An analytical and flexible approach for the Life Cycle Assessment of stone products

AN ANALYTICAL AND FLEXIBLE APPROACH FOR THE LIFE CYCLE ASSESSMENT OF STONE PRODUCTS

Isabella Bianco[a], Gian Andrea Blengini[a]

[a] *DIATI, Department of Environmental, Land and Instrastructure Engineering, Politecnico di Torino - Corso Duca degli Abruzzi 24, 10129, Italy*
isabella.bianco@polito.it; gianandrea.blengini@polito.it

ABSTRACT: The need to improve the sustainability of dimension stone products has generated considerable research interest. This ongoing PhD research examines the environmental impact of stone with a Life Cycle Assessment (LCA) approach, analyzing all the processes from the extraction of the rock to the finished product (*from-cradle-to-gate* analysis). The project aims to contribute to fill the gap of LCA datasets specific to stone industry processes in order to allow producers and researchers to more accurately evaluate the sustainability of stone products. Moreover, a flexible LCA model was created to enable the calculation of environmental burdens of specific quarries and specific productions. To achieve this goal, the most common Italian granite and marble industrial processes were identified and an LCA parameterized model was developed. The advantage of this approach lies in the possibility of transversally supporting the stone sector with an analytical but flexible tool.

Keywords: dimension stone, Life Cycle Assessment, stone products sustainability, LCA for waste prevention

1. INTRODUCTION

The sustainability of dimension stones such as marbles and granites is a field of growing interest because of the recent European regulations on construction materials and due to the increasing competition from other building materials and imported products. Much research in recent years has focused on complementary aspects of stone sustainability. The scientific literature presents, from one side, experimentations about treatments and reuse of slurry wastes and, from the other side, studies with a prevention approach for minimizing the waste production. Among the experimentations, (Marras et al., 2010) suggested using marble wastes to partially replace clay in bricks production; (Almeida et al., 2007) and (Alzboon et al., 2009) state that stone dust can be recycled in the production of concrete. Attempts to use it in agriculture have been made with Interreg projects (Carraro et al., 2005) and studies such as the (Sivrikaya et al., 2014) one, which propose to reuse it in clayley soil. However, an important factor that frequently hinders the use of stone slurries is the contamination of some polluting substances. As stated in the final Interreg report (Carraro et al., 2005), contamination

Proceedings SUM2016, Third Symposium on Urban Mining, 23 - 25 May 2016
Old Monastery of St. Augustine, Bergamo, Italy

of hydrocarbons comes from machineries releasing oils and lubricants from the mechanisms. In addition, tests have confirmed that slurries also contain harmful heavy metals due to the abrasion of diamond tools (cobalt and copper in particular) or frame-cutters (chrome, nickel, manganese) (Dino et al., 2005). In order to lower the concentrations, treatment processes have been studied. However, at the same time, a prevention approach could avoid extra costs from both the economic and the environmental point of view. The prevention aim can be reached by analyzing and quantifying the environmental consequences of stone products during their life cycle, from the extraction of raw materials to the realization of the final product (*from-cradle-to-gate* approach). The standardized method of Life Cycle Assessment (LCA) is a useful tool in order to identify the causes of contaminations, to calculate alternatives by improving the production quality and to have a more global view on the environmental impacts involved in the production. Some studies on LCA have been developed in the major stone production countries. A Sicilian research team has focused on the assessment of sustainability performance of “Perlato di Sicilia” marble (Traverso et al., 2010; Capitano et al., 2014). In Brazil, the CETEM research centre is studying the LCA of Brazilians quarries and plants in order to develop a Brazilian database (Castoldi et al., 2012). The Natural Stone Council in USA has launched a project to improve the environmental profile of natural stone industry (University of Tennessee Center for Clean Products, 2009). Nevertheless, the LCA databases lack datasets about specific processes and specific materials employed in stone plants. For example, there are no data about diamond wires, a tool which is directly related to the cobalt concentration in slurry wastes. As a consequence, the life cycle assessments found in literature are often over-simplistic, presenting a high percentage of assumptions.

The ongoing PhD research aims to expand the availability of necessary LCA datasets for a more accurate calculation on the environmental impact of Italian stone production and to allow firms and researchers to understand which processes and materials create most harmful wastes and emissions and use most of resources and energy. The approach used in this study investigates, from the LCA point of view, the most representative processes and materials of the Italian stone industry and provide a parametric model to calculate firms specific impacts.

2. METHODOLOGY

This project studies the environmental impact of the processes involved in the production of 1 m^2 of stone slabs and tiles. To this aim and as stated by the ISO 14040-44 standard, an inventory analysis is required to investigate all the physical exchanges between the production system and the environment. To define the input raw materials and energy it was necessary to firstly carry out an investigation about the most representative processes of the Italian stone industry. Three relevant areas of extraction were taken into account as references: the quarries of Verbano-Cusio-Ossola (Figure 1) and Luserna-Rorà (Figure 2), in Piedmont, and the Carrara quarries in Tuscany. In this way stones with different hardness (such as granites and marbles) are considered. Materials and processes were analyzed in part through the literature (Primavori, 1999; Turchetta, 2003; Vaudagna, 2011) and in part through the dialog with firms and people working in quarries and transformation plants. After having defined the processes and materials, available LCA databases (in particular, PE and Ecoinvent) were consulted. Secondary data from existing databases are indeed used for common industrial processes, such as the provision of electrical energy, the production of steel tools, the transports, etc. For the processes which are specifically related to the stone industry (e.g. use of diamond wire, of explosives, etc.) almost any data is available in databases. This means that, to properly calculate the impact of stone products, primary data occurs. As a

Figure 1. Quarry of *beola Formazza* in Crevoladossola (VCO Province, Italy).

Figure 2. Quarry of *Luserna stone* in Bagnolo Piemonte (Italy)

consequence, investigations about the most common processes and materials are in progress. In particular, a special focus concerned the calculation of environmental impacts related to the diamond wire, tool often employed during the extraction and cutting phases. The presence of heavy metals in the diamond bead matrix is partly responsible of the contamination of slurry wastes and the composition of the matrix alloy is consequently of relevance for the impact calculation. Through data shared by an Italian firm and data found in scientific papers and patents, the diamond wire was modeled with the possibility of setting specific chemical composition for the matrix alloy.

All the processes were gathered in a general model created with an LCA software. Since the aim is to easily adapt it to the different specific working plants, the model has been realized with parameters that allow it to be fitted according to specific ratio between consumption of resources and quantities of production.

3. RESULTS AND DISCUSSION

The main purpose of this stage of the research project was to create a tool able to support firms and researchers in quantification of stone products sustainability. This tool needs at the same time to include the processes generally taking place in working plants and to be flexible enough to fit the specific situations. As described in the previous section, visits to extraction and transformation sites and additional information from scientific literature allowed the most widespread processes to be identified (Table 1). Based on the life cycle approach, all these processes have to be analyzed in order to define the input materials and energy and the output products and emissions. Starting from the collected processes, a model has been created with the LCA software Gabi. As shown in Figure 3, the model is organized into three

	Extraction	**Cutting**	**Finishing**
Techniques	Explosive drilling	Diamond monoblade	Natural Splitting
	Expansive mortar drilling	Diamond monowire	Brush hummering
	Diamond wire cutting	Multiblade gangsaw	Sand blasting
	Chain cutting	Giant disk saw	Chiseling
		Bridge Cutter	Flaming
			Polishing

Table 1. The most common techniques for the phases of extraction, cutting and finishing of natural stones in Italy.

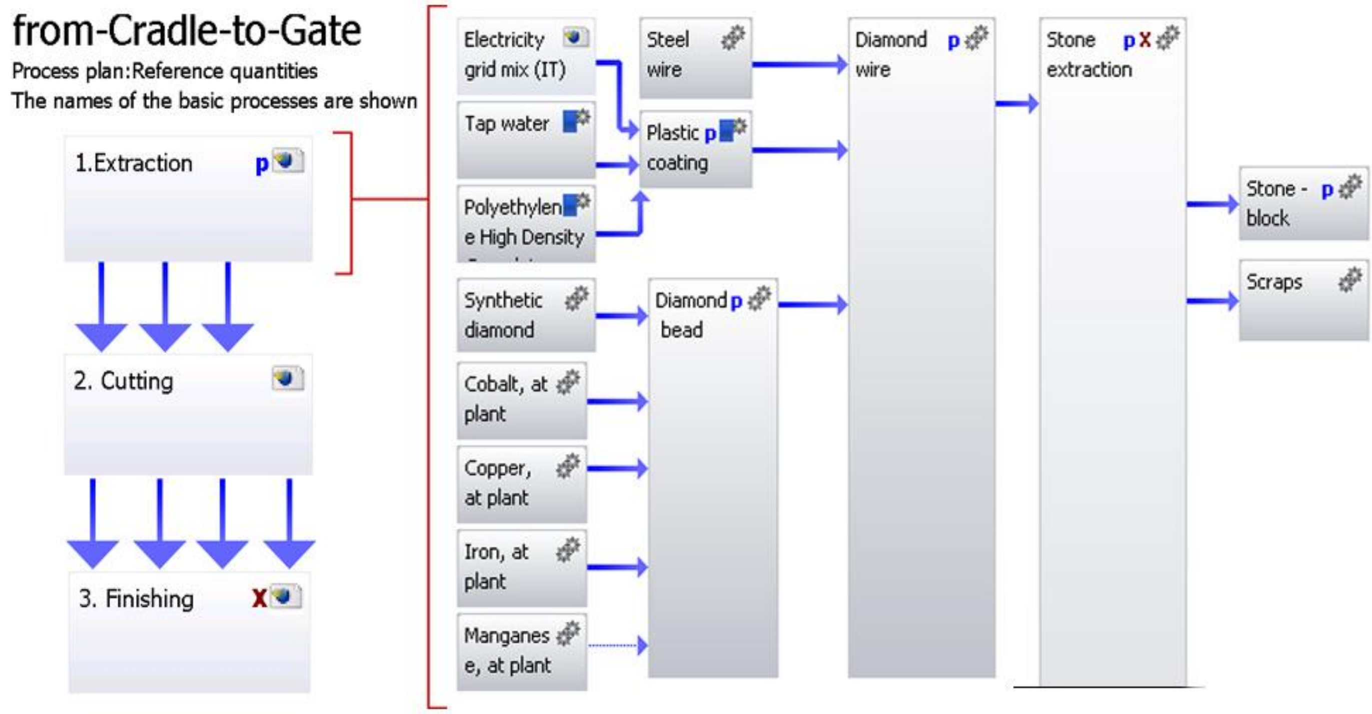

Figure 3. Structure of the LCA model. The macro phases of stone production are modeled with linked plans (at the left) containing the relative processes; at the right, some processes modeled within the extraction plan.

plans, one for each of the three macro phases of the production: extraction, cutting and finishing. Plans are connected via flows, which describe the interaction within the product system and quantify the inputs and outputs. Each plan contains the processes related to the corresponding phase, as shown in Figure 3 (at the right) for the extraction phase. The processes whose data were already available in LCA databases have been directly connected to the model. For more specific processes and materials, for which no data is available in the databases, it was necessary to investigate their impact contribution. As mentioned before, the diamond wire, for example, is a very common tool used both in quarries and transformation plants, but whose environment impact is not known. Diamond wires are composed by a steel wire where sy diamond beads are placed at regular distances, spaced out by plastic or rubber elements. In order to quantify its impact it was necessary to understand and analyze the steps that lead to the production of this tool. The existing databases helped the work for some components of the diamond wire such as the steel wire and the plastic or rubber coating, but primary data were necessary in order to define the diamond beads. This part is composed of a metal support where diamonds are sintered or electrodeposited on a metal matrix. The matrix chemical composition is directly connected to the quality of wastes. An Italian company producing sintered diamond beads has shared data quantities of electrical energy needed for bead production. Some common compositions of matrixes have also been listed with percentages in weight. These data have been employed to model the diamond wire as input material. With the purpose of creating a flexible tool, parameters have been set within the model to allow LCA analyses in different situations or to evaluate possible changes in the production chain. As can be seen in Figure 4 (at the left), producers and researchers can, for example, set the quantities of raw materials and energy that are employed during the extraction phase in relation to the quantities of extracted stone. Moreover, it is also possible to evaluate changes in industry materials by setting the related parameters. As far as diamond wires are concerned, for example, parameters allow the operator to set the chemical

Name	IT	Stone_extraction

Parameter

Parameter	Formula	Value	Mir	M	St	Commer
Block	1	1				m3
Diamond_wire	0,074*Block	0,074				m
Diesel	0,016*Block	0,016				l
Drill_bits	0,068*Block	0,068				kg
Drill_staff	0,056*Block	0,056				kg
Electrical_deto	0,00005*Block	5E-005				kg
Electricity	0,016*Block	0,016				kWh
Exp_det_cord	9,848*Block	9,85				m
Expl_Al_detonat	0,000628*Block	0,000628				kg
Expl_I_category	0,130*Block	0,13				kg

Object: 1.Extraction

Free parameters

Object	Parameter	Formula	Value
1.Extraction	BeadSleeve_leng	11	11
1.Extraction	BeadSleeve_Φest	5	5
1.Extraction	BeadSleeve_Φint	3,5	3,5
1.Extraction	Carbon_perc	0	0
1.Extraction	Cobalt_perc	0,1	0,1
1.Extraction	Copper_perc	0,2	0,2
1.Extraction	Iron_perc	0,7	0,7
1.Extraction	Manganese_perc	0	0

Figure 4. (Left) Some parameters of the LCA model for the setting of quantities of materials and energy used for the extraction. (Right) Some parameters concerning the diamond beads. In the figure the matrix alloy is set with a composition of 70% iron, 20% copper and 10% cobalt.

composition of the specific diamond wire employed in the working plant (Figure 4, at the right).

This analytical approach requires the operator to monitor the consumption of materials and energy during the processes in detail in order to properly set the parameters and get reliable results. This extra effort is however repaid by more accurate and significant data on the stone products sustainability; furthermore, in this way, it is possible to find out the most critical phases and to develop hypothesis on how to improve the production system.

4. CONCLUSIONS

The environmental impact of stone products is a source of current concern among many producers and researchers, in particular in Italy, where the stone sector plays an important role for the economy. In line with other studies, this project faces the problem with a life cycle approach, taking into account the processes of the stone industry, from the extraction phase to the finishing one (*from-cradle-to-gate* assessment). The results of previous research contained unavoidable approximations due to the lack of information about specific quarry and working plants processes in LCA databases. For this reason, the current project aims to fill this gap through the investigation, from the environmental point of view, of the most common processes and materials of the Italian stone sector, with particular reference to granite and marble processing techniques. The final purpose of this work is indeed to allow professionals to develop more accurate LCA and close some data gaps. Particular attention is currently paid to the relation between diamond tool compositions and the contamination of stone slurries. Moreover, the approach of this research has the advantage of not being related to a specific working site but, on the contrary, to provide a framework that is able to be adapted to the different industry realities. The flexibility is achieved by setting parameters that allow producers and researchers to adjust the LCA model according to specific quantities and processes and calculate the production impacts more accurately. Furthermore, the customization of the model through the setting of parameters will encourage the involvement of producer responsibility; the possibility of changing some variables will indeed facilitate the detection of the most damaging processes and the analysis of alternatives.

The current model still needs to be integrated with LCA data concerning some specific processes, such as, for example, the use of different kinds of explosives in quarries. Further work is in progress to provide these datasets and to make the LCA model available to the stone industry and to researchers interested in stone sustainability.

AKNOWLEDGEMENTS

The authors are pleased to thank people who contributed to the realization of this paper. We thank in particular: Luca Risso (Mimitalia owner) for his knowledge about diamond tools he shared; Marco Cerutti (Confartigianato official) and Massimo Marian (geologist, CSL of VCO Province) for their aid in organizing visits at VCO quarries and transformation plants; Marilena Cardu (professor at Politecnico di Torino) and Nina Karimbetova (PhD student) for information on Carrara quarries; Laura Mancuso and Pierpaolo Varetto (public officials at Regione Piemonte authority) for the Piedmont mineral statistics they made available.

REFERENCES

Alzboon K.K., Mahasneh K.N. (2009). Effect of Using Stone Cutting Waste on the Compression Strength and Slump Characteristics of Concrete. International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering, vol. 3, 83–88.

Capitano C., Traverso M., Rizzo, G., Finkbeiner M. (2011). Life Cycle Sustainability Assessment: an implementation to marble products. In: Proceedings of the LCM 2011 Conference, Berlin.

Carraro G., Castelli S. (2005). Il limo di segagione quale risorsa: biorisanamento e potenzialità di impiego nel settore verde. Interreg IIIA - project report, Locarno.

Castoldi M., Fernández N., De Andrade A., Ribeiro C. E., Fernandes P., Pimentel D. (2012) Life-cycle inventory of dimension stones, Brazil. In: Proceedings of Global Stone Congress 2012, Borba.

Dino G.A., Fornaro M. (2005). L'utilizzo integrale delle risorse lapidee negli aspetti estrattivi, di lavorazione e di recupero ambientale dei siti. Giornale di Geologia Applicata 2, 320–327.

Marras G., Careddu N., Internicola C., Siotto G. (2010). Recovery and reuse of marble powder by-product, in: AIDICO (Ed.), Proceedings of Global Stone Congress 2010, Valencia.

University of Tennessee Center for Clean Products. (2009). A Life-Cycle Inventory of Granite Dimension Stone Quarrying and Processing, Report for the Natural Stone Council, USA.

Sivrikaya O., Kiyildi K., Karaca Z. (2014). Recycling waste from natural stone processing plants to stabilise clayey soil. Environmental Earth Sciences. 4397–4407.

Traverso M., Rizzo G., Finkbeiner M. (2010). Environmental performance of building materials: life cycle assessment of a typical Sicilian marble. The International Journal of Life Cycle Assessment. 104–114.

Vaudagna A. (2011), Ottimizzazione dell'impiego dell'esplosivo in cave di pietra ornamentale, I level degree thesis, Politecnico di Torino.

Turchetta S. (2003), Tecnologie di lavorazione delle pietre naturali, PhD thesis, Università degli studi di Cassino.

Primavori P. (1999), Pianeta Pietra, Giorgio Zusi Ed., Verona.