken into consideration by increasing the equivalent bearing capacity of the underlying subgrade soil. For soft subgrade soils, the bearing capacity factor, N_C, for unreinforced, unpaved roads is 2.8, while N_C for geotextile-reinforced roads is 4.2 and N_C for geogrid and geotextile-reinforced soils is 6.7. Some agencies do not include separation as a structural design consideration; it is only used to prevent aggregate/subgrade intermixing.

Other Design Values: None.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support, taking into account the improved strength from the geosynthetic product.

Other Comments: The road surface should be sloped to promote surface drainage and prevent ponding on the road surface that can promote softening of the reinforced materials.

Geotextiles and geogrids are more effective when used with thin aggregate layers. As the base layer thickness increases, the stresses and strains near the bottom of the base layer decrease and the influence of the lateral base course restraint decreases as well. In addition, the mechanisms causing base/subgrade intermixing are reduced as the aggregate base thickness increases.

CONSTRUCTION

Availability of Experienced Personnel: Geotextile/geogrid-supported aggregate is a fairly common treatment and qualified contractors are, in general, widely available.

Materials: Geotextiles and/or geogrids and aggregate are required for construction of geotextile/geogrid-supported aggregate. Geotextiles/geogrids are shipped to the site in rolls. Nonwoven geotextiles perform better than woven geotextiles; nonwoven geotextiles offer better abrasion resistance, drainage capabilities, and interface friction with aggregates. Geogrids offerer higher strengths and better abrasion resistance than geotextiles.

Equipment: Equipment required for geotextile/geogrid-supported aggregate construction includes: rear or bottom dump trucks for hauling material, grading equipment (i.e. bulldozer or motor grader), water truck, and compactor. Equipment is widely available in most areas.

Manufacturing/Mixing Process: N/A

Placement Process: When using a geotextile, the geotextile is rolled out onto the prepared subgrade. The material should be placed so that there are no, or very few, wrinkles. Material from different rolls should be overlapped to ensure complete coverage. When using a geogrid, the geogrid is placed on the subgrade or geotextile separation layer, or after a thin lift of the aggregate material is placed. The geogrid should be placed taut and with no wrinkles. The unbound wearing course material is dumped by the haul trucks and spread using grading equipment, typically a motor grader, until the unbound layer has a uniform and adequate thickness and is graded to the proper slope. The use of a water truck and compaction equipment is highly recommended to adequately compact the surfacing layer.

Weather Restrictions: Avoid construction during heavy rain or snow events and when the soil is frozen.

Construction Rate: Geotextile/geogrid-supported aggregate construction rates are in the range of 8,000 to 10,000 m^2/day (9,600 to 12,000 yd^2/day).

Lane Closure Requirements: The road is closed to traffic during construction but can be opened once construction is completed.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: Geotextile/geogrid-supported aggregate is a common base and surfacing material. Research, design and construction information, and project experience are available.

Life Expectancy: Life expectancy varies depending on traffic, surfacing material characteristics, and weather conditions. Unbound gravel/aggregate surfaced roads can typically lose 25 mm (1 in.) of thickness per year; a geotextile separation layer will help reduce this loss rate by preventing aggregate loss due to aggregate/subgrade intermixing. Regular maintenance and periodic applications of additional material must be performed to maintain the structural integrity of the unbound layer. Even with regular maintenance, many unbound gravel/aggregate surfaced roads must be reconstructed after 6 to 10 years; however, some roads will last much longer with regular maintenance.

Ride Quality: Fair to good ride quality can be achieved with unbound gravel/aggregate road surfacings supported by geotextile/geogrid. Ride quality deteriorates with time if timely maintenance is not conducted.

Main Distress / Failure Modes: Aggregate loss, rutting, washboarding, potholes

Preservation Needs: The geotextile/geogrid material does not require maintenance. For unbound gravel/aggregate surfacings, regrading of the road surfacing is periodically required, depending on traffic conditions; a regrading frequency of 6 months is typical, but can easily range from 3 months to 2 years. In addition gravel has to be added to repair potholes and replace the aggregate lost due to erosion and dust. Depending on the thickness of the unbound layer, new material may have to be added to the surface every 1 to 3 years.

SAFETY

Hazards: Loose aggregate can create a windshield hazard. Large quantities of fugitive dust, which reduces driver visibility, can be produced by untreated surfacings during dry weather conditions.

Skid Resistance: Unbound gravel/aggregate road surfacings can provide poor to good skid resistance, depending on the type of aggregate and gradation. Hard, durable crushed aggregates can provide good skid resistance. The wearing course must also be well graded and compacted to reduce the amount of loose particles on the surface that can reduce skid resistance.

Road Striping Possible?: No.

Other Comments: None.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Geotextiles and geogrids are manufactured products for the construction industry and are made of high density polyethylene (HDPE).

Delivery and Haul Requirements: Geotextiles and/or geogrids must be transported to the site from the distributor. Haul distances may be significant for remote sites.

Potential Short-Term Construction Impacts: Construction process can damage vegetation adjacent to the road

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: None. The amount of surface runoff will depend on the permeability of the surface material. Water infiltration into a dense, well-graded unbound wearing course that is adequately sloped will generally be small, with the majority of the water becoming surface runoff.

Erosion: None. Poorly graded and compacted gravel/aggregate surfacing material can be highly susceptible to erosion. Dense, well-graded wearing course materials are generally less susceptible to erosion. Surface water control and management should be considered in the road design to minimize the potential for surface erosion.

Water quality: None. Sediment loading from erosion of gravel/aggregate surfacings can possibly impact water quality. A buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles.

Aquatic species: None. Sediment loading from erosion of gravel/aggregate surfacings can possibly impact aquatic species. A buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles.

Plant quality: None. Dust generated from untreated gravel/aggregate surfacings can impact plant quality by covering the leaves and reducing the amount of sunlight received by the plant. Particularly in agricultural areas, studies have shown that dust generation from roads adjacent to farmland can significantly reduce crop outputs. Dust suppression products can be used to reduce fugitive dust generation.

Air Quality: None. Dust generated from untreated gravel/aggregate surfacings can have a long-term impact on air quality. Dust suppression products can be used to reduce fugitive dust generation.

Other: None.

Ability to Recycle/Reuse: The treated soil/aggregate can be reused as a construction material. The geotextile/geogrid material cannot be reused or recycled.

Other Environmental Considerations: For unbound gravel/aggregate surfacings, tire/road noise will depend on the material gradation and surface smoothness, but will generally be high.

AESTHETICS

Appearance: Geotextile/geogrid support does not alter the appearance of a soil/aggregate material. The color will be determined by the gravel/aggregate material type and source. The texture can vary depending on the aggregate gradation and maximum particle size, but will generally be rough (texture).

Appearance Degradation Over Time: Gravel/crushed aggregate surfaces can experience appearance degradation over time due to surface distresses, such as rutting, washboarding, and aggregate loss.

COST

Supply Price: N/A

Supply+Install Price: \$2.80 to \$5.00/m^2 (\$2.30 to \$4.20/yd^2), not including aggregate.

EXAMPLE PROJECTS

Marshall Municipal Airport, Marshall, MO.
IWV Road, Johnson County, IA.

SELECT RESOURCES

Geosynthetic Materials Association (GMA), (800) 225-4324, www.gmanow.com.

GRAVEL (CRUSHED OR UNCRUSHED)

GENERAL INFORMATION

Generic Name(s): Gravel, Crushed Aggregate, Pebbles, Crushed Rock

Trade Names: N/A

Product Description: Unbound gravel/crushed aggregate surfaced roads make up a significant portion of the rural low volume road system in the United States. Unbound surfaces typically have the lowest initial cost and can provide a durable riding surface when constructed with quality materials and adequately maintained. Unbound surfaces are generally restricted to low volume roads and slower speeds due to issues regarding safety, ride quality, dust, and vehicle damage from loose surface particles; however, well designed and maintained unbound surfaces can be used for high speed applications.

Product Suppliers: Representative list of manufacturers, suppliers, and contractors can be obtained from: National Stone, Sand, and Gravel Association (NSSGA), 1605 King Street, Alexandria, VA 22314, (800) 342-1415, www.nssga.org.

APPLICATION

Typical Use: Road surfacing.

Traffic Range: As a road surfacing, unbound gravel/aggregate roads are best suited for Very Low to Low traffic volume applications (less than 250 AADT). However, they are frequently used for traffic volumes up to 400 AADT. Above this traffic range, the surface will require more frequent grading and maintenance, which increases cost.

Restrictions:

Traffic: For high speed applications (e.g. 100 km/hr [60 mph]), surface must be well maintained with good ride quality and smoothness to preserve safe driving conditions.

Climate: None; however, wet and/or cold climates will lead to more frequent deterioration and more frequent maintenance.

Weather: Unbound road surfacings, are very susceptible to adverse weather conditions. They will soften significantly in very wet weather and during periods of thaw.

Terrain: None.

Soil Type: N/A

Other: Unbound gravel/aggregate surfacings are susceptible to damage from snow plows in snow plowing areas.

Other Comments: Pebbles often have an aesthetically pleasing quality that can be desirable for a road surfacing. However, the often uniform gradation and smooth, rounded particle shape are not desirable qualities for a surface wearing course. Therefore, pebbles should be limited to particular applications where aesthetics are important and vehicle speeds are low (less than 30 km/hr [20 mph]). Stabilizers can be used to improve the performance and durability of materials.

DESIGN

SLC: 0.14 for good quality, crushed aggregate material, 0.08 to 0.11 for lower quality gravel.

Other Design Values: None.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support.

Other Comments: The road surface should be graded to promote surface drainage and prevent ponding on the road surface that can promote softening of unbound materials. The base thickness and appropriate road surfacing should be selected based on anticipated traffic volumes. The minimum design thickness for the unbound gravel/aggregate layer is 100 mm (4 in.).

The strength and durability of unbound surfaces is significantly affected by the type and gradation of the surfacing material. In addition, the life expectancy and maintenance costs are strongly influenced by the quality of aggregate used. The use of poor quality material may initially be cheaper; however, the life cycle costs can be significantly greater than if a high quality aggregate was initially used. Well graded mixes of hard, durable, skid resistant, crushed aggregates with a small amount of fines are the best materials for use as an unbound surface. Various agencies have developed specific gradation requirements for unbound surface courses based on experience with local materials. Typically, fines contents of up to 15% are preferred for gravel surfacings. Most aggregate base materials restrict fines content to 10%.

A persistent performance problem with unbound road surfacings is the generation of dust as the surface dries. Several dust suppression and stabilization products have been developed to reduce the amount of fugitive dust originating from the unbound surface. Many of these products also improve the strength and durability of the surfacing and reduce surface erosion.

CONSTRUCTION

Availability of Experienced Personnel: Unbound gravel/aggregate surfaced roads are very common and qualified contractors are, in general, widely available. Maintenance crews are used by some agencies for gravel/aggregate road construction and maintenance.

Materials: Gravel/crushed aggregate/pebbles is the only material required. Well graded mixes of hard, durable, skid resistant, crushed aggregates with a small amount of fines are the best materials for use as an unbound surface. Depending on the application, marginal or poor quality aggregates may be acceptable if high quality materials are not locally available; however, some form of modification/stabilization may be required. Road aggregates can be obtained from natural gravel deposits or from quarried rock sources.

Equipment: Equipment required for unbound gravel/aggregate surfaces includes: rear or bottom dump trucks for hauling material, grading equipment (i.e. bulldozer or motor grader), water truck, and compaction equipment. Equipment is widely available in most areas.

Manufacturing/Mixing Process: Unbound materials, whether from pit or quarry sources, are processed at the aggregate plant to obtain certain particle characteristics (number of crushed faces, length-to-width ratio) and specified material gradation. The processing can involve crushing, screening and washing.

Placement Process: The unbound wearing course material is dumped on the prepared base/subbase/subgrade by the haul trucks and spread using grading equipment, typically a motor grader, until the unbound layer has a uniform and adequate thickness and is graded to the proper slope. The use of a water truck and compaction equipment is highly recommended to adequately compact the surfacing layer. The handling of the material needs to be minimal to reduce segregation, which reduces structural capacity and promotes potholing, raveling, and premature deterioration.

Weather Restrictions: Avoid construction during heavy rain or snow events and when the soil is frozen.

Construction Rate: Unbound gravel/aggregate surfacing construction rates are in the range of 300 to 1,150 m^3/day (400 to 1,500 yd^3/day).

Lane Closure Requirements: It is recommended that the roadway lane be closed during construction. The lane can be reopened once construction is completed.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: Unbound gravel/aggregate road surfacings have been used for centuries. Significant research, design and construction information, and project experience are available. Performance is highly dependent on the material source and properties. Local experience and construction practices for certain materials should be considered, when available.

Life Expectancy: Life expectancy varies depending on traffic, surfacing material characteristics, and weather conditions. Unbound gravel/aggregate surfaced roads can typically lose 25 mm (1 in.) of thickness per year. Regular maintenance and periodic applications of additional material must be performed to maintain the structural integrity of the unbound layer. Even with regular maintenance, many unbound gravel/aggregate surfaced roads must be reconstructed after 6 to 10 years; however, some roads will last much longer with regular maintenance.

Ride Quality: Fair to good ride quality can be achieved with unbound gravel/aggregate road surfacings. Ride quality deteriorates with time if timely maintenance is not conducted.

Main Distress / Failure Modes: Aggregate loss, rutting, washboarding, potholes, raveling.

Preservation Needs: Regrading of the road surfacing is periodically required, depending on traffic conditions; a regrading frequency of 6 months is typical, but can easily range from 3 months to 2 years. In addition gravel has to be added to repair potholes and replace the aggregate lost due to mixing with underlying soils, erosion, and dust. Unbound gravel/aggregate surfaced roads can commonly lose 25 mm (1 in.) of thickness per year. Depending on the thickness of the unbound layer, new material may have to be added to the surface every 1 to 3 years. Regrading operations can undo the benefits of dust suppressants so they may need to be reapplied after regrading.

SAFETY

Hazards: Loose aggregate can create a windshield hazard. Large quantities of fugitive dust, which reduces driver visibility, can be produced by untreated surfacings during dry weather conditions.

Skid Resistance: Unbound gravel/aggregate road surfacings can provide poor to good skid resistance, depending on the type, shape, and gradation of aggregate. Hard, durable crushed aggregates can provide good skid resistance. The wearing course must also be well graded and compacted to reduce the amount of loose particles on the surface that can reduce skid resistance. The difference in surface condition between the tightly packed traveled lanes and the loose shoulder material can create a driving hazard at higher speeds.

Road Striping Possible?: No.

Other Comments: None.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Gravel/aggregates/pebbles are natural materials that are obtained by excavation, quarrying or dredging. The material must be mechanically processed to obtain the proper gradation and physical characteristics prior to shipment. On larger projects, blasted rock or gravel from road cuts may be suitable for processing as road aggregate.

Delivery and Haul Requirements: Gravel/aggregate must be transported to the site from the source location or distributor. Haul distances may be significant if quality materials are not available locally.

Potential Short-Term Construction Impacts: Construction process can damage vegetation adjacent to the road. Special handling procedures, such as siting of stockpiles, etc., may be needed in environmentally sensitive areas.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: The amount of surface runoff will depend on the permeability of the surface material. Water infiltration into a dense, well-graded unbound wearing course that is adequately sloped will generally be small, with the majority of the water becoming surface runoff.

Erosion: Poorly graded and compacted gravel/aggregate material can be highly susceptible to erosion. Dense, well-graded wearing course materials are generally less susceptible to erosion. Surface water control and management should be considered in the road design to minimize the potential for surface erosion.

Water quality: Sediment loading from erosion of gravel/aggregate surfacings can possibly impact water quality. A buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles. Surface water should be managed in such a way that the eroded material is removed before the runoff enters the receiving waterbody.

Aquatic species: Sediment loading from erosion of gravel/aggregate surfacings can possibly impact aquatic species. A buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles. Surface water should be managed in such a way that the eroded material is removed before the runoff enters the receiving water body.

Plant quality: Dust generated from untreated gravel/aggregate surfacings can impact plant quality by covering the leaves and reducing the amount of sunlight received by the plant. Particularly in agricultural areas, studies have shown that dust generation from roads adjacent to farmland can significantly reduce crop outputs. Dust suppression products can be used to reduce fugitive dust generation.

Air Quality: Dust generated from untreated gravel/aggregate surfacings can have a long-term impact on air quality. Dust suppression products can be used to reduce fugitive dust generation.

Other: None.

Ability to Recycle/Reuse: The gravel/aggregate can be reused as a construction material.

Other Environmental Considerations: For unbound gravel/aggregate surfacings, tire/road noise will depend on the material gradation and surface smoothness, but will generally be high.

AESTHETICS

Appearance: The color will be determined by the material type and source. The texture can vary depending on the aggregate gradation and maximum particle size, but will generally be rough (texture).

Appearance Degradation Over Time: Gravel/crushed aggregate surfaces can experience appearance degradation over time due to surface distresses, such as rutting, washboarding, and aggregate loss.

COST

Supply Price: \$18.30 to \$20.90/m^3 (\$14.00 to \$16.00/yd^3).

Supply+Install Price: \$22.20 to \$32.70/m^3 (\$17.00 to \$25.00/yd^3).

EXAMPLE PROJECTS

Gravel/crushed aggregate surfaces are used extensively throughout the United States.

SELECT RESOURCES

National Stone, Sand, and Gravel Association (NSSGA), (800) 342-1415, www.nssga.org.

Bolander, P., Marocco, D., and Kennedy, R. (1995). *Earth and Aggregate Surfacing Design Guide for Low Volume Roads*, FHWA-FLP-96-001, Federal Highway Administration, Washington, D.C., 302 pp.

Skorseth, K., and Selim, A.A. (2000). *Gravel Roads Maintenance and Design Manual*, Report No. LTAP-02-002, South Dakota Local Transportation Assistance Program.

SAND

GENERAL INFORMATION

Generic Name(s): Sand

Trade Names: N/A

Product Description: Sand can be a naturally occurring material obtained directly from a pit, produced from a pit by screening, or manufactured by crushing and screening a bedrock source. Sand, like other granular materials, obtains its shear strength from interparticle locking and is greatly influenced by confining stress. Manufactured sands, because of their angular particle shape, are generally more stable than pit run products which are composed of more rounded particles. When used as a subgrade or subbase material, dense sand can provide good support for a pavement system, although not as good as a well graded gravel and sand mixture. When used as a road surfacing, clean, dry sands can present problems such as rutting, shoving, and erosion. Sands are only suitable for very low traffic volumes and for periodic access, preferably by four-wheel drive vehicles. Sand surfaces will likely become impassable in wet conditions. Sands with fines bind together better than clean sands, but typically will have a lower strength. Sand materials can be treated/stabilized using stabilizers, emulsions, or geosynthetics to create a more durable riding surface.

Product Suppliers: Representative list of suppliers can be obtained from: National Stone, Sand, and Gravel Association (NSSGA), 1605 King Street, Alexandria, VA 22314, (800) 342-1415, www.nssga.org.

APPLICATION

Typical Use: Can be used as a road surfacing, but more typically used as subgrade or subbase layer, or for roadway shoulders.

Traffic Range: As a road surfacing, Very Low.

Restrictions:

Traffic: Sand should not be used as a surfacing for traffic with a high percentage of heavy wheel loads. As a surfacing, sand should be limited to low speed applications (less than 30 km/hr [20 mph]).

Climate: Erosion can be a significant problem in windy, arid, or wet climates; sand surfaces in these climates should be stabilized or reinforced to reduce erosion.

Weather: Sand surfaces are very susceptible to adverse weather conditions; they can quickly become impassable in very wet weather and will soften significantly during thaw periods in areas subject to freezing temperatures.

Terrain: Sand surfaces should be limited to relatively flat terrains.

Soil Type: N/A

Other: Sand surfacings are generally not usable in winter in regions that receive heavy snowfall due to the damage from snow plow operations.

Other Comments: Sand is a poor surfacing material and should only be considered when other materials are not available or when sand is readily available and regular maintenance is allowable. In cases where sand is readily available, some method of stabilization or reinforcement is recommended to increase the performance of the sand surfacing.

DESIGN

SLC: 0.05 (sand with some fines) to 0.10 (clean, angular sand).

Other Design Values: None.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support.

Other Comments: The minimum design thickness for the sand layer is 100 to 150 mm (4 to 6 in.).

The strength and durability of a sand surface is significantly affected by the type, particle shape, and gradation of the sand and the percent fines. Where possible, a well graded sand with some gravel sizes, if available should be selected. Typically, fines contents of up to 10% are preferred for sand surfacings.

A persistent performance problem with sands with fines is the generation of dust as the surface dries. Several dust suppression and stabilization products have been developed to reduce the amount of fugitive dust originating from an unbound surface. Many of these products also improve the strength and durability of the surfacing and reduce surface erosion.

CONSTRUCTION

Availability of Experienced Personnel: Sand surfaced roads are typically used in areas where sand is abundant, such as coastal areas. In these areas, qualified contractors experienced in construction with sands are, in general, widely available. Maintenance crews are used by some agencies for sand road construction and maintenance.

Materials: Sand is the only material required. Well graded sand mixes of hard, angular, durable fine aggregates with a small amount of fines are the best materials for use as a sand surface. Depending on the application, marginal or poor quality sands may be acceptable if high quality materials are not available; however, some form of modification/stabilization may be required. However, in practice, sand would only be used in the absence of gravel and only because it is the only available local material.

Equipment: Equipment required for sand surfacing construction includes: rear or bottom dump trucks for hauling material (if not available on site), grading equipment (i.e. bulldozer or motor grader), water truck, and compactor. Equipment is widely available in most areas.

Manufacturing/Mixing Process: Sands can be processed from a pit or quarry source to obtain a certain gradation or to remove organic material or excess fines. However, on-site material or material from a nearby source is usually used without modification.

Placement Process: The sand is dumped on the prepared base/subbase/subgrade by the haul trucks and spread using grading equipment, typically a motor grader, until the unbound layer has a uniform and adequate thickness and is graded to the proper slope. The use of a water truck and compaction equipment is highly recommended to adequately compact the surfacing layer.

Weather Restrictions: Avoid construction during heavy rain or snow events and when the subgrade is saturated or frozen.

Construction Rate: Sand surfacing construction rates are in the range of 300 to 1,150 m^3/day (400 to 1,500 yd^3/day).

Lane Closure Requirements: It is recommended that the roadway be closed during construction. The road can be reopened once construction is completed.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: Sand has been used as a road surfacing for centuries, but generally by default There is only a limited amount of information available on design and construction and project experience. Performance is highly dependent on the material source and properties. Local experience and construction practices for certain materials should be considered, when available.

Life Expectancy: Life expectancy varies depending on traffic, surfacing material characteristics, and weather conditions. Sand surfacings will lose material annually due to erosion, mixing with subgrade, dust, and shoving. However, a single heavy storm event can significantly damage the sand surfacing and make the road impassable. The sand surfacing can be repaired/reconstructed, but it will remain susceptible to damage during the next storm event unless the sand is stabilized. Regular maintenance and periodic applications of additional material must be performed to maintain the structural integrity of the unbound sand layer. Even with regular maintenance, many sand surfaced roads must be reconstructed after 4 to 6 years; however, some roads will last much longer with regular maintenance.

Ride Quality: Poor to fair ride quality can be achieved with sand surfacings. Ride quality deteriorates with time.

Main Distress / Failure Modes: Sand loss, rutting, erosion, washouts.

Preservation Needs: Regrading of the road surfacing is periodically required, depending on traffic conditions; a regrading frequency of 3 months is typical, but can easily range from monthly to yearly. In addition, sand has to be added to repair distressed areas and replace the aggregate lost due to mixing with underlying soils, erosion, and dust. Depending on the thickness of the unbound layer, new material may have to be added to the surface every 1 to 3 years and possibly after major storm events.

SAFETY

Hazards: Rutting can lead to water accumulation on the pavement surface, causing a driving hazard. Larger sand particles can create a windshield hazard, although the sand particles are usually too small to cause vehicle damage. Large quantities of fugitive dust, which reduces driver visibility, can be produced by untreated surfacings during dry weather conditions. If the sand surfacing is loose, vehicle handling and maneuverability can be reduced and conventional two wheel drive vehicles can easily become bogged down.

Skid Resistance: Sand surfacings usually provide poor to marginal skid resistance, depending on the type of aggregate and gradation. Hard, durable particles provide better skid resistance. The sand layer must also be well graded and compacted to reduce the amount of loose particles on the surface that can reduce skid resistance.

Road Striping Possible?: No.

Other Comments: None.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Sands are natural materials that are obtained from pits or by dredging.

Delivery and Haul Requirements: Sands are usually obtained from on-site or nearby sources.

Potential Short-Term Construction Impacts: Construction process can damage vegetation adjacent to the road.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Sand surfacings are typically somewhat permeable, which allows for increased infiltration into the road structure and less surface runoff.

Erosion: Poorly graded and compacted sands can be highly susceptible to erosion. Dense, well-graded sands are generally less susceptible to erosion, but erosion is still a primary concern for these materials as well. Surface water control and management should be considered in the road design to minimize the potential for surface erosion. Side ditching is difficult to maintain and tends to fill in quickly. Adjacent cut slopes and ditch back slopes should be cut as flat as possible and vegetated.

Water quality: Sediment loading from erosion of sand surfacings can possibly impact water quality. If the surrounding environment is sensitive to sand sediment loading, then a buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles. Surface water should be managed in such a way that the eroded material is removed before the runoff enters the receiving waterbody.

Aquatic species: Sediment loading from erosion of sand can possibly impact aquatic species. If the surrounding environment is sensitive to sand sediment loading, a buffer zone should be provided between the roadway and nearby bodies of water and the road surface should be properly maintained to minimize erosion of surface particles. Surface water should be managed in such a way that the eroded material is removed before the runoff enters the receiving water body.

Plant quality: Sedimentation of large enough quantities of eroded sand can adversely affect plant species.

Air Quality: Dust generated from sand surfacings can have a long-term impact on air quality. Dust suppression products can be used to reduce fugitive dust generation.

Other: None.

Ability to Recycle/Reuse: The sand can be reused as a construction material.

Other Environmental Considerations: None.

AESTHETICS

Appearance: The appearance and color will be determined by the sand type and source. The texture can vary depending on the aggregate gradation and maximum particle size, but will generally be rough (texture). The surfacing will also show vehicle tracks and wheel rut paths.

Appearance Degradation Over Time: Sand surfaces deteriorate over time, in terms of surface uniformity. Sand surfaces can experience appearance degradation over time due to surface distresses, such as rutting, shoving, and sand loss. Without maintenance, the sand surface can develop, over time, an abandoned appearance and begin to support the growth of vegetation.

COST

Supply Price: N/A

Supply+Install Price: $7.30 to $10.90/Mg ($6.60 to $9.90/ton).

EXAMPLE PROJECTS

New Jersey Pinelands, NJ.
Oregon Dunes National Recreational Area, Siuslaw National Forest, Corvallis, OR.

SELECT RESOURCES

National Stone, Sand, and Gravel Association (NSSGA), (800) 342-1415, www.nssga.org.