



# Review of the Influences of Paper Waste Incorporation to Compressive Strength in Concrete

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**Abstract:** The development of new construction materials is a crucial issue in the building construction industry, as it is one of the most energy and resource-intensive industries. Paper has played a significant role in daily activities since its creation, a wide range of applications thanks to its adaptable qualities. Paper waste can be found in a variety of places, including newspapers, offices and schools. Paper waste is a rich source of fibre and can be utilised as a building material. Utilization of paper wastes can help to reduce pollution and waste in the environment. The purpose of this review study is to highlight and examine some current studies that look into the potential applications of post-consumer paper waste in concrete specimens. The review had been conducted on the research paper between the year 2010 till 2023, paper waste does have potential to be incorporated with cement-based material with the right formulation and percentages. This review data focused on the mechanical properties of concrete.

**Keywords:** Waste paper, application of paper waste, mechanical properties

## 1. Introduction

The term "building material" refers to the materials that are utilised in the construction of a structure. Many naturally existing materials have been used to construct buildings including clay, pebbles, sand, wood and even twigs and leaves. Many man-made items, some more synthetic than others, are used in addition to naturally existing materials. Many decades ago, human civilizations were supported by cement-based materials. These materials have been adapted to keep their functions in our lives as human activities have progressed [1]. Cement's fundamental role is to act as a hydraulic binder, increasing the binding between fragmented particles and allowing them to be used in various industries [1].

Paper waste can be found in the environment from a variety of places including offices, newspapers and marketplaces. Utilisation of the widely spread paper wastes within the civil construction practice may cause a true possibility of a big decrease in environmental pollution and perceptibly economise the value of civil construction [2]. The use of paper includes a role in getting rid of their huge quantities, which constitute a fundamental, environmental problem due to the issue of its degradation. Various attempts are, therefore made, within the artefact manufacturers to use waste product products. During this study, the paper pulp was utilised in mortar and concrete to review the mechanical properties of the produced mix and some mechanical properties. it has been possible to provide low-cost concrete with better properties, incorporating paper pulps with cement [3].

Paper waste is actually paper that has been used. Paper waste is defined as used-up papers that are no longer useful for the reason for which they were created, or that have already served that purpose and are destined for the landfill. Paper waste mostly comes from companies, schools and households [2]. Paper is a common material found in everyday

items such as printing papers, books, sanitary and home products (such as kitchen towels and toilet paper) and packaging materials. Paper is a thin sheet material made by physically or chemically processing cellulose fibres from wood, rags, grasses, or other vegetable sources in water, then draining the water through fine mesh to leave the fibre equally spread on the surface, pressing and drying [15].

## 2. Characterization of Paper Waste

Knowledge of paper qualities and how they react to relative humidity, temperature, radiation, and pollution will be able to help to better comprehend the rationale for research design. The precise selection of test materials and methodologies could contribute to the production of precise results and debates [2]. Understanding the characteristics of paper and how they respond to various environmental factors such as humidity, temperature, radiation and pollution. Hydrolysis, oxidation, and crosslinking breakdown processes are brought about by environmental factors [2].

### 2.1 Chemical Properties

Chemical qualities of a paper sheet are primarily determined by furnish or pulp component factors, as well as formation or manufacturing procedures. Fibre type, pulp stock, refining procedures like beating or bleaching, and composition which includes fillers, sizes, coatings and colourants are all factors to consider basis weight, calendaring and manufacturing variables such as speed, drainage, drying and fiber bonding are examples of formation variables. Each variable has its own set of characteristics [5] as shown in Fig 1.

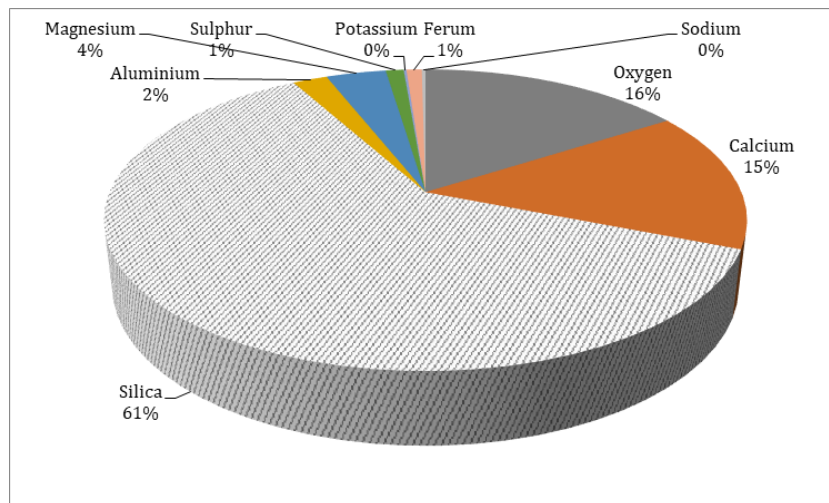


Fig 1 - Chemical composition of waste paper [5]

### 2.2 Physical Properties

Factor of weight, thickness, density, two-sidedness, smoothness, permeability, handling, stiffness, roughness, and porosity influence the physical qualities of paper sheets which affect softness, hardness, compressibility, dimensional stability, curl and strength [6]. This can be referred to Table 1.

Table 1 - Physical properties of office paper [6]

Physical properties of Office Paper	Values
Thickness value	105-110µM
Typical moisture value	4-4.5%
Smoothness value	100-300mls/min
Bursting strength value	250-300kPa
Tear resistance value	500-600mN
Static coefficient of friction	0.5-0.65
Kinematic coefficient of friction	0.35-0.50

### 3. Methodology Outlines

The review methodology has been structured in five stages;

#### 3.1 Formulate Research Questions

Formulating research questions is an important part of the research process because it clarifies theoretical assumptions about what the researcher is primarily interested in learning about in the context and the most important features. Many factors were examined in the formulation of the research question in this study, one of which was the study's aims [7]. The major goal of this research is to see the potential of paper waste can be incorporated into cement-based materials. As a result, the study topic will focus around the impact of paper waste in cement-based materials as well as the methods used to incorporate paper waste into cement-based materials and the cement-based materials' qualities.

#### 3.2 Literature Sources

It has been executed by using the Google Scholar platforms and webpage. The selection based on the massive materials coverage.

#### 3.3 Descriptive Analysis

Descriptive analysis is a sort of data analysis that helps to explain, show or summarise data points in a constructive way so that patterns might develop that satisfy all of the data's conditions. It has been applied in the quantitative approach where the data will be turned to tables, diagrams and pictures [7]. Rearranging, ordering and altering data to offer meaningful information about the presented data, i.e., converting raw data into a form that is easier to understand and analyse. This is because quantitative data is data that can be counted or measured in numerical values.

#### 3.4 Categories Descriptive Analysis

To obtain a quality and pinpoint review literature, the specific associated problems, structures, and interest criteria were examined in the review technique. The purpose is to develop precise parameters that can be utilised to decide whether or not a piece of research should be included in the analysis [8]. This strategy will undoubtedly aid in the collection of study-related materials. The materials had been divided into two categories: the effect of paper waste contents to compressive strength of concrete and the factors influencing the increment and decrement of compressive strength.

#### 3.5 Material Evaluation

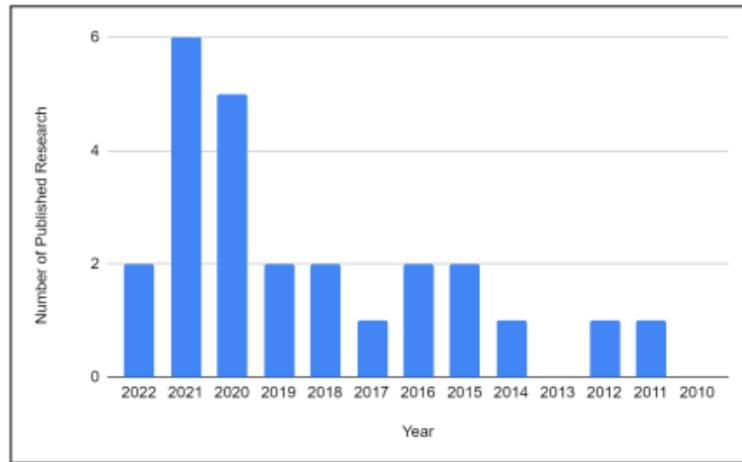
All of the material collected for this study has been finalised and analysed using the previously indicated categories. It's crucial to evaluate how the article will be used for effective analysis after evaluating the literature and deciding on the final sample. When the final sample was chosen, a systematic method of extracting relevant data from each report will be applied [8]. As a result, when evaluating a review, it's critical to use certain criteria to establish whether or not the review article meets the scope criteria.

### 4. Results and Discussions

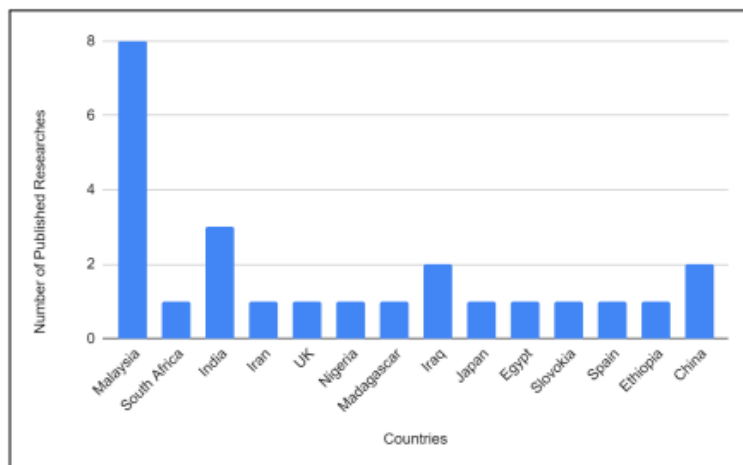
In this study, the potential for paper waste incorporation in cement-based materials, the methods used and the influences between the percentage of waste paper incorporation and the mechanical and physical characteristics of the cement-based materials were investigated. The result also included the demand of studies on paper waste on previous research.

#### 4.1 Distribution of Times and Sources

Fig 2 shows the rise of research on paper waste in the engineering field especially in recent years. Seventy percents (70%) of the world population now are more aware and concerned about the environment. It may explain why the research on recycling waste products as construction materials spiking in recent years [9]. Fig 3 also shows the distribution of published research on paper waste in engineering over the countries. Most of the studies are done in Malaysia followed by India, China, Iraq and so on as can be seen in Fig 3. Malaysia has shown an interest in exploring the potential of paper waste especially in the engineering field.



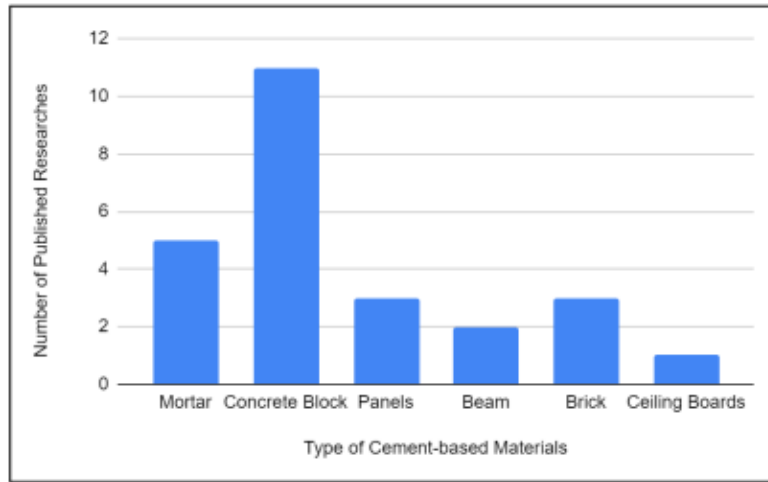
**Fig 2 - The number of published papers conducted on paper waste in engineering areas**



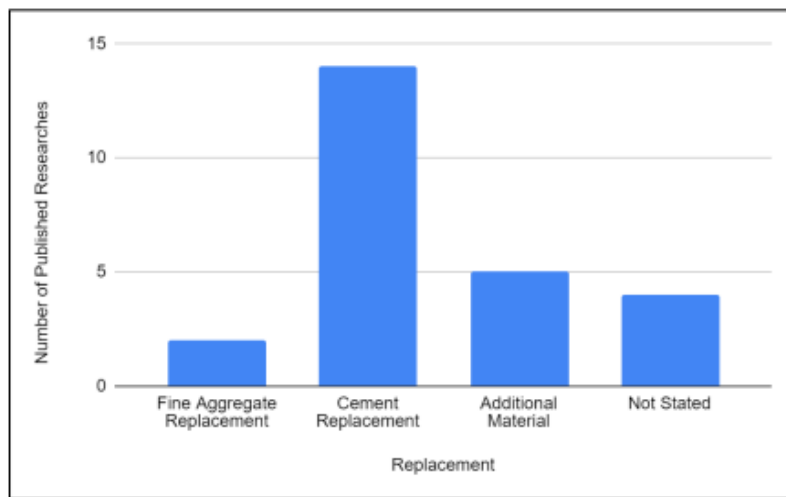
**Fig 3 - Countries distribution on the interest in paper waste studies**

**4.2 Type of Research and Keyword Families**

Fig 4 shows the type of cement-based materials infused with waste paper utilised in the previous researches. From evaluation that has been conducted on 25 previous researches from the year 2010 till the recent year, we can see that most of the studies conducted focused on concrete blocks followed by mortar, panels, bricks and ceiling board. From the observation that has been made, the reason why concrete infused with paper waste also known as ‘Papercrete’ is so popular is because it was already being introduced to the world back in 1928 by Eric Patterson and Mike McCain, and was revived during the 1980s [18]. Fig 5 tabulates the most demand of the studies on paper waste were carried out to replace cement followed by as additional material. Paper waste replacements were used in concrete with different percentages. Paper waste was seen as a good alternative material for construction because of its properties,



**Fig 4 - Number of published resources**



**Fig 5 - Paper waste as replacement in cement-based**

## 5. Results And Discussions

This section discusses the outcome obtained from incorporation of paper waste in concrete in order to investigate their potential in enhancing the compressive strength and the factors contribute to their increment.

### 5.1 Effect of Paper Waste to Compressive Strength of Concrete

The effect of waste paper to compressive strength of concrete were discussed. The properties that have been investigated are compressive strength and density of the concrete contains paper waste.

### 5.2 Compressive Strength

Generally, the paper waste was incorporated in concrete specimens between 5% and 70% as cement replacement [14-19]. The findings recorded the incorporation of paper waste above 30% in concrete specimens does not record in high compressive strength. Fig 6 shows the average compressive strength of the previous studies conducted on concrete specimens containing paper waste at 28 days. Concrete grade prepared was between 25 and 30 containing 5% to 20% paper waste replacement with cement.

Table 2 records the comparison of increment and decrement compressive strength of concrete specimens containing paper waste. Optimum contents of paper waste contributed high compressive strength was 5%. Therefore, it can be concluded that is the most suitable contents of paper waste to be added in concrete specimens. The increment of compressive strength of concrete specimens containing paper waste can vary depending on several factors that might be due to proportion of paper waste and ingredients of paper waste which contains a significant amount of aluminosiliceous material that is coupled with calcium. The increase in compressive strength is mostly attributed to the alkalis'

activation of the hydraulic and pozzolanic activity of waste paper, as well as to the release of  $\text{Ca(OH)}_2$  during the hydration process. Flexural strength values, however, were lower than reference mixes for all test ages [11].

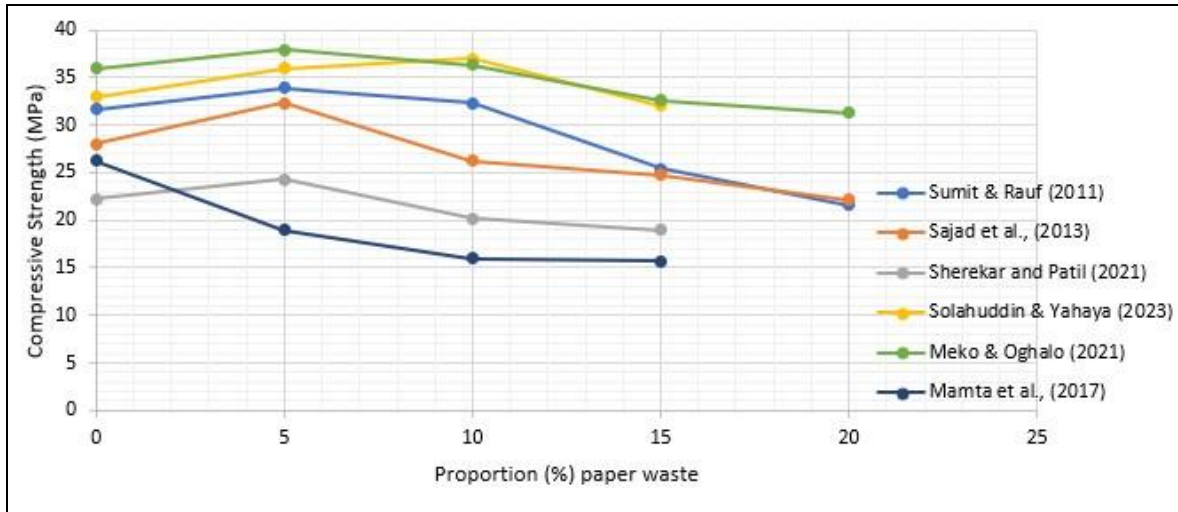


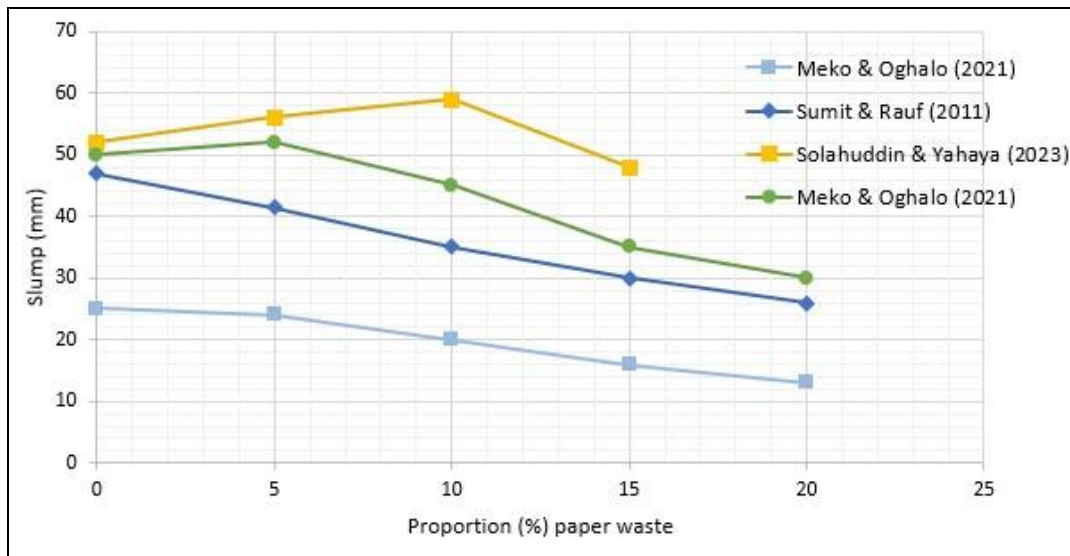
Fig 6 - Average of compression strength at 28 days

Table 2 - Comparison between compressive strength and improvement made of concrete containing paper waste (PW) as cement replacement by several researchers [13-19]

Authors	Proportion (%)	Concrete grade	Compressive strength at 28 days (MPa)	Increment (%) with reference to control specimens
Sumit and Rauf (2011)	5% - 20%	30	Control: 31.63 5PW:33.93	+7.5%
Sajad et al., (2013)	5% - 20%	30	Control:28.07 5PW:32.34	+15.2%
Mamta et al., (2017)	5% - 15%	30	Control:26.3 5PW:19	-27.7%
Sherekar & Patil (2021)	5% - 15%	30	Control:22.22 5PW:24.29	+9.3%
Meko & Oghalo (2021)	5% - 20%	25	Control:36 5PW:37.9	+5.3%
Solahuddin & Yahaya (2023)	5% - 15%	30	Control:33 10PW:37	+12.1%

### 5.3 Factors Influencing the Increment of Compressive Strength

A broad and arbitrary word, "workability of concrete" refers to how quickly freshly mixed concrete may be mixed, put, solidified and finished with little loss of homogeneity [1]. Fig 7 shows the average slump test result of the previous studies conducted on concrete infused with paper waste. It shows that the result increases then decrease steadily after it hits the 5%. When there was a greater percentage of paper pulp material, slump and density both dropped. The pulp as it was received had a great capacity to absorb water. As a result, more water was needed to obtain a given slump when more paper pulp was present in the combination [11].



**Fig 7 - Average of slump test result**

However, limited studies published in investigating the effects of compressive strength increment to the microstructure examination and pore characteristics profiles. Therefore, it is recommended to investigate extensive studies related on future.

## 6. Conclusions

This study was carried out in accordance with the objectives, which called for the analysis of some data from earlier studies about the use of paper waste in cement-based materials. All of the goals set forth in the first chapter of this review were accomplished by the time this study was completed. This study reviewed the existing literature on the potential of paper waste incorporation in cement-based materials from the year 2010 till the 2023. Based on the data gathered from the previous literature, paper waste does have the potential to be a replacement or additional materials in cement-based materials. The use of waste paper in making civil engineering construction materials and other engineering products seems to be a viable option for their disposal, provided that the less desirable properties are improved upon, in light of the significant insight into the behaviour and properties of building materials containing paper waste provided by the investigations discussed in this review [16].

From the investigation and analysing that has been made, paper waste incorporated in cement-based materials does affect the potential of the cement-based materials. The concrete compressive strength increases with 5% and 10% replacement of cement with paper waste pulp. More than that, the compressive strength gradually reduced. Paper incorporated in concrete has a higher fire resistance [5]. On the other hand, waste paper infused cement-based materials cannot be used on external structures due to its higher water absorption capacity. The use of waste paper in making civil engineering construction materials and other engineering products seems to be a viable option for their disposal, provided that the less adequate properties are improved upon [6].

Based on the review that has been conducted, the best percentage of paper waste that can be incorporated into the cement-based materials are the 5% and 10%. In most of the research that has been analysed, it shows that cement-based materials with lower percentage of paper waste show higher and better results than the sample without and more than 10% of paper waste. Results of compressive strength for mixtures of 10%, 15%, and 20% paper waste decreased as wastepaper content increased. Since paper waste contains a significant amount of alumino-siliceous material that is coupled with calcium, the strength was higher in the mixture with (5%), compared to the reference [11].

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## References

- [1] Balea, A., Fuente, E., Monte, M. C., Blanco, A., & Negro, C. (2021). Recycled Fibers for Sustainable Hybrid Fiber Cement Based Material: A Review. *Materials*, 14(9), 2408. <https://doi.org/10.3390/ma14092408>
- [2] Alava, M., & Niskanen, K. (2006). The physics of paper. *IOP Science*, 69(3). <https://doi.org/10.1088/0034-4885/69/3/R03/meta>



- [3] Raelivololona, T., Ramaroson, M., & Raminosoa, C. (2020). Paper recycling for the making of construction materials. MATEC Web of Conferences, 307, 01041. <https://doi.org/10.1051/mateconf/202030701041>
- [4] Mamta, Anshu, Amit Singhal, (2017), Behaviour of Concrete Mix with Wastepaper as an Additional Materials, International Journal of Engineering Research & Technology (IJERT), Vol.5, Issue 3.
- [5] Solahuddin, B. A., & Yahaya, F. M. (2022). Inclusion of Waste Paper on Concrete Properties: A Review. *Civil Engineering Journal*, 7, 94–113. <https://doi.org/10.28991/cej-sp2021-07-07>
- [6] Asha, P., Dipti, S., Rupali, P., & Prerana, P. (2017). EFFECT OF PAPER WASTE ON CONCRETE PROPERTIES: SUSTAINABILITY APPROACH. CERN European Organization for Nuclear Research - Zenodo. <https://doi.org/10.5281/zenodo.556341>
- [7] Lawless, H. T., & Heymann, H. (2010). Descriptive Analysis. Food Science Text Series, 227–257. [https://doi.org/10.1007/978-1-4419-6488-5\\_10](https://doi.org/10.1007/978-1-4419-6488-5_10)
- [8] López-Illescas, C., Noyons, E. C., Visser, M. S., De Moya-Anegón, F., & Moed, H. F. (2009). Expansion of scientific journal categories using reference analysis: How can it be done and does it make a difference? *Scientometrics*, 79(3), 473–490. <https://doi.org/10.1007/s11192-007-1975-6>
- [9] Sumit A Balwaik and S P Raut (2011), Utilization of Waste Paper Pulp by Partial Replacement of Cement in Concrete, International Journal of Engineering Research and Applications (IJERA), Vol. 1, Issue 2, pp.300-309.
- [10] Sajad Ahmad, M. Iqbal Malik, Muzaffar Bashir Wani, Rafiq Ahmad (2013), Study of Concrete Involving Use of Waste Paper Sludge Ash as Partial Replacement of Cement, IOSR Journal of Engineering (IOSRJEN), Vol. 3, Issue 11, 2250-3021.
- [11] Zaki, H., Gorgis, I., & Salih, S. (2018c). Mechanical properties of papercrete. MATEC Web of Conferences, 162, 02016. <https://doi.org/10.1051/mateconf/201816202016>
- [12] Ramachandrudu, K., & Natarajan, C. (2018). Mechanical Properties and Flexural behavior of Papercrete Concrete. *Journal of Mechanical and Civil Engineering*, 15(4), 31–36. <https://www.iosrjournals.org>
- [13] Shrekar V. S. and Patil S. K. (2021), Experimental Assessment of the Effect of Paper Waste on Improvement of Concrete Behavior, International Journal of Trend in Scientific Research and Development (IJTSRD), Vol. 5, Issue 4. <http://www.ijtsrd.com/papers/ijtsrd42532.pdf>
- [14] Meko, Bikila & O. Ighalo, Joshua. (2021). Utilization of waste paper ash as supplementary cementitious material in C-25 concrete: Evaluation of fresh and hardened properties. *Cogent Engineering*. 8. 1938366. <http://10.1080/23311916.2021.1938366>.
- [15] Feed, N., Zulkifli, L., Zulkifli, J. L., Wafi, A., Feed, N., Yusoff, R., & Yusoff, R. (2022, February 8). *Towards a sustainable paper consumption and printing practices*. IUM Today. <https://news.iium.edu.my/?p=162372>
- [16] Feed, N., Zulkifli, L., Zulkifli, J. L., Wafi, A., Feed, N., Yusoff, R., & Yusoff, R. (2022, February 8). *Towards a sustainable paper consumption and printing practices*. IUM Today. <https://news.iium.edu.my/?p=162372>
- [17] Dynata. (2022, September 27). World's Largest First Party Data Platform. <https://www.dynata.com/>
- [18] Roberts, T. (2021, June 18). What is Papercrete? Rise. [https://www.buildwithrise.com/stories/what\\_is\\_papercrete](https://www.buildwithrise.com/stories/what_is_papercrete)