Sustainability aspects of SMC/BMC based products

Position paper from the European Alliance for SMC/BMC

June 2011

1. Introduction

The choice of a material for producing a part of a car or making a bridge is estimating for a large part the impact that such a product has on the environment and on the human being. The choice for steel, concrete, wood or plastic is very often made on economical arguments, but with the increasing awareness of the influence of men on the environment and the climate, also sustainability arguments become of more influence on the selection of the material.

The European Alliance for SMC/BMC, the European branch organization in which all steps in the value chain are represented by the leading companies, has recognized this and has taken the initiative to write this publication.

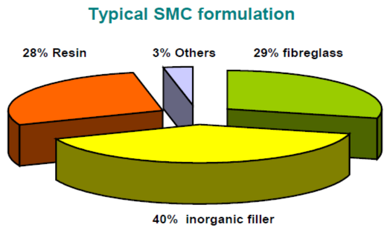
The Alliance supports raising the standards of technical competence and knowledge in the field of SMC and BMC throughout Europe via workshops, seminars, press articles and publications.

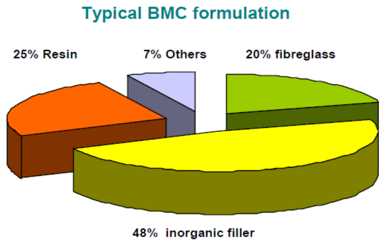
The base of this publication are official documents from governmental bodies, results from independent investigations, publications from the industry itself and the experience of the members of the Alliance. All members of the alliance have contributed to this publication.

The objective of this document is to provide information regarding all sustainability aspects of the use of SMC and BMC during its production, use and end-of-use phases. It can be used as reference for other publications and press articles.

2. What is SMC/BMC

SMC and BMC are abbreviations of respectively Sheet Molding Compound and Bulk Molding Compound. SMC and BMC form a family of structural, fiber reinforces thermosetting resins. SMC and BMC are intermediate materials from which a large variety of products can be manufactured by compression molding or injection molding.





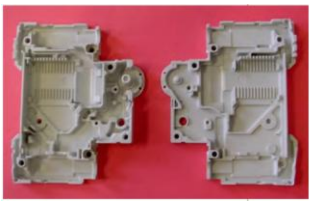
Base materials of SMC and BMC are, generally spoken, unsaturated polyester resins, glass and mineral filler materials, such as chalk or aluminum trihydrate. The composition of the compounds can be adapted to the application where it is used for. Specific properties such as flame retardancy, surface quality and paintability can be achieved by adding specific, functional materials.

SMC and BMC product are used in a very broad range of applications, such as:

- **Automotive**: cars, trucks and other commercial and agricultural vehicles (body parts, structure and engine parts)

- **Mass transport**: trains, trams, light railways and monorail

- **Electrical & electronics**; housing, fuses, switchgear, etc.
- **Building & construction**: civil engineering and household fixtures
- **Domestic appliances**: coffee machines, toasters, irons, etc.
- **Sanitary** : bathroom suites and hygienic surfaces

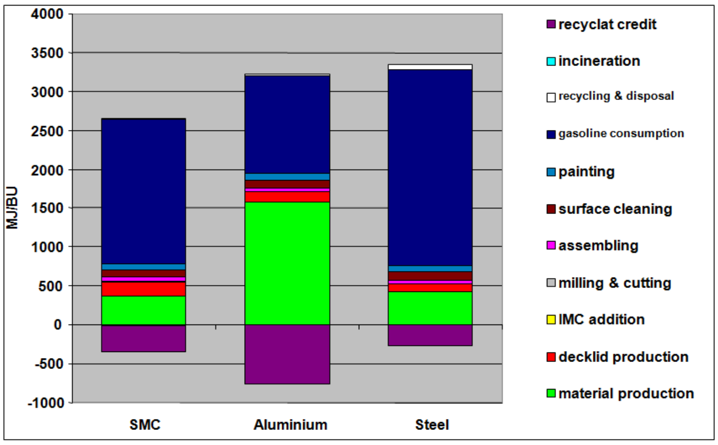


SMC and BMC are used in this wide variety of applications due to the combination mechanical and physical properties at the lowest system cost, without compromising on quality.

Feature	Benefit
Excellent mechanical properties even at very high and very low temperatures	From the Arizona desert to the Arctic Circle, SMC/BMC parts retain their mechanical strength without ageing.
Design freedom	Shapes are possible that could not be produced via metal stamping, and additional strength can be 'engineered-in.'
Low thermal expansion coefficient comparable to steel	Enables steel / aluminium / SMC/BMC hybrid assemblies to be produced with complete compatibility.
Low weight	Low weight means energy savings over the lifetime of a part: greater fuel efficiency and reduced CO_2 emissions throughout the life of a vehicle.
High temperature paintability	No loss in properties during and after paint cycle (online painting / paint ovens).
Chemical resistance	Resistant to acidic and alkaline chemical environments, water, moisture, many organic solvents and all fuels being used under the hood.
Excellent dimensional accuracy and stability	High part stiffness and heat stability enables close tolerances to be achieved.
Low system costs through integration of parts and functions	Screws and inserts can be moulded in and multi functional SMC/BMC parts can replace many separate metal parts requiring sub-assembly. Easy to bond.
Favourable life cycle comparison	Life Cycle Analysis (cradle to grave) comparisons show that SMC/BMC parts compare favourably to steel and aluminium.
Flame retardant and low smoke emission, halogen-free formulations	Fire safety in mass transit vehicles and public buildings. Fully compatible with the most stringent fire standard (BS 6853) and the new European standard (EN45545).
Superior sound dampening compared to aluminium and steel	SMC car and truck body panels absorb more sound and engines fitted with SMC/BMC sumps and valve covers are quieter than aluminium equivalents.
Fully permeable to radio signals	GPS, GSM, FM and AM antennae and amplifiers can be invisibly mounted within the component. This integration of functions means optimised design and savings in assembly time.
Speed to market	Low system costs mean model changes are easier and less expensive to implement. The timeframe from design concept to production can be shortened in SMC/BMC versus metals. An important benefit especially for consumer electrical/electronic goods and automotive OEMs.
Customization	SMC/BMC are highly versatile materials that can be custom formulated and moulded to meet exact performance and end-use specifications.

3. SMC/BMC and Sustainability: executive summary

SMC and BMC based products have in many applications a lower environmental impact than the same products made in other materials such as metals, thermoplastic polymers and concrete. Due to a combination of a limited impact in production of the base material, lower weight in service, longer lifetime due to its high durability and the possibility to recycle SMC and BMC parts, the total life cycle impact is lower than for other materials.
Earlier Life Cycle Assessments (LCA) have already shown this in specific applications. The European Alliance for SMC/BMC has done an LCA on a deck lid of a passenger car in 2005. In this comparison with steel and aluminum, it was made clear that SMC has the lowest environmental impact.



Comparison of the life-cycle energy content of different material concepts

"The environmental benefits of metals are only based on the possibility to recycle metals. SMC/BMC has much more environmental arguments, such as light weight, low energy consumption, long lifetime AND recyclability"

4. What is sustainability about?

The environmental impact of SMC/BMC has a wide range of different aspects during the life time, or better, the use time of a part that is made in these materials. It is important to look at the total life cycle of a product: the total environmental impact is the total of the effects during all the different phases of the life of a product.
This publication will address these aspects in more detail. The themes that will be described with practical examples are:

- used materials and emissions in production: styrene and other materials
- energy use in production: all steps until finished parts
- use of renewable vs. scarce materials: bio materials, use of local available materials
- energy reduction due to use of composites/SMC: weight reduction and thermal insulation
- composites as material in greener applications: renewable energy, aerodynamic design, etc.

- longer lifetime & end-of life solutions: low maintenance and recycling/re-use

There where possible, comparisons will be made with other materials that are used in the same or similar applications. Most important is that the statements that will be made in the publication are supported by examples and evidence.

5.The six sustainability themes of SMC BMC

5.1 used materials and emissions in production

SMC and BMC are mix of different materials which give the specific properties to the material and the end product. Generally spoken an SMC or BMC consists of

- unsaturated polyester resin, with styrene as reactive solvent
- continuous filament glass fibers, in the form of typically 25mm long strands
- inorganic filler, such as chalk or aluminum trihydrate (for flame retardancy)
- additives for specific properties

With the introduction of the REACH legislation in Europe, the European SMC and BMC industry has taken all the actions to be in compliance. Some specific used materials require some more attention in this publication:

"the SMC/BMC industry is fully compliant with REACH"

An important component in the unsaturated polyester resin is **styrene**. Since styrene is used as a reactive solvent in the resin, it will react completely when the resin is cured. However, during processing the resin and the SMC/BMC, some styrene can evaporate. Also after curing of the resin, some ret-styrene can be left in the product and migrate out later on.
Under the REACH legislation, that became active in June 2007, producers and users of chemicals are sharing the responsibility of safe using and proper registration of chemicals. Under this new legislation and responsibilities, a so-called DNEL value of 20 ppm. has been evaluated and is proposed for styrene by the styrene producers. DNEL stands for Derived No Effect Level, in other words: below a concentration of 20 ppm styrene has no effect on the human health.
The styrene producers and the downstream users of styrene (among which the SMC/BMC producers and molders) have demonstrated that workers can safely work with styrene using recommended protective equipment and by limiting possible exposure to emissions. Safe Handling Guides can been found on the CEFIC UPR website: http://www.upresins.org/safe-handling-guides.

"styrene, as important component in SMC/BMC, is safe for the environment and can be handled in the industry in such a way that it has no effect on the human body"

Next to the effect on the human body, it is also concluded from the new classification, that needed to be done under the REACH legislation, that styrene is not harmful for the environment.

As a common practice, producers of raw materials, producers of SMC and BMC and producers of parts have taken precautions to minimize the emission of styrene (and other volatile materials) to the environment by using air extraction systems and cleaning the air by means of incineration, active carbon filters, or biological cleaning.

"styrene is not harmful to the environment"

Apart from the possible exposure to styrene during the production and processing of SMC/BMC, there might be a low concentration of styrene left in the final SMC/BMC product. This so-called rest styrene can migrate out of the material during its use phase under specific conditions (for example at high temperature). New developments of resin producers and compound producers have resulted in new SMC/BMC formulation that meet with the requirements of the automotive industry, which can be considered as the toughest requirement for migration and emission of chemicals in the whole industry.

"products that are manufactured by the SMC/BMC industry are meeting the strict requirements of the automotive industry with regard to emissions of styrene and other volatile materials"

Glass fibers are used to give the SMC and BMC its high mechanical properties. Glass fiber consists of long glass filaments with a diameter that is higher than 6 micron (Continuous Filament Glass Fiber – CFGF). According to the definition of the World Health Organization, CFGF for SMC BMC application are not respirable filaments (diameter smaller than 3 micron) and are therefore not classified as a suspected carcinogen. When handled as instructed and in complying with the occupational exposure levels for general dust, they do not represent a health hazard.
Several European and US investigations have supported this. The European Glass Fiber Producers Association has published a detailed document on this topic: "Continuous Filament Glass Fiber and Human Health", by APFE, July 2010.

"continuous filament glass fibers are not respirable and not classified as a suspected carcinogen"

Since the start of this century the SMC/BMC industry has taken the pro-active decision to eliminate all **heavy metals** (mainly used in color pigments) from its compounds. Today SMC and BMC parts do not contain heavy metal based pigments anymore and is in compliance with the legal restrictions on heavy metals in materials.

"heavy metals are pro-actively eliminated from the SMC/BMC industry"

The use of **halogen containing flame retardancy additives and compounds** has been seized by the European SMC and BMC producers. Other additives (such as aluminum tri-hydrate) and technologies are used today to achieve high level of fire safety in applications.

"SMC/BMC does not contain halogens to achieve good fire properties"

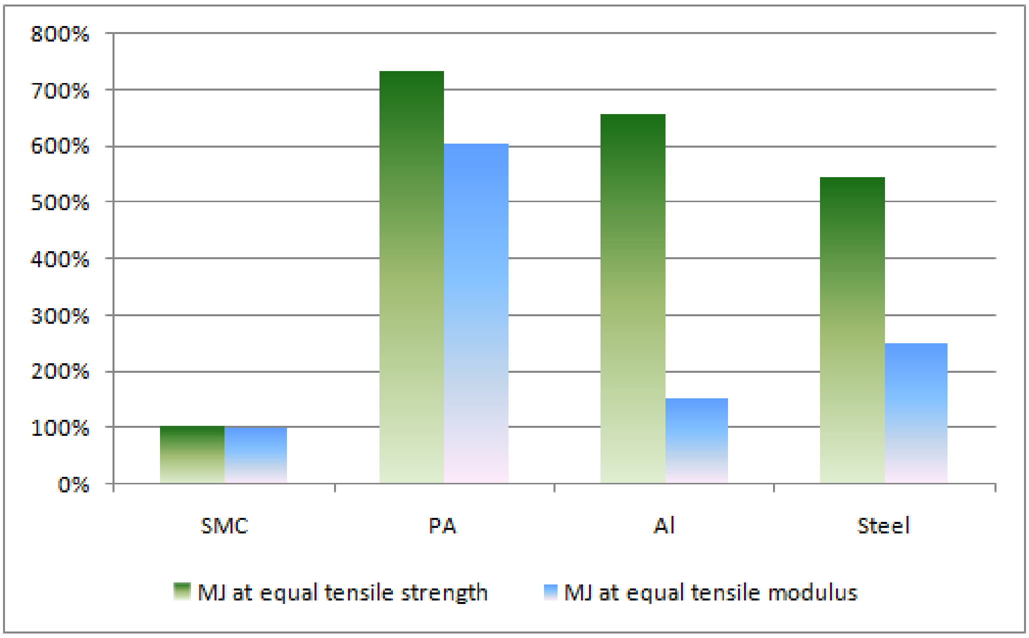
The emission to the environment in the SMC/BMC is very low. All producers of resins and compounds treat their ventilation air and emission to the air either by incineration, by active carbon or by biological cleaning.
The processes of making resin and compound do not generate polluted water and no hazardous by-products are resulting from the processes that are used in the SMC/BMC industry.
All members of the European Alliance for SMC/BMC have started improvement programs to reduce scrap and waste production in order to avoid landfill

"all members of the Alliance have scrap reduction programs in place to reduce and avoid landfill"

In general it can be concluded that the total emission of the industry, to the water, the air or to land, is very limited and measures are taken to further reduce.

5.2 energy use in production of parts

Apart from using raw materials, energy use is an important element in the total environmental impact of a product.
Producing materials from its base materials requires energy in all steps of this process. When the traditional construction materials are compared per kilogram, the possibility to reduce the weight by using light weight materials is neglected.
Another way to compare the energy use for the production of a part is to calculate back to equal properties. In the graph below the relative energy use for producing a part with equal tensile strength and equal tensile stiffness is represented:



"a part produced in SMC requires 5-7 times less energy to be produced than producing the same part in steel, aluminum or thermoplastic materials at equal strength"

Because of the act that SMC and BMC have a very goof corrosion resistance, they do not need to be painted for protection reasons (only for esthetical reasons: colors). Therefore about 50% of the SMC/BMC parts that are produced, are not painted which saves substantial energy that is used in the painting process

"50% of the finished part in SMC/BMC do not need painting, due to the intrinsic durability, and therefore can safe on the energy for painting"

5.3 use of renewable vs. scarce raw materials

SMC and BMC based parts are only for 1/3 based on crude oil. 2/3 of the raw materials are inorganic raw material based that are locally available and are not scarce. This makes SMC/BMC less sensitive to the availability of crude oil and import of scarce raw materials from remote parts of the globe.

The part of the SMC/BMC that today is still based on crude oil has the potential as well to be produced from bio-based raw materials. Some resins for SMC/BMC are already today produced from bio-masses, with the retention of all physical and mechanical properties of the oil-based resins.

"2/3 of an SMC/BMC is based on inorganic raw materials, only 1/3 on crude oil"

Technical developments in natural fibers in SMC show also that bio-based reinforcement is possible. Well known natural grown fibers such as flax, hemp and bamboo are under investigation to be used in SMC/BMC. They combine low weight with reasonable good mechanical performance. Some properties, such as mechanical damping, make natural fibers already today a material of choice in some specific applications.

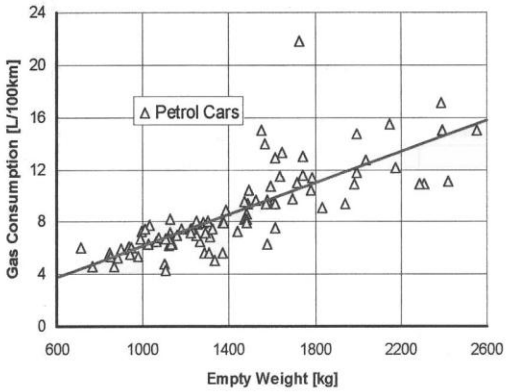
Apart from bio-based fibers, also bio-based fillers are an option for SMC/BMC. This means that the industry has the potential to be based fully on bio-based raw materials.

"SMC/BMC has the potential to be 100% bio-based"

The availability of the main raw materials of SMC/BMC is very wide. This means that the transportation distance of these base materials is limited and therefore the environmental impact can also be reduced from a transportation point of view. For many of the other construction materials, such as steel and aluminum, the base materials require very often transportation distances to the material production installations

"SMC/BMC parts are based on raw materials that are all locally available"

5.4 energy reduction due to the use of SMC/BMC



Reduction of weight has a major effect on the fuel consumption of all vehicles. Boeing is claiming a 20% kerosene consumption reduction due to the fact that the weight of the plane is substantially reduced by using FRP for 50% of the weight of the new Boeing 787 “Dreamliner”.

Also on passenger cars, weight reduction is directly resulting in better fuel economy. The reduction is 0,6 liter fuel per 100km. for every 100 kg. of weight reduction.

The use of SMC/BMC on vehicles will reduce the weight of it and therefore lead to lower fuel consumption, when compared to the same parts produced in **steel**.

When compared to **aluminum** parts, today’s standard versions of SMC and BMC will result in the same weight, however new developments towards low weight SMC are running, for example by using carbon fiber as reinforcement fiber.

“SMC and BMC parts equal nowadays the weight of aluminum and are substantial lighter than steel”

To get a better feeling for what this means for the environment, the following analysis can be made: Assume that all passenger cars in Europe would be 10 kg lighter, due to the use of SMC/BMC instead of steel. This would result in the following CO_2 emission reduction calculation:

	amount	unit	source
number of cars produced in 2009 in EU-27	13,9	million	ACEA economical report 2010
weight saving per car	10,0	kg.	assumption
total weight saving for all 2009 produced cars	139,0	million kg.	
fuel saving per 100km per 100 kg	0,6	liter	Verpoest cs. , KU Leuven
total fuel saving for all 2009 produced cars	83,4	million liter	
emission per liter fuel	2,0	kg./liter	chemistry
total emission reduction	166,8	million kg.	
emission for 1 kWh in NL	0,4	kg.	www.tegenstroom.nl
number of 20 W lightbulbs for 3 hours per day	6.950.000.000		
yearly kWh consumption dutch family	3.480	kWh	www.nibud.nl
total nr. of dutch families emission savings	120.000		

Since this is already the effect for the production of passenger cars for 1 year, it would mean that every year the same effect can be added.

In terms of use of electrical power plants: After 2 years of producing cars with a 10 kg. lower weight, the emission of 1 average sized power plant would be eliminated (data from Harculo power plant, Zwolle, operated by Electrabel; data from yearly environmental report 2009).

5.5 SMC/BMC as material in greener applications:

The use of SMC/BMC allow engineers, designers and producer to create products that have a positive contribution to the environment. A very well known example of how a material contributes, from its properties and processing behavior, very strong to a reduced CO_2 emission are the wings of wind turbines: the wings of today's wind power generators are up to 60 meter long and can only be produced in fiber reinforced plastics.

Similarly SMC/BMC is used in fuel cells and blades of hydropower installations.

Frames for photovoltaic cells and solar collectors are produced in SMC/BMC as well. The durability of the material, the mechanical properties, the thermal stability and the possibility to integrate functions, such as connectors and installation details, make it a material of choice

"SMC/BMC facilitates the generation of green energy"

The freedom of design allow car and truck designers to improve the aero dynamical shape of the vehicle and reduce the air drag. A good example are the roof wind deflectors (1), side covers (3) and fairings (2) of trucks, which guide the air stream over the trailer behind the truck in such a way that the fuel consumption can be reduced. Investigations in wind tunnels show that a fuel consumption reduction up to 16 % can be realized using these measures. The use of SMC allow the designer and engineer to make the optimal, 3-dimensional shape that is required to minimize the air drag of the truck-trailer combination.

Further to add-on parts on trucks and trailers, SMC/BMC facilitate designers to integrate aerodynamic design with functionality, such as front ends of passenger cars. Important part of the front-end design are the headlamps. The use of BMC allow the designers to create flatter, more aerodynamic lines in the front of the car. The heat resistance of BMC, combined with the freedom of shaping and the integration of functions in the headlamp reflector result in new designs of car front ends.

"SMC/BMC makes cars, trucks and trailers more aerodynamic"

Electrical cars are growingly introduced by the car brands, often in limited series length. The series length, in combination with new engine technology, battery casings, low weight and new designs, make SMC/BMC the material of choice for the successful market introduction of E-cars. Further, the electrical insulation properties of SMC/BMC, the outdoor durability and, again, the freedom of design, makes the material perfectly fitting for re-loading stations for E-cars.

"SMC/BMC facilitates the successful introduction of small and light E-cars"

5.6 longer lifetime and end-of-life solutions of SMC/BMC

The life time, or better, the use-time of a products has a high influence on the environmental impact of is; if a product can be used twice as long, the impact will be reduced with 50%. Fiber reinforced materials in general and SMC/BMC specifically, have track records of very long lifetime under sometimes harsh conditions.

Some examples of fiber reinforced plastics can be highlighted:

- fiber reinforced plastics (FRP) are used in aircrafts already for decades.; apart from the long lifetime and low need for maintenance, the fatigue properties makes FRPs for the first time successfully applied in aircrafts (first full FRP sailplane was commercial success in 1957). 50% of the weight of the newest generation of passenger aircrafts is FRP (Boeing 787, Dreamliner)

- waterworks like lock gate doors have been made in FRP; an instrumented lock gate door was installed in the year 2000 in Werkendam, NL; after 11 years the doors are still in perfect condition with no maintenance during this period. SMC in large water storage installation are already in use for decades

- several patrol boats of the US coast Guard are still in service after their introduction in the 60-ies; the mine hunters of the French, Belgian and Dutch Navy have been launched in the late 70-ies and are still in perfect condition with very limited maintenance

- SMC and BMC electrical cabinets have a long track record as durable application. Outdoor exposed cabinets are already in service for more than 30 years, without the need for maintenance.

- The first SMC application on a passenger car was the bumper of the Renault 5, 1972. The use of SMC allowed for the first time to have a non-steel bumper on a series car. On later versions the bumper was produced in injection molded poly propylene, due to the very large amounts of Renault 5's that were produced and sold.

"SMC/BMC parts have a long lifetime, without the need of maintenance"

Next to the long lifetime of SMC/BMC, the products can be re-used after its use period. There are several options for re-using and re-cycling of SMC/BMC:

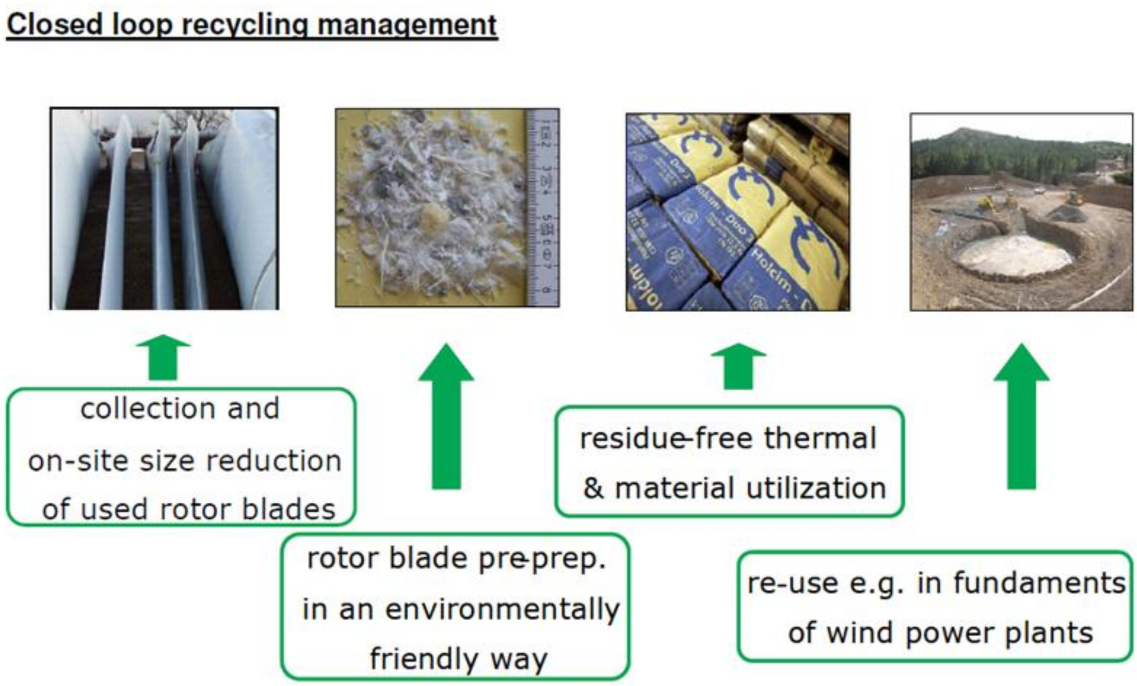
1. **Grinding and re-use as valuable filler in new SMC and BMC parts (no-downgrading, up to 15% of recycled material)**: this technology has been developed on industrial and commercial scale. The ECRC (European Composite Recycling Service Company) has been formed by a large number of players in the value chain, in order to organize and facilitate the recycling process and waste streams. Several installations are running nowadays.

Swimming pool made with recycled SMC

2. **SMC/BMC parts as fuel for cement production**: SMC and BMC waste material and end-of-life material have a high value as fuel for cement ovens for several reasons:

    a. Resin has high caloric value to be used in firing the cement oven
    b. Glass fiber will melt and contribute as SiO_2 to the quality of the cement
    c. Typical fillers in SMC/BMC are valuable additives in cement

    The EU has accepted the cement route as a re-cycling route for composites. The European Composite Industry Association (EuCIA) has written a position paper on this (to be found on the EuCIA website: http://www.eucia.org/publications/documents).
    Today this technology is commercially developed and applied, amongst others by the German company Zajons Zerkleinerungs GmbH, who specialized on the recycling of rotor blades of wind turbines. This technology will be extended to production waste of SMC and BMC and can be used for end-of-life waste of SMC and BMC parts as well

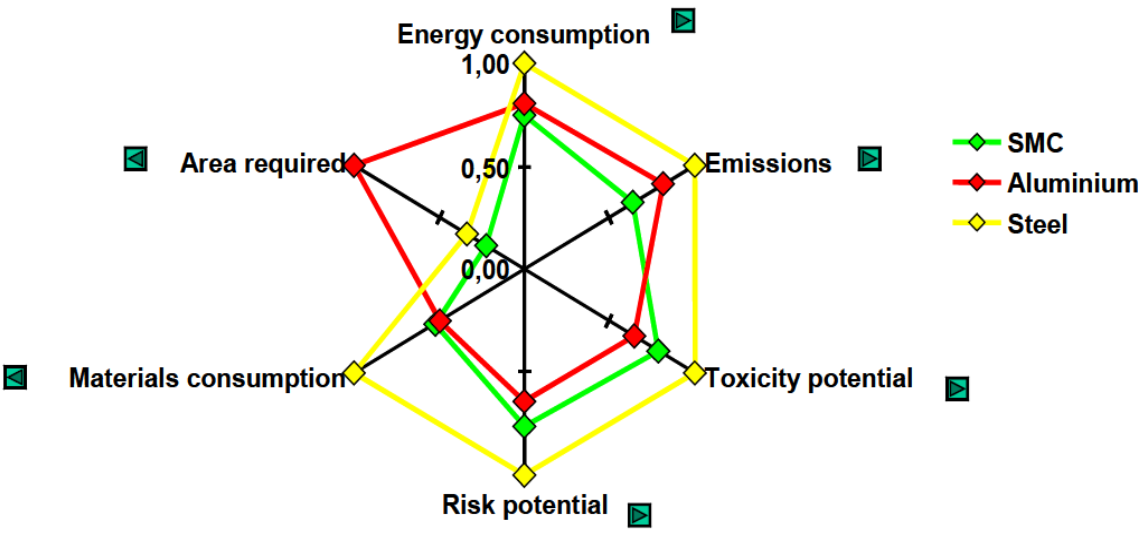


3. Since the use time of SMC/BMC parts is very often shorter than the life time, it should be considered how end-of-use parts could be re-used. In the design phase, this should already be taken into account in the design phase of a part: how can it be reduced in the same application (easy dis-assembly) or as another application. **Design for re-use** should therefore be promoted already at design academies and universities, as well at engineering departments in the different industries

"SMC and BMC products can be re-cycled"

6. The Life Cycle Assessment

To make a fair judgment about the environmental impact of a product it is necessary to include all steps of the life cycle of the product. This includes the production of the product, from raw material to the final product as it is used, the impact of the product during this use phase (including maintenance and service, if required) and finally the end-of-use impact:



how can the product be reduced, recycled or disposed. A fair comparison can only be made between material-product combinations when all these steps are included.
There are several methods for quantifying the environmental impact of a product over its total life cycle. All of them include several sustainability aspects, such as the impact on the human health, the impact on the environment, the impact on climate and depletion of natural resources.

"The sustainability of a product consist of different aspects and is health related, environment related, climate related and scarce resource related"

The European Alliance for SMC/BMC has done an LCA already in 2005, using the BASF method that includes all the aspects as mentioned above. A comparison is made between a specific product of on a passenger car, namely a deck lid, compared in steel, aluminum and SMC. The analysis shows that sustainability has different aspects and that the different material concepts have for each aspect different scores. In general it can be concluded that the SMC solution has the lowest average impact for this application.

"Applied in a deck lid of a passenger car, the SMC version has the best average sustainability score, when compared to the steel and aluminum versions"

7. Conclusion

The choice for a material can be driven by many arguments. Of course the mechanical properties of the material need to be good enough to fulfill the requirements of the product that needs to be made. But next to that, arguments with respect to the use of the product are very important: low weight, low maintenance costs, durability, good esthetics, etc. will all be considered when a material is chosen.
Today more and more the environmental impact that a product has, is taken as an important argument.
SMC and BMC are materials that bring, next to the basic requirements on mechanical performance, opportunities to produce lightweight, good looking and sustainable products.
In comparison with traditional materials, such as steel, aluminum and concrete, SMC and BMC products have a low environmental impact, which is given by a total set of arguments:

- Low energy content in production
- Low emissions in production
- Low weight
- Low maintenance
- Long lifetime
- Recyclable

These arguments make products made in SMC and BMC an excellent construction material to contribute to a better world.

7. Acknowledgements

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European Alliance for SMC/BMC
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