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Life cycle assessment of reinforced concrete units

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Abstract.
Construction industry is one of the most important industries of today. The term construction refers to many activities as the building of a dam, a road, a monument, a wooden structure, a bridge, etc. But construction has high impacts on the environment which need to be minimized. These impacts occur from initial on-site work through the construction period, the operational period, and to the final demolition, when a construction comes to the end of its life.

Nowadays reinforced concrete is the material mostly used in the sector of civil construction. Different studies about its behaviour when using different types and amounts of materials have been carried out, but only few researches have investigated how these choices can affect the environmental impacts.

Life Cycle Assessment (LCA) allows for determination of the environmental impacts at each stage of a construction life cycle, beginning at the point of raw materials extraction, and then through processing, manufacturing, fabrication, use, and disposal. Transportation of materials and products to each process step is also included. So LCA allows the optimization of materials and energy in order to promote sustainable development.

The final aim of the present work is to use the LCA methodology to compare environmental performances by using different scenarios, as changing the plants where the cement is produced or changing the type of cement used (CEM I 42.5 R, CEM II/A-LL 42.5 R, CEM IV/A 42.5 R) always guaranteeing the same resistance to compression.

The analysis follows the methodology defined by ISO 14040 and 14044 and it is performed using SimaPro 8.2 software adopting a cradle-to-gate perspective, from the materials extraction to the manufacturing phase.

Primary data come from the manufacturing phase (energy consumption of the mix design, energy consumption of the installation, steel transport, cement transport, aggregates transport) while the secondary data used are the mix design and the cement type emissions that have been derived from the EPD (Environmental Product Declaration) provided by Buzzi Unicem.

The analysis is carried out using ReCiPe 2008 method starting with a comparison between the different cements produced in each plant. Then, the distance of the cement supplier for each type of cement is varied to compare the different plants.

At the end a validation study is conducted on a particular type of cement (CEM II/A-LL 42.5 R produced in Trino plant) comparing the EPD data with real primary data of the cement production provided by Buzzi Unicem, in order to verify the reliability of EPD secondary data.

The results obtained from the simulations have made possible to conclude which is the scenario that reduces the most the consumption of resources and the emissions to air and water under a sustainable point of view.

In particular, the results obtained by the ReCiPe 2008 method comparing both different cements and different materials production plants show that the most significant changes are reported for the

categories of climate change, ozone depletion, terrestrial acidification, photochemical oxidant formation and metal depletion.

The results obtained comparing the different cements show that the materials phase is the phase which gives more significant differences. In addition, among the considered cements, the most impacting is CEM I 42.5 R while the least one is a pozzolanic cement (CEM IV/A 42.5 R), confirming literature data. The manufacture of Portland cement is proved to consume a great deal of energy resulting in high embodied energy and carbon dioxide emissions from clinker calcination, becoming less energy intensive by utilizing higher levels of pozzolanic materials such as fly ash.

When changing the plants and keeping constant the type of cement, the plant characterized by the highest transport impacts is Augusta. On the other hand, the one having less transport impacts is Vernasca, which is the closer to Milano, where the reinforced concrete structures are produced. So it can be concluded that also the transport impacts can play a significant role when distance is long and road transportation is used.

At the end, the validation study confirms the simulations carried out with the EPD: the error between the use of primary and secondary data is also estimated and is very little, ranging from about 0.001% in metal depletion and being its maximum of about 18% in only one of the eighteen categories, natural land transformation.

As a general conclusion, it can be stated that, from all the scenarios considered to guarantee a compression resistance of cement of 42.5 R in reinforced concrete structures, the cement which gives lower environmental impacts is CEM IV/A 42.5 R and the best plant to have lower transport impacts needs to be near the place where the mix design and installation is performed.

Future work will involve the impacts assessment of the total life cycle - from cradle-to-grave - including maintenance, service life and end of life treatment.