

## Using recovered materials in highway construction

Wisconsin industry and consumers generate a considerable volume of waste each year. While some must be disposed in a sanitary landfill or as a hazardous material, other materials can be recovered and recycled. Recycling materials into high value-added products is most desirable if it is economically feasible. However, many recovered materials cannot be used effectively this way. Using them in highway construction projects helps dispose of them constructively and avoids filling up expensive landfill space. Quite often these materials can replace expensive, and sometimes scarce, virgin aggregates.

This publication describes methods and procedures for reusing materials in highway construction. Practical examples exist all over Wisconsin. Many state agencies, including the Departments of Commerce, Natural Resources and Transportation, are working together to encourage appropriate, cost-effective and environmentally sound use of waste materials.

Since transportation costs often dictate economic limits on using these bulk materials, local highway agencies and contractors must play an important role in their efficient recycling. This fact sheet is intended to provide information to help highway builders efficiently use recycled materials available near their communities.



The primary focus here is on four recovered products: waste glass, bottom ash, foundry sand, and steel slag. Other materials are also available locally and can be considered for use in highway construction.

Resources for helping agencies and contractors identify locally available materials are listed at the end of this publication, as are technical resources for highway construction projects. A videotape illustrating many uses of these materials is also available.

### Benefits

There are many benefits of using reclaimed materials in highway construction. Simply burying these products in landfills is expensive, adding to landfill costs and shorten-

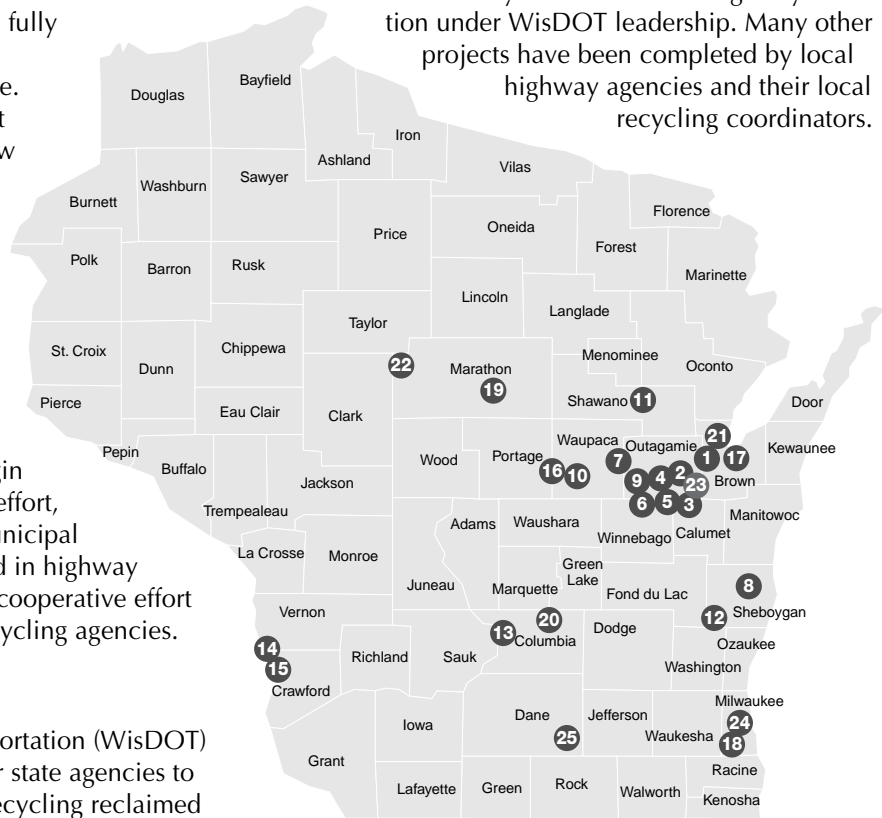
ing their useful life. Siting and operation costs of landfills are becoming a burden for local government, state government and private industry.

Reclaimed materials can replace virgin aggregates in highway construction. This provides a benefit in reducing the demand for new quarries and extending the lives of existing pit and quarry operations.

Economical re-use of these materials also benefits responsible industries and local governments by reducing the collection, transportation and disposal costs normally associated with putting the materials in landfills.

Developing economical recycling procedures requires an effort from all involved. An initial investment may often be necessary to fully develop re-use applications. Asphalt pavement recycling is a good example. Many years ago old asphalt pavement material was landfilled or buried. Now we recognize its value and recycle it in hotmix asphalt and use it as pulverized asphalt material for high quality base. What was once considered a liability is now in increasing demand for recycling and those who formerly paid for disposal now have a valuable resource. Recycling not only reduces construction costs but also saves valuable virgin aggregates and asphalt. With similar effort, many industrial, commercial, and municipal recovered products can likely be used in highway construction. To do so will require a cooperative effort of local agencies, contractors and recycling agencies.

and chart show a sampling of successful projects that have used recycled materials in highway construction under WisDOT leadership. Many other projects have been completed by local highway agencies and their local recycling coordinators.



### Successful applications

The Wisconsin Department of Transportation (WisDOT) has worked for many years with other state agencies to develop appropriate techniques for recycling reclaimed products into highway construction projects. The map

Material	Application	Location
1. Fly Ash	Fill	USH 41, Brown Co., Kaukauna–DePere/CTH F Int G/G
2. Fly Ash	Fill	STH 441 Outagamie Co., Tri-County/CTH CE-USH 41
3. Fly Ash	Fill	STH 441 Outagamie Co., CTH OO/USH 41 So. Sect.
4. Fly Ash	Fill	STH 441 Outagamie Co., Tri-County/CTH OO/USH 41/North
5. Fly Ash, Foundry Sand	Fill	STH 441, Calumet Co., Tri-County/USH 10-CTH KK
6. Fly Ash	Fill	USH 10, Winnebago Co., USH 45-USH 41, USH 10 Ext. (3 installations)
7. Fly Ash, Foundry Sand	Fill	USH 45, Outagamie Co., New London Bypass/Wolf River - STH 54
8. Fly Ash	Fill	STH 28, Sheboygan Co., Sheboygan Falls-IH 43/28-CTH PP
9. Fly Ash	Fill	USH 10, Outagamie Co., STH 76 Interchange
10. Foundry Sand	Fill	STH 54, Waupaca Co., Soo Line RR approach
11. Foundry Sand	Fill	STH 29, Shawano Co., CTH K overhead
12. Foundry Sand, Fly Ash	Flowable Fill	CTH D, CTH G, Sheboygan Co.
13. Fly Ash CL C&F	CLSM	I-90/94, Columbia Co., fill for several culverts
14. Screened Bottom Ash	Base course	STH 35, Crawford Co., STH 82 for 14 & 15 to DeSoto Rd.
15. Natural Bottom Ash	Base course	STH 35, Crawford Co., CTH C to STH 82
16. Cupola Slag	Base course	USH 10, Waupaca Co.
17. Tire	Chipped tire noise berm	STH 172, Brown Co., Ashwaubenon
18. Foundry Materials	Fill	STH 100, Ryan Rd., Milwaukee Co.
19. Papermill Ash	Fill	Mosinee Airport, Marathon Co.
20. Glass	Base course fill	STH 44, Columbia Co.
21. Glass	OGBC edge drains	STH 54, Brown Co., West Mason St., City of Green Bay
22. Bottom Ash	Fill	STH 29, Clark/Marathon Co., STH 29/STH 13 Interchange
23. Fly Ash	Fill	Just south of USH 41 on STH 441, Outagamie Co.
24. Fly/Bottom Ash	Fill	Airport Spur Freeway, Milwaukee Co.
25. Bottom Ash Glass Pottery Cull, Foundry Sand, Steel Slag	Base course fill	US 12 Cottage Grove to Cambridge, Dane Co.

## Sources of reclaimed materials

The Wisconsin Recycling Market Development Board (RMDB) and the University of Wisconsin-Green Bay have cataloged the locations and types of reclaimed materials available in Wisconsin. This detailed information is available from the RMDB or the Industrial Recycling Specialist at UW Extension-Green Bay.

Effective use of reclaimed materials requires close cooperation among local highway agencies, contractors, material suppliers and those industries and local governments responsible for material handling and disposal. The RMDB can be helpful in initiating contacts and providing technical assistance.

## Environmental considerations

The environment must be protected when reclaimed materials are used in highway construction. The Wisconsin Department of Natural Resources (WDNR) is working closely with industry and local governments to establish reasonable and effective procedures for this use.

Regulations have been developed in NR538 and NR 500.08 of the Wisconsin Administrative Code. The booklet *Guidance for the Beneficial Use of Industrial By-products*, published by the WDNR Bureau of Waste Management explains procedures and limitations for reuse of industrial by-products in construction. Guidelines on storage, transportation, notification, etc. are also included.

The rules are intended to be largely self-implementing to ease the process and encourage use in highway construction. Industrial waste and by-products are classified in five categories. The adjoining table illustrates their appropriate uses in a variety of applications. Once a material is classified, most beneficial uses allowed under these rules can proceed without specific WDNR approval.

Categorization and analysis of the by-product is the responsibility of the organization that generates it. This material generator should be able to describe appropriate use of its material to potential users. The generator is also responsible for coordinating with WDNR and will have certified its specific industrial by-products for beneficial use. Transportation and storage of a by-product as it is normally used in highway construction project will not require additional permits or certification. Good house-keeping practices to protect air and water quality should be used. Storage on site longer than two years should be coordinated with WDNR. Local highway agencies and contractors are encouraged to contact their WDNR district office with any specific questions or for help in environmental compliance.

There may be a concern about possible future limitations on recycling the reclaimed materials when the highway is reconstructed. The rules encourage using the previously recycled material in the same location or project. This use would not normally require any additional environmental approvals, but WDNR notification and appropriate record keeping are advised.

Beneficial use methods	Industrial byproduct category
1. Raw material for manufacturing a product	5 4 3 2 1
2. Waste stabilization / solidification	5 4 3 2 1
3. Supplemental fuel source / energy recovery	5 4 3 2 1
4. Landfill daily cover / internal structures	5 4 3 2 1
5. Confined geotechnical fill	4 3 2 1
(a) commercial, industrial or institutional building subbase	
(b) paved lot base, subbase and subgrade fill	
(c) paved roadway base, subbase and subgrade fill	
(d) tank, vault, or tunnel abandonment	
(e) utility trench backfill	
(f) bridge abutment backfill	
(g) slabjacking material	
6. Encapsulated transportation facility embankment	4 3 2 1
7. Capped transportation facility embankment	3 2 1
8. Unconfined geotechnical fill	3 2 1
9. Unbonded surface course	2 1
10. Bonded surface course	2 1
11. Decorative stone	2 1
12. Cold weather road abrasive	2 1

*The categories (5–1) in this table define beneficial uses of industrial byproducts as described in the Wisconsin Administrative Code. NR 538 of the code establishes guidance for the beneficial use of coal ash and slag, foundry sand and slag, and other non-hazardous solid waste. NR 500.08(2)(f) applies to recycled glass. Beneficial use is determined by ASTM water leach tests and elemental analysis. The generator is responsible for analysis and categorization.*

## Materials

### Glass

Glass is collected as post-consumer containers and bottles. Local communities are normally responsible for recovering glass at recycling centers or Material Recovery Facilities (MRF). These MRFs separate glass from other recyclables and most also further sort glass by color for re-use in container production. There is, however, considerable broken and mixed-color glass that has little or no commercial recycling value. This mixed broken glass, called “mixed cullet” has excellent potential for use in highway and general building construction. In Wisconsin mixed cullet volumes are relatively small and localized.

Considerable technical evaluation work has been completed on the use of glass cullet in construction. An excellent technical report, **Evaluation of Cullet as a Construction Aggregate**, reviews in detail the properties, limitations and requirements for use of recycled glass in construction. The Federal Highway Administration and WisDOT have also done extensive work in this area.

Typical applications include: general structural backfill, utility backfill, roadway and drainage applications, and many others. Crushed glass can be used by itself as a backfill material but more generally it is blended with natural aggregate to provide backfill, structural fills or base course.

Glass must be crushed to produce an aggregate-like material. Larger particles may be acceptable for general backfill applications. However, crushing to a maximum particle size of 1/4-3/8 inch has the added benefit of eliminating sharp, elongated particles that may cause handling problems or damage construction equipment tires.

Broken glass will often contain debris, generally paper, plastic labels, and plastic and metal caps. The amount of debris can vary significantly, depending upon the MRF's recycling process. Higher concentrations of debris may be tolerated for non-structural field applications. Limits in the range of 5% by volume are generally recognized as desirable for structural fill and base course applications.

Glass is inert but not as mechanically sound as crushed rock. However, blends of glass and aggregate, even up to 50% glass in the mixture, would normally meet abrasion and soundness test requirements for highway aggregate. Compaction testing indicates that glass can be easily compacted with conventional equipment especially when blended with aggregate.

Aggregate-glass mixtures are somewhat more resistant than pure aggregate to softening during wet weather construction. The permeability of glass aggregate blends is similar to natural aggregate of similar gradations. Shear testing results indicate that glass aggregate is similar to natural aggregate.

Strength testing using California Barring Ratio (CBR) or resistance value tests show aggregate-glass blends can meet most strength requirements for structural fill and base course. Testing of CBR by the Wisconsin Department of Transportation did show some loss of strength with higher percentages of glass. Current recommendations include limiting the amount of recycled glass to 10%-15% by weight in applications where high strength is required.

A report by The Clean Washington Center concludes in part:

*Glass cullet will perform very well as a construction aggregate....The data shows that both the 1/4 inch and 3/4 inch minus cullet are durable and mechanically sound. Cullet resistance to abrasion is lower than that of natural aggregate. However, when cullet is mixed with natural aggregate the resulting material will most likely have acceptable L.A. abrasion, R-Value and resilient modulus properties for use as roadway aggregate....*

*The cullet-aggregate mixtures have favorable compaction characteristics which provide good workability of the material....The debris level does affect some engineering properties of the cullet, but based on test data, good engineering performance can be expected for cullet containing up to 5% debris.*

Processing recycled glass or cullet requires crushing and blending with aggregate if a blended product is required. Conventional rock crushing equipment can be used for processing glass. Additional space and handling costs will dictate the final cost of a glass-aggregate blend.

Glass has been used successfully as granular base or fill for many years in Wisconsin and throughout the country. Other applications, including utility trench backfill and embankments, have used a blend of aggregates with a very high percentage of glass. Some applications for utility trenches have used 100% recycled glass as backfill aggregate.

Glass has also been recycled into asphalt or PCC concrete pavements. To be successful this application requires special engineering and materials testing. In general, the final products do not exhibit enhanced properties over virgin materials. Additionally, concerns linger about safety and about asphalt stripping from the glass aggregate. The chemical reaction between glass and cement also requires additional investigation. Most agencies seem to prefer using waste glass mixed with aggregate as a base or a structural fill rather than incorporating it into the pavement surface.

### ***Fly ash, bottom ash, boiler slag***

Coal-fired power plants produce a variety of coal combustion by-products. These include fly ash, bottom ash, and boiler slag. Wisconsin power plants alone produce about 800,000 tons of coal combustion by-products.

Fly ash is the lighter ash particles that are suspended in exhaust gases. These are removed before leaving the stack. Some fly ash is pozzolanic, meaning it can be self-cementing when combined with water and lime. This very desirable property has made it a valuable resource in concrete products, stabilization of road bases, and flowable fill. The majority of fly ash produced in Wisconsin is being successfully recycled.

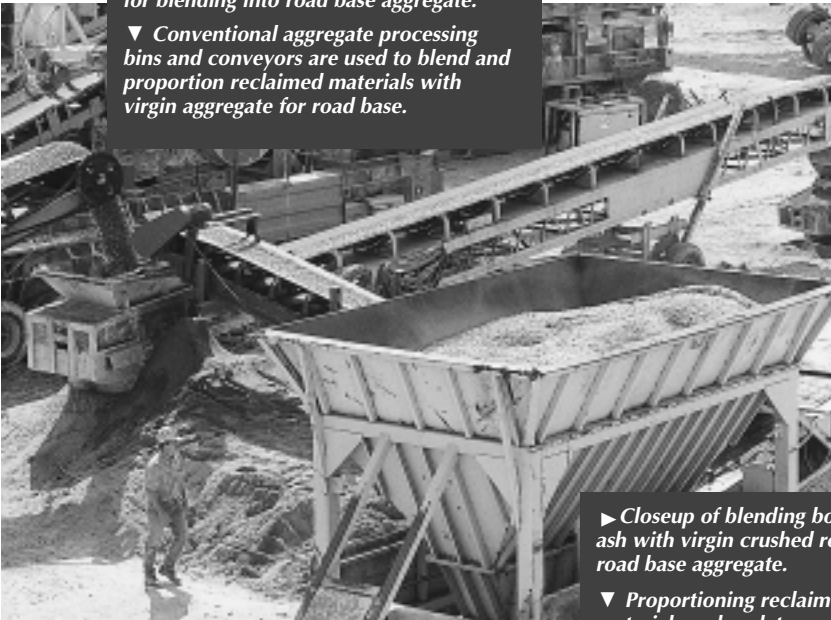
## Preparing and using reclaimed materials — Mixed with rock for road base



▲ Reclaimed broken glass ready for crushing and blending into aggregate products for construction uses.

▶ Stockpiles of reclaimed materials ready for blending into road base aggregate.

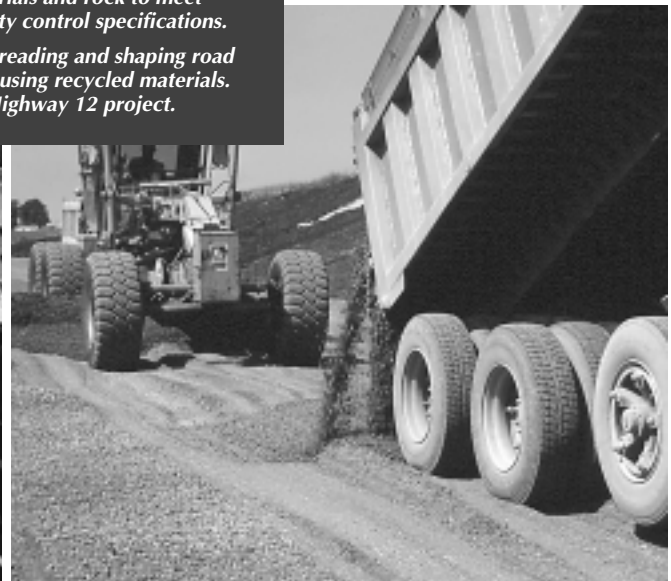
▼ Conventional aggregate processing bins and conveyors are used to blend and proportion reclaimed materials with virgin aggregate for road base.



▶ Closeup of blending bottom ash with virgin crushed rock for road base aggregate.

▼ Proportioning reclaimed materials and rock to meet quality control specifications.

▶ Spreading and shaping road base using recycled materials. US Highway 12 project.



# Three uses of glass in construction

## 1 Mixed with sand for deep backfill



(TOP) Mixed cullet (broken multi-colored glass) crushed to 1/2 inch size by Brown County Materials Recycling Facility and stored by Brown County Highway Department.

(CENTER) Field mixing by alternate bucket loads of glass and sand (one glass to three sand). Piling and working toward destination produced very good mixture.

(BOTTOM) Excavation and removal of muck and deep backfilling (15-20 feet) with sand glass blend. The mixed material compacted well with properties like a sandy granular material with some crushed aggregate. Cardinal Lane extension.

## 2 Unmixed glass as trench backfill



(TOP) Reclaimed glass, crushed to 3/8 inch, unmixed with aggregate is used as backfill over storm sewer. CTH J Brown County.

(CENTER) Backfilling trench with 2 1/2 foot depth of crushed glass. Highway employees who handled the glass material encountered no problems with glass dust or skin cuts.

(BOTTOM) 14" of crushed stone covers glass in storm sewer trench.

### 3 With rock for culvert trench backfill



**Compacting backfill blend of broken glass and aggregate in culvert trench. Dodge County Highway Department.**

Heavier ash products, commonly referred to as bottom ash and boiler slag, are coarse, granular and combustible. They are collected from the bottom of the power plant furnaces. The bottom ash is a dark gray or sandy brown, granular, porous material commonly sand size (1/2-inch minus).

So-called wet-bottom boilers produce bottom ash in a molten state that is tapped off as a liquid. This molten ash is collected and quenched with water. It fractures instantly when quenched and forms crystals or pellets. The resulting boiler slag is a coarse, hard, black, angular, glassy, material.

Coal combustion by-products may also contain some leachable contaminants and heavy metals. The generator should be responsible for testing and evaluating these materials before categorizing and approving them for use. Encapsulation of coal ash fill with clay liners is common practice.

Bottom ash and boiler slag have been used as aggregates in hot mix asphalt, granular base embankment, or backfill material, and as aggregate for sealcoats and flowable fill. These materials are considered fine-graded aggregates and generally need to be blended with coarser virgin aggregate if they are being used as a base course. They may not need to be blended with virgin aggregates when used as embankment fill or backfill.

Bottom ashes are angular particles with a porous surface texture. They are relatively light weight and may need to be covered with tarps when transported in open trucks. They often contain salt and have a low pH which means they can exhibit corrosive properties. Care should

be taken when they are used in backfill around metal structures.

When used as aggregates these materials have soundness, hardness and strength that are comparable to gravel base course materials. During placement and compaction bottom ash may crush further while boiler slag is essentially resistant. Shear and bearing tests indicate these materials are comparable to conventional virgin aggregates. Hauling, spreading and compaction also are similar to conventional aggregate.

Bottom ash may tend to dry out more quickly than other materials. It may also be used in stabilized base courses and as aggregate in concrete or asphalt surfacing. Bottom ash can be used as an abrasive for winter roadway maintenance.

#### **Foundry sand**

Foundry sand is clean, uniformly-sized, high quality sand that has been used in molds to make metal castings. The sand is cleaned before use and is reused numerous times until it loses the required physical properties and can no longer be used for casting. Wisconsin produces about 550,000 tons of foundry sand each year.

Foundry sand has been used as a substitute for fine aggregate in asphalt mixes and for embankment fill as well as an aggregate in flowable fill. The spent sand often contains metal from the casting process and pieces of core material (sand and binders). Before it can be used as a graded aggregate it must be crushed and screened.

Spent foundry sand may also contain some leachable contaminants and heavy metals. The generator should be responsible for testing and evaluating these materials before they are categorized and approved for use.

Spent foundry sand is low absorption and is non-plastic. Hydrophilic sand is often used and has the property of attracting water to its surface. This could lead to moisture-accelerated damage if it is used with aggregate in an asphalt pavement.

#### **Steel slag**

Steel slag is a by-product of steel making, produced when the molten steel is separated from the impurities. Slag occurs as a molten liquid that solidifies upon cooling. The specific properties of steel slag will vary significantly with the grade of steel being produced. Currently there is only one producer of steel slag in Wisconsin.

Steel slag may be obtained from processors who collect it from various producers. The slag processor should be familiar with the general characteristics of the material being provided. Steel slag aggregates have a tendency to expand when exposed to humid environments. If they are stockpiled outdoors and exposed to natural moisture for a few months, however, these

problems can be minimized. Steel slag is commonly used as an aggregate for granular base, embankments and structural fills. It must be crushed and screened first to meet specific gradation requirements for the application.

Steel slag aggregate is generally highly angular and has a rough surface texture. It has a high bearing capacity with good aggregate interlock and good durability. It is resistant to weather and erosion, free draining, and not susceptible to frost action. It can be handled and compacted with conventional construction equipment. This material can have high pH values that can corrode galvanized or aluminum pipes when they are placed in direct contact with it.

## Resources

For information on the availability of reclaimed materials for highway construction contact the Wisconsin Recycling Market Development Board (800/435-7287) or John Katers, Industrial Recycling Specialist, University of Wisconsin Extension-Green Bay (920/465-2941). In addition, your municipal recycling and solid waste agency or department will have detailed information on materials available in your area.

The Wisconsin Department of Transportation has provided leadership in evaluating and using recycled materials in highway construction. Contact your WisDOT district office materials section for help with construction materials specifications and for advice on the appropriate use of reclaimed materials. Bruce Pfister (608/246-7945), Steve Shoher (608/246-5399) and Robert Schmiedlin (608/246-7950), in the WisDOT Truax Center, are also resources.

## References

**The Beneficial Reuse of Recovered Materials**, HVIB Guidebook, Solid and Hazardous Waste Education Center, UW-Extension, 1999.

**Bottom Ash Recycling Program**, Wisconsin DOA, Division of Facilities Development, DOA-4470P (c12/94), 1994.

**Evaluation of Bottom Ash as a Base Course**, Wisconsin Department of Transportation, Interim Report WI/FEP-01-96, March 1996.

**Facility Development Manual**, Wisconsin Department of Transportation.

**Glass as a Road Base Substitute**, Public Works Magazine, April 1997.

**Glass Feedstock Evaluation Project, Evaluation of Cullet as a Construction Aggregate, Final Report**, The Clean Washington Center, Department of Trade & Economic Development, Seattle, Washington, June 1993.

**Glasphalt Test Sections in Virginia**, Virginia Transportation Research Council, 98-R6RB, October 1997.

**Guidance for the Beneficial use of Industrial By-products**, CH.NR538, Wisconsin Administrative Code, Publication-WA-882-98, Wisconsin DNR, April 1998.

**Performance Evaluation of Highway Embankment Constructed Using Waste Foundry Sand**, Transportation Research Board, preprint 980838 B.K. Partridge, J.E. Alleman, T.J. Fox and D.G. Mast, January 1998.

**Progress Report-Reclaimed Materials/Natural Aggregate Blends Demonstration Project**, Wisconsin Department of Transportation Materials Laboratory, June 1998.

**Standard Specifications for Highway and Structure Construction**, Wisconsin Department of Transportation, 1966 and current supplements.

**Use of Recycled Glass in Edge Drain Trench**, Wisconsin Department of Transportation, Report WI-03-96, August 1996.

**Where to look for help on Waste Reduction, Recycling and other Environmental Issues**, Wisconsin Business Development Assistant Directory, Solid and Hazardous Waste Education Center, UW-Extension, 1998.

**User Guidelines for Waste and By-product Materials in Pavement Construction**, FHWA-RD-97-148, April 1998.

**Using Coal Combustion By-products (CCBP) in Public Works**, Energy and Environment Research Center, University of North Dakota, April 1998.

**Using Recovered Materials in Construction**, video, 30 min., Transportation Information Center, UW-Madison, 800/442-4615.

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