Closing the Lifecycle Loop of Glass

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Abstract

Glass is one of the fundamental material of our civilization, offering the support for unique achievements as lighting, functionalities of buildings, cars and other transport vehicles, but also food processing and distribution etc. At European scale the total annual production of glass is estimated at 20.320.848 tones within EU 27 member states. The average recycling share at the EU scale is 70.28% of which Romania reached 25.55%.

The manufacturing of glass is one of the most resource intensive and energy intensive, as for each kg of glass there are consumed on average9 MJ energy.

Taking into considerations the entire life cycle of glass products an important concern is related to the recycle link and disposal of glass wastes.

The aim of the presented project was to develop an approach of closing the loop of the lifecycle of glass by identification of new glass reused chains and reduction of waste glass quantities to be send to the landfill units.

The approach that has been followed is based on the principles of sustainability oriented engineering and eco-innovation.

In the present report paper there are presented the results of the research project and recommendations for policy measures that could facilitate the practical implementation of recycling and green engineering in the glass waste processing sector.

Keywords: Glass recycling, Green economy, Glass Blasting, Life Cycle Assessment, Eco-Innovation.

Closing the Lifecycle Loop of Glass

Circular Economy – Green Sustainability Loops

Glass is one of the fundamental material of our civilization, offering the support for unique achievements as lighting, functionalities of buildings, cars and other transport vehicles, but also food processing and distribution etc. At European scale the total annual production of glass is estimated at 20.320.848 tones within EU 27 member states. The average recycling share at the EU scale is 70.28% of which Romania reached 25.55%.

In the case of glass used in food and beverage packaging, this is the only material that is endlessly recyclable back to its original use. Made from all natural resources – sand, soda ash, limestone, and recycled glass – glass has been and continues to be a safe container.

As an overview of the glass industry sector and its impact on the environment, there were analyzed several options, that could be used for the life cycle assessment of the glass.

Life Cycle Assessments allow for analysis at various stages of a product's life cycle:

1) Gate-to-gate — focusing on one particular plant or operation;

2) Cradle-to-gate — gate-to-gate findings with the addition of up-stream providers (mining of raw materials, processing and transportation);

3) Cradle-to-grave —encompassing the entire linear life cycle of the product from extraction through disposal;

4) Cradle-to-cradle—that includes the entire cradle-to grave life cycle of the product with the addition of recycling the product back to its original purpose. (Glass Packaging Institute, Environmental Overview).

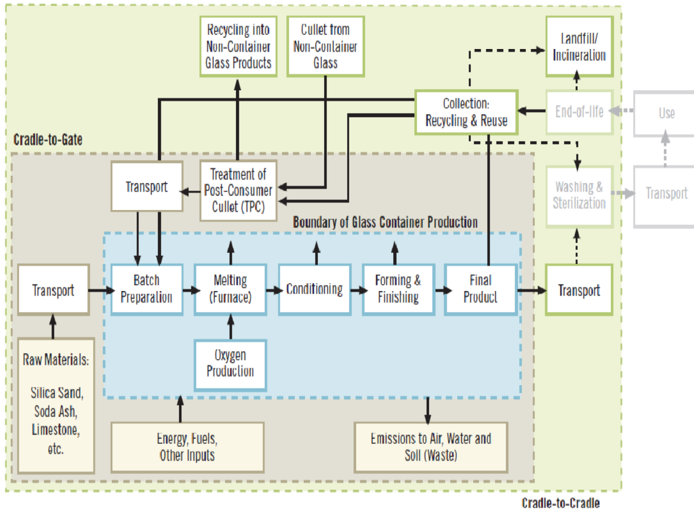

Figure 1 LCA of Glass

In the present project it was supposed a cradle-to-cradle approach, in the sense that glass is reused as crushed cullet for blasting in shipyards and ship repair yards. A subsequent reuse supposes the washing and sterilization of the used cullet and its integration in heavy clay products such as bricks, tiles, concrete etc.

In this respect, the need to consider the entire lifetime of the development of the product or services is obvious. The analysis and optimization of each single element of the value chain integrates in the objective function, the minimization of the environmental impact. Many examples exist where incremental improvement of existing technologies has increased resource productivity two to four times. This approach opens new perspectives to the implementation of the sustainable development concepts.

The strategic mix for the implementation of sustainable development concepts in the manufacturing cycles includes three main pillars that are intimately bundled together:

- To continue improving the efficiency of the use of resources;
- To re-engineer the industrial, economic and social processes in order to be consistent with the natural cycles;
- To educate the people to have a fundamental new understanding of welfare, shifting from opulence towards sufficiency.

From an engineering perspective, the most important challenge today is the accurate description of the complexity of the systems and processes. The main characteristics of such a complexity might be categorized as follows:

- Systems of systems - The systems are embedding sub-systems and sub-sub-systems;
- Emergent behavior - Behavior at a higher level is the result of many behaviors at lower levels;
- Adaptive – Changing the properties according to the constrains;
- Synergy - Cannot predict the properties of the system from its constitutive parts.

The classical definition of engineering as the application of scientific and mathematical principles to practical ends such as the design, manufacture and operation of efficient and economical structures, machines, processes and systems, in shipbuilding and ship repair industry, is not suitable to address such a complexity. In the current context of the development of the mankind society, the complexity of the needs require to address them by emphasizing a more cross-disciplinary, whole-systems approach to engineering.

Such an approach is called Holistic Engineering as the Art and Science of creating effective systems, using whole system and whole life principles. As the basic tools in Holistic Engineering, there were developed the multi-dimensional models.

The fundamental objective of holistic engineering is innovation. In a traditional acceptation, innovation is “the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations". Such a definition is neutral in the sense that it does not determine the content or the direction of change.

The term environmental innovation, or shortly ‘eco-innovation’, relates to innovations aiming at a decreased negative influence of innovations on the natural environment.

Eco-innovation is the development of manufacturing activities by creation of novel and competitively priced materials, equipment, processes, systems, services and procedures designed to satisfy all requirements of the customers and related activities with a life-cycle minimal use of natural resources (materials including energy and surface area), and a minimal release of toxic substances".

Energy Consumption and Environmental Impact

According to (UNIDO, 1993) the energy consumed for glass production could be characterized as following:

- The glass industry uses approximately 40% electric energy and 60% on fuels and natural gas used as booster energy in melting tanks and throughout the plant for lights, pumps, fans, forming equipment and compressed air systems.
- Glass isn't the biggest energy consumer, but the 30 MJ/Kg consumed at the beginning of glass processing are considered important too. Considering this, we are following to minimize the glass energy consumption and in the last years the value has been reduced to 5-7 MJ/Kg.
- Unit energy consumption varies greatly depending on the production scale. It also depends on the kind of glass because it is related to the quality level.

This is an example of energy consumption in one random unit:

MJ/glass tone	Heavy Oil	Kerosene	LPG	City Gas	Electricity	Total	%
Batch					61.5	61.5	0.58
Melter	6774.2				710.1	7484.3	71.03
Forehearth	74106.4		618.0		3.3	809.3	6.89
Forming				3.3	1124.1	1127.5	10.70
Lehr			401.5		119.7	521.2	4.95
Printing, Working			264.6	3.8	64.5	332.9	3.16
Package					19.7	19.7	0.19
Others	2.1	0.8	13.4	5.9	149.9	172.1	1.63
Total	6850.0	0.8	1297.5	13.0	2375.6	10537.3	
(%)	65.0	0.01	12.3	0.12	22.5		100

Table 1 Energy consumption in one random unit

The consumption of energy may be connected also to the environmental impact issues. Based on the analysis that have been conducted during the implementation of the project it has been observed that the environmental issues are mostly regulated by dedicated documents for pollution control and prevention.

CLOSING THE LIFECYCLE LOOP OF GLASS

The Integrated Pollution Prevention and Control (IPPC) Regulations Directive, introduced in 2004, sets out targets within permit conditions to reduce pollution and emissions which glass companies will be required to meet. The use of waste glass reduces CO_2 emissions from two sources: reductions in energy requirements and reductions in CO_2 production. For aspects of an installation not regulated, permit conditions will require companies to use Best Available Technologies (BAT) to prevent and reduce emissions.

Use of cullet in glass making will reduce CO_2 emissions from two sources. First, the reductions in energy requirements associated with increased use of glass cullet in furnaces will produce similar reductions in gaseous emissions such as CO_2 from the burning of fossil fuels. Second, melting cullet glass instead of using virgin raw materials will avoid CO_2 production from the thermal degradation of raw materials containing carbonates such as soda ash, limestone and dolomite. It has been estimated that for every ton of glass produced from virgin raw materials, approximately 200 kg of CO_2 are released from the breakdown of carbonate raw materials. Increased cullet use will also reduce particulate and nitrogen oxide emissions from the glass furnace. Unlike other abrasives, glass does not contain significant chlorides or other salts which can accelerate the corrosion of cleaned surfaces.

On the matter of air pollution, the use of glass cullets does not increase the amount of particles which are normally released. At the same time, the technologies used for blasting in general and for grit blasting or glass blasting, need to be equipped with systems which are able to reduce or to cancel the impact on air. Such systems for example are using water spray at the blasting nozzle, which is not affecting the efficiency of the blasting system and at the same time, the water is mixing with the glass cullets and prevents them to become airborne. The same system prevents the broken glass of dissipating on a large area as well.

Directive 2008/1/EC is a codified version of the first IPPC directive which came into force on 24th of September 1996. The Directive 2008/1/EC 2008 concerning integrated pollution prevention control is amended by Article 37 of the Directive 2009/31/EC of the European Parliament and of the Council (OJ L 140, 5.6.2009, p. 114), will be repealed with effect from 7 January 2014 by the Directive 2010/75/EU of 24 November 2010 on industrial emissions (integrated pollution prevention and control), without prejudice to the obligations of the Member States relating to the time limits for transposition into national law and application of the Directive as set out in the Annex IX, Part B.2 of the Directive 2010/75/EU.

Sector/activity	**Pollutants**
Container Glass	
Material handling	Dust, crystalline silica
Melting process	Dust, CO, NOx, SO_x, HF, HCl, heavy metals
Hot-end coating or treatment	Dust, organic and inorganic tin, HCl, SO_x
Flat Glass	
Material handling	Dust, crystalline silica
Melting process	Dust, CO, NOx, SO_x, HF, HCl, heavy metals (for colored glasses)
Surface treatment	SO_x
Continous Glass Filament	
Material handling	Dust, crystalline silica
Melting process	Dust, CO, NOx, SO_x, HF, HCl, boron compounds
Downstream activities	Dust, VOC, formaldehyde, ammonia, waste water
Domestic Glass	
Material handling	Dust, crystalline silica, heavy metals
Melting process	Dust, CO, NOx, SO_x, HF, HCl, heavy metals, boron compounds
Downstream activities	HF, Pb, waste water, (from polishing and gridding)
Special glass	
Material handling	Dust, crystalline silica, heavy metals
Melting process	Dust, CO, NOx, SO_x, HF, HCl, heavy metals, boron compounds
Downstream activities	Dust, Pb, waste water, (from polishing and gridding)
Mineral wool	

Material handling	Dust, crystalline silica,
Melting process	Dust, CO, NOx, SO_x, HF, HCl, boron compounds, H_2S
Downstream activities	Dust, Voc, phenols, amines, ammonia, formaldehyde, NO_x, waste water

Table 2 Main pollutants that have to be taken into consideration in the glass industry (JRC Reference Report-Best Available Techniques (BAT), 2013)

In particular, glass waste from surface blasting has the property of not mixing with water as an absorbent. The process is based on adsorption, which implies the adhesion of water to the surface of the glass particles, without permeation into the volume. This means, that in terms of separating the glass particles from the water, the process is simpler. The separation systems for other types of blasting media can be complicated and energy consuming (e.g. filters, use of chemicals etc.). The systems for glass-water separation are mostly based on gravimetric separation and the collection of uncontaminated water at the surface and glass from the bottom.

Decision 2000/532/EC establishes a list of hazardous wastes, among which we can find glass. Glass is found under Chapters 10. Inorganic wastes from thermal processes, Chapter 15. Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified, under Chapter 17, Construction and demolition wastes (including road construction) and under Chapter 20. Municipal wastes and similar commercial, industrial and institutional wastes including separately collected fractions.

Commission Regulation (EU) No 1179/2012 of 10 December 2012 establishing criteria determining when glass cullet ceases to be waste under Directive 2008/98/EC of the European Parliament and of the Council establishes the criteria on which glass cullet ceases to be waste: cullet resulting from a recovery operation meet the technical requirements of the glass producing industry, comply with existing legislation and standards applicable to products and do not lead to overall adverse environmental or human health impacts. This Regulation applies from 11 June 2013.

The Landfill Directive (Council Directive 1999/31/EC) aims to prevent, or to reduce as much as possible, the negative environmental effects of landfill. One of its provisions is the classification of wastes under hazardous, non-hazardous and inert. Landfill tax regulations come to complete this measure by increasing taxes for hazardous wastes.

As it was presented in previous paragraph, one of the aims of the project is the minimization of landfill waste by using glass in concrete and clay products. As it was presented in an article from Michigan University (Parviz Sorousian , 2012), the team of experts managed to replace some of the concrete with milled glass, which achieved a 15-20% of replacement of concrete with glass.

The manufacturing of concrete is one of the most energy consuming elements from the entire asphalt mix. Another fact is that only around 30% of the glass which is disposed in various ways is reused. The rest is send to landfills. According to the Thematic Strategy on the Prevention and Recycling of Waste, there were estimated around 510 – 970 million tons of waste glass which are sent to landfills annually.

As the activities of the project are aiming the sustainable and efficient use of glass, the identification of and marketing of closed loops for the use of recycled glass in surface blasting and the integration of the glass after blasting into concrete structures or clay products, will lead to a decrease in glass which will be sent to landfills and an increase in sustainable and energy efficient use of glass.

Life Cycle Impact Assessment

The increased awareness of the importance of environmental protection, and the possible impacts associated with products, both manufactured and consumed, has increased interest in the development of methods to better understand and address these impacts. One of the techniques being developed for this purpose is life cycle assessment (LCA). LCA can assist in:

- identifying opportunities to improve the environmental performance of products at various points in their life cycle,
- informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign),
- selecting relevant indicators of environmental performance, including measurement techniques, and

- marketing (e.g. implementing an eco-labeling scheme, making an environmental claim, or producing an environmental product declaration).

Pathways for Reusing Glass Waste

The collection and different end-of-life management options for glass packaging that have been analyzed are as following:

1. Closed-loop of glass packaging back to new packaging
2. Recycling of glass packaging into non-packaging products or fiberglass
3. Losses via aggressive landfill cover, incineration
4. The integration of glass in heavy clay products

The short overview of the lifecycle of glass points out the necessity to identify the big actors with an over plus of glass, along the lifecycle, from producers to users and to waste collectors and recyclers and the heavy clay manufacturers willing to further process the glass and integrate it in their products. These actors have been included in a special application organized as a Geographic Information System (GIS) which is available from http://greenblast.greenshipyards.eu

There were also studied the connected aspects such as:

- the cost of transport;
- who washes and sterilizes the glass and for what costs;
- further crushing of the glass, according to heavy clay requirements and the costs.

The integration of glass in heavy clay products has previously been investigated by WRAP Report "Full scale operational trials involving the use of recycled glass in the heavy clay industry (bricks and tiles)", which proved the feasibility of including glass especially in extruded products as opposed to soft clay bricks. An important aspect in this study was the breakeven point, meaning that the cost of transportation and of preparation of the powdered glass may surpass the financial benefits of its use and therefore there is a high sensibility to any market variations.

The methodology used for the development of the current report is based on the morphological analysis of the most relevant areas that might be subject to regulations and standards. Essentially, general morphological analysis is a method for identifying and investigating the total set of possible relationships or "configurations" contained in a given problem complex. In this sense, it is closely related to typology analysis, although GMA is more generalized in form and has far broader applications. The approach begins by identifying and defining the parameters (or dimensions) of the complex problem to be investigated, and assigning each parameter a range of relevant "values" or conditions. A morphological box - also fittingly known as a "Zwicky box" - is constructed by setting the parameters against each other in an n-dimensional matrix. Each cell of the n-dimensional box contains one particular "value" or condition from each of the parameters, and thus marks out a particular state or configuration of the problem complex. (General Morphological Analysis. http://www.swemorph.com/ma.html)

Green Glass Value Chains

The concept of green supply chain has emerged as a result of the growing concerns due to environmental pollution (Zhu, Q., Sarkis, J. and Lai, K., 2007). “Green supply chain is defined as the integration of environmental concerns into the inter-organisational practices” (Sarkis, J., Zhu, Q. and Lai, K., 2011). As it was presented in the first paragraph, the current concerns on environmental pollution and sustainable development are leading towards a new approach that is called eco-innovation. In the very simple understanding a supply chain designed to avoid pollution can be termed as a green supply chain, but the pollution has to be taken into consideration both from the perspective of operational pollution and life cycle pollution. Unfortunately the economical, commercial and social aspects might be in many cases much more important for the decision makers and the general approach for green supply chains is much more complex.

Basically, a supply chain is typically a network of processes or organizations working together for the purpose of achieving their common goals (Chan, H. and Chan, F., 2010). According to Gupta et al, (2013), each of the processes or organization in the supply chain network performs a unique or separate task of adding value to a product or service along the supply chain with the overall aim to satisfy customers at the end of the supply chain (Arlbjorn, J., Freytag, P. and de Haas, H., 2011). For example, the task of a material recycling plant will perform the task of adding customer value to a recycled material. The customer value discussed in this research refers to the value of recycled material from waste to an end user based on end users requirements in terms of standards.

The introduction of recycled materials which are usually classed as green products in green market is likely to be successful with an innovative supply chain design involving necessary processes in place to deliver recycled resources that meets customer requirements. An inclusion of a process in the supply chain network with the overall aim of meeting an end-user requirement will encourage an end user to adopt the use of the recycled material thereby avoiding landfill, which is major aim of the green supply chain.

A material recycling facility is an entity that adds value to a product (mainly waste products) in a supply chain for the purpose satisfying customers by recycling products to fit end users requirements (Beamon, B., Fern, and es, C., 2004). However the need for inclusion of material recycling process is determined by customer requirements. If after a careful evaluation of properties of recycled material based on end users requirements, the material is found to be of no use to any end user, the materials can be recommended for processing so as to satisfy an end users requirement. This will be the only way to avert landfill. Therefore the decision to include a material recycling plant in the supply chain comes with the necessity of delivering customers' needs at the same time, avoiding pollution. For example, if customers will only accept recycled material that has been fully recovered or processed, then it is important to include a material processing facility in the network design of the supply chain.

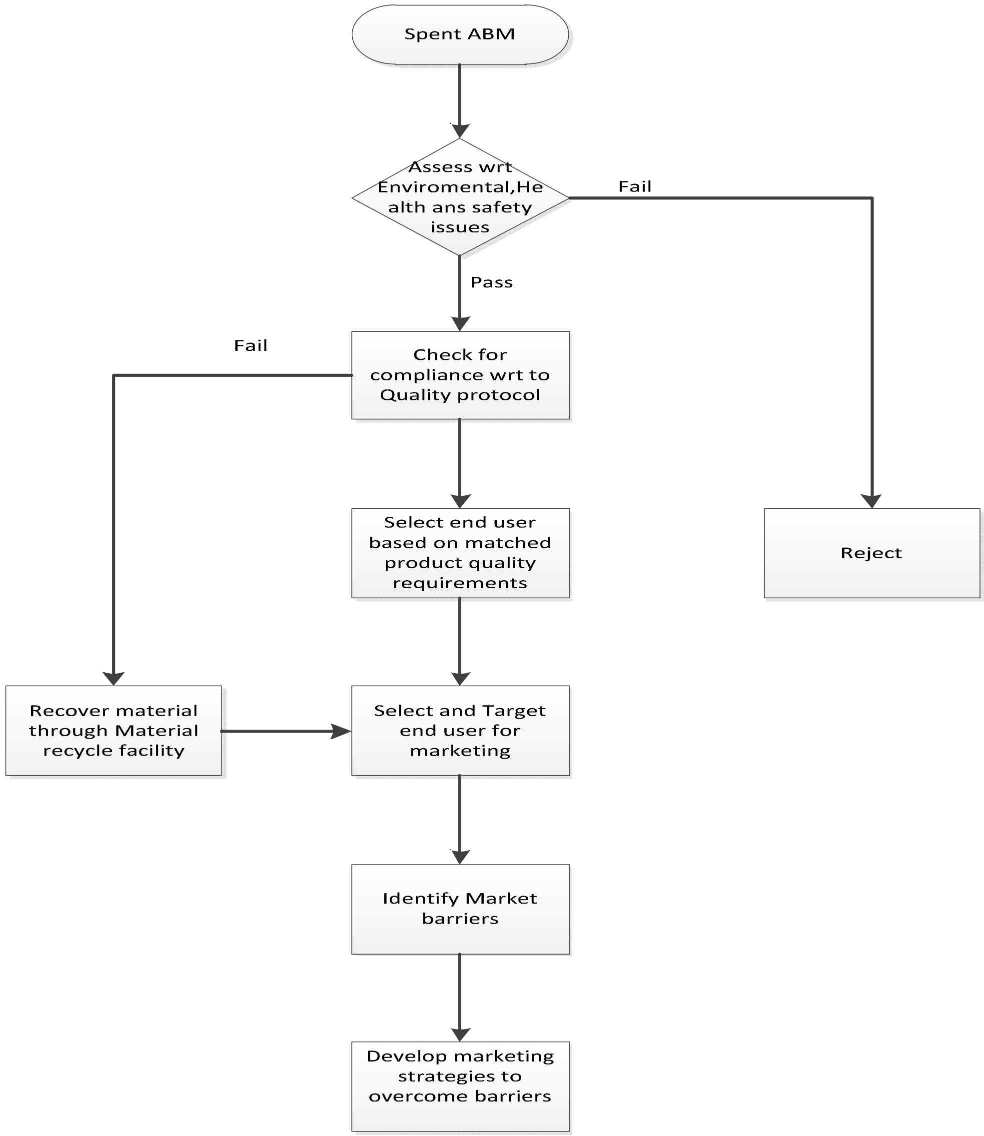

Figure 2 The research frame work for identification and selection of end users of spent ABM from ship yard

Case study for the Constanta Region:

Starting with 2012 under the coordination of Shipbuilders and Shiprepairers Association and a consortium involving partners from UK, Croatia and Romania, it is under implementation the project GREENBLAST ”Using Recycled Glass for Pressure Blasting Steel Surfaces and the Waste Produced in Firing Heavy Clay Constructed Products”. As one of the outcomes of this project it has been developed a map of glass recycling companies, processing, shipyards and clay manufacturers. As it may be seen in the figure bellow:

Figure 3 Map with the positions of glass recycling companies, process in, shipyards and clay manufacturers

Using the interactive map as a tool, it has been developed a dedicated application for the Constanta Region.

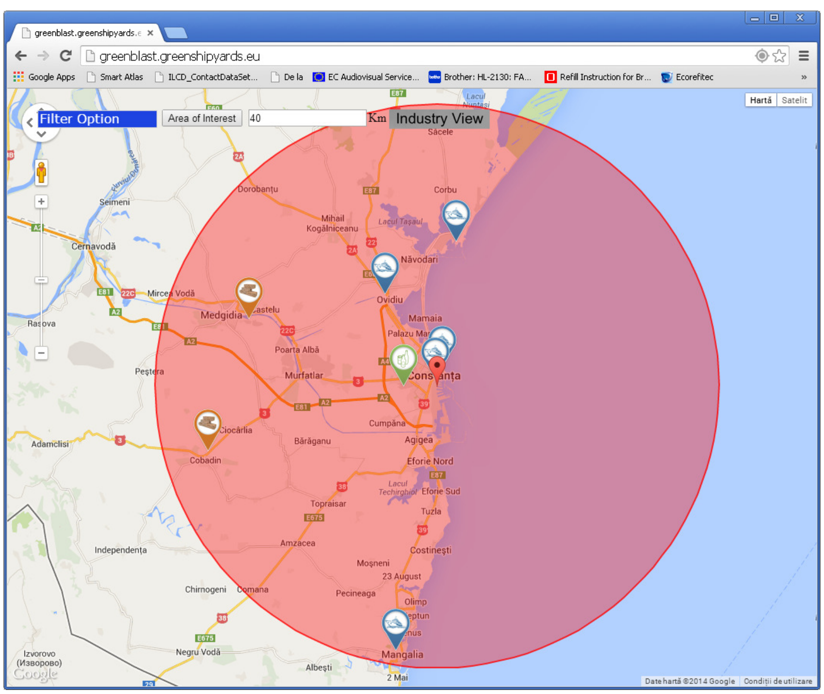

Figure 4 The positioning of the main actors involved in a green supply chain in the Constanta Region

From Figure 4 there were selected two main players as following:

CLOSING THE LIFECYCLE LOOP OF GLASS

GREMLIN (www.gremlincom.ro) that is specialized in selective waste collection, processing and recycling. Specifically, in the case of glass wastes, Gremlin provides services as collection, transport, treatment, recovery and recycling. At the same time, Gremlin has a specialized unit for construction materials that is incorporating waste glass and other type of solid wastes in pavements, bricks or other similar products.

METACOM (www.metacom.ro) is one of the foremost providers of marine repair, building and conversion services and a leading provider of construction and repair services to the energy, commercial and industrial markets in Romania. Their highly qualified workforce and state of the art equipment, as well as the satisfaction of our local and international business partners make us proud our achievements.

For this simple case, there were identified the following tasks:

- Collection, transport and processing of waste glass that is provided by Gremlin. As an outcome there is obtained a mixture of glass culets with the size between 1-3 mm;
- Transport of glass culets to the ship repair company Metacom;
- The use of glass culets as ABM at the premises of Metacom;
- Recovering of used ABM and transport to the premises of Gremlin;
- Incorporation of recovered glass culets in the structure of pavement bricks.

The process that is followed at GREMLIN consists on a first phase where the glass is sorted by color, in order to be treated according to their final destination. For the treatment of waste glass there are available two automatic technological lines dedicated to the processing of waste glass from damaged car windshields and to crushed glass containers. The installation for treating windshield glass has a capacity of 4 tones/hour allowing to obtaindifferent granulations of glass, from 0.01 mm up to maximum 50 mm.

In our research it has been imposed to use a granulation from 1 mm up to 3 mm for glass blasting.

The buying price of the glass is about 40 euro/ton, making it a lot cheaper than the grit that cost up to 90 euro/ton. With that in mind and the fact that the resulting mixture after grit blasting, contains other substances developing a dangerous waste that becomes very expensive for transport and disposal, particularly when it gets in contact with hexavalent chromium, it is very obvious the advantage of using waste glass as blasting media.

As a consequence the transport cost for glass cullets is in the range of 1euro/ton*km and in the case of blasted materials with grit the price may raise with the factor of 20.

For the specific tests that have been carried out in Constanta there were selected usual samples of glass cullets from the waste windshields glass treatment line located at GREMLIN. In Figure 5 there is presented a sample of glass cullets as it was selected for tests.

Figure 5 Selected sample of glass cullets. Granulation between 1-3 mm

As a measure for assuring the safety of the equipment for blasting, the glass cullets have been filtered and checked with a precision sieve of 2 mm.


Figure 6 Testing with laboratory test sieve

The characteristics of the blasting equipment that was offered for testing by METACOM were the following:

- The working pressure: 9-12 bar
- The consumption of blasting material depending of the required roughness 25-100 kg/m^2
- Annual capacity: 400000 m^2/year

The tests have been conducted with different types of plates in different conditions and the typical results that were obtained are presented in Figure 7.

Figure 7 Results of blasting with glass cullets

The samples that have been obtained have been tested at the laboratory for mechanical measurements from “Ovidius” University of Constanta using a dedicated micrometer for measurements of roughness. As it may be seen in Figure 8 the instrument was type Elcometer and the average roughness was in the range of 149.6 μm.

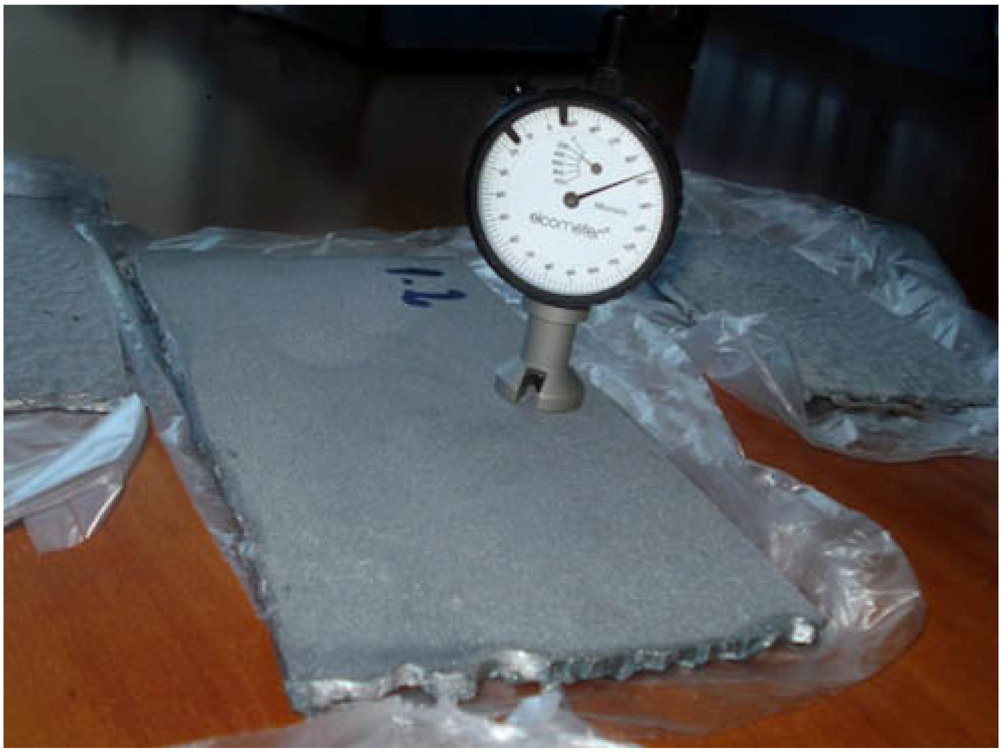

Figure 8 Measurement on the roughness of obtained samples

Advanced investigation has been done also on the quality and specific characteristics of the resulting surfaces after the blasting and as it may be seen in Figure 9 the quality of the surface look excellent in images that have been taken with optical microscope.

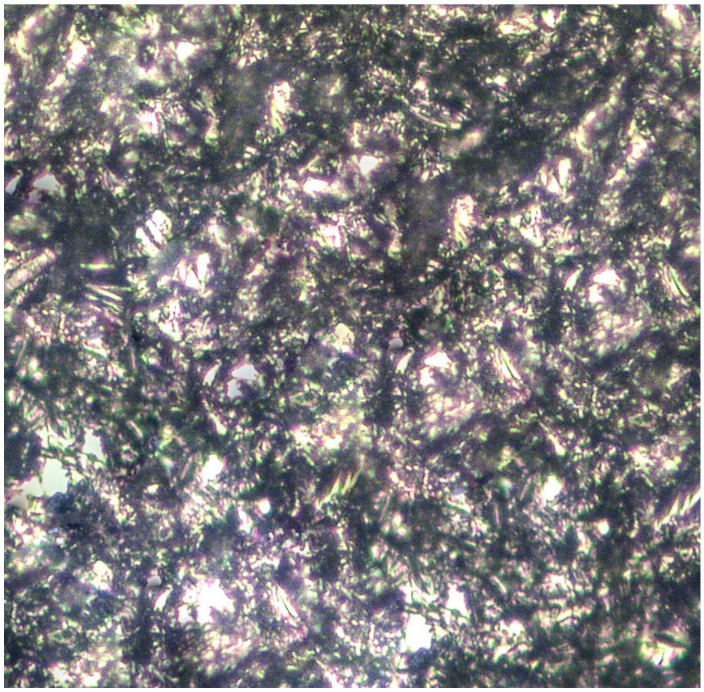

Figure 9 Obtained images of the quality of the surface after blasting using an optical metallographic microscope at a resolution of x20

After caring out the tests and measurements, the quality and efficiency of using glass cullets as blasting media were excellent. In the next phase it has been studied the possibility to recover the wasted glass cullets after the blasting process that have been transported back to GREMLIN premises where it is organized a specific platform for manufacturing pavement bricks by integration of waste glass in different types of mixtures.

The dedicated platform from GREMLIN has the capacity to integrate a broad range of waste materials in different types of mixtures using adequate recipes.

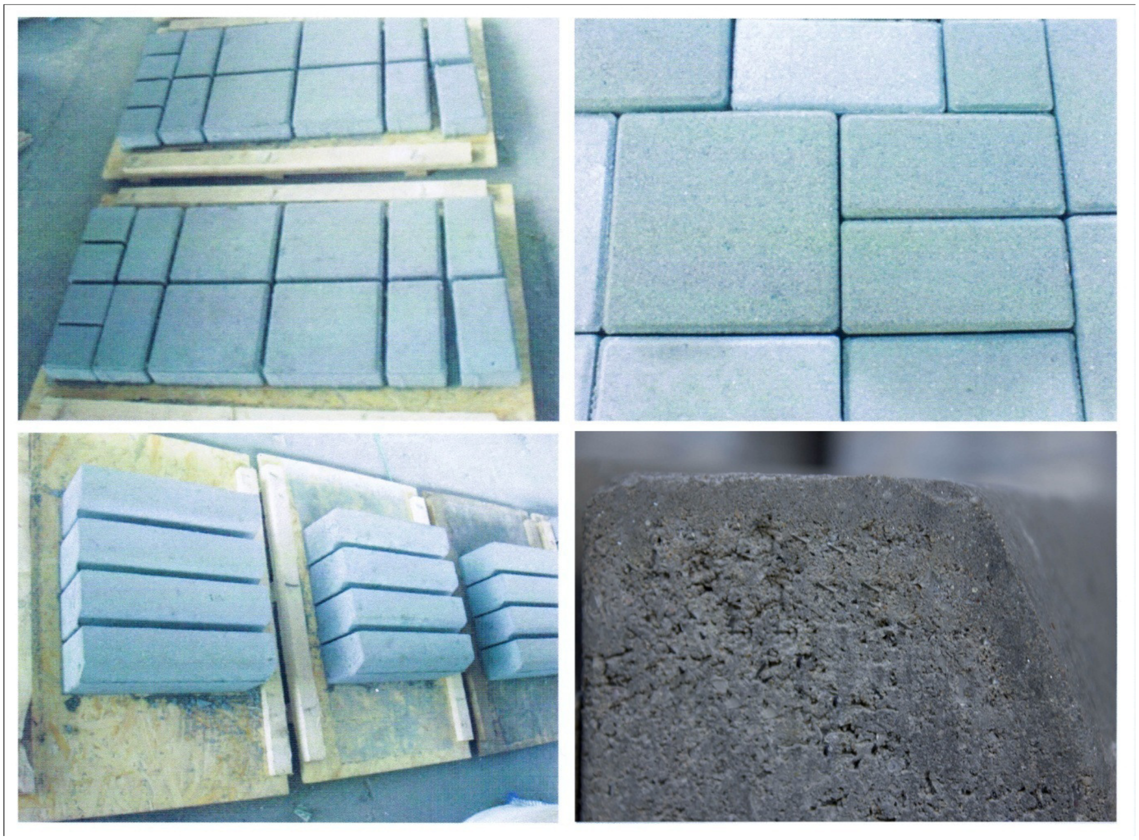

Figure 10 Integration of waste glass in construction materials

At present the technology that have been identified are in the phase of technical and economical evaluation in order to select the appropriate parameters and to design the logistics for an economical feasible concept.

Health Protection

Although recycled glass as a blasting media is inert and non-toxic, COSHH assessment of the blasting operations should be carried out, as operators need to be aware of the possible risks such as eye or lung irritation, which is why protective equipment has to be worn. Glass size less than 5 mm represents no special hazards; at this particle size no sharp edges are evident, although, as with other shot blast media, gloves are recommended when handling.

When comparing glass with copper slag, glass is a clean abrasive which does not cause such harm to human health, while cooper slag contains heavy metals that can cause harm to human health.

Silicosis is a disabling, non-reversible and sometimes fatal lung disease caused by overexposure to breathable crystalline silica. There are three types of silicosis, depending upon the airborne concentration of crystalline silica to which a worker has been exposed (NIOSH, 1999):

Chronic silicosis usually occurs after 10 or more years of overexposure.

Accelerated silicosis results from higher exposures and develops over 5-10 years.

Acute silicosis occurs where exposures are the highest and symptoms may develop within a few weeks or up to 5 years.

Silicosis is caused by inhalation of crystalline silica but the glass manufacturing process destroys crystalline silica and all the silica is bound within the glass matrix. Therefore, unlike sand, it is safe to use and any dust generated is virtually free of crystalline silica and is classified merely as a nuisance dust.

Glass does not contribute to the lung disease silicosis.

Surface blasting by means of glass cullet does not require any specific safety precautions. Furthermore, glass is safe around electrical equipment. In comparison, copper slag, steel shot and UHP present hazards around electrical equipment.

Conclusions and recommendations

The paper is summarizing the results of a research activity that has been developed in collaboration with a group of research and experts from specialized companies.

By conducting the research activity included in this project it has been demonstrated that the glass waste could be successfully used as blasting media by appropriate processing and the results that are obtained are competitive with the classical technologies that are used for blasting at present.

The important advantage of using glass cullets as blasting media is that after blasting, the resulting mixtures could be integrated in construction materials, offering the possibility to obtain high performance structures at lower costs.

From environmental impact point of view the use of glass in blasting processes has a very low impact both from operational point of view and for a life cycle reasoning.

The impact of glass particles on health and safety of human operators is very low and is avoiding one of the most common professional diseases as silicosis. Glass does not contribute to the lung disease silicosis.

Taking into account all the above mentioned arguments, the integration of glass waste in blasting and other similar technologies is offering an excellent opportunity to develop a very high rate of recycling and an almost closed loop value chain with minimal harm on the environment.

Policy recommendations: During the implementation of the research project, we had the possibility to observe that even if there are strong arguments for the implementation into practice of the results of this project, there is a need to develop a systematic approach on behalf of local and national authorities.

A possible approach might be to introduce a system of taxation of the wastes that are sent to the landfill disposal in order to encourage the initiation and sustainability of the businesses specialized on reuse and recycling of glass wastes.

An alternative approach might be to subsidize the companies that are specialized in the collection, selection of recycling of wastes by specific programs dedicated to the development of the sustainable culture.

In order to encourage the integration of different types of solid wastes, including glass in construction materials, bricks, pavements, concrete, road coverage and so on, it might be a possibility to reduce the Value Added Tax (VAT) in a percentage according with the quantities of integrated wastes.

Acknowledgement

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