PennDOT Partners with Private Industry to Determine Select Properties of Glass Cullet

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 were performed on the glass cullet samples in its freshly processed (crushed or sieved), i.e. 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) $\gamma_{d,max}$ [kN/m^3] w_{opt} (%)	111.9 17.6 11.9	93.5 14.7 6.5	107.5 16.9 13.2	99.2 15.6 12
Modified Compaction ASTM D1557	$\gamma_{d,max}$ (lb/ft^3) $\gamma_{d,max}$ [kN/m^3] w_{opt} (%)	117 18.4 10.8	108.1 17.0 7.8	111.9 17.6 10.8	108.7 17.1 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 AR samples were almost identical. It is interesting to note that the loss of fines (CF samples) had a minimal effect on the measured friction angles (2º 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 visit PennDOT's Recycling Homepage or contact the PennDOT Bureau of Environmental Quality at 717 787-1024.