A Review Paper on The Effect of Waste Paper on Mechanical Properties of Concrete

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Abstract. Cement, sand, coarse aggregate and water are the materials to make concrete. The waste paper has been dumped as waste and causes environmental pollution behind 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 cement replacement or addition in concrete production will reduce environmental pollutions. This review paper is to investigate the effect of waste paper on mechanical properties of concrete such as compressive strength and flexural strength. From many previous studies before this, 5% and 10% waste paper as cement replacement and additions were the ideal percentages to increase the compressive and flexural strengths of concrete. This study indicates waste paper can give benefit by using it as additional material in concrete production.

1. Introduction

Nowadays, carbon dioxide (CO_2) gas emission from houses is 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 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 measuring quality, workability, and other papercrete properties [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, papercrete usage will decrease the dead load of the structure, the depth of foundation required and 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]. The effect of waste paper on mechanical properties of concrete such as compressive strength and flexural strength are reviewed in this paper based on numerous research papers before this.

2. Mechanical Properties

This section discusses the effect of waste paper on mechanical properties of concrete such as compressive strength and flexural strength based on previous studies before this.

2.1 Compressive Strength

[19] has researched the effect of waste paper pulp as partial Portland cement replacement on M20 and M30 concrete mixtures properties. The percentage of Portland cement replacements were 0%, 5%, 10%, 15% and 20%. 14 and 28 days were the compressive strength test. The compressive strength advancement of a paper-mill residual concrete mixture was fundamentally the same as the reference mixture, demonstrating a high early strength gain. The compressive strength of concrete mixture with paper pulp at a certain percentage was less than the reference mixture. The result showed that, when higher paper pulp content was included in the concrete mixture, there will be a reduction of the compressive strength [19]. When the paper pulp content increased, the concrete compressive strength decreased. The mechanical properties of the concrete mixture were played by a great role in the paper pulp content. Nonetheless, the impacts of paper pulp on the concrete's mechanical properties do not change much from the findings of previous researchers. Replacement of Portland cement with paper pulp in concrete on a one-for-one basis, either by volume or by weight, resulted in lower compressive strength up to around one month of curing. [19] concluded that, the most suitable mix proportions were 5% and 10% replacement of cement with waste paper pulp. Generally, for M20 and M30 concrete mixture, at 14 and 28 days, the compressive strength increased up to 10% replacement of cement with waste paper pulp and a further increment in waste paper pulp lessened the strength continuously [19].

[20] investigate the compressive strength of concrete containing 0%, 5%, 10% and 15% addition of paper pulp. Compressive strength increased initially with the addition of paper pulp, however, it decreased significantly on further addition of paper pulp. The compressive strength values increased to 10% of paper pulp addition at 7, 14 and 28 days curing. Concrete mixes containing 5% and 10% of paper pulp have demonstrated an increased compressive strength compared to control mix and there was a decreased of the compressive strength on the 15% addition of paper pulp [20]. The reduction in compressive strength with the increase in the percentage of paper pulp was due to the presence of low silica content in the composition, which tended to decrease its strength [20].

[21] studied 0%, 5%, 10%, 15% and 20% addition of waste paper on compressive strength of concrete. The compressive strength was conducted according to [22]. The reading was taken from the average compressive strengths recorded from three cube specimens. The tests were conducted at 7, 28 and 56 days. The test outcomes indicated an increase in strength with curing ageing progression because of the hydration process. The concrete compressive strength mix results with waste paper pulp were less than the reference mix for all test ages except the mixture with 5% of paper pulp addition [21]. There was a reduction of the compressive strength when there were more than 5% and higher paper pulp contents in the concrete mixture [21]. Other than that, including a waste paper in a concrete mixture, will hold volume in the samples and any expansion will weaken the concrete. The mechanical properties of concrete were performed by a great role of the paper pulp content in the concrete mixture. However, as the paper mass content increased, the strength decreased. [21] observed the results of compressive strength reduced for 10%, 15% and 20% additions of waste paper. In

comparison, for 5%, the strength was higher than the reference mix, 0% since waste paper contains a considerable amount of alumino-siliceous material that combines with calcium, leading to the improvement in its strength [21]. The advancement was caused by hydraulic and pozzolanic activities of waste paper that activated by the alkalis and calcium hydroxide $Ca(OH)_2$ was released from the hydration process [21].

[23] experimented with concrete containing coarse aggregate replaced with paper pulp with the percentages varying from 0%, 2.5%, 5%, 7.5%, 10% and 12.5% by volume. There were two types of concrete grades designed, such as M20 and M25. The M20 and M25 concrete mixes were done according to IS 10262:2009. The hardened properties of the papercrete were studied. For both mixtures M20 & M25 concrete grade, it was observed that 10% and 12.5% replacement of paper pulp with aggregate could be considered as an acceptable percentage limit for replacement as the strength observed was the well acceptable range [23]. This paperweight is a non-government approval, but it can be utilized in the construction industries and also an excellent choice to use waste paper as it is economical [23]. Table 1 shows the compressive strength of papercrete.

Table 1. Compressive strength of papercrete

Percentage of waste paper (%)	Optimum percentage (%)
0%, 5%, 10%, 15%, 20%	5%, 10% replacement of cement with waste paper pulp [19]
0%, 5%, 10%, 15%	5%, 10% of paper pulp addition [20]
0%, 5%, 10%, 15%, 20%	5% of waste paper addition [21]
0%, 2.5%, 5%, 7.5%, 10%, 12.5%	10%, 12.5% replacement of paper pulp with aggregate [23]

2.2 Flexural Strength

This paper writes about the investigation of waste paper usage as extra material in concrete mixtures to be utilized for housing projects. It must be guaranteed proper mechanical strength can be produced from the resulting concrete. Concrete mixtures containing different paper contents were prepared, and essential strength like flexural strength was determined and compared with the control mixture. [24] prepared four concrete mixtures: control mixture and three mixtures containing 5%, 10% and 15% of waste paper as extra material in concrete were set up with a ratio of 1:2:3 by weight of cement, sand, and aggregate respectively. The biggest size of the aggregate was 20 mm. The flexural strength of the concrete mix was determined by [25]. Mixtures 10% and 15% indicated lower strength than the mixture 0% and 5% [24]. This higher strength may ascribe that mixtures 10% and 15% had low water to cement ratio compared to mixture 0% and 5%. Based on the results of the study, it very well may be reasoned that as a rule. Each group of concrete mixtures containing waste paper except 0% as a control mixture. At 7 days, the flexural strength of concrete diminished with the increment of 10% and 15% of the waste paper amounts, but a concrete mixture with 5% waste paper indicated higher flexural strength than the control mixture [24]. Great relationships were seen in flexural strength and relationship between density and strength of concrete mixture containing waste paper.

A sum of 10 concrete mixtures was prepared and produced. The college provided materials such as Portland pozzolanic cement, fine aggregate (sand) and coarse aggregate to be utilized for the experiment. The concrete mixtures were produced by utilizing a sufficient amount of the waste paper pulp and water and compared in terms of their strength to the conventional concrete. The paper-mill residual concrete mixture flexural strength advancement was fundamentally the same as the reference mixture, indicating a high early strength increased. The reference mixture flexural strength had a lower strength than the concrete mixture with paper pulp [26]. The result showed that the flexural strength diminished when high paper pulp contents were included in the concrete mixtures. When the paper pulp content increased, the flexural strength of the concrete mixture decreased. The concrete mixture mechanical properties were played by the significant role of the paper pulp content in the concrete mixture. [26] concluded that generally, the flexural strength increased with 5% and 10% additions of waste paper pulp and a further rose in waste paper pulp reduced the strength gradually.

One control and seven papercrete mixes were investigated with 0%, 5%, 10%, 15%, 20%, 30% and 35% replacement of ordinary portland cement with waste paper pulp [27]. The ratio of the mix (cement:sand:coarse aggregate = 1:1.5:2) with a w/c ratio of 0.4. The beam specimens with a 700 mm x 150 mm x 150 mm size were used for the flexural strength test. All the specimens were cured for 28 days in a curing tank. The demand for water mixing increased with the increasing percentage of paper mass. This increasing demand was due to the absorption characteristic of cellulose materials in water. [27] described that the flexural strength showed drastically decreasing values at 28 days as the percentages of ordinary portland cement replacement were 15%, 20%, 30% and 35% except for 5% and 10%. The cellulose fibre caused these increasing values of flexural strength to bend adequately to get the bending stress produced during the flexural test [27]. The bending stress produced shows that this application is suitable for boards, partitions, beams, and roofing sheets. The fibrous cellulosic material absorbs a high amount of impact forces. Thus, pavement tiles, partition boards, ceiling boards, and other lightweight parts of structures are quite fit to be made using this papercrete material [27].

An experiment was studied on fine aggregate replacement with paper pulp with various percentages such as 5%, 10% and 15% in M30 concrete mix [28]. This experiment wanted to test the concrete flexural strength containing paper pulp. Hence, it was compared with conventional concrete. Each concrete mix proportion has six concrete 500 mm x 100 mm x 100 mm beams. The flexural machine applied a three-point loading point. At 7 days, the flexural strength increased by 10% and 15% replacement of fine aggregate with paper pulp, while at 28 days, the flexural strength decreased by 5%, 10% and 15% replacement [28]. At 7 days, the maximum flexural strength was at 15% replacement while at 28 days, the maximum flexural strength was at 0% replacement [28]. Table 2 shows the flexural strength of papercrete.

Table 2. Flexural strength of papercrete

Percentage of waste paper (%)	Optimum percentage (%)
0%, 5%, 10%, 15%	5% of waste paper addition [24]
0%, 5%, 10%, 15%, 20%	5%, 10% of waste paper pulp addition [26]
0%, 5%, 10%, 15%, 20%, 30%, 35%	5%, 10% replacement of cement with waste paper pulp [27]
0%, 5%, 10%, 15%	10%, 15% replacement of fine aggregate with paper pulp [28]

3. Conclusion

From the extensive literature review done on the topic, the following conclusions can be drawn about the effect of waste paper on concrete mechanical properties.

Compressive Strength

1. The concrete compressive strength increases with 5% and 10% replacement of cement with waste paper pulp, but 15% and 20% gradually reduce the strength.
2. 5% and 10% additions of paper pulp increase the compressive strength of concrete. Above 10%, the strength decreases.
3. 5% of waste paper addition increase the concrete compressive strength compared to 10%, 15% and 20% additions.
4. 10% and 12.5% replacement of paper pulp with aggregate increase the concrete compressive strength compared to 0%, 2.5%, 5%, 7.5%.
5. 5% and 10% are the best percentages of cement and aggregate replacement with waste paper and waste paper addition in concrete.

Flexural Strength

1. The concrete flexural strength increases with 5% of the waste paper edition and diminishes by 10% and 15%.

2. The flexural strength of concrete increases with 5% and 10% of waste paper pulp additions, and a further increase reduces the strength gradually.
3. 5% and 10% replacement of cement with waste paper pulp increase the flexural strength of concrete, but 15%, 20%, 30%, and 35% reduce the strength.
4. The concrete flexural strength increases with 10% and 15% replacement of fine aggregate with paper pulp and decreases with 5% replacement.
5. 5% and 10% are the ideal percentages of waste paper addition and replacement of cement and fine aggregate with waste paper in concrete.

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