Foundry Sand: Charactereistics, Specifications, Environmental Considerations, Availability

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RMRC

What is Foundry Sand?

- Foundry sand is a high-quality uniform silica sand that is used to make molds and cores for ferrous and nonferrous metal castings.

- Foundry sands typically comprise of >80% high-quality silica sand, 5-10% bentonite clay, 2 to 5% water and less than 5% sea coal.

Photos Courtesy of AFS-FIRST

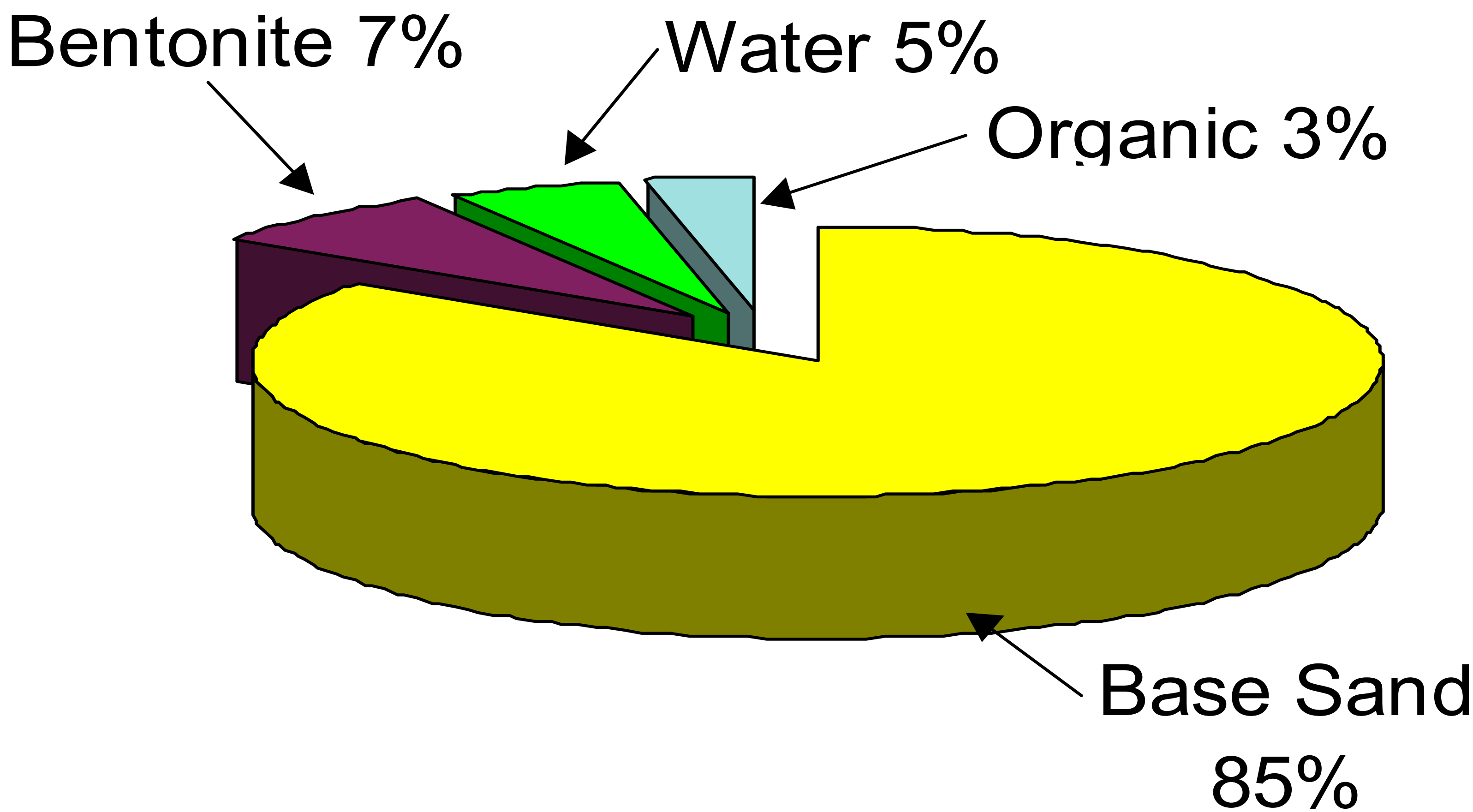
Engineering Properties

- Physical properties of foundry sand and natural sand

Foundry Sand: 45X Mag

Natural Ohio Fine Grained Sand : 45X Mag

Foundry Sand Composition



Foundry sands are sand-bentonite mixtures.

How is Foundry Sand Used?

- Foundry sand is reused within the foundry several times until the sand becomes unsuitable for mold construction.

- Approximately 9 to 10 million tons of foundry sand is discarded yearly.

- An estimated 28% of discarded foundry sand is reused in primarily construction-related applications.

Why Use Foundry Sand in Infrastructure Construction?

- Recycled foundry sand is generally considered a higher quality material than virgin construction sands.

- Reduce energy and financial expenses associated with obtaining virgin construction sands.

- Project managers can promote green construction and gain sustainability points for their projects.

State of the Industry and Future Goals

- The EPA (2008) estimates that current foundry sand recycling rates prevents 20,000 tons of CO_2 emissions and 200 billion BTUs of energy consumption.

- U.S. EPA, the Federal Highway Administration, the U. S. Department of Agriculture, the Recycled Materials Resource Center (RMRC), state environmental agencies, the foundry industry and end users have partnered together to increase foundry sand recycling to **50%** by **2015**

Foundry Sand Being Used as Fill

Foundry sand grades and shapes easily.

Fines facilitate compaction with modest amount of moisture.

Foundry sand being spread as highway sub-base.

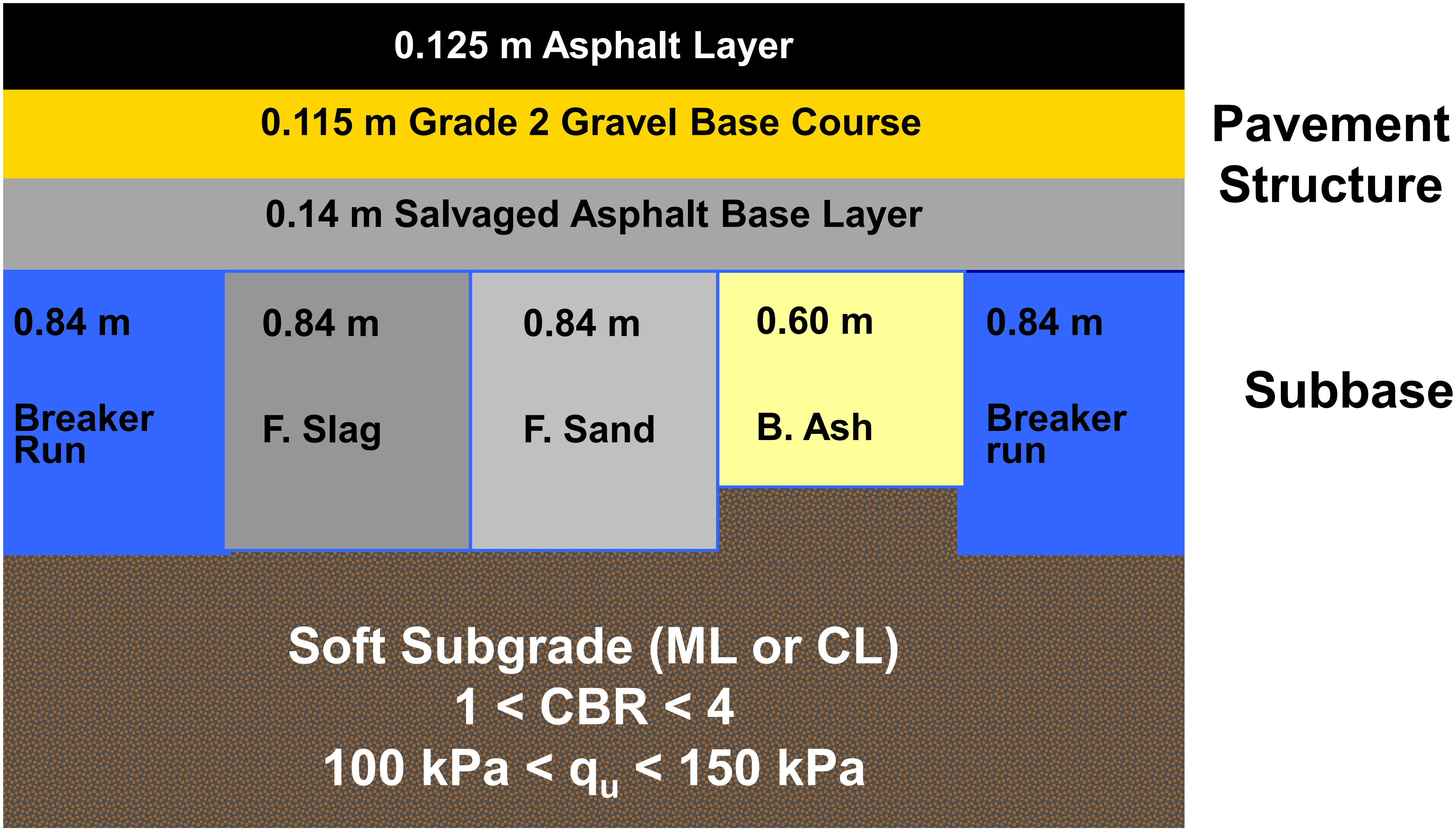
Foundry sand sub-base being compacted.

Design Considerations

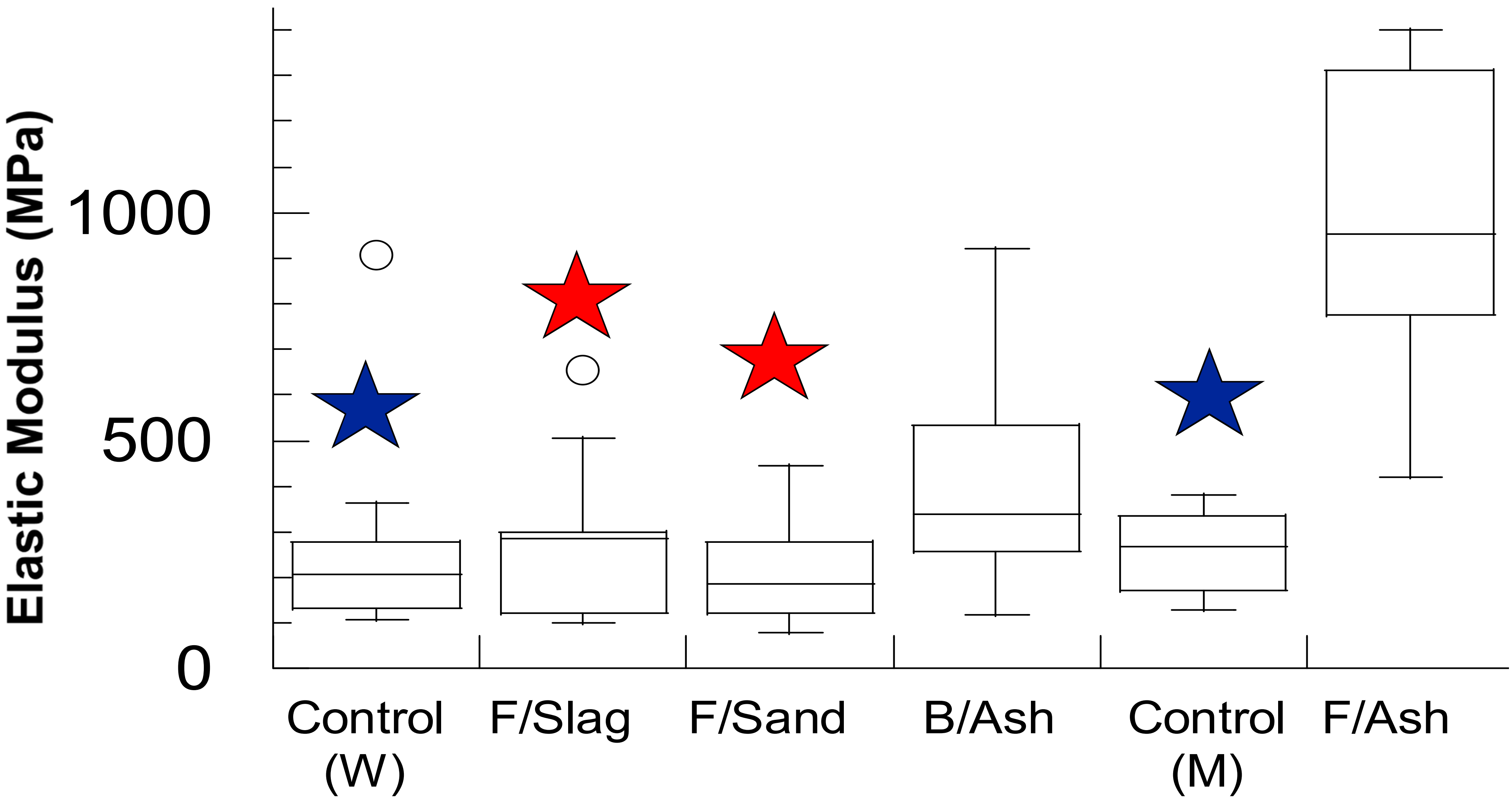
Highway Subbase

- California Bearing Ratio
- Resilient Modulus
- Uncompressive Strength
- Design charts and methodology for constructing working platforms with FS found in Tanyu et al 2004 and 2005
- FS found to resist degradation due to winter conditions better than typical reference materials

Full-Scale Field Test: Wisconsin State Highway 60



Field Performance: Five Years After Construction



Design Considerations -Embankment

- **Draft AASHTO and ASTM standards for the incorporation of FS in embankment/structural fill designs is being balloted**
- **Typical embankment design parameters include:**

Design Parameter	Foundry Sand Performance
Specific Gravity	2.39 – 2.70
Bulk Relative Density, lb/ft^3	160
Standard Proctor Max Dry Density, lb/ft^3	109
Optimum Moisture Content, %	~ 12%
Hydraulic Conductivity (cm/sec)	10^{-3} - 10^{-9}
Plastic Index	NP to 12
Internal friction angle (drained)	33° - 43°
Cohesion intercept (drained), lb/ft2	145-585

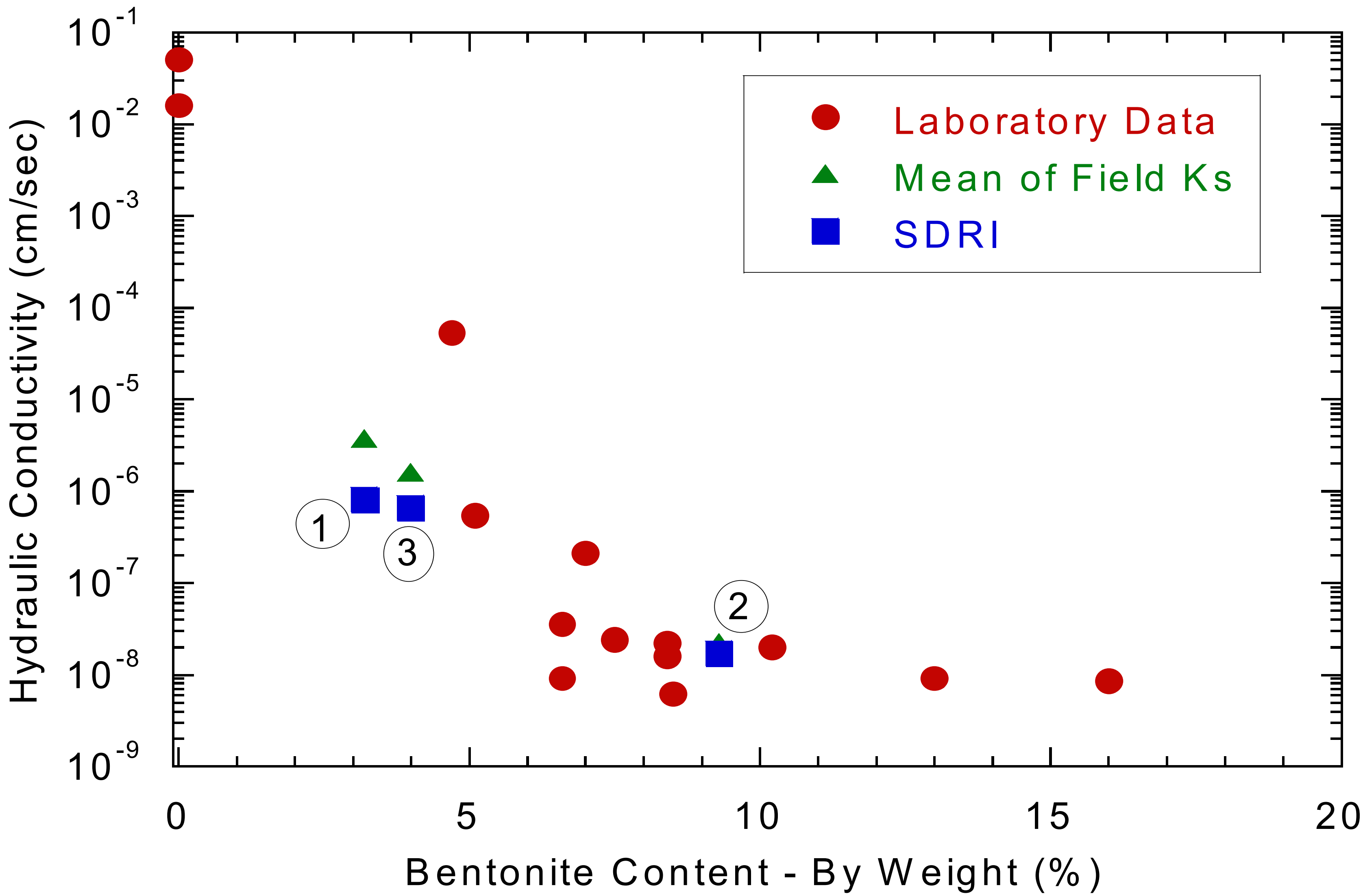
Retaining Wall and Structural Fill Design Recommendations for Foundry Sands

- $\phi' = 40^{o}$, $c' = 0$
- E = 55% for geogrids
- E = 65% for geotextiles
- Compact dry of optimum water content

Frictional Efficiency E(%) = $\tan\delta'/\tan\phi' \times 100$

δ' = interface friction angle ϕ' = internal friction angle

Drainage & Foundry Sands



Design Considerations

Hot Mix Asphalt

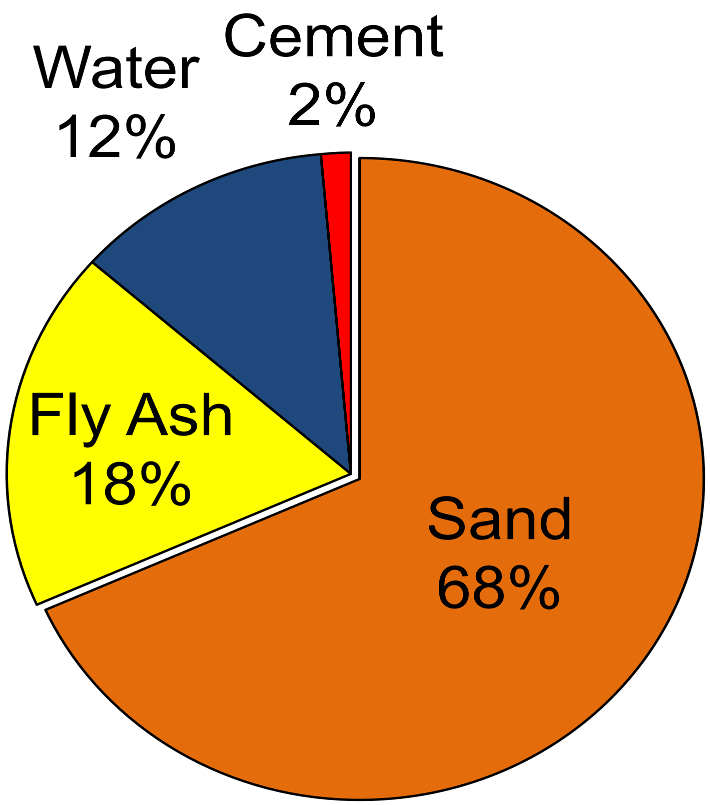
- FS replaces fine aggregate in standard asphalt mixes and conventional AASHTO pavement design and field testing methods can be employed

- The fines content of the FS determines the amount used to replace aggregate (usually replaces 8-25% fine aggregate)

- HMA-FS mixes demonstrate better resistance to weathering

Foundry Sands in Flowable Fill

- Flowable slurry mixed & delivered like concrete.
- Modest strength, but excavatable
- Trench backfill, underground void backfill, pipeline grouting.
- Use water-cement ratio of 9 to 12 to ensure strength in correct range (0.3 – 1.0 MPa)



Design Considerations

Flowable Fill

- FS replaces fine aggregate in flowable fill mixtures
- Bentonite content of FS >10% can impede flow causing an increase in water requirements
- For bentonite contents greater than 6 percent, no fly ash is necessary because the bentonite will be sufficient to prevent segregation
- FS may not satisfy gradation requirements but the uniform, spherical nature of the particles creates a free flowing mixture
- The same methods and equipment used for conventional flowable fill mixes can be use for FS mixes

Design Considerations

Portland Cement Concrete

- FS replaces some fine aggregate in Portland cement concrete
- FS should be screened and crushed to obtain the desired gradation, and magnetic particles should be separated. These processes will prevent technical problems when mixing the cement components.
- FS may cause a gray/black tint to finished concrete. Color change is minimized with <15% fine aggregate replacement.
- FS should have less than 5% fines to maintain durability of concrete

Is Foundry Sand safe to use in Infrastructure Construction?

- Discarded foundry sand can contain trace amounts of leachable metals and organic constituents

- Ferrous and aluminum foundry sands have been approved for use as a construction material
  - Brass and Bronze foundry sands may contain high concentrations of heavy metals

- Leaching studies of ferrous and aluminum foundry sands generally show metals and organic constituents are below designated environmental threshold levels

Environmental Assessment: Issues to Consider

- Does a standard method exist to evaluate environmental impacts associated with foundry byproducts?
- Do leachates from foundry byproducts have more contaminants or greater concentrations than conventional construction materials?

Wisconsin NR 538 Code

164–1 DEPARTMENT OF NATURAL RESOURCES **NR 538.06**

Unofficial Text (See Printed Volume). Current through date and Register shown on Title Page.

Chapter NR 538

BENEFICIAL USE OF INDUSTRIAL BYPRODUCTS

NR 538.01 Purpose. The purpose of this chapter is to allow and encourage to the maximum extent possible, consistent with the protection of public health and the environment and good engineering practices, the beneficial use of industrial byproducts in a nuisance–free manner. The department encourages the beneficial use of industrial byproducts in order to preserve resources, conserve energy, and reduce or eliminate the need to dispose of industrial byproducts in landfills. This chapter is adopted under ss. 289.05, 289.06, 289.43 (4), (7) and (8), Stats. and 227.11, Stats.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.02 Applicability. (1) Except as otherwise provided, this chapter governs the beneficial use of industrial byproducts, except hazardous waste and metallic mining waste.

(2) This chapter does not apply to the design, construction or operation of industrial wastewater facilities, sewerage systems and waterworks treating liquid wastes approved under s. 281.41, Stats., or permitted under ch. 283, Stats., nor to facilities used solely for the disposal of liquid municipal or industrial wastes which have been approved under s. 281.41, Stats., or permitted under ch. 283, Stats., except facilities used for the disposal of solid waste.

Note: The landspreading of wastewater treatment sludges is regulated under chs. NR 206 and 214. The landspreading of solid wastes is regulated under ch. NR 518.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.03 Definitions. The following definitions as well as the definitions in ch. 289, Stats., and s. NR 500.03 are applicable to the terms used in this chapter unless the context requires otherwise.

(1) "Base course" means the layer or layers of specified or selected material of designated thickness placed on a subbase or subgrade to support a pavement or other structure.

(2) "Industrial byproduct" means papermill sludge, coal ash including slag, foundry excess system sand, foundry slag or other non–hazardous solid waste with similar characteristics as determined by the department.

(3) "Residential area" means properties that are zoned as residential, are in areas planned for residential zoning under a master plan approved or adopted by a local municipal authority or those portions of properties on which there is a residence for human habitation that are within 200 feet of the residence.

(4) "Subbase" means the layer or layers of specified or selected material placed on a subgrade to support a base course.

(5) "Subgrade" means the top soil surface upon which a subbase or base course are placed.

(6) "Subgrade fill" means the layer or layers of material placed above the natural ground surface to achieve a subgrade.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.04 Performance standards. No person may store, handle or beneficially use an industrial byproduct in a manner that may cause any of the following:

(1) A significant adverse impact on wetlands.

(2) A significant adverse impact on critical habitat areas.

(3) A detrimental effect on any surface water.

(4) A detrimental effect on groundwater quality or will cause or exacerbate an attainment or exceedance of any preventive action limit or enforcement standard at a point of standards application as defined in ch. NR 140.

(5) The migration and concentration of explosive gases in any structures, or in the soils or air at or beyond the project property boundary in excess of 25% of the lower explosive limit for the gases at any time.

(6) The emissions of any hazardous air contaminant exceeding the limitations for those substances contained in s. NR 445.03.

Note: The placement of materials in a floodplain where an obstruction to flood flows or an increase in regional flood event or an adverse affect upon a drainage course is regulated under ch. NR 116.

Note: The emissions of particulates and volatile organic compounds are regulated under s. NR 415.03 and chs. NR 419 to 424.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.05 Solid waste rules exemption. (1) GENERAL. Persons who generate, use, transport or store industrial byproducts that are characterized and beneficially used in compliance with this chapter are exempt from licensing under s. 289.31, Stats., and the regulatory requirements in chs. NR 500 to 536.

(2) EXISTING EXEMPTIONS. This chapter does not abrogate, rescind or terminate an approval or grant of exemption in effect on January 1, 1998 that was issued under s. 289.43 (7) or (8), Stats. Nothing in this subsection limits the authority of the department to modify, terminate or rescind any approval or grant of exemption as provided by law.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.06 Industrial byproduct characterization. (1) GENERAL. Industrial byproducts that are beneficially used under this chapter shall be characterized as specified in this section to determine their appropriate categorization under s. NR 538.08. The results of this characterization shall be reported to the department as specified in s. NR 538.14. The testing program for materials not specifically listed in tables 1A to 3 shall be approved by the department prior to characterization. For those materials not listed in tables 1A to 3 the department may modify the list of parameters required to be analyzed for and may establish standards on a material specific basis for additional parameters.

(2) INITIAL CHARACTERIZATION. A representative sample of an industrial byproduct shall be properly characterized prior to beneficial use to determine its category under s. NR 538.08.

(3) CHARACTERIZATION METHODS. (a) The limits of detection used in the characterization shall be at or below the concentration listed in tables 1A to 3 for each parameter for the specific target category where possible. When a limit of detection at or below a target category standard is not achievable, or if no concentration is listed, the method that will achieve the lowest detection limit shall be used. All material sampling, total elemental analyses and analyses of elutriate from leach testing shall be performed using

- Evaluate byproducts based on total elemental analysis and water leach tests.
- Define byproduct categories based on test data.
- Define suitable application based on category.

Applications Based on Category

Table 4

Beneficial Use Methods

	Industrial Byproduct Category				
	5	4	3	2	1
(1) Raw Material for Manufacturing a Product	X	X	X	X	X
(2) Waste Stabilization / Solidification	X	X	X	X	X
(3) Supplemental Fuel Source / Energy Recovery	X	X	X	X	X
(4) Landfill Daily Cover / Internal Structures	X	X	X	X	X
(5) Confined Geotechnical Fill (a) commercial, industrial or institutional building subbase (b) paved lot base, subbase & subgrade fill (c) paved roadway base, subbase & subgrade fill (d) utility trench backfill (e) bridge abutment backfill (f) tank, vault or tunnel abandonment (g) slabjacking material		X	X	X	X
(6) Encapsulated Transportation Facility Embankment		X	X	X	X
(7) Capped Transportation Facility Embankment			X	X	X
(8) Unconfined Geotechnical Fill			X	X	X
(9) Unbonded Surface Course				X	X
(10) Bonded Surface Course				X	X
(11) Decorative Stone				X	X
(12) Cold Weather Road Abrasive				X	X
Note: General beneficial use in accordance with s. NR 538.12 (3)					X

Note: Refer to s. NR 538.10 for description of each beneficial use
History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

Lower category number provides more stringent limits on leaching characteristics.

Water Leach Test Criteria – NR 538

Category 4 ASTM Water Leach Test

Standard (mg/l)	Parameter	Ferrous Foundry Excess System Sand	Ferrous Foundry Slag	Coal Ash	Other[1]
0.03	Antimony (Sb)				X
0.25	Arsenic (As)				X
10	Barium (Ba)	X			X
0.02	Beryllium (Be)				X
0.025	Cadmium (Cd)	X	X	X	X
2500	Chloride (Cl)				X
0.5	Chromium, Total (Cr)			X	X
6.5	Copper (Cu)				X
1	Total Cyanide				X
20	Fluoride (F)				X
3	Iron (Fe)	X	X		X
0.075	Lead (Pb)	X	X		X
0.5	Manganese (Mn)				X
0.01	Mercury (Hg)	X	X		X
0.5	Nickel (Ni)				X
50	Nitrite & Nitrate (NO_2+NO_3–N)				X
30	Phenol				X
0.25	Selenium (Se)			X	X
0.25	Silver (Ag)			X	X
2500	Sulfate			X	X
0.01	Thallium (Tl)				X
50	Zinc (Zn)				X

1 As provided under s. NR 538.06 (1), the testing program for materials other than ferrous foundry system sand, ferrous foundry slag and coal ash must be approved by the department prior to characterization. For other materials the department may modify the list of parameters required to be analyzed for and may establish standards on a material specific basis for additional parameters.

Note: All testing is to be conducted on a representative sample of a single industrial byproduct prior to commingling with other materials, unless otherwise approved by the department.

- Contaminants of concern depend on byproduct being considered.
- Category 1 has the most test requirements.

Methods to Assess Leaching

- Batch tests:

- solid and liquid in a vial
- tumbled to ensure local well-stirred
- supernatant analyzed for contaminants of concern

- Column tests:

- flow through experiment simulating field scenario
- effluent analyzed for contaminants of concern.

Batch Tests

- TCLP – toxicity characteristic leaching procedure (EPA Method 1311)

- purpose: to determine if a waste is hazardous waste under RCRA (40 CFR Part 261)

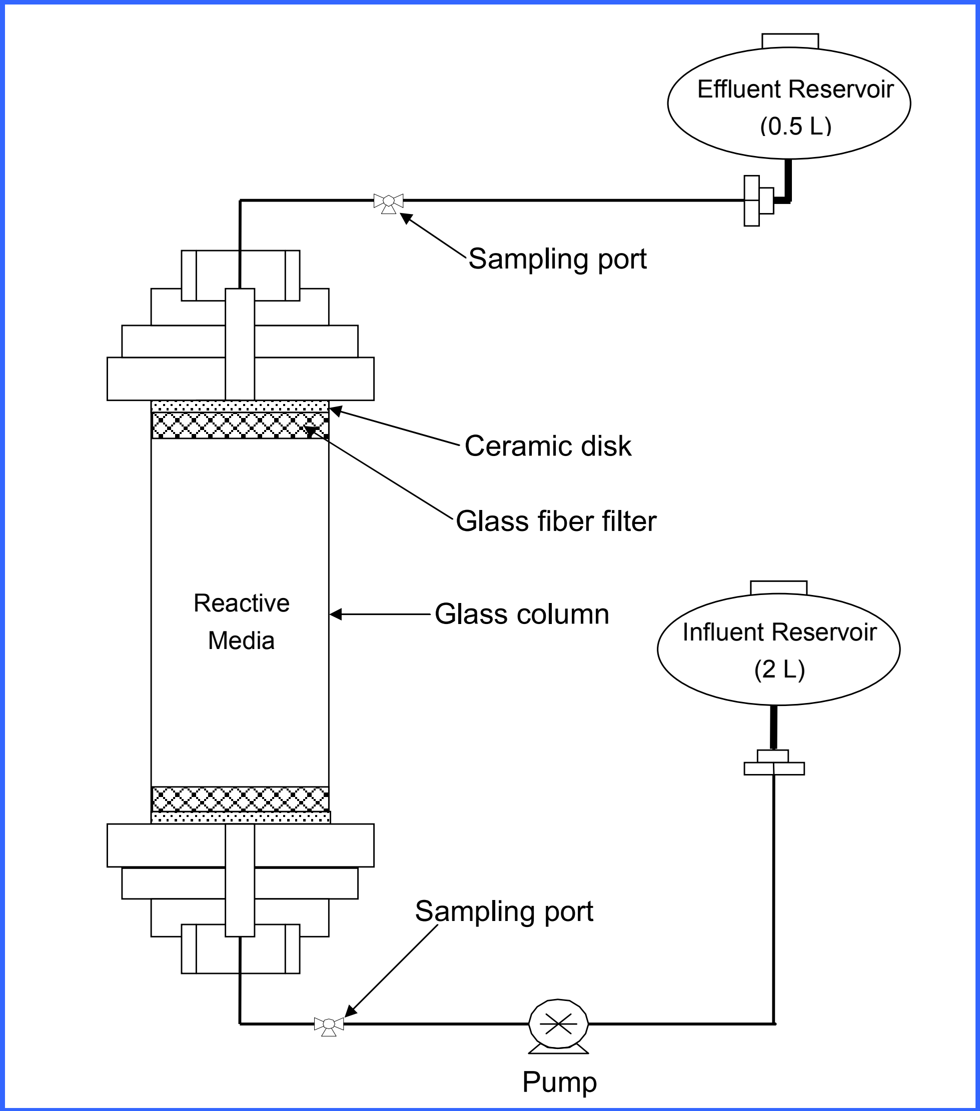
- SPLP – synthetic precipitation leaching procedure (EPA Method 1312)

  purpose: to evaluate leaching of waste in response to precipitation

- ASTM Water Leach Test (D 3987)

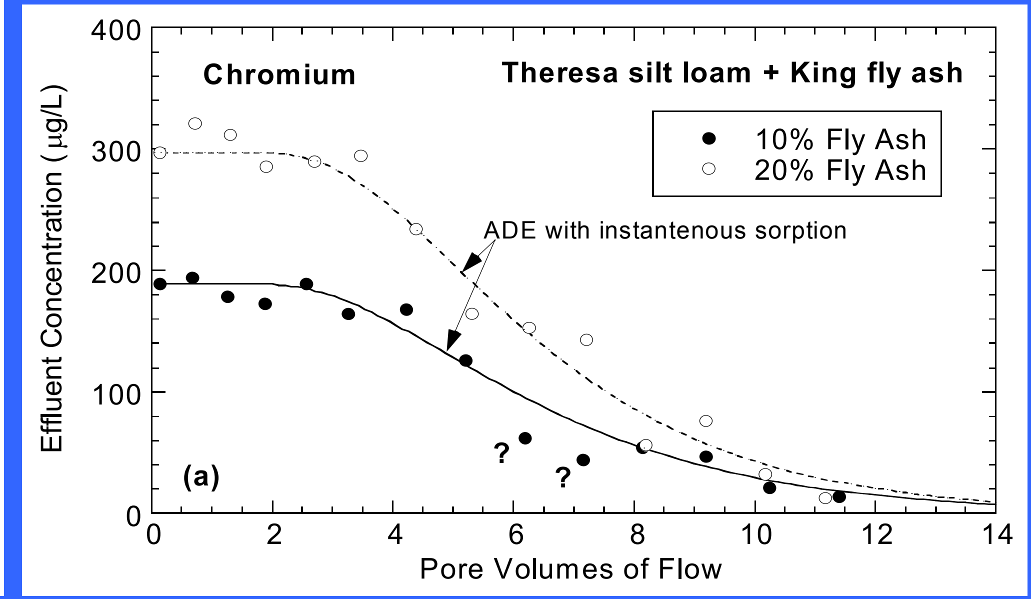
  purpose: to evaluate leaching of waste

Column Test Schematic

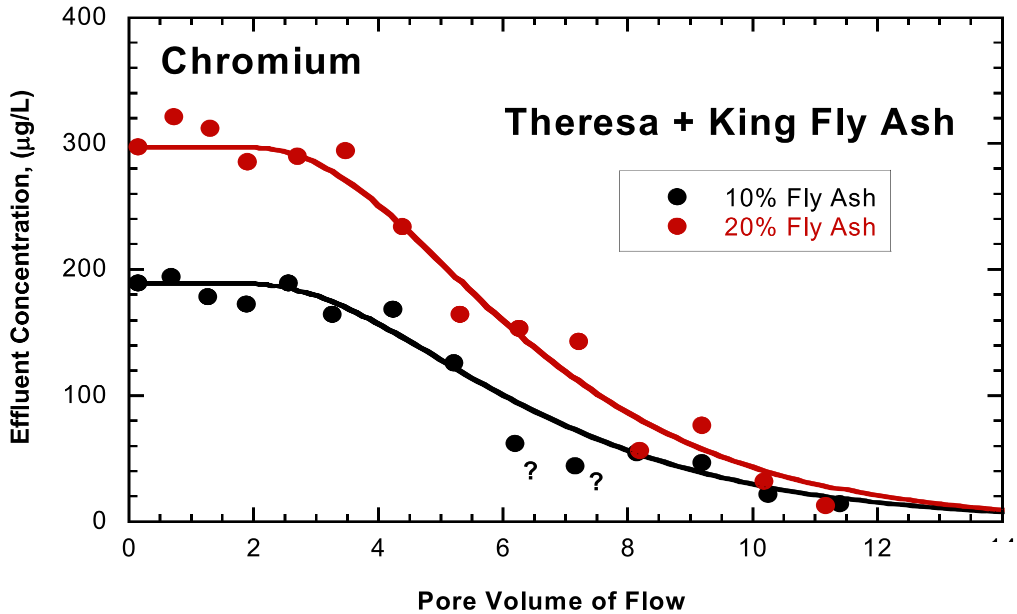


Column test example

Effluent concentrations

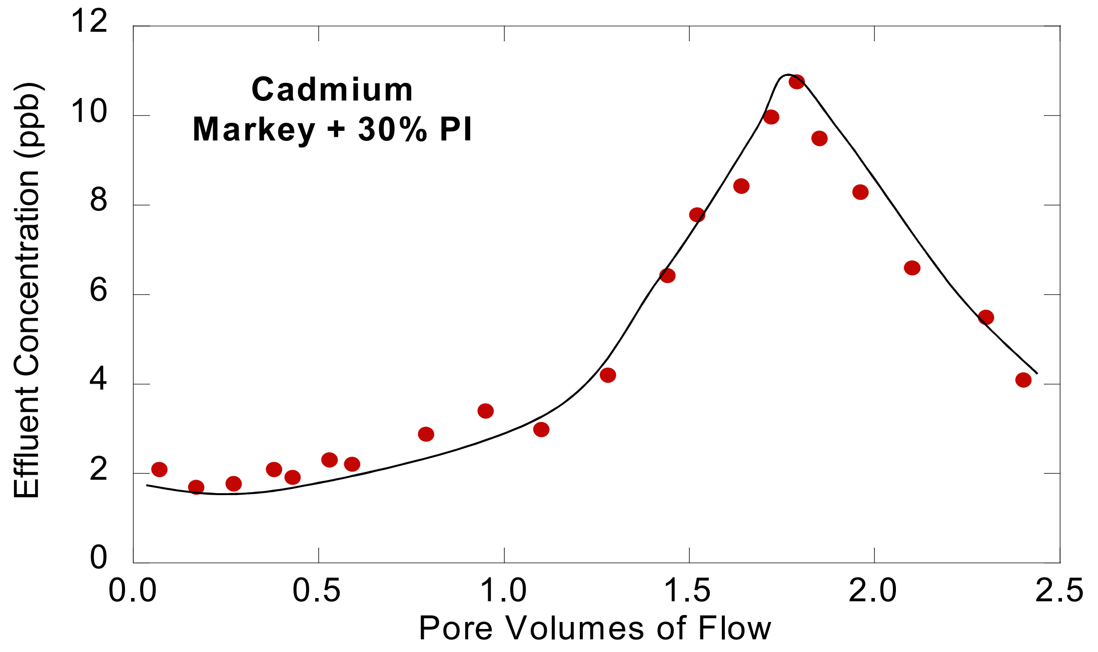


Leaching Patterns



First flush following ADRE

Delay response (user defined)

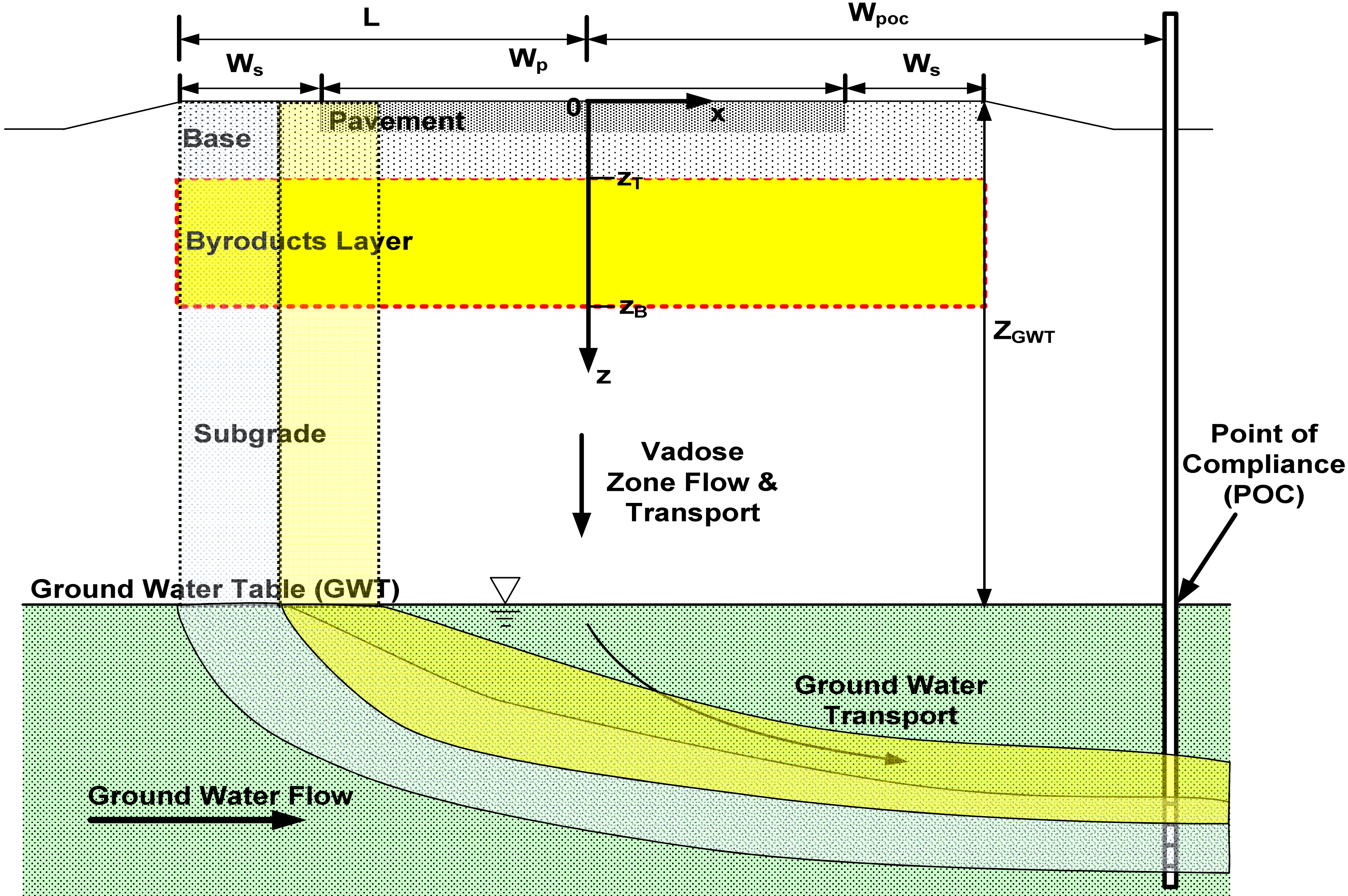


Environmental Impact Modeling Tools:

- **IMPACT**
- **WiscLEACH**
- **IWEM (Industrial Waste management Evaluation Model)**
- **STUWMPP (Screening Tool for Using Waste Materials in Paving Projects)**

Detailed information on assessing risk and protecting groundwater is available in EPA "Guide for Industrial Waste Management" which can be found at http://www.epa.gov/epaoswer/non-hw/industd/guide/index.asp

WiscLEACH Conceptual Model



Environmental Profile

- Summarized on AFS-FIRST website http://www.foundryrecycling.org
- DOE funded a joint Penn State/Univ. of Wisconsin study completed in 2004. An extensive analysis of foundry sand data concluded that "*the concentrations of most regulated metallic elements are less than or in the same level as those of soil. This illustrates that excess foundry sands do not pose greater threats to the environment than soil.*"

Environmental Profile

- A second major national study undertaken by U.S. Dept. of Agriculture resulted in 11 peer-reviewed journal articles
- In May 2009, U.S. EPA circulated a peer review draft of "Risk Assessment of Spent Foundry Sand in Soil-Related Applications" developed jointly with USDA. This exhaustive study of all risk pathways concluded that "*there is overwhelming evidence that the metal constituents found in SFS are not only present at levels protective of human health and the environment, but present at levels that are very similar to those found in native soils.*"

Summary Environmental Comments

- Look for regulations in your state. If none exist, propose using Wisconsin's NR 538.
- Column tests provide a more realistic depiction of leaching, but batch tests are more common.
- Peak concentrations in effluent from column tests and from the field typically are larger than those measured in batch tests.
- Conduct tests with eluent that resembles field condition if possible. Do not use acidic eluents unless justified by site conditions.

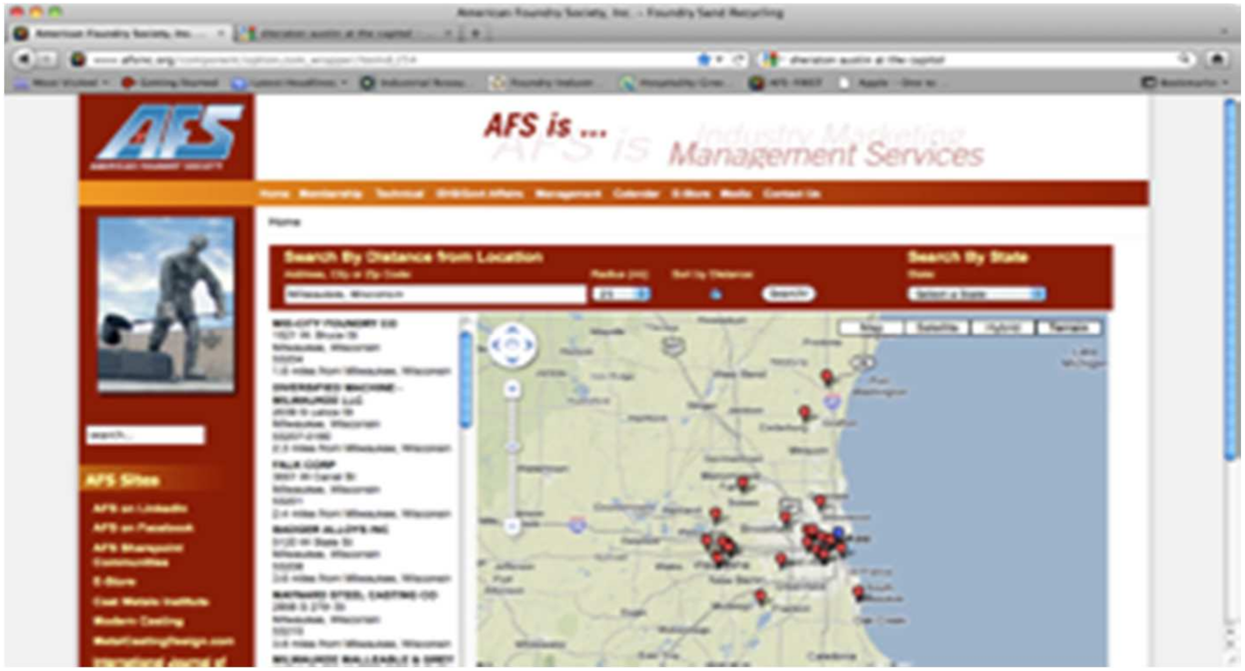
Summary Environmental Comments

- Do not use TCLP for assessing suitability of foundry byproducts (or other industrial resources) for use in construction applications. ASTM D 3987 preferred.
- Determination of "non-hazardous" by TCLP does not mean OK. Only inference is that solid would not need to be disposed in a hazardous waste landfill.
- Compare leaching from byproducts against leaching from conventional materials. Leaching is expected from nearly all materials used for unbound applications in highway construction.

Summary Environmental Comments

- Models exist to evaluate groundwater impacts from reuse applications when a code providing predefined reuse options (e.g., Wisc. NR 538) does not exist. Comparison should be made considering byproducts as well as conventional materials.

Availability



http://www.afsinc.org/component/option,com_wrapper/Itemid,254

Acknowledgements

Federal Highway Administration

United States Environmental Protection Agency

Wisconsin Recycling Market Development Board

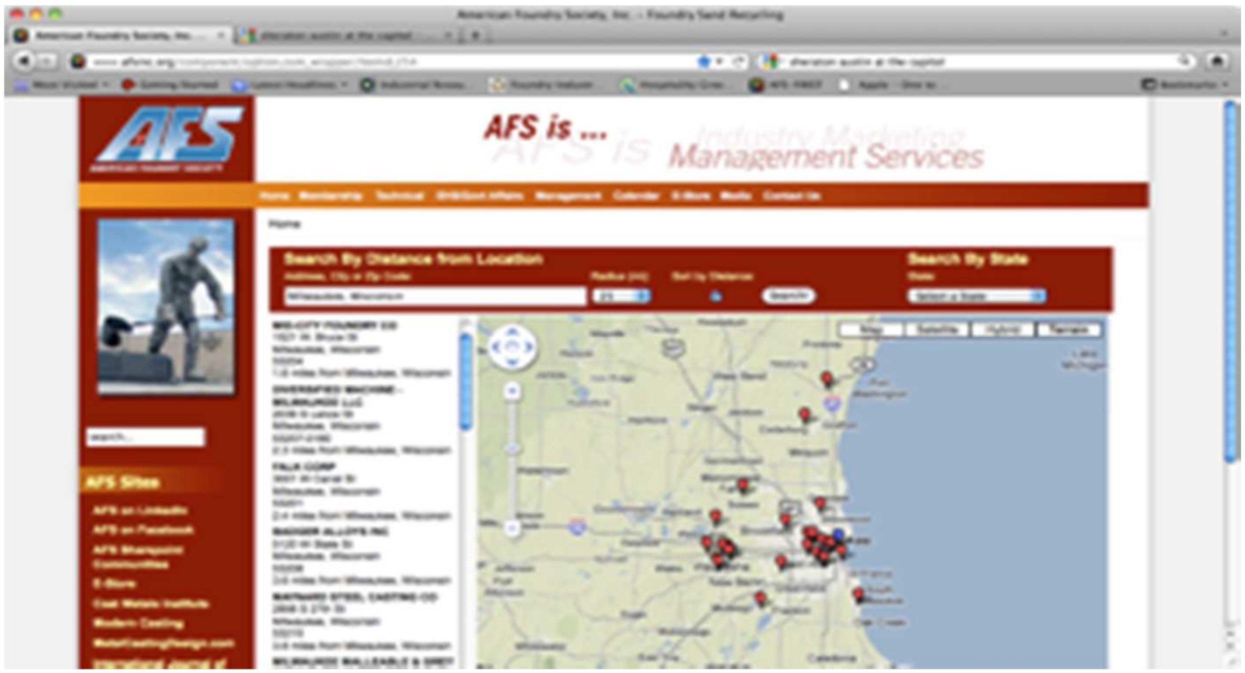
Wisconsin Solid Waste Research Program

Wisconsin Department of Natural Resources

Wisconsin Cast Metals Association

Wisconsin Department of Transportation

Availability



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