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Effect of Shredded Waste Paper on Properties of Concrete

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Abstract. Cement, sand, coarse aggregate and water are the materials to make a concrete mixture. The waste paper has been dumped as waste and causes environmental pollution behind the mill or landfill. The industry paper wastage for every year is increasing gradually. More spaces are being needed for landfills, uses energy loss of natural resources and increase of expenditure and various types of pollutions. Utilizing waste paper as an addition in concrete production will reduce environmental pollutions. This research is conducted to investigate the effect of shredded waste paper using copier and cardboard waste paper as additions to the compressive and flexural strengths and water absorption of hardened concrete. All specimens are subjected to water curing at 7 and 28 days. The results of compressive and flexural strengths increase at 5% and 10% additions of shredded copier and cardboard waste paper at 7 and 28 days of water curing. The finding shows that concrete containing 10% addition of shredded copier and cardboard waste paper exhibit the highest compressive and flexural strengths. For concrete water absorption, the higher water absorption is caused by the higher addition of shredded copier and cardboard waste paper. Furthermore, the results also show that shredded cardboard waste paper has higher strength and water absorption than shredded copier waste paper for all percentages of addition. This study indicates that shredded copier and cardboard waste paper can be used as additional materials in concrete production.

1. Introduction

Nowadays, CO_2 emissions from houses are attributed to cement usage, which is a massive issue for all nations. Consequently, people's crave for eco-living is increasing. This research is conducted to address these kinds of problems. Using waste paper in concrete can produce a new and modern construction material. By using waste paper, the cement amount used reduces as it provides an environmentally friendly construction material [1]. Portland cement and waste paper are the materials that make a fibrous cemented material called papercrete. Papercrete might be a material initially developed 80 years ago that has recently been rediscovered. It should be noted that papercrete has a limited-range concept [2]. For decades, as an alternative building material stated by [2], a committed environmentalist has designed homes and structures made of cement, other materials and waste paper. They argued that this papercrete structure is perfect and durable for insulating and durability. A paper reinforced structure is a structurally and economically viable alternative based on the indicated result within a range of size [3]. Portland cement or clay with re-pulped paper fibre develop a new construction material that called papercrete. They identified their discovery of adobe and fibrous cement and found themselves independently [4]. Due to the alternative building material known as papercrete, the dead load of the main structure can be diminished [5]. Water and any types of papers such as cardboard, sparkling magazine stock, daily paper, waste mail advertising or any other types of papers are the fundamental components of papercrete. The paper mill publishes most of the paper recycling works [6-11] or to manufacture cement board [12-13]. Other than that, it can end up a reasonable and productive substitute in landfills, incinerators, or other utilize choices [14]. Moreover, waste paper can be used in the right way by using it in construction materials to reduce its density, as stated by [15]. The building expenses can be reduced by studying on measuring the quality, workability and other properties of papercrete [16]. Furthermore, due to its lightweight characteristic, papercrete can also be used for the interior wall of a high-rise building in seismically active regions. Moreover, usage of papercrete will decrease the dead load of the structure, the depth of foundation required and also the percentage of steel used, so the labour amount and energy expense will be decreasing significantly [17]. Papercrete can grant numerous benefits and wide utilization in concrete. In addition to that, papercrete persuades waste paper recycling, particularly in a community without recycling activity. It cuts the waste space, holds paper production and chemical printing out of the water table [18].

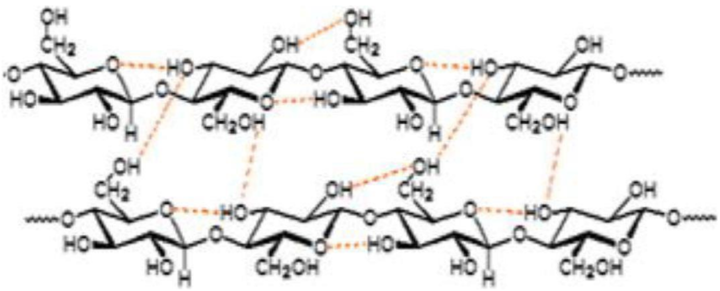
2. Materials and Methods

This research uses cement, sand, coarse aggregate, water, shredded copier and cardboard waste papers. Ordinary Portland Cement (OPC) used Orang Kuat brand produced by YTL Cement Marketing Sdn. Bhd. to ensure the cement has the same chemical properties and compositions. This type of cement follows [19] for Portland cement specifications. A local supplier supplied the river sand used in this study. It was obtained from the concrete laboratory at the Faculty of Civil Engineering Technology, Universiti Malaysia Pahang (UMP). The sand used as fine aggregate. Physical properties of sand meet the requirements of [20]. Gravel was used as coarse aggregate in this research. The minimum and maximum sizes of gravel are 5 mm and 20 mm. The gravel physical properties meet the prerequisites of [20]. Copier and carboard waste paper were used in this research by collecting them from the office. Both types of paper were then shredded using a paper shredder machine. All sizes and dimensions of shredded waste paper (SWP) used in this research were the same after shredded. Figure 1 and 2 show the shredded copier waste paper (SCPWP) and shredded cardboard waste paper (SCBWP) used in this research.

Figure 1. Shredded copier waste paper (SCPWP)

Figure 2. Shredded cardboard waste paper (SCBWP)

A paper is primarily made of wood cellulose fibre which is known to be a fibrous material. Cellulose is a genuine polymer made by smaller molecules composing associated sugar with a long chain. A sugar type: ß-D glucose is the bonding of the cellulose chain. The polar-OH cellulose bristles make up many hydrogen bonds with OH groups on approaching and bundling together the chains, as shown in Figure 3 [21-23]. The chains also pack in orderly places to form hard and strong regions of crystalline to enable more balance and strength in the bundled chains.



—— Cellulose linear polyglucose joined by ß 1-4 bonds

------ Intra and intermolecular hydrogen bonds

Figure 3. Paper chemical structure (Cellulose hydrogen bond)

Table 1 and Table 2 show the fibre and strength properties of two types of waste paper after disintegration [24].

Table 1. Fibre properties after disintegration

Type of waste paper	Fibre average length (mm)	Medium fibre content (%)	Long fibre content (%)	Fine fibre and and non- fibre contents (%)
Copier	0.42	14	18	68
Cardboard	0.47	25	32	60

Table 2. Strength properties after disintegration

Type of waste paper	Percentage (%)	Strength of Bending (N/mm^2)	Internal Bond (N/mm^2)	Modulus of Elasticity (N/mm^2)	Thickness Swelling (%)
Copier	0	18	0.30	1800	5
	5	22	0.33	2100	7
	10	28	0.37	2500	12
	15	12	0.25	1400	18
Cardboard	0	18	0.30	1800	5
	5	26	0.35	2300	9
	10	30	0.41	2600	15
	15	16	0.28	1500	20

The mixing process of concrete was done by using standard concrete making procedures. The concrete was copier using a concrete mixer. Before mixing, all the specimens were weighed according to the mix design. SCPWP and SCBWP used as addition in concrete with 0%, 5%, 10% and 15% by weight of the mixture. A total of 7 mixes is used in this experiment. The cement: sand: aggregate ratio used in this research is 1:0.75:1.5 by weight of the materials, and 0.5 is the water to cement ratio used. This ratio fixes for all specimens. This experiment uses a concrete mix proportion, as presented in Table 3.

Table 3. Concrete mix proportion

Mix	Cement (Kg)	Sand (Kg)	Coarse Aggregate (Kg)	Shredded Waste Paper (%)	Shredded Waste Paper (Kg)	W/C
C	40	30	60	0	0	0.5
SCPWP1	40	30	60	5	6.5	0.5
SCPWP2	40	30	60	10	13	0.5
SCPWP3	40	30	60	15	19.5	0.5
SCBWP1	40	30	60	5	6.5	0.5
SCBWP2	40	30	60	10	13	0.5
SCBWP3	40	30	60	15	19.5	0.5

The mechanical properties that are compressive strength and water absorption were investigated using 150 mm x 150 mm x 150 mm cubes while for the flexural strength, beams with a size of 700 mm length x 150 mm wide x 150 mm height were used. Water curing was imposed on all the specimens. A Universal Testing Machine (UTM) was used to conduct the compressive strength test, according to [25]. The specimen flexural strength was determined by performing a four-point flexural test using a flexural testing machine, which based on the method suggested in [26]. The water absorption test follows the procedures as described by [27].

3. Results and Discussion

The section presents the compressive strength, flexural strength and water absorption results of concrete.

3.1 Compressive Strength

Figure 4 and 5 show the compressive strength test results of hardened concrete at 7 and 28 days with water curing. The specimen result is affected by the percentages of SWP addition and curing ageing. At 7 and 28 days of water curing, the concrete compressive strength increases at 5% and 10% additions of SCPWP and SCBWP while at 15% addition, both strengths start to drop compared to 0% addition of SCPWP and SCBWP. However, even the strengths of the specimen containing 15% SCPWP and SCBWP drop compared to the specimen containing 5% and 10% of SCPWP and SCBWP, their strengths are still lower than the control specimen. This experiment shows that the acceptable percentages of SCPWP and SCBWP additions are 5% and 10%. At 7 days, 10% SCBWP addition records the highest compressive strength, which is 28.3 MPa while the lowest strength is recorded at 15% of SCPWP addition, which is 21.1 MPa. At 28 days, 10% SCBWP addition records 38.7 MPa compressive strength values which is the highest value while the lowest strength is recorded at 15% SCPWP addition, which is 31.1 MPa.

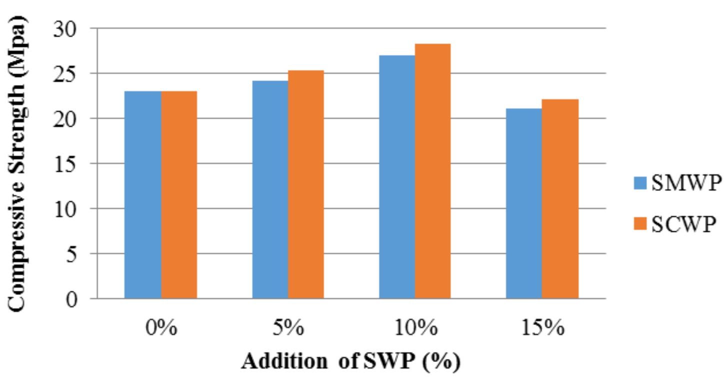


Figure 4. Concrete compressive strength at 7 days

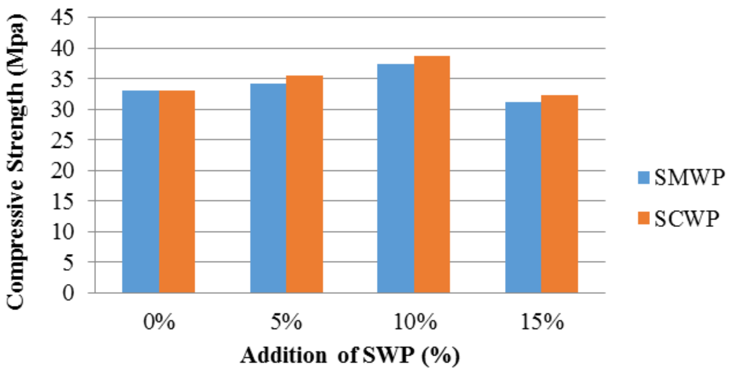


Figure 5. Concrete compressive strength at 28 days

3.2 Flexural Strength

Figure 6 and 7 show the flexural strength test results of hardened concrete at 7 and 28 days with water curing. The specimen result is affected by the percentages of SWP addition and curing ageing. The concrete flexural strength increases at 5% and 10% additions of SCPWP and SCBWP while at 15% addition, both strengths start to drop compared to 0% addition of SCPWP and SCBWP at 7 and 28 days of water curing. However, even the specimen strengths containing 15% SCPWP and SCBWP drop compared to the specimen containing 5% and 10% of SCPWP and SCBWP, their strengths are still lower than the control specimen. This experiment shows that the acceptable percentages of SCPWP and SCBWP additions are 5% and 10%. At 7 days, 10% SCBWP addition records the highest flexural strength, which is 6.1 MPa while the lowest strength is recorded at 15% of SCPWP addition, which is 4.6 MPa. At 28 days, 10% SCBWP addition records 7.4 MPa flexural strength value which is the highest value while the lowest strength is recorded at 15% SCPWP addition, which is 5.8 MPa.

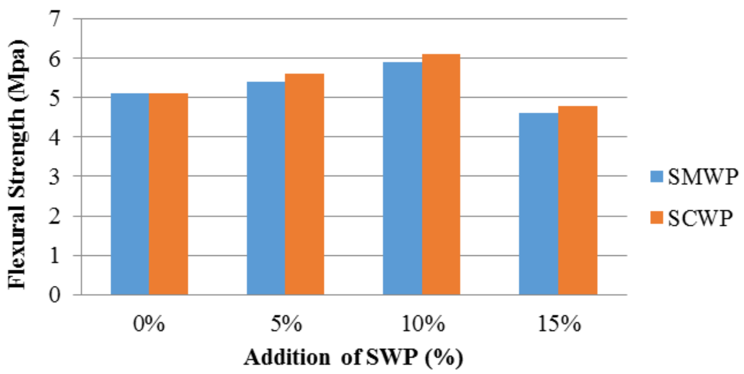


Figure 6. Concrete flexural strength at 7 days

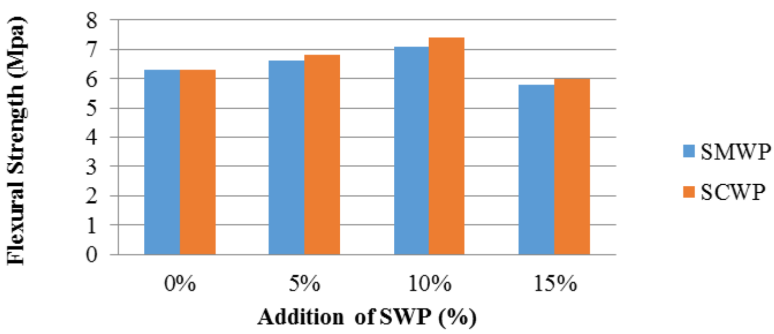


Figure 7. Concrete flexural strength at 28 days

There is no significant difference in terms of compressive and flexural strengths containing 5%- 15% in both 7 and 28 days compared to the control mixture as proven by [28]. Mixtures with 5% and 10% show marginally higher compressive and flexural strengths compared to the control mixture since the paper is made from cellulose. Cellulose is considered as a fibre material and consists of a molecule containing carbon and hydrogen atoms. Water is a molecule composing hydrogen and oxygen atoms. When mixing paper in water, the oxygen atom from the water molecule snatches the hydrogen atom from the cellulose creating hydrogen bond. This bonding of hydrogen provides the basis for papercrete strength [22-23]. Furthermore, the paper contains a large amount of alumina-siliceous content which is united with calcium, thereby enhancing its strength [22-23]. The enhancement of strength is abundantly related to waste paper hydraulic and pozzolanic activities that actuated by the alkalis and to some extent, the hydration process discharges $Ca(OH)_2$ [22-23]. The compressive and flexural strengths begin to diminish because of cohesion loss as well as the cellulosic material binding of calcium-hydrate-silicate (C-S-H) gel is acutely miserable [22-23]. The most reasons for the concrete compressive and flexural strengths reduction are the amount of waste paper addition, physical properties and carbon content [22-23]. From both strengths, it can be observed that the strength of SCBWP is more than SCPWP. SCBWP is thicker and heavier than SCPWP. SCBWP contains more fibre average length, a higher proportion of medium and long fibre contents, higher strength of bending, internal bond and modulus of elasticity than SCPWP [24]. So the cellulose in SCBWP is higher than SCPWP. SCBWP has more carbon and hydrogen atoms than SCPWP since cellulose consists of carbon and hydrogen atoms. More oxygen atoms from the water grab the hydrogen atoms from the cellulose because there are many hydrogen atoms in SCBWP. This reaction will create more hydrogen bonds. More hydrogen bonds will produce higher compressive and flexural strengths. Moreover, SCBWP would be tougher and long-lasting compared to SCPWP. It is also more costly and expensive than SCPWP.

3.3 Water Absorption

Figure 8 shows the hardened concrete test result based on water absorption. The specimen test result is affected by the percentages of SCPWP and SCBWP additions. The concrete water absorption increases with 5%, 10%, and 15% additions of SCPWP and SCBWP. The lowest water absorption is recorded at 0% of SCPWP and SCBWP addition (plain concrete), which is 6.3%, while the highest is 11% at 15% of SCBWP addition. Increasing the SWP addition increase the concrete water absorption due to increasing of cellulose content in the paper [29].

Figure 8. Water absorption of concrete

More utilization of SWP will increase concrete water absorption. The high concrete porosity stored in the air could lead to high water absorption. Typically, as we know, paper is a natural element that has high water absorption and water permeability characteristics. Moreover, paper is also made of a base plant material. The web of tine plant fibre in the paper can be seen through micropore. The magnifying paper will discover further that the strand consists of long chains of linked sugar molecules known as cellulose. Cellulose materials, which easily absorb water and retain them for a long period, are significant factors of water absorption [22-23]. Water likes to be soaked up and pulled by sticking to cellulose in the paper. The paper absorbency is affected by the empty spaces between the fibres. The water likes to stick and fill these spaces as the cellulose attracts water. More spaces can contain more water. Cellulose fibres in paper have much space like tiny air bubbles between them. That's why the paper is mainly an absorbent material. Water molecule fills the gap spaces by following one another as the cellulose absorbs the water molecule. It is also like to stay together with each other. By overall results, it can be seen that in term of the type of SWP used, SCBWP has higher water absorption and water permeability than SCPWP. Concrete is considered as high-quality concrete when the concrete water absorption percentage is less than 10% [30]. In conclusion, 15% addition of SCPWP and SCBWP are unsuitable to be used in concrete because they have a high water absorption rate more than 10%. Thus, the presence of moisture in water curing condition has essential effects on water absorption of concrete containing SCPWP and SCBWP.

4. Conclusion

The compressive strength increases up to 10% addition of SWP. However, above 10%, the strength reduces gradually. The flexural strength increases up to 10% addition of SWP, and more than 10% SWP content decreases the strength gradually. Adding SWP to concrete mix prompts increment in water absorption. The higher SWP addition causes higher concrete water absorption. Generally, 5% to 10% addition of SWP is the most suitable mix proportion. SCBWP has higher compressive and flexural strengths and water absorption than SCPWP because SCBWP has higher cellulose, more fibre average length, a higher proportion of medium and long fibre contents than SCPWP. By using SWP in concrete, the disposal cost of a paper industry can be saved, and sustainable concrete can also be produced in the construction and civil engineering fields. The utilization of waste material such as SWP as an additional alternative material in concrete will give advantage to the environment. The advantage of using this waste material also gives benefit to the economy in term of cost-effectiveness.

References

[1] Yun H., Jung H., Choi C., "Mechanical Properties of Papercrete Containing Waste Paper", Architectural Institute of Korea, 2007.
[2] Fuller, Fafitis, and Santamaria J. " Structural properties of a new material made of waste paper" Building Integration Solutions (AEI) 2006, pp 1-16.
[3] Titzman L.C., "Analysis of Low Cost Building Material for the Mix Alco Process" Texas A & M University, 2006.
[4] Wikipedia, The Free Encyclopedia, https://en.wikipedia.org/wiki/Papercrete.
[5] Gunarto A, Satyarno I, Tjokrodimuljo K. Newsprint Paper Waste Exploiting for Papercrete Panel. Institute of Research Center, Gadjah Mada University. 2008.
[6] Bai, J. et al. (2003). Compressive Strength And Hydration of Wastepaper Sludge Ash–Ground Granulated Blastfurnace Slag Blended Pastes. Cement and Concrete Research, Volume 33, Issue 8, August 2003, Pages 1189-1202.
[7] Chin, T.L., et al. (1998). A Novel Method to Reuse Paper Sludge and Co-Generation Ashes from Paper Mill. Journal of Hazardous Materials, Volume 58, Issues 1-3, February 1998, Pages 93-102.
[8] Chun Y. et al. (2006). Pulp and Paper Mill Fibrous Residuals in Excavatable Flowable Fill. International Conference on Sustainable Construction Materials and Technologies, June 2007. Coventry, UK.
[9] Gallardo, R.S., Adajar, M.A. (2006). Structural Performance of Concrete with Paper Sludge as Fine Aggregates Partial Replacement Enhanced With Admixtures. Symposium on Infrastructure Development and the Environment 2006, 7-8 December 2006, SEAMEO-INNOTECH. University of the Philippines, Diliman, Quezon City, Philippines.
[10] Kraus, R.N. et al. (2003). Concrete Containing Recycled Fibers from Pulp and Paper Mills. Sixth CANMET/ ACI International Conference June 2003, Recent Advances in Concrete

Technology. Bucharest, Romania.
[11] Naik et al. (2004). Use of Pulp and Paper Mill Residual Solids in Production of Cellucrete. Cement and Concrete Research, Volume 34, Issue 7, July 2004, Pages 1229-1234.
[12] Fuwape, J.E. et al. (2007). Technical Assessment of Three Layered Cement-Bonded Boards Produced From Wastepaper and Sawdust. Waste Management, Volume 27, Issue 11, 2007, Pages 1611-1616.
[13] Okino, E.Y.A. et al. (2000). Utilization of Wastepaper to Manufacture Low Density Boards. Bioresource Technology, Volume 73, Issue 1, May 2000, Pages 77-79.
[14] Shukeri, R. B. and a Naser, A. G. "Concrete Mix with Wastepaper" 2nd international conference on built environment in developing countries (ICBEDC 2008), pp. 567-575.
[15] Mr. Yogesh D. Shermale, Dr. Mahaveer B. Varma IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 14, Issue 2 Ver. VII (Mar. - Apr. 2017), PP 27-32.
[16] Titzman, L. C., "Analysis of Low Cost Building Material for the Mix Alco Process" Texas & M University, 2006.
[17] Yogesh D. Shermale, M. B. Varma, "Papercrete: A Lightweight Concrete", Aurangabad, Maharashtra, India, 2016.
[18] Malthy R, Jegatheeswaran D. Comparative study on papercrete bricks with conventional bricks. ICI Journal. January-March 2011.
[19] Ms 522 Part 1:2003 Portland Cement (Ordinary and Rapid-hardening) Part 1 Specification (Second Revision)-709539.
[20] British Standards Institution. 1992. Specification for Aggregates from natural sources for concrete: BS 882.
[21] G.V.S. Prasad, P.P. Reddy, M.Swathi, P.D.V.Kumar, T. Praveenraja, M.Naveen, In. J.of Eng. R., 3 (2015).
[22] Iqbal N. Gorgis, Harith M. Zaki, and Shakir A. Salih, Properties of Papercrete, Journal of Engineering and Applied Sciences, Asian Research Publishing Network (ARPN), ISSN 1819-6608, Vol. 12, No. 24, December 2017.
[23] Harith Zaki, Iqbal Gorgis, and Shakir Salih, Mechanical Properties of Papercrete, Building and Construction Engineering Department, University of Technology, Baghdad, Iraq, BCEE3-2017, MATEC Web of Conferences 162, 02016 (2018).
[24] Piotr Borsyiuk, Danuta Nicewicz, Jerzy Pawlicki, Marcin Klimczewski, The Influence of The Type and Preparation of Ligno-Cellulose Fibres on The Properties of MDF, Faculty of Wood Technology (WTD) SGGW Warszawa, Warsaw, Poland, Wood Research, 79-88, 52 (4): 2007.
[25] British Standard. (2009). Testing Hardened Concrete. Compressive Strength of Test Specimens. London: BS EN 12390: Part 3.
[26] British Standard. (2009). Testing Concrete. Method for Determination of Flexural Strength. London: BS EN 12390: Part 5.
[27] British Standard. (2011). Method for Determination of Water Absorption. London: BS EN 1881-122.
[28] R. Illakkiya and G. Dhanalakshmi, Experimental Investigation on Concrete Using Waste Paper, International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, p-ISSN: 2395-0072, Volume 5, February 2018.
[29] Print Wiki, The Free Encyclopedia of Print, http://printwiki.org/Cellulose.
[30] Neville, A. M. (2011). Properties of concrete (Vol. 5th Edition). London: Pitman International Text.

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