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Recycled Glass and Dredged Materials

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PURPOSE: This technical note explores the concepts and applications of recovering and reusing two common disposable materials (crushed glass and dredged spoil) for beneficial engineering purposes. Dewatered fine-grained dredged material (DM) amended with glass cullet may prove to be a marketable combination especially useful as an engineered material and construction aggregate substitute.

RECYCLED GLASS: Glass is manufactured from silica sand (SiO2) and other compounds, and occurs naturally as black obsidian rock (volcanic deposit) and fulgurite (from lightning strikes). Man-made glass was first made by heating a sand, soda, and lime mixture, which formed a clear liquid that turned into a hard solid when cooled. Glass has been made into containers since about 1500 BC, and glass-making evolved from the Roman times about 50 AD when transparent glass with various colors was formed into mouth-blown shapes. By the early Middle Ages, the Italians had developed an advanced glass industry, which eventually spread across Europe. Today, there are over 1000 chemical formulations known to produce glass, and the glassmaking industry has gone global (Glass Packaging Institute 2005).

Glass is a recyclable product at just about any stage in its life cycle. A visit to a crystal factory where lead-oxide glass is transformed into beautiful pieces of art allows one to observe broken or imperfect pieces being placed back into the manufacturing process. Glass containers are recyclable when empty, and are processed for remanufacture into glass containers after being color-separated. Glass can also be recycled into numerous other products such as substitutes for construction aggregates.

Sources and Processing. Recycled glass processed from containers (also referred to as "cullet") comes mainly from empty soft drink, beer, food, wine, and liquor containers collected at residential curbside, drop boxes, trash barrels, deposit stations, or recycling stations, and is either source-separated or co-mingled with plastics, aluminum cans, ceramics, or colored glass containers. In the United States in 2001, approximately 11 million tons of glass entered the municipal waste stream, but only about 2.4 million tons (22 percent) of this glass was recovered and recycled. The remainder ended up in landfills. Recovery rates are improving; since 1980, municipal glass recovery and post-consumer recycling has increased by about 320 percent (U.S. Environmental Protection Agency 2005).

The post-consumer glass is processed as either container glass cullet (for new bottles and other containers) or non-container glass cullet (all other uses), and non-container processed cullet production is growing at a much faster pace than the container cullet (approximately 60 percent more over the period 1992 to 1998 alone) (Reindl 2002). In the United States there are approximately 70 cullet processing companies. California and Pennsylvania have eight processors each, followed by Ohio with six, and Georgia with five. The remaining states have only one or two processors (Glass Packaging Institute 2005).

Markets and Applications. There are approximately 30 grades and sizes of processed cullet, with prices ranging from $3 to $64 per ton (Recycler's World 2005). The cullet becomes feedstock for numerous applications such as building materials (countertops, etc.), concrete (as an additive and aggregate source), paving (as an aggregate, asphalt additive, etc.), construction aggregate (drainage, highway fill, landfill cover, base course, etc.), sandblasting, fiberglass insulation, artwork, water filters, and many others (Reindl 2002).

When glass is crushed and screened to pass the 3/8-in. (9.5-mm) sieve, it closely resembles crushed natural aggregate and has engineering properties similar to natural aggregate materials. Glass cullet can be used for structural applications (pavement base course, subbase course, embankments, backfill, etc.) as well as drainage applications (foundation drains, sand filters, drainage blankets, etc.) and studies have been performed to determine crushed glass engineering properties (Soil and Environmental Engineers, Inc. and Re-sourcing Associates, Inc. 1998; Wartman et al. 2004; Delaware Valley Geo-Institute 2004; European Union 2000; Clean Washington Center 1996). Some obstacles which prevent more glass cullet usage include bias in favor of natural aggregates (i.e. opposition to change), cost, and regulations.

Contamination and Safety Issues. Recycled container glass may contain debris (defined as anything other than container glass). The debris may contain contaminants including ceramics (from dishware, pottery, window glass, light bulbs, crystal, porcelain, etc.), metal (from bottle caps), organics (from food, paper labels, etc.), and other inorganics (from soil, concrete, bricks, etc.). Most of the contamination found in glass cullet is from paper labels. No toxic or hazardous materials from post-consumer glass should be introduced into the recycling process, but it is generally the waste collector's responsibility to separate those items. Co-mingled curbside collection and unattended drop boxes have the highest debris levels, while source-separated curbside collections have the lowest debris levels (Clean Washington Center 1996).

Ceramic contaminants are removed from the cullet manually or with automated systems. Ferrous metal is removed with magnetic separation techniques, while non-ferrous metal is removed with non-magnetic techniques. Organics may be removed by washing or burning. Physical screening and washing also help remove deleterious particulates.

A study was conducted to measure the chemical contaminants found in post-consumer glass cullet and leachate including biochemical oxygen demand, total phosphorus, total Kjeldahl nitrogen, dissolved solids, semi-volatile organics, pH, total organic carbon, metals, lead, and biological impacts (Soil and Environmental Engineers, Inc. and Re-sourcing Associates, Inc. 1998). Toxic Characteristic Leachate Procedures (TCLP) tests were included. Results indicated that neither the glass cullet nor its leachate had contaminant levels above regulatory concerns or above those normally found in construction material aggregates.

Another study performed TCLP and synthetic precipitation leaching procedure (SPLP) tests on glass cullet from both a commercial industry recycler and a post-consumer co-mingled glass recycler (Wartman et al. 2004). The results indicated metal concentrations similar to those allowed in drinking water.

Figure 1. Glass cullet crushed and sieved to minus 3/8-in. size

The most common health concerns are the potential for skin cuts and breathing glass dust during physical handling. Wearing gloves eliminates the concern for skin lacerations, but glass cullet smaller than 3/8 in. will not cause problems unless it is squeezed or compressed in an ungloved hand. Figure 1 shows typical 3/8-in. minus glass cullet held without need of protective gloves.

Glass dust contains silica. Silica in an amorphous structure is not considered to be a health hazard, but silica in a crystalline structure is a known hazard. Based on tested samples (Soil and Environmental Engineers, Inc. and Re-sourcing Associates, Inc. 1998), glass cullet dust was within the nuisance dust category (permissible exposure limit (PEL) lower than 10 mg/m^3) with less than 1 percent crystalline silica (PEL lower than 0.1 mg/m^3). Jobsite monitoring and proper personal protective equipment should be included in any construction site safety plan.

SUBSTITUTE FOR NATURAL CONSTRUCTION AGGREGATE: Glass cullet is being used as a bound aggregate substitute in both concrete and asphalt, especially in locations where natural sand and gravel deposits are not as plentiful or are associated with higher trucking costs. Glass cullet is also useful as an unbound aggregate substitute for pavement subbases and base courses.

As a material that is bound in concrete ("glascrete") and asphalt ("glasphalt"), glass cullet is not as common in either the United States or in Europe as other recycled materials such as reclaimed pavement aggregates, blast furnace slag, foundry sands, and construction debris (Holtz and Eighmy 2000). Glass cullet has not worked very well as a concrete aggregate because of the alkali-silica reaction (Polley et al. 1998), but as this problem is being overcome it will open up a wider market for crushed glass in concrete (Meyer 2002).

In asphalt pavements, bituminous mixtures containing 30 percent of broken recycling glass showed some problems with adhesion between binder and the smooth glass surface in a series of tests conducted for the European Commission (European Commission 2001), and the performance of the blended mix was generally worse than the reference mixture. The blended mix proved to be very sound (durable), was not prone to additional crushing, and it successfully met specifications for asphalt pavement. If the adhesion property could be improved, for example by roughening of the surface, crushed recycled glass could be an even better alternative material for bituminous mixtures.

Numerous other projects have demonstrated that glass cullet performs well as a construction aggregate substitute. Case histories and updates are readily available (Reindl 2002; Clean Washington Center 2005; Soil and Environmental Engineers, Inc. and Re-sourcing Associates, Inc. 1998; Northeast Recycling Council 2004; London Remade 2005; Lee and Welp 2004).

Geotechnical Properties. The geotechnical parameters of cullet feedstock as an aggregate substitute depend on the glass percentage, glass gradation, compaction effort, and to a lesser degree on the glass source, water content, and debris content (Clean Washington Center 1996). The insensitivity to water content is because glass has smooth non-porous surfaces and clay particles are absent. Quality control rejection due to visual debris content is likely to occur before any engineering properties are affected by the amount of debris, since debris is measured by weight and a visually observed large amount of debris typically constitutes a very small amount by weight.

For 100-percent glass cullet, the following general properties are typical (Clean Washington Center 1996):

Compacted unit weight: 95 to 115 lb/ft^3
Bearing capacity: 1000 to 1500 lb/ft^2
Angle of repose: 2H:1V (or 26 deg)
Permeability: 0.05 to 0.25 cm/sec

A testing program sponsored by the Pennsylvania Department of Transportation (DOT) was conducted to determine selected engineering properties of 100 percent cullet from two recycling sources (Wartman et al. 2004). Both sample gradations passed the 3/8-in. sieve and were classified as well-graded sand, SW, or AASHTO Number 10. Results are summarized in Table 1.

Table 1
Engineering Properties of 100-percent Cullet from Two Recycling Sources

Property	Value
Specific gravity G_s	2.48 to 2.49
Relative density	72 to 79 lb/ft^3 (minimum) 109-118 lb/ft^3 (maximum)
Durability	LA abrasion averaged 24.5 percent Sodium sulfate soundness averaged 6.7 percent
Compaction	Modified Proctor maximum dry density averaged 114 lb/ft^3 Standard Proctor maximum dry density averaged 106 lb/ft^3
Permeability	0.00014 - 0.00066 cm/sec
Shear strength	Effective friction angle average from triaxial testing was 47.5 deg
Leaching	TCLP and SPLP tests showed the samples were non-hazardous

Dames and Moore, Inc. conducted a comprehensive testing program for the Clean Washington Center's Glass Feedstock Evaluation Projects to determine geotechnical engineering properties of pure and blended glass cullet useful as a construction aggregate substitute (Dames and Moore, Inc. 1993). Numerous tests were conducted on cullet sampled from two sources, with two sizes (1/4-in. minus and 3/4-in. minus), and 100, 50, and 15 percent glass cullet content in natural aggregate mixtures. The following is a synopsis of results:

Specific gravity (G_s). For the 1/4-in. cullet, the G_s ranged from 2.49 to 2.52. Crushed rock and gravelly sand aggregates are normally in the range of 2.60 to 2.83, so the glass cullet has a considerably lower G_s. This difference affects the relative density and compaction unit weight values of cullet, and is a negative attribute when materials are specified by properties (i.e. compaction density) instead of performance.

Relative density. Maximum relative density increased as the cullet percentage decreased.

Durability. The LA abrasion tests showed that the cullet was not as mechanically sound as natural crushed rock, with losses at least two times greater than that of the crushed rock. Of course, less-durable crushed rock would not have fared as well, as durability is dependent on the type of crushed rock.

Weathering. Cullet is inert to the test standard materials for determining soundness, so it cannot be measured. Cullet has been shown to be insusceptible to freeze-thaw cycles (Henry and Morin 1997).

Compaction. Compaction is an important construction criteria since all engineered fills are compacted in some fashion, and the compaction effort is monitored for quality control. Dry density and optimum water content are controlled to achieve proper compaction. In this study, as the cullet content increased, the dry density decreased. The moisture-density curves were relatively flat due to cullet's insensitivity to water content. Optimum water contents ranged from 5.5 percent to 9.2 percent and maximum dry density ranged from 111 lb/ft^2 to 142 lb/ft^2 as cullet content decreased, using the Modified Proctor compaction method (American Society for Testing and Materials (ASTM) 2000a).

The type of laboratory compaction test selected depends on the expected field compaction procedure. The Modified Proctor compaction method simulates the effect of heavy impact field compaction equipment. This method physically changed the particle size distribution (gradation) of the cullet by making the particles finer (the more cullet the higher the gradation change). The Standard Proctor compaction method (ASTM 2000b) simulates the effect of light field compaction equipment. This method did not change the particle size distribution.

Using a nuclear density gauge for field verification of compaction specifications is typical for natural aggregates and has also been shown to be applicable to cullet/natural aggregate mixtures used in road subbase and base courses. If vibratory compaction is utilized, the nuclear density gauge reading must be in the direct transmission mode instead of the backscatter mode due to glass fines separation and higher density at the bottom of each lift caused by vibration (Soil and Environmental Engineers, Inc. and Re-sourcing Associates, Inc. 1998).

Permeability. As the degree of compaction increased, the constant-head permeability decreased. As the cullet percentage increased, the constant-head permeability increased. The permeabilities ranged from about 0.01 cm/sec to 0.06 cm/sec.

Shear strength. The shear strength of an engineered system (embankment, highway fill, CDF cap, landfill cover, etc.) is critically important. For granular materials, the shear strength is expressed in terms of the interparticle friction angle, and the friction angle and other shear strength parameters are measured by the direct shear test, the triaxial shear test, the California Bearing Ratio (CBR) test, the Resistance R-value test, and/or the resilient modulus test, depending on the engineering application. The CBR, R-value, and resilient modulus tests are almost exclusively used for roadway and airfield design and construction.

Friction angles from the direct shear tests of the pure cullet ranged from about 49 deg to 53 deg, which is about the same as dense natural aggregate. Increasing cullet percentage did not appear to affect the shear strength. The direct shear test generally does not reproduce in situ stress conditions, and is less expensive than the triaxial test.

Friction angles from the triaxial tests with cullet/natural aggregate mixtures ranged from about 42 deg to 46 deg, and a 50-percent cullet percentage appeared to reduce the shear strength. Triaxial testing simulated three-dimensional loading and modeled the stress-strain behavior of the samples tested.

The CBR values for the 15-percent cullet mixture did not decrease from the natural aggregate CBR (with a typical CBR range from 40 to 80), but as the cullet content increased to 50 percent, the CBR values decreased by about 25 percent. A higher reduction was observed when the samples were prepared using a vibratory compactor.

The Resistance "R"-value tests showed that cullet percentages up to 50 percent added to crushed rock is adequate to meet high R-values from State Department of Transportation (DOT) strength requirements, although adding cullet to crushed rock does reduce the R-value.

The Resilient Modulus tests showed that adding cullet does reduce the resilient modulus, which is a measure of a material's stiffness for pavement design (the higher the value, the better). The minimum requirement should be satisfied in up to about a 50/50 cullet/crushed rock mixture.

Challenges for Acceptance. Perhaps the biggest challenge to acceptance of glass cullet in the construction industry is local, State, and Federal regulations. Building codes and specifications either ignore the beneficial uses for these recycled materials or they specifically prohibit them (Wartman et al. 2004).

Federal military and civil works construction specifications address recycled materials only in the context that they are used for non-constructed applications such as recycled office products (Maryland Port Administration 2004). Until the reference testing organizations such as the American Concrete Institute, American Society for Testing and Materials, etc. develop standards specifically for construction aggregate substitutes using crushed glass, the Federal guide specifications will not likely address blanket acceptance of those materials. Job-specific approval would likely be based on performance criteria instead of materials-specific criteria.

State DOTs also do not encourage crushed glass as natural aggregate substitutes in structural fill due mainly to their established minimum acceptable criteria specifications, which are usually materials-specific instead of performance-based. For example, Maryland DOT regulations require a maximum dry density no less than 100 lb/ ft^3, and Delaware DOT regulations require a maximum dry density no less than 92 lb/ft^3 (Wartman et al. 2004). The crushed glass blends, with their typical low specific gravity, may not achieve these requirements.

RECYCLED DREDGED MATERIALS: Dredged materials from Federal navigation and maintenance dredging operations may be reclaimed (i.e. mined, recycled, re-used, recovered, etc.) for numerous applications within the dredging operation itself including CDF dikes, berms, roads, and containment capping. Reclaimed materials are utilized for engineered applications, not including agricultural top soil, land reclamation, beach nourishment, and wetlands restoration. For example, dredged materials may be substituted for natural aggregates (sands, gravels, clays) used in construction.

Regulatory constraints play a large role in reclaiming dredged materials for beneficial construction material use. Depending on local, State, and Federal regulations, clean uncontaminated material can be used for construction fill, while slightly contaminated material can be used where leaching impacts are minimized such as fill beneath an asphalt parking lot.

Un-amended Dredged Material. Clean, dewatered dredged materials may be directly utilized as bulk unscreened or screened and graded aggregates (gravels and sands). For example, coral has been dredged as a source of coarse aggregate for runway base courses, and clean dredged sand is utilized as fine aggregate material when onshore quarries are not available or sufficient. Offshore dredging is more common in areas with limited natural aggregate sources. Coastal communities typically do not have gravel pits or rock quarries and they are required to transport natural aggregate at an increased cost compared to inland locations where rock, gravel, and sand sources may be more plentiful.

Fine-grained dredged materials (silts and clays) are not generally adopted as aggregate substitutes due to their general unsuitability compared to sands and gravels. Particle size is important, and in general any material containing appreciable fines passing the No. 200 sieve is usually blended with coarser materials for most engineering applications.

Amended Dredged Material. Comprehensive regional or port-specific dredged material management plans include goals such as reducing the dredging volumes, reducing contaminated sediment (source reduction), recycling as much material as possible, and disposing as little as possible. For example, Maryland's goal is to reclaim approximately 30 percent of its annual dredged material volume. San Francisco Bay stakeholders have a target of approximately 80 percent dredged material being reclaimed for beneficial use. A number of pilot projects and commercial projects have been accomplished for the purpose of reclaiming and amending dredged material as feedstock for construction materials (Maryland Port Administration 2004).

Most reclaimed dredged material must first be processed to remove debris and reduce the water content (i.e. increase the solids content). Numerous dewatering methods are available ranging from passive site consolidation (natural weathering, wick drains, engineered filters, etc.) to active dewatering (pumps, wiers, etc.) to manufactured thermo-chemical processes. A manufactured process typically also includes material decontamination, which is another major consideration for dredged material recycling. Numerous decontamination technologies have been proposed and/or accomplished, including chemical oxidation, enhanced natural attenuation, georemediation, thermal and non-thermal treatments, and sediment washing (Maryland Port Administration 2004).

One of the methods for amending recycled dredged material is dewatering it and blending it with other recycled products such as coal combustion byproducts, incinerator ash residue, waste lime products, and cement production byproducts. Two commercial recyling operations for amending dredged material with such products are located in New Jersey and Pennsylvania, and are owned by Clean Earth Dredging Technologies, Inc. Manufactured structural and non-structural fill materials are produced by these operations, which have processed over 2 million yd^3 of dredged material to date (Maryland Port Administration 2004).

Another technique (for non-hazardous dredged material) will blend natural graded aggregate with stabilized dredged material, stockpile it, and then use it as construction aggregate. Targeted uses are parking lots, roadbeds, foundations, dikes, levees, and construction fills (Maryland Port Administration 2004).

Lightweight aggregate similar to pumice has been manufactured from dredged material. A rotary kiln is part of the process that converts dredged material stored in a CDF to lightweight aggregate, and the proprietary technique has been tested in over 12 locations in the United States (Maryland Port Administration 2004).

Another method mixes virgin shale (clay-slate rock) with dredged material to produce lightweight aggregate. Thermal processing is necessary for this method also, and the lightweight aggregate that is produced looks like gravel, but weighs about 30 percent less than gravel. Pilot testing is planned in New Jersey to demonstrate this proprietary manufacturing process (Maryland Port Administration 2004).

Municipal harbor dredged material (fine-grained silts and clays) was dewatered, amended with hydrated lime, and used as a road subbase aggregate in New York. The dredged material was pumped into geotubes at 10 percent solids by weight, allowed to dewater (aided by liquid polymeric conditioners to speed up the process), and removed from the geotubes at 50 percent solids by weight. The addition of 10 percent hydrated lime by weight increased the shear strength (CBR value) of the dewatered material by 67 percent after 2 hours (Gaffney and Gorleski 2005).

A lab study was performed using organic and inorganic silts and silty sands prior to dredging from a Rhode Island port to determine beneficial use alternatives such as construction applications. Some of the organic materials met regulatory standards for landfill covers, and other organic materials were too contaminated for residential or commercial applications. Lime stabilization (up to 7 percent by weight) increased the compressive strength of the inorganic silts up to 2500 psf, which is a typical bearing capacity for soil. Blending the clean inorganic silty sand with coarser natural aggregate could be used for DOT embankments if the costs justified that application. Mixing clayey silt and silty sand with Portland cement increased the compressive strength to 360 psi and 1170 psi, respectively (Silva et al. 2003).

FINE-GRAINED DREDGED MATERIAL AMENDED WITH CRUSHED GLASS: The U.S. Army Corps of Engineers' Philadelphia District partnered with Pennsylvania's Department of Transportation (Strategic Environmental Management Program Office) to look for a joint solution to their separate problems. The Corps is running out of dredged material disposal sites, and the municipal waste system is generating glass cullet available for recycling. Dewatered dredged material stockpiled from previous dredging in the Delaware River was blended with municipal glass cullet in a field and laboratory study for the primary purpose of evaluating applicability for embankments or as structural fill material (Pennsylvania Dept. of Transportation 2005).

Pilot Study. Dewatered non-contaminated fine-grained dredged material stockpiled at the Corps' Ft. Mifflin CDF (Basin A) was chosen to demonstrate the feasibility and constructability of blending glass cullet feedstock obtained from municipal sources at a field site (Delaware Valley Geo-Institute 2004, Lee and Welp 2004). The DM was classified as an organic silt (OH) of moderate plasticity with approximately 80 to 100 percent passing the No. 200 (75-micron) sieve. The glass cullet was screened to a gradation equivalent to AASHTO No. 10 aggregate (passing the 3/8-in. sieve) with less than 1 percent passing the No. 200 (75-micron) sieve. The glass cullet was classified as SP.

Blending by weight was accomplished using a trailer-mounted pugmill with an operational capacity of 200 tons per hour. The targeted blending ratios were held to within a ±5wt percent tolerance based on samples collected randomly within every 30-minute window of blending and stockpiling operations (Figure 2). Blend ratios of 20/80, 50/50, and 80/20 (glass/DM ratio by weight) were placed in 8-in.-thick lifts and compacted with a roller compactor. Figure 3 shows a handful of the 80/20 mix, and Figure 4 shows the roller compactor with the constructed embankment.

Figure 2. Pugmill blending operation

Three 12-ft-high, single-lane embankments were compacted to a minimum of 90-percent Modified Proctor compaction (20/80 embankment) and 95-percent Modified Proctor compaction (50/50 and 80/20 embankments). Comparisons to the laboratory results showed that the addition of glass cullet increased the dry density up to 30 lb/cu ft over that of un-amended compacted DM while lowering the optimum water content to a water content 20 percent below that of un-amended compacted DM. Average cone penetrometer (CPT) tip resistances were 10 tsf (20/80 mix), 15 tsf (50/50 mix), and 20 tsf (80/20 mix) through each embankment profile, which approaches the strength achieved with Portland cement-amended DM (Delaware Valley Geo-Institute 2004). The laboratory and field results indicate that glass cullet-amended DM significantly improved the engineering properties of dewatered DM, and glass cullet-amended DM should be given due consideration as a feedstock substitute for construction aggregate.

Figure 3. 80/20 blended mix

Figure 4. Roller compactor with test embankment in background

Challenges for Acceptance. Blending crushed glass and fine-grained dredged material is an innovative application of forward-thinking technology. Combining two surplus "waste" feedstock materials into one material and demonstrating its applicability to the transportation and construction industries opens new doors for recycling markets while potentially reducing landfill inflow and allowing additional engineering design options.

Glass-amended dredged material will face challenges greater than those faced by the recycled glass industry for product acceptance and selection, especially as a structural fill material (subbase, base course, embankments, etc.) because typical fine-grained materials are less desirable as construction aggregate, and construction specifications do not favor "unsuitable" materials. The potential for contaminants is also greater in fine-grained dredged materials with their typically high organic matter and sulfide content, and processing costs of amended dredged materials increase as the contamination levels increase (Maryland Port Administration 2004). State DOT regulations present another obstacle due to definitions (i.e. is amended DM a soil?), restrictions (minimum compacted density requirements), and/or exclusionary language. For example, Washington State DOT regulations limit the amount of crushed glass in structural fills to no more than 15 percent, but up to 100 percent is allowed as drainage fill (Reindl 2002). Connecticut law allows up to 10 percent by volume of crushed glass as an aggregate substitute (State of Connecticut 2004). Costly testing would be required to demonstrate that such low glass percentages mixed with fine-grained dredged material would meet minimum compaction density criteria for structural fill.

The industry-wide acceptance depends on economics (i.e. cost savings compared to trucking in clean natural aggregate), regulatory definitions and requirements, and development of material testing standards. Specifying material performance criteria instead of material-specific criteria (based on traditional aggregate material standards) will also encourage further development, acceptance, and utilization of this innovative material.

SUMMARY AND CONCLUSIONS: Recycled post-consumer glass that is crushed and screened is being utilized as a construction aggregate substitute in numerous applications in the United States and Europe. Numerous studies have shown it to be a viable engineering material with characteristics of a lightweight granular aggregate, with lower specific gravity, lower dry density, similar shear strength, similar permeability, and similar durability. Blending dewatered dredged material with crushed glass also offers the possibility of providing an engineered material alternative. Combining these two recyclable materials into an innovative product will create a win-win situation.

ADDITIONAL INFORMATION: Questions about this technical note can be addressed to Landris T. Lee, Jr. (601-634-2661, Landris.T.Lee@erdc.usace.army.mil). This technical note was funded by the Dredging Operations and Environmental Research (DOER) Program's Innovative Focus Area. Focus Area Manager is Mr. Tim Welp (601-634-2083. Timothy.L.Welp@erdc.usace.army.mil), and the DOER Program Manager is Dr. Todd S. Bridges (601-634-3624, Todd.S.Bridges@erdc.usace.army.mil). This technical note should be cited as follows:

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