Driving Indiana’s Economic Growth

SOLVI NG GEOTECHNICAL PROBLEMS WITHOUT BREAKING THE PROJECT BUDGET

by:

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Office of Geotechnical Engineering
Mission Statement

“The primary mission of the Office of Geotechnical Engineering is to deliver our customers the most accurate and cost-effective Geotechnical recommendations for the design of Hoosier highways and bridges, in a timely manner.”
This session will focus on recent innovations and uses of recyclable materials which have provided solutions to complex geotechnical problems within the project budget.
Historical Background

The Indiana General Assembly in the early 1980’s mandated to find ways to utilize waste/recycled materials for Highway Construction, thereby starting research projects.
INDOT’s Approach to Use Recycled Materials for Highway Construction

1. Research Study
2. Demo Projects
3. Monitoring
4. Evaluation
5. Development of Std. Specification
The primary focus was on the following:

1. Coal Combustion By-products
2. Recycled Foundry Sand
3. Shredded Tires
4. Crushed Glass
5. Lime-Kiln Dust
6. Cement Kiln Dust
7. Steel Slag
Coal Combustion By-products
Coal-burning power plants in the United States produce, annually, over 180 million tons of coal combustion by-products, mostly fly ash and bottom ash. As a by-product, coal ash has generally been treated as a solid waste. A common disposal method consists of transporting the fly ash and bottom ash through separate pipelines to a single discharge location, at which the fly ash and bottom ash become mixed together and flow to a disposal pond. Eventually, disposal ponds and landfills become filled with ash, and alternative disposal location must be found, leading to large additional costs to the utility companies. Efforts are still underway to find economically feasible and environmentally sound geotechnical applications of these materials.
Use of Coal Combustion By-products (bottom ash, co-mingled ponded ash, fly ash) in place of natural soils in embankment construction may benefit the environment in two ways:

1- **Reduction** of coal ash problem and

2- **Preserving** natural soils and energy.
What are Coal Combustion By-products?

- **Coal combustion by-products** (CCPs) include several types of materials which are left over from the burning of coal: fly ash, bottom ash, boiler slag and flue gas desulphurization (FGD) materials (either wet or dry). In the past, Coal Combustion By-products were treated largely as a waste. However, since the 1960's, many applications have become identified such as using CCBs as a substitute for Portland cement, in cement manufacturing, in roofing tiles, structural fills, sheetrock, and fertilizers to name a few, which placed these residues into the category of a "product" and the term has become commonly used as coal combustion products or "CCPs."

- Coal Combustion By-products contain basic mineral elements which make them similar to the earth's crust: silicon dioxide, aluminum oxide, iron oxide, calcium oxide and trace amounts of sulfur trioxide, sodium oxide and potassium oxide. Thus, they are an excellent replacement for natural materials.

- While the term "by-product" may include residues from other combustion processes, **Coal Combustion By-products do not include** products derived from the burning of waste; municipal, industrial, or commercial garbage; sewage sludge or other refuse, or both. It does not include ash from derived fuels; wood; wood waste products; rice hulls; agricultural waste; or other non-coal fuels or other fuels blended with coal or some combination thereof.
## Production vs. beneficial use of Coal Combustion By-product’s in Indiana

<table>
<thead>
<tr>
<th>By-product</th>
<th>Production (tons)</th>
<th>Beneficial use (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash</td>
<td>3,300,000</td>
<td>1,100,000</td>
</tr>
<tr>
<td>Bottom ash</td>
<td>1,200,000</td>
<td>500,000</td>
</tr>
<tr>
<td>Boiler Slag</td>
<td>300,000</td>
<td>200,000</td>
</tr>
<tr>
<td>FGD Materials</td>
<td>3,700,000</td>
<td>1,800,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,500,000</strong></td>
<td><strong>3,600,000</strong></td>
</tr>
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</table>
Location of Source of Coal Combustion By-products in Indiana
Coal Combustion By-Products
U.S. 12/20 in Lake County

Coal Combustion By-Products
S.R. 641 in Vigo County

Coal Combustion By-Products
U.S. 50 in Knox County

Coal Combustion By-products Project
56th Street at I-465 in Marion County

Coal Combustion By-Products
U.S. 231 in Spencer County

INDOT Projects
Utilizing Recycled Coal Ash
Typical Gradation Ranges for Fly Ash, Bottom Ash, and Boiler Slag

Coal Combustion By-products
Location of Project: U.S. 12 in Lake County

<table>
<thead>
<tr>
<th>Project Features</th>
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<tbody>
<tr>
<td>Embankment Length</td>
<td>290 ft.</td>
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<tr>
<td>Fill Height</td>
<td>12 ft.</td>
</tr>
<tr>
<td>Proposed Slope</td>
<td>2H:1V</td>
</tr>
<tr>
<td>Foundation Soils</td>
<td>Sand</td>
</tr>
<tr>
<td>Existing Embankment Soil</td>
<td>Sand</td>
</tr>
<tr>
<td>Fill Material Used</td>
<td>Bottom Ash</td>
</tr>
<tr>
<td>Quantity Used</td>
<td>5000 yd³ (approx.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineering Properties</th>
<th></th>
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<tbody>
<tr>
<td>AASHTO Classification</td>
<td>A-1-a</td>
</tr>
<tr>
<td>Passing # 200 Sieve</td>
<td>1%</td>
</tr>
<tr>
<td>Maximum Dry Density</td>
<td>92 pcf</td>
</tr>
<tr>
<td>Specific Gravity (AASHTO T-100)</td>
<td>2.37 ~ 2.47</td>
</tr>
<tr>
<td>Hydraulic Conductivity (AASHTO T-215)</td>
<td>3.3x10⁻³ ft/ sec</td>
</tr>
<tr>
<td>Friction Angle (AASHTO T-236)</td>
<td>35° to 45°</td>
</tr>
<tr>
<td>CBR (AASHTO T-193)</td>
<td>45 ~ 70</td>
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</table>

<table>
<thead>
<tr>
<th>Compaction Requirements</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>% Compaction</td>
<td>95% of Standard Proctor</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>Drier of OMC</td>
</tr>
<tr>
<td>Lift Thickness</td>
<td>6 inches</td>
</tr>
<tr>
<td>Roller Passes</td>
<td>6 passes with a Vibratory Roller (10 T)</td>
</tr>
</tbody>
</table>
North Slope between RR & Kennedy Avenue
South Slope between RR & Kennedy Avenue
Coal Combustion By-products
Location of Project: 56th Street at I-465 in Marion County
56th Street And I-465 In Marion County
56th Street overlooking I-465 in Marion County
Observations on the project:

Jerry Pullen, Project Engineer states:

“I was very impressed with the coal ash used for embankment on 56th Street over I-465 on the northwest side of Indianapolis. Drainage was excellent. We were able to achieve the required density with minimal effort. Independent testing of water which filtered thru the coal ash to a storage tank showed no leaching or adverse effects. To this date there does not appear to be any settlement. The roadway over this material is still good.”

“We encased the total area where coal ash was to be placed with an impervious clay layer to contain all the water. This is probably not needed since all water tests came back negative.”
Coal Combustion By-products:
Location of Project: U.S. 50 in Knox County
Coal Combustion By-products: Location of Project: S.R. 641 in Vigo County
S.R. 641 in Vigo County, Project Pre-Construction
Photographs were taken May 6, 2005
S.R. 641 in Vigo County, CCP Project Pre-Construction
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Photographs were taken May 6, 2005
S.R. 641 in Vigo County, Project Pre-Construction
Photographs were taken May 9, 2005
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Photographs were taken May 9, 2005
S.R. 641 in Vigo County, Project Pre-Construction
Photographs were taken May 9, 2005
**Instrumentation of Fly Ash Embankment**

- **Note:** - Monitoring Well should be installed within 6 meters from the toe of the embankment.
- Vertical and Horizontal inclinometers are installed at 10 meter distance longitudinally.

**- Settlement plates: top, middle and bottom of fly ash fill at 1.0 m apart longitudinally.**

*Not to Scale*
These studies and demonstration project provided...

1. A wealth of literature.
3. Evaluation and acceptance by the highway industry.
4. Provided design, construction, and specifications for CCBP.
Fly Ash Contract Price: $3.04 per m³ Final quantity used: 46,100 m³ (86,000 T)

Encasement Material Contract Price: $5.80 per m³ Final quantity used: 2,496 m³

Borrow Contract Price: $3.82 per m³

46,100/m³ x $3.04/m³ = $140,144.00 for placement of Fly Ash
2,496/m³ x $5.80/m³ = $14,476.80 for Fly Ash encasement material & placement

Total Cost for Fly Ash Placement:
$140,144.00 + $14,476.80 = $154,20.80

Total Volume for Fly Ash Placement:
46,100/m³ + 2,496/m³ = 48,596/m³

CONCLUSION:
Total Contract cost per m³
= $154,620.80/48,596/m³ = $3.18/m³

Contract cost for Borrow: $3.82/m³ vs. Fly Ash: $3.18/m³

SAVINGS OF APPROXIMATELY:
$0.64/m³ x 46,100 m³ = $29,500.00
Using the Contract Price for Borrow of $3.82/m³ and the final cost of Fly Ash as $3.18/m³ there is a cost savings of approximately $0.64/m³ utilizing Fly Ash. However, the fly ash was supplied at no cost to the Contract and subsequently does not reflect the transportation costs that would be associated with delivery, et cetera on a Contract that designated use or allowed use of Fly Ash as fill. Conversely, the project does not reflect the savings to a contract that may be possible with the use of a relatively uniform material which can be placed quickly, requires less compactive effort and possibly less moisture manipulation.
As you know, we placed bottom ash from the American Electric Power Plant @ Rockport in the north embankment for the Northbound lane of U.S. 231 over the AEP R/ R.

Much to my surprise, the bottom ash was much easier to place and compact than soil.

The bottom ash proved to be a very stable material to work with. I had envisioned it being very difficult to work on and that vehicles & equipment would constantly be hung up in it. But it proved to be very stable, being able to support cars, truck, and heavy equipment with little or no rutting and no equipment getting hung up in it.

Compaction was achieved very easily, after watering, and was very uniform throughout placement.

Weather had very little effect on placement, as long as the haul road could be maintained. If there was a heavy thunderstorm the afternoon or evening before, additional bottom ash lifts could be placed immediately the next morning.

I was amazed that cars & light trucks could drive across an uncompacted lift with no worry of getting hung-up.
The Contractor shall, if requested, furnish the Engineer with a copy of the most recent testing results upon which the certification is based. This information shall include the following:

- entity performing the test;
- date samples were obtained;
- data sample tested;
- test methods used;
- frequency of sampling, and;
- stockpile sampling locations including depths and available historical testing results.

The Department reserves the right to conduct independent quality assurance testing at any time and may reject non-conforming material.

**Construction Requirements**

C.C.B.P. not incorporated into the contract through placement, compaction, and encasement within five calendar days will be considered to be in storage. Prior to storing C.C.B.P. within the contract limits the Contractor shall have an approved erosion control plan to prevent C.C.B.P. runoff and erosion. Total C.C.B.P. in storage shall not exceed 120,000 cubic yards (7000 cubic meters) and the maximum time in storage shall be 180 calendar days.

Adequate measures shall be taken during construction to control dust. Spraying with water, lime water, bituminous sprays, or other sealing sprays will be considered to be acceptable methods for dust control.

**Type III C.C.B.P. shall not be placed as follows:**

- Below the seasonal high water table;
- Within 100 horizontal feet (30 m) of a perennial stream, river, and lake/reservoir;
- Within 150 horizontal feet (45 m) of a well, spring, or other ground water source of potable water;
- Adjacent to a wetland or other protected environmental resource area.

It will be the Contractor's responsibility to prepare bids for this item by anticipating placement limits and estimating quantities of C.C.B.P. by referencing to the restrictions set out by a. through d.

The placement and compaction of C.C.B.P. shall be performed in accordance with 203-R-360 except that unless otherwise approved in writing, the Contractor shall arrange to conduct test strips to determine appropriate compaction methods and moisture control limits. The construction of these test strips shall be as directed by the Department's Division of Materials and Tests.

C.C.B.P. shall be placed in 8 in. (200 mm) loose lifts.

They shall be compacted using a vibratory steel wheel roller unless otherwise approved. The minimum total compactive effort shall be 4,000 lb (1.8 kN m) if the manufacturer's charts do not list the static weight mass. Acting upon the compaction drum, the roller shall be weighed. The weight (mass) shall be added to the centrifugal force.
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</tr>
<tr>
<td>Borrow</td>
<td>No Restrictions</td>
<td>Embankment construction</td>
<td>Covered in Spec. 903</td>
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<tr>
<td>B-borrow</td>
<td>Below water table</td>
<td>Excavation and replacement</td>
<td>Covered in Spec. 211</td>
</tr>
<tr>
<td>Structure backfill</td>
<td>Within a MSE Wall or near metal pipes/piles or metal structures</td>
<td>Backfill pipe (PVC and Concrete) structures for culverts</td>
<td>Covered in Spec. 904</td>
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**Testing Frequency:** testing per every 10,000 tons/source

The testing shall be performed by an Approved Geotechnical Consultant.
Indiana Recycled Foundry Sand Producers
What is foundry sand?

Foundry sands are sand-bentonite mixtures.
Index Characteristics

- Plasticity: Plasticity Index (PI) between Non-plastic (NP) and 5
- Unified soil classification: clayey sand (SC), poorly graded sand (SP), silty sand (SM) or SP-SM
- AASHTO Classification: A-2-4 or A-3
- Roundness: Subrounded to subangular (R = 0.5 to 0.7)
Hydraulic Conductivity

- Foundry sands will drain less effectively than conventional sands.
- Foundry sands with bentonite content < 6% preferred for better drainage.
Foundry sand grades and shapes easily.

Compacts well with modest amount of moisture.
Recycled Foundry Sand
Location of Project: C.R. 206 in Dekalb County
C.R. 206 in Dekalb County
C.R. 206 Test Pad
C.R. 206 in Dekalb County
C.R. 206 in Dekalb County
C.R. 206 in Dekalb County
C.R. 206 During Construction
Recycled Foundry Sand Cut Section
Total Pressure Cells (2)
Both at Elev. 880 ft.
STA. 347+60 at CL
STA. 347+60 23 ft. Right

Pneumatic Piezometer
STA. 348+50 23 ft. Right
Elev. 860 ft.

Horizontal Inclinometers (2)
Both at STA. 347+65
Elev. 880 280 ft. in length
Elev. 898 140 ft. in length

Vertical Inclinometer
STA. 347+50 80 ft. Right

Bridge

Conrail

Bridge

C.R. 206

U.S. 6
Recycled Foundry Sand Special Provision

Indian DOT Recurring Special Provisions Menu

www.in.gov/dot/div/contracts/standards/rsp/mar05/mar.htm

200-R-401 RECYCLED FOUNDRY SAND

Revised 01-12-07

Description

Recycled foundry sand (RFS) consists of a mixture of residual materials used from ferrous or non-ferrous metal castings and natural sands. The Contractor shall have the option of incorporating RFS into applicable operations in accordance with 106.02.

Materials

RFS sources are to be selected from the Department's list of approved Foundry Sand Sources. RFS may be substituted for B borrow (111) or Borrow (103) upon the approval of the Department's Geotechnical Section.

The Contractor shall provide the Engineer with a copy of the Material Safety Data Sheet (MSDS) and a copy of the Indiana Department of Environmental Management's (IDEM) waste classification certification for Type III or IV residual sands prior to use. IDEM certification and MSDS shall clearly identify the stockpiles with regard to their extent and geographical location.

The Contractor shall provide the Engineer with a copy of the Material Safety Data Sheet (MSDS) and a copy of the Indiana Department of Environmental Management's (IDEM) waste classification certification for Type III or IV residual sands prior to use. IDEM certification and MSDS shall clearly identify the stockpiles with regard to their extent and geographical location.

The Contractor shall provide the Engineer with a type A certification in accordance with Sec 103.02. The materials shall be placed and compacted concurrently with the Borrow (103). Assessment materials shall satisfy the requirements of Sec 103.02.

Mixing of Blast Furnace Dust with Borrow (103) or Borrow (111) shall be permitted.

RFS use is restricted to the following additional requirements:

1. RFS derived from Type III residual sand shall not be permitted within 30 m (100 ft) horizontally, or a stream, river, creek, wetland, or other protected environmental resource area
2. RFS derived from Type III or Type IV residual sand shall not be placed within 50 meters (150 ft) horizontally, or a well, spring, or other ground source of potable water
3. RFS shall not be placed adjacent to metallic pipes, or other metallic structures
4. RFS shall not be used as a replacement material
5. RFS shall not be used in MSE wall applications

If RFS is used in embankment, excavation and replacement operations as a replacement for B borrow or Borrow, the following additional requirements shall be considered:

1. Borrow RFS shall be in accordance with 903
2. Borrow RFS shall be in accordance with 111

Construction Requirements

RFS shall be handled in a manner that prevents the release of dust and loss of material. Adequate measures shall be taken during construction operations to control dust from RFS. RFS shall not be applied when wind conditions create problems in adjacent areas or create a hazard to traffic on any adjacent roadway. The spreading of RFS shall be limited to an amount that can be enclosed within the same roadway. If weather causes storage of RFS or exposure of RFS to wetting or drying, additional RFS may be spread when the work resumes. Spreading with water, lime-water, or other similar type sprays will be conducted to be acceptable methods for dust control.

When RFS is used as borrow or B borrow, compliance with the Department's Geotechnical Section for the design and conduct of compaction must be obtained. Nuclear density testing of RFS is not allowed.

When RFS is used in embankment construction, the construction of the embankment of the RFS shall be initiated with a 1 ft (30.5 cm) of Borrow materials. The Borrow materials shall be placed and compacted concurrently with the RFS. Assessment materials shall satisfy the requirements of Sec 103.02.

RFS applications will be measured in accordance with the respective uses for Borrow or B borrow.

Basis of Payment

RFS will be paid for at the contract unit price in accordance with the respective uses for Borrow or B borrow.

Payment will be made for the transportation, handling, or any special construction requirements such as alternative compaction methods or excavation activities, when using RFS materials.

The cost of the use of water, lime-water, sprays, or any other activities necessary for dust control, shall be included in the cost of the respective pay item.

The costs of geotechnical testing for the use of RFS materials shall be included in the cost of the respective pay item.
### Various RFS Applications and Requirements (As per INDOT Material Classifications)

<table>
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<tr>
<td>Borrow</td>
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<td>Embankment construction</td>
<td>None</td>
</tr>
<tr>
<td>B-borrow</td>
<td>Not to be used below water table</td>
<td>Excavation and replacement</td>
<td>Std. Spec. 211</td>
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<td>Structure backfill</td>
<td>Not to be used within an MSE Wall or near metal pipes/piles or metal structures</td>
<td>Backfill pipe (PVC and Concrete) structures for culverts</td>
<td>Std. Spec. 904.05</td>
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</tbody>
</table>

**Testing Frequency:** testing per every 10,000 tons/source

The testing shall be performed by an Approved Geotechnical Consultant.
Recycled Sand? Foundry Sand
Indiana
Shredded Tire Processors
As a guideline, 30-40 tires yield about 1 cubic yard of compacted tire chip fill, and 500 tires will fill a 15-cubic-yard dump truck.

Large volumes of tires can be used in civil engineering construction applications.
Scrap tires are fed into the shredding unit
(Courtesy of Dillion Tires Recycling)
Shredded tires are sieved, and shreds not passing the sieve are conveyed back into the shredder for further size reduction. (Courtesy of Dillion Tires Recycling)
Magnet is used to remove the steel wires present in shredded material

(Courtesy of Dillion Tires Recycling)
Tire Shredder
Tire chips (scrap tires cut into 1- to 12-inch pieces) have a number of qualities that make them well-suited for use in road and bridge construction. Tire chips are:

- Lightweight
- Low-Pressure
- Free-Draining
- Good Thermal Insulators
- Durable
- Low Price
Compaction Tests Performed

(Percent shown in the figures are by weight of tire shreds in the mixture)
Tire Shred Project Locations

- Tire Shred Project: U.S. 31 in St. Joseph County
- Tire Shred Project: U.S. 31 in Marshall County
- Tire Shred Project: S.R. 110 in Marshall County

Tire Shred Project: I-80/94 in Lake County
Tire Chips and Sand Project: US 31 in Lakeville, St. Joseph County
Plan View of Tire Shreds Embankment

- South Wall
- North Wall
- Bridge Pier
- Instrumentation zone at middle section
- Settlement plates at two different depths (West side)
- Settlement plates at two different depths (Center line)
- Settlement plates at two different depths (East side)
- Lateral side slope with 1:3 angle
- 5’ – 10’
- 57’
- 30’

US 31 in St. Joseph County
Geotextile Details at Side Slopes

US 31 in St. Joseph County
US 31 in St. Joseph County
Tire Chips and Sand Mixture Level

US 31 in St. Joseph County
Tire Chips Embankment on US 31 in St. Joseph County
Tire Chips Embankment on U.S. 31 in St. Joseph County
Tire Chips Embankment on U.S. 31 in St. Joseph County
Tire Chips Embankment on U.S. 31 in St. Joseph County
Shredded Tire Project
Project Location: SR110 in Marshall County
SR110 in Marshall County:
Filling procedure using mixtures of Shredded Tires and Sand

Mixed material taken to construction site and dumped in place
Mixture spread in lifts of 12 inches using tracked bull dozer
Paving laid on 9-inch compacted aggregate (No. 53)

Compaction of paved material
SR110 in Marshall County. Road open to traffic in the 3rd week of October 2008
Tire Shreds/EPS as backfill for a MSE Wall Project Location: I80/94 in Lake County
180/194 in Lake County: Hauling and compacting the Tire Shred mixture (10 ton roller, lifts of 12 inches)
I80/94 in Lake County Installing the reinforcement
Research utilizing tire shreds as fill material for embankments resulted in a new specification, saving dollars and providing an environmental benefit.

The Office of Geotechnical Engineering looked at utilizing tire shreds and soil as fill material for embankments. Using tire shreds from discarded, used tires in highway construction is a green solution that not only prevents this waste material from ending up in a landfill, but reduces the use of crushed stone and soil. It has also helped to stimulate a new industry in Indiana. Three projects on SR 110 in Marshall County, US 31 South Bend Bypass in St. Joseph and Elkhart Counties, and SR 19 in Elkhart County all used tire shreds in embankments and realized a material savings over $3.2 million.
Shredded Tires Special Provision

EARTHWORK WIDENING AND BACKFILL USING TIRE SHREDS-GRANULAR, TSG, MIX

Revised 6-19-09

Description
This work shall consist of using tire shred-granular, TSG, mix for constructing embankment widening in accordance with 105.05 and as structure backfill for the reinforced concrete three-sided drainage structure in accordance with 725. Adherence to the provisions herein does not preclude applicability of local, state or federal regulations, and laws.

MATERIALS

Materials shall be in accordance with the following:

Geogrid, Type 1 .................................................. 918.05
Geotextile ...................................................... 918.02
Granular soils .................................................. 903.04

Tire shreds are defined as tires that have been chipped or shredded and shall be in accordance with ASTM D577. Tire shreds shall be covered by a Type A certification in accordance with 916.

Tire shreds shall be in accordance with the following:
1. All the pieces shall have at least 1 sidewall covered from the face of the tires. The largest allowable piece shall be 300 mm (12 in.) or less in length.
2. A minimum of 80% of the material by mass (weight) shall pass a 100 mm (4 in.) screen.

The tire shreds shall be substantially free of loose metal fragments. Exposed metal along the cut faces of the tire shreds will not be considered loose metal fragments. However, attached residual metal protrusions such as beads and bolts extending beyond the cut faces of tires shall be kept to a minimum.

Cohesive excavation soils shall be Sandy Clays Loam, clay loam, clay, silty clay loam in accordance with 903.02.

Siting Criteria
TSG mix shall not be placed in the following cases:
1. Below the seasonal high water table.
2. Within 45 m (150 ft) horizontally of a well, spring, or other ground water source of potable water.

Limitations
The limitations of TSG use shall be as follows:
1. TSG mix shall be used as fill, excluding excavation and pavement, up to a maximum 3 m (10 ft) high embankment. Fill heights above 3 m (10 ft) shall be separated by 0.6 m (2 ft) of Borrow at a maximum of 3 m (10 ft) increments.
2. Tire shreds and granular soils mix shall be 60/40 by volume.

TSG mix embankment shall be covered with 0.3 m (1 ft) of embankment material.
3. If the structural integrity is compromised or if the tire shreds become exposed, the structure must be repaired or the tire shreds must be removed.
4. If the project is suspended for two weeks or more, the tire shreds incorporated into the project must be covered with a temporary cover.
5. roadway excavation shall not exceed 15 m (50 ft) at any given time during the operation. The Engineer may increase or decrease the length of the excavation.

Storage
Tire shred-granular soils, TSG, may be stored within the right-of-way of the project with the approval of the Engineer. Tire shreds shall be incorporated into the fill within 16 calendar days of the inception of the stockpile. The stockpile volume shall not exceed 350 cubic meters (500 cubic yards).

Tire shred storage at the worksite shall be in accordance with the Indiana Fire Code and Solid Waste Land Disposal Facilities. The Indiana Fire Code includes rules as adopted by the fire prevention and building safety commission at 675 IAC 22. The Solid Waste Land Disposal Facilities rules are found at 329 IAC 15. In particular, storage must be consistent with discharge of storage in accordance with 329 IAC 10-2-181.

CONSTRUCTION REQUIREMENTS

The subgrade shall be prepared in accordance with 291. The existing slope should be benchcut and a geotextile should be placed on the slope. Geotextile should be embedded at the top of the slope and shall be laid transversely, machine direction perpendicular to the embankment line, with an overlap between rolls of 150 mm (6 in.). End to end splice in the geotextile will not be permitted. The transverse splices of the geotextile shall be pinned with hog ring clips. A layer of geogrid, type 1 shall be placed in accordance with 214 as shown on the general plan sheet.

A 300 mm (12 in.) thick lift of TSG mix shall be placed on the geogrid and should be wrapped at the end with geotextile. The wrapped length of geotextile shall be 1 m (3 feet) from the toe. A TSG mix lift shall be placed across the full width of the roadway cross section. Compaction of TSG mix shall be performed in accordance with 609.03[4] with a smooth static or vibratory compactor weighing minimum 5.4 Mg (6 tons). It is expected that 6 to 8 passes shall be required to achieve proper compaction in each 300 mm (12 in.) lift. However, the number of passes may increase if the deflection in each lift is more than 6 mm (1/4 in.). The top of TSG mix embankment slope shall be constructed with 6.9 m (21 ft) cohesive excavation in accordance with section 203.09.

The cohesive excavation material shall be placed and compacted at the same time as the TSG lift is placed. The slope shall be sprayed with a red dye to ensure it will be placed in accordance with 621.

Method of Measurement

Unique Special Provision - Embankment Using Tire Shreds Granular Mix 1 of 3
Shredded Tires?
Crushed Glass
Project Location: Bruceville, Indiana Knox County
Andela Hopper used to crush glass
Bruceville, Indiana
Bruceville, Indiana
Bruceville, Indiana
Crushed Glass Special Provision

Indiana DOT Recurring Special Provisions Menu
www.in.gov/dot/div/contracts/standards/rsp/mar05/mar.htm

211-R-415 CRUSHED GLASS AS BEDDING MATERIAL
(Adopted 09-01-05)

Description
This work shall consist of using 100% crushed glass as bedding material beneath pipes and storm sewers in accordance with 105.03. Adherence to the provisions herein does not preclude applicability of local, state, or federal regulations and laws.

Materials
The source shall be recycled glass beverage and food containers that have been processed by equipment specifically designed to crush glass into aggregate. The resultant material shall be relatively free of bottle caps, labeling paper, clay balls, and other unsuitable materials. The crushed glass shall be in accordance with the following gradations.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 in. (12.7 mm)</td>
<td>0 – 100</td>
</tr>
<tr>
<td>14 (4.76 mm)</td>
<td>45 – 95</td>
</tr>
<tr>
<td>10 (2 mm)</td>
<td>25 – 75</td>
</tr>
<tr>
<td>4 (0.425 mm)</td>
<td>10 – 30</td>
</tr>
<tr>
<td>200 (0.075 mm)</td>
<td>0 – 50</td>
</tr>
</tbody>
</table>

Crushed glass shall be Type III or Type IV per IDEM’s restricted waste typing criteria.

The source shall be approved by the Department’s Environmental Services Section. Sampling in accordance with AASHTO T 2, sieve analyses in accordance with AASHTO T 11 & 27, and standard proctor test in accordance with AASHTO T 99 shall be performed by a Department approved laboratory and test results submitted to the Department’s Materials and Tests Division for approval at least three days prior to use.

Method of Construction
Construction shall be in accordance with 200 and 700.

Method of Measurement
The method of measurement will be in accordance with 211.

Basis of Payment
Payment will be in accordance with 211.
Subgrade Treatment Utilizing By-products

- Lime Kiln Dust: Lime by-products

- Cement Kiln Dust: Cement by-products
UN-MODIFIED SUBGRADE

RUTTING
MODIFIED SUBGRADE
#53 STONE OVER LIME KILN DUST
MODIFIED SUBGRADE
Summary of Recycled Materials Used on INDOT Projects

1. Coal Combustion By-products
2. Foundry Sand
3. Shredded Tires
4. Crushed Glass
5. Lime-Kiln Dust
6. Cement Kiln Dust
Indiana Coal Combustion By-product Production

Indiana Foundry Sand Sources
Indiana Waste Tire Processors

Indiana Crushed Glass
Map showing all recycled materials: Coal Combustion By-products, Recycled Foundry Sand, Shredded Tires, and Crushed Glass.

CCBP-
Foundry Sand-
Shredded Tires-
Crushed Glass-
## Summary of Demo Projects Utilizing Recycled Materials

<table>
<thead>
<tr>
<th>Project</th>
<th>Material Type</th>
<th>Quantity</th>
<th>Application</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>US12 in Lake County</td>
<td>Bottom Ash</td>
<td>5,000 yd³</td>
<td>As borrow-Road Widening</td>
<td>Product was donated by NIPSCO. Not evaluated as this was the 1st Demo project. Landfill space saved: 5,000 yd³</td>
</tr>
<tr>
<td>56th Street over I-465 in Marion County</td>
<td>Co-mingled Ash</td>
<td>10,000 yd³</td>
<td>As borrow-Road Widening</td>
<td>Product was donated by IPL. Landfill space saved: 10,000 yd³</td>
</tr>
<tr>
<td>US50 in Knox County</td>
<td>Co-mingled Ash</td>
<td>45,000 yd³</td>
<td>As borrow-Embankment Construction</td>
<td>Product was donated by Cinergy. Landfill space saved: 45,000 yd³</td>
</tr>
<tr>
<td>SR641 in Vigo County</td>
<td>Fly Ash</td>
<td>218,000 yd³</td>
<td>As borrow-New Road Construction</td>
<td>Product was donated by Cinergy. Landfill space saved: 218,000 yd³</td>
</tr>
<tr>
<td>US231 in Spencer County</td>
<td>Bottom Ash</td>
<td>35,000 yd³</td>
<td>As borrow-New Road Construction</td>
<td>Product was donated by AEP. Landfill space saved: 35,000 yd³</td>
</tr>
</tbody>
</table>
## Summary of Demo Projects Utilizing Recycled Materials (Con’t.)

<table>
<thead>
<tr>
<th>Project</th>
<th>Material Type</th>
<th>Quantity</th>
<th>Application</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR206 in Dekalb County</td>
<td>Foundry Sand</td>
<td>45,000 yd³</td>
<td>Borrow Embankment Correction</td>
<td>Product was donated by Auburn Foundry, INDOT save on purchase of material, Auburn Foundry regained 1.5 yrs of life of its monofilfill Landfill space savings: 456,000 yd³</td>
</tr>
<tr>
<td>US31 in Lakeville, Indiana-St. Joseph County</td>
<td>Shredded Tires</td>
<td>800 yd³</td>
<td>Embankment Construction</td>
<td>Embankment construction completed well ahead of schedule-wet season did not affect project. Shredded tires provided by Dillon Tires. Landfill space savings: 800 yd³</td>
</tr>
<tr>
<td>US 31 Bypass in Marshall County</td>
<td>Shredded Tires</td>
<td>12,000 yd³</td>
<td>Lightweight Fill</td>
<td>Lightweight Fill over Peat Bog. Dillon Tires supplied tires $2,000,000.00</td>
</tr>
<tr>
<td>SR110 in Marshall County</td>
<td>Shredded Tires</td>
<td>800 yd³</td>
<td>Light Weight Fill in lieu of Expanded Shale</td>
<td>Lightweight embankment constructed over a peat bog saving $95,000.00</td>
</tr>
<tr>
<td>SR 67 in Bruceville, Indiana Knox County</td>
<td>Crushed Glass</td>
<td>20 yd³</td>
<td>Structural Backfill Around Pipe</td>
<td>This demo was funded by IDEM. No cost to INDOT for material-For local community use. Landfill savings: 20 yd³</td>
</tr>
</tbody>
</table>
## Listing of Projects Suggested to Utilize CKD in 2009

<table>
<thead>
<tr>
<th>Des. #</th>
<th>District</th>
<th>Subgrade Type</th>
<th>Area yd²</th>
<th>Letting Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>0600806</td>
<td>Ft. Wayne</td>
<td>1-A</td>
<td>1,800</td>
<td>1/14/2009</td>
</tr>
<tr>
<td>0501140</td>
<td>LaPorte</td>
<td>1-A</td>
<td>1,500</td>
<td>2/11/2009</td>
</tr>
<tr>
<td>0100687</td>
<td>Ft. Wayne</td>
<td>1-A</td>
<td>37,206</td>
<td>2/11/2009</td>
</tr>
<tr>
<td>9881930</td>
<td>Crawfordsville</td>
<td>1-A</td>
<td>60,000</td>
<td>2/11/2009</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>194,206</strong></td>
<td></td>
</tr>
</tbody>
</table>
Utilization of By-products in 2009

<table>
<thead>
<tr>
<th>By-product type</th>
<th>Quantity yd²</th>
<th>In lieu of</th>
<th>Net Savings to INDOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CKD</td>
<td>194,206</td>
<td>Portland Cement</td>
<td>$ 728,272.00</td>
</tr>
<tr>
<td>LKD</td>
<td>1,205,794</td>
<td>Quick or Hydrated Lime</td>
<td>$1,808,691.00</td>
</tr>
</tbody>
</table>
## Average Cost for Subgrade Treatment in 2009

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Cost per yd²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate</td>
<td>$16.50</td>
</tr>
<tr>
<td>Cement</td>
<td>$8.35</td>
</tr>
<tr>
<td>CKD</td>
<td>$4.60</td>
</tr>
<tr>
<td>Lime</td>
<td>$7.85</td>
</tr>
<tr>
<td>LKD</td>
<td>$6.35</td>
</tr>
</tbody>
</table>
## Cost of Lightweight Fill Materials in 2009

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Cost per yd³ range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/ Tire Mixture</td>
<td>$20.00</td>
</tr>
<tr>
<td>Expanded Shale</td>
<td>$83.00</td>
</tr>
<tr>
<td>EPS</td>
<td>$100.00 to $200.00</td>
</tr>
<tr>
<td>Cellular Concrete</td>
<td>$50.00</td>
</tr>
<tr>
<td>Recycled Product Type</td>
<td>Applications</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------</td>
</tr>
<tr>
<td><strong>Coal Combustion By-Products</strong></td>
<td>Borrow, B-borrow, Flowable Fill, Structure Backfill, Fly Ash-As Lightweight Fill</td>
</tr>
<tr>
<td><strong>Recycled Foundry Sand</strong></td>
<td>Borrow, B-borrow, Flowable Fill, Structure Backfill</td>
</tr>
<tr>
<td><strong>Shredded Tires</strong></td>
<td>Borrow, Lightweight Fill Material, Structure Backfill</td>
</tr>
<tr>
<td>** Crushed Glass**</td>
<td>B-borrow, Structure Backfill</td>
</tr>
<tr>
<td><strong>Lime Kiln Dust</strong></td>
<td>Chemical Modifier For Subgrade Treatment, Ground Modification</td>
</tr>
<tr>
<td><strong>Cement Kiln Dust</strong></td>
<td>Chemical Modifier For Subgrade Treatment, Ground Modification</td>
</tr>
</tbody>
</table>
INDOT Recommendations

Designer:

- Possibility of getting material free of charge
- Reduction of construction cost and time
- Less expensive when compared to other lightweight fill materials
- Shredded tires and fly ash can be utilized to solve engineering design issues
- Good materials to be used for Soil modification/ stabilization in lieu of excavation and replacement
For Contractor:

- Review available source of Recycled Materials in the project vicinity (within 5 to 15 miles)
- Talk to Producer of Recycled Material to ascertain availability of product
- Negotiate with the producer for free product including transportation costs
- Producers may be willing to supply the material free of charge and may share some transportation costs
- It is more economical for the producer to give the material free of cost rather than taking it to the landfill
- It is advisable to inform the Project Engineer as soon as possible of his intention to utilize recycled materials
Advantages of Utilizing Recycled Materials

Contractor:

- Possible free material
- More uniform material to work with
- Reduce significant time of placement during construction
- Need fewer passes than on natural materials
- Requires less testing and inspection
- Since the material is relatively free-draining, it requires little or no aeration/disking
- Savings on labor as well as equipment costs
Future Plans for Recycled Materials
Recycled Material Under Consideration for Future Use

1. EAF (Electric Air Furnace) Steel Slag Use for Soil Modification
2. Green Lime/Carbide Lime for Soil Modification
3. LKD Slurry for Soil Modification to avoid dusting in urban applications
Useful Links
EPA’s Resource Conservation Challenge
www.epa.gov/rcc
Indiana Department of Environmental Management Office of Land Quality
www.in.gov/idem/programs/land/index.html
Statues and Rules:
Indiana Code 13-19-3-3 Pertains to CCPs
Indiana Code 13-19-3-7 Pertains to Foundry Sand
Indiana Code 13-19-3-8 Pertains to Slag
www.ai.org/legislative/ic/code/title13/ar19/ch3.html#IC13-19-3-8
329 IAC 10-9-4 Pertains to Foundry Sand Waste Classification
www.in.gov/legislative/iac/T03290/A00100.PDF
Case-by-Case Approvals are Covered under 329 IAC 10-3-1
www.in.gov/legislative/iac/T03290/A00100.PDF
Land Application is Covered under 327 IAC 6.1
www.in.gov/legislative/iac/T03270/A00061.PDF
Indiana DOT Construction Standards and Specifications
Indiana DOT Recurring Special Provisions Menu
www.in.gov/dot/div/contracts/standards/rsp/mar05/mar.htm
Questions?