Use of Crushed Recycled Glass in the Construction of Local Roadways

Current Status of Recycled Glass Collection and Processing in the State of Ohio

Prepared by:
Junliang (Julian) Tao

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16. Abstract

Glass cullet is produced from crushing waste glass collected in municipal and industrial waste streams to a specific size. In Ohio, it is primarily used in new glass container manufacturing. One possible alternative is to use crushed glass in the construction of civil infrastructures. This study was initiated to assess the feasibility of using crushed recycled glass as an aggregate in local roadway construction. The current recycled glass market was surveyed to evaluate whether there will be sustained supply of recycled glass for construction use in Ohio. It was found that the State of Ohio has both a huge supply (as high as 319,000 tons in 2015) and manufacturing demand (as high as 295,000 tons in 2015) for recycled glass and currently the supply can meet the manufacturing demand in a practical manner. Both glass processors and material recycle facilities (MRFs) in Ohio showed strong interest in utilization of recycled glass in roadway constructions. However, the collected data indicate that projected annual supply of the recycled glass that may be available for road construction is not sufficient for wide scale use on local applications. A cost-effective solution for a sustained supply of recycled glass for roadway construction use is to source glass directly from local MRFs and involve local aggregate suppliers. To achieve a cost effective use of recycled glass in roadway construction requires leadership from ODOT, ODNR and OEPA to encourage better coordination of MRFs, aggregate suppliers, and end users.

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Prepared by:
Junliang Tao, Ph.D.
Assistant Professor
Department of Civil Engineering
University of Akron

May 2017

Prepared in cooperation with the Ohio Department of Transportation,
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Executive Summary

Glass cullet is produced from crushing waste glass collected in municipal and industrial waste streams to a specific size. In Ohio, it is primarily used in the manufacturing of new glass containers; however, only clear glass cullet can be used. As a result, colored glass cullet has a relatively low market value as color sorting can be expensive. When market prices drop too low for long periods of time, some of the glass is sent to landfills instead of being recycled because storage space may be limited or costly. One possible alternative is to use crushed glass in the construction of civil infrastructure.

The potential to mix crushed glass cullet into aggregates exists for many applications including roadway and parking lot base or leveling courses, glasphalt, pipe bedding and backfill, drainage material, fill and concrete. Local roads have different traffic types, volumes, and patterns that require different types of mixtures and aggregates than those typically utilized for interstates and highways. This study was initiated to assess the feasibility of using crushed recycled glass as an aggregate in local roadway construction.

The current recycled glass market was surveyed to evaluate whether there will be sustained supply of recycled glass for construction use in Ohio. It was found that:

1) The State of Ohio has both a huge supply (as high as 319,000 tons in 2015) and a high manufacturing demand (as high as 295,000 tons in 2015) for recycled glass;
2) In 2011, the recycled glass supply did not meet the demand for recycled glass for glass manufacturing;
3) As a result of efforts by Ohio Environmental Protection Agency (EPA), in, the recycling rate of container glasses doubled between 2009 to 2015, and the current supply can now meet the manufacturing demand in a practical way; however, the recycling rate is still low (about 22% in 2015);
4) Both glass processors and material recycle facilities (MRFs) showed strong interest in participating in ODOT's project;
5) A better understanding of the recycling processes and the roles played by different stakeholders is critical to formulating effective strategic plans for further use of recycled glass in roadway construction;
6) If sourcing glass cullet from processors, the guaranteed continuous supply for construction applications includes 12,000 to 15,000 tons of Cathode Ray Tube (CRT) glass cullet per year from NovoTech and at least 6,000 tons of container glass cullet per year from Rumpke. In addition, the study identified a one-time stockpile of 50,000 to 60,000 tons of container glass cullet that is readily available from Strategic Materials, Inc.
7) If sourcing glass directly from MRFs, a continuous supply could be very promising, since MRFs receive very little benefit from glass recycling at the present time. Sourcing directly from MRFs might be the most cost-effective solution for a sustained supply of recycled glass for construction uses. Better coordination between MRFs, aggregate suppliers, and the end user is needed for cost-effective use of recycled glass for roadway construction. Currently, this level of coordination does not exist.

After reviewing these findings, the Ohio's Research Initiative for Locals (ORIL) Board decided to discontinue additional research on this topic for the following reasons:

1) The projected annual supply of the materials that may be available is not sufficient for wide-scale use on local applications. Therefore, further investigation is not warranted at this time.
2) Considerable concern was expressed that the costs associated with shipping and processing of the glass for use in transportation projects would be excessive to the point that it would not be cost competitive with other materials.
3) The contamination of the primary supply of glass with lead is a significant concern given current EPA regulations. Appropriately addressing this issue is expected to cause the cost of the product to increase. Given that the costs are already high, this would further reduce the potential for its use in roadway applications.

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1. Introduction

Waste glass is generated from various sources, such as consumer containers, float (plate) glass, windshields, computer monitors, and TV sets. Waste glass can be recycled for a variety of uses, including production of raw material for new containers, fiberglass insulation and other glass products, or as construction materials. Otherwise, waste glass is landfilled at a cost.

There are three ways to recycle glass: single-stream recycling by material recovery facilities (MRFs), drop-off programs, and voluntary programs for bars and restaurants. Among these three approaches, MRFs play a leading role in collecting waste container glass. MRFs are facilities that are designed to sort, store and market municipal solid waste recyclables. MRFs can be classified into different types, depending on the materials they collect and the capacity they have for processing different materials. These include clean MRFs that are capable of handling both single-stream and multi-stream recyclables and dirty MRFs that are capable of handling mixed wastes. Single-stream MRFs are capable of sorting container glass and some MRFs crush whole bottles to reduce their volume.

Recycled glass is only available for reuse once it is processed to meet the requirements of the end users. Such processing activities are also called beneficiation and include the removal of contaminants and the creation of specific gradations. The facilities capable of processing recycled glass are termed "processors". The processed glass is referred to as "glass cullet" in this report. The typical mass-flow involved in glass recycling is illustrated in Figure 1.

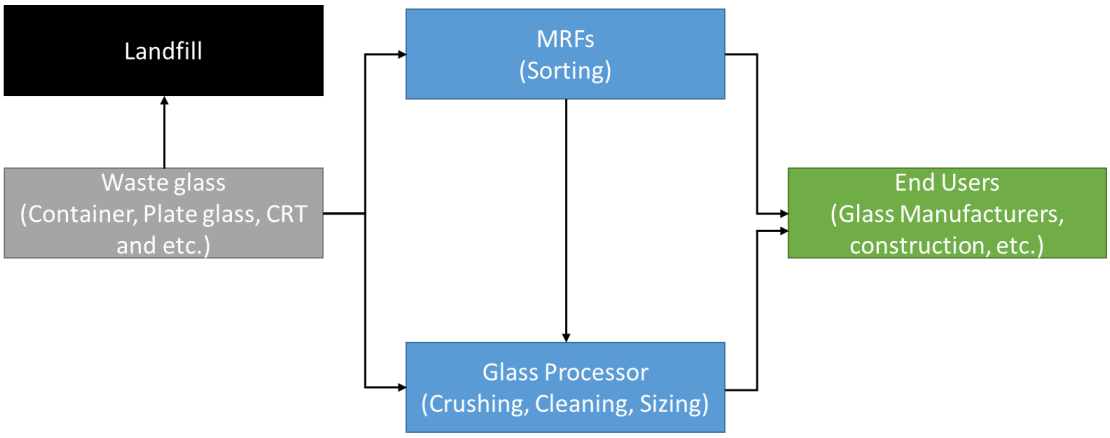

Figure 1. Mass-flow involved in glass recycling

One major challenge in glass recycling is that the value of glass cullet is relatively low, given the low cost of the raw materials that glass cullet is commonly substituted for in manufacturing or construction. Secondly, landfill costs in Ohio are relatively low, while the cost involved in collecting, transporting and processing waste glasses is relatively high. These two primary factors limit the incentive to increase the supply of recycled glass.

The objective of this research is to evaluate the feasibility of using recycled glass for roadway construction in Ohio based upon supply availability, cost-effectiveness and technical soundness. This report summarizes the findings concerning the current supply and demand of recycled glass in Ohio. Surveys were conducted to determine whether a sustained supply of recycled glass for future construction use on local roadways in Ohio exists.

2. Methodology

Two types of surveys were conducted in this study: a survey of the literature and questionnaires/phone interviews.

2.1. Literature Survey

The research team performed a literature survey to evaluate the current status of glass recycling in Ohio. Key sources included the following:

a. Ohio Department of Natural Resources (ODNR): Ohio Glass Recycling Study [1]
b. Ohio Environmental Protection Agency (EPA): Solid Waste Management Districts (SWMDs) Annual District Reports (ADRs) [2]
c. Ohio EPA: Material Recovery Facility and Commercial Recycling Data [3]
d. Studies from other states in the USA [4]

The Ohio Glass Recycling Study sponsored by ODNR Division of Recycling and Litter Prevention provides "*comprehensive data that reflects the overall market status of glass in Ohio and identifies strategies to assist communities in designing programs to maximize the quality of glass recovery for recycling and to ensure that recovered glass effectively moves from the market for a beneficial end use.*" [1].

Ohio EPA SWMDs are responsible for Ohio's plan for reducing the state's reliance on landfills for the management of solid waste generated in the state. Every year, SWMDs submit ADRs summarizing annual materials recycling in the geographic region, by material category. The ADRs can be accessed via the Ohio EPA website. The research team reviewed the most recent 2015 ADR and extracted the glass recycling data in each SWMD for further analysis. Note that for each SWMD, recycling data are available for both container glass (either from residential or commercial sources) and industrial glass (e.g., plate glass). Therefore, SWMD ANRs reflect the total amount of recycled glass.

Ohio MRFs also report annual recycling quantities handled by material category. Some materials are comingled and are reported as mixed recyclables. Since MRFs handle either curb-side collection or drop-off collection, the glass reported by MRFs mainly accounts for container glasses.

2.2. Questionnaires and Phone Interviews

The research team conducted questionnaire surveys and phone interviews to further understand glass recycling procedures and the market for the same. More importantly, from communications

and discussions with glass recycling stakeholders, the research team was able to understand better their interests in advocating the use of recycled glass in roadway construction. This is very important, since their participation is the key for the future successful implementation of the proposed strategies (discussed in Section 4).

Surveyees and interviewees include:

e. Glass Processors in Ohio
f. MRFs in Ohio
g. Ohio EPA Environmental Administrators

3. Survey Results

3.1. Results from Literature Survey

3.1.1 Glass Generation in Ohio

At present, no data sets exist that give an accurate estimate of the total glass generation in Ohio. However, according to a 2011 ODNR study [1], an evaluation was performed on the generation and recycling of **container glass** only. It was estimated that roughly 390,000 tons of residential glass and 126,000 tons of glass from businesses were generated in Ohio in 2009. Therefore, Ohio roughly generates a total of ***516,000 tons of container glass annually***.

3.1.2 Glass Recycling in Ohio

According to the ODNR glass study [1], most of the waste industrial glass is already being recycled and used in manufacturing. Based on the data from the SWMDs ADRs, the total amount of recycled industrial glass in Ohio was ***205,399.76 tons*** in the year 2015.

However, the recycling rate for container glass is very low. In 2009, only about ***54,400 (rounded) tons*** of container glass were recycled, which resulted in a recycling rate of about 10% [1]. After the 2011 ODNR glass study, Ohio EPA initiated several major glass recycling campaigns to increase the recycling rate of container glass. The goals of those campaigns were: 1) expansion of single-stream recycling, which was expected to result in 60,000 tons of recycled glass; 2) voluntary glass recycling programs for bars and restaurants, which was expected to result in 53,000 tons of recycled glass; and 3) source-separated collection at glass drop-off locations, which was expected to result in 14,400 tons of recycled glass. The campaigns were successful. Based on the data from the 2015 SWMD ANR, the total amount of recycled residential and commercial ***container glass was 113,153.70 tons***, resulting in an increase of 108% as compared to the 2009 data. Assuming that the total container glass generation did not change much due to relatively stable population and economic conditions, the recycling rate of container glass climbed to ***22%***.

According to the 2015 MRF Annual Report [3], the total annual recycled container glass by all the Ohio MRFs was *86,006.05 tons*. While this number is smaller than that reported in SWMDs ANRs, it is reasonable because the majority of the container glass from MRFs is single-stream, while other sources, such as drop-off and bar/restaurant programs, are also counted in the SWMDs ADRs. Also from both the SWMDs ADRs [2] and the MFR Annual Report [3], it is also obvious that the amount of recycled glass is well correlated to the population's geographical distribution. The recycled container glass by source in 2015 is shown in Figure 2.

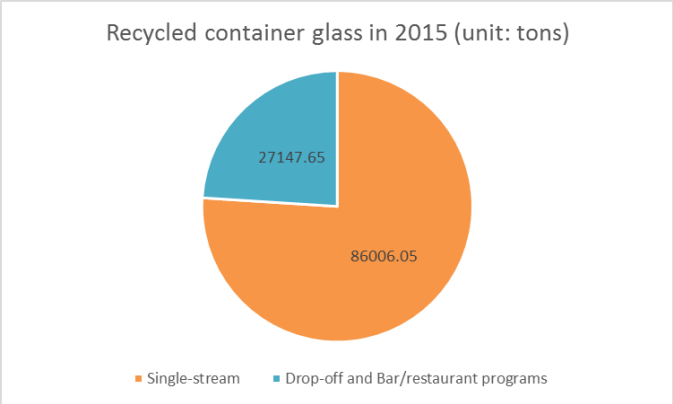

Figure 2. Recycled Container Glass in Ohio by Source.

3.1.3 Glass Processing Capacity in Ohio

Ohio has significant traditional recycled glass processing capacity and hosts four, large regular processing plants: the Rumpke facility in Dayton, the Dlubak facility in Upper Sandusky, and Strategic Materials plants in Cleveland and Newark. In Ohio, most of the recycled glass from MRFs are transferred to one of the four major traditional glass processors for further processing.

Based on the ODNR study [1], the processing capacity of the four glass processors in 2011 was about ***209,000 tons/year*.** However, it should be noted that the processing capacity (the amount of glass that can be processed) is not equal to the output (the amount of glass that can be distributed for further use). The output of glass processors in 2011 was about ***174,000 tons/year***, with a residual (also called loss, or the difference between capacity and output) rate of about 17%. However, with the recent expansion and upgrade of the Rumpke facility in Dayton and recent changes in the number of shifts per day at two other facilities, the current processing capacity is believed to be higher than ***275,000 tons/year,*** which matches the projected recycled glass processing in the 2011 ODNR glass study. This capacity is still lower than the total amount of recycled glass (***319,000 tons***) reported in 2015 from the SWMDs ADRs data. However, there is no data or information from the processors showing that the current processing capacity cannot handle all of the recycled glass. Therefore, it is reasonable to assume that the current recycled glass processing capacity is roughly equivalent to the current recycled glass supply of ***319,000 tons***. Assuming a similar residual rate of 17%, current processors are expected to generate roughly ***264,770 tons per year*** of cullet.

3.1.4 Glass Demand in Ohio

Ohio hosts six major glass manufacturing plants for container glass, fiberglass, windshield glass and reflective coatings. According to the ODNR study [1], the recycled glass cullet use by Ohio manufacturers was approximately ***110,000 tons in 2011***. However, it is estimated that the **real demand** is between ***275,000 and 295,000 tons*** of glass cullet per year. At the time the ODNR study was completed in 2011, the glass supply did not meet the manufacturing demand.

3.1.5 Comparison Among Recycled Glass Supply, Processing Capacity and Demand Based on the Literature Survey

The recycled glass supply, processing capacity and demand in Ohio are compared in Figure 3. Comparing the total recycled glass supply in Ohio (319,000 tons) in 2015 to the maximum industry demand (295,000 tons), the supply presently appears to meet the demand. However, as discussed above, roughly 17% of the weight of recycled glass is lost during processing. Therefore, the net supply is roughly 264,770 tons per year, which is slightly lower than the manufacturing demand.

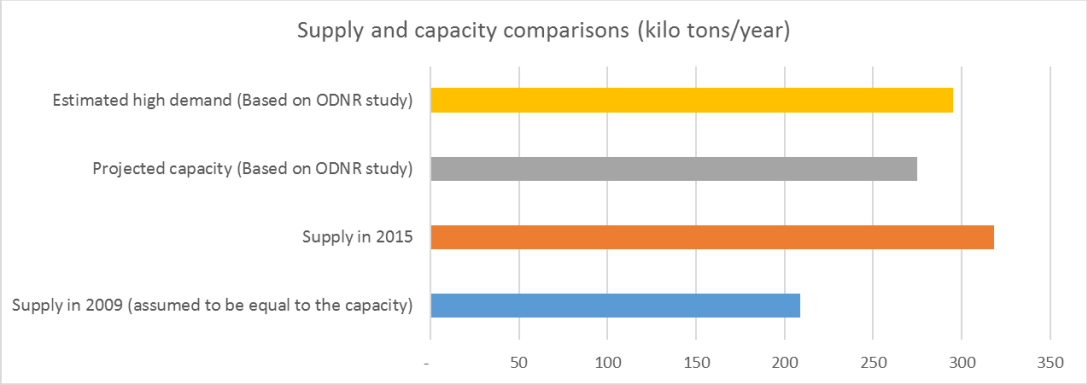

Figure 3. Comparison of Recycled Glass Supply, Processing Capacity and Demand in Ohio
(Note that the current processing capacity is believed to be larger than the projected number based on the ODNR study.)

However, based on the ODNR study [1], some processed glass in Ohio may also be exported out of state, while industries in Ohio may import recycled glass from out-of-state sources as well. In addition, similar to the ODNR study, "*the glass recycling amount in Ohio is more likely to represent an under-count rather than over-count because some small supplies of glass collected for recycling may have been missed*" [1].

Furthermore, the above estimations on recycled glass supply and processing capacity are only from traditional recycled glass stakeholders. Another recycled glass supply is available from a non-traditional glass processor, NovoTech, which specializes in cathode ray tube (CRT) glass recycling. This is discussed in detail in Section 3.2.1. Last, but not least, there still exists a huge

potential to increase the container glass supply in Ohio, since currently just 22% is recycled (see Section 3.1.2 for justification). Overall, the research team believes that the current recycled glass supply in Ohio can meet the manufacturing demand in a practical manner.

3.2. Results from Questionnaires and Phone interviews

The objective of the questionnaires and phone interviews was to determine whether there will be a sustained recycled glass supply for roadway construction purposes, with a better understanding of the glass recycling processes and the willingness of the MRFs or processors to participate in future roadway projects.

3.2.1 Survey Results from Glass Processors

In addition to the four major traditional glass processors, there is a recycling company, NovoTech in Columbus, which is an industry leader for compliant, responsible CRT processing and leaded glass recycling. NovoTech specializes in collecting, de-manufacturing and recycling of CRT, LCD and Plasma Displays. All five glass processors were contacted and the major findings from the survey are shown in Table 1.

Table 1. Major Findings from Survey of Glass Processors

Processor	Location	Capacity	End User	Interested in Roadway construction?
Dlubak Glass	Upper Sandusky	Not disclosed	Glass beads	Not so much
NovoTech	Columbus	12k-15k tons/yr	None (stored or landfilled)	Very interested; willing to collaborate and donate materials
Rumpke	Dayton	Total: 96k tons/yr; Container glass: 5000 tons/month	Container, Fiberglass	Interested; can provide at least 500 tons/month for ODOT use
Strategic Materials, Inc.	Cleveland	14.1k ton/yr Stockpile of 50-60k tons;	Container, Fiberglass	Very interested; currently doing research for EPA; willing to collaborate
Strategic Materials, Inc.	Newark	Not disclosed	Glass beads, sandblasting	Not so much

Dlubak Glass in Upper Sandusky and Strategic Materials, Inc., in Newark focus on higher-end glass materials, such as glass beads for reflective coatings. Such coatings are widely used in transportation infrastructure, for example, as beads for pavement markings. They are not interested in exploring lower-end markets, such as construction aggregates.

The research team had in-depth discussions with managers in the other three plants. The Principle Investigator (PI) also visited Strategic Materials, Inc., in Cleveland and NovoTech in Columbus. The planned visit to Rumpke was canceled, due to their unavailability. Nevertheless, the PI managed to have conversations with engineers and market managers of all three plants. ***All of them are very interested in using their products in roadway construction and have expressed willingness to provide a sustained supply to ODOT, if necessary.***

- **NovoTech in Columbus**

NovoTech recycles 12,000 to 15,000 tons of "clean" CRT glasses each year. CRT glass contains lead, so normally the public and some agencies categorize CRT glasses as toxic and limit their use. Glasses at NovoTech are typically stored in their plant and only very limited portions are used for fiberglass industry or construction. The majority of their glass ends up in landfills. According to the CEO of NovoTech, "*CRT panel glass is plentiful and clean, if processed properly. The major obstacle to its use is lack of understanding by users and governmental agencies who oversee and regulate construction projects.*"

In fact, CRT has various parts that contain lead. The lead in the funnel and face plate glass is physically and chemically bound up in the glass matrix and **does not leach** very readily. The lead in the frit, which joins or welds the face plate glass to the funnel glass, is in the form of a lead oxide paste. The lead in the frit **does leach** quite readily when subjected to the Toxicity Characteristic Leaching Procedure (TCLP) test used to determine whether a discarded material is a hazardous waste or not. At NovoTech, the treatment of the face plate, the funnel and the frit is separate. The frit part is readily separated and can be safely disposed of.

NovoTech produces two cullet sizes. One matches the specifications for #57 aggregate and the other is a ¼" minus material (similar to coarse sand). NovoTech also conducted TCLP tests of the recycled CRT glass, as required by EPA. Test results reveal that lead is non-detectable. NovoTech indicated that they can provide 100% of their glass for ODOT use.

The PI also contacted the Ohio EPA Environmental Administrator and asked for an opinion on using NovoTech glass in construction work. This Administrator is familiar with NovoTech and their glass. Her opinion is "*any use of recycled glass is beneficial and encouraged, and I don't see why you cannot use their glass for construction*". She offered to further assist the ORIL project and will provide more feedback, after she reviews their archived documents and has additional discussions with her colleagues.

- **Strategic Materials, Inc. in Cleveland**

Strategic Materials, Inc. (SMI) in Cleveland currently has a stockpile of 50,000 to 60,000 tons of cullet ready for construction use. They are currently conducting a research project with Ohio EPA to study the feasibility of using their cullet as embankment material. They have completed some small-scale compaction tests with a test area approximately 10' by 20'. Different levels of moisture content and compaction efforts (as measured by rolling passes) were tested and the

performance of compaction behavior of cullet was studied. They are eager to collaborate with ODOT to further evaluate the materials and use their material in roadway construction.

The PI visited the plant on January 5, 2017. It was found that SMI in Cleveland intends to discontinue producing cullet of larger sizes (plus ¼"). They are upgrading their facilities and will focus on the production of sand blasting materials in the future.

Therefore, although SMI can currently provide a one-time, large amount of cullet, they cannot sustain the supply over a long period of time.

- **Rumpke in Dayton**

Rumpke was originally just a recycling company that focused on collecting and sorting. They started to process glass about 10 years ago. Rumpke is unique in that they have a vertically integrated streamline for glass recycling: they collect, transport and process glass. They also accept glass from various MRFs and drop-off collections. Recently, Rumpke expanded and updated their glass processing facilities with capital investments and grants from Ohio EPA. Currently, Rumpke can process about 94,000 tons of recycled glass per year, of which 60,000 tons are from containers.

Rumpke produces cullet with different sizes. The plus ½" cullet is further color-sorted optically and is used by container glass manufacturers. The minus ½" cullet is further ground into a fine, sand-like mixture (minus ¼" or minus 1/16") that is used by fiberglass insulation manufacturers.

Both the recycling marketing manager and the sales manager at Rumpke are very interested in exploring new markets for their glass. After communicating with additional details (such as specifications and demand), Rumpke estimated that they can provide a sustained supply of about 500 tons per month or 6,000 tons per year for transportation construction use by ODOT. They also indicate that in order to guarantee a sustained supply, they must *"discuss contracts for providing materials for a designated time period, along with required tonnage"*.

3.2.2 Survey Results from MRFs

From the list of Ohio's MRFs compiled by Ohio EPA, a total of 74 MRFs capable of handling single-stream or multi-stream recyclables were identified. Surveys were sent via email first, but only three responses were received. Efforts were then made to contact each MRF by phone and solicit feedback. As shown in Figure 4, a total of 56 facilities (76%) responded, of which 31 facilities do not recycle glass and 25 facilities responded to the questionnaire. Eighteen (18) facilities (24%) did not provide feedback because of outdated contact information, no connection, or no interest.

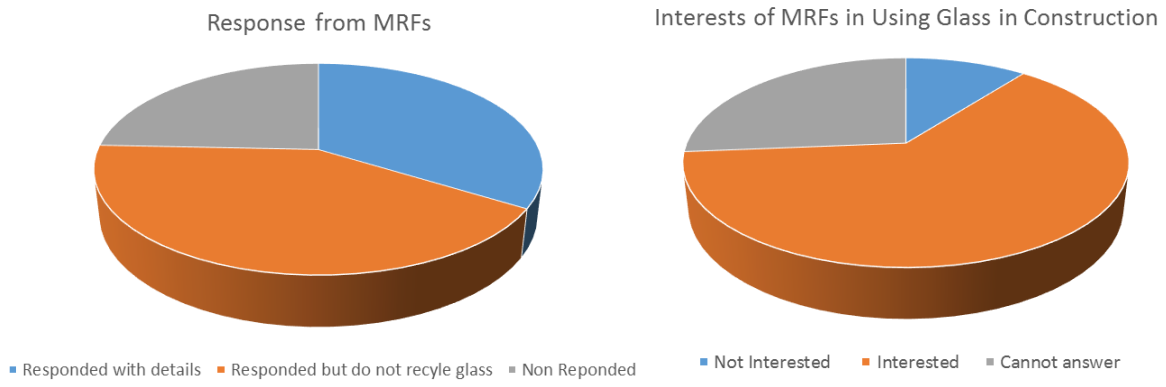

Figure 4. Response from MRFs

The recycling capacities among the responded facilities are shown in Figure 5.

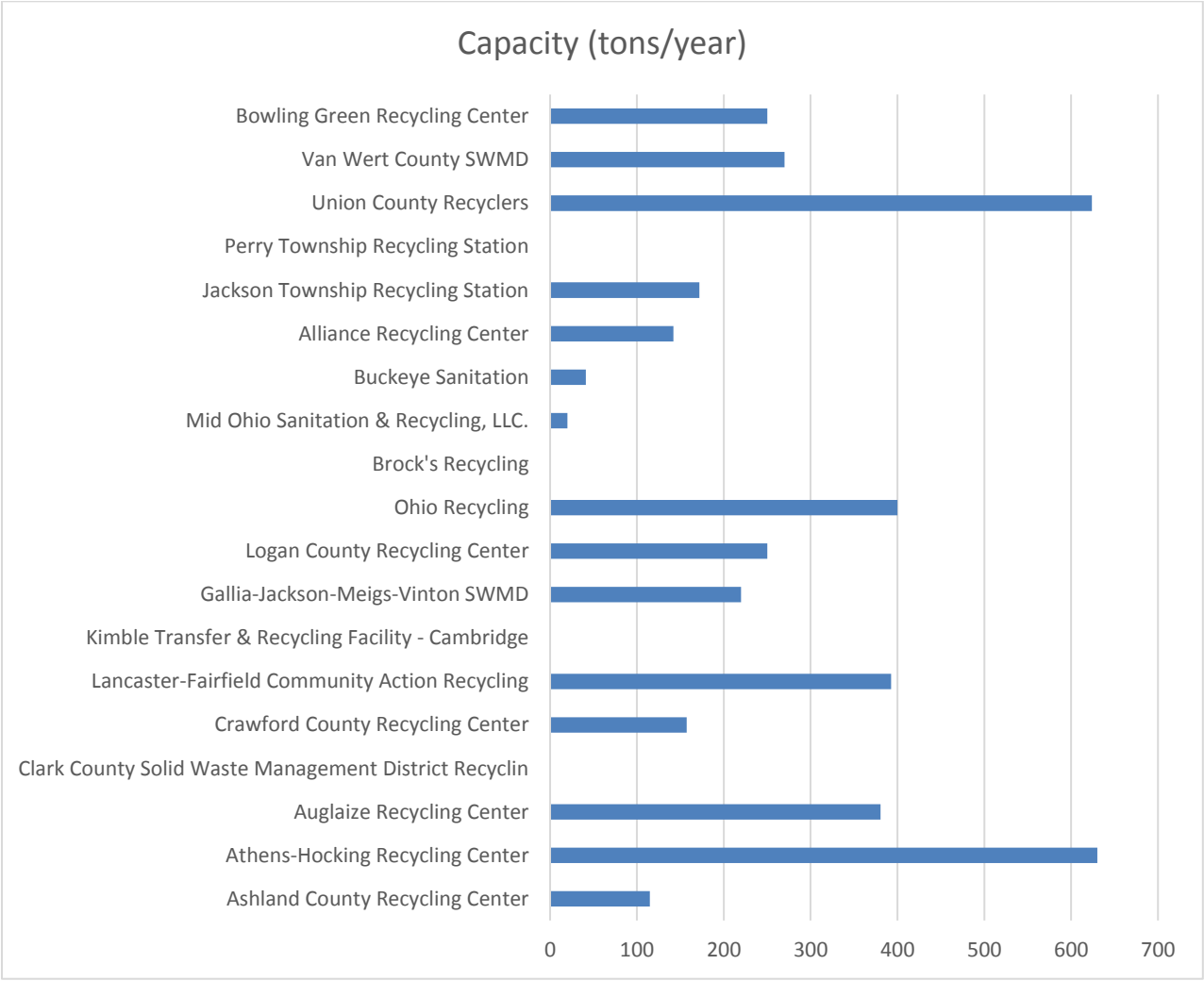

Figure 5. Recycling Capacities of Responded MRFs

Efforts were also made to compare the survey result and the MRF Annual Report for 2015, which found that the amounts of recycled glass by each responding MRF were consistent.

- **Dilemma Regarding Glass Recycling by MRFs**

Through discussions with MRFs, it seems that recycling glass is not very profitable for them due to the low value of glass and high freight costs. Most of the facilities will send the glass to one of the four traditional glass processors. Among the responding facilities, the majority ship their glass to Rumpke's plant in Dayton.

Originally, the processors paid the freight, so the MRFs benefitted from glass recycling, since the processors also paid for the glass itself. MRFs typically receive $21 per ton for flint glasses and $11 to $15 per ton for brown glasses. For green glasses, the MRFs either ship for free or pay the processors approximately $6 per ton. Alternatively, the processors pay a lump sum of $15 per ton for on-sorted (all color) glasses.

However, there have been some recent changes regarding the coverage of the freight cost. Several MRFs (Lancaster Recycling Facility, Bowling Green Recycling Facility and others) mentioned that they now have to pay for the freight cost. As an example, MRFs in Bowling Green now ship their glass to Rumpke with a cost as high as $40 per ton. Apparently, this cost significantly exceeds the material cost ($15/ton). The number was verified a second time with the Bowling Green Facility manager, who mentioned an interest in exploring new markets or glass recycling operations may be discontinued. Currently, they receive some subsidy from the state to cover freight and operation costs.

4. Strategies to Use Glass Cullet in Roadway Construction in Ohio

The above survey results indicate that the current glass supply can meet the manufacturing demand in Ohio in a practical manner. Moreover, both glass processors and MRFs are interested in exploring the construction market.

As shown in Figure 6, there are a variety of mass-flow strategies in which glass cullet can be used in construction. Each strategy has its own advantages and disadvantages as discussed below.

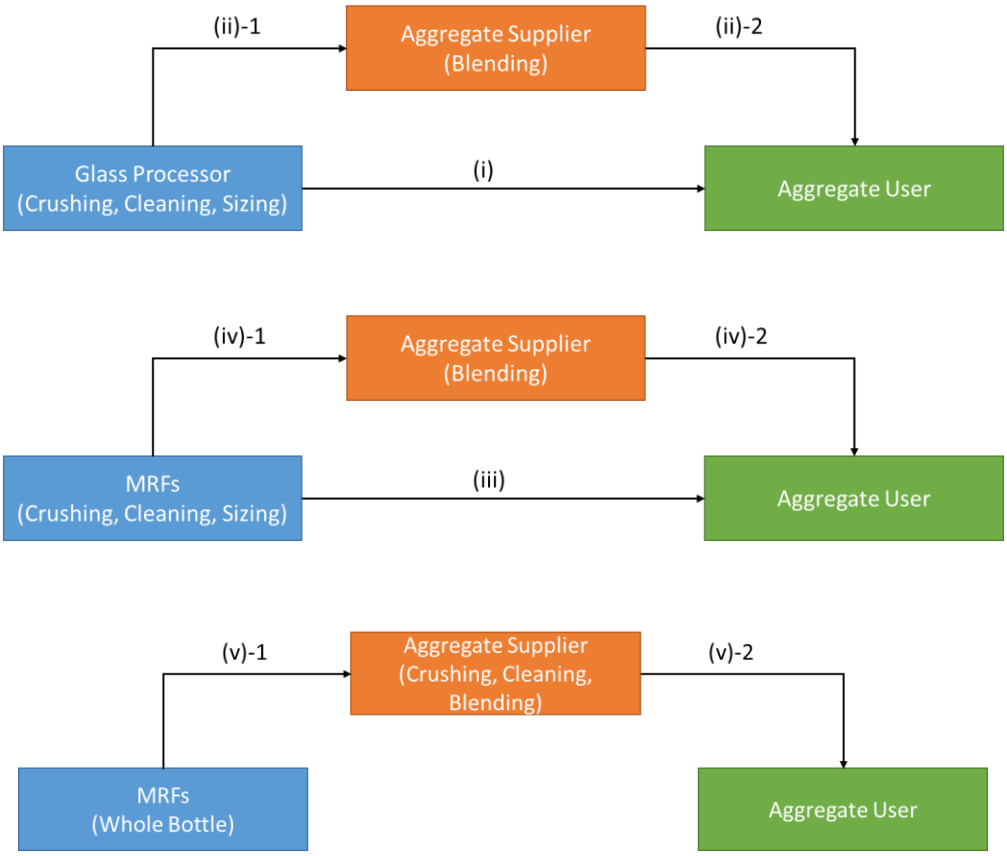

Figure 6. Mass-flow Alternatives for Use of Glass as Construction Aggregate

Glass cullet can be used as construction aggregate only when properly crushed, cleaned and sized. Apparently, glass processors already have the corresponding capabilities. The approach (i) indicates direct-use of processed glass in construction. This only works for applications that require 100% glass aggregates. Such applications include, for example, drainage fill, French drains, non-loading backfill and landscaping fill. Some MRFs are also capable of crushing glass and controlling the debris level, so approach (iii) is equivalent to approach (i), but will be more cost-effective, since it does not involve the freight cost from the MRFs to the processors.

However, 100% glass cullet is not recommended for other applications, such as load-bearing backfill, embankment fill, base course, subbase course, drainage backfill for walls and abutments, etc. Such applications typically require blending glass cullet with traditional aggregates at a specified replacement ratio, which is usually 10% to 30% depending on the application. There are three approaches to achieve aggregate blending: approach (ii) involves glass cullet from processors; approach (iv) involves crushed glass cullet from the MRFs; and approach (v) involves whole bottles from the MRFs, with crushing and blending by the aggregate supplier.

To choose from the proposed five alternatives, material availability, application type and cost are the determining factors. Assuming that material availability is not an issue (based on the survey), the final cost of the glass cullet for construction use depends on the costs for glass processing (crushing, cleaning and sizing), aggregate processing (blending), handling (loading/unloading) and transporting. The comprehensive cost analysis is beyond the scope of this report.

The advantages and disadvantages for each approach are summarized in Table 3.

Table 3. Advantages and Disadvantages of Various Approaches

Approach	Advantage	Disadvantage
(i)	Ready to use	Might be costly; limited application
(ii)	Easy to achieve different glass/aggregate mixtures; A variety of applications	Costly
(iii)	Cost effective	Limited MRFs with the required facility; Limited application
(iv)	Relatively cost effective; A variety of applications	Limited MRFs with the required facility
(v)	Very cost effective; Minimum requirement for MRFs; A variety of applications; Successful implementation in Minnesota can serve as a good reference [4]	Requires aggregate supplier to crush the glass with the virgin aggregate; Whole bottles have much larger volume/weight

5. Summary, Recommendation and Future Considerations

5.1. Summary

The current recycled glass market was surveyed to evaluate whether there will be a sustained supply of recycled glass for construction use in Ohio. It was found that:

1) The State of Ohio has both a huge supply (as high as 319,000 tons in 2015) and manufacturing demand (as high as 295,000 tons in 2015) for recycled glass;
2) In 2011, the recycled glass supply did not meet the demand of recycled glass from glass manufacturing;
3) With the efforts by Ohio EPA, the recycling rate of container glasses doubled between 2009 to 2015, and the current supply can now meet the manufacturing demand in a practical way; however, the recycling rate is still low (about 22% in 2015);
4) Both glass processors and material recycle facilities (MRFs) showed strong interest in participating in ODOT's project;

5) A better understanding of the recycling processes and the roles played by different stakeholders is critical to formulate effective strategic plans for further use of recycled glass in roadway construction;
6) If sourcing glass cullet from processors, the guaranteed continuous supply for construction applications includes 12,000 to 15,000 tons of Cathode Ray Tube (CRT) glass cullet per year from NovoTech, and at least 6,000 tons of container glass cullet per year from Rumpke. In addition, the study identified a one-time stockpile of 50,000 to 60,000 tons of container glass cullet is readily available from Strategic Materials, Inc.
7) If sourcing glass directly from MRFs, a continuous supply could be very promising, since MRFs receive very little benefit from glass recycling at the present time. Sourcing directly from MRFs might be the most cost-effective solution for a sustained supply of recycled glass for construction uses. Better coordination of MRFs, aggregate suppliers, and the end user is needed to cost-effectively use recycled glass for roadway construction. Currently, this does not exist.

After reviewing these findings, the Ohio's Research Initiative for Locals (ORIL) Board decided to discontinue additional research on this topic for the following reasons:

1) The projected annual supply of the materials that may be available is not sufficient for wide-scale use on local applications. Therefore, further investigation is not warranted at this time.
2) Considerable concern was expressed that the costs associated with shipping and processing of the glass for use in transportation projects would be excessive to the point that it would not be cost competitive with other materials.
3) The contamination of the primary supply with lead is a significant concern given current EPA regulations. Appropriately addressing this issue is expected to cause the cost of the product to increase. Given that the costs are already high, this would further reduce the potential for its use.

5.2. Recommendations

Maximization of the beneficial usage of recycled materials always requires joint efforts by all related stakeholders. Specific to this project, stakeholders involve ODOT districts, counties, cities, recyclers, MRFs, glass processors, aggregate suppliers, Ohio EPA, ODNR, etc. In order to expedite the process, ODOT can play a leading role by:

1) Developing specifications for using glass in roadway construction.
2) Coordinating the establishment of partnerships between select MRFs or glass processors and aggregate suppliers. This can start with a pilot program, coordinating one MRF with a local aggregate supplier. If this results in a win-win outcome, more MRFs and aggregate suppliers may participate.
3) Developing a certified list of glass/aggregate providers at some point in the future.

5.3. Future Considerations

To advocate using glass in construction, it is necessary to show the benefits of doing so to glass and aggregate stakeholders.

Current glass recycling and re-use in Ohio relies on the central role of major glass processors. However, the high cost involved in processing glass, as well as the cost for transporting to/from the processors reduces the already low value of glasses. Therefore, the current mechanism is not optimized and the upstream MRFs barely benefit from recycling glasses. On the other hand, glass processors need to increase their sale price to compensate for the high costs mentioned above.

Without a sufficient financial subsidy, the MRFs may reduce the recycling amount, processors will have lower supply and have to further increase the sale price, the manufacturers' demand will not be met and the competitiveness of recycled glass will be compromised due to higher cost. These results may cause a negative feedback loop to the recycling chain.

Mobilizing the enthusiasm of MRFs by providing them alternative mechanisms has the potential to improve the situation. MRFs have to send the glass to the glass processors, simply because they do not have other options. One alternative is to encourage MRFs to collaborate with local aggregate suppliers to provide glass/aggregate mixtures to the construction community, as shown in Figure 6.

There are many benefits of adopting glass cullet in roadway construction for different stakeholders.

For ODOT, ODNR and OEPA, benefits include:

- Potential construction cost savings
- Leveraging the credentials for Leadership in Energy and Environmental Design (LEED) and National Green Building Standards (NGBS) certifications
- Reservation of natural resources
- Reduction in landfill and waste

For MRFs, benefits include:

- Saving freight cost and generating profit
- Reducing storage space

For Aggregate Suppliers, benefits include:

- Conservation of virgin aggregate
- Potential reduction of freight cost since glass is lighter than virgin aggregate
- Leveraging the credentials as green aggregate suppliers

Reference:

[1] ODNR-Division of Recycling & Litter Prevention (2011) *Ohio Glass Recycling Study Final Report,* available at http://epa.ohio.gov/Portals/41/recycling/OhioGlassRecyclingStudy.pdf

[2] Ohio EPA, 2015 SWMD Annual District Reports, available at http://epa.ohio.gov/Portals/34/document/general/2015%20ADR%20Review%20Forms%20all%20SWMDs.pdf

[3] Ohio EPA, 2015 Material Recovery Facilities Annual Report, available at http://epa.ohio.gov/portals/34/document/general/2015FDR.pdf

[4] Minnesota Pollution Agency, Reclaimed Glass Information Kit, available at https://www.pca.state.mn.us/sites/default/files/glasstoolkit.pdf