

PennDOT RECYCLING MATERIAL BRIEF

Recycled Glass Fact Sheet

Introduction and Background

Pennsylvania 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. If economically feasible, recycling materials into high value-added ways like in highway construction projects helps dispose of them constructively and avoids using landfill space. Successful recycling programs produce large quantities of glass, primarily in the form of bottles and jars. In 2017, waste glass comprised 4.2% of approximately 2.68 million tons of municipal solid waste generated. Overall the United States recycles approximately 33% of waste glass annually, a significant amount of glass is recycled directly back to the manufacturer. In the recycling process, some of the glass becomes broken, color-mixed, or otherwise contaminated, and cannot be used in container manufacturing. The possibility of using mixed color crushed glass in roadway construction has shown to be an attractive cost-efficient alternative to aggregate, especially where virgin aggregate sources are scarce. Crushed glass also known as glass cullet refers to waste glass produced as a result of breakage and rejection on quality control grounds during the manufacturing process. Some of this glass cullet is again used by manufacturers for the production of new glass containers, but it does have limitations such as color sorting and transportation.

PennDOT is also incorporating other products generated from waste glass into their projects, these products include: glass beads used in reflective paints and foamed glass aggregate generated from glass cullet.

This fact sheet provides information on the 2001 Pennsylvania Department of Transportation (PennDOT) and Pennsylvania Department of Environmental Protection (PADEP) supported Drexel research project on glass cullet material, glass cullet material properties, use applications, and approved PennDOT Specifications for all products generated using waste glass.



Did you know?

Recycled glass is substituted for up to 95% of raw materials.

Drexel University Research Project

In 2001, PennDOT in conjunction with the PADEP embarked on a research program at Drexel University (Drexel) to determine several of the basic physical, mechanical, and hydraulic properties of

two sources of glass cullet in Southeastern Pennsylvania. Two glass cullet manufacturers, D.M. Stoltzfus & Son, Inc. (Talmage, PA) and Todd Heller, Inc. (Northampton, PA) provided glass cullet for this program. The physical property tests were performed in its fully processed (crushed or sieved), or its as-received (AR) condition. Tests were also conducted on the coarse fraction (CF) of each cullet sample which was selected to represent minimally processed glass cullet.

General Observations

Well processed and screened glass cullet typically does not contain debris (deleterious materials) in sufficient quantities to affect the engineering properties of the glass cullet (when within the less than 2% by weight). The debris consisted primarily of bottle labels, and metal and plastic caps. The supplied materials were angular; however, the particles were sufficiently small so as to not pose a handling hazard to the laboratory personnel, who were able to safely handle the glass using their bare hands.

Engineering tests

The following series of tests were completed to evaluate and compare glass cullet properties (physical and engineering) to traditional aggregate material properties. The below table provides a summary of the test results.

Summary of Engineering Parameters of Glass Cullet

Test	Parameter	Results ¹ AR	Results ¹ CF
Water Content ASTM D2216	w _n (%)	2.4-4.2	---
Debris Content Gravimetric	w _{debris} (%)	0.3-1.8	---
Specific Gravity ASTM D854	G _s (-)	2.48-2.49	---
LA Abrasion ASTM C131	wear (%)	24-25	---
Standard Compaction ASTM D698	γ _{d, max} (kN/m ³)	107.5-111.9	93.5-99.2
	γ _{d, max} (lb/ft ³)	16.9-17.6	14.7-15.6
	W _{opt} (%)	11.9-13.2	6.5-12
Modified Compaction ASTM D1557	γ _{d, max} (kN/m ³)	111.9-117	108.1
	γ _{d, max} (lb/ft ³)	17.6-18.4	17.0-17.1
	W _{opt} (%)	10.8	7.8-9.9
Hydraulic Conductivity* ASTM D3080	k (cm/s)	1.61-6.45 x 10 ⁻⁴	4.91 x 10 ⁻³ 7.22 x 10 ⁻⁴
Direct Shear Test* ASTM D3080	φ _{ds} (°)	56-61	48-54
CD** Triaxial Test* US Army COE	φ _{tx} (°)	46-47	44-45

*completed at 90% min. modified proctor density; ** Consolidated-drained

¹ Values based on two sources.

--- Not applicable

Research Conclusion

Results of the tests performed, indicated that glass cullet has excellent strength and workability characteristics. Its hydraulic conductivity equals that of a similarly graded natural aggregate. The durability and abrasion resistance of glass cullet were somewhat less than that of a natural aggregate, but within an acceptable range for earthwork and roadway construction use.

This study suggests that glass cullet may be used in a number of civil, construction, and geotechnical engineering applications; including compacted fill, trench backfill, retaining wall or MSE wall backfill, and roadway subbase among others.

A copy of the full laboratory research report can be found here:

(<http://www.dot.state.pa.us/public/Bureaus/design/SEMP/CG/Glass%20Cullet%20Report%20-%20Drexel%20University.pdf>).

Glass Cullet Applications

Glass cullet is typically classified as well graded sand by the Unified Soil Classification System (USCS), or as a Number 10 aggregate by the American Association of Highway Transportation Officials (AASHTO). Potential aggregate applications for glass cullet and cullet-aggregate mixtures are categorized below:

General Construction Backfill

- Stationary loads (fill beneath foundations)
- Landscaping fill

Roadway Construction

- Base course
- Subbase or subgrade layer
- Embankment

Utility Construction

- Pipe Bedding
- Trench Backfill

Drainage

- Retaining Wall Backfill
- Foundation Drainage

Septage Field Media

- Sand Filters (Wastewater)
- Drainage Blanket
- French Drains

Landfill Construction

- Leachate collection layer system

Other uses may exist, but the incorporation of glass in hot mix asphalt and structural concrete (other than flowable fill) may lead to performance problems; therefore, it is not recommended.

Specifications

Historically, recycled glass aggregate has been successfully used in PennDOT projects for pipe-bedding and trench backfill in place of virgin rock aggregate. As shown in the table below, there are several ways in which recycled glass can be utilized applicable to PennDOT projects. Specifically, PennDOT's Publication 408 – Construction Specifications includes the following:

Section	Application
206	Embankment Fill
220	Flowable Backfill
344	Full Depth Reclamation
703*	Aggregate
960	Pavement Markings

*Coarse aggregate containing glassy particles consisting of waste glass may not be used in cement concrete or asphalt wearing courses.

To identify a producer of approved aggregates, see PennDOT Bulletin 14 which is a listing of “aggregate producers that have demonstrated their capability to produce material meeting the Department's specification requirements for the type and source listed.” To identify a manufacturer of reflective marking or paint products see Bulletin 15 which provides a listing of “Qualified Products List for Construction.”

Special Provisions

The below table provides a listing of recycled glass Standard Special Provisions (SSP) that have been approved for use, copies of these SSP are available on PennDOT's Engineering and Construction Management Website (ECMS).

Special Provision Number	Application	Use Specification
b06011	Pipe Culvert Fill	*Revise Section 601.2 by adding the following: (d) Crushed Glass
c80050	Lightweight Fill	For embankments and backfilling behind structures
B02061	Embankments	Change Section 206.2 (a): 1.b Crushed Glass

*Other requirements are listed in the body of the SSP.

Conclusions

The utilization of glass in civil engineering applications has and remains an emerging market, subject to variability in costs of materials and contractors' perceptions of risk associated with glass uses in construction. However, the viable applications for glass offer many benefits including: creation of a product market for mixed glass; diversion of recyclable glass from disposal in a landfill; reduction in need for natural mineral resources; and improving the performance of poor quality gravel in cullet-aggregate mixtures.

Although, there are various established ways to efficiently and effectively utilize waste glass, it is imperative to realize that technology is ever evolving and the need for environmental accountability is endless, to account for this PennDOT continuously evaluates new methods and techniques to use waste glass as well as other recycled materials in roadway applications.

References

Chemical & Engineering News, 2019. <https://cen.acs.org/materials/inorganic-chemistry/glass-recycling-US-broken/97/i6>.

PennDOT, 2020a. Publication 408 Construction Specifications. http://www.dot.state.pa.us/public/PubsForms/Publications/Pub_408/408_2020/408_2020_1/408_2020_1.pdf.

PennDOT 2020b. Bulletin 14 Qualified Product List for Construction. http://www.dot.state.pa.us/public/pdf/construction/bulletins_supporting_docs/Bulletin%2014%20-%20Supporting%20Information.pdf.

PennDOT 2020c. Bulletin 15 Qualified Product List for Construction. http://www.dot.state.pa.us/public/pdf/bocm_mtd_lab/publications/pub_35/current_edition/bulletin15.pdf.

USEPA, 2020. <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/glass-material-specific-data>.

Joseph Wartman, M.ASCE1 ; Dennis G. Grubb, et. al., 2004. Select Engineering Characteristics of Crushed Glass. <https://pdfs.semanticscholar.org/ecbf/9185122fc172ee7183b5bb3fb13370774e5f.pdf>.