ELSEVIER
Construction and Building Materials
Volume 345, 22 August 2022, 128294

Eco-efficient transformation of mineral wool wastes into lightweight aggregates at low firing temperature and associated environmental assessment

Ana B. López-García, Manuel Uceda-Rodríguez, Sara León-Gutiérrez, Carlos Javier Cobo-Ceacero, José Manuel Moreno-Maroto

https://doi.org/10.1016/j.conbuildmat.2022.128294

Highlights

- Rock wool and glass wool were used to manufacture lightweight aggregates (LWAs).
- The new LWAs exhibited technological properties analogous to the commercial ones.
- Glass wool allows LWAs to be obtained at temperatures of 500 °C below the usual.
- Life Cycle Assessment has shown significant environmental benefits of the new LWAs.

Abstract

Waste recycling is one of the key elements to mitigate the environmental problems that threaten our society. Mineral wool is currently the most widely used insulation material in the European Union, so the amount of waste generated in the demolition and restoration of buildings has increased alarmingly. This work investigates for the first time the use of glass wool (GW) and rock wool (RW) as a component in the manufacture of lightweight aggregates, showing that both can be suitable raw materials considering the density (1.3–1.5 g/cm^3) and mechanical strength (2–6 MPa) obtained. In addition, the use of GW would help to reduce the firing temperature significantly (700 °C) compared to that normally used in the manufacture of these materials (around 1200 °C), which would imply significant energy savings. Considering that thermal insulation materials and lightweight aggregates are among the most widely used materials in the construction sector, the work presented here also evaluates the environmental impact associated with the manufacture of lightweight aggregates with RW and GW in comparison with the traditional process, using the Life Cycle Assessment (LCA) methodology. A significant environmental improvement has been observed in almost all the analyzed impact categories of the artificial aggregates manufactured with mineral wool with respect to traditional LWAs.

Introduction

Since the Industrial Revolution, the European economic model has been based on the linear sequence of "extract, produce, waste". As this was reaching the limits of its environmental and economic viability, it was necessary to look for a new alternative. This new model is known as the circular economy and its basic principles include maintaining the value of resources for as long as possible and reducing the waste generated. This allows them to be reintroduced into the cycle. The new EU Waste Framework Directive 2008/98/EC [1] establishes that, by 2020, 70% of construction and demolition waste (CDW) should be reused, recycled or recovered. Mineral wool waste accounts for 0.2% of the volume of all CDW. Different studies show that this waste is increasing annually by 1.2%, and its increase is expected to continue in the coming years [2]. Although it is difficult to estimate the actual volumes of this waste, as reliable data are scarcely available, it is estimated that by 2020 it will exceed 2.5 million tons [3], which could end up in landfill.

The large amount of mineral wool, as waste, which is estimated to be generated at present, represents a challenge for society. Therefore, there are several studies on its reuse in different areas of industry, such as in the manufacture of concrete [[4], [5], [6], [14]], mortar [7], [8], wood-plastic composites [9], [10], gypsum [2], ceramic foams [11] and asphalt mixtures [[12], [13], [14]]. Some studies have also been carried out using these wastes as precursors for alkaline activation, as they present theoretically suitable chemical and mineralogical compositions [15], [16]. After consulting the literature, it was decided to pursue a line of research for the utilization of mineral wool for which there are no bibliographic precedents: the manufacture of lightweight aggregates.

According to Cheeseman et al. [17] a lightweight aggregate is considered as such, if it presents a strong porous sintered ceramic core, but of low density, a dense external surface to avoid water absorption and an almost spheroid shape to improve the workability of fresh concrete. The EN 13055–1 [18] standard states that for an aggregate to be considered as 'lightweight' it must have a particle density (ρ_{rd}) of less than 2000 kg/m^3 and/or a bulk density (ρ_B) of less than 1200 kg/m^3. The technological advantages offered by lightweight aggregates over conventional aggregates, together with the transition towards a circular economy, are being reflected in numerous investigations on the valorization of waste as raw materials for manufacturing. Examples are different types of solid waste, from coal-fired power plants, mining, metallurgical and agricultural industry among others [19]. No evidence has been found that mineral wool has been used for this purpose.

However, studies focused on the development of new materials should not only focus on the improvement of their technological and mechanical properties. The analysis of their environmental properties should also be a priority [19], [20].

Until a little more than a decade ago, efforts to minimize environmental pollution were focused on cleaning or purifying the environment (air, water or soil) where effluents or polluting emissions were released. These types of solutions have proven ineffective since they deal with the problem once the processes have taken place, the products have been manufactured and the waste and emissions have been generated, in addition to nullifying the competitive possibilities of companies due to their high cost. Sustainability is not only linked to the research sector. Aggregates companies such as LECA, have been working for some time on the circular economy with different sustainable alternatives throughout their European centers where they incorporate local wastes for the production of aggregates. The adoption of an integrating and global perspective, throughout the entire life cycle of the product, at the time of allocating, assessing and making decisions to minimize the environmental impacts associated with it, seems the most reasonable thing to do. For this purpose, the Life Cycle Assessment methodology, defined by ISO 14040 [21], is available as a technique for evaluating the environmental aspects and potential impacts associated with a product.

Different studies on Life Cycle Assessment in the construction sector have shown that the environmental impact of building products can be significantly reduced by promoting the use of best available techniques and that eco-innovation in production plants, substituting the use of finite natural resources for waste generated in other production processes, preferably available locally, stimulating the creation of more sustainable products and encourage the generation of new business and job opportunities [22], [23], [24], [25].

Section snippets

Initial preparation of raw materials

Two types of mineral wool were used, a rock wool (RW) and a glass wool (GW), which were supplied in panel form by Saint Gobain Isover, S.L. (Azuqueca de Henares, Spain). They were cut into pieces and then, following a procedure analogous to that of other authors [11] were powdered for one hour in a Siemens® ball mill [26]. Since mineral wool alone is not a workable material, small proportions of <200-μm-milled sepiolite by-products from Tolsa plant (Vallecas, Spain) were used to improve…

Characterization of raw materials and their mixtures

The particle size distribution in the ground raw materials indicates a large degree of fineness (Fig. 4), with mean particle sizes of 56.1, 34.0 and 18.5 μm and d_{50} values of 35.8, 21.0 and 10.9 μm in GW, RW and the added sepiolite, respectively. The carbon content of the blends comes mainly from the mineral wool, which would be linked to the resins that usually incorporate this type of material. The carbon is therefore mainly organic, reaching 5.5 wt% in GW and 2.5 wt% in RW, which translates…

Conclusions

The work presented shows how two types of mineral wool (GW and RW) are used in the manufacture of lightweight aggregates. The main conclusions that can be drawn are shown below:

- Although a priori the lack of plasticity of mineral wool could be an impediment for its pelletization, the addition of clay (in this case a 20 wt% of by-products rich in sepiolite) can facilitate the adequate workability of the final mixtures.…
- The most suitable temperature for sintering was 700 °C and 1180 °C for the…

…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Acknowledgments

This research was conducted as a part of the ECO-MET-AL Project (PID2019-109520RB-I00) funded by the Spanish Ministry of Science, Innovation and Universities and ERDF funds, framed in the "Ayudas a "Proyectos I + D + i" en el marco de los Programas Estatales de Generación de Conocimiento y Fortalecimiento Científico y Tecnológico del Sistema de I + D + i y de I + D + i orientada a los Retos de la Sociedad, Convocatoria 2019". The authors are also grateful for the following funds: Predoctoral…

Reference (54)

A. Cheng *et al.*
Application of rock wool waste in cement based composites
Materials and Design. (2011)

W.T. Lin *et al.*
Improved microstructure of cement-based composites through the addition of rock wool particles
Materials Characterization. (2013)

O. Väntsi *et al.*
Utilization of recycled mineral wool as filler in wood-polypropylene composites
Construction and Building Materials. (2014)

Z. Chen *et al.*
Reuse of mineral wool waste and recycled glass in ceramic foams
Ceramics International. (2019)

C.R. Cheeseman *et al.*
Properties of lightweight aggregate produced by rapid sintering of incinerator bottom ash
Resources Conservation & Recicling (2005)

M. Dondi *et al.*
Lightweight aggregates from waste materials: Reappraisal of expansion behavior and prediction for bloating
Construction and Building Materials (2016)

R.J. Galán-Arboledas *et al.*
Energy environmental and technical assessment for the incorporation of EAF stainless steel slag in ceramic building materials
Journal of Cleaner Production (2017)

J.M. Moreno-Maroto *et al.*
A study on the valorization of a metallic ore mining tailing and its combination with polymeric wastes for lightweight aggregates production
Journal of Cleaner Production. (2019)

J.M. Moreno-Maroto *et al.*
What is clay? A new definition of "clay" based on plasticity and its impact on the most widespread soil classification systems
Applied Clay Science. (2018)

E. Fakhfakh *et al.*
Effects of sand addition on production of lightweight aggregates from tunisian smectite-rich clayey rocks
Appl. ClaySci. (2007)

View more references

Cited by (4)

Investigation of sisal fiber incorporation on engineering properties and sustainability of lightweight aggregates produced from municipal solid waste incinerated bottom ash
2024, Construction and Building Materials
Show abstract

Effects of mineral wool waste in alkali activated-artificial aggregates for high-temperature applications
2023, Construction and Building Materials
Show abstract

Effect of curing time and temperature on the mechanical properties of green and ultra-high-strength non-sintered aggregate via autoclave technology
2023, Construction and Building Materials
Show abstract

The Influence of Structural Elements on the Measurement of Thermal Conductivity Using the Hot Disc Method of Wood-based panels
2023, ICWST 2023 - 32nd International Conference on Wood Science and Technology: Unleashing the Potential of Wood-Based Materials, Proceedings