D7.77 FINAL SET OF POLICY BRIEFS

Author: SOLINTEL
Contributor: ALL
Project acronym: ECO-CEMENT

Issue Date:	February 2015
WP Number:	WP7
Status :	Released

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Document History			
Version	Date	Author	Description
1	DEC. 2014	SOL	First version
2	February 2015	SOL	Second version
3	February 2015	CNR	Review
4	February 2015	SOL	Final version

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INTRODUCTION

This deliverable presents ECO-CEMENT policy brief, which outlines the rationale for selecting ECO-CEMENT against its competitors. The purpose of this brief is to present the findings and recommendations of the ECO-CEMENT project to a non-specialised audience.

This document is the contractual deliverable d 7.77: "Final set of policy briefs", correspondent to work package 7: Awareness, Dissemination and Training, and is part of the Task 7.1 Awareness and Dissemination.

1 WHAT IS A POLICY BRIEF?

A policy brief is a short document that presents the findings and recommendations of a research project to a non-specialised audience. It outlines the rationale for choosing a particular product within the existing options. It is usually produced in response to a request from a decision-maker.

The purpose of the policy brief is to convince the target audience of the urgency of the current problem and the need to adopt the preferred alternative or course of action outlined and therefore, serve as an impetus for action. The key to success is targeting the particular audience for your message. The most common audience for a policy brief is the decision-maker. In constructing a policy brief that can effectively serve its intended purpose, it is common for a brief to be:

- **Focused:** all aspects of the policy brief need to focus on achieving the goal of convincing the target audience.
- **Professional,** not academic: The audience for a policy brief is not interested in the research/analysis procedures conducted to produce the evidence, but are very interested to know the writer's perspective on the problem and potential solutions based on the new evidence
- **Evidence-based:** The policy brief is a communication tool and therefore all potential audiences not only expect a rational argument but will only be convinced by argumentation supported by evidence that the problem exists and the consequences of adopting particular alternatives.
- **Limited:** the focus of the brief needs to be limited to a particular problem or area of a problem.
- **Succinct**: Commonly, policy briefs do not exceed 6 – 8 pages in length (i.e. usually not longer than 3,000 words).
- **Understandable;** providing a well explained and easy to follow argument targeting a wide but knowledgeable audience.
- **Accessible:** the writer should facilitate the reading using clear descriptive titles to guide the reader.
- **Practical and feasible:** the brief must provide arguments based on what is actually happening in practice with a particular policy and propose realistic recommendations to the target audience.

The most common elements of the policy brief are as follows:

- **Context and importance of the problem:** The purpose is to convince the target audience that a current problem exists which requires them to take action. The context and importance of the problem is both the introductory and first building block of the brief. Answer the question of why the topic is important, i.e.: why should people care. Hence, create curiosity about the rest of the brief.

- **Findings and results:** The aim of this element is to detail what has been implemented, the shortcomings that have been encountered and the main findings of the research.
- **Recommendations:** State clearly what should happen next.

2 CONTEXT

Industrial waste is now a global concern, causing environmental and economic harm. Industries are rapidly trying to find solutions, searching for optimal ways to manage waste and change the most common practices, as landfill or incineration. Industrial waste is a very heavy burden for the environment, where a significant proportion is attributable to construction and demolition waste. To mitigate these threats, a novel biomimetic technology for enzyme-based microbial carbonate precipitation was tested, converting industrial wastes into an ecological product. Within the European ECO-CEMENT Project, a novel eco-cement product was obtained by recovering valuable resources from different industries such as the dairy industry, cement industry and poultry growing industry. The eco-cement product involves the microbial carbonate precipitation process, via urea hydrolysis, in the presence of *Sporosarcina pasteurii,* a common soil ureolytic bacterium. This paper presents the general concept of the project and the main obtained results.

Currently the production of one ton of cement commonly results in the release of 0.65 to 0.95 tons of CO_2 depending on the efficiency of the process, fuels used, and specific type of cement product. Considering the scale of the worldwide cement production, even a slight decrease in the average global emissions per ton has a large CO_2 reduction potential. Every 10% decrease in the cement CO_2 intensity by 2050 could save around 0.4 Gt CO_2, and substantially contribute to slow down climate change. Further abatement could originate from the more efficient use of cement and concrete. Additionally, innovative low CO_2 cementitious materials are to be considered as a reduction measure. The use of waste materials in the cement industry, also referred to as co-processing, contributes towards achieving these objectives.

An attempt to use treatments more in line with the nature of these materials has, in the past few decades, directed attention to biomaterials, generally carbonates, produced by living organisms, particularly bacteria.

Microbial carbonate precipitation has gained interest in the past 20 years particularly with regard to the potential role marine systems may play as ”carbon sinks” for the increasing global production of CO_2. The feasibility of microbial calcite precipitation is well established in literature, as a great number of researchers work on these type of processes, from one standpoint or another.

3 RESEARCH FINDINGS

The medium ingredients in biotechnology processes are a major cost factor, ranging between 10 to 60% of the total operating costs. The medium cost increases proportionally with the size of the scale up. Because of this, it is important to give consideration to optimization of the medium prior to scale up. Given that biocementation process does not require ease of removal of medium components or use of a defined medium, we are able to look at a range of more economical components to replace the existing expensive analytical grade chemicals.

Reusing industrial by-products as a source of calcium, urea and nutrients for producing eco-cement is explained here. This alternative waste recycling has dual benefits as it contributes, not only to reduce the process costs, but to minimize environmental impacts associated to the disposal of such wastes.

3.1 BIOMINERALIZATION CONCEPT AND WASTE RECYCLING

3.1.1 BIOMINERALIZATION CONCEPT

The mechanism of microbial induced calcium carbonate precipitation process (MICCP) involves the ureolytic bacteria that hydrolyze urea to produce carbonate ions (1), and in the presence of free calcium ions (2), the calcium carbonate will precipitate.

$$(NH_2)_2CO + 2H_2O \rightarrow CO_2^{-3} + 2NH_3 \quad (1)$$
$$Ca^{2+} + CO_2^{-3} \rightarrow CaCO_3 \quad (2)$$

Urea is needed as primary reagent. If the saturation levels of the calcium carbonate produced are sufficiently high, it will precipitate forming bonds and consolidating its surroundings in the MICCP process. There are bacteria that produce urease in the cytoplasm of the cell for ATP generation. This enzyme hydrolyses the substrate urea. The urease enzyme is non-constitutive in nature, where its activity is independent of urea and ammonia, but varies with the presence of calcium, pH, temperature and calcium nitrate.

Urease producing bacteria can be divided into two groups, according to their urease response to ammonium: (i) those, whose activities are repressed by high ammonium concentrations, such as *Pseudomonas areuginosa*, *Alcaligenes eutrophas*, *Bacillus megaterium* and *Klebsiella aerogenes*, and (ii) those whose activities are not repressed by ammonium, such as *Sporosarcina pasteurii*, *Proteus mirabilis*, *Proteus vulgaris*, *Helicobacter pylori*, *Ureaplasma* sp., but some of them are pathogens.

Sporosarcina pasteurii was considered the most suitable for the biocementation process as it was the most resistant in alkaline conditions and do not present hazards to the human health. Its favorable growth condition is 30°C. In order to provide them with oxygen, it needs to be slightly shaken and it needs to be feed with media and urea.

To produce a high urease rate, the bacteria need urea and a protein source to grow. This will be assimilated by the bacteria and used as energy for its metabolism and reproduction. For producing bio-calcite grains, the presence of free calcium ions is compulsory as well.

3.2 ALTERNATIVE NUTRIENTS FOR BACTERIAL GROWTH

The cost of well-defined media is prohibitively expensive for large scale cultivation of bacteria. The medium ingredients are a major cost factor, ranging between 10 to 60% of the total operating costs. Hence, large scale growth media is complex and waste or by-products from different industries should be identified to be used as nutrient substitutes. There are many industrial effluents that are rich in proteins, which if released in the altered form could be hazardous for the environment, so the dual benefits of cost reduction and environment protection are feasible by reusing these wastes.

Low cost substrates are generally subject to lowered quality control and reproducibility. The effects of variable feedstock and additional processing required (e.g. for the presence of insoluble particles, when dissolved in water) should be considered in relation to the application of the enzyme produced.

A reduction in the medium costs without loss of urease activity could be possible by the substitution of laboratory grade nutrient medium with several alternative protein sources such as: **(i)** yeast extracts and its derivative products (Vegemite™, Marmite™, brewery waste yeast, *Torula* yeast), **(ii)** corn steep liquor (CSL) and **(iii)** dairy wastes and by-products (lactose mother liquor (LML), whey, buttermilk and waste water from cleaning system).

MICCP by the bacterium *Sporosarcina pasteurii* (NCIM 2477) using LML as growth medium was demonstrated for the first time by Achal et al. The effect of LML as sole source of growing bacterium *S. pasteurii* was investigated and the calcification effect of its usage was compared. LML served as a better nutrient source for the growth of bacteria and also for calcite precipitation as compared to nutrient broth and yeast extract media, which are quite expensive. The compressive strength of cement mortar was increased by *S. pasteurii* in all the media used compared to control. No significant difference in the growth, urease production and compressive strength of mortar among the media suggesting LML as an alternative source for standard media.

After an extensive research work, beside LML, whey and waste water from cleaning system have been identified as the better nutrient sources for the growth of the bacteria and also for the calcite precipitation. These wastes are available around Europe as a by-product of the dairy industries and may have a regular supply.

3.3 ALTERNATIVE UREA SUBSTITUTES FOR THE BIOENZIMATICALLY INDUCED CEMENTATION PROCESS

Apart from the bacteria, urea is needed as well. Urea is a key component used in the biocementation process. At present, the pure chemical form is being used.

Urea is a colorless crystalline chemical compound, with formula CO(NH2)2, that is the major end product of protein metabolism in man and in other mammals. It can be found abundantly in the urine and faeces. In the industrial sectors, urea is used for many functional uses, e.g. as adhesives, binders, sealants, resins, fillers, analytical reagents, catalysts, intermediates, solvent, dyestuffs, fragrances, deodourisers, flavouring agents, humectants and dehydrating agents, formulation components, monomers, paint and coating additives, photosensitive agents, fertilizers, surface treatment agents. Urea is also the key synthetic ingredient in the manufacture of some medicines. It is also widely used as an animal feed supplement.

Alternative sources of urea are the animal manure (i.e. faeces and urine). Urea is one of the major nitrogen excretory products of dairy cattle, sheep and many other large animals and hence, large animal operations located near waterways may be a source of urea. Non-ruminants animals are also a source of this nitrogen nutrient. Uric acid is the primary nitrogen form released by poultry, and the first decomposition product of uric acid is urea. The time scale of conversion from uric acid to urea depends on the microbial activity of the poultry litter and its moisture content.

The urea recycled from mammalians livestock and sewage sludge cannot be recommended as alternative urea source to produce ECO-CEMENT, as the supply quantity is inconstant, unreliable, and hazardous for the human health. The presence of pathogens adds an extra cost that, in certain cases, can be unaffordable if we want to lessen the process expenses.

Cheaper alternatives were found in the fertilizer industries, such as the fertilizer urea, and therefore considered for the production of eco-cement products. Fertilizers offer a good urea source without the need of being pre-treated. It is clear that they are not industrial by-products but they are cheap (around 1€/kg), even when compared with urea rich by-products that require expensive pre-treatments. As a consequence, fertilizers will be the urea source recommended to be used in the eco-cementation process. However, taking into account the negative environmental impact for urea production, an ecological urea has been individuated for the scale-up of the process. It is obtained from the gasification of biomass waste.

3.4 CALCIUM AND SILICA SOURCES

Cement kiln dust (CKD) is a fine powdery material similar in appearance to Portland cement. CKD consists primarily of calcium carbonate and silicon dioxide and high amounts of alkaline, chloride and sulfate. The CKD may result from three different types of operations: long-wet. long-dry, and alkali by-pass with precalciner.

The rice husk ash (RHA) was selected for its pozzolanic property due to the amorphous phase content of the silica. It is obtained by the combustion of rice husk. RHA is a highly reactive pozzolanic material suitable for use in lime-pozzolana mixes and for Portland cement replacement. RHA contains a high amount of silicon dioxide, and its reactivity related to lime depends on a combination of two factors, namely the non-crystalline silica content and its specific surface.

3.5 PRODUCING ECO-CEMENT WITH WASTES

The Eco-Cement process is subdivided into three aspects: (i) preprocess, (ii) process, and (iii) components:

i) The eco-cement pre-processes deal with the S. pasteurii bacterial culture preparation, conservation/storage and reactivation.
ii) The eco-cement process is a function of several parameters like the mixture protocol, the curing temperature and humidity, the moulds dimension and material. The process is dependent on the pre-processes and its components.
iii) The eco-cement components are classified in aggregates, binder and liquid. The aggregate selected is the washed sand. The binder consists out of two types of waste: the CKD and the RHA. The liquid contains the S. pasteurii bacterial culture (biomass). Depending on the pre-process, the liquid also may contain the growth medium of the bacteria and urea, or only water and urea.

The preparation of the mixture firstly followed the same ratio used for preparing the standard hydraulic cement (usually 1 binder: 3 aggregate: 1 water), even if in the eco-cement, no binder is present as in the Ordinary Portland Cement (OPC). Eco-cement is a mixture of bacteria, calcite, lime, silica acid and not reactive compounds. If in the CKD is enough amount of available lime (> 40-50%), it can be considered as an aerial mortar (binder).

A comprehensive study varying the parameters of the recipe was performed. Varying amounts of CKD, RHA, sand, urea concentration and biomass were used in the manufacturing of standard blocks of eco-cement. The final ratios used did not follow the ration of the hydraulic cement as strictly as the variation of a single parameter at a time was essential. Excessive care was given for the wet material to have similar, if not identical, consistency for reproducibility reasons. Five identical blocks corresponding to each recipe were manufactured in order to obtain a good statistical sample. The blocks were poured into 5 cm x 5 cm x 5cm moulds. Curing took place under controlled conditions (temperature 30 C, humidity 82%) in a sealed chamber. After a curing time of 28 days, the blocks were used for a variety of crash tests to gain inside on strength and resistance.

The MICCP process in the presence of industrial waste gives final ECO-CEMENT products with three different applications: (i) plaster, (ii) bedding mortar, (iii) tiles and (iv) dried biomass pack:

The dry biomass can be stored at room temperature for several months. This can be easy revitalized at the moment of use. The revitalization consists in the incubation of the biomass in urea solution (2%) at around 30°C for 3-4 hours. All the solid components are therefore mixed thoroughly for a few minutes in a concrete mixer, adding the urea solution and biological mass after its revitalization and filtering, in order to create a fluid paste with constant amalgamating and slow action.

Figure 1”Tiles”; ”Plaster”; ”Bedding mortar”

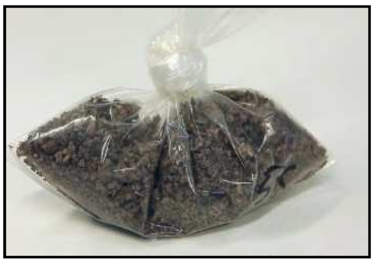

Figure 2 ”Dried Biopack”

A Life Cycle Analysis (LCA) was carried out to assess the global environmental impact of the project's Eco-Cement, as well as the materials that constitute it, in order to compare it to Ordinary Portland Cement (OPC) and Ecocem Ireland's GGBS product. The system boundaries of the LCA were cradle-to-cradle looking at all possible stages in the life cycle of Eco-Cement. The LCA followed ISO 14040 and 14044 standards using the SimaPro 8.0.2 software. The results indicated that the ECO-CEMENT product and its components created minimal environmental impact overall, displaying positive environmental values in some categories. In comparison to OPC and Ecocem, Eco-Cement has an environmental impact, which is approximately 77% lower.

3.6 USES

ECO-CEMENT, as a rendering mortar (UNE EN- 998-1) has obtained had the following characteristics: **GP CII WO**

- Compressive strength: 2.6 N / mm2; Type CII
- Water absorption by capillarity: 10.3 kg / m2 0.5 min; W0
- Thermal conductivity; pendant, relevant property for thermal insulation applications.

It can be used in inner liners, as capping layers and / or partition and interior plaster sheets. In addition it can be used for the rehabilitation and restoration of historical works, as it does not contain Portland cement.

In the case of masonry mortar, it can be classified as **Type M 2.5** for either standard or fine joints applications, equally suitable for internal uses or without structural reinforcements, applications that do not involve isolation. Indeed, it could be used for parts terrazzo, cement tiles, etc., in short simple extension screeds.

Enhance the mechanical behaviour of the material will be a priority. Alternatives will be explored before launching the products to the market. In this way, its marketability will be implemented. The consortium has already identified some areas to continue the research:

- Substitute the CKD with biomass ashes. These coming from wooden matter are rich in CaO and could be used instead of the CKD avoiding the presence of unwanted components. This aspect needs some experiments in order to verify the best ashes and concentration.
- Insert in the paste some fibers. These could be from wool residues or from basalt.
- Realize the tiles using vibrocompress system.

4 RECOMMENDATIONS

The great challenge faced by the economies today is to integrate environmental sustainability with economic growth and welfare by decoupling environmental degradation from economic growth and "doing more with less". In parallel to the significant progress being made with regard to energy efficiency, there is a need for more holistic approach which considers resource efficiency throughout the whole life cycle. The main focus for sustainable construction is the reduction of the environmental impact of resources such as materials, water and embodied energy, from the extraction of materials to demolition and the recycling of materials.

The specific objectives are to set environmental performance standards, provide incentives for citizens and public authorities to choose resource-efficient products and services and stimulate companies to innovate. The EU is focused on the following 4 key areas:

- Energy efficiency in buildings as the key answer to the climate change challenge. 40% of energy consumption is due to usage of building. The construction sector represents a huge potential in the area of reducing energy consumption. Broad policy guidelines are already in place, policy makers have to ensure their implementation at national level through appropriate legislation.
- Smart improvements in infrastructures and adaption to demographic changes. A leading economy needs efficient infrastructures. Invest in upgrading existing infrastructures is a way to contribute to economic recovery with both short-term and long-term effects. Residential buildings must be adapted to two distinct demographic trends. First, the aging population requires an in depth adaption of existing infrastructures. Second, the increase of young and low qualified people requires affordable and enjoyable new buildings.
- **An integrated policy on raw materials. Keeping an innovative and sustainable manufacturing industry is of strategic importance for achieving the objectives of the European Union. The principal industry need is the access to quality primary and secondary raw materials in a constant and affordable way; policies on mineral materials, locally available in large quantities, should favour this accessibility in a sustainable manner.**
- A stable and coordinated policy framework. Policy setting should be driven by a long term strategy shared by decision makers at the EU and national levels. Industrial development and innovation is possible only in a stable framework, where policies covering the construction sector are well coordinated between the different actors involved.

The European Union has put in place a comprehensive legislative and regulatory framework, including corresponding European standards, financial tools, information platforms, labelling schemes and other instruments, which are presented in the next sections.

4.1 DIRECTIVE 2010/31/EU ON THE ENERGY PERFORMANCE OF BUILDINGS

The *Energy Performance of Buildings Directive (EPBD)* promotes the improvement of the energy performance of buildings, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. It applies to new buildings and renovated ones and indicates the minimum requirements for energy performance together with the role certificates and inspections.

According to the EPBD, all new buildings shall be nearly zero-energy buildings by 31 December 2020, and 2 years earlier for buildings occupied and owned by public authorities. Part of the energy required should be covered by renewable sources, including energy produced on site or in the vicinity.

4.2 DIRECTIVE 2012/27/EU ENERGY EFFICIENCY DIRECTIVE

The *Energy Efficiency Directive* (EED) establishes a common framework of measures for encouraging the energy efficiency implementation in order to ensure the achievement of the Union's 2020 targets. All EU-28 countries are thus required to use energy more efficiently at all stages of the energy chain, from the transformation of energy and its distribution to its final consumption. The Member States have to transpose the Energy Efficiency Directive by 5 June 2014. The EED requires the Member States to set the targets for 2020 based on different indicators such as energy saving, wherein the innovative technology can contribute to achieve the targets after its implementation.

The EU aims for a 20% reduction in its annual primary energy consumption by 2020. The building sector, together with public transportation, has the greater potential for savings.

The energy performance and resource efficiency of buildings have an important impact on energy savings, the fight against climate change and the environment in general. This has triggered important innovations and built expertise in Europe for the design of sustainable buildings and construction products, including renovation. Sustainable buildings combine improved energy performance and reduced environmental impact throughout their life cycle. Buildings have the potential to reach a 90 % reduction in their greenhouse gas emissions by 2050.

Public authorities should set the example by renovating each year 3% of central government buildings with insufficient performances, as required by this Directive. This is complemented by the EED obligation for Member States to put in place long-term renovation strategies.

4.3 EUROPE 2020 TARGETS

The *Europe 2020 Targets* presents an integrated approach to climate change and energy policy that aims to struggle against climate change. Among the 2020 milestones, the European Union intends to meet its ambitious climate and energy targets for 2020. These targets, known as the "20-20-20" targets, set three key objectives for 2020:

- 20% of reduction in EU Green House Gas emissions from 1990 levels
- Increase of 20% the availability of EU energy from Renewable Energy Resources (RES)
- 20% improvement of EU energy efficiency

As such, the construction sector plays an important role in the delivery of the European Union's 'Europe 2020'1 goals for smart, sustainable and inclusive growth. The strategy for the sustainable competitiveness of the construction sector focuses on five objectives:

- stimulating favourable investment conditions;
- improving the human-capital basis;
- improving resource efficiency,
- environmental performance and business opportunities;
- Strengthening the EU internal market and fostering the global competitiveness of enterprises.

4.4 THE 2050 ROADMAP

The *ROADMAP 2050* presents policies to achieve European's long-term decarbonisation goal and implications for energy policy decisions therewith. The European Union legislation established more than 130 environmental targets and objectives to be achieved from 2010 to 2050. All these aspects can provide useful milestones to support the transition of Europe towards a so called 'green economy'. The above mentioned roadmap sets out a framework for the design and implementation of future actions. It also outlines the structural and technological changes needed by 2050, including milestones to be reached by 2020 through targets.

4.5 DIRECTIVE 2008/98/EC ON WASTE

The *Waste Directive* aims to reach 70% of preparation for reuse, recycling and other forms of material recovery of construction and demolition waste. Hence, it contributes to the European initiatives towards increased resource efficiency in the construction sector and to treating waste as a secondary raw material. This Directive seeks to lower the environmental impacts and reduce the use of resources, beginning with the extraction of raw materials moving through manufacture, distribution and use, and ending with reuse, recycle and ultimate disposal.

4.6 ECO-CEMENT BENEFITS

ECO-CEMENT results are expected to contribute to the European polices improving the competitiveness of the construction sector trough a re-engineering of the whole processes on site. Moreover, the results coming from ECO-CEMENT project support the achievement of the objectives established by the Kyoto protocol regarding the reduction of CO_2 emission. Furthermore, the energy policies are also satisfied, with particular reference to the Action Plan on Energy Efficiency in Europe. The energy efficiency targets are addressed by the **Energy Performance of Buildings Directive (EPBD)** and the **Energy Efficiency Directive (EED)** (2012/27/EU). The ECO-CEMENT project results indeed are relevant for the energy efficiency target achievements and contribute to have an appropriate management of the wastes from several points of view with the final aim of reducing the energy consumption and decreasing the CO_2 emission, in line also with the **Waste Directive.**

In precast production a number of specific environmental concerns typically emerge. The main environmental burdens in precast manufacturing are associated with cement content and transportation. Cement manufacture accounts for nearly 65% of CO2 emissions and 46% if embodied energy for precast manufacture. In addition, considering the economic aspects of production, two more environmental impacts need to be considered. These are energy consumption and raw materials use / waste generation levels. ECO-CEMENT is able to make this industry more sustainable and contribute to improve competitiveness in the sector by a full re-engineering of the process. ECO-CEMENT contributes to have an appropriate management of the wastes, as it reuses them, reducing the energy consumption and decreasing the CO2 emission. However, in all the cases, transportation impacts for precast products can be significant due to the size of units transported, and the sourcing distances for raw material and finished products.

The next steps involve enhancing the mechanical behaviour of the material, which will be a priority. Alternatives will have to be explored before launching the product to the market. In this way, its marketability will be implemented. The consortium has already identified some areas to continue the research activities:

- Substitute the CKD with biomass ashes. These coming from wooden matter are rich in CaO and could be used instead of the CKD avoiding the presence of unwanted components. This aspect needs some experiments in order to verify the best ashes and concentration.
- Insert in the paste some fibers. These could be from wool residues or from basalt.
- Realize the tiles using vibrocompress system.

5 CONCLUSIONS

This deliverable has presented ECO-CEMENT policy brief outlining the rationale for selecting ECO-CEMENT against its competitors on the market. The purpose of this brief is to convince the stakeholders of the opportunity to adopt the ECO-CEMENT in order to work on sustainable and environmentally friendly basis.

6 REFERENCES

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