



DATE: August 5, 2002

400-02-02

SUBJECT: Provisional Special Provision
Embankments Incorporating Crushed Glass

TO: DISTRICT ENGINEERS/ADMINISTRATOR

FROM: Gary L. Hoffman, P.E.
Chief Engineer
Highway Administration

Attached please find a Provisional Special Provision and use guidelines for incorporating crushed glass in highway embankment construction projects.

Crushed glass derived from industrial sources or defined as Act 101 "Post Consumer Materials," may be used as an embankment material, either on its own or when blended with other embankment materials. The attached research brief, *PennDOT Partners with Private Industry to Determine Select Properties of Glass Cullet* summarizes experimental research conducted at Drexel University, which demonstrates the excellent strength and drainage characteristics of crushed glass.

The Provisional Special Provision for Embankments Incorporating Glass Cullet has been issued as follows:

Specification Version	Special Provision Number
METRIC	S00(PD02061A)
ENGLISH	S00(PD02061A)

ITEM numbers are not required as crushed glass already qualifies as embankment material under Section 206 (payment under Section 205), but each application will require that the Districts forward use information and project quantities to the Strategic Environmental Management (SEM) Program Office for tracking purposes. As such, one of the main motivations for issuing this special provision is to draw attention to this opportunity to increase recycling opportunities in the Commonwealth in accordance with Act 101.

The provisional status of this special provision will allow the use of this type of product on projects in accordance with the attached guidelines. In the use of any provisional special provision the District is requested to monitor the performance and report any problems to the Engineering Technology and Information Division, Bureau of Construction and Materials at (717) 787-7287. Any problems regarding environmental compliance of crushed glass should be reported to the Chief Engineers' Office, SEM Program at (717) 783-3616.

As suitable embankment materials require no listing in Publication 34, Bulletin 14 "Aggregate Producers," or Publication 35, Bulletin 15 "Approved Construction Materials," for locally available sources of crushed glass please contact the SEM Program Office, Professional Recyclers of Pennsylvania (PROP) at (814) 742-7777, (800) 769-PROP, or www.proprecycles.org.

If you have any questions, please call Mr. Ken Thornton at (717) 783-3616.

Attachments

4000/GLH/kjt

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USE GUIDELINES FOR EMBANKMENTS INCORPORATING CRUSHED GLASS

Attached is a new Provisional Special Provision for the construction of embankments incorporating crushed glass. There are two main sources of glass: Glass cullet and waste industrial glass. Crushed glass derived from these sources performs very similarly from a geotechnical perspective, and its drainage and frictional strength characteristics are very favorable. *Glass cullet* is an Act 101 “post consumer material” comprised of the mixed colored glass fragments resulting from the breakage of colored glass containers (predominantly food, juice, beer and liquor bottles). Occasionally, glass cullet will contain fragments of broken ceramics (coffee mugs, china plates, pottery) though these are not viewed to compromise the overall geotechnical performance of the glass cullet. Waste *industrial* glass includes such materials as broken, obsolete, and/or off-specification glass from the manufacturing of plate, window and analytical glassware, etc. While the beneficial use of *glass cullet* is not regulated by the Pennsylvania Department of Environmental Protection (PADEP), the suppliers of crushed glass should verify that crushed glass incorporating *industrial* sources of glass has a *coproduct determination* according to PADEP regulations. The supplier should also certify that the crushed glass does not contain glass from automobiles, lead crystal, TV monitors, lighting fixtures and electronics applications.

Crushed glass passing the 9.5-mm (3/8-inch) sieve closely resembles natural aggregates and does not retain the remnant shape of the original container. Currently, crushed glass already satisfies the requirements of Pub 408 Sections 206.2(a) 1.b, e and 206.2(a)2 and 703.2 Table B, Type C aggregates, except in the latter case that glass is not listed in Publication 34, Bulletin 14, Aggregate Producers even though some quarries and recycling centers can consistently and reliably crush glass to AASHTO 8 and 10 gradations. The main purpose for this provisional special provision is to specifically identify glass related opportunities for purposes of increasing recycling in the Commonwealth. Accordingly, the contract may be let with crushed glass as alternate bid items or the District may choose to put it into the contract as the sole item for a chosen embankment application. If used as a sole item in a contract, then limit to three projects per district for monitoring purposes.

Two main embankment configurations are envisioned for construction. The first configuration involves the use of pure (100%) crushed glass used as a primary embankment core material (Type 1a) or for individual fill layers (Type 1b), see attached schematics. The second configuration involves the use of crushed glass blended in all proportions with other suitable embankment materials (Type 2, not shown). In both cases, crushed glass should not be used in the final top and side slopes in order to prevent erosion and to support vegetation. When crushed glass is used in core sections or layers at weight percents exceeding 80% with other very permeable materials, these layers should be in direct contact with, or directly keyed into, an internal or subgrade drain installed every 500 lineal ft. of the roadway. Accordingly, it is strongly recommended that drains be provided in accordance with Publication 408, Section 612, and as shown on RC-30M (sheet 2 of 4), or equivalent, as indicated. Drains are to be considered incidental to the work. Provisional approval is granted for crushed glass based upon its high strength and drainage characteristics.

Until widespread experience with crushed glass in embankments is gained statewide, this product will retain provisional status. Provisional status also requires the use of crushed glass in embankments to be monitored by the District, and the Engineering Technology and Information Division (ETID), Bureau of Construction and Materials. Monitoring by the Districts will be limited to advising ETID of where crushed glass is used in embankments and of any problems encountered during construction, and of any problems observed during the life of the project. Monitoring is limited to visual inspection of the stability and/or integrity of the embankments incorporating crushed glass and should continue every six months over five years. If further experience gained by the Districts demonstrates a problem with the embankments incorporating crushed glass, the Provisional Special Provision will be withdrawn immediately. Any problems regarding the engineering performance or environmental compliance of crushed glass should be reported to the Strategic Environmental Management Program (SEMP) Office in the Chief Engineers Office at (717) 783-3616.

S00 (PD02061A)

SECTION 206 - EMBANKMENTS INCORPORATING CRUSHED GLASS: This may be used as an alternate or as a sole item. If it is used as a sole item, limit its use to three projects per District. Use in accordance with Strike-off Letter 400-02-02, dated August 5, 2002.

I. DESCRIPTION - This work is the construction of embankments incorporating crushed glass.

II. MATERIAL - Section 206.2(a), add the following:

(1b) Crushed glass

1. Provide crushed glass as defined by Act 101 "Post Consumer Material" and/or having a coproduct determination in accordance with Pennsylvania Department of Environmental Protection regulations. Do not accept crushed glass derived from sources that include automobile glass, lead crystal, TV monitors, lighting fixtures and electronics applications. Provide glass of any color, free of toxic materials and hypodermic needles meeting the following specifications:

- Quality requirements - Section 703.2(a), Table B; Type C. Glass particles can be up to 100 percent by weight.
- Non-Glassy Material - 5 percent by weight, maximum, excluding ceramics and pottery.
- Gradation - 100 percent of glass particles must pass the 9.5 mm (3/8-inch) sieve. Less than 5 percent must pass the 75 um (No. 200) sieve.

(b) Embankment material - Section 206.2

III. CONSTRUCTION - Section 206.3 and as follows:

Do not use 100 percent crushed glass for final grade, slopes, and in sliver fills. Bench 100 percent crushed glass fill sections into existing slopes for sidehill fills.

(a) Provide a minimum of 300 mm (12-inch) cover of embankment on top slopes over single fill sections (Type 1a) and layered systems (Type 1b) using 100 percent crushed glass. Provide a minimum of 1 m (36 inches) of embankment material on exposed side slopes over Type 1a and Type 1b configurations using 100 percent crushed glass. Provide drainage as indicated.

(b) Use crushed glass uniformly blended with other embankment materials (Type 2) in all aspects of embankment construction except in top and side slopes as described in (a), and as directed by the Engineer.

IV. MEASUREMENT AND PAYMENT - Section 205.4, add the following:

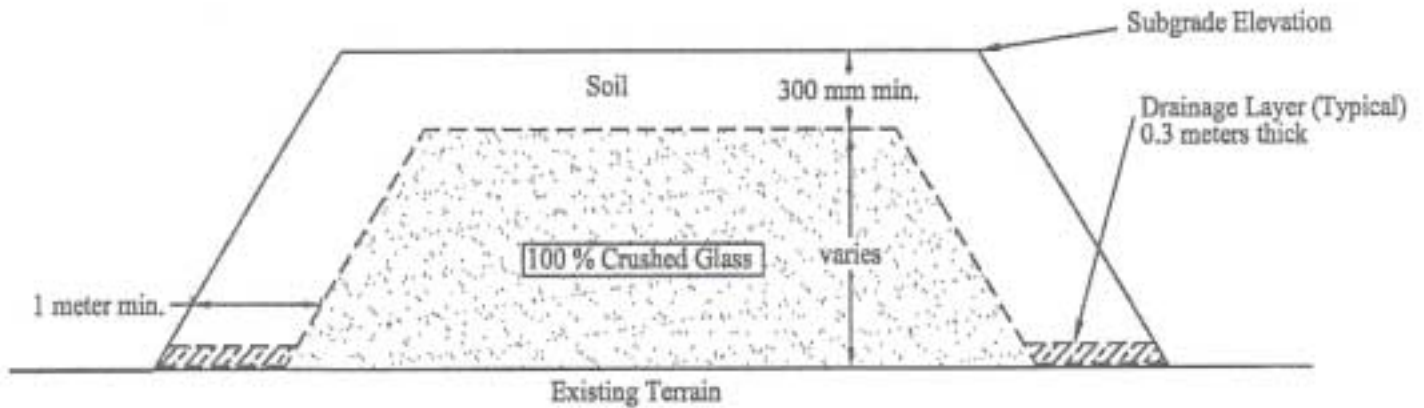
- (a) Crushed glass. Cubic Meter (Cubic Yard).
- (b) Embankment Material. Cubic Meter (Cubic Yard).

Provide copies of certified scale receipts for all crushed glass to the Engineer for forwarding to the PENNDOT SEM Program Office.

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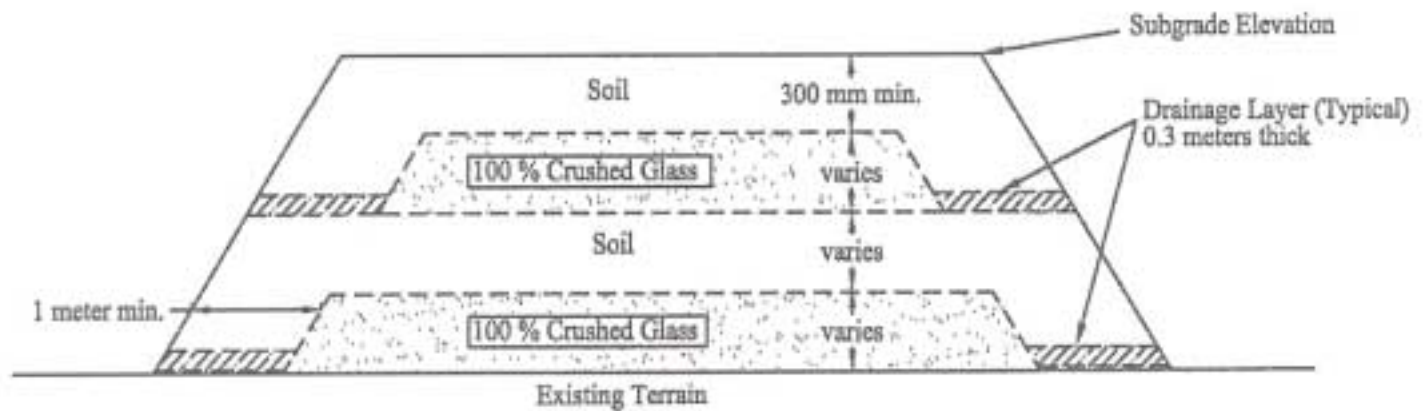
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Type 1a. Schematic of Embankment Using 100 Percent Crushed Glass as a Core Section.



Notes: Drawing Not to Scale.
Thickness of glass layer varies on a project by project basis.

Type 1b. Schematic of Embankment Using 100 Percent Crushed Glass in Individual Fill Sections or Layers.



Notes: Drawing Not to Scale.
Thickness of glass layer varies on a project by project basis.

PENNDOT Partners with Private Industry on Glass Recycling

The Pennsylvania Department of Transportation (PennDOT) in conjunction with the Pennsylvania Department of Environmental Protection (PADEP) recently sponsored an experimental research program at Drexel University to determine several of the basic physical, mechanical, and hydraulic properties of two sources of glass cullet in Southeastern Pennsylvania. Glass cullet is the mixed colored glass fragments resulting from the breakage of colored glass containers (predominantly food, juice, beer and liquor bottles) that cannot be re-used by bottle manufacturers. Glass cullet passing the 9.5 mm (3/8-inch) sieve closely resembles natural aggregates and does not retain the remnant shape of the original container. D.M. Stoltzfus & Son, Inc. (Talmage, PA) and Todd Heller, Inc. (Northampton, PA) provided the glass cullet for the research program.

Example Applications

While the glass cullet is primarily silica (as are most sands and gravels) and is perceived to have several applications, its reuse potential has been hindered by the limited knowledge of its engineering characteristics. In addition, the engineering parameters of glass cullet were believed to vary on a supplier-by-supplier basis depending on the processing equipment used to control the gradation. The glass cullet evaluated in this research program was classified as SW (well graded sand) a by the Unified Soil Classification System (USCS), or as a Number 10 aggregate by the American Association of Highway Transportation Officials (AASHTO). Materials of this kind may be used in a variety of strength, filtering, and drainage applications such as:

Base Course	Foundation Drainage
Subbase	Drainage Blankets
Embankments	French/Interceptor Drains
Structural Fill	Sand Filters (Wastewater)
Nonstructural Fill	Well Packing Media
Utility Bedding and Backfill	Septage Field Media
Retaining Wall Backfill	Leachate Collection Media

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. The data provided in the next section is provided explicitly for engineers, architects and designers to evaluate the suitability of glass cullet for specific applications for private sector, local government and state applications.

Engineering Data

A suite of physical property tests was performed on the glass cullet samples in its freshly processed (crushed or sieved), or its as-received (AR) condition. Tests were also conducted on the coarse fraction (CF) of each cullet sample, i.e., the material retained on the (2.36-mm (No.8) sieve. This coarser material was selected to be representative of a minimally processed glass cullet, or of a fully processed glass cullet that has lost a significant fraction of its finer material due to vibration-induced material segregation during transportation, or from rainfall-induced “washing” of nonplastic fines from glass cullet stockpiles. Additional physical property tests were performed on exhumed samples of compacted glass cullet to assess the effects of compaction-induced practical breakage. Two sets of friction angles were measured using direct shear and triaxial testing equipment. While direct shear tests are relatively easy to perform, the CD triaxial test is arguably one of the most accurate tests to evaluate the shear strength of soils and aggregates under insitu conditions. The results are summarized below:

Summary of Engineering Parameters of Glass Cullet

Test	Parameter	Stoltzfus-AR	Stoltzfus-CF	Heller-AR	Heller-CF
Water Content ASTM D2216	w_n (%)	4.2	---	2.4	---
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	---
Soil Classification ASTM D421, D422	USCS AASHTO	SW No. 10	GP No. 8	SW No. 10	GP No. 8
Standard Compaction ASTM D698	$\gamma_{d,max}$ (lb/ft ³)	111.9	93.5	107.5	99.2
	$\gamma_{d,max}$ [kN/m ³]	17.6	14.7	16.9	15.6
	w_{opt} (%)	11.9	6.5	13.2	12
Modified Compaction ASTM D1557	$\gamma_{d,max}$ (lb/ft ³)	117	108.1	111.9	108.7
	$\gamma_{d,max}$ [kN/m ³]	18.4	17.0	17.6	17.1
	w_{opt} (%)	10.8	7.8	10.8	9.9
Hydraulic Conductivity [†] ASTM D2334	k (cm/s)	1.61×10^{-4}	7.22×10^{-4}	6.45×10^{-4}	4.91×10^{-3}
Direct Shear Test [†] ASTM D3080	ϕ_{ds} (°)	61	54	56	48
CD* Triaxial Test [†] US Army COE	ϕ_{tx} (°)	47	45	46	44

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

Debris refers to non-glassy particles such as ceramics, paper, bottle caps, etc. Synthetic Precipitation Leaching Procedure (SPLP; US EPA Method 1312) extractions of both cullet samples detected no concentration of heavy metals. Particle breakage induced by modified compactive effort did not alter the gradation of the glass cullet from AASHTO No. 10.

The summary table indicates that both glass cullet suppliers were able to process glass cullet with consistent, reproducible properties. The engineering characteristics of the glass cullet varied slightly between suppliers, although it appears that these variations are more closely related to grain size distribution than the parent glass characteristics or processing procedures. While some differences in compaction were observed, the real implications of this difference on the perceived strength are negligible, because the measured friction angles (CD triaxial) of the as-received samples were almost identical. It is interesting to note that the loss of fines (CF samples) had a minimal effect on the friction angles (2° difference).

The results suggest that as long as glass cullet meets the AASHTO No. 10 (or No.8) classifications, its strength characteristics and overall engineering performance will be comparable to or exceed those of natural aggregates of the same gradation, regardless of the actual processing procedure (i.e., quarry crushing equipment versus recycling center operations). This is an important finding because with gradation as the only control variable, it should be possible for local municipalities to generate reliable sources of glass cullet with these attributes without the sophisticated crushing equipment commonly associated with quarry operations. This not only offsets processing costs, but it also reduces the transportation costs of hauling recyclables.

For more information on this project contact Kenneth J. Thornton of the PennDOT SEM Program Office at (717) 783-3616.