The Law of Unintended Consequences:

Impediments to Glass Recycling from PENNDOT references in Chapter 73 Regulations
Understanding PENNDOT Specifications

- Publication 408, Section 703—Aggregate Specifications
  - Section 703 geared for concrete and asphalt
  - Glass not an approved source material (i.e. geology)
  - Glass treated as deleterious material

- Publication 34, Bulletin 14—Approved Aggregate Producers
  - Mostly quarries, sand & gravel pits, utilities
  - Required QA/QC Testing ($20,000 to $30,000/yr)
  - Glass not approved, therefore not tested or included.

- Pennsylvania Test Methods (PTMs)—Field and Laboratory
  - Only available through PENNDOT Bookstore (not online)
  - Obscure reference for those not conducting business with PENNDOT
  - Most PTMs reference AASTHO and ASTM specifications
Section 703.2 Aggregates

- Approved Source Materials (Section 703 & Bulletin 14)
  - Stone
  - Gravel
  - Blast Furnace Slag
  - Steel Slag
  - Granulated Slag
  - Lightweight Aggregate
  - Recycled Concrete
- Quality Specifications (Types A to C; C lowest)
- Size and Gradation Specifications (AASHTO designations)
# Section 703.2 Quality Requirements

<table>
<thead>
<tr>
<th></th>
<th>Type A</th>
<th>Type B</th>
<th>Type C</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soundness, Max. %</strong></td>
<td>10</td>
<td>12</td>
<td>20</td>
<td>6.38-7.1</td>
</tr>
<tr>
<td><strong>Abrasion, Max. %</strong></td>
<td>45</td>
<td>45</td>
<td>55</td>
<td>24-25</td>
</tr>
<tr>
<td><strong>Thin and Elongated Pieces, Max. %</strong></td>
<td>15</td>
<td>20</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Material &lt;75um (No. 200), Max. %</strong></td>
<td>*</td>
<td>*</td>
<td>10</td>
<td>1.2-3.2</td>
</tr>
<tr>
<td><strong>Crushed Fragments, Min. %</strong></td>
<td>55**</td>
<td>55**</td>
<td>50</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Compacted Density (Unit Weight), Min. kg/m³ (lbs./cu.ft.)</strong></td>
<td>1100 (70)</td>
<td>1100 (70)</td>
<td>1100 (70)</td>
<td>(72-79)</td>
</tr>
<tr>
<td><strong>Deleterious Shale, Max. %</strong></td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td><strong>Clay Lumps, Max. %</strong></td>
<td>0.25</td>
<td>0.25</td>
<td>3</td>
<td>--</td>
</tr>
<tr>
<td><strong>Friable Particles, Max. % (excluding shale)</strong></td>
<td>1.0</td>
<td>1.0</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td><strong>Coal or Coke, Max. %</strong></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td><strong>Glassy Particles, Max. %</strong></td>
<td>4 or 10***</td>
<td>4 or 10***</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td><strong>Iron, Max. %</strong></td>
<td>3*****</td>
<td>3*****</td>
<td>3*****</td>
<td>--</td>
</tr>
<tr>
<td><strong>Absorption, Max. %</strong></td>
<td>3.0****</td>
<td>3.5****</td>
<td>-</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Total Deleterious Shale, Clay, Lumps, Friable Particles, Coal, or Coke Allowed, Max. %</strong></td>
<td>2</td>
<td>2</td>
<td>15</td>
<td>--</td>
</tr>
</tbody>
</table>
Glassy Particles:

Determine the percentage by mass (weight) by visual identification and hand separation. Pieces of slag containing more than 50% glass are considered to be glassy particles. **Waste glass is also considered to be glassy particles.** For coarse aggregates used in cement concrete, the maximum percentage of glass particles allowed is 4%. **For other uses, the maximum percentage of glass particles is 10%**. Coarse aggregate containing glassy particles consisting of waste glass may not be used in concrete or bituminous wearing courses.
Understanding PENNDOT Specifications

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## PTMs

<table>
<thead>
<tr>
<th>TEST</th>
<th>PTM</th>
<th>AASHTO</th>
<th>ASTM</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve analysis of coarse &amp; fine aggregate</td>
<td>616</td>
<td>T27</td>
<td>C136</td>
<td>$100*</td>
</tr>
<tr>
<td>Material &lt;0.075mm (No. 200) sieve</td>
<td>100</td>
<td>T11</td>
<td>D1140</td>
<td>$30**</td>
</tr>
<tr>
<td>Coefficient of Uniformity, Cu</td>
<td>149</td>
<td>--</td>
<td>D653</td>
<td>---*</td>
</tr>
<tr>
<td>Sodium Sulfate Soundness</td>
<td>510</td>
<td>T104</td>
<td>C88</td>
<td>$300***</td>
</tr>
</tbody>
</table>

* Based on AASHTO T88 / ASTM D422. Once run, data for Cu obtained.  
** No cost if AASHTO T27 / ASTM C136 performed, i.e., it is a subset.  
*** Data already collected by PENNDOT—no need to reproduce for ACT 101 or industrial glass

Estimated cost to certify MRF CG stockpile: ~$100, $300 for triplicate  
PENNDOT QA/QC Program: $20,000 to $30,000/yr
§73.1. Definitions… *Aggregate*. Coarse material manufactured from stone, gravel or slag, having Type B characteristics as described in Department of Transportation specifications, Form 408, section 703.3, Table B and uniform size and grading equivalent to American Association of State Highway and Transportation Officials No. 57, as described in Form 408, Section 703.3, 2 Table C.
§73.1. Issues

- Glass (& tire chips) excluded as source material
- Glass excluded by Type B quality designation.
- PENNDOT improperly referenced:
  - Characteristics ⇒ Quality
  - Form 408, Section 703.3 ⇒ Pub. 408, Section 703.2
  - Section 703.3, 2 Table C ⇒ Section 703.2, Table C
- Fine aggregate and/or sand not defined, only coarse (by AASHTO No. 57).
- To be in compliance with Section 703.2, all points must be satisfied (invokes QA/QC program and Bulletin 14 listing). In other words—Suppliers will not certify glass.
- Glass excluded by AASHTO No. 57 gradation
- AASHTO reference can be stand alone
§73.1. Definitions… *Aggregate*. Quarried, manufactured or recycled material from an inert, non-calcareous source.

(i) *Coarse Aggregate*. Unless otherwise specified, material meeting AASHTO No. 57 size and grading requirements, with less than 2% by weight material passing the No. 200 (0.075 mm) sieve.

(ii) *Fine Aggregate*. Unless otherwise specified, material meeting the AASHTO No. 8 size and grading requirements.

(iii) *Certification*. Size and grading requirements must meet the most current versions of AASHTO M43 /ASTM D448. Material conformance with these requirements must be certified by a source listed in PENNDOT Bulletin 14, or a third party AASHTO/ASTM certified commercial soil testing laboratory.
Alternative §73.1 -- Rationale

- Glass/tire chips now qualify as source material
  - (However, glass unsafe until crushed to AASHTO No. 8)
- Hydraulic conductivity (permeability) main design parameter (limit fines)
  - AASHTO No. 57 gradation ensures this
- PENNDOT not mandated, but quarried aggregates useable
- Soil testing labs very cost effective ($100/test)
- SEO approval and lengthy DEP review process avoided
- Contractors can’t wait—give them pre-approval
§73.51.(a) In all systems, if an absorption area is proposed, the top of the limiting zone shall be at least 4 feet below the bottom of the aggregate. Coarse aggregate used in the distribution system shall meet the requirements of the Department of Transportation specifications, Publications #408 (1994) section 703 available from the Department of Transportation. The size and grading of the aggregate shall meet AASHTO No. 57 requirements from a PADOT certified stockpile and shall be of Type B quality requirements.
§73.51.(a). Issues

- PENNDOT improperly referenced:
  - 1994 edition obsolete → e-spec now online
- PENNDOT certified stockpile—QA/QC required, Bulletin 14 source only (i.e., no glass/tire chips)
- Glass/tires excluded by Type B quality
- Glass excluded by AASHTO No. 57 gradation
- AASHTO reference can be stand alone
Suggested Alternative--§73.51(a).

§73.51.(a) In all systems, if an absorption area is proposed, the top of the limiting zone shall be at least 4 feet below the bottom of the aggregate. Coarse aggregate used in the distribution system shall meet the requirements of §73.1.
Alternative §73.51.(a).  -- Rationale

- Referencing §73.1 streamlines specification, eliminates duplicative language, and simplifies future updates.
§73.55(c) Sand. Sand suppliers shall provide certification in writing to the sewage enforcement officer and permittee, with the first delivery to the job site from every sand source listing the amount of sand delivered, and that all sand supplied meets the requirements posted in the Department of Transportation specifications Publication #408, section 703. The size and grading shall meet bituminous concrete sand Type B #1 or #3 requirements from a Department of Transportation certified stockpile. The sieve analysis shall be conducted in accordance with PTM #616 and #100.
§73.55(c). Issues

- Sand implies geologic origin & mineralogy
  - glass explicitly disallowed.
- Consider “fine aggregate” terminology throughout Chapter 73—glass allowed.
- Requirements posted? Does this mean complying with PENNDOT or not? Industry will take most conservative interpretation → full compliance → glass excluded.
- “Certified stockpile” implies full compliance with Section 703 → glass excluded.
- If Section 703 compliance required, PTMs implied. AASHTO/ASTM tests should replace PTMs.
- Do you really need gradation of B#1 and B#3? Overkill?
  - How about AASTHO No. 8 or No. 10?
  - Minus 3/8” glass with limit on fines?
  - All have essentially same permeability as B#1 and B#3
  - BUT: These have different filtration properties
Comparison:

5 gpd/ft² recirculating sand filter

\[ D_{10} = 1.5 \text{ to } 2.5 \text{ mm}; \quad C_u = 1 \text{ to } 3 \]
Suggested Alternative-- §73.55(c)

§73.55(c). Fine aggregate suppliers shall provide certification in writing to the sewage enforcement officer and permittee, with the first delivery to the job site from each source listing the quantity of material delivered. The fine aggregate shall meet B#3 concrete sand or AASHTO No.10 size and grading requirements, and meet all other requirements of §73.1.
Alternative §73.55(c). -- Rationale

- Fine aggregate allows for glass, stone, slag, tire chips, etc.
- Value of K (permeability) preserved
- Concrete sand can still be used
- MRFs can stockpile glass with third party certification
- No SEO or PADEP approval delays
- Most sand mounds in rural areas—same as MRFs—transportation cost becomes competitive
- Cite size and gradating only—quarries and labs know required tests—invoked by standards.
§73.162(b)(2)(i) … The fine aggregate shall have an effective size of between 0.3 to 0.6 mm, a uniformity coefficient of less than 3.5 and less than 4% of the coarse aggregate passing the #100 sieve. The sieve analysis shall be conducted in accordance with Department of Transportation PTM#616 and the uniformity coefficient shall be determined by using Department of Transportation PTM #149.
Filter Criteria
AASHTO No. 8
AASHTO No. 10
B#3 Sand

USCS grain size categories

Percent finer by weight

Grain size (mm)

§73.162(b)(2)(i) gradation

(dots)

gravel
sand

coarse
fine
coarse
medium
fine

fines (silt or clay)
§73.162(b)(2)(i) Issues

- Fine aggregate not defined—sand called out in §73.162(b)(2)
- Effective size ($D_{10}$) not defined.
- Testing certification?
§73.162(b)(2)(i) … The fine aggregate shall have a $D_{10}$ of between 0.3 to 0.6 mm, a $C_u$ less than 3.5, and less than 4% by weight passing the #100 sieve determined in accordance with the most current version of AASHTO T27 / ASTM C136 and ASTM D653. Except for size and grading, the other requirements of §73.1 shall be met.
Alternative §73.162(b)(2)(i) -- Rationale

- Use engineering terminology & acronyms to be as specific as possible.
- PTMs avoided.
- Once AASHTO 27 /ASTM C136 performed, ASTM D653 definition applied to data.
- Streamlined referencing to earlier sections.
§73.162(b)(2)(ii) ... The sand may not contain more than 15% by weight deleterious material as determined by Department of Transportation PTM #510.
§73.162(b)(2)(ii) Issues

- Sand → fine aggregate in §73.162(b)(2)
- PTM not necessary
- Certification?
Suggested Alternative--§73.162(b)(2)(ii)

§73.162(b)(2)(ii) … The fine aggregate may not contain more than 15% by weight deleterious material as determined by AASHTO T104 / ASTM C88 for a minimum of 5 cycles.
§73.162(b)(4)(iii) … Coarse aggregate used in the underdrains and distribution system shall meet the Type B requirements posted in the Department of Transportation specifications Publication #408, section 703, Table B and uniform size and grading of the aggregate shall meet AASHTO No. 57 requirements, as described in Form 408, Section 703.2, Table C from a Department of Transportation certified stockpile.
§73.162(b)(4)(iii) Issues

- Glass/tire chips excluded by:
  - PENNDOT quality requirements
  - Certified stockpile
- PENNDOT improperly referenced
  - Form → Publication #408
- Coarse aggregate already defined in §73.1
Suggested Alternative--§73.162(b)(4)(iii)

§73.162(b)(4)(iii) … Coarse aggregate used in the underdrains and distribution system shall meet the requirements of §73.1.
§73.162(b)(4)(iv) … Coarse aggregate used in the transition layer shall meet the **Type B** requirements posted in the Department of Transportation specifications Publication #408, section 703, Table B. Size and grading shall meet **AASHTO No. 8** requirements, as described in … Table C, from a Department of Transportation certified stockpile.
§73.162(b)(4)(iv) Issues

- Posted? Wording is ambiguous. Does this mean compliance with entire section?
- “Certified stockpile” implies compliance with entire Section 703—i.e., glass excluded.
- Take similar approach to sand in §73.55(c)
Suggested Alternative--§73.162(b)(4)(iv)

§73.162(b)(4)(iv) … Coarse aggregate used in the transition layer shall meet AASHTO No.8 size and grading requirements. Except for size and grading, all other requirements of §73.1 shall be met.
Chapter 73 Implications: Lost CG markets

- Glass directly excluded due to PENNDOT and PADEP requirements, indirectly by SEO/DEP review process (~45 days).
  - PENNDOT QA/QC Program: $20,000 to $30,000/yr
  - Estimated cost to certify MRF CG stockpile: ~$100, $300 for triplicate.
  - Glass liability: $50/ton landfill disposal fee

- Quarry price of AASHTO No. 8 aggregate and B#1, B#3 sands -- ~$7/ton.

- Sand mound uses ~100 tons sand \( \rightarrow \) $700/mound.

- 67 counties, 100 sand mounds annually (est.)

- 670,000 tons aggregate \( \rightarrow \) $4.7 million industry !!!
Conclusions

- Referencing PENNDOT, while common in civil engineering applications, can often lead to the exclusion of recycled materials in non-PENNDOT applications.
- Equivalent “non-PENNDOT” specifications available.
- Danger: Referencing AASHTO has same pitfalls—are transportation aggregate specs really suitable for filtration? No. AASHTO size and grading designed for high compaction—need fines for void infilling—opposite objective for filtration.
- While PENNDOT requires QA/QC, equivalent QA/QC & certification available from testing laboratories at fraction of cost.
- PENNDOT moving toward performance specifications—continued referencing to PENNDOT may produce unanticipated results.
- Approval delays mean contractors and builders will forego recycled materials—must be as easy to use as conventional aggregates or CG markets will not emerge.
- CG Suppliers must meet specifications or markets will not emerge.
Path Forward

- Results of PENNDOT CG studies have enabled PADEP to issue alternate guidance on CG use in Chapter 73 applications.
- Look for alternate guidance from PADEP to be issued in 2004 which addresses these issues by:
  - Pre-qualifying CG for use in select aggregate applications
  - Allowing soil testing lab certification for CG stockpiles
  - Requiring lab certifications with bill of ladings
For More Information

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