

THE COMPRESSIVE STRENGTH OF LIGHTWEIGHT CONCRETE CUBE WITH
RECYCLED PAPER AS AGGREGATE REPLACEMENT

SITI FARRAH NADZIRAH BINTI AWALUDIN

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Faculty of Civil Engineering & Earth Resources
UNIVERSITY MALAYSIA PAHANG

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ABSTRACT

Construction field is widely developed from day to day. The development is causing the increasing needs of raw material such as gravel. This high demand is causing the materials becoming extinct. Apart from that, this world also had facing the high amount of waste products which including waste paper. Research has proven that the waste paper can be used as recycled paper in the construction field. The advantages of using the recycled paper is it can help in reducing the amount of waste product as well as preserving the raw material from extinct. However, there is no exact value of compressive strength of concrete containing recycled paper. The type of recycled paper, size and density does affect the compressive strength. Hence, the objective of this research is to determine the compressive strength of papercrete cube with different density of 1.3, 1.4 and 1.5 kg/m³. The other objective of this research is to identify the compressive strength of papercrete cube from three different shredded paper sizes of 2mm x 15mm, 3mm x 25mm and 4mm x 50mm. The total sample of 81 papercrete cubes with a curing period of 7, 14 and 28 days. From the result, the highest 28-day compressive strength is papercrete cube produced by density of 1.5 kg/m³ using shredded paper size of 3x25 mm which is 3.238 MPa. Meanwhile the lowest 28-day compressive strength is papercrete cube produced by density of 1.4 kg/m³ using shredded paper size of 4x50 mm which is 1.233 MPa. This shows that the most suitable density is 1.5 kg/m³ with shredded paper size of 3x25mm.

ABSTRAK

Bidang pembinaan maju secara meluas dari hari ke hari. Pembangunan ini menyebabkan peningkatan keperluan bahan mentah seperti kerikil. Permintaan yang tinggi ini menyebabkan bahan-bahan mentah menjadi pupus. Selain itu, dunia ini juga menghadapi jumlah yang tinggi bahan buangan yang termasuk kertas sisa. Penyelidikan telah membuktikan bahawa kertas buangan boleh digunakan sebagai kertas kitar semula dalam bidang pembinaan. Kelebihan menggunakan kertas yang dikitar semula adalah ia dapat membantu dalam mengurangkan jumlah bahan buangan serta memelihara bahan mentah dari pupus. Walau bagaimanapun, tidak ada nilai sebenar kekuatan mampatan konkrit yang mengandungi kertas kitar semula. Jenis kertas kitar semula, saiz dan ketumpatan mempengaruhi kekuatan mampatan. Oleh itu, objektif kajian ini adalah untuk menentukan kekuatan mampatan kiub papercrete dengan ketumpatan yang berbeza iaitu 1.3, 1.4 dan 1.5 kg/m³. Objektif lain kajian ini adalah untuk mengenal pasti kekuatan mampatan kiub papercrete daripada tiga saiz kertas yang dicincang berbeza iaitu 2mm x 15mm, 25mm x 3mm dan 4mm x 50mm. Jumlah sampel 81 kiub papercrete dengan tempoh pengawetan 7, 14 dan 28 hari. Dari keputusan, 28 hari kekuatan mampatan kiub yang tertinggi adalah papercrete dihasilkan oleh ketumpatan 1.5 kg/m³ menggunakan saiz kertas cincang 3x25mm iaitu 3.238 MPa. Sementara 28 hari kekuatan mampatan kiub yang terendah adalah papercrete dihasilkan oleh ketumpatan 1.4 kg/m³ menggunakan saiz kertas cincang 4x50mm iaitu 1.233 MPa. Ini menunjukkan bahawa ketumpatan yang paling sesuai ialah 1.5 kg/m³ dengan saiz kertas cincang 3x25mm.

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LIST OF ABBREVIATIONS

mm	Millimetre
kg/m ³	Kilogram Per Metre Cube (Density)
kg	Kilogram (Weight)
MPa	Mega Pascal (Pressure)

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia has a total capacity pulp and paper production at over one million per year (Asia Pro Eco Program 2006). A Most of the waste paper is end up in landfill or dump site than those recycled. This is one of the factors of increasing in the number of solid waste at the landfill. Fortunately, from the recent research study it has proven that paper also can be used as a construction material. Apart from reducing the number of solid waste the usage of recycled paper also can reduce the demand pressure and global natural resources.

In the recent study, quite a number of researchers had done a study on the usage of paper as a recycled waste in construction. There is a point where papercrete were produced. Papercrete is a construction material which consists of Portland cement, water, waste paper and/or sand. It is also like replacing coarse aggregate and/or sand in the concrete mixture with recycled paper. This is a new composite material that is using the recycled paper to produce a lightweight concrete material. Its advantages are there is a reduction of dead load, faster building rates in construction and lower haulage and handling costs.

Other than that, lightweight concrete also easy to carry and easily transferred to construction site as it is light and does not required heavy machineries. Besides,

papercrete is a structural lightweight concrete that has an in-place density of 1440 to 1840 kg/m³ compare to normal-weight concrete with density in the range of 2240 to 2400 kg/m³. As Hussein and Mugahed (2013) carried out their study, for structural applications the concrete strength should be greater than 17.0 MPa.

1.2 PROBLEM STATEMENT

Nowadays, as we already known construction fields has widely develop in all around the world. This is leading to the decreasing amount of raw material such granite and gravel. In order to overcome this problems arising, the alternative ways should be implemented. The application of lightweight concrete in the construction industries is a bit helpful in preventing the depleted resources. This is because in producing a lightweight concrete, recycled paper will be used as an aggregate replacement.

In addition, an increasing amount of waste product is also a problem that we had facing. High number of waste paper is one of a factor in the increasing amount of waste product. In order to help reducing the waste product, the waste paper can become one of a material in producing lightweight concrete. It can be used as an aggregate replacement or as an addition in producing a lightweight concrete. Even though it has been used as building materials for decades, there is still no research result on the use of waste paper in the structural concrete.

Meanwhile, there are several types of lightweight concrete that are quite expensive. For example shale, expended clay and pulverized fuel. From this matter, by using recycled paper in the concrete cost of producing the lightweight concrete could be saving. Besides, the recycled paper is also easily got and low cost is needed in produced the lightweight concrete.

The aim of this research is to study the usage of recycled paper as an aggregate replacement in producing a lightweight concrete cube for structure purpose

1.3 RESEARCH OBJECTIVES

These are the objectives of this study:

- i. To determine the compressive strength of papercrete cube with different density of 1.3, 1.4 and 1.5 kg/m³ at 7,14 and 28 days
- ii. To identify the strength of papercrete cube from three different shredded paper size of 2mm x 15mm, 3mm x 25mm and 4mm x 50mm.

1.4 SCOPE OF WORK

The following is the scope of work of this study. In this study, recycled paper was used as an aggregate replacement in producing a lightweight concrete cube.

The recycled paper used is simili paper.

- i. The simili paper is shredded using paper shredder machine with three different sizes of 2x 15mm, 3 x 25mm and 4 x 50mm
- ii. The materials are batch by weight in producing papercrete cube with three different density of 1.3, 1.4 and 1.5 kg/m³
- iii. Preparing the concrete mix with simili paper with a ratio of cement: sand: simili paper with 1:1:1
- iv. The concrete will be cast into the mould with a dimensions of 100x100x100 mm³ by a compression method using Cinva Ram machine
- v. Method of curing that is used during this research is water curing with curing period of 7, 14 and 28 days
- vi. Carry out a concrete test to determine the concrete properties that consists of compressive strength test

1.5 SIGNIFICANCE OF STUDY

At the end of the research, the expected results by using the recycled paper which is simili paper as aggregate replacement in production of lightweight concrete is the compressive strength with different density of 1.3, 1.4 and 1.5 kg/m³.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Papercrete has been used for many decades as a lightweight concrete and it has become an attention in building construction from various countries. It was first introduced by the Romans in the second century where ‘The Pantheon’ has been constructed using pumice, the most common type of aggregate used in that particular year. From there on, the use of lightweight concrete has been widely spread across other countries such as USA, United Kingdom and Sweden. The building is still standing eminently in Rome until now for about 18 centuries (Hjh Kamsiah, Shazli and Norpadzlihatun, 1997). There are quite a number of research studies on it properties in term of compressive strength, flexural strength, water absorption capacity, fire resistance, density and etc. Even though papercrete has become an attention and used for decades but it should not be used for external walls and near-ground walls because of its high water absorption capacity (Isaac I. Akinwumi Ota, 2014). There are many different ratio of recycled paper were used in the previous studies. When the wastepaper increased the water absorption of the concrete mixes also increased (Ritzawaty and Naser, 2013).The component in producing the papercrete are cement, recycled paper, sand and water.

2.2 ORDINARY PORTLAND CEMENT (OPC)

There are many different types of cement in market. Different type of cement has different percentages of its ingredients. Cement is also a stabilizing agent. To achieve the final cast product the cement acting as glue which bonds together the mixture. In this study, Ordinary Portland cement is used (ASTM C150). Portland cement consists of several complex chemical compounds. OPC is a commonly used in the construction industry. The concrete will achieves its strength through a chemical reaction by hydration process.

2.3 RECYCLED PAPER

Recycled paper used in this study is simili paper. The simili paper is shredded using paper shredder machine with three different sizes of 2x 15mm, 3mm x 25mm and 4mm x 50mm. Then the recycled papers were being soaked with desired amount of water for 24 hours.

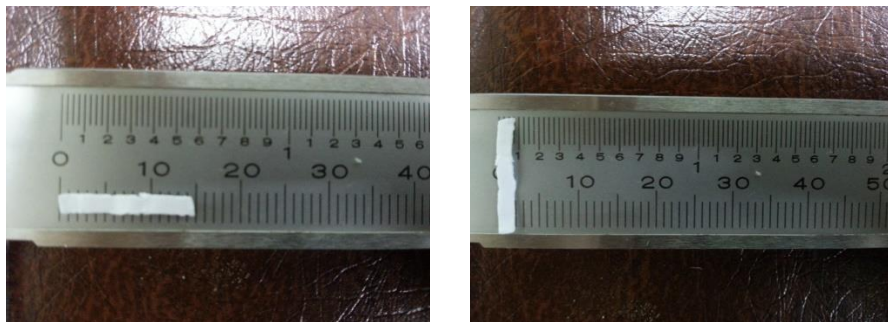


Figure 2.1: Shredded paper size 2x15mm

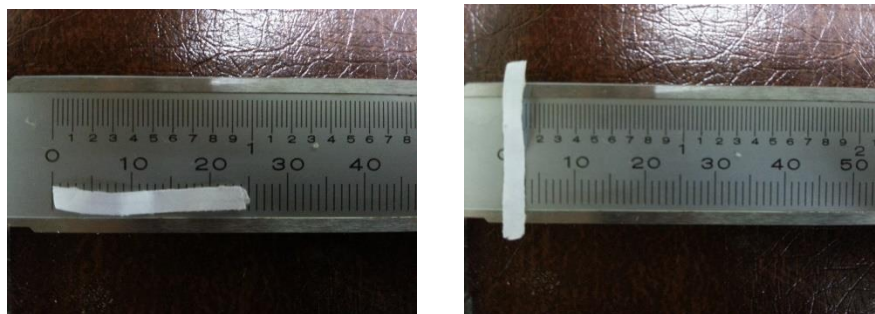


Figure 2.2: Shredded paper size 3x25mm

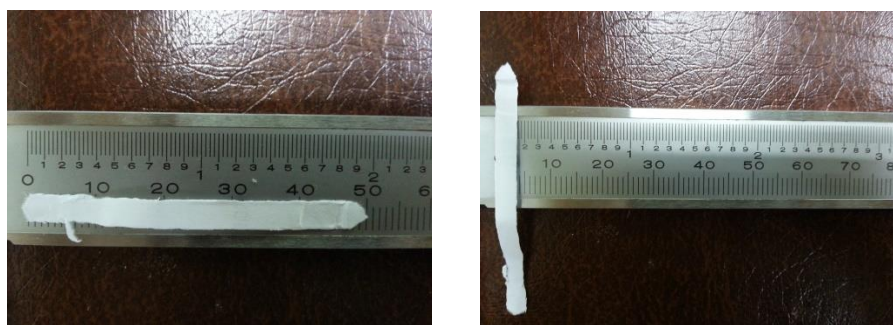


Figure 2.3: Shredded paper size 4x50mm

2.4 WATER

Water is important in producing a cement paste and hydration of Portland cement. The determination amount of water is important because with excessive of water it will cause the concrete with higher slump and cause a free-flowing concrete. The less of amount of water is used, the higher the strength. Any clean water and potable water which is free from harmful material can be used.

2.5 METHOD OF CURING

For freshly cast concrete for a definite period of time immediately following placement curing is the process of maintaining temperature and moisture content. The result of this process is increased strength and decreased permeability. Besides, curing process also helps to prevent and replenishes the loss of moisture from the concrete as well as to maintain a good temperature for hydration to occur in the period of time. In this study, curing period observed is for 7, 14 and 28 days. The samples are being cast by compression method using Cinva Ram machine. Then the samples will undergo air curing process for the period of day 7, 14 and 28 days. Water curing is an effective method as uniform temperature in the concrete can be maintains and also the loss of the moisture from the concrete could be prevents (Nirav, 2013). In this research the papercrete cubes are produced by compression method and the mix used is not the normal wet mix hence water curing is not suitable even though water curing is more

effective compared to air curing. Concrete that is allowed to dry in air will only gain 50% of the strength of the concrete that is continuously moist-cured.

From the previous study, with 1:1:0.8 mix proportion, the compressive strength of wastepaper is 1.5 N/mm^2 while 1:1:0.6 mix proportions after 28 days has a compressive strength greater than 2.5 N/mm^2 . Other than that, the result obtained from (Ritzawaty and Naser, 2013) shows that 7 days compressive strength for various mixes with newspaper which are containing 5%, 10%, 15% has decreased from 16.03 to 11.0 N/mm^2 . For 28 days the compressive strength had increased from 19.0 to 15.67 N/mm^2 . The mixture of 5% and 15% showed higher strength than mixture 10% because of high water to cement ratio of the mix.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology is the systematic, theoretical analysis of the methods applied to a field of study and also the principle associated with knowledge. This is a review of research methodology includes methods used to get the data collection analysis. The methods of analysis consist of several phase which are material collecting, production of papercrete concrete and papercrete laboratory testing.

3.2 PHASE OF ANALYSIS

3.2.1 Material collecting

Material needed for the concrete mixture such as cement, sand, water and recycled paper is collected from various sources. In this study, for the replacement of aggregate which is recycled paper the type of paper used is simili paper. Then, the simili paper was shredded into smaller pieces using paper shredder machine with three different sizes of 2 x 15mm, 3 x 25mm and 4x 50mm. The simili papers then soaked into the desired amount of water for 24 hours before mix.

3.2.2 PRODUCTION OF PAPERCRETE CONCRETE

The papercrete cube was produced using cement, sand, water and recycled paper. The type of recycled paper used in this study is simili paper. The simili paper that has been soaked in the water for 24 hours was mixed together to form a papercrete concrete with the desired amount of cement and sand respectively. The ratio that was carried out in this study is 1:1:1. The total sample of 81 cubes was prepared with nine cubes per density using three different sizes of shredded paper in producing the papercrete cube. The three different densities used in this research are 1.3, 1.4 and 1.5 kg/m³. Apart from that, the sizes of shredded paper used to produce the papercrete cube are 2x 15mm, 3x 25mm and 4x 50mm. The papercrete cube was produced by compression method using Cinva Ram machine. The papercrete cubes were cured for 7, 14 and 28 days. The method of curing used was air curing. In this method, the papercrete cube was left at the open air area at the laboratory to undergo the air curing process for the desired period of days before proceeding with the laboratory testing.

3.2.3 LABORATORY TESTING

This phase is focused on the test that carried out in determining the compressive strength of the lightweight concrete cube with recycled paper as aggregate replacement. Before proceeding with the laboratory testing, the papercrete cube must firstly undergo the air curing process for 7, 14 and 28 days. After completed with the curing process with the respective days, the compressive strength was carried out.

Table 3.1: Mix design for papercrete cube

Density (kg/m ³)	Water (kg)	Cement (kg)	Sand (kg)	Recycled paper (kg)
1.3	2 4.68	1 2.34	1 2.34	1 2.34
1.4	2 5.04	1 2.52	1 2.52	1 2.52
1.5	2 5.40	1 2.70	1 2.70	1 2.70

3.3 SPECIMEN PREPARATION

As explained in the phase one from the phase of analysis, the recycled paper need to be shred into smaller pieces using paper shredder machine with size of 2x 15mm, 3x 25mm and 4x 50mm. In order to make them mushy and pulp the shredded paper was soaking into the water for 24 hours. Therefore, they tend to easily become mushy because of the smaller size compared to regular size of paper. The materials used such as cement, sand and wastepaper were batch by weight.

Firstly, the recycled paper that has been soaked for 24 hours was added into the mixer. The mixer runs for about 2 minutes to avoid them become clotted during the mix. This situation may cause the concrete to fail if there is unevenly mix and if the recycled paper clotted together. Next, sand was added into the mixer and the machine was start again until they evenly mix with the recycled paper. It is important to make sure the paper and the sand is well mix before adding the cement into the mixer to avoid any uneven mix. Finally, cement was added into the mixer and the mixture is mixed thoroughly.

The samples were cast in the mould with size 100 x 100 x100 mm³ using Cinva Ram machine. The concrete was poured into the mould and the cube was produced by compression method. A total of 81 cubes samples were prepared. All the papercrete cubes was marked for easy identification. After the casting process, they were left at the open air area to set and harden by undergo air curing process.

The method of curing used is air curing for period of 7, 21 and 28 days respectively. After curing the samples at each specified period of days, the papercrete then go through laboratory testing. The laboratory testing conducted gave the compressive strength of the papercrete cube.

3.4 LABORATORY TESTING

3.4.1 COMPRESSIVE STRENGTH TEST

The objective of this study is to determine the compressive strength of a lightweight concrete with wastepaper as aggregate replacement. The laboratory testing were conduct on a cube sample that has been undergoes a curing period of 7, 14 and 28 days. This test was conduct based on Reference Standard: BS 1881: part116:1983

- i. The concrete cube is prepared follows the standard.
- ii. The papercrete cube sample will be weighted and dimension of each the specimen will be recorded.
- iii. Place a papercrete cube between the compression plates in the compression strength testing machine.
- iv. Start the machine and slowly apply the load, when the load is begin to decrease remove the sample.
- v. The highest load achieve will be recorded and tabulated.
- vi. The process is repeated for all 81 samples of papercrete cubes.

- vii. The average compressive strength for each density of papercrete cube samples will be calculated.



Figure 3.1: Compressive strength test of papercrete cube



Figure 3.2: Papercrete cube cracks



Figure 3.3: Production of papercrete cube using
Cinva Ram machine