

Bibliometric review of sustainable structures: a look at the history of global scientific production

Mohamed Mehdi Hadi Mohamed¹, Andres Camargo Caysahuana², Geovany Vilchez Casas³, Sarmiento Janampa Fausto Cesar⁴, Cevero Rómulo Rojas León⁵, Ide Gelmore Unchupaico payano⁶

¹Universidad Peruana Los Andes. Perú
d.mhadi@upla.edu.pe

<https://orcid.org/0000-0003-1940-8383>

²Universidad Nacional Intercultural de la Selva Central Juan Santos Atahualpa. Perú
andres_fiq@hotmail.com

<https://orcid.org/0000-0003-3509-4919>

³Universidad Nacional Intercultural de la Selva Central Juan Santos Atahualpa. Perú
geovany_gvc@hotmail.com

<https://orcid.org/0000-0002-6617-5239>

⁴Universidad Nacional Intercultural de la Selva Central Juan Santos Atahualpa. Perú
cesar_sj4@hotmail.com

<https://orcid.org/0000-0002-5246-550X>

⁵Universidad Peruana Los Andes. Perú
romulorojas3030@gmail.com

<https://orcid.org/0000-0001-6544-5869>

⁶Universidad Nacional Intercultural de la Selva Central Juan Santos Atahualpa. Perú
ide_85@hotmail.com

<https://orcid.org/0000-0002-6441-5016>

Abstract

A documentary review was carried out on the production and publication of research papers related to the study of the variable sustainable structures. The purpose of the bibliometric analysis proposed in this document is to know the main characteristics of the volume of publications registered in Scopus database during the period 2017-2021 globally, achieving the identification of 9283 publications in total. The information provided by said platform was organized by means of graphs and figures categorizing the information by Year of Publication, Country of Origin and Type of Publication. Once these characteristics were described, a qualitative analysis was used to refer to the position of different authors on the proposed topic. Among the main findings of this research, it is found that China, with 2382 publications, is the country with the highest number of scientific production related to the variable under study, and the type of publication that was most used during the period mentioned above was the journal article, which represents 56% of the total scientific production.

Keywords: sustainable structures

1. Introduction

In recent years, the industry has undergone major changes in the execution of its processes and in its approach, since the consequences of man's work on the earth are increasingly alarming, suffering the ravages of global

warming and the scarcity of some resources, so it is necessary to implement sustainable structures that allow to mitigate the harmful effects in the environment. It is well known that the social development is at the cost of environmental impacts, so it is important to create a balance to continue advancing as

humanity and in turn safeguard renewable and non-renewable resources, thus being more aware of what to consume.

At the same time, the construction sector has presented a great development since the beginning of the 20th century and will continue to increase, so it is necessary to implement environmental policies in the elaboration of structures that allow society to be more practical, this aimed at meeting the objectives of sustainable development given by the UN, so the creation of new requirements for construction has resulted in a change in the actions of civil engineering, implementing an environmental component responsible to society and conscious of the use of resources. The amount of waste generated by the construction sector as well as the number of resources consumed in the whole life cycle contribute decisively to the increase of the human ecological footprint (Fernando & Gonzalo, 2010). Therefore, environmental policies seek to increasingly reduce this footprint that we leave as humanity translated into pollution and soil deterioration.

Sustainable structures in addition to helping environmental conservation, help organizational growth by implementing corporate social responsibility actions gives a plus in the market since it has been shown that people consume products while they are more sustainable. Therefore, the construction of sustainable structures helps both environmental conservation and cost reduction by using recyclable substances in this process and stronger substances such as concrete, one of the most used elements in the construction of sustainable structures thanks to its properties.

Therefore, it is important to know in terms of bibliographic resources, the current state of research related to sustainable structures, so a bibliometric analysis of the scientific production registered in Scopus database during the period 2017-2021 is proposed to answer the question: How has been the production and publication of research papers related to the study of the variable sustainable structures during the period 2017-2021?

2. General Objective

To analyze from a bibliometric and bibliographic perspective, the production of high impact research papers on the variable sustainable structures during the period 2017-2021.

3. Methodology

Quantitative analysis of the information provided by Scopus under a bibliometric approach on the scientific production related to sustainable structures is carried out. Likewise, from a qualitative perspective, examples of some research works published in the area of study mentioned above are analyzed from a bibliographic approach to describe the position of different authors on the proposed topic.

The search is performed through the tool provided by Scopus and the parameters referenced in Table 1 are established.

3.1 Methodological design

	PHASE	DESCRIPTION	CLASSIFICATION
PHASE 1	DATA COLLECTION	Data was collected using the Scopus web page search tool, through which a total of 9283 publications were identified.	Published papers whose study variables are related to sustainable structures. Research papers published during the period 2017-2021.

			Without distinction of country of origin. Limited to the engineering area. Without distinction of type of publication.
PHASE 2	CONSTRUCTION OF ANALYSIS MATERIAL	The information identified in the previous phase is organized. The classification will be made by means of graphs, figures and tables based on data provided by Scopus.	Word Co-occurrence. Year of publication Country of origin of the publication. Type of publication
PHASE 3	DRAFTING OF CONCLUSIONS AND FINAL DOCUMENT	After the analysis carried out in the previous phase, the study proceeds to the drafting of the conclusions and the preparation of the final document.	

Table 1. Methodological design.

Source: Own elaboration (2022)

4.1 Co-occurrence of words

Figure 1 shows the co-occurrence of keywords within the publications identified in the Scopus database.

4. Results

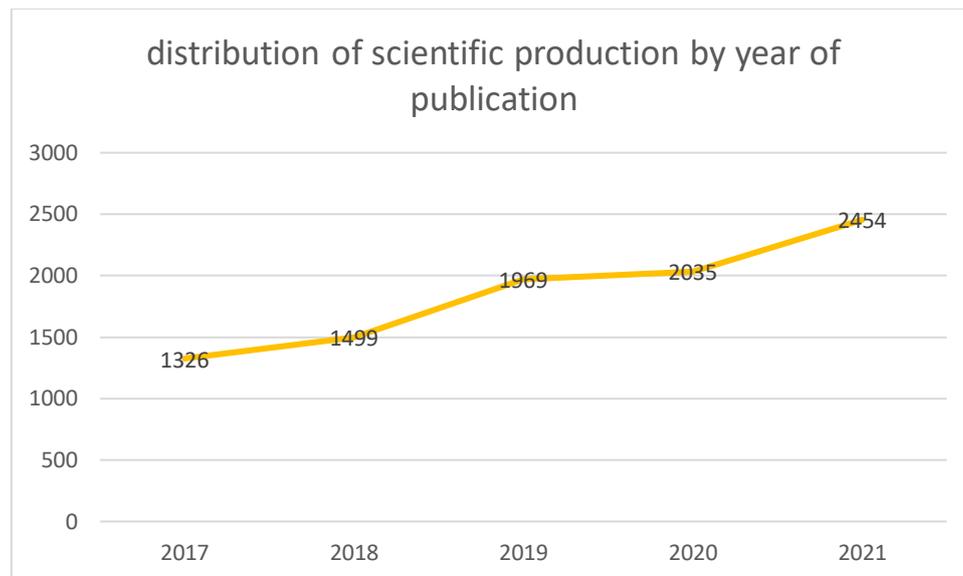


Figure 2. Distribution of scientific production by year of publication.

Source: Own elaboration (2022); based on data provided by Scopus.

2021 is the year with the highest number of publications related to the variable under study presenting 2454 documents registered in Scopus, within these is the paper entitled “*Development and evaluation of an updated tool for the design of soil and water conservation structures in the South African sugar industry*” (Otim D.a, Senzanje, van, & Thornton-Dibb, 2021). This document was created because it was identified that sugarcane in South Africa is grown on soils of great variety, sometimes in non-ideal climates and on steep topographies where soils are vulnerable to erosion so it aims to develop and evaluate updated design standards for soil and water conservation structures in the sugar industry in South Africa. In the analysis of these standards, it was found that although they are the most updated, they are not adapted to the different types of soils, climates and others, so it is suggested to continue using conservation models that allow implementing a sustainable structure in South Africa.

2020 is the second year with more documents registered in Scopus related to sustainable structures having 2035 publications in total, within these documents is “*Use of untreated phosphogypsum as filler and binder material in the preparation of grouting materials*” (Gu, Chen, & Pan, 2020). This document presents

phosphogypsum as an environmentally harmful element, so they propose Recycling phosphogypsum as a filler and binder material in the preparation of grouting materials is not only an effective solution for phosphogypsum disposal, but also a new approach to replace conventional cement-based grouts that is in line with sustainable development. Therefore, a study was carried out to analyze its properties and how it benefits the construction industry, concluding that phosphogypsum as a filler or binder material serves both to recycle and to improve the fluidity and setting time of grout.

In third place is 2019, with 1969 publications registered in Scopus within which is “*Green building rating systems and the new framework levels: a critical review of sustainability certification in Europe*” (Cordero, Melgar, & Márquez, 2019). This paper analyzes the green building rating systems in the European Union taking into account that there is heterogeneity among these and it is necessary to align them. So, the creation of a transparent and robust framework of indicators that can be used in any country within the European Union, for this was conducted a comprehensive review of the most common green building rating systems within the EU, the 4 most popular were identified and found several differences within these, which means that the researcher should work for the unification of technological building assessment systems to be in line with what the European Union requires.

4.3 Distribution of scientific production by country of origin.

Figure 3 shows the distribution of scientific production according to the nationality of the authors.

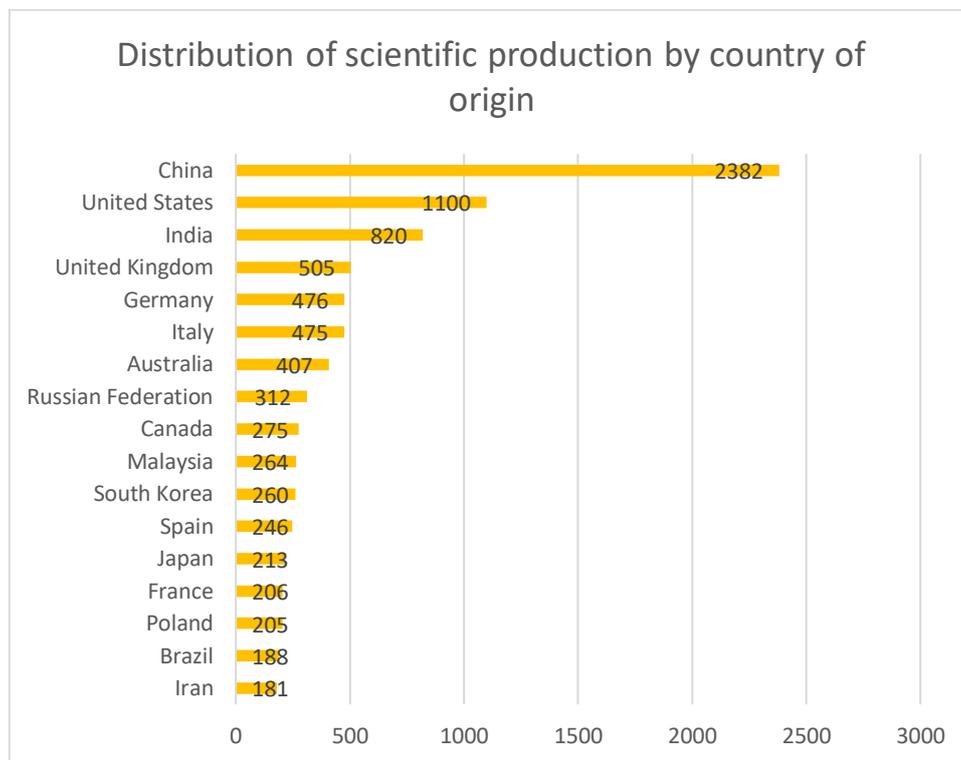


Figure 3. Distribution of scientific production by country of origin.

Source: Own elaboration (2022); based on data provided by Scopus.

China is the country with the highest number of publications related to sustainable structures presenting 2382 papers in total, among which is the article entitled “Recent advances in engineering cobalt carbonate hydroxide to improve alkaline water splitting” (Zhang, Yi, An, & Song, 2021). The main objective of this paper is to review the engineering strategies to activate cobalt carbonate hydroxide towards improved alkaline water splitting, which mainly includes morphology/support engineering, elemental doping, heterostructure engineering because of the current energy crisis. It is necessary to face this crisis with solutions that are environmentally friendly, so cobalt carbonate hydroxide is being used for electro catalysts in alkaline electrolytes due to its low price, chemically versatile structure and high durability, but it has low electrical conductivity so new activation strategies are needed. It is

necessary to conclude by highlighting the usefulness of this study in helping scientists to develop a strategy that will allow them to create an electrocatalyst for water splitting based on sustainable structures.

In second place is United States, with 1100 papers registered in Scopus during the period 2017-2021. Within these papers is the one named “Review of approaches, opportunities and future directions for improving the aerodynamics of tall buildings with smart facades” (Jafari & Alipour, 2021). This paper analyzes the available approaches and potential opportunities to utilize the capabilities of the existing adaptive façade system trying to make these structures more sustainable and in turn useful. This in order to alter the aerodynamics of the building to improve the use of facades as active, dynamic and intelligent systems that not only improve the performance of tall buildings under wind-induced vibrations, but can also generate long-term energy savings.

At this point, it should be noted that the production of scientific publications, when classified by country of origin, presents a special characteristic and that is the collaboration between authors with different affiliations to both public and private institutions, and these institutions can be from the same country or

from different nationalities, so that the production of an article co-authored by different authors from different countries of origin allows each of the countries to add up as a unit in the overall publications. This is best explained in Figure 4, which shows the flow of collaborative work from different countries.

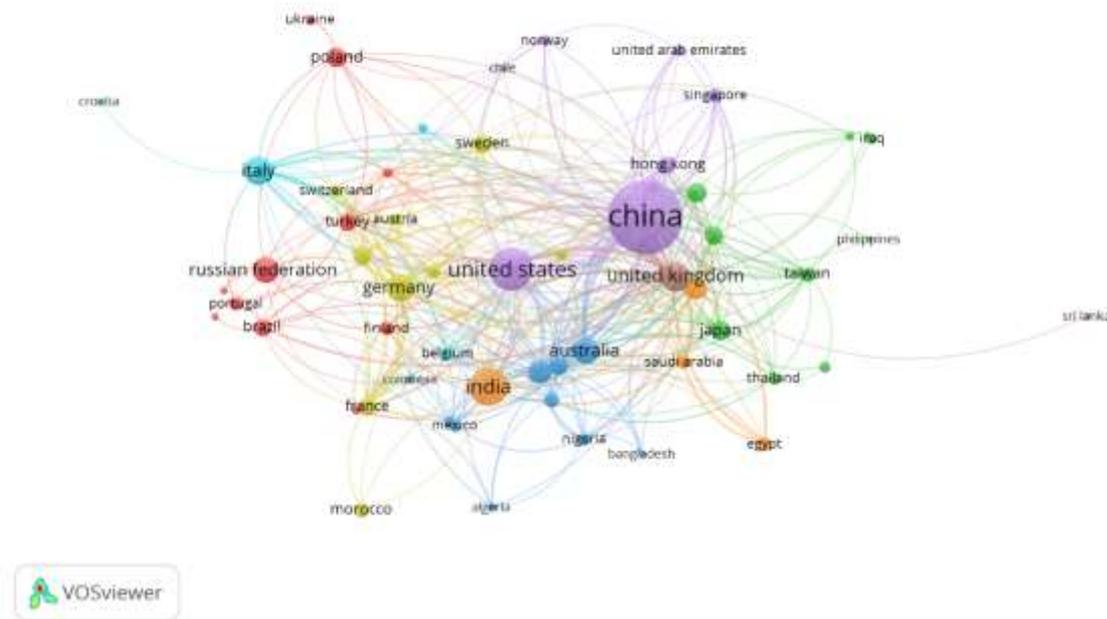


Figure 4. Co-citations between countries.

Source: Own elaboration (2022); based on data provided by Scopus.

As mentioned above, China and the United States are the countries with the greatest contribution in research related to sustainable structures, collaborating with other countries in order to carry out research depending on the social contexts and comparing them in order to analyze their variations. In third place is India with 820 documents within which we can identify “*Past, present and future of knowledge management for business sustainability*” (Chopra, et al., 2021). This document aims to carry out an extensive review of knowledge

management for sustainability research, so a literature review was conducted where 1136 documents were identified in Web of Science where different sustainability strategies were identified in organizations in order to improve their structures in accordance with the objectives of sustainable development. It was concluded that the current understanding of knowledge management for sustainable structures is of vital importance for future research.

4.5 Type of publication

Figure 6 shows how the bibliographic production is distributed according to the type of publication chosen by the authors.

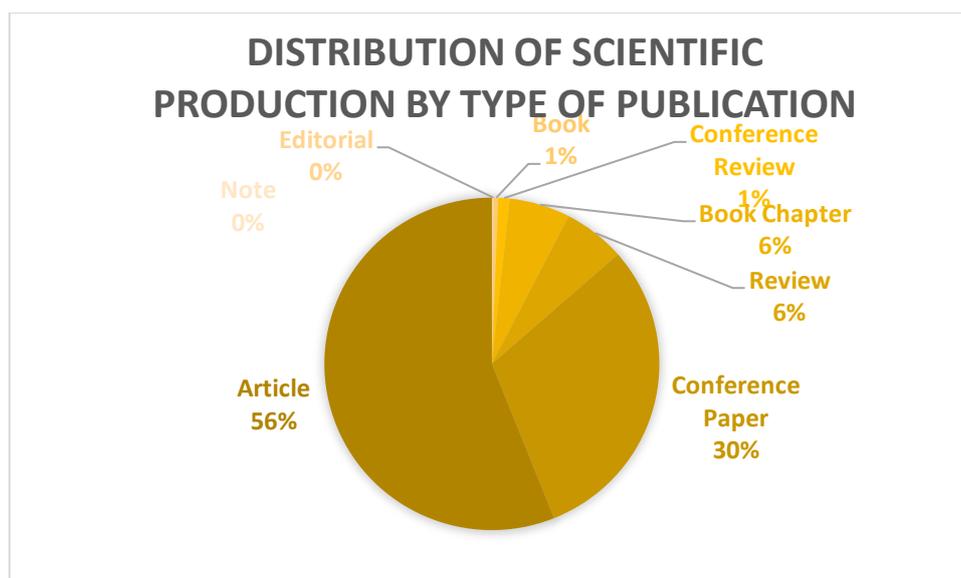


Figure 6. Type of publication

Source: Own elaboration (2022); based on data provided by Scopus.

As shown in Figure 6, within the different types of publications, 56% of the total number of documents identified through Phase 1 of the Methodological Design, correspond to Journal Articles, among which is the one entitled “*Evaluation of the physical and mechanical properties of concrete prepared with recycled refractory brick aggregates after exposure to elevated temperatures*” (Khattab, Hachemi, & Al Ajlouni, 2021). This paper determines the importance of concrete in the transition to more sustainable structures, since although it has proven to be a recyclable substance that helps the reuse of products. So, this paper determines the influence of elevated temperature on the physical and mechanical properties of concrete manufactured by replacing 20% of Natural Coarse Aggregate (NCA) with recycled Refractory Brick Aggregate (RBA) demonstrating that this helps concrete to maintain its properties in different conditions in sustainable structures.

In second place are the conference proceedings which represent 30% of the total number of papers identified in this study, within these is “*A model-based systems engineering approach to support continuous validation in PGE - Product Generation Engineering*” (Mandel, Boning, Behrendt, & Albers, 2021). This document

raises the usefulness of model-based systems engineering for the discovery of new sustainable forms of models since through this process it is possible to support validation in product development. Thus, usability is determined to ensure individual and organizational acceptance.

In third place are the reviews which represent 6% of the total of the documents studied in this research, within these documents is “*Ultra high-performance concrete as an alternative repair method: a review*” (Rosseli, et al., 2021). This paper studies the behavior of ultra-high performance concrete (UHPC) in the concrete industry by applying and analyzing previous techniques and definitions in order to understand the applications of concrete. It is concluded that the application of concrete in structures can be an alternative to a sustainable and economical design that can last longer with less supervision.

5. Conclusions

Thanks to the bibliometric analysis proposed in this research, it can be determined that China is the country with the largest number of bibliographic records in Scopus database during the period between 2017 and 2021 with a total of 2382 documents. The scientific production related to the study of sustainable structures, has presented an important growth during the previously mentioned period, going from 1326

publications in 2017 to 2454 units in 2021, that is to say, it was possible to increase greatly the creation of bibliographic records in a period of 4 years, which indicates the importance that sustainable structures represent in society and in the application of organizational processes since it is sought that these are increasingly friendly to the environment.

The objectives of sustainable development are increasingly used in business processes both administrative and production, in order to safeguard renewable resources and cause the least possible damage to the environment while developing our economy. This sustainability is of great importance in the construction sector since it is one of the sectors that has presented the greatest growth in the last decades and one that emits more gases that intervene in the greenhouse effect; for such reason, it is necessary the adoption of policies that allow the elaboration of sustainable structures with recyclable substances in order to take a greater advantage and at the same time improve the structures by being compatible with the environment.

This creation of sustainable structures allows to have a balance between economic growth and environmental protection by being able to reduce costs while taking advantage of as many resources as possible and avoiding a large amount of waste that can be harmful to the soil. All of the above, allows this article to conclude, highlighting the importance of knowing the theory or bibliographic resources that seek to awaken the interest in organizations, to manage healthy and sustainable policies in the construction of structures in order to maximize the use of available resources and reduce the ecological footprint of human beings while developing socially. That is why it is necessary to highlight the need for studies such as the one presented in this document, which make a tour of those texts that address the aforementioned topic, in order to give the reader a broad view of the current situation of the literature on sustainable structures.

References

- [1] Chopra, M., Saini, N., K. S., Varma, A., Mangla, S., & Lim, W. (2021). Past, present, and future of knowledge management for business sustainability. *Journal of Cleaner Production*.
- [2] Cordero, A., Melgar, S., & Márquez, J. (2019). Green building rating systems and the new framework level(s): A critical review of sustainability certification within Europe. *Energies*.
- [3] Fernando, R., & Gonzalo, F. (2010). Sustainable engineering: new objectives in construction projects. *Revista Ingeniería de Construcción*, 147- 160.
- [4] Gu, K., Chen, B., & Pan, Y. (2020). Utilization of untreated-phosphogypsum as filling and binding material in preparing grouting materials. *Construction and Building Materials*.
- [5] Jafari, M., & Alipour, A. (2021). Review of approaches, opportunities, and future directions for improving aerodynamics of tall buildings with smart facades. *Sustainable Cities and Society*.
- [6] Khattab, M., Hachemi, S., & Al Ajlouni, M. (2021). Evaluating the physical and mechanical properties of concrete prepared with recycled refractory brick aggregates after elevated temperatures' exposure. *Construction and Building Materials*.
- [7] Mandel, C., Boning, J., Behrendt, M., & Albers, A. (2021). A Model-Based Systems Engineering Approach to Support Continuous Validation in PGE - Product Generation Engineering. *ISSE 2021 - 7th IEEE International Symposium on Systems Engineering, Proceedings*. Vienna: th IEEE International Symposium on Systems Engineering, ISSE 2021.
- [8] Otim D.a, e. m., Senzanje, A., van, A. R., & Thornton-Dibb, S. (2021). Development and assessment of an updated tool for the design of soil and water conservation structures in the sugar industry of South Africa. *Agricultural Engineering International: CIGR Journal*, 1 - 16.
- [9] Rosseli, S., Sidek, M., Saman, H., M.F., A., Jaafar, M., Ridzuan, A., & J. R. (2021). Ultra High-Performance Concrete as Alternative Repair Method: A Review. *Journal of Failure Analysis and Prevention*, 2072 - 2080.

- [10] Zhang, X., Yi, H., An, Q., & Song, S. (2021). Recent advances in engineering cobalt carbonate hydroxide for enhanced alkaline water splitting. *Journal of Alloys and Compounds*.
- [11] 2021 7th international conference on information management, ICIM 2021. (2021). Paper presented at the *2021 7th International Conference on Information Management, ICIM 2021*, Retrieved from www.scopus.com
- [12] AHFE conference on human factors in architecture, sustainable urban planning and infrastructure, 2021 (2021). Retrieved from www.scopus.com
- [13] Computational methods and experimental measurements XX. (2021). Paper presented at the *WIT Transactions on Engineering Sciences*, , 130 Retrieved from www.scopus.com
- [14] Erratum regarding missing declaration of competing interest statements in previously published articles (frontiers of architectural research (2021) 10(1) (3-16), (S2095263520300698), (10.1016/j.foar.2020.10.001)). (2021). *Frontiers of Architectural Research*, 10(1), 224-225. doi:10.1016/j.foar.2020.12.008.
- [15] Erratum regarding previously published articles (transportation research interdisciplinary perspectives (2019) 3, (S2590198219300661), (10.1016/j.trip.2019.100067)). (2021). *Transportation Research Interdisciplinary Perspectives*, 9 doi:10.1016/j.trip.2020.100258.
- [16] IABSE congress, ghent 2021: Structural engineering for future societal needs. (2021). Paper presented at the *IABSE Congress, Ghent 2021: Structural Engineering for Future Societal Needs*, Retrieved from www.scopus.com
- [17] International colloquium on computational and experimental mechanics, ICCM 2020. (2021). Paper presented at the *IOP Conference Series: Materials Science and Engineering*, , 1064(1) Retrieved from www.scopus.com
- [18] International conference on “advances in materials processing and manufacturing applications”, iCADMA 2020. (2021). Paper presented at the *IOP Conference Series: Materials Science and Engineering*, , 1017(1) Retrieved from www.scopus.com
- [19] Azlina Ramlee, N., Jawaid, M., Abdul Karim Yamani, S., Syams Zainudin, E., & Alamery, S. (2021). Effect of surface treatment on mechanical, physical and morphological properties of oil palm/bagasse fiber reinforced phenolic hybrid composites for wall thermal insulation application. *Construction and Building Materials*, 276 doi:10.1016/j.conbuildmat.2020.122239.
- [20] Bach, R., Wolf, A., Wilfinger, M., Kiziltoprak, N., & Knaack, U. (2021). A full performance paper house. *Journal of Facade Design and Engineering*, 9(1), 117-130. doi:10.7480/jfde.2021.1.5533.
- [21] Bae, H., Lee, G. -, Hur, J., Park, J. -, Kim, D. -, Kim, M. -, & Choi, Y. -. (2021). Gateless and capacitorless germanium biristor with a vertical pillar structure. *Micromachines*, 12(8) doi:10.3390/mi12080899.
- [22] Bagathi, A. K., Balagtas, C., Boppana, S. V. K., Coste-Manière, I., Vincent, F., Le Troquer, F., & Boyer, G. (2021). *Lab-grown Diamond-The shape of Tomorrow's jewelry* doi:10.1007/978-981-16-2454-4_11 Retrieved from www.scopus.com
- [23] Baghi, Y., Ma, Z., Robinson, D., & Boehme, T. (2021). Innovation in sustainable solar-powered net-zero energy solar decathlon houses: A review and showcase. *Buildings*, 11(4) doi:10.3390/buildings11040171.
- [24] Bettarello, F., Gasparella, A., & Caniato, M. (2021). The influence of floor layering on airborne sound insulation and impact noise reduction: A study on cross laminated timber (CLT) structures. *Applied Sciences (Switzerland)*, 11(13) doi:10.3390/app11135938.
- [25] Betts, D., Sadeghian, P., & Fam, A. (2021). Experiments and nonlinear analysis of the impact behaviour of sandwich panels constructed with flax fibre-reinforced polymer faces and foam cores. *Journal of Sandwich Structures and Materials*, 23(7), 3139-3163. doi:10.1177/1099636220925073.
- [26] Betts, D., Sadeghian, P., & Fam, A. (2021). Post-impact residual strength and resilience of sandwich panels with natural fiber composite faces. *Journal of Building*

- Engineering*, 38
doi:10.1016/j.job.2021.102184.
- [27] Bezpалov, V. V., Goncharenko, L. P., Sybachin, S. A., & Ionkin, S. A. (2021). Trends and specifics of electric power industry development in the Russian Federation. *Periodicals of Engineering and Natural Sciences*, 9(3), 132-152. doi:10.21533/pen.v9i3.2108.
- [28] Bharath, B., Sami, A., & Rastogi, K. (2021). Analysis of a structure for efficient energy utilization using design builder. Paper presented at the *IOP Conference Series: Materials Science and Engineering*, 1017(1) doi:10.1088/1757-899X/1017/1/012016 Retrieved from www.scopus.com