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1.3.3. CARBON FOOTPRINT ASSESSMENT STUDY IN CONSTRUCTION IN ITALY

OERCO2
ONLINE EDUCATIONAL RESOURCE FOR INNOVATIVE STUDY OF CONSTRUCTION MATERIALS LIFE CYCLE

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1. Introduction

Energy efficiency and reduction of greenhouse gas (GHG) emissions are currently key issues in all the economic sectors and, in particular, in buildings which are acknowledged worldwide as one of the most energy consuming. In this context, the *Global Warming Potential* (GWP) is one of the most important indicator to estimate the environmental impacts due in particular to CO_2 emissions. Indeed, carbon footprint is defined as the sum of greenhouse gas emissions and removals caused by an individual activity, an organisation or a product processing, expressed as net impact on global warming in terms of CO_2 equivalent[1].

For what concerns construction sector in Italy, many studies have been conducted to analyse carbon footprint of products and processes, in order to estimate the environmental impact of buildings and materials, taking into account their whole life cycle. Therefore, several Italian literature studies have dealt with carbon footprint assessment, with mainly reference to:

- materials, taking into account their whole life cycle, from raw materials extraction, to transport, processing, usage and disposal;
- residential buildings, considering both the emissions due to energy demand during building life time and those caused by construction and demolitions processes;
- civil works or industrial building sector, associated to the single phases of building realization or to retrofit actions.

With reference to these issues, this paper will show some Italian studies with the aim to highlight the several fields of construction sector in which carbon footprint and, in particular, CO_2 emissions can be estimated and analysed.

2. Carbon footprint assessment with reference to construction materials

Construction of buildings is responsible for nearly half of the raw materials and energy consumed across the planet. Therefore, it has major impacts on the depletion of finite resources and on the emissions of greenhouse gases. In this context, the researches on new buildings materials and new technologies more environmentally friendly are increasing, in order to reduce both the consumption of materials, energy and CO_2 emissions.

With regards to construction materials, several Italian studies have been considered. Specially, a high number of these deal with the development of more sustainable materials.

[1] *ISO/TS 14067:2013*

For instance, Alessandro Arrigoni[2] et al. [1] investigates the environmental impact of the hempcrete blocks production. Hempcrete is a natural building material that, in recent years, has known an increased usage in non-bearing walls and as finishing plasters and floor/roof insulators. Through a life cycle assessment of hempcrete blocks, the author analyses the environmental performance of the product. The study identify that the production phase of raw materials is the main responsible of environmental impacts. Nevertheless, the overall emission balance is very favourable. Indeed, thanks to biogenic CO_2 uptake during hemp growth and CO_2 uptake by carbonation, hempcrete blocks have negative carbon footprint and act therefore as effective carbon sinks.

Hemp concrete has been investigated in other several experimental and numerical studies, such as, for instance Francesco Asdrubali[3] et al. [2] and Carlo Ingrao[4] et al. [3]. Both these published studies are focussed upon the assessment of the environmental and energy impacts related to the use of hemp-based materials in buildings applications. The studies aim at testing and improving hygro-thermal properties and eco-friendliness of these materials for reduction of both embodied and operational energy. In particular, Asdrubali underlines the role of hemp-lime concrete as insulating layer in building façades, by a comparison among their use in Italy and in France. Carbon footprint assessment is carried out considering both the estimated energy demands and the life cycle emissions factors. Moreover, all studies concluded that the main strength in the use of hemp-based materials comes from the production phase.

With reference to building envelope, Flavio Scrucca[5] et al. [4] carries out a comparative life cycle assessment of external wall-compositions. The aim of his paper is to compare four external-wall solutions, constituted by different materials and characterized by different technologies, through the LCA approach, in order to identify the best solution from both the energy and environmental point of view. The assessment is made taking into account assembly, use and end-of-life phases of walls. For any wall-solutions considered, the environmental impact category with the highest achieved score is Global warming, associated with CO_2 emissions.

Referring to insulating materials, several analyses are carried out in terms of environmental impact and, in particular, carbon footprint estimation of a product. Stefania Proietti[6] et al. [5] carries out a study aims to evaluate the environmental impact assessment of the production/manufacture of a reflective foil in terms of carbon footprint. The analysis considers the whole life cycle of the product, from the extraction of raw materials to the product's disposal, i.e. *"from cradle to grave"*. On the basis of obtained results, different measures are proposed in

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order to reduce emissions in the life cycle and minimize residual carbon footprint. Moreover, results allow to make an important comparison concerning the environmental performance of the reflective foil and other type of insulating materials.

Besides eco-friendly materials, traditional ones are also subjected to several studies about environmental impact level. For instance, Laura Moretti[7] et al. [6] investigates the environmental impact of the Italian cement industry, since this material is the second most used substance around the world after water, and its production is associated with high amounts of CO_2 emissions. The environmental assessment is conducted through a life cycle analysis of this industrial process, taking into account grey cement and clinker industry. The analysis of results demonstrates that among the different phases involved in the production process of these materials (i.e. extraction and production of raw materials, transportation and core production process), the core phase is responsible for most of the greenhouse emissions: more than 85% of the total process for clinker and more than 79% of the total process for cement.

The analysis of building products is integrated in LCA studies of technical elements as well as of the whole building. For instance, a research conducted through the collaboration with the Department of Design and Construction of Genoa University (Italy) and ENEA (Italian National Agency for new technologies, energy and sustainable economic development) is focused on LCAs of external walls, comparing the environmental impact of two different construction techniques for residential buildings: traditional load-bearing walls and load-bearing steel structure [7]. Referring to Sicilian context, a similar analysis is carried out to improve eco-efficiency of an external masonry veneer wall, in order to evaluate the best insulation, which produces the least environmental impact with the same thickness [8]. In the first part of their research, Torricelli et al. [9] take into consideration the environmental assessment of brick elements, as members of some technical solutions selected in the design phase concerning load-bearing walls, masonry veneer walls, partition walls, floors and roofs. Referring to whole buildings, the collaboration between ENEA and the Department of Raw Materials of ‘‘La Sapienza’’ University in Rome (Italy) concerns the application of LCA methods to assess the environmental impact of energy saving renovation measures [10].

3. Carbon footprint assessment with reference to residential buildings

Besides environmental impact of construction materials, it’s important also to evaluate the environmental impact of the building as a whole. Several studies, with reference to residential buildings, are carried out with the aims to identify building sustainability parameters.

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For instance, Roberta Moschetti[8] et al. [11] investigates a methodology to define reference values for representative building sustainability parameters. In particular, given the increasing interest in the overall quality assessment of buildings, the research is focused on specific indicators, representing essential outputs for a complete building sustainability evaluation. For this aim, four exemplary Italian residential categories are analysed, through their life cycle assessment, in order to define specific values linked to the environmental impacts and to the total energy spent. The results show that the use phase implies the largest contribution to the environmental and energy impacts.

Moreover, Paolo Sdringola[9] et al. [12] carries out a study aims to estimate the environmental impact of a low-energy consumption building, complying with the "PassivHause"s standards. All life cycle phases are included in the research: acquisition and production of materials, on-site construction and use /maintenance, demolition and material disposal, taking into account a life span of 70 years. The results show that applying energy saving measures (highly insulated building envelope and passive-house standard, solar PV, waste recycling and recycled products in pre-production phase) can be achieved a significantly decreasing in the environmental impact.

Since the Italian building heritage can't be defined as "recent", historical building restauration represents one of the main activities nowadays protagonist in the construction sector. For this reason, some studies are carried out in order to evaluate the impact of energy and structural performance improvements into historical building on the environmental sustainability. For instance, A. Magrini[10] et al. [13] carries out a study which considers the possibility to increase energy performance of historical buildings through actions compatible with the preservation constraints to which they are subdued. The sustainability of the restoration actions can be considered as a benefit, and it can be increased with some attention to materials and resources management.

4. Carbon footprint assessment with reference to civil works

The world-wide effort to reduce the environmental impact associated to the industrial sector is quickly producing an increasing feedback on national and international decision makers. In this context, the analysis of life-cycle based assessments on the main impact categories associated to the pre-production, production and use phases represents an important tool towards the interpretation of the footprint from industrial buildings.

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[10] *Department of Civil Engineerign and Architecture, University of Pavia, Italy*

As highlights E. Bonamente[11] et al. [14] the Italian prefabricated building sector, characterized, on average, by local enterprises with regional coverage, is investigated in order to study the carbon and energy footprints. The quantification of the carbon and the energy footprint, associated to the prefabricated industrial building sector, is performed through a parametric modeling of the building properties bases on the analysis of different sizes and designs. Moreover, the comparison of the environmental performance depending on different construction requirements is included.

Besides buildings, several studies of environmental impact are also carried out referring to civil works. For instance, Filippo Giustozzi et al. [15] takes into account airports and air transport entail. Indeed, there is a need to improve airport pavements constructions and maintenance practices, in order to limit greenhouse gasses and set environmental standards towards the development of more "sustainable airports". The author analyses emission saved in reusing and valorising existing in-situ soils, through a cement stabilization to improve the bearing capacity of the runway. The analysis is carried out by evaluating emissions due to equipment and materials, and providing a case study of a major Italian airport.

5. Carbon footprint assessment carried out into Italian Universities

Many Italian Universities have carried out several studies to implement carbon management strategies, taking into account CO_2 emissions related to university-facilities and student's behaviour.

For instance, Genoa University (Italy) and the Italian Ministry for the Environment, Land and Sea, have signed in 2014 a voluntary agreement in order to estimate the carbon footprint of the University-facility [16]. For this aim, energy consumptions analysis both of the building and related activities are carried out, in order to reduce CO_2 emissions. Identification of possible energy saving actions and monitoring activities are also taking into account in the study.

Venice University "Ca Foscari" has carried out a similar study inside the project "Carbon Management" [17]. The main goals of the project are to quantify CO_2 emissions related to school-facility and its users, in order to define the carbon footprint of the University and produce reference guidelines for the carbon management of all Italian Universities. The first energy report of the project shows a reduction of 113 tonnes of CO_2 emissions and a saving of the 11,43% in heating costs.

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A degree thesis developed inside Milano University "Politecnico" in 2011 deepens this issue [18]. The study aims to estimate the carbon footprint of the university- facility and its related activities, through the evaluation of energy consumptions and the related CO_2 emissions. Main goals of this researching work are to promote energy saving activities inside the University and the reduction of CO_2 emissions.

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