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PRODUCING BRICKS FROM STAINLESS STEEL SLAGS: AN ENVIRONMENTAL EVALUATION BASED ON LIFE CYCLE ANALYSIS

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Introduction

Nowadays, the production of stainless steel is one of the fastest-growing sectors of the manufacturing industry all over the world.[1] A wide literature is available on strategies for recovery of by-products from stainless steel production. However there is a need for research focused on the valorisation of many steel production residues, whose potential for recycling is not explored at present. Among these residues, Stainless Steel Slag (SSS) is usually treated and disposed as hazardous waste or recycled after stabilization as low-quality aggregates. Approximately 270 kg of SSS is originating when producing 1 tonne of stainless steel, for a world production of approximately 8.7 Mt in 2011.[1] Since chromium is used in the production of stainless steel alloy, a fraction of it appears also in the slag, together with other heavy metals, posing environmental and health threats.[1] Different kinds of slag are generated during stainless steel production: Electric Arc Furnace (EAF), Continuous Casting (CtCs) and Argon Oxygen Decarburization (AOD) slag. In particular AOD slag is produced during the refining stage of the production process and it presents a dusty texture (in the scale of some µm diameter) that makes the handling of the slag difficult and the disposal in landfills for hazardous waste less attractive.[2] Treatments including the addition of boric oxide, aiming at preventing the disintegration of the AOD slag, have been successfully implemented in industry.[3] However slag stabilized with boric oxide can only be used in low value applications (for instance as base in roads construction) since the issues of leaching. Therefore due to the costly and energy intensive process, hazardous content (Cr), additives (boron) and low value final product, research for more sustainable solutions is needed.[4]

An alkali activation process can be a valuable procedure to produce alternatives construction materials from AOD slag. Its high alkalinity makes it suitable for alkali activation.[5] Alkali activation combines an alkali-reach binder matrix and clinker free (like steel making slag or geopolymers). The main environmental benefit offered by

the production of alkali-activated materials is their use as viable alternative to Ordinary Portland Cement (OPC).

Materials & Methods

For the presented study, two different types of bricks (called SSSBricks) have been developed using AOD slag coming from stainless steel making process. The first type of brick, called *Solid SSSBrick*, presents a solid and compact structure, with high compressive strength (between 15-25 MPa). The second type, called *Aerated SSSBrick*, has lower strength but high porosity (> 50 %), which gives to the brick a low thermal conductivity (0.30 W/mK), making it suitable to be used as an insulating brick. Both SSSBricks were produced by mixing AOD slag with river sand at 1:3 wt. ratio and a mixture of Na/K hydroxides and Na/K silicates. Subsequently they were cured in a steam curing chamber to enhance the hardening process. For the Solid-SSSBrick, the steam curing temperature was maintained at 90 °C at atmospheric pressure, whereas the Aerated was cured at 150 °C and 4 bar pressure. 0.05 wt.% aluminium powder was used to generate air voids within the Aerated S-Block. The whole process of SSSBricks production is shown in Figure 1.

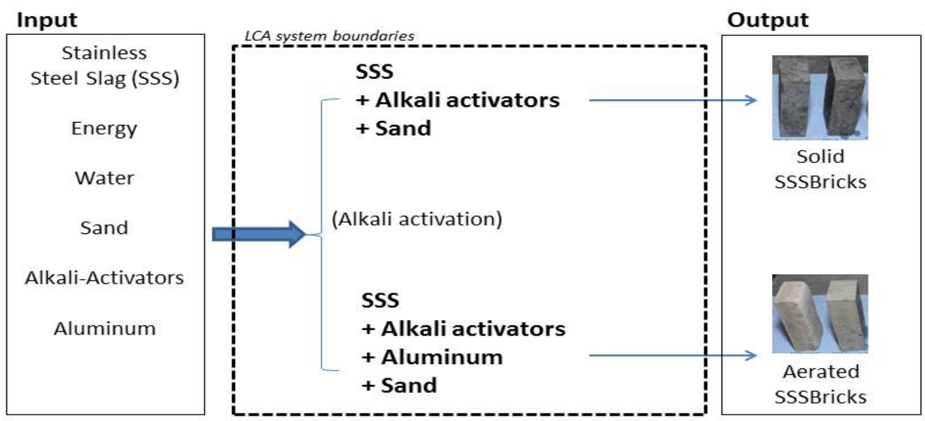

Figure 1: Production process for SSSBricks and LCA system boundaries

Environmental Evaluation

The environmental evaluation seeks to investigate the environmental performances of the SSSBricks production process. In particular, looking at the production phase, this study wants to highlight the main environmental gains and drawbacks in producing SSSBricks compared with the production of traditional concrete bricks with similar characteristics.

LCA of SSSBricks

In order to evaluate the environmental performances of SSSBricks, a Life Cycle Assessment (LCA) is performed. LCA is a tool allowing assessing the environmental consequences of a product production process (cradle to gate approach). The inputs of a LCA for a product comprise in general diverse aspects as resource extraction, manufacturing of materials and energy, manufacturing of the product, use, maintenance, and waste treatment.[6] The results (the accounted environmental impacts) of the LCA for the SSSBricks will be compared with results of the LCA for the traditional concrete bricks. In particular the production of Solid-SSSBrick is compared with the production of traditional concrete paver brick, while the production of Aerated-SSSBrick is compared with the production of traditional concrete aerated brick.

The functional unit provides a reference to which the inputs and outputs can be related. For the presented analysis a 1 m^2 of bricks has been chosen as functional unit. This means that all the inputs (raw material, energy and water) and all the outputs (emissions) are related to the production of a 1 m^2 of bricks.

Figure 1 illustrates the production flows of SSSBricks, concrete paver bricks and concrete aerated bricks, with the system boundaries considered for the Life Cycle inventory.

The ReCiPe endpoint methodology has been chosen to perform the Impact Assessment. Figure 2 shows the aggregated results in environmental ecopoints (Pt) of the impact assessment for the production phase of SSSBricks, according with the system boundaries defined in Figure 1. As comparative scenario, also the results of the LCA of paver concrete bricks and concrete aerated brick are reported in the same graphs.

The results of the Life cycle impact assessment show that the environmental impact of the traditional concrete bricks (paver and aerated bricks) are higher than the SSSbricks, indicating an environmental benefit in producing SSSbricks compared to traditional concrete bricks.

The two categories that contribute most to the final ecopoints for all the considered bricks are climate change and fossil depletion. For concrete bricks, the impacts of this two categories is related to the manufacturing of clinker for the cement production, which requires high quantity of fuels (fossil depletion) and causes air emissions (climate change). Since SSSBricks overcome the need of cement, climate change and fossil depletion are mostly related to energy consumption and alkali activators production.

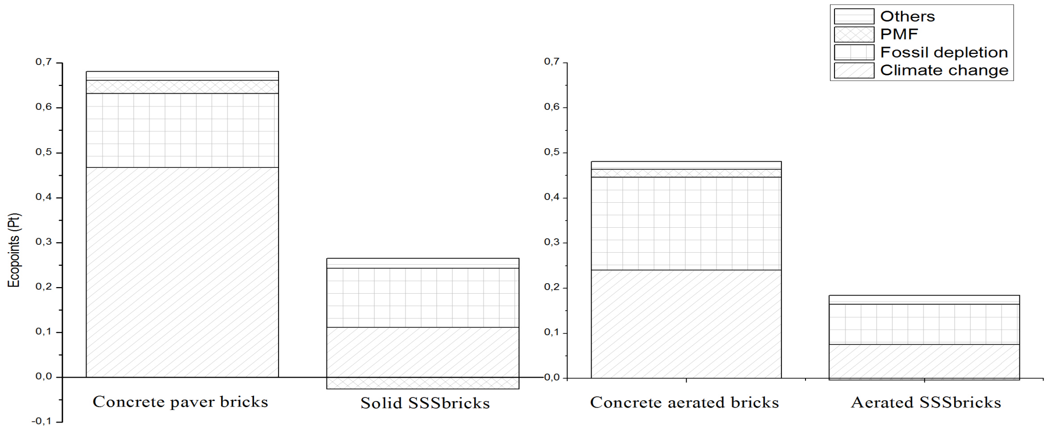

Figure 2: Life Cycle Impact Assessment

Conclusions

In the present study, the environmental impact related to the production of two new developed bricks (Solid SSSBrick and Aerated SSSBick), made from stainless steel slag, have been compared with the environmental impact due to the production of traditional concrete bricks. The life cycle assessment shows that SSSBricks have overall lower impact compared with traditional concrete bricks. This is mostly due to the avoided use of Portland Cement in SSSBricks production. The energy consumption and the alkali production during the alkali activation process for slag carry the highest contribution in the final environmental impacts of SSSBricks. Further research has to focus on finding process optimization procedures and alternative sources of alkali.

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