

BIBLIOMETRIC ANALYSIS OF PUBLICATIONS ON ECOLOGICAL CONCRETE

*Elena MARICA¹
Maria POPA²*

Abstract: *Waste management is a major problem, so solutions to prevent and reduce waste are constantly being sought. One of the methods of recovering construction waste is the manufacture of environmentally friendly concrete by incorporating waste into technological processes. Legislation sets targets for recycling and reducing the quantities of waste generated, failure to meet these targets entails significant financial penalties, which is why the emphasis is on the circular economy, which aims to manage the resources used efficiently by reducing the quantities of waste and by recovering them efficiently, in particular through reuse. Construction waste management is a significant problem considering the intensity of construction, the high volume of waste generated and the insufficiency of waste recovery methods, therefore we intend to show through this study the progressive increase of interest in the use of ecological concrete resulting from waste recovery. The aim of the research is the bibliometric analysis of publications on ecological concrete using the Scopus database and the VOSviewer software. The study analysed 590 publications from more than 76 countries, published between 1986 and 2022, which had the keywords: concrete and ecological as a common topic. The research results highlight the countries most concerned with ecological concrete, the period in which the subject was of major interest, and the field from which most researchers interested in ecological building materials come.*

Keywords: *concrete, ecological, VOSviewer, bibliometric analysis*

JEL Classification: L61, L74

Introduction

Concrete can be defined as "a composite material consisting of a homogenous mixture of cement, sand, gravel, gravel and slag, to which are added in technically motivated situations, admixtures and/or mineral additives, whose properties are developed through the hydration and hardening of the cement" (NE 013-2002). The main stages of the technological process of concrete manufacturing are the supply of raw materials, the batching of raw materials, the mixing of components, the unloading of the manufactured concrete into the truck, the weighing and the delivery to customers. Of the components of concrete, aggregates are the most important in its production and the bond between cement and aggregate sets the upper limit of concrete strength (Neville, 1997).

Among the negative effects of concrete production on the environment, several aspects are worth mentioning, such as: the alteration of habitats for the extraction of materials and the use of large amounts of energy for the extraction, production and transport of cement. Cement dust contains free

¹ Lucian Blaga University of Sibiu, DoctoralSchool, Faculty of Engineering, Sibiu, România, E-mail: elenamarica93@yahoo.com

² Decembrie 1918 University of Alba Iulia, Faculty of Economic Science, Alba Iulia, România, E-mail: mariapopa2010@yahoo.com

silica crystals, limestone and chromium oxides, all of which have a negative impact on human health and the environment (Kubba, 2012). In order to reduce the impact of concrete manufacturing on the surrounding environment, several principles need to be followed, such as the inclusion of a controlled content of recycled materials, the optimisation of the cement content in concrete and the use of low-impact cement with lower clinker content (Damtoft et al., 2008).

The concept of ecological concrete or eco-concrete is a new idea of using less energy and producing less CO₂ emissions in the production of concrete based on environmentally friendly materials. Three major goals are pursued in the production of eco-concrete: reduction of greenhouse gas emissions, reduction of natural resource use and waste use (Șerbănoiu G. 2019). Several methods have been identified to obtain green concrete: graphene-based concrete, concrete with glass waste aggregates, concrete with sawdust, concrete with rubber granules, etc.

Due to the significant increase in the global demand for concrete, and the large amounts of CO₂ emissions generated by the technological process of concrete production, there is a growing demand for environmentally friendly concrete and mortars and a continuous search for solutions to improve it. Ecological concrete is the result of the use of some materials in the category of vegetable, animal or industrial waste as substitutes for cement, sand and/or aggregate, or concrete whose production process does not significantly affect the environment. (C.M Grădinaru, A.A Șerbănoiu, 2019). Ecological mortars containing additives (GO-Ag and GO-Fly ash) show resistance to compression and bending, respectively to chemical attacks, therefore these types of mortars can be used in restoration processes of cultural heritage (Popa D. et al., 2022).

Ecological concrete can be used in residential and non-residential civil construction, industrial construction (industrial halls, warehouses), civil engineering works (bridges, viaducts); special construction for water transport (canals, harbours), special industrial construction (silos, sewage treatment plants), hydrotechnical construction (dams). (<https://econcept.holcim.ro/inovatie/ecosolutii/ecopact>)

In consideration of the above, we will make a bibliometric analysis of the literature based on the keywords "concrete" and "ecological" to observe the evolution of the interest of researchers in this subject.

Research methods

To perform this study we used the Scopus database, namely the VOSviewer software. Scopus is a database of abstracts and citations for articles in research-related publications. The database was created in 2004 by Elsevier Publishing . Scopus is regularly updated and provides approximately 25,000 articles from over 5,000 international publishers, including: 16,500 peer-reviewed journals in scientific, technical, medical and social fields; 600 trade publications; 350 book editions; extensive global conference coverage with 3.5 million conference papers. ([https://koaha.org/wiki/Scopus_\(base_di_dati\)](https://koaha.org/wiki/Scopus_(base_di_dati)))

VOSviewer version 1.6.18, released on 24 January 2022, has been used. VOSviewer is a software tool for building and visualizing bibliometric networks. These networks can include, for example, journals, researchers or individual publications and can be built based on citation, bibliographic pairing, co-citation or co-author relationships. VOSviewer also provides text mining functionality that can be used to build and visualize co-occurrence networks of important terms extracted from a body of literature. ([https://koaha.org/wiki/Scopus_\(base_di_dati\)](https://koaha.org/wiki/Scopus_(base_di_dati)))

The study analysed 590 publications from more than 76 countries, published between 1986 and 2022, which had the keywords concrete and green as a common subject. The information on the 590

publications was downloaded in early May 2022 in csv format from the Scopus database and then loaded into the VOSviewer software.

Results and discussions

Analysis of published documents according to the period of publication

During the review period 1986 to 2022, 590 publications were published with the common subject of ecological concrete. The graph in Figure 1 shows the increase in the number of publications over time. In 1986 only 1 article was registered in the Scopus database, while in 2021 89 publications were registered, and 29 articles in the period January - April 2022. The increase in interest in the topics analysed has not been constant, for example in 2014 a number of 32 publications were registered, and in the following calendar year, only 21 articles were published, with 11 fewer articles.

The most prolific year in terms of publications was 2021 with 89 publications and the period 1986-1990 is the weakest with an average of 2.91 articles published. The interest shown by researchers in the subject under analysis increases by 80% considering the period under analysis.

Of the 590 papers studied, 319 are scientific articles, 229 are conference papers and 28 are reviews. Of the documents considered, only 0.1% are books. Most of the publications are written in English (522 of the publications), 52 of the articles are written in Chinese, 14 in German and the rest are published in French, Russian, Spanish.

Regarding the field of papers studied, the first place is given to the field of engineering with 34.6%, meaning 373 papers published, followed by Materials Science with 172 papers published and Environmental Engineering with 15.7% publications out of the total of 590.

The National Natural Science Foundation of China sponsored the most papers (54 papers), followed by two other Chinese institutions, namely the European Commission, which ranks 4th in terms of research sponsorship in this field.

Documents by year

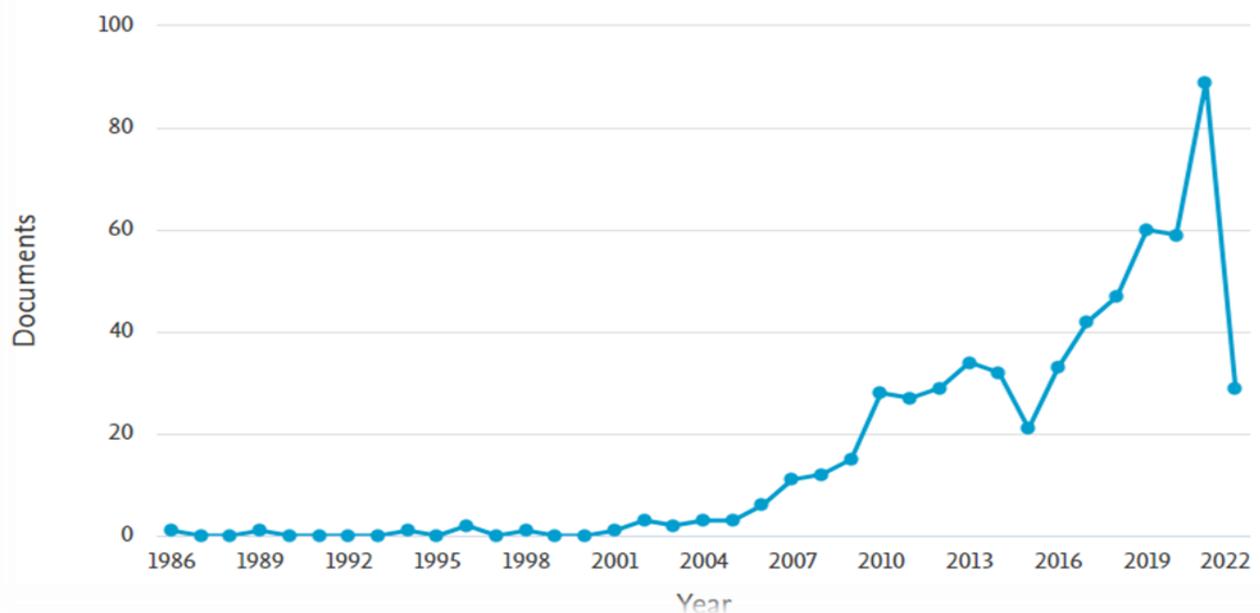


Figure 1. Analysis of published documents according to the period of publication

Bibliometric analysis of the countries

Figure 2 presents the bibliometric analysis of the countries that are interested in ecological concrete. The 37 countries (indices) considered have been divided into 9 groups as follows: with red colour is marked cluster 1 consisting of 9 countries (Brazil, India, Iran, Portugal, Russian Federation, Saudi Arabia, South Korea, Vietnam); with green colour is marked cluster 2, cluster 2 consisting of Canada, Canada, Denmark, Germany, Spain, Sudan) Cluster 3 is marked with dark blue colour consisting of 6 countries; cluster 4 is represented with yellow and consists of 4 countries; cluster 5 is coloured with purple and consists of 3 countries. Based on the results obtained, we can state that the countries most concerned by ecological concrete, as evidenced by the large number of publications, belong to the category of developed countries with significant economies.

The size of the nodes represents the frequency of publications, and the curves between the nodes represent the appearance in the same publication, in this context China has published the most papers on green concrete, over 230 publications, followed by the Russian Federation with 37 publications, the United States, Germany and India which have between 30-32 publications. Romania ranks 14th in this ranking with 14 publications.

Among the countries less interested in this topic are Hungary, Serbia, Monaco, Morocco which have only one article published in the period under review.

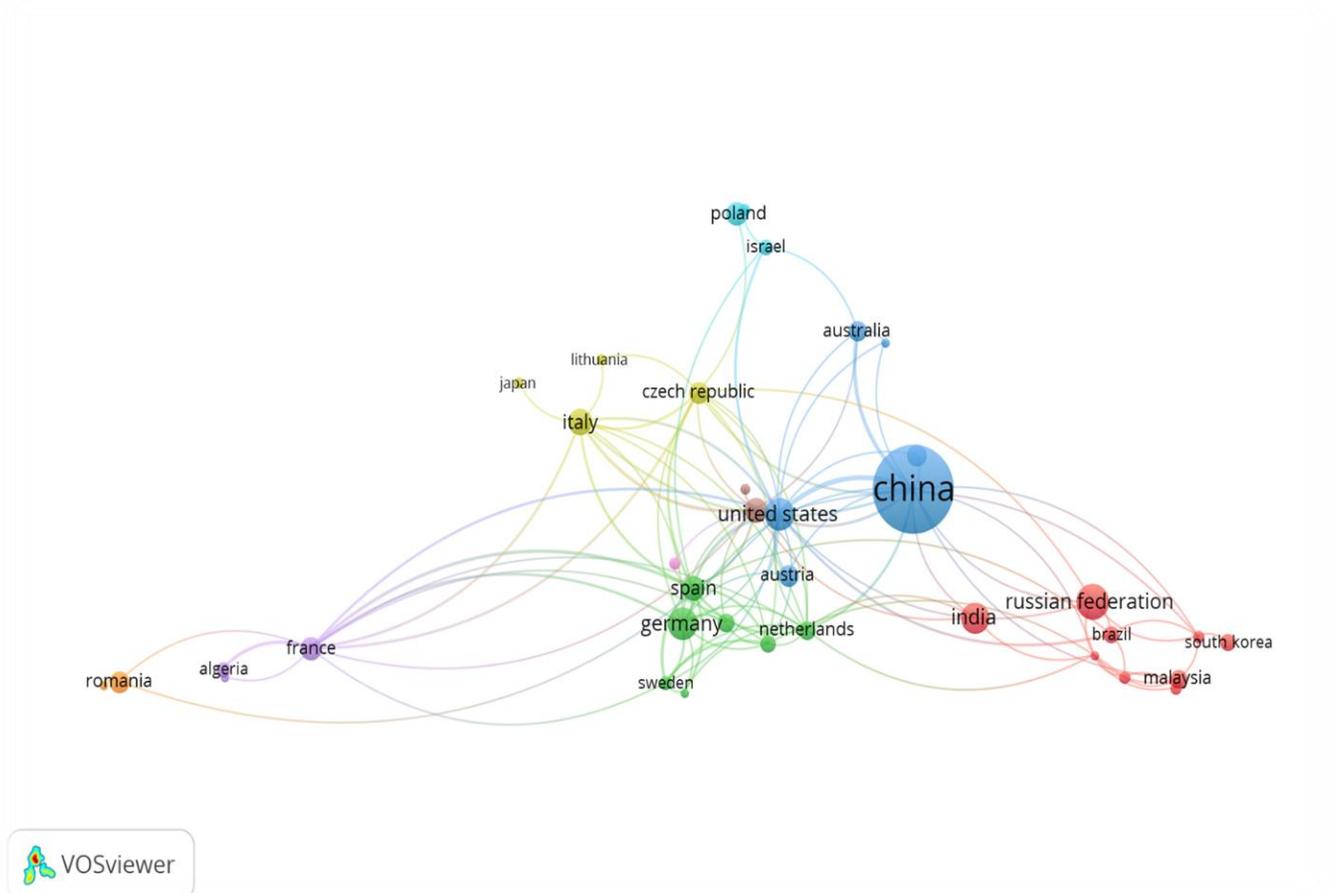


Figure 2. Bibliometric analysis of the countries

Bibliometric analysis of the authors

Figure 3 illustrates the bibliometric analysis of the authors cited in the papers studied. Out of the 1752 authors, only 236 authors were selected, in accordance with the requirement of a minimum of 2 authors and a maximum of 25 authors per document. According to the analysis, the most cited authors are Gupta R.C. with 2 articles written on ecological concrete, respectively with 273 citations, followed by Shui and Yu with 5 publications, respectively 233 citations.

Gruota R.C and collaborators consider that eco-concrete with rubber content can be applied on concrete pavements, floors and highways, hydraulic structures such as tunnels and dam spillways or for other surfaces where abrasive forces are applied by moving objects during service. (Grupta R.C, 2016). The same author along with his collaborators observed from experiments that rubberized concrete is highly resistant to aggressive environments and can be deployed in areas where there is potential for acid attack (Thomas B.S. et al., 2016).

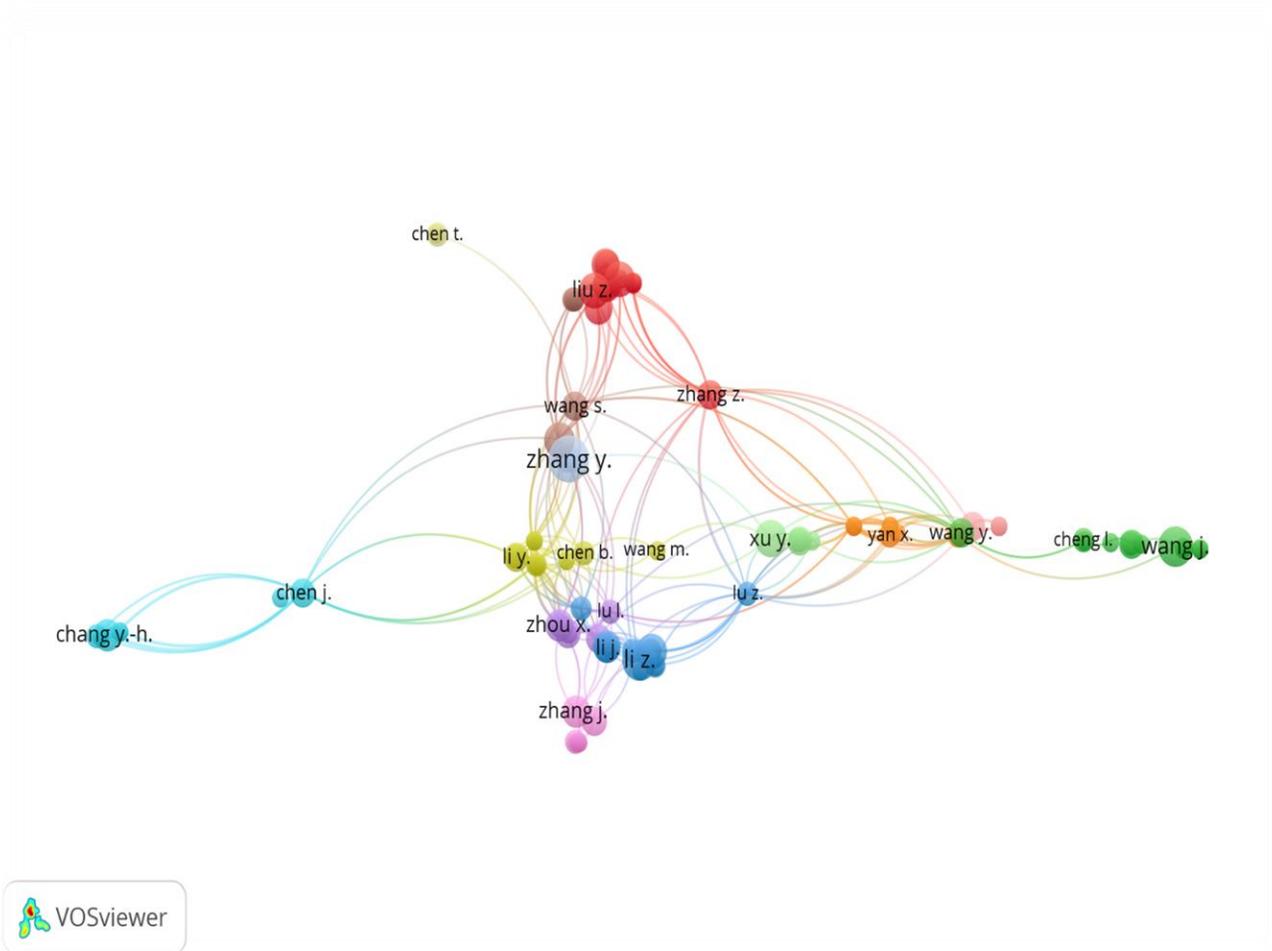


Figure 3. Bibliographic analysis of citation – authors

The bibliometric analysis of cited authors includes 47 factors/authors divided into 13 clusters/clusters. The cluster with the most links, consisting of 14 authors, is shown in red. The most cited articles were published between 2018-2021.

Bibliometric analysis of the keywords

Figure 4 reveals the result of the bibliometric analysis of the use of keywords by authors in the 590 publications studied. The size of the nodes represents the frequency of use of the words, therefore the most used keywords are concrete, ecological, sustainability, (94) cement, aggregates, but the first place is the keyword concrete, used about 213 times. We estimate that the frequent use of the keyword "concrete" in the publications studied is due to the complexity of the subject, as it includes in its definition the main components such as cement, aggregates, etc.

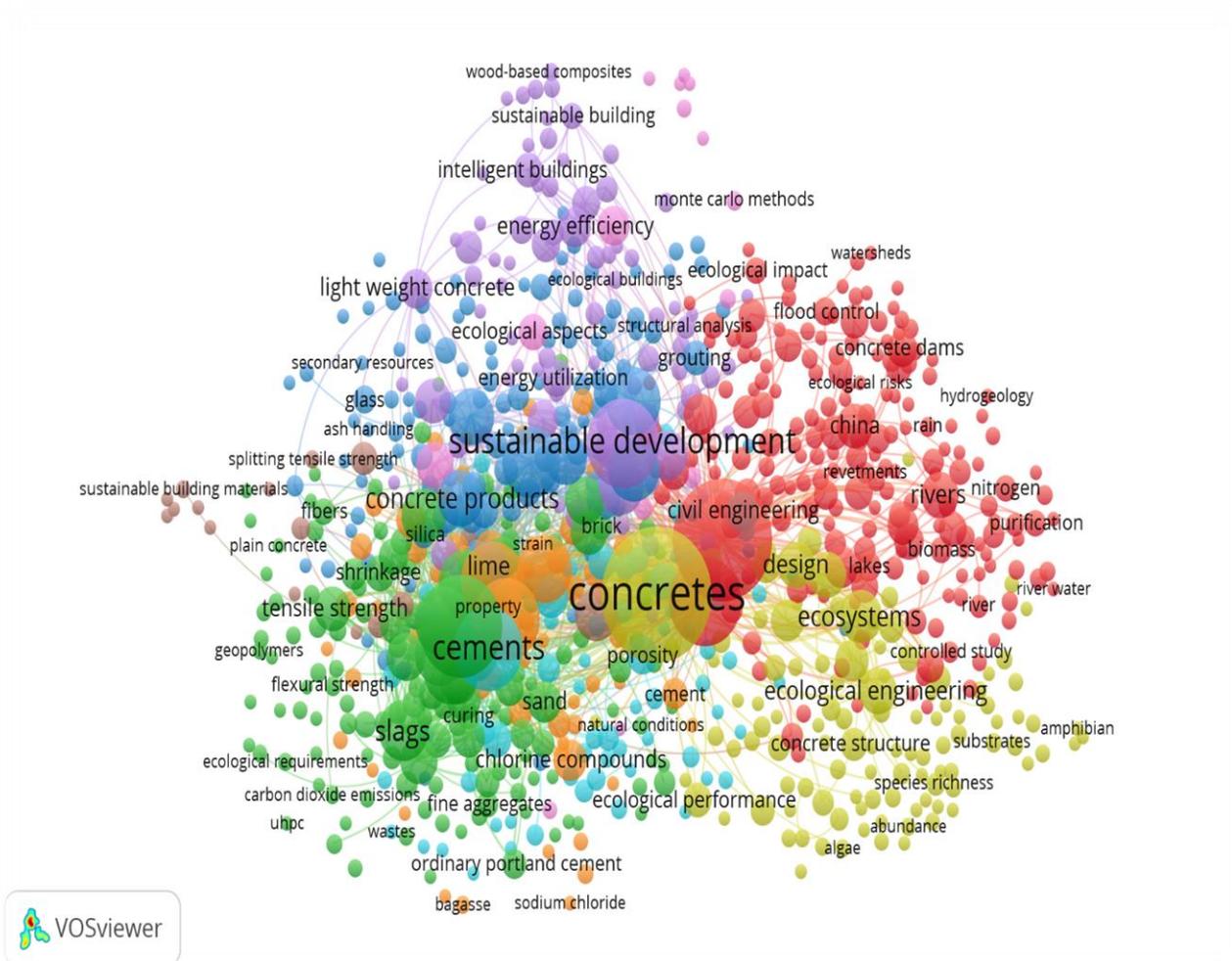


Figure 4. Bibliometric analysis of the keywords

Conclusions

Environmentally friendly concrete will gradually replace conventional concrete due to the significant environmental impact of concrete manufacturing processes. Solutions to improve the technological processes for the production of ecological concrete are constantly being sought, and this is also reflected in the gradual increase in the number of publications, for example in the period 1986-1990 one article was published and in the year 2021 89 articles were published.

More developed countries with a significant economy are more interested in the development of recipes for the manufacture of ecological concrete, according to the bibliometric analysis carried out, most publications belong to researchers from China, the United States, Brazil.

The most used keyword in the 590 publications is the word "concrete", used 213 times, followed by the word "ecological". We believe that the frequent use of the keyword "concrete" in the publications studied is due to the complexity of the subject, as it includes in its definition the main components such as cement, aggregates, etc.

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