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Innovation-ecofriendly employment of waste paper for producing lightweight aggregate for concrete

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ABSTRACT

Lightweight concrete mentions to any concrete produced to an oven-dry density less than 2000 kg/m3. This can reached by replacement of natural aggregates with lightweight aggregate, no fine aggregate and or adding foamed agent to the concrete. This research usage of recycled paper as an aggregate replacement in producing a lightweight concrete for construction purpose. It was used two type of production of paper aggregate (The paper aggregate treatment with cement and paper aggregate treatment with wood glue) and then replacement with natural aggregate. The results shown increasing of replacement natural aggregate (gravel) with paper aggregate will leads to decreasing in density of concrete. The paper aggregate treatment with cement give a significant compressive strength than the concrete made with paper aggregate treatment with wood glue. Paper aggregate treatment with wood glue give a significant reduction in density than the concrete made with the paper aggregate treatment with cement. The large decreasing in splitting strength due to presence of paper when the replacement is 100% from the natural aggregate (gravel). However, the percentage of replacement 50% of paper aggregate given better splitting strength than the replacement of 100%.

Keywords: Lightweight aggregate, concrete paper aggregate, waste paper, eco-friendly

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1. Introduction

Utmost of the waste paper materials are end up in dump location or landfill than recycling it. This is one of the aspects of accumulative in the solid waste amount at the landfill. Opportunely, some recent investigations have been confirmed that the waste paper can be utilized as a construction material. The utilization of waste paper as building materials has twofold; first reducing the amount of the solid waste, and second reducing the pressure of demand on other natural building materials [1,2].

Recent years many experimental researches have been conducted for incorporating of the waste of paper in concrete. Anandaraju et al. [3] executed an experimental investigation to produce lightweight papercrete bricks. Various containing of paper mixes was adopted. Some of mechanical and physicals properties of produced bricks (compressive strength, water absorption, and fire resistance) were measured. The authors found that the waste paper can be employed for production very lightweight bricks with satisfactory properties utilization in non-load bearing walls with good sound and thermal insulation. Chung et al. [4] investigated the influence of the incorporating of the waste paper on the papercrte concrete properties. Fifteen mixes of papercrete with paper content ranged from 5% to 35% replacement from cement were prepared. The obtained results confirmed that the mechanical properties (compressive strength and modulus of elasticity) significantly reduced as the waste paper to cement increased. Despite of the increasing the paper to cement ration led to

reducing of compressive strength and modulus of elasticity, the failure mode of the higher ratio exhibited a ductile mode of failure.

Momin and Sayyad [5] executed an experimental investigation for producing fly ash papercrete bricks. Nine mix proportion were adopted for optimization of papercrete mix proportion. Several parameters of the produced brick like as density, strength, water absorption, durability were examined to assess the feasibility of produced bricks. The authors conformed that the produced bricks (fly ash papercrete bricks) have good properties as durable and load carrying bricks.

In other experimental study directed by Kumar and Ghandu [6] for using the waste paper as partial replacement from coarse aggregate in the conventional concrete. The mechanical properties such as flexural strength and compressive strength were examined at 28 days after air curing. The authors found as the waste paper increase in the concrete, the mechanical properties decrease, that also stated by Abhishek [7] in anther experimental work for examining the effect of adding waste paper on the properties of concrete (the percentage of the waste paper ranged between 10 % to 40%) .

Pandy [8] conducted anther study to investigate the utilization of the waste paper in production of lightweight and low cost concrete. Different mix proportion was adopted and the production process involved two stages. First stage the generation of the pup from the waste paper, and the second stage mixing the pulp with other constituents of concrete. The hardened and fresh properties of papercrete were measured. The author conformed that the produced papercrete can be only used as non-load bearing construction materials in the inner walls or partitions, that also confirmed an experimental study directed by Rajan et al. [9] to producing innovative bricks by utilizing various waste materials such newspaper, powder of eggshell, and fly ash. Sarkar [10] executed an investigation to improve cost effective building materials from the waste paper. Portland cement was replaced paper pulp in different fractions. Also, the author confirmed that the produced building materials can be used as non-load bearing with interior partitions due to the low strength and high water absorption.

The incorporating of waste paper in concrete in the most earlier studies as paper pulp which the waste paper thoroughly mixes with water to produce the pulp then combined with other concrete constituents. This method led to considerably lower the workability and increase the drying shrinkage of produced building materials. Thus, in the existing study the waste paper was incorporated in concrete as lightweight aggregate. The main goal of present investigation is to employ the waste materials such as waste paper, in the process of producing an innovative kind of eco-friendly lightweight aggregate for concrete. Additionally, some mechanical and physical properties of lightweight concrete that produced from the new kind of lightweight aggregate are examined in order to assess the efficiency of the new construction material. The objective of this project is to study the usage of recycled paper as an aggregate replacement in producing a lightweight concrete for that may can be used in construction purpose and with different density.

2. Materials

In this research, they used Portland cement, fine aggregate, coarse aggregate, office papers, and tap water. The description and details of materials that used in this investigation are as below.

2.1 Cement

Type V (Sulfate-resisting Portland cement) factory-made by plant of Karbala cement that called Al-Jeser they used in this research. According to the American specifications of ASTM C 150-15 [11] the physical and chemical property are conformed to it.

2.1. Fine aggregate

AL-Ukhaider natural sand, locally obtainable from Karbala was used as a sand conforming to zone 2, of the Iraq specification stander (IQS No. 45/1984) [12].

2.2. Coarse aggregate

Local crushed river gravel as coarse aggregate with a maximum size of 19.5 mm from Al-Nebaii region was used in all mixes. which matches to the Iraqi standard (IQS No.45/ 1984) [12].

2.3. Office papers

Office paper that all the waste paper can get from an office like, the paper that used by printers, fax machine, photocopier, books, and all white paper which can be used in office that are usually accepted by office paper that can be recycling.

2.4. Wood glue

Wood glue is an important tool for crafts-man ship and home enhancement plans. This kind of adhesive is prepared to make bond very well with the wood. The chemicals and bases of all glues that manufactured to create them a sticky and all type has been a distinctive formulation. In this research, they used commercial glue with polymers base.

2.5. Water

Tap water was to be utilized for research of the preferred in the soaking, mixing and in curing of the test specimens.

3. Preparation Method of producing lightweight Paper aggregates

There are two methods for producing lightweight paper aggregates as following:-

3.1. First method (treatment with cement paste)

Paper Preparation Stages can by summarized as start with cutting paper to small pieces. Paper cut into small pieces by shredded machine or manually. After making paper as small pieces it, will immersion the paper in the tap water at less for 3 days to extricate of harmful substances. During that, 3 days of soaking, they must mixing paper upside down to making it more homogenous and like as a paste. After extract the paper paste they formation to aggregate, the paper shaped in the form of coarse aggregate manually to the size desired. Then exposure the paper formed to the air for one day to get drying or by using drying oven. Preparation cement paste to used it to covered the paper aggregates with small thin shall from cement paste around the aggregates, then let it to drying and after that curing with spraying water. The stages of manufactured illustrated in Figure 1A.

3.2. Second method (treatment with glue)

The paper preparation stages can by summarized as in the first method from cutting, soaking, formation, and drying. The producing different during stage of formation ,the wood glue will put the paper paste and mixing well, then formation as an aggregates, after that it will let it to drying.
Before using the lightweight aggregates that produced from waste paper, it need to make some sieve analysis for paper aggregate that treatment and produced from the two methods above. The sieve analysis as shown in Table 1 and the stages of manufactured illustrated in Figure 1B.

Table 1. Sieve analysis for both types of paper aggregate that treated by cement paste and wood glue

Sieve size (mm)	**Cumulative passing % of aggregate treatment by**		**IQS.No.45/1984 [12]**
	cement paste	**wood glue**	**grad 5-20 mm**
37.5	100	100	100
20	95	95.8	95 - 100

Sieve size (mm)	Cumulative passing % of aggregate treatment by		IQS.No.45/1984 [12]
	cement paste	wood glue	grad 5-20 mm
14	48	45.2	-
10	30	30.3	30-60
5	1.9	0.7	0 - 10

A

B

Figure 2. Stages of manufactured of paper aggregate A: treatment by cement paste, B: treatment by wood glue

4. Mix proportion

Lightweight concrete from lightweight Paper aggregates is, this concrete is an innovation and one of the new types of lightweight concrete currently. Principally composed from cement, fine aggregate, coarse aggregate and paper aggregates. The mix proportion of the control mix in this investigation is based traditionally concrete with compressive strength not less than 35 MPa and it taken as 1:1:1 to reducing aggregate as possible (taken high density in this case). Moreover, to reach the objective of this investigational research, the paper aggregates was partially replaced by volume with ordinary coarse aggregate in different portion. The considered paper aggregates portion were 50% and 100% for paper aggregates that treatment by cement paste and wood glue respectively. Table 2 and Figure 2 illustrates the mix proportions for the all mixtures.

Table 2. Mix proportion of all mixes

Mixture des.	**Cement kg/m^3**	**Fine aggregate kg/m^3**	**Ordinary coarse aggregate kg/m^3**	**Aggregate treatment by (replacement by volume)**		**W/C**
				cement paste	wood glue	
Ref.	300	300	300	0	0	0.4
Mix-C50%	300	300	150	150	0	0.4
Mix-C100%	300	300	0	300	0	0.4
Mix-G50%	300	300	150	0	150	0.4
Mix-G100%	300	300	0	0	300	0.4

Figure 2. Mix proportion of mixture

4.1. Experimental works

Two types of molds were used, including steel molds cubes with dimensions (10 * 10 * 10) cm in order to check the compressive strength and measure the density and absorption ratio. It was used cylindrical molds with dimensions (10 * 20) cm for testing the tensile strength. Before starting the mixing the paper aggregate will used with saturated surface dry to prevent absorb the mixing water. The casting process was completed

by filling two layer with using the vibrator machine to get rid of air bubbles and after finishing adjusting the surface of the models and covering it with a polyethylene sheet to prevent the evaporation of the mixing water. After completing the process of casting the concrete, the concrete molds left in the laboratory for 24 hours, then opening the molds and submerging it in a tap water for curing. The curing method was used with a conventional temperature (20-25) º until the testing day at (7, 14, 28) days.

5. Results and discussion

5.1. Compressive strength

From Table 3 and Figure 3 the reference mix increase with age. The replacement of natural gravel with 50% of paper aggregate that treatment by cement paste (mix-C50%) showed reduction in compressive strength about 44.7% and 45% at age 7 and 28 days respectively. However, when replacement 100% of natural gravel with paper aggregate that treatment by cement paste the compressive strength will be reducing about 71.4% and 63.6% at age 7 and 28 days respectively. The paper aggregate that treatment by wood glue (mix-G) showed results less value than that of treatment by cement paste. The results of mix-G50% showed reduction about 59% and 47% at age 7 and 28 days respectively. For age 7 and 28 days the reduction in compressive strength about 84% and 73% respectively for mix-G100%. The value of compressive strength of mix-C50% and mix-G50% is nearest than the requirement of structural lightweight concrete [13] . The reduction in compressive strength when incorporated the waste paper aggregate in the concrete as volumetric replacement from the coarse aggregate can be attributed to the difference between strength properties and density of the waste paper gravel and natural gravel. The lightweight aggregate concrete largely controlled by the mechanical properties of the aggregate [14][15][16].

Table 3. Ccompressive strength results for all mix

Mix Designation	**Compressive strength MPa***		
	7 days	***14 days***	***28 days***
Ref.	32.2	35.38	39.38
Mix-C50%	17.8	18.7	21.6
Mix-C100%	9.2	12.9	14.3
Mix-G50%	13.1	15.9	20.7
Mix-G100%	5.1	7.7	10.5

* The result represents the mean of three specimens.

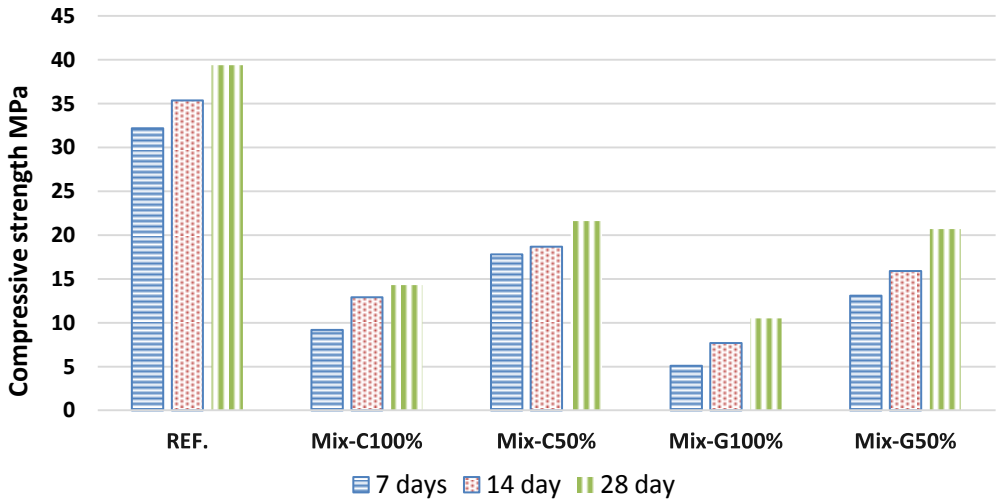

Figure 3. Compressive strength for all mixes

5.2. Splitting tensile strength

From Table 4 and Figure 4 the splitting tensile strength of reference mix increase with age. The replacement of natural gravel with 50% of paper aggregate that treatment by cement paste showed reduction in splitting tensile strength about 16.3% and 40% at age 7 and 28 days respectively. However, when replacement 100% of natural gravel with paper aggregate that treatment by cement paste for mix-C100%, the compressive strength will reducing about 46% and 55.4% at age 7 and 28 days respectively. The paper aggregate that treatment by wood glue showed results less value than that of treatment by cement paste. The results of mix-G50% showed reduction about 41% and 52.6% at age 7 and 28 days respectively. For age 7 and 28 days the reduction in splitting tensile strength about 56.8% and 69.6% respectively for mix-G100%. The reduction in splitting strength when incorporated the waste paper aggregate in the concrete as volumetric replacement from the coarse aggregate can be attributed to the difference between strength properties of the waste paper gravel and natural gravel. The lightweight aggregate concrete largely controlled by the mechanical properties of the aggregate [14][15][16].

Table 4. Results of Splitting tensile strength for all mixes

Mix Designation	**Splitting tensile strength MPa***		
	7 days	**14 days**	**28 days**
Ref.	2.2	2.91	**3.59**
Mix-C50%	1.84	1.92	**2.15**
Mix-C100%	1.19	1.25	**1.6**
Mix-G50%	1.3	1.46	**1.7**
Mix-G100%	**0.95**	**1.01**	**1.09**

* The result represents the mean of three specimens.

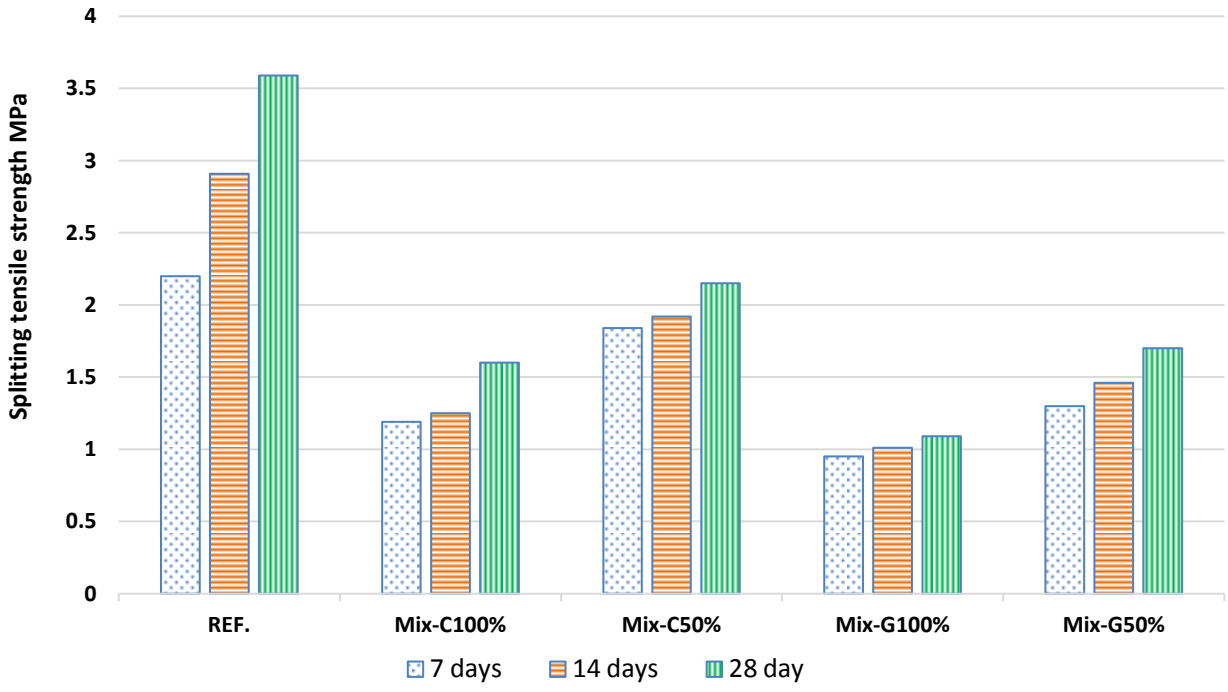

Figure 4. Splitting tensile strength for all mixes

5.3. Density

From Table 5 and Figure 5, the effects of replacement paper aggregate showed a significant decrease in weight and density than the Ref. mix. The paper aggregate that treatment by wood glue showed results better value than that of treatment by cement paste in reduction of density. The results of mix-G50% showed reduction about 13.4% and 18.5% at age 7 and 28 days respectively. For age 7 and 28 days the reduction in dry density about 17.7% and 23.7% respectively for mix-G100%. The replacement of natural gravel with 50% of paper aggregate that treatment by cement paste showed reduction in density about 12.3% and 16.5% at age 7 and 28 days respectively. However, when replacement 100% of natural gravel with paper aggregate that treatment by cement paste for mix-C100%, the density will be reducing about 15.6% and 21.6% at age 7 and 28 days respectively. This tendency in density after incorporating the paper aggregate can be practiced due the lighter weight of the paper aggregate compared to the natural aggregate, many researchers stated that incorporation the paper in concrete clearly reduce depending on the percent of the paper [17] [18][19]**.**

Table 5. Results of dry density for all mixes

Mix Designation	**Dry density* kg/m^3 at 7 days**	**Dry density* kg/m^3 at 28 days**
Ref.	2200	2431
Mix-C50%	1928	2028
Mix-C100%	1855	1904
Mix-G50%	1904	1982
Mix-G100%	1810	1853

* The result represents the mean of three specimens.

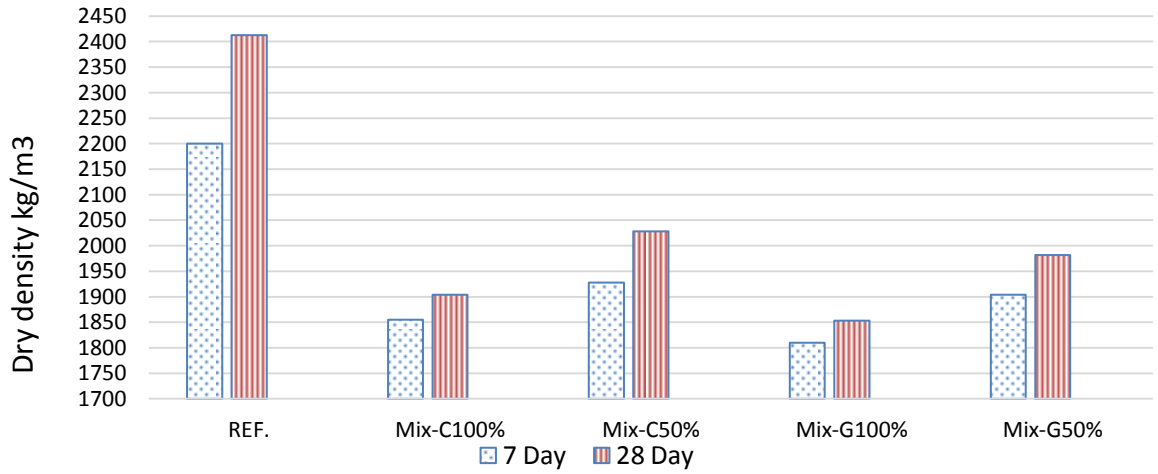

Figure 5. Dry density for all mixes.

5.4. Total absorption

The results of total absorption in Table 6 and illustrated in Figure 6 that the increasing replacement of natural aggregate with paper aggregate will led to increasing absorption. The mix-G showed results high absorption value than that mix-C. The results of mix-G50% showed increasing in absorption about 54% and 333% at age 7 and 28 days respectively when compared with reference mix. For age 7 and 28 days the increasing in absorption about 142% and 916% respectively for mix-G100%. However, the increasing of absorption of

mix-C50% about 62.8% and 261% at age 7 and 28 days respectively when compared with reference mix. The mix-C100 showed increasing in absorption about 279% and 750% at age 7 and 28 days respectively when compared with reference mix. The increase of the water absorption may due to the nature of paper that absorption high content of water.[20]. water absorption of the lightweight aggregate concrete significantly affected by the water absorption of the lightweight aggregate [21][22].

Table 6. Results of Total Absorption for All Mixes

Mix Designation	Absorption* at 7 days %	Absorption* at 28 days %
Ref.	3.5	1.8
Mix-C50%	5.7	6.5
Mix-C100%	13.27	15.3
Mix-G50%	5.4	7.8
Mix-G100%	8.5	18.3

* The result represents the mean of three specimens.

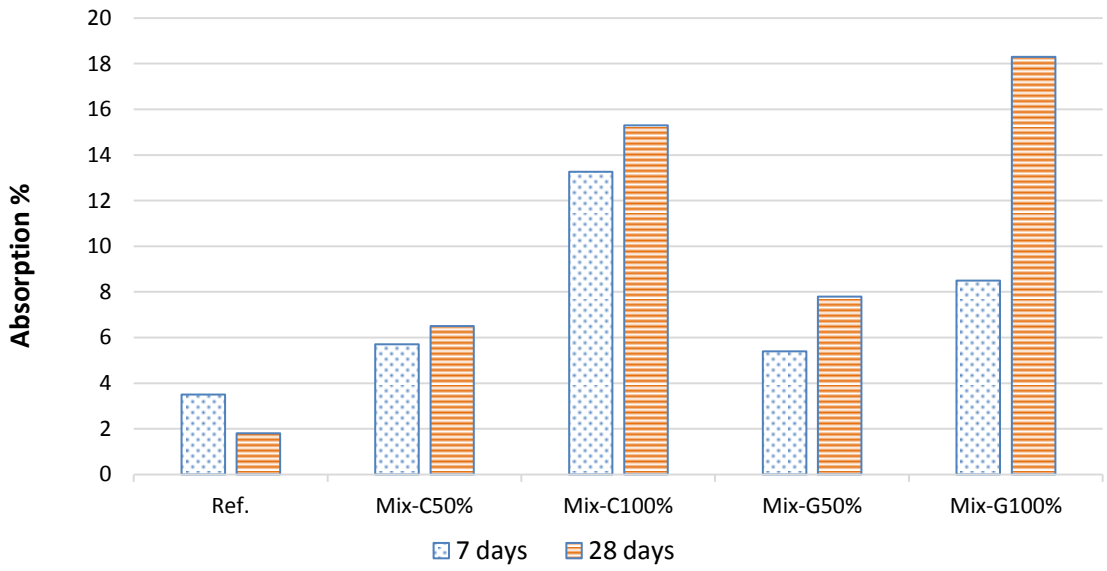

Figure 6. Total absorption for all mixes

6. Conclusion

From the tests results of the experimental research, the following conclusions can be drawn:

1. The increasing of replacement natural coarse aggregate (gravel) with paper aggregate will leads to decreasing in density of concrete.
2. The concrete producing from paper aggregate classifying as a lightweight concrete.
3. The paper aggregate treatment with wood glue give a significant reduction in density than the concrete made with paper aggregate treatment with cement.
4. The large decreasing in compressive strength when the replacement is 100% from the natural aggregate (gravel).
5. The presence of 50% paper aggregate give a better results of compressive strength than 100% because the gravel effect on the compressive strength .

6. Concrete made with paper aggregate treatment with cement give a significant compressive strength than the concrete made with paper aggregate treatment with wood glue.
7. The large decreasing in splitting strength due to presence of paper when the replacement is 100% from the natural aggregate (gravel). However, the replacement of 50% paper aggregate give a better splitting strength than the replacement 100%.
8. The paper aggregate treatment with cement give significant results in splitting strength than the concrete made with paper aggregate treatment with wood glue.
9. The results of absorption show that increasing with increase percentage of paper aggregate replacement.

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