Ramsey County Demonstrations of Recycled Glass as an Aggregate Supplement

Final Report

January 25, 1999

Prepared for
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January 25, 1999

Larry K. Feldhahn, Design Engineer
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Dear Larry:

I am proud to submit the enclosed Final Report for the Ramsey County Demonstrations of Recycled Glass as an Aggregate Supplement. Ramsey County’s Department of Public Works is to be congratulated for its leadership in continuing to develop new markets for recyclable materials. Not only has the Department aggressively developed its utilization of recycled concrete and salvaged bituminous, it now can lay claim to being one of the key pioneers in utilizing glass in road construction projects.

Thank you, Terry Noonan and Jim Tolaas for your helpful comments on the earlier draft of this Report.

This Report leverages the experience of the Larpenteur Phase Two (1998) Project by providing more in depth comparison to the Larpenteur Phase One (1997) demonstration. Other, less intensive comparisons are made to four other demonstrations using glass as aggregate. Much of the information from two of these other projects came from your write-ups as given to various meetings and conference presentations.

I’ve tried to reference the other more detailed and more technical reports that have already been published. For example, readers may want to have copies of the Mn/DOT February, 1998, report to more fully understand the depth and details of lab research summarized in this Report.

As we have discussed many times, I recommend that the County continue to require the use of reclaimed glass in the aggregate base for Larpenteur Phase III as per the proposed new Mn/DOT specification (3138). As you know, Mn/DOT has no schedule at this time to develop a similar specification for the use of glass in select granular borrow as subgrade aggregate. Note that this Report now goes into further depth of discussion about the barrier of limited supply of glass and recommends interim and long-term steps based on our meeting with Jim Tolaas this past Friday, January 22.

My sincere thanks for the opportunity to serve Ramsey County and its Department of Public Works. It truly has been a pleasure.

Sincerely,

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<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project #1</th>
<th>Project #2</th>
<th>Project #3</th>
<th>Project #4</th>
<th>Project #5</th>
<th>Project #6</th>
</tr>
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<tbody>
<tr>
<td><strong>Sponsor</strong></td>
<td>Ramsey County PWD</td>
<td>Ramsey County PWD</td>
<td>Ramsey County PWD</td>
<td>Super Cycle, Inc.</td>
<td>Ramsey County PWD</td>
<td>City of St. Paul</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td>Class 5 (Aggregate base)</td>
<td>Class 6 (Aggregate base)</td>
<td>Bituminous base and Class 5 Aggregate base</td>
<td>Select Granular Borrow (First 2” of subgrade)</td>
<td>Granular Borrow (First 2” of subgrade)</td>
<td></td>
</tr>
<tr>
<td><strong>Project</strong></td>
<td>Aldrich Arena parking lot</td>
<td>Larpenteur Avenue, Phase I</td>
<td>Co. Rd. D and Edgerton</td>
<td>County Recycling Center, parking lot and tipping pad</td>
<td>Larpenteur Avenue, Phase II</td>
<td>Residential paving, &quot;Thomas / McKubin&quot;</td>
</tr>
<tr>
<td><strong>Glass Pre-Processing</strong></td>
<td>Unknown</td>
<td>Pre-crushed, screened (1/2” minus)</td>
<td>Pre-crushed, screened (1/2” minus)</td>
<td>Pre-crushed, screened (1/4” minus)</td>
<td>Screened, hand-picked</td>
<td>Screened, hand-picked</td>
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<tr>
<td><strong>Pre-Blended</strong></td>
<td>Unknown</td>
<td>Yes</td>
<td>No</td>
<td>Yes (into bituminous and aggregate base)</td>
<td>No</td>
<td>No</td>
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<tr>
<td><strong>Ratio (glass to traditional aggregate)</strong></td>
<td>Unknown</td>
<td>5 percent</td>
<td>100 percent</td>
<td>5 percent (nominal)</td>
<td>100 percent of first subgrade lift</td>
<td>100 percent of first subgrade lift</td>
</tr>
<tr>
<td><strong>Approved By:</strong></td>
<td>Ramsey County and Mn/DOT</td>
<td>Ramsey County only</td>
<td>Ramsey County only</td>
<td>Super Cycle and Frattalone Paving</td>
<td>Ramsey County only</td>
<td>City of St. Paul</td>
</tr>
<tr>
<td><strong>Specification Wording</strong></td>
<td>None</td>
<td>“…may use…”</td>
<td>“…shall use…”</td>
<td>“…shall use…”</td>
<td>“…shall use…”</td>
<td>“…shall use…”</td>
</tr>
<tr>
<td><strong>Amount of Glass Used</strong></td>
<td>Unknown</td>
<td>715 tons</td>
<td>108 tons</td>
<td>10 tons est.</td>
<td>128 tons (net)</td>
<td>122 tons</td>
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<tr>
<td><strong>Performance Results</strong></td>
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<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>Some change (Some additional quality control needed)</td>
<td>No change</td>
</tr>
<tr>
<td><strong>Glass Supplier</strong></td>
<td>NRG (Newport RDF Facility) (a)</td>
<td>Super Cycle</td>
<td>Super Cycle</td>
<td>Super Cycle</td>
<td>Super Cycle</td>
<td>Super Cycle</td>
</tr>
<tr>
<td><strong>Aggregate Producer</strong></td>
<td>Unknown</td>
<td>Carl Bolander &amp; Sons, Inc.</td>
<td>Super Cycle</td>
<td>Commercial asphalt</td>
<td>Super Cycle</td>
<td>Super Cycle</td>
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<td><strong>Cost Differential to Road Construction Contractor</strong></td>
<td>Unknown</td>
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<td>$0 per ton</td>
<td>Unknown</td>
<td>$0 per ton</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Price Paid to Glass Supplier</strong></td>
<td>$0</td>
<td>$0 per ton</td>
<td>About $1 per ton</td>
<td>$0</td>
<td>About $1 per ton</td>
<td>About $1 per ton</td>
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<tr>
<td><strong>Cost to process</strong></td>
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<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Environmental Impacts</strong></td>
<td>Unknown</td>
<td>None</td>
<td>Minimal risk</td>
<td>None</td>
<td>Minimal risk (c)</td>
<td>Minimal safety risk (d)</td>
</tr>
</tbody>
</table>

(a) "Glass" supplied by NRG, Inc. (a subsidiary of NSP) the owner - operator of the Ramsey - Washington Counties' Resource Recovery Facility located in Newport, MN.

(c) Project #5 involved a negligible increased risk of contaminated storm water run-off. (See report text and Mn/DOT report for more details.)

(d) Project #6 involved a negligible increased safety risk due to stockpiling of glass pile overnight by road construction contractor in a non-secured residential area.

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Dan Krivit & Associates
INTRODUCTION

PROJECT BACKGROUND

In the fall of 1997, Ramsey County Public Works Department initiated a structured research and demonstration program to prove the technical and economic feasibility of using reclaimed mixed glass as a partial supplement to other aggregates for roadbed subgrades within reconstruction projects. Two sources of internal County grant funds were awarded to help pay for the research and development of this glass recycling demonstration. The County’s Environmental Management Group awarded $10,000 as an “Environmental Innovations Projects.” In addition, the County’s Innovative Programs awarded another $10,000, for a total grant amount of $20,000.

History of Other Related Projects

Glass to aggregate recycling research and development efforts by the County’s Department of Public Works have taken place over the past seven years. Table 1 displays the relevant details of six glass to aggregate projects sponsored by, or related to, Ramsey County.


Project #2 - Five percent reclaimed glass into Class 6 aggregate as base within portions of the Larpenteur Avenue reconstruction project, 1997. The product used was first pre-crushed by Super Cycle using a dedicated glass crusher and then screened such that it was best described as “pre-crushed, screened” reclaimed glass.

Project #3 - 100 percent reclaimed glass as aggregate base for County PWD Maintenance Division turn lane at County road D and Edgerton. The product used was basically the same “pre-crushed, screened product” used for Project #2 except that more of the “fine” grade (nominal ¼-inch minus) was preserved for higher value application testing. It was transferred to County PWD property for storage and ultimate utilization.

Project #4 - 5 percent into bituminous hot-mix asphalt base course at Ramsey County Recycling Center parking lot and commingled tipping area in 1997. (Plus, 10 percent into aggregate base.) The reclaimed glass used for the hot-mix base course was the “pre-crushed, screened,” ¼-inch minus Table 1 Project #4 Glass Pre-processing lists this as 3/8” minus, “fine” grade product derived from the 1997 Super Cycle glass processing operations. (Similar to, but slightly more refined than the product used in “Projects #2 and #3.)
Project #5 - 100 percent reclaimed glass for first lift of subgrade in Larpenteur Avenue, 1998 phase. This product was not pre-crushed but was screened using a purchased, stationary-mounted, ¾-inch, vibrating deck screen.

Project #6 - (CITY OF ST. PAUL) 100 percent reclaimed glass for first lift of subgrade in the City’s residential street paving project. The reclaimed glass product was essentially the same as the for Project #5.

The specific focus of this demonstration Project under grant funding was to test the use of 100% mixed broken container glass in the first layer of select granular borrow subgrade correction (Project #5). The intent was to research and demonstrate this more innovative application as an alternative glass market. However, its value as a demonstration is leveraged when comparing results to other road construction applications.

Recycled glass for various road construction projects has been tested extensively by other states around the country and found to be suitable if prepared to given specifications for particular applications. This Ramsey County project is building directly on that body of knowledge, but focused on this specific select granular borrow subgrade application utilizing 100% glass.

Past County use of the recycled material focused primarily on blending crushed mixed glass into Class 5 or Class 6 aggregate base in a blend of up to 10% glass. This application required crushing, additional trucking, blending and separate stockpiling of the “Glass 6” blended product. This Project (#5) was designed to avoid those additional glass processing, blending and other handling steps to help improve economic feasibility.

**PREVIOUS STUDIES**

This Final Report pulls together the results of two years of Ramsey County sponsored demonstrations. As part of Project #5, environmental lab tests were conducted on a similar product and reported to the Minnesota Department of Transportation (Mn/DOT). The County’s research and demonstration projects were designed based on extensive research by other agencies and states.

**Mn/DOT**

The Minnesota Department of Transportation, in cooperation with Sibley County and the Minnesota Office of Environmental Assistance (OEA), conducted research on the use of mixed glass in a mixture with Class 5. As a result of this research, recommendations were developed by Mn/DOT that led to publication of a fact sheet, a “boiler plate” specification to allow the use of crushed glass in 3138 Class 5 aggregate base, and a generic “supplemental agreement”.
In the case of Sibley County, low quality “sandy” aggregate was enhanced by the introduction of crushed glass. This blending with glass increased the utilization of low quality aggregate and utilized the glass that would otherwise have been landfilled at a significant cost for hauling and landfill tipping fees.

**State of Washington, Clean Washington Center**

Extensive research was conducted for the Clean Washington Center (CWC) by Dames and Moore consulting engineers in 1993. The research, entitled “Glass Feedstock Evaluation Project”, resulted in a series of publications on glass recycling and forms the largest source of technical assistance and training information available on the subject. The brochure, *Using Recycled Glass as Construction Aggregate, A Summary of the Glass Feedstock Evaluation Project*, from CWC states:

> Both laboratory analysis and equipment evaluation point to the technical and economic viability of using (reclaimed glass) cullet as a construction aggregate feedstock. Cullet is strong, clean, safe and economical. Its benefits from an engineering standpoint include permeability, good compaction characteristics, and compatibility with conventional construction equipment. Many states, counties, municipalities and private contractors, in fact, have already approved cullet for use as construction aggregate and conducting field trials.

Other related research has been conducted by a number of government and private institutions and has been summarized in the recent CWC publication “A Tool Kit for the Use of Post-Consumer Glass as a Construction Aggregate”.

**RECYCLING POLICIES AND PAST PRACTICES**

Ramsey County has been a leader in recycling. The County has a very mature recyclables collection and processing system that is part of an overall comprehensive solid waste management system.

The Ramsey County Solid Waste Management Master Plan is in its final stages of being updated as required by the Minnesota Waste Management Act and the Regional Solid Waste Policy Plan as adopted by the Minnesota Office of Environmental Assistance (OEA). For the first time, the County’s Solid Waste Plan was completed as part of a six-county, Regional joint powers board, the Solid Waste Management Coordinating Board.

The County’s draft Solid Waste Plan has one key policy that directly addresses this Project. Under Chapter VII - Recycling, Section C. Ramsey County Recycling, policy #8 states:

> Ramsey county will engage in procurement practices that favor purchase of products with recycled content where feasible.
Further County Board direction and decisions have made it clear that County Departments are encouraged, if not required to do what they can to purchase recycled materials and collect their own recyclables to the maximum extent practicable.

The County’s Department of Public Works has utilized substantial amounts of recycled content products for years. In terms of tons, probably the largest category of recycled products used by the County is salvaged bituminous and crushed concrete from road reconstruction and building demolition sources. This past experience and compliance with County recycled product procurement policy provides an informative precedent for this research and demonstration project to purchase reclaimed glass as an aggregate supplement.

ROAD RECONSTRUCTION SPECIFICATIONS AND CONTRACT AWARDS FOR LARPEN'TEUR

The Larpenteur reconstruction project was designed with 200 mm (8 inches) of new concrete pavement on top of 150 mm (6 inches) of Class 6 aggregate base. The subgrade beneath the aggregate base is specified to be 600 mm (2 feet) of select granular borrow (Mn/DOT specification (3149.2B2).

LARPEN'TEUR PHASE ONE (1997): GLASS PROJECT #2

For purposes of the Project #2 glass demonstration, the Larpenteur Phase One (1997) bid specifications allowed the use of reclaimed glass in as a 10 percent blend in the aggregate base, normally made up of material that meets Class 6 gradations. Using other “recycled” materials, salvaged bituminous and crushed concrete, as part of the aggregate for road base, has been a common practice by the County for a number of years. The verbatim bid specification language in 1997 on this issue was as follows:

S-25 (2211) AGGREGATE BASE

The aggregate base shall be constructed in accordance with the provisions of 2211 except as modified below:

......

S-25.3 The Class 6 aggregate base shall be produced from up to 100 percent recycled material. The use of up to 10 percent crushed glass will be permitted.

Early in the Spring of 1977, the County awarded the Larpenteur Phase One (1997) reconstruction contract to Palda & Sons. Soon after the award announcement, Super Cycle, as the glass supplier, contacted Palda and Sons to discuss the potential for use of glass as allowed in the specs. Palda stated that, as the construction contractor, they would not object to the use of glass under the following conditions:
1. The County wanted the glass included and would provide oversight and take responsibility for the performance of the “Glass 6” aggregate;

2. The use of glass did not jeopardize the construction schedule (the county had built in some severe penalties to the Contractor for construction delays);

3. The “Glass 6” blended product met all “Class 6” specifications; and

4. It did not cost them any more than the normal product they planned to use.

Palda notified Super Cycle that Carl Bolander & Sons was the local aggregate producer on contract to supply Palda with the Class 6 aggregate base. Super Cycle contacted Bolander and arranged for a limited demonstration of glass blending and application of the “Glass 6” product.

**LARPENTEUR PHASE TWO (1998): GLASS PROJECT #5**

The Phase Two (1998) project bid specifications required the use of recycled glass as a partial substitute for traditional select granular borrow and the Class 6 aggregate base. This prescriptive wording was intended to demonstrate the additional application as a first lift subgrade aggregate for purposes of the glass Project #5. The bid specification providing for reclaimed glass as a blend into Class 6 aggregate for the road base was added as a contingency in case the more innovative select granular borrow test did not proceed for any reason. The verbatim wording was as follows:

S-42 (2112) SUBGRADE PREPARATION

……..

Select Granular Borrow

Select Granular borrow shall be constructed as follows:

The bottom 75 mm of select granular borrow shall be constructed of recycled glass. The use of glass shall be subject to availability as determined by the Engineer. Additional work required to utilize glass in this manner will be incidental to select granular borrow.

……..

S-45 (2211) AGGREGATE BASE

Aggregate base shall be constructed in accordance with the provisions of 2211, except as modified below:

S-45.2 ……..
The Class 6 aggregate base shall be produced from up to 100 percent recycled material.

The Contractor shall use 5 to 10 percent crushed glass cullet in the aggregate base for this project which use shall be subject to availability as determined by the Engineer. Additional work required to utilize this glass material will be considered incidental and no direct compensation will be made therefor.

The Phase Two reconstruction project was awarded to PCI (Progressive Contractors, Inc.) in the Spring of 1988. They inquired to the county representatives as to how the glass demonstration would work. A special demonstration project meeting was held in June, 1998 to arrange the logistical details. Pricing was negotiated between PCI and Super Cycle, the glass supplier.

**COMPARISON OF ENABLING VS. MANDATORY BID LANGUAGE**

This experienced gained from the two projects (#2 vs. #5) indicates that the mandatory “…shall use…” language is preferable to the enabling “…will be permitted…” language. Without the requirement, there is little to no incentive for road construction contractors to take on the added logistical tasks of utilizing reclaimed glass. However, it has been shown that there was essentially no extra work by Palda in Project #2 in 1997 and very little added work by PCI in Project #5 in 1998. But without the mandatory requirement to use reclaimed glass, it is unlikely that the contract bidders will explore the use of glass before completing their cost estimates and submitting a bid.

The mandatory “…shall use…” language provides an immediate market demand for the reclaimed glass. Contractors read this in the bid specifications and then demand their aggregate suppliers provide the required grade and composition. Also, now that a new Mn/DOT specification has been developed, product quality and more standardized material composition is established. Glass suppliers and aggregate producers have a more common point of reference.

A downside to the mandatory “…shall use…” approach is that it can put the burden on the County for determining suitable availability of reclaimed glass as a feedstock to glass-amended aggregate. During these demonstrations in 1997 and 1998, the supply of glass was provided exclusively by Super Cycle, the operator of the County’s Recycling Center. Therefore, amount and quality of supply of glass was easy to determine during these limited demonstrations. However, in the future, a more competitive approach could be taken to allow any certified source of glass to supply to any willing aggregate producer. An enabling “…may use…” approach could allow the private sector marketplace to work out its own arrangements and prices for the reclaimed glass and the glass-amended aggregate without the burden to the County of determining availability.
CHARACTERIZATION OF RECLAIMED GLASS

DESCRIPTION AND SOURCE

Super Cycle is the contract operator of the Ramsey County Recycling Center at 775 Rice Street in Saint Paul. One of the by-products of Super Cycle’s processing operations is mixed broken glass. The material is derived from residential and commercial collections of recyclables. Residents and businesses are instructed to set out only food and beverage container glass after rinsing to remove residue. The primary recycling market for the glass containers, if sorted by color, is Anchor Glass Corp. in Shakopee. Glass that is broken, and therefore unable to be manually color-sorted, remains at the end of Super Cycle’s processing line as a usable by-product. Super Cycle also receives a minor portion of mixed broken glass directly from other haulers serving primary commercial customers such as bars and restaurants.

The mixed glass is comprised of broken pieces of food and beverage containers. Minor amounts of non-glass material inevitably remains at the end of the sort line and becomes a contaminant for glass aggregate uses. These non-glass items are defined for purposes of this project as “debris”.

MIXED GLASS PROCESSING SYSTEMS

Projects #2 and #3

This glass crusher was fed by the “mixed-broken” glass stream from the end of Super Cycle’s commingled container processing line. Also, there was a separate yard infeed hopper / conveyor allowing direct input from other sources of mixed-broken glass such as independent haulers. The crushed glass, in general terms, was about 75% from Super Cycle’s commingle line and 25% from other sources via the yard hopper. Super Cycle then stored the material off-site at a nearby leased yard. Later, in the Spring of 1997, the crushed glass was further screened to a nominal ½-inch minus grade “medium” product. A rented portable deck screen was utilized with two screen decks (½-inch upper deck and ¼-inch lower deck), with both the fine and medium products basically combined. Rejects (non-glass debris and oversized glass particles) from the screening operation were used as landfill cover, basically ½-inch “overs”.

Project #5

The material used in the Larpenteur demonstration Project #5 as a partial supplement to traditional select granular borrow was screened to remove oversize material and debris. Debris included non-glass material such as: paper, plastic and metal fragments. The material was then be stored at Super Cycle’s yard and then trucked directly to the construction project site on a schedule determined by the County’s construction contractor.
RESULTS

LARPENTEUR PHASE ONE (1997): GLASS PROJECT #2

About 715 tons of reclaimed (pre-crushed, screened) glass from Super Cycle was consumed by Bolander at their crushing operation in the Midway area of St. Paul. Bolander’s crusher operator, Bob Reents, stated that he needed to blend closer to the ratio of about five percent glass to attain gradation requirements. Apparently, the pre-crushed, screened glass contained too much fines to blend at the allowed 10 percent maximum ratio.

At the estimated five percent ration, the 715 tons of glass was blended with other aggregates (mostly recycled concrete and salvaged bituminous) to produce about 14,300 tons of the Class 6 as used in Larpenteur phase one as aggregate base.

The 715 tons of glass used was determined by the availability of suitable supply from Super Cycle and the production schedule at Bolander’s crusher site. Bolander’s production of glass-amended Class 6 was limited by demand from Palda for the Larpenteur project aggregate base. Because of this special order for Larpenteur, Bolander’s operator needed to work in the glass in a manner that allowed him to maintain a separate inventory of the “Glass 6” product.

Bolander attempted to sell the “Glass 6” blended material to other customers on an open market basis with only limited success. Bolander’s operator, Bob Reents, stated his opinion as follows:

Our customers will be wary of any such product containing recycled glass that is not fully accepted and acknowledged by the State in the Mn/DOT “spec book.”

Mn/DOT has now drafted (but not yet finally developed) an updated specification for reclaimed glass blended into aggregate for base (nicknamed herein as “Glass 7”). This, plus the continued economic influences on recycling, will help increase the demand for this relatively new recycled product. It is hoped and expected that this increased demand will reduce the need for separate product inventories. If aggregate producers such as Bolander can produce a recycled glass product that will be more generally accepted and purchased, this should bring down the unit costs of producing “Glass 7”.

County public works engineering and field inspection staff were generally satisfied with the pre-blended product (“Glass 6”). The primary indication of such review was that there were no complaints received about the use of the glass. One of the County’s Public Works staff felt that is more difficult to get the proper gradation with the glass included in the aggregate, although the “Glass 6” product as produced by Bolander did pass County gradation tests. “Otherwise it filled the voids and created a nice tight aggregate base.”
LARPENTEUR PHASE TWO (1998): GLASS PROJECT #5

Description of Relevant Field Operations

The notice to proceed from Ramsey County came late in the Spring. Thus, there was only limited amount of production time left before the material was scheduled for direct shipment to Larpenteur Phase Two project site. During the Spring of 1998, Super Cycle was developing its equipment and procedures for production of the reclaimed glass for Project #5. The Super Cycle yard is very space limited and did not allow extensive stockpiling of glass for this application. No off-site storage was utilized in 1998. Therefore, Super Cycle needed to continue to use alternative markets for the mixed broken glass.

The amount of glass used, about 128 net tons, was determined by the availability of suitable supply from the County’s recycling contractor, Super Cycle, Inc. Two sets of material was delivered on a schedule prescribed by the contractor, PCI. Super Cycle and PCI arranged for trucking for delivery of 13 loads on June 2 and 2 more loads again June 10, 1998.

On June 2nd, a total of 162 tons was delivered by contract tandem trucks averaging about 12 tons per load. The first eight loads were of suitable quality, however the last five loads delivered that day were too contaminated, were rejected as unacceptable by the County, and were reloaded and trucked back to Super Cycle. A total of 66 tons were rejected that day. Therefore, the net total amount that was accepted and utilized as the first lift of the subgrade as select granular borrow was 96 tons. This material was received directly in the subgrade embankment cut and, upon acceptance by County staff, immediately worked in by PCI crews as the first 3-inch lift within the subgrade embankment.

Contamination within the rejected loads was clearly deleterious material and included: sod, cans, whole bottles, and miscellaneous scrap metal. Obviously, something had gone wrong at the Super Cycle plant and reject material destined for disposal (i.e., trash) somehow cross-contaminated the reclaimed glass product bunkers.

The County inspection staff did collect samples from the first eight, acceptable loads and the reclaimed glass was tested in the County’s soil lab. The material passed the gradation requirements for select granular borrow (3149.2B2).

The rejected loads was cause for great concern by all parties. On June 4th, Super Cycle requested one more chance to improve its quality control procedures within the yard and recommended one more set of test loads. The County staff and PCI agreed.

Super Cycle instituted additional quality control procedures to insure that no cross contamination would occur. On June 10th, two Super Cycle end dumps delivered a total of about 32 tons. This material was acceptable and was immediately incorporated as the first 2-inch lift of the subgrade.
Critical Review by County Staff and PCI

County public works engineering, field inspection staff and the construction contractor were generally not satisfied with the 100 percent glass product as select granular borrow delivered directly to the project site (i.e., not pre-blended) in 1998. The County design engineer and County glass project manager, Larry Feldhahn, conducted an informal interview of knowledgeable County and PCI staff involved in the field operations. The following are project staff debriefing comments as reported by Mr. Feldhahn:

County Staff Person “A” (This 100% glass and direct shipment from the recycler is) not a good idea. The Material control to date was inadequate, excess moisture content, contamination which included insulin bottles, possible syringes / needles caused worker concerns. Glass which has been only screened and not (pre-) crushed seems to exhibit sharper edges (with greater) injury potential. Also resulting flat pieces have less compaction ease (because) pieces slide on one another rather than pack down. Summary comment: “After 30 years of wanting to remove the debris from the roadway grades to improve (material quality), it seems we are now putting it back in….”

County Staff Person “B” The material delivered on June 2, 1998 was definitely too contaminated and not as promised. The material did not compact well, had an offensive odor, and left a bad taste figuratively speaking. (The material is not expected) to ever set up (and would receive a) low performance rating. (It does have) good permeability. (Additional concerns are the) worker hesitation factor (including) worrying about cuts, infection potential, unknown hazards, etc.

County Staff Person “D” Glass in general is a good way to go probably; pros and cons exist. Pros are we’ve already got glass and (as) a construction material with rules obeyed it is a beneficial usage of the glass. It seems environmentally friendly. Cons are potential delay in product delivery, objectionable odor, excessive debris potential, fear of future subsidence of the grade. In summary, “Its great”.

PCI (Road Construction Contractor) Staff Person “E” The product delivered was not as promised. The glass was too contaminated. Product delivery timing was satisfactory. With proper material (quality) control, glass in the select granular is a viable option. (PCI) would like to see a significant layer (e.g., 1 foot) of 100% reclaimed glass to better observe its behavior there. The construction machines behaved differently on 100% glass, (although we are) uncertain of (exact) effect.

LAB TESTS ON A SIMILAR PRODUCT

Ramsey County and Mn/DOT sponsored a series of physical and environmental tests of the glass product to determine its suitability for this use. An independent analytical lab, Interpol, was contracted to perform selected chemical analyses. Mn/DOT’s Materials lab in Maplewood conducted some of the physical tests.
The tests were conducted on a sample derived from the Super Cycle facility in December, 1997 and then screened on the County’s stationary deck screen. The County’s screen is normally used primarily for salt / sand blending at its Rice Street yard in Shoreview. The screen deck was changed to use a 1-inch mesh. Only 1-inch minus material was sampled as product. The larger pieces of glass and debris passing over the screen were considered rejects for purposes of road construction aggregate and were sent to alternative markets. The intent was to collect a representative set of reclaimed glass samples, screen the material, and then perform appropriate physical and chemical tests. Results of these tests are discussed in more detail in the Ramsey County February, 1998 report to Mn/DOT. The following is an abridged summary of the results of this report to Mn/DOT.

1. The material had an estimated debris content of 35% using the AGI visual method as measured by Mn/DOT. This compares with 2.2% by weight for similar samples as conducted by Braun InterTech for Super Cycle. It is important to note that the sample as measured by Mn/DOT was uncrushed and screened over a 1-inch deck. No further processing was utilized.

2. Organic matter as measured by loss on ignition averaged 3.35%. This compares favorably with the control product, natural sand, of 2.25% organic matter.

3. Moisture varied in previous Super Cycle samples from 0.1% to 2.8%.

4. Gradation tests conducted by Mn/DOT and Ramsey County both indicated that the material met requirements of select granular borrow (3149.2B2).

5. Permeability as measured by Mn/DOT, averaged 0.41 Cm/Sec at an average compacted density of 87.0 lbs/ft$^3$ for the two test samples run for this project.

6. The specific gravity of the Project samples was not tested by Mn/DOT. Previous research conducted for the Clean Washington Center indicated a range of specific gravity for coarse cullet from 1.96 to 2.41 with the variance depending mostly upon the amount of debris. 

7. The were some elevated levels of biological oxygen demand (BOD) and chemical oxygen demand (COD) when compared to the control samples of sand. This is expected in that food and beverage residue remains on the glass particle surfaces. The average difference in BOD levels of glass vs. sand was 26 mg/l. The average difference in COD levels was 58 mg/l. It is known from sequential time studies done for this Project, as well as other studies, that this residue readily washes off due to solubility with normal water.

8. A wide “priority pollutant” scan of other potential metals and organic contaminants was conducted to determine if any detectable levels of other compounds would be released from the glass samples as compared to the control sand samples. Thirteen (13) metals were analyzed with no detectable amounts released from the glass samples. Ninety-two (92) semi-volatile compounds were analyzed and only one had any trace amounts.
above detection limits: di-n-butyl phthalate. Di-n-butyl phthalate results did indicate a slightly elevated average for glass samples of 6.9 micro grams per liter (ug/l). This compares with the Interpoll Lab’s detection limit of 3.5 ug/l. The sand samples did not result in any di-n-butyl phthalate above lab detection limits.

Further analysis of the lab data, or field monitoring, is necessary to estimate actual impacts on the environment in field conditions underneath the road surface within the subgrade.

AVAILABLE SUPPLY

Super Cycle currently generates about 8,000 tons per year of mixed container glass. This includes both the “internal” material derived from the commingled processing line and mixed commercial glass from other haulers. They have estimated that as much as 15,000 tons could be produced at the Ramsey County Recycling Center if additional outside sources were obtained from other companies. Other recyclers in the region will be able to add their own supplies to these estimates, but there are very few recycling centers producing a high-quality of mixed-broken glass that may be eligible for use as an aggregate supplement.

This amount of reclaimed glass as a potential feedstock for blending into aggregate base is tiny in comparison to the amounts of aggregates used in road construction in Ramsey County and the eastern metropolitan area. Even when blended at a five percent ratio, the estimate range of mixed glass from Super Cycle would produce only 160,000 to 300,000 tons per year of aggregate for road base. By comparison, the amount of traditional aggregates produced is in the millions of tons per year.

This limited supply of reclaimed glass is one of the key barriers in developing aggregate as an alternative market for the mixed-broken glass. Proper planning and appropriately-scaled procurement incentives will be necessary. For example, the County may wish to require use of glass as aggregate base (pursuant to the new Mn/DOT specification) on a mandatory “…shall use…” basis only every other year on a scheduled road project. All other road projects could allow the use of reclaimed glass in road base on a voluntary “…may use…” basis. This two-year mandatory project cycle could allow construction contractors, aggregate producers, and glass suppliers to plan well in advance for production and stockpiling of the required glass-amended Class 7-G aggregate for use as road base.

ALTERNATIVE MARKETS

Super Cycle has successfully marketed this mixed broken glass material as an aggregate substitute for over three years. One of Super Cycle’s primary markets for the glass was Ashbach Construction Co. in St. Paul. Ashbach stopped accepting Super Cycle’s glass over two years ago as part of their relocation plans. Since that time, Super Cycle has been developing a variety of alternative markets for its mixed-broken glass.
The current, primary end-use market for mixed broken glass is recycling as daily cover at a landfill outside the Twin Cities area. The material is charged a tipping fee and the haul costs are high due to distance from St. Paul.
CONCLUSIONS

1. When standard product quality control procedures are in place, the reclaimed glass can perform satisfactorily as an aggregate supplement.

2. Reclaimed glass can be used either directly (as 100% glass) into the first lift of subgrade as demonstrated in 1998 or as a pre-blended mixture (as 10% glass) into the aggregate base as demonstrated in 1997.

3. If used directly into the subgrade, additional quality control procedures will be needed. The glass supplier must provide guarantees of quality glass aggregate and the County may wish to implement more intensive inspections of the material before being unloaded, perhaps at the glass supplier’s facility before it is loaded for shipment to the road project site.

4. Mn/DOT is in the final stages of developing an updated specification (3138 and 2211) for the use of reclaimed glass as a 10% blend in aggregate for use as roadbed base. Mn/DOT has not set a schedule for development of any specification for use of 100% reclaimed glass within the first lift of subgrade.

5. Mn/DOT’s new specification for aggregate base (3138) will allow other sources of recycled aggregates including salvaged bituminous and salvaged crushed concrete.

6. Lab results from the 1997 Project #2 and subsequent review by County and Mn/DOT staff indicate the following for reclaimed glass used in a 10% ratio with other aggregates to produce a “Glass 7” product:
   • The “Glass 7” product can meet Mn/DOT gradation requirements for Class 5 or Class 6 as needed for the particular project.
   • Screening of mixed broken glass is the minimum amount of pre-processing that may be necessary to remove debris from commingled container systems. This step may possibly be avoided if more intensive source separation and hand-sorting systems are utilized in producing the mixed broken glass.
   • Pre-crushing of the glass may be necessary depending on the quality of the glass, the aggregate producer’s processing system and the final product.
   • Use as aggregate base is a suitable application for the product.
   • No appreciable environmental impact could be detected.
   • Since glass contains amorphous silica rather than crystalline silica, it does not pose the health risks associated with natural sand.
   • While bottle cullet normally does not cause skin cuts, routine handling precautions are recommended.
• Depending on local conditions, glass can be competitive in price or less expensive than utilizing conventional aggregates.\textsuperscript{18}

7. Lab and field results from the 1998 Project (#5) and subsequent review by County staff indicate the following for reclaimed glass used in 100% form as the first 2 to 3 inch lift in road bed subgrade:

• The reclaimed glass, needs to be pre-processed in some fashion before delivering to the road project sites in order to meet Mn/DOT maximum debris requirements. At a minimum screening may be necessary.
• Pre-crushing followed by screening may also be necessary depending on the glass feedstock quality.
• The lab results indicate that permeability, specific gravity, and moisture content are not a problem. In fact, the relatively high permeability of the reclaimed glass is an asset compared to other aggregates.
• The environmental lab tests indicate cause for some concern and additional protections due to organic matter residue on the glass (i.e., elevated BOD levels). This is the reason Mn/DOT has developed a specification for using glass that requires glass pile storage on locations with: a. a minimum of four (4) feet depth of suitable soils separating groundwater; b. a minimum of 150 feet away from any surface water body; and c. a maximum slope for four percent (4%) if sloped to any surface water body.\textsuperscript{19}
• Because five of the 15 loads were contaminated and rejected, there is an overall negative impression about the quality of the reclaimed glass by some of the County Public Works staff. This experience clearly highlights the need for additional quality control procedures to be put in place by the glass supplier.

8. Recycled glass suppliers, as they become alternative aggregate producers, should continue to improve quality control systems as part of ongoing production operations to reduce debris in the glass aggregate and provide a consistent product.

9. Previous studies conducted by other states have concluded that using reclaimed glass as an aggregate supplement can have an overall positive effect on engineering performance.

10. Research by Sibley County has indicated that blending with glass during the gravel crushing operation can actually help upgrade a substandard virgin “sandy” aggregate into a suitable aggregate base that meets Mn/DOT gradation requirements.

11. There will be higher costs at the County’s Recycling Center, and other recycling plants handling glass, if alternative markets for mixed-broken glass are not developed. This application, use of reclaimed glass as a 10 percent blend in aggregate for road base, is the most promising and most well developed alternative market for mixed-broken glass.
12. With proper planning and product quality control, the use of reclaimed glass as a supplement to other aggregates for road base can be very cost-effective.

13. It may take two or more years of lead-time for road construction contractors, aggregate producers and glass suppliers to: (a) become familiar with the new Mn/DOT specification 3138; (b) develop business relationships; (c) make necessary arrangements (e.g., equipment and production changes); and, (d) produce sufficient inventories of glass-amended aggregate for road base.
RECOMMENDATIONS

1. Ramsey County Department of Public Works should specify the use of reclaimed glass as a pre-blended part of the aggregate base for Larpenteur Phase III to be constructed in 2000.

2. This specification should require the reclaimed glass and final glass blended product to meet relevant requirements of the new Mn/DOT specification 3138.

3. The specification should provide that the Engineer shall determine availability.

4. The County should develop an internal definition of adequate reclaimed glass supply availability as:
   (a) Quantities of reclaimed glass should be sufficient to meet the Class 7 production schedule necessary for Larpenteur III construction needs;
   (b) Quality of reclaimed glass should meet requirements of the new Mn/DOT specification 3138;
   (c) Price of the reclaimed glass should be reasonably competitive to other traditional aggregate feedstocks for producing base material, Class 6 or Class 7 (without glass); and
   (d) Adequate competition should be present among aggregate suppliers producing Class 7 with reclaimed glass. A primary indicator of this level of competition would be two or more aggregate producers utilizing reclaimed glass (meeting requirements of 3138). A secondary indicator of this potential competition would be two or more reclaimed glass suppliers (with product meeting requirements of 3138).

5. Other eligible sources of recycled aggregate should be encouraged, if not required in the Larpenteur III aggregate base specification, similar to past project bid specifications. That is, the aggregate base should include salvaged bituminous mixtures and / or salvaged crushed concrete pursuant to 3138.

6. The wording in the Larpenteur Phase III project bid specifications should be similar to the following:

   (2211 Aggregate Base)
   Aggregate base shall be constructed in accordance with the provisions of 2211 except as modified below:
   ..........
   The (3138) Class 7 aggregate base shall be produced from up to 100 percent recycled material. The final Class 7 aggregate base material shall meet gradation requirements of Class 6. The composition of the Class 7
aggregate base may be made up from any combination of salvaged bituminous, crushed concrete or reclaimed glass, subject to the restrictions in 3138 and as specified immediately below.

The Contractor shall use aggregate base constructed with material meeting Mn/DOT specification 3138 for Class 7 utilizing reclaimed glass. The use of glass shall be subject to availability as determined by the Engineer. Additional work required to utilize glass in this manner will be incidental to aggregate base.

The Engineer shall publish a list of reclaimed glass suppliers that have been certified.

7. In 1999, the County may wish to “prime the market development pump” by publishing a list of certified reclaimed glass suppliers along with its Larpenteur project bid specifications.

8. Construction project specifications should require contractors to verify that the reclaimed glass suppliers and aggregate producers certify that the reclaimed glass and final blended aggregate product meets 3138 requirements (i.e., pursuant to Mn/DOT’s proposed “Class 7-G” specifications).

9.a In 1999, the County should specify the use of reclaimed glass on the Highway 96 project on a voluntary “…may use…” basis. This approach should require the private construction contractor and materials subcontractors to supply the County with adequate documentation that, if Class 7-G was used, the glass and final blended aggregate are certified pursuant to the new Mn/DOT 3138 requirements.

9.b As a part of the Highway 96 project bid specifications, a bid alternative should allow bidders to specify a separate unit contract price for Class 7-G material, IF proposed to be used. The project bid specifications should state that this alternative is for any amount of certified Class 7-G used at the contractor’s discretion and therefore cannot be used in calculation of bottom-line bid estimate. Because the amount of Class 7-G that may be used is uncertain, the County will not be able to use the alternate bid price for this material in its decision for contract award.
APPENDIX A

ABBREVIATIONS AND DEFINITIONS

**Aggregate Producer** Company or organization responsible for blending and / or crushing of the reclaimed glass with other aggregates to produce a final product that meets Mn/DOT specifications. May include public or private operators of gravel crushing or asphalt / concrete recycling facilities.

**Certification** The process identified in the new Mn/DOT Specification 3138 for certifying that reclaimed glass contains no prohibited items and meets other specified requirements.

**Cullet** Broken glass ready for recycling into a new product. (“Cullet” is the term used by the Clean Washington Center and is synonymous with the term “reclaimed glass” as used in this Report.

**Glass** Hard, brittle manufactured products, including containers, ceramic dinnerware and window glass. Unless otherwise qualified, is used within this Report to mean reclaimed glass comprised only of eligible items without prohibited materials.

“**Glass 5**” or “**Glass 6**” A nickname given to Class 5 aggregate produced with a portion of reclaimed glass (e.g., 10% glass vs. 90% other aggregates). Implies project and production prior to 1999 when the new Mn/DOT specification 3138 will suggest a “Glass 7” nickname for the same product.

**Glass Generator** Residential homes or commercial establishments that set out recyclables, including glass, for collection and recycling.

**Glass Supplier** Recyclers or other large volume handlers of recyclable glass. May include multi-material recycling centers and industrial manufacturers. Intended to exclude small, single residential and commercial generators (e.g., households, bars, restaurants).

**Mn/DOT** Minnesota Department of Transportation

**Mn/DOT Specification 3138** New “Class 7” for aggregates made with recycled concrete, asphalt or reclaimed glass. [Note that the specification is currently under development in draft form.] Provides for a maximum glass content of 10 percent glass with other aggregates. Reclaimed glass blended with natural aggregates for use as road base would be identified by the label “Class 7-G”.

**MPCA** Minnesota Pollution Control Agency

**OEA** Minnesota Office of Environmental Assistance

**Prohibited Glass Items** Types of glass from generators, for purposes of the new Mn/DOT specification 3138, that shall NOT be included to make reclaimed glass for aggregate as road base. Prohibited items include: car windshields and other car glass, light bulb glass, porcelain
products (such as bathroom fixtures), laboratory glass, and any glass with hazardous components such as CRT’s from TV sets, computers, etc.

**Recyclable Glass**  Glass that is set out for recycling by generators and collected for further sorting or processing.

**Reclaimed Glass**  Glass that has been inspected for use as a certified as an aggregate supplement pursuant to the new Mn/DOT specification 3138. Reclaimed glass may or may not have been further processed. For example, reclaimed glass may include whole bottles or processed glass produced from pre-crushing and / or pre-screening.

**Recycled Glass**  Glass that has been incorporated into an end product including, but not limited to, new containers or aggregate

**Recycling Center**  A recycling facility that accepts various materials for further processing and / or consolidation in preparation for recycling to an end market. May include facilities ranging from simple transfer operations to industrial product manufacturers.
APPENDIX B
ENDNOTES AND REFERENCES


4. Minnesota Department of Transportation, Office of Materials and Research conducted research on the use of waste glass for use in the Class 5 aggregate base (circa 1991). Three documents were produced: Fact Sheet Number 13: Glass 5 Instead of Class 5, September, 1992; Boiler Plate (Contract Amendment) to Allow the use of Crushed Glass in 3138 Class 5 Aggregate Base, (3138.2A3 “Crushed Glass”) May 4, 1993; and a generic Supplemental Agreement resolution (undated, circa 1993).

5. The Clean Washington Center, Glass Feedstock Evaluation Project, by Dames & Moore, including the following five volumes:

   Following these Dames & Moore reports, two publications were released:
   - “Using Recycled Glass as Construction Aggregate: A Summary of the Glass Feedstock Evaluation Project” (undated brochure)

   After additional Clean Washington Center studies, and after the CWC was reorganized as a nonprofit division of the Pacific Northwest Economic Region (PNWER), CWC published Best Practices in Glass Recycling on October, 1997.


9. Ramsey County Department of Public Works, Larpenteur Avenue Reconstruction Project, Phase Two, (project bid specifications) as released in January 1998


11. Ramsey County Public Works Staff Person (identified as “C”); Informal interviews as conducted by Larry Feldhahn, Internal memo dated September 30, 1998.
12 Ramsey County Public Works; Informal interviews as conducted by Larry Feldhahn, Internal memo dated September 30, 1998


15 Florida Institute of Technology, Developing Specifications for Waste Glass and Waste-to-Energy Bottom Ash as Highway Fill Materials, Volume 2 of 2 (Waste Glass), June 1, 1995. By Paul J. Cosentino, et. al. (Produced under contract to the Florida Department of Transportation.)


19 Minnesota Department of Transportation, Offices of Materials and Research, Grading and Base Section; DRAFT proposed specification for Mn/DOT specification number 3138 - Aggregate for Surface and Base Courses; as it pertains to use of reclaimed glass. (Duane Young’s Version 9, 12/10/98 draft.)