EFFECT OF DIFFERENT SHREDDED SIMILI PAPER SIZE ON COMPRESSIVE STRENGTH OF MORTAR

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Thesis submitted in fulfilment of the requirements for the award of the degree of
B. Eng (Hons.) Civil Engineering

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ABSTRACT

Paper waste is the third largest pollutant consumer as it threatens the environment. In 2010, from 96.5 million tonnes of Europe production generates to 8.9 million tonnes of waste. At the same time, 49 million tonnes production of recycled paper produces 8.2 million tonnes of solid waste. Hence, utilisation of paper waste in mortar material is an approach in preserving the nature. This experimental work is conducted to investigate the compressive strength of mortar containing different shredded paper size as partial replacement for sand (fine aggregates), known as papercrete. Two types of specimens' size, 100x100x100 mm was made using two different shredded paper sizes and control mix. The specimens were subjected to compressive strength and water absorption test. The type of shredded paper use is simili paper with the size of 3x25 mm (Mix 1) and 2x8 mm (Mix 2), collected from the Faculty of Civil Engineering & Earth Resources (FKASA) and Concrete Laboratory in UMP. Then, the specimens were subjected to two types of curing that is air curing and seal curing up to 120 days. The results show that the specimen prepared using smaller size of shredded paper exhibit better performance in terms of compressive strength and water absorption compared to the one produced with larger size of shredded paper.

ABSTRAK

Pencemaran daripada sisa kertas merupakan ancaman ketiga terbesar kepada persekitaran. Pada tahun 2010, jumlah pengeluaran di Eropah adalah 96.5 juta tan yang menjana 8.9 juta tan sisa. Pengeluaran kertas kitar semula dalam tempoh yang sama adalah 49 juta tan menghasilkan 8.2 juta tan sisa pepejal. Bagi memulihara alam sekitar, penggunaan sisa kertas dalam bahan mortar akan membantu untuk mengurangkan pencemaran. Kajian eksperimen yang dijalankan ini adalah untuk menyiasat kekuatan mampatan mortar yang mengandungi kertas yang dicincang berbeza saiz sebagai gantian separa untuk pasir (agregat halus), juga dikenali sebagai *papercrete*. Dua jenis spesimen yang menggunakan dua kertas dicincang berbeza saiz dan campuran kawalan telah disediakan dengan saiz berukuran 100x100x100 mm. Specimen ini akan dikenakan terhadap dua kajian iaitu kekuatan mampatan dan penyerapan air. Jenis penggunaan kertas adalah kertas simili dengan saiz 3x25 mm (Campuran 1) dan 2x8 mm (Caampuran 2), dikumpulkan dari Fakulti Kejuruteraan Awam & Sumber Alam (FKASA) dan Makmal Konkrit di UMP. Dua kaedah pengawetan dijalankan keatas kedua-dua spesimen iaitu, pengawetan udara dan balutan selama sehingga 120 hari. Keputusan ujian ini menunjukkan bahawa specimen yang menggunakan kertas yang dicincang yang lebih besar menghasilkan prestasi yang lebih baik dalam kedua-dua kekuatan mampatan dan penyerapan air berbanding dengan penggunaan kertas yang dicincang yang lebih kecil.

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LIST OF SYMBOLS

%	Percent
µ	Micro
ºC	Celcius
mm	Millimeter
kg	Kilogram
kg/m^3	Kilogram per meter cube
N/s	Newton per second
MPa	Mega pascal

LIST OF ABBREVIATIONS

PM	Particulate Matter
TSP	Total Suspended Particulate
FKASA	Fakulti Kejuruteraan Awam dan Sumber Alam
EPA	Environment Protection Agency
CEPI	Confederation of European Paper Industry
EPD	Environmental Protection Department
IEA	International Energy Agency
PCA	Portland Cement Association
ASTM	American Society for Testing and Materials
PPE	Personal Protective Equipment

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Paper waste is one of the known problems nowadays and has affected our environment fatally. To pursue better environment, recycling of paper waste is a strategy to reduce the effect. It is thought to offer most remarkable greenhouse gas emissions thus save in waste management practices (Friedrich and Trois, 2011). Notably, the pressure and influences of natural sources such as forest can be reduced by recycling. Recycling is an essential strategy to reduce demand for energy and finite resources where alleviated the water pollution, air emissions and the problem of solid waste disposal (Beukering and Duraiappah, 1996).

The following research by using the shredded paper from the paper waste in mortar as a partial replacement for fine aggregates (sand) may help in overcomes the environmental issue. Mortar cement is a composite material which its performance capacity is affected when mix with other elements (shredded paper). The mortar cement that is using paper as it's mixing also known as papercrete. Therefore, the research conducted is to seek the performance capacity on compressive strength of mortar in response to the effect of different shredded paper.

1.2 PROBLEM STATEMENT

Environment disturbance due to the paper waste has become a menace to the surrounding and has been the third largest consumer to the pollutants of air, water and soil (Das et al., 2016). Uses of sand also have created pollution to our environment especially by aggregate and stone mining. Its impact to the environment and health become aggressively day after day parallel to the rising in the construction industry. All particle emitted by a mine measured by Total Suspended Particulates (TSPs), whereas PM-10 particles signify for some of the smallest particles (<10 μ in diameter). It can stay suspended in the air for extended periods of time and pose the greatest respiratory health hazards (Blodgett, 2004). Worry on preserving the nature from being the victim, the use of paper waste in mortar has been studied to reduce the amount of paper waste and sand consume. Even though the use of paper waste on mortar can produce, it is still essential for further research and investigation on this material so that its behaviour and effect can be known.

1.3 OBJECTIVES

This study was conducted to achieve the following objectives:

i) To investigate the effect of different shredded simili paper size on compressive strength of mortar
ii) To investigate the effect of different shredded simili paper size on water absorption of mortar

1.4 SIGNIFICANCE OF RESEARCH

The research is to provide information on the behaviour of mortar for the future purposes when using the different size of shredded simili paper waste as a partial replacement for fine aggregates (sand). Through this research, it is essential to help in overcoming the environmental problems. The uses of paper waste as a partial replacement for sand can reduce the amount of paper waste thus reduce the amount uses of sand which can help to minimise the aggregate and stone mining. The introduction of this new papercrete also can develop into an environmental friendly mortar that may contribute to green technology nowadays. The exploration of the effect of this research towards its performance capacity may contribute to better understanding. The further research can be carried through to develop papercrete that can commit well and efficient in given situation.

1.5 SCOPE OF RESEARCH

This study focus on the mortar performance capacity regards to its compressive strength and water absorption using the different size of shredded simili paper waste as a mixing ingredient. The sources of paper waste collected from the Fakulti Kejuruteraan Awam Dan Sumber Alam (FKASA) and Concrete Laboratory. The sizes of shredded paper used are 3x25 mm and 2x8 mm. Shredded paper of 3x25 mm size is by using the paper shredder machine from the Concrete Laboratory. For the shredded paper of 2x8 mm size is by using the paper shredder machine at the FKASA office.

For the first stage, the specimen is ready by using the five (5) kg mixing ingredient of cement, sand and wet shredded paper with a size of 100 x 100 x 100 mm. There are two types of curing method used throughout this research which is air curing and seal curing. The specimens which subjected to air curing placed inside the laboratory. For seal curing the specimens are sealed first with plastic and then placed on covered racks outside the laboratory. All the specimens subjected to compressive strength and water absorption test with the curing age of 28, 60, 90, and 120 days.

1.6 LAYOUT OF THESIS

Chapter one consist the Introduction and problem statement of the research. The objectives, significance, and scope of the research were also stressed out to define the purpose of this research. Chapter two explains about the type of waste occurred and its distribution to surrounding beside the effects of paper waste on the environment. Furthermore, the properties of paper and cement mortar also been discussed on their characteristics.

Chapter three elaborates about the methodology and experimental workflow. The method starts with the explanation on the materials preparation consists of Portland composite cement, sand, shredded paper, and water. Preparation of specimens for casting process for the testing methods and curing process also discussed in this chapter. The chapter ended with the discussion of testing methods used to investigate the effect of the different shredded simili paper size of mortar on its compressive strength and water absorption.

The results obtained from every testing method were discussed in chapter four of the research from the experiment conducted. The weight of every prepared specimen is recorded to discuss afterwards in the early part of the chapter. The conducted test of the specimen for its compressive strength and water absorption were analysed and the results obtained were presented at the end of the chapter in the form of graphs and tables for its comparison. To conclude, chapter five presents the conclusion and recommendation for the future study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The environmental disturbance caused by the waste materials in this coming day is worsening from day to day. Environment means all physical, chemical, and biological agents together with the social factors capable of having the direct or indirect effect, immediately or in the long run, on living organisms and human activities considered in a given time (Obeadalla and Abdelmagd, 2013). Many acts such as reuse, recycling, and reduction of construction materials have been promoted for years while various methods have been investigated to help. As increasing demands of dumping areas for never-ended waste thrown away, there is a shortage of landfills thus reducing waste generation becomes a pressing issue around the world (Tam, 2010). There are many types of waste material such as paper, plastic, timber, metal, glass, construction debris and so on. This rising problem has lead towards the use of paper waste as a partial replacement in cement mortar.

The application of paper waste in the construction industry is not that surprising nowadays. There is also the study of concrete involving the use of waste paper sludge ash as partial replacement of cement. It is a concern to ensure that construction activities and products are dependable with the enforcement of environmental policies and good environmental practices on waste reduction (Environmental Protection Department, 2005). Despite the fact that the use of paper waste in many construction industries is well known, its effects using on mortar still need to investigate throughout this research so that its properties can be known.

2.2 TYPE OF WASTE

According to Serpell & Alarcon (1998), explains waste as any material by-product of human and industrial activity that has no residual value. An undesirable or unnecessary by-product, emission, residue or remainder of any process or activity, any matter; either in the state of gaseous, liquid or solid or any mixture thereof inventing from any residential, commercial or industrial area. As it discarded, accumulated and deposited by anyone with the determination of eventually abandoning it with or without prior treatment allied with the disposal. Thereof, either kept by any person with the purpose of recycling, reusing or extracting a usable product from such substance (Environment Conservation Act, 1989). These wastes can be created and contributes to a large environmental problem and pollution. Pollution can define as an undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that can dangerously affect health survival or activities of humans or other living organisms (National Academy of Science, 1969). The waste materials may consist of the left over from a manufacturing process (industrial, commercial, or mining) or the community and household activities. Figure 2.1 below shows the three (3) types of waste that is commonly known.

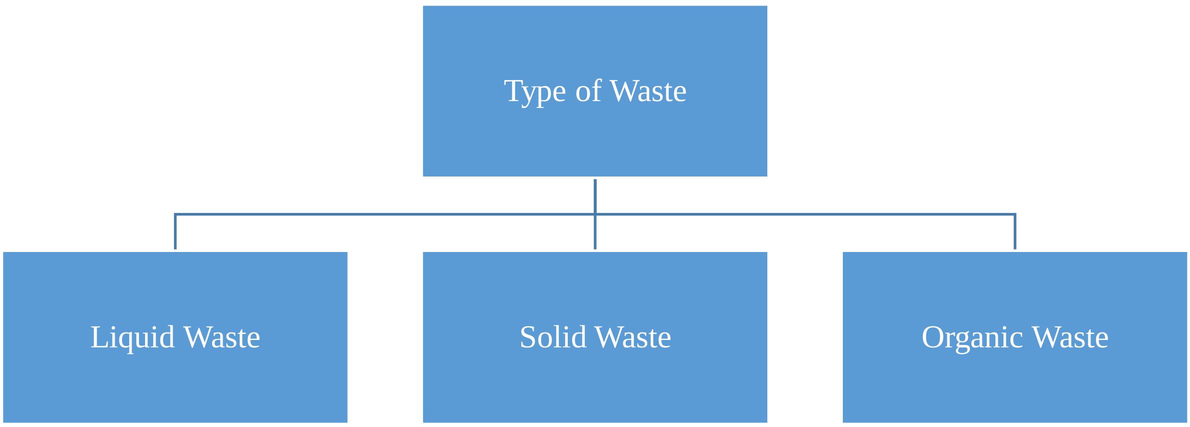

Figure 2.1: Type of waste

2.2.1 Liquid Waste

EPA (2009) explains the liquid waste comprises of any waste that is liquid at 20ºC regardless either it is packaged or contained, and irrespective of either or not the packaging or container is to dispose of together with contains liquid. Waste can come in the non-solid form where some solid wastes can also convert into a liquid waste state for disposal. It consists of point source and non-point source discharges such as stormwater and wastewater. Water pollution occurs when a body of water is adversely affected due to the addition of varietys materials to the water (Obeadalla and Abdelmagd, 2013). An additional source of methane releases into the atmosphere are from wastewater treated in wastewater treatment plants can be an where capture and destruction or utilisation is a distinct possibility for reducing greenhouse gas emission. Otherwise, it may be aerated to avoid anaerobic conditions and the uncontrolled release of methane. Figure 2.1 shows an example of liquid waste that pollutes the environment.

Figure 2.2: Liquid Waste

Source: EPD, 2005

2.2.2 Solid Waste

The term solid waste means that material such as household garbage (includes recycling), food wastes, yard wastes, and demolition or construction debris. Many of environmental problem in the major cities caused by severe construction waste (Chen et al., 2002, Teo and Loosemore, 2001). Massive amounts of infrastructure and building work have built, so numbers of demolished structures are also increasing in construction work (Kawano, 1995). Solid waste also includes discarded items like household appliances, furniture, scrap metal, machinery, car parts and abandoned or junk vehicles. Different types of sources depend on the solid waste produced, for example, municipal waste, hazardous waste, and infectious waste where paper waste is under the category of municipal solid waste (MSW). Table 2.1 shows the waste generation in peninsular Malaysia while in Table 2.2 shows average composition percentage of MSW in Kuala Lumpur, Malaysia.

Table 2.1: Waste generation in peninsular Malaysia

States	Population (2002)	Waste generated (tons/day) (2002)
Johor	2,366,934	2093
Kedah	1,636,095	1447
Kelantan	1,278,368	1131
Melaka	636,007	562
N. Sembilan	935,683	827
Pahang	1,183,004	1046
Perak	1,887,527	1669
Perlis	241,644	214
Penang	1,344,243	1189
Selangor	3,493,602	309
Terengganu	1,091,007	965
Kuala Lumpur	1,470,875	2755

Source: Badgie et al., 2012

Table 2.2: Average composition percentage of MSW (paper) in Kuala Lumpur, Malaysia

Sources	Residential high income (%)	Residential medium income (%)	Residential low income (%)	Commercial (%)	Institutional (%)
Mixed paper	9.75	7.22	6.37	8.92	11.27
Newsprint	6.05	7.76	3.72	7.13	4.31
High-grade paper	0	1.02	0	0.35	0
Corrugated paper	1.37	1.75	1.53	2.19	1.12

Source: Badgie et al., 2012

2.2.3 Organic Waste

Organic waste as shown in Figure 2.3, is a material that is biodegradable and comes from either a plant or animal. It is usually broken down by other organisms over time and may also refer to as wet waste. Most of the time, it is made up of vegetable and fruit debris, paper, bones, and human waste which quickly disintegrate. In a way to keep the environment clean and safe, organic waste is suggested to replace items that can damage the earth which also do not disintegrate. For example, plastic shopping bags and plastic water bottles take a long time to fragment and leave their imprint in their wake.

Figure 2.3: Organic Waste

2.3 PAPER AS WASTE MATERIAL

Nowadays, paper mill industries produce lots of wastes, which removed to landfilling or incinerating. In the year 2003, 187 million tonnes of pulp and 325 millions of paper and board were produced in the world (Peltola, 2004). In 2010, total production in Europe was 96.5 million tonnes which generated 8.9 million tonnes of waste (CEPI, 2010) which decreased compared to 11 million tonnes produced in 2005 (Monte et al., 2009). Besides, the production of recycled paper, during the same period was 49 million tonnes generating 8.2 million tonnes of solid waste (CEPI, 2010). In today's electronic age, people are starting to consider going paperless, but there's still a long way to go before losing on dependence on this product. From newspaper to paper wrappings, paper is still everywhere, and most of them are ending in landfills, creates a staggering amount of paper waste. Paper products are high demand for enabled literacy and cultural development in society. Nevertheless, without altering recent paper production and consumption practices, the growing demand for paper adds pressure on the Earth remaining natural forest and thus endangered wildlife.

Pulp and paper manufactured on all continents where the largest producer countries are US, China, Japan, and Canada, which make up more than half of the world's paper production, 400 million tonnes a year. For example, the Chinese demand for paper products has grown by approximately 1-% per year since 1995 (FAO, 2012), accounting for more than half of the worldwide increase in demand (WRAP, 2007). Conversely, in Europe and North America, the production and consumption of paper products have decreased, while waste paper collected has increased (FAO, 2012).Therefore, China depends heavily on the importation of fibres to produce sufficient pulp for its paper production were in other hands, there has been an excess of supply of waste paper in Europe and North America which has resulted in significant flows to Asia (NEP, 2009).

From the Table 2.3, it shows the total of paper and board production and consumption from the year 2009 to 2010 while Figure 2.4 shows the percentage distribution of paper and board production by various countries in 2010, whereas the most production made from Germany with 23.9%. In Malaysia, Table 2.4 and Figure

2.5 show the solid waste composition and waste generation in the city of Kuala Lumpur in the year 2012.

Table 2.3: Paper & board production and consumption

CEPI Paper & Board Production and Consumption 2009-2010

'000 Tonnes	PRODUCTION 2009	PRODUCTION 2010	% Change 2010/2009	CONSUMPTION 2009	CONSUMPTION 2010	% Change 2010/2009
Newsprint	9 281	9 787	5.5	8 676	8 958	3.3
Uncoated Mechanical	6 323	6 495	2.7	5 341	5 263	-1.5
Coated Mechanical	7 722	8 918	15.5	6 725	7 187	6.9
Uncoated Woodfree	9 348	9 903	5.9	8 542	8 733	2.2
Coated Woodfree	8 085	8 977	11.0	7 291	7 678	5.3
Other Graphic Papers	31 477	34 293	8.9	27 899	28 862	3.5
TOTAL GRAPHIC PAPERS	40 758	44 080	8.2	36 575	37 820	3.4
HOUSEHOLD & SANITARY	6 567	6 724	2.4	7 092	7 176	1.2
Case Materials	22 735	24 926	9.6	21 570	22 864	6.0
Carton Board	7 925	8 499	7.2	6 902	7 703	11.6
Wrappings	3 797	4 139	9.0	3 040	3 336	9.7
Other Paper & Board for Packaging	3 561	3 901	9.5	2 867	3 164	10.4
TOTAL PACKAGING PAPERS	38 018	41 466	9.1	34 379	37 067	7.8
OTHER PAPERS	3 943	4 259	8.0	3 131	3 433	9.7
TOTAL PAPER & BOARD	89 286	96 529	8.1	81 177	85 496	5.3

Source: CEPI (2010)

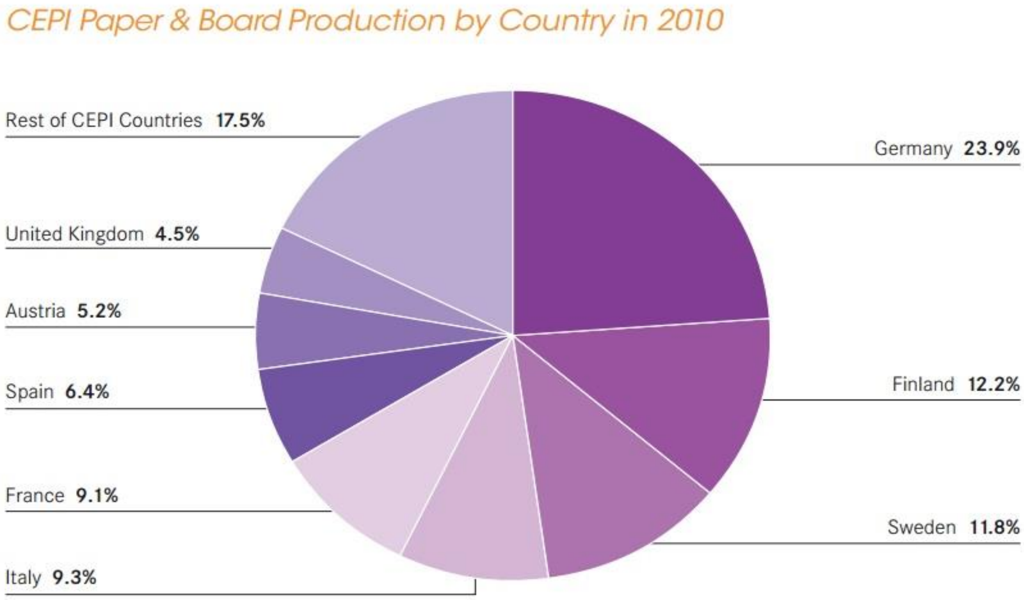

Figure 2.4: Paper and board production by country in 2010

Source: CEPI (2010)

Table 2.4: Solid waste composition and waste generation from Kuala Lumpur City

MUNICIPAL SOLID WASTE COMPOSITION FROM KUALA LUMPUR

Type of Solid Waste	Percentage of Total Solid Waste Sample
Food Waste (and its mixtures)	74 percent
Plastics (and its mixtures)	21 percent
Paper (and its mixtures)	1 percent
Mixed Organic	1 percent
Wood	1 percent
Others	2 percent

WASTE GENERATION RATE FROM KUALA LUMPUR CITY

Type of Solid Waste	Generation Rate/person/day
Food Waste (and its mixtures)	0.6 kg / capita / day
Plastics (and its mixtures)	0.24 kg / capita / day
Paper (and its mixtures)	0.18 kg / capita / day
Others	0.18 kg / capita / day

Source: Budhiarta et al. (2012)

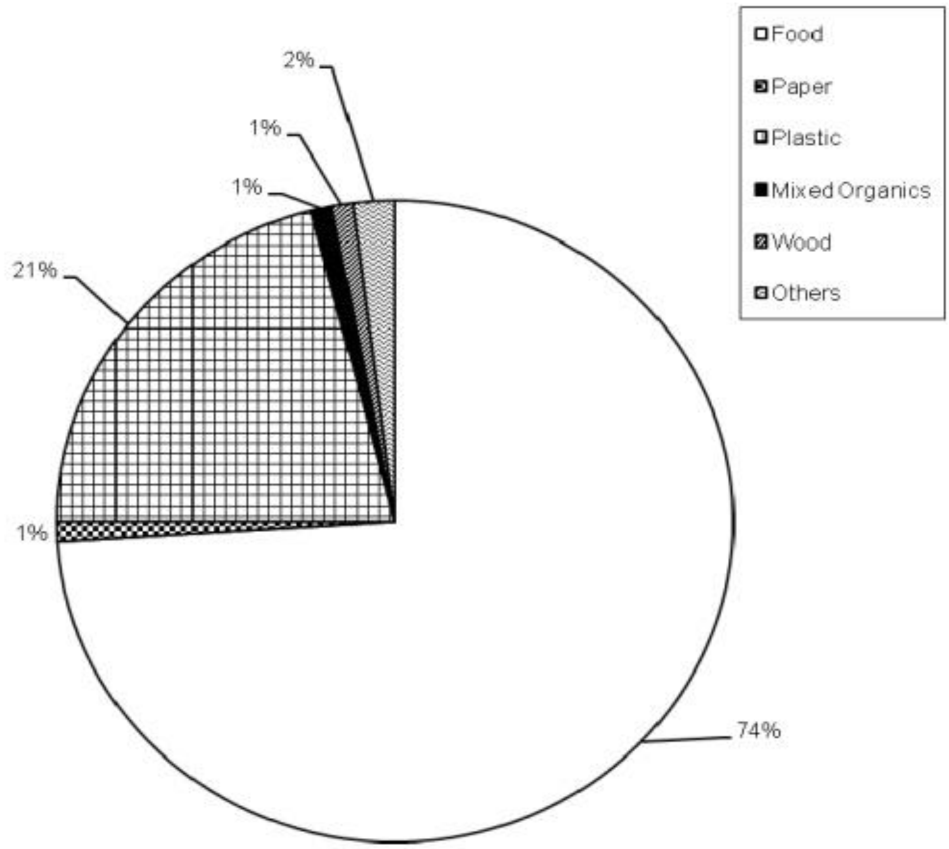

Figure 2.5: Municipal solid waste from Kuala Lumpur
Source: Budhiarta et al. (2012)

2.4 EFFECT OF PAPER WASTE ON ENVIRONMENT

A paper based product typically contains 90-99% cellulose fibres which are the primary structural element and the most important component influencing end user properties. A network of self-bonding cellulose fibres within network structure affects the chemical and physical characteristic of the paper products (Sahin and Arslan, 2007). The properties of the end products depend on properties of fibres and other raw materials. For paper and paperboard, strength, the ability to tolerate applied stressed, is one of the most relevant properties. Single fibre strength is paramount to paper and paperboard strength (Van Den Akker et al., 1958).

The fourth largest industrial user of energy is pulp and paper industry, by consuming 6.4 EJ in 2005, as well significant emitter of greenhouse gas (EIA, 2008). Truthfully, the greatest share of greenhouse gas released in pulp and paper manufacturing comes from the energy production to power the mills. One of the primary sources which are greenhouse gases causes the climate change or global warming. In fact, paper mills may also release many pollutants in surrounding water bodies, triggering damage to aquatic ecosystems and threatening the health of people living near the mill. While new technology has substantially reduced water emissions from many mills, there is significant variation around the world in the use of this technology and major polluting incident occur. Water pollutants are including persistent toxic chlorine compounds like dioxins, organic materials that consume oxygen during decomposition, Sulphur dioxide that contributes to lake acidification, and air-polluting nitrogenous compounds and phosphates that boost algae growth. Figure 2.6 below shows the environmental impacts caused by the pulp and paper industry from year 1990 to 2009.

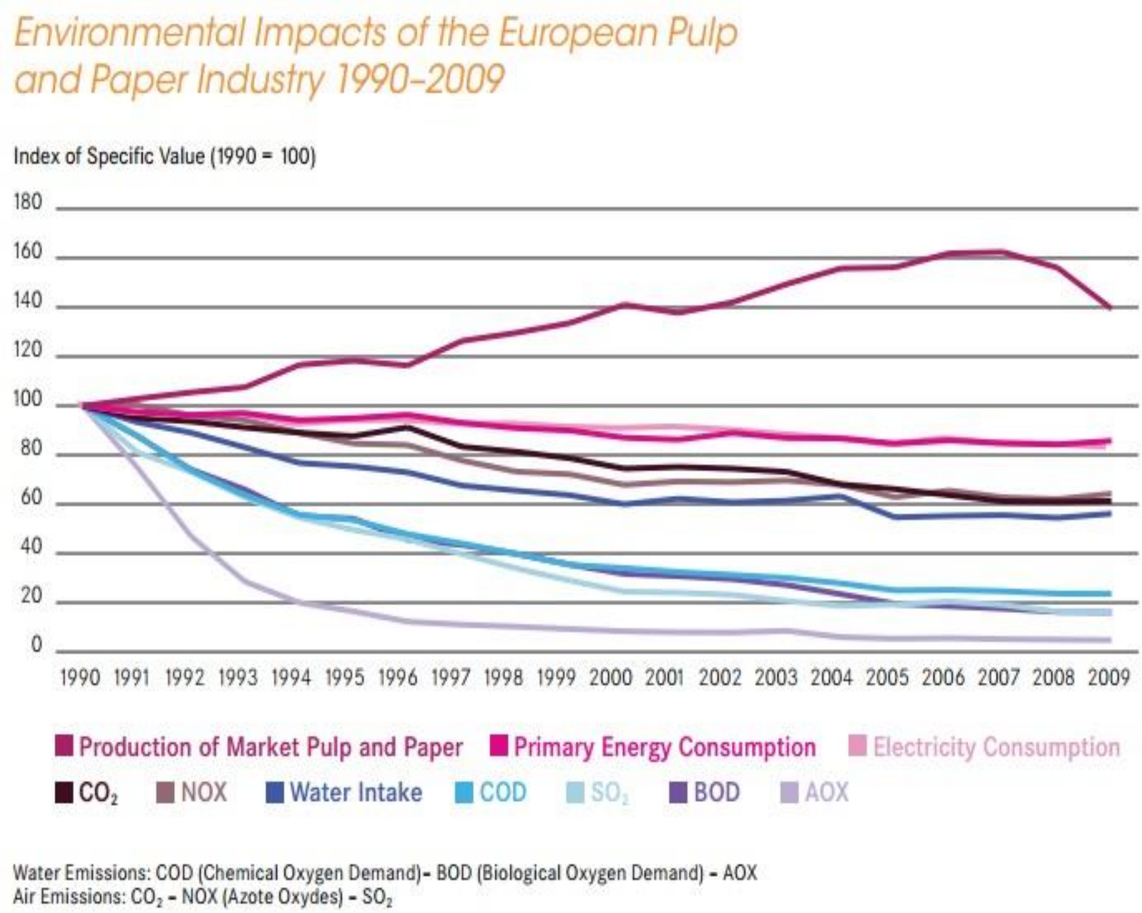

Figure 2.6: Environmental impacts of the pulp and paper industry

Source: CEPI (2010)

2.5 SAND MINING

The soil is a primary source of raw materials such as clay, sand, gravel and minerals. It is a non-renewable natural resource with potentially rapid degradation rates and very slow formation and regeneration processes (Mwangi, 2007). Sand is inexpensive and massive resource consisting of minuscule pieces of rocks and minerals, a result of weathering that forms beaches and deserts. The soil is a valuable source of mineral which protects the environment, buffer to high tidal waves and storms, habitat for crustacean species and marine organisms (Saviour, 2012). The mining of pit sand and gravel can be complete in open areas, beaches, inland dunes, mountainsides while river sand extracted from riverbeds and banks. The practice is becoming an environmental issue as the demand for sand as a valuable mineral resource is increasing in the construction industry.

Soil mining and gravel extraction are an everyday activity in the United States of America. From 1920, many states in the USA relied on mining of gravel and sand for road and cement aggregate and the users had doubled by 2008 to date (Schaetzl, 1990). Draggan (2008) stated sand and gravel quarried more than all other minerals in most States in America. It makes the USA as the largest producer and consumer of sand and gravel in the world as well as the leading exporter of silica sand to every region of the world. The high consumer of minerals because it has extensive high-quality deposits of the resource combined with technology to process it into any product. In fifty states produce construction sand, and gravel with the highest producers are California, Texas, Michigan, Minnesota, Ohio, Arizona, Utah, Colorado, and Washington. They all produce about 52% of total amount of construction sand and gravel. More than a billion tonnes of sand and gravel are produced and used annually. Due to high demand in these States, some sand and gravel are still imported from Canada, Mexico, Bahamas, and Australia (Draggan, 2008).

In California and Michigan, many prime sources of sand and gravel are glacial deposits, eskers, deltaic deposits and old lake beds (Schaetzl, 1990). These states have an abundant of sand and gravel which are well distributed. Many minerals mined, but sand and gravel are the most extracted. River sand, pit sand, and gravel excavated around large expanding urban areas whereas the most urbanised and most primary states have greatest areas of sand and gravel pits. The chart in Figure 2.7 below shows that about 58000 acres of land are used to mine sand and gravel which is more compared to all other minerals mined.

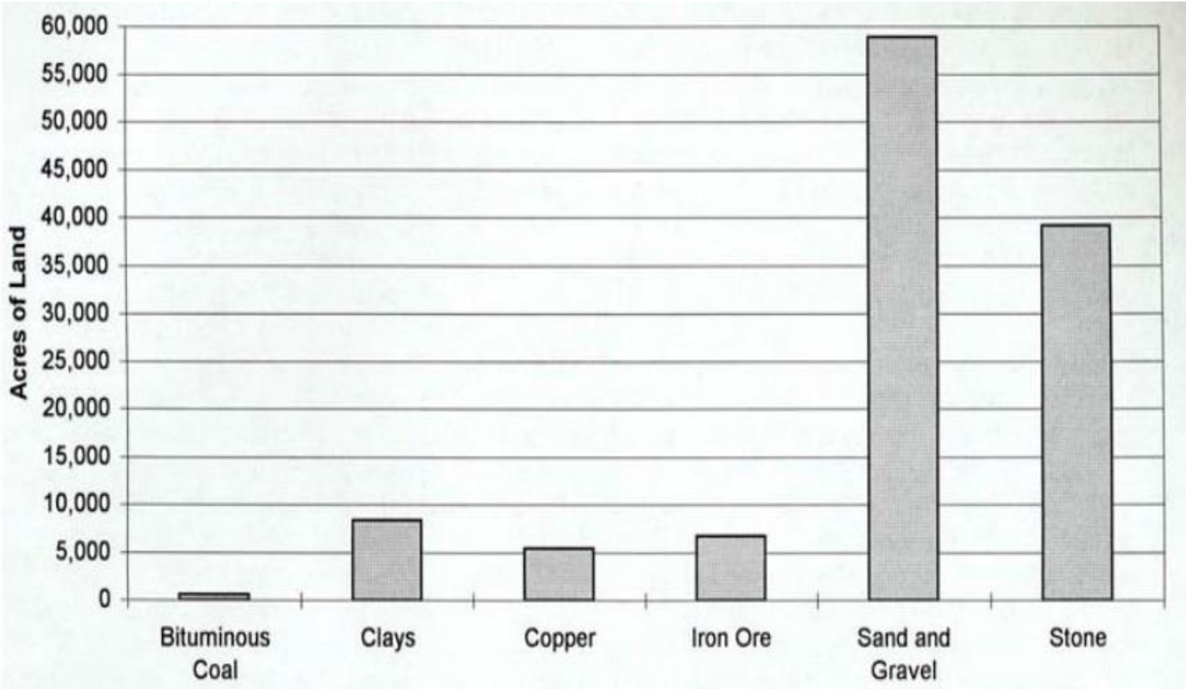

Figure 2.7: Land covered by mining pits in Michigan

Source: Schaetzl (1990)

2.6 IMPACTS OF SAND MINING ON ENVIRONMENT

Sand mining and gravel extraction are the global activity in both developed and developing countries. Industrial sand and gravel are produced, processed and used in construction and industry all over the world. The country of Australia, Austria, Belgium, Brazil, India, Spain, Nigeria, Kenya, South Africa and the United States of America are the leading nations in mining and processing sand and gravel. As a cheap and readily accessible resource, many companies are involved in its mining both legally and illegally without considering the damage they are causing to the environment (Draggan, 2008).

Negative environmental impacts seem to outweigh benefits in mining worldwide. Different adverse effects have been noted in the United States of America due to in-stream mining occurring in rivers and streams. Stream mining is the mechanical removal of gravel and sand directly from an active channel (Kondolf, 2007). Forms of in-stream mining such as pit excavation and bar skimming cause bed degradation of rivers known as channel incision where the process occurs as head cutting or hungry water. When the head cutting extraction is done on the active channel, it lowers stream bed to create a nick point which steepens channel slope and increases flow energy. Figure 2.8 shows the development of Nick point during more pit excavation, which develops positions of bed erosion that gradually moves upstream, thus leads to bank erosion, bed degradation, high water flow, and excavation.

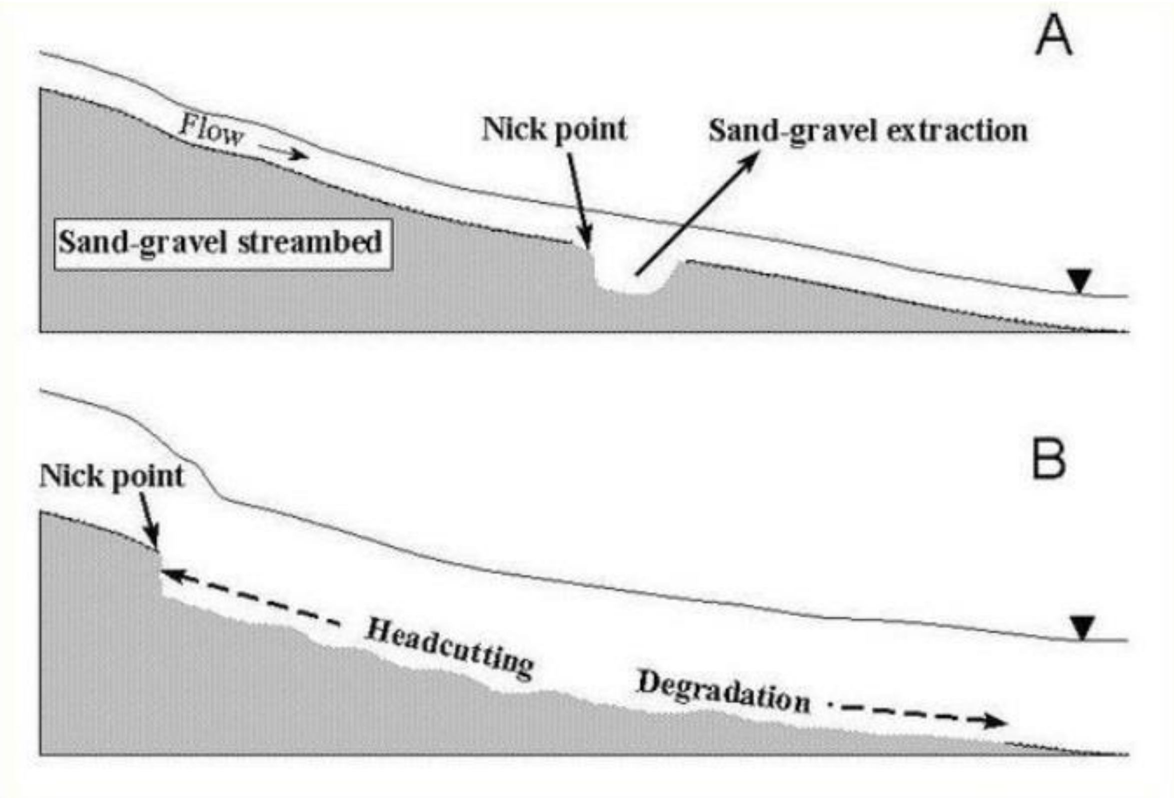

Figure 2.8: Nick point formation

Source: Kondolf (2007)

Environmental land and surface degradation is a severe impact of in-stream mining on Indian rivers (Bagchi, 2010). There is damage to river banks and global ecosystems due to access ramps to riverbed where soil erosion occurs as there is a disturbance of groundwater and changes in river courses. Continuous removal of sand from river bed increases the velocity of flowing water which erodes beds and banks. As the velocity increases, the river bed can propagate both upstream and downstream for many kilometres which then can lower alluvial water tables (Kondolf, 2007). In-stream sand mining causes the destruction of aquatic and riparian habitat through large changes in channel morphology, reduced water table, instability and sedimentation at mining sites due to stockpiling and dumping of excess mining materials (Stebbins, 2006).

Figure 2.9 shows channel cross sections. A is a typical sand and gravel bar about the low-flow of the channel, riparian zone, and water table. B shows the impacts of continuous mining as a wide shallow channel has been formed due to unrestricted mining characterised by bank erosion, braided flow, falling vegetation, sedimentation, lowered the water table and increased water temperature.

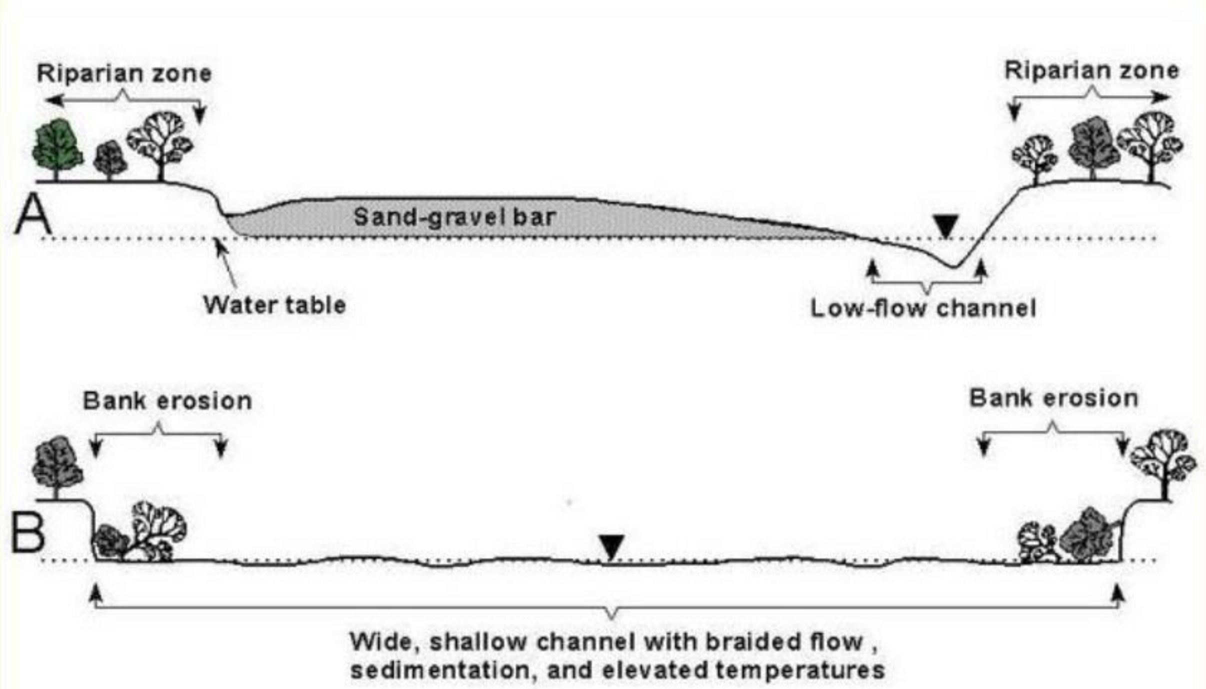

Figure 2.9: Impact of sand mining on active channel

Source: Stebbins (2006)

2.7 PROPERTIES OF CEMENT MORTAR

In more than 80 countries produced cement where its manufacture is very energy intensive and results in significant energy-related and process emission of greenhouse gases, mainly CO_2. Energy costs represent 30-40% of the costs of cement production (Ellis, 2001). Cement is the key component of concrete, used in the construction of building for example. The raw materials needed for cement production such as limestone, chalk, clay, and sand are widely available. Global cement production in 1995 estimated at 1.45 billion tonnes (International Energy Agency, 1999). Mortar cement consist of a mixture of Portland cement or blended hydraulic cement and plasticizing materials such as limestone or hydrated cement lime, together with other materials introduced to enhance one or more properties such workability, water retention and durability. Mortar cement produced in Type N, Type S and Type M classifications in the producer of preparation ASTM Specification C270 Type N, S, or M mortar respectively, without further addition of cement. The recommended guide for the selection of mortar type and physical properties of mortar cement are shown in Table 2.5, Table 2.6 and Table 2.7 respectively.

Table 2.5: Recommended guide for selection of mortar type

Building Segment	Type
Exterior, above grade,	
load-bearing	N or S
non-load bearing	N
parapet wall	N or S
Exterior, at or below	
grade	S or M
Interior	
load-bearing	N or S
non-load bearing	N

Source: PCA (2008)

Table 2.6: Physical properties of mortar cement (ASTM C1329)

Mortar Cement Type	N	S	M
Finess, residue on a 45-µm (No. 325) sieve, maximum %	24	24	24
Autoclave expansion, Maximum, %	1.0	1.0	1.0
Time of Setting Initial Set, minimum hr. Final Set, maximum hr.	2 24	$1\,{}^{1}/_{2}$ 24	$1\,{}^{1}/_{2}$ 24
Compressive strength minimum, MPa (psi) 7 days 28 days	3.4 (500) 6.2 (900)	9.0 (1300) 14.5 (2100)	12.4 (1800) 20.0 (2900)
Bond strength minimum, MPa (psi) 28 days	0.5 (70)	0,7 (100)	0.8 (115)
Air content, % Minimum Maximum	8 17	8 15	8 15
Water retention, flow after suction as % of original flow Minimum	70	70	70

Source: PCA (2008)

Table 2.7: Physical properties of mortar cement (ASTM C270)

Mortar type	Compressive Strength Minimum, MPa (psi)	Water Retention Minimum, %	Air Content Maximum, %
M	17.2 (2500)	75	12
S	12.4 (1800)	75	12
N	5.2 (750)	75	14*
O	2.4 (350)	75	14*

Source: PCA (2008)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter focused on the methodology. The early part of this chapter discussed in a preparation of all materials needed to carry out the experimental work. Later, it is discussed in detail the procedure in the discharge of the experimental work and laboratory test to achieve the object as set in this project.

3.2 EXPERIMENTAL WORKFLOW

The experimental workflow is a process flow of the research carried out from the beginning until the finish. Firstly, it is started with the materials preparation for the specimens used in this experiment. The materials used are Portland composite cement, sand, shredded simili paper and water. Second, preparations of the specimens were carried out where it starts with the process of soaking, mixing, casting and then curing. Lastly, the specimens made were going through for testing. Specimens were subjected to the compressive strength and water absorption test as to achieve the initial objectives of this research. Experimental workflow for this research has simplified in a form of the chart shown in Figure 3.1.

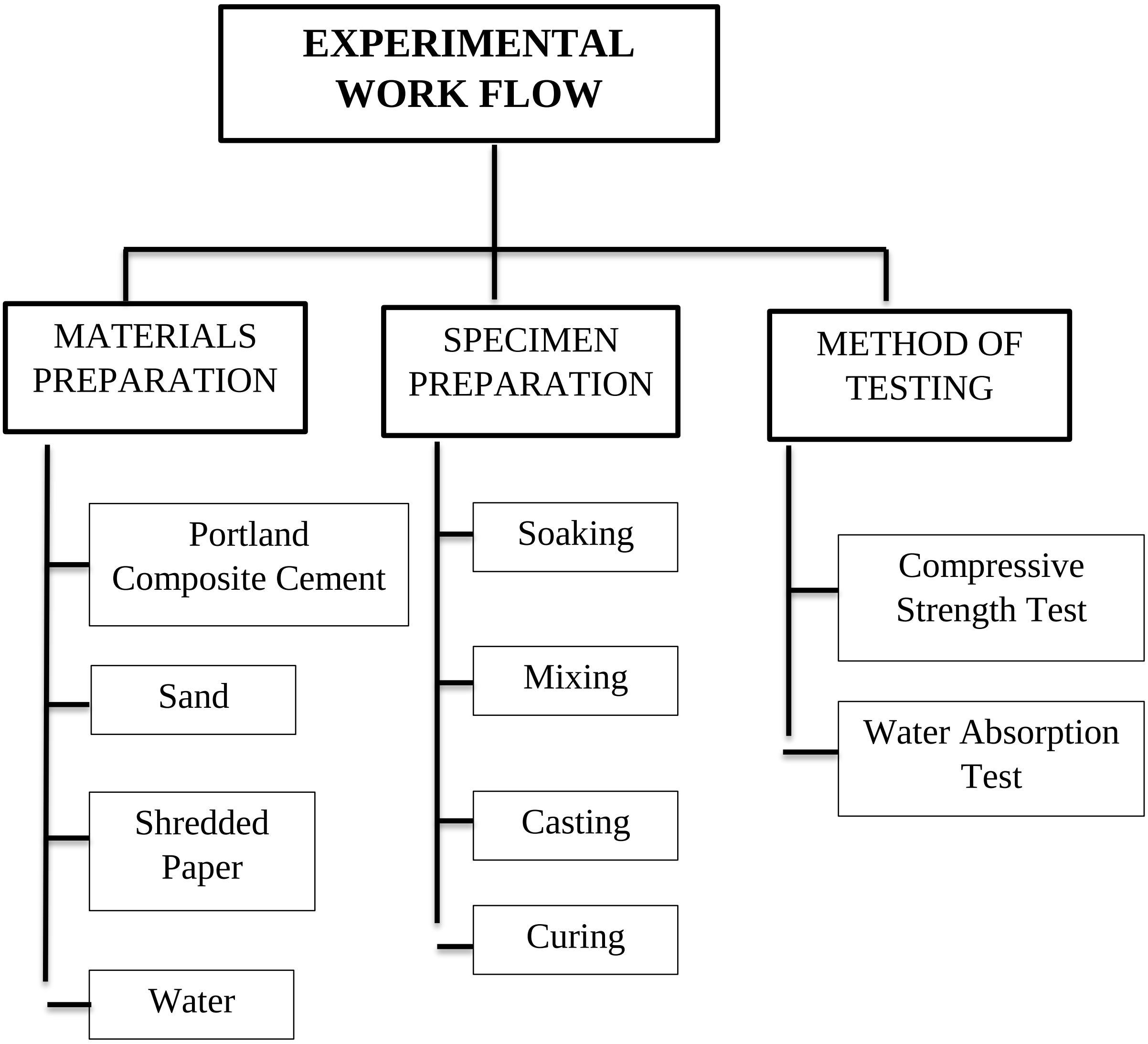

Figure 3.1: Experimental workflow

3.3 MATERIALS PREPARATION

Materials for this experimental works need to be prepared first before progressing to the next step to produce the cube cement mortar. The materials used throughout the entire research are cement, fine aggregates (sand), paper waste and water. The shredded paper acted as the partial replacement for sand in making the cube cement mortar.

3.3.1 Portland Composite Cement

The design of cement is to achieve the required strength with enhanced workability for general purpose mortar and concrete application. Cement used for this research obtained from the Concrete Laboratory, UMP where all the cement here are stored and keep away from the damp floors in a clean and dry place to guarantee its quality always in good condition. Type of the cement used for this research is CASTLE Composites Portland Cement as illustrated in Figure 3.2, produced by YTL Cement Berhad. The specification of the cement certified to MS 522-1: 2007 (EN 197-1: 200), CEM II/B-L 32.5N and approved by SIRIM. Grinding Portland cement clinker and specially selected high-quality limestone used and its properties as described in Figure 3.2 and Table 3.1.

According to the supplier, YTL Cement Marketing Sdn Bhd, CASTLE is suitable for all general purpose application besides its environmental advantage. CASTLE is produced using the most innovative energy efficient cement manufacture process. The use of high-quality limestone to replace a portion of the clinker also served to reduce the carbon footprint of the product. It produced under stringent quality assurance, environmental management, and health & safety system which certified to MS ISO 9001, MS ISO 14001 and OHSAS 18001. However, for health and security precaution, cement is classified as an irritant and should be avoided direct contact with skin. The uses of Personal Protective Equipment (PPE) recommended which include eye, hand, skin protection and dust masks. For any accident occurs, first aid treatment should involve the immediate bathing of the affected area with water.

Figure 3.2: CASTLE Portland composite cement

Table 3.1: Properties of CASTLE Portland composite cement

Tests	Units	Specification MS 522-1 : 2007	Test Results
		Chemical Composition	
Sulfate Content (SO_3)	%	Not more than 3.5	2.8
Chloride (Cl)	%	Not more than 0.10	0.01
		Physical Properties	
Fineness (According to Blaine)	m^2/kg	N/A	440
Setting Time : Initial	mins	Not less than 75	130
Soundness	mm	Not more than 10	0.6
Compressive Strength (Mortar prism) : 2 days : 28 days	 MPa MPa	 N/A $32.5 \leq x \leq 52.5$	 12 36.0

Source: YTL Cement Marketing Sdn Bhd

3.3.2 Fine Aggregate (Sand)

Natural sand results from the deterioration of rock or stone from weathering, erosion, or chemical reactions with air and water. The size of natural sand is larger than clay or silt but smaller than pebbles, usually mined from pits and riverbank or dredged from the bottom of river sand lakes. Sand can affect the compressive strength, bond strength, workability, board life, drying shrinkage, and appearance of mortar. In the mortar, water and cementitious materials form a paste that fills the voids between sand particles. It is includes coating and lubricating the particles to create a workable mix. Sand can reduce shrinkage that occurs in setting and drying thus helps minimise cracks. For the sand material preparation for this research, it is obtained from the Concrete Laboratory, UMP as illustrated in Figure 3.3, where the sand is well-placed under the roofed area to maintain its good condition. The sand obtained is going through for sieving process first as for the control size of sand and only the sand passed through the 1.18mm sieve is used for the entirely experimental works in this research. The standard specification of sand used is accordance to the ASTM Standard C778-13.

Figure 3.3: Fine aggregate (sand)

3.3.3 Shredded Paper

In this research, paper is used as a partial replacement for sand and mixing ingredient in producing the cube cement mortar. This paper waste composed from the various sources, but the only type of paper waste used is simili paper as to serve the control variable for this research. The primary source of paper waste collected from the Fakulti Kejuruteraan Awam & Sumber Alam (FKASA), UMP. Every collected paper waste is checked first to ensure the paper used is of the same type and also not affected from any chemical reagent. The collected paper waste is then shredded using the shredder machine. The paper is shredded into two different sizes using the two different shredder machines. The shredder machines used are from the Concrete Laboratory and FKASA Office, which are shredding the paper into the size of 3x25 mm and 2x4 mm respectively. The shredded paper is then gathered in a container and stored in a clean and dry area of the laboratory to maintain its condition from any damage. Figure 3.4 till Figure 3.7 shows the preparation process from collected of paper waste to shredded paper.

Figure 3.4: Paper waste

Figure 3.5: 3x25 mm Shredder machine

Figure 3.6: 2x8 mm Shredder machine

Figure 3.7: Shredded paper

3.3.4 Water

The water used for this whole research especially during the experimental works obtained from the water tap in the Concrete Laboratory, UMP as shown in Figure 3.8. Water acted as a reagent, which the cement mortar is hardening as the result of the chemical reaction between them. The quality of water plays the significant role in the preparation of concrete. Impurities in water may interfere with the setting of the cement and may adversely affect the strength and durability of the concrete also. The standard specification water used in this research is accordance to the ASTM C1602.

Figure 3.8: Water obtained from concrete laboratory

3.4 MIX PROPORTION

The mixing ingredients in producing the cube cement mortar for the testing in this research are mainly of cement, sand, shredded paper and water. Two mix proportions, Mix 1 and Mix 2, are used for the experimental works not included the control mix. The mix ratio for both Mix 1 and Mix are same where the different is the using of shredded paper size in a mortar. Control mix which is not using any shredded paper is to serve as guideline comparison to the Mix 1 and Mix 2 where its proportion based on the standard ratio in the market. These mixes are to determine which mix proportion serves the best in producing cube cement mortar using the shredded paper waste. The mix proportions of the cube cement mortar tabulated in Table 3.2.

Table 3.2: Mix proportion

Mix	Cement (kg)	Sand (kg)	Shredded Paper (kg)	Water (kg)
Control Mix	1	6	-	0.5
1 (3x25 mm)	1	1	1	2
2 (2x8 mm)	1	1	1	2

3.5 SPECIMEN PREPARATION

The flows preparation of the specimen for the experimental works is essential and necessary to follow as to ensure the specimen is not undergoing and affected from any damage or mishandling during the preparation. The preparation of specimens starts with soaking process till the specimens ready for testing and analysis. The flow preparation of specimen is shown in Figure 3.9.

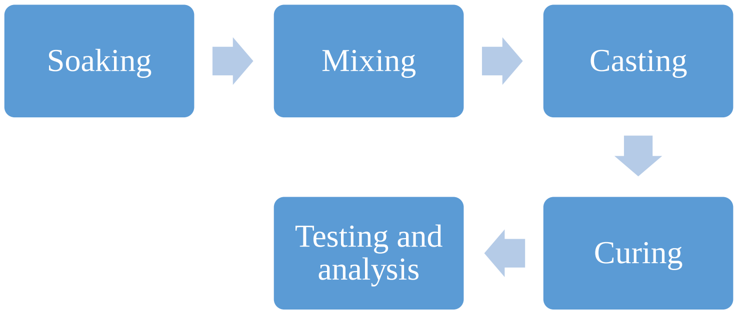

Figure 3.9: Flow of specimen preparation

3.5.1 Soaking

The collective of shredded paper then soaked in the water with the minimum duration of the soaking process is 24 hours. The weight of shredded paper to water ratio for the soaking process is 1:2. A sealed container is essential to use for the soaking process to make sure the wet shredded paper is always in maintain condition and stored in an area at room temperature in the laboratory. The wet shredded paper left for 24 hours soaked in a sealed container. The soaking process illustrated as below in Figure 3.10.

Figure 3.10: Soaking process

3.5.2 Mixing

Before going through to the mixing process on materials, sieving process on the cement and sand is done first as shown in Figure 3.11. Cement and sand are going through to the sieve size of 1.18mm. It is to ensure that the cement and sand used are at controllable variable throughout the entire experimental works in this research to avoid any miscalculated at the end results. Later, the mixing process of the materials preceded with designated mix proportions using the electrically powered mixer as illustrated in Figure 3.12. Cement and sand weight first for one (1) kg then put into the bowl and mix using the electronically powered mixer while the wet shredded paper is weights for three (3) kg then put into the bowl to mix with cement and sand.

Figure 3.11: Sieve machine

Figure 3.12: Mixing process

3.5.3 Casting

After the materials are mixed equally, the specimen is divided into a portion weighed of 1.5 Kg. The mixed material cast using the special compressive machine, Cinva Ram designed by Prof. Datin Dr Nasly Binti Mohamed Ali. The previous mix specimen is then put into the machine and compressed. Each mixed cast material using the machine can produce two specimens of cube cement mortar with size 100x100x100 mm. Below is the process of casting as illustrated in Figure 3.13.

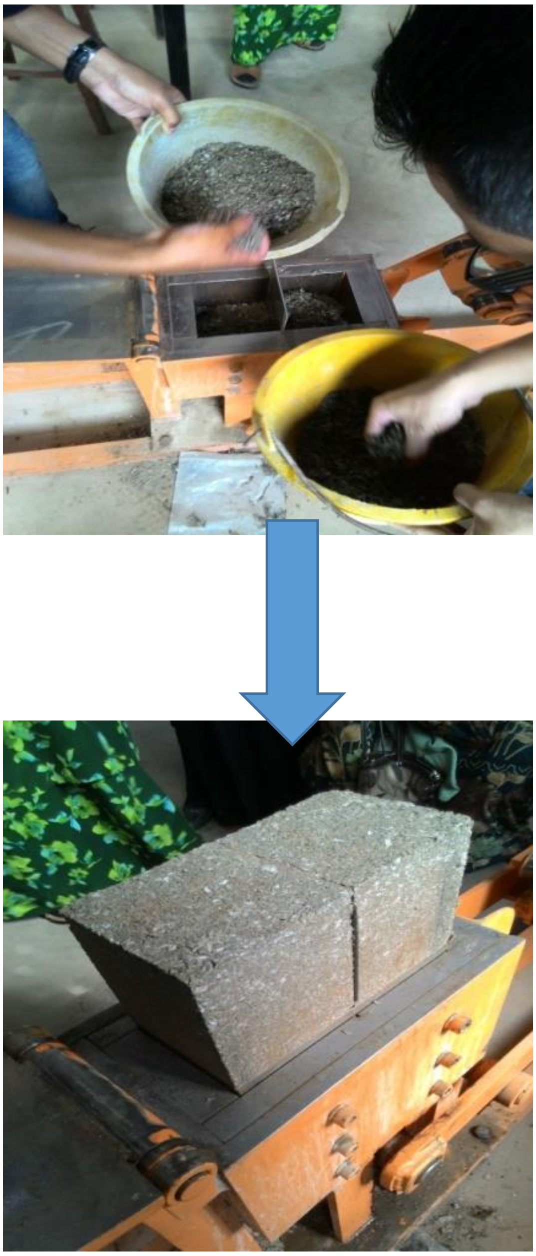

Figure 3.13: Casting process

3.5.4 Curing

The finish cube cement mortar is weighed first after the casting process is done. It is necessary to record every weight of cube as to determine the end results. The cube is then taken for the curing process with the curing age of 28, 60, 90, and 120 days. There are two types of curing method used in this research which is air curing and seal curing as shown in Figure 3.14 and Figure 3.15 respectively. For the air curing, the cube specimen is left inside the laboratory at the room temperature. For the seal curing, the cube specimen is sealed first using the plastic seal and then placed on covered racks outside the laboratory.

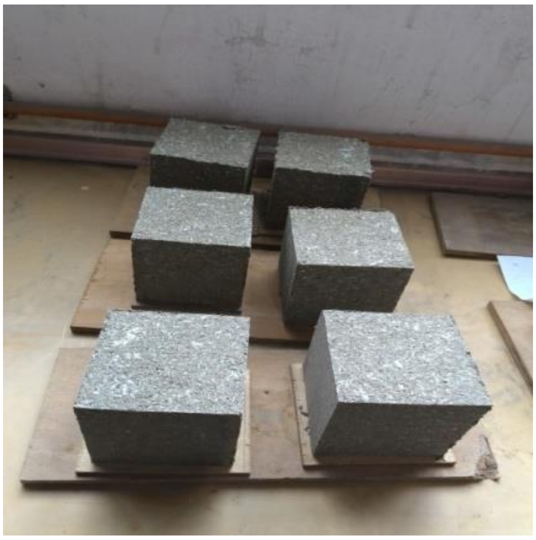

Figure 3.14: Air curing

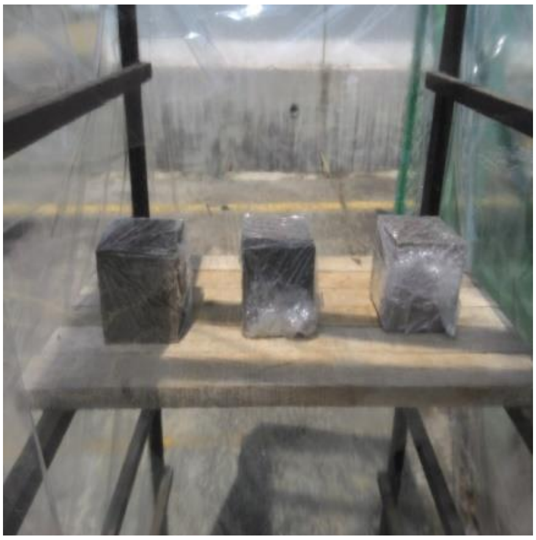

Figure 3.15: Seal Curing

3.6 METHOD OF TESTING

All the specimens made are then subjected to the testing after every curing process of determined curing age is done. The testing is carried out to determine their compressive strength and water absorption as stated earlier on the objectives of this research. Three specimens will use for the test from each mix, curing method, and curing age to ensure the results obtained are only slightly different and to avoid any irrelevant.

3.6.1 Compressive Strength Test

Determination of compressive strength of cube is conducted accordance to the ASTM International Standard C109/C109M-13. The relative rate of movement between the upper and lower platens is applied equivalently to the specimen with the range of 900 to 1800 N/s. The total maximum load indicates by the testing machine is then recorded. The Matest compressive test machine is used to carry out the test as in Figure 3.16 which is available in the Concrete Laboratory. During this test, there were a total numbers of 72 specimens made subjected to air and seal curing with duration up to 120 days.

Calculation on compressive strength:

$$fm = P/A$$

Where,

fm = Compressive strength (MPa)

P = Total maximum load (N)

A = Area of loaded surface (mm^2)

Figure 3.16: Matest Compressive Strength Test Machine

3.6.2 Water Absorption Test

The water absorption test is conducted based on ASTM International standard C1403-05, Standard Test Method for Rate of Water Absorption of Masonry Mortars. As for the procedure, the specimens is dried and cooled to get constant mass before it submerged in a clean water tank for 24 hours. Then, the specimen is removed from the water tank, and the weight is recorded. The excess water must be wiped off completely from the surface of the cube cement mortar to get a better result. For the result, it is taken to the nearest 0.1% of cold-water absorption. During this test also, there were a total numbers of 72 specimens made subjected to air and seal curing with duration up to 120 days The water absorption process is illustrated in Figure 3.17.

Calculation on water absorption:

$$\text{Absorption, \%} = 100\,(W_s - W_d) / W_d$$

Where,

W_d = Dry weight of the specimen

W_s = Specimen saturated weight after submersion in cold water

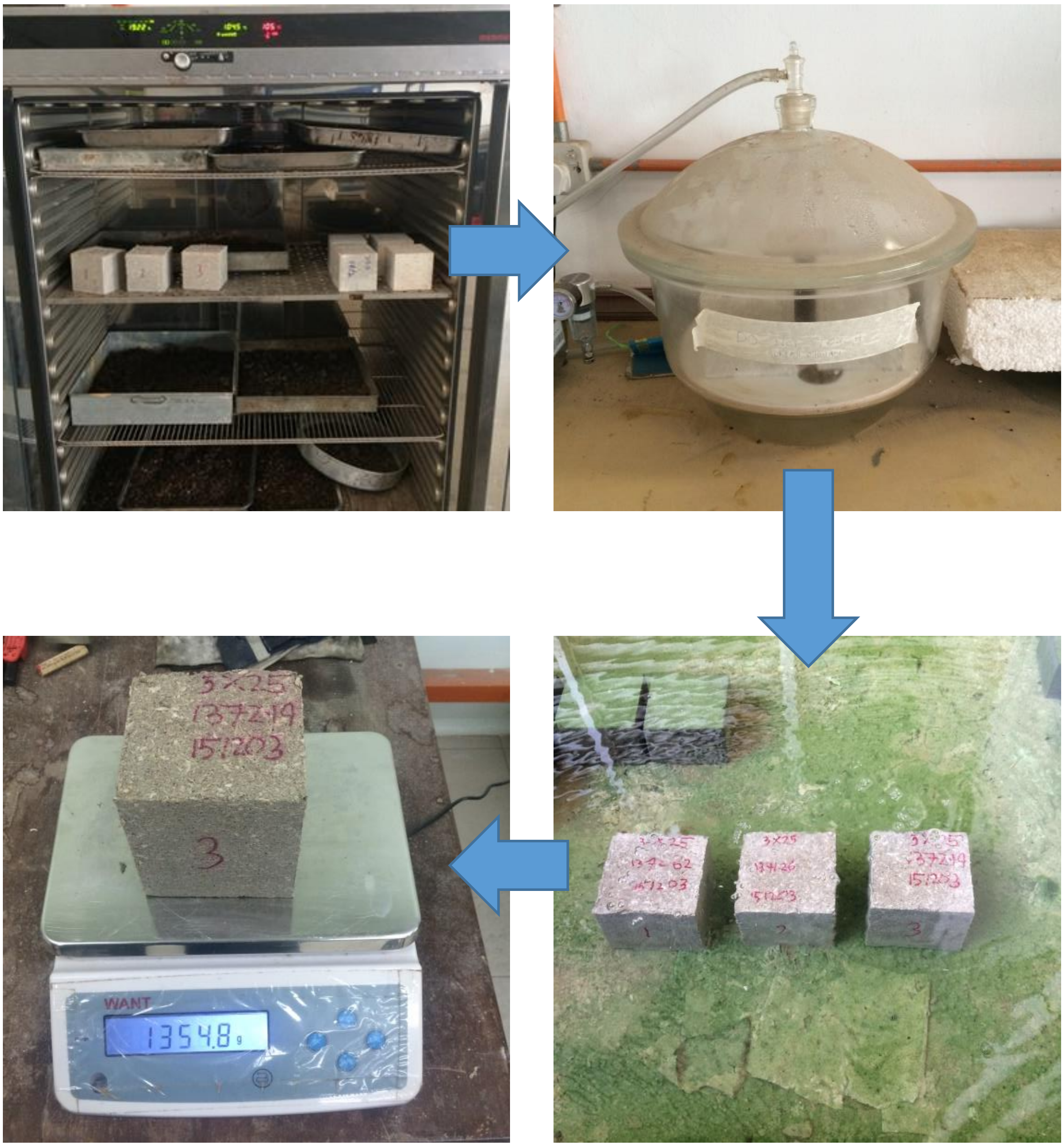

Figure 3.17: Process of water absorption test

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter has represented the data collected from tests during the laboratory testing. The effect of different shredded simili paper size on compressive strength of mortar as a partial sand replacement is observed and summarised into figures. The relationship between the various shredded paper sizes used as the partial sand replacement and the compressive strength is being discussed in this chapter.

4.2 EFFECT OF DIFFERENT SHREDDED SIMILI PAPER SIZE ON COMPRESSIVE STRENGTH OF MORTAR

The compressive strength of cube specimens has been done by measuring its final strength using the Matest Compressive Test machine which available in the laboratory. The performance of specimens contains two different shredded paper sizes of 3x25 mm for Mix 1 and 2x8 mm for Mix 2 were then observed. From the figures showed, specimens from Mix 2 with air curing method exhibited better performance on its compressive strength than Mix 1 for all curing period.

Based on the results shown in Table 4.1 and Figure 4.1 for the compressive strength for air curing method, Mix 2 shows a higher compressive strength compared to Mix 1 at all curing ages. At the 120 days of curing, Mix 2 was significantly higher about 4 MPa than Mix 1. To concluded that Mix 2 has better performance on its compressive strength due to the use of paper with smaller shredded size in the Mix 2. The small size of paper give a better performance on its mixture as it can fill more void in the cement mortar, thus brings better strength than bigger shredded size. However, the use of paper for sand replacement not gives superior strength when compared to the control mix, which is not containing paper. The control mix from the results below shows that bigger difference between them where it gives much more compressive strength. Between the two mixes used of paper, Mix 2 shows a greater strength which means, the smaller shredded paper size gives a better result in its compressive strength.

Table 4.1: Results of compressive strength for air curing (MPa)

Curing Age	Mix 1	Mix 2	Control
28	5.0516	6.1624	35.246
60	6.1875	9.6788	38.872
90	5.2741	9.9825	46.133
120	6.6413	10.7716	48.673

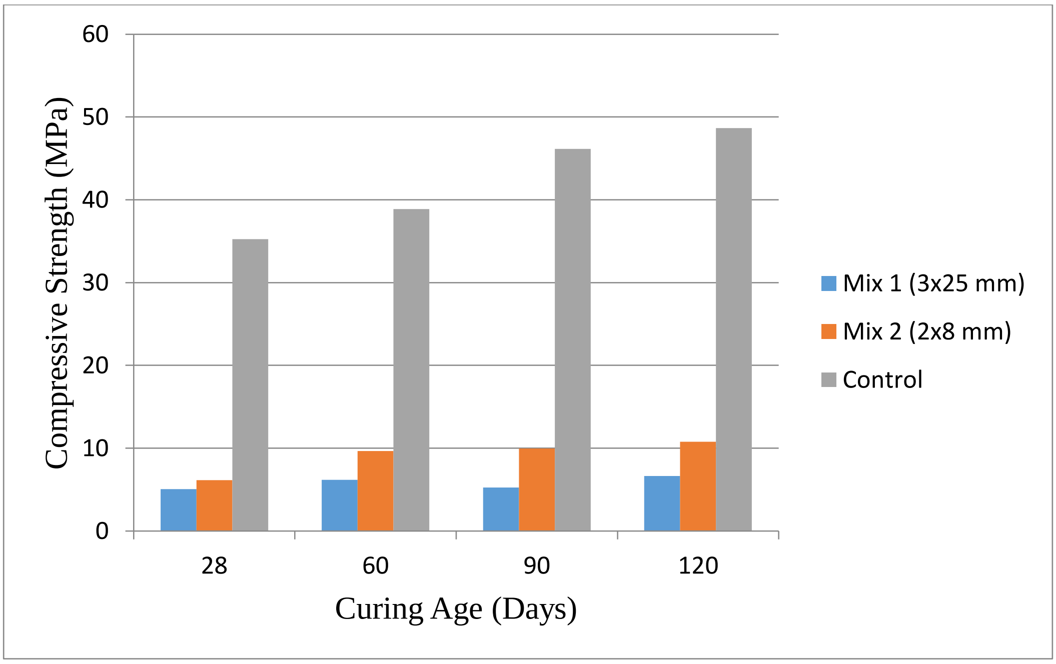

Figure 4.1: Compressive strength result for air curing specimens up to 120 days

From the Table 4.2 and Figure 4.2, the results showed the compressive strength of cement mortar for seal curing. From the comparison between these two mixes, Mix 2 produced greater strength about 1.5 MPa higher compared to the Mix 1 at the 28 days of curing. However, the strength of Mix 2 for the 60 days of curing is increased but slightly 2 MPa less than Mix 1. For the 90 and 120 days of curing, Mix 2 slowly built more strength than Mix 1 and begins to show better performance. From the results obtained, the performance of compressive strength of mortar gets better for every increasing of curing duration.

The variable data from this curing might be because of its method. The seal curing method which is the implementation the use of plastic wrap to seal the specimens can trap the water inside the specimens. The sealed specimens prevented the dehydration of water thus made the specimens cannot dry up. On overall, it can be concluded that the results show Mix 2 exhibited higher compressive strength than Mix 1 for all curing durations. Figure 4.3 and Figure 4.4 show the specimen before and after subjected to the compressive strength test.

Table 4.2: Results of compressive strength for seal curing (MPa)

Curing Age	Mix 1	Mix 2	Control
28	1.3749	1.5011	35.256
60	1.9883	1.7136	38.872
90	1.9747	2.1033	46.133
120	2.2184	2.5276	47.673

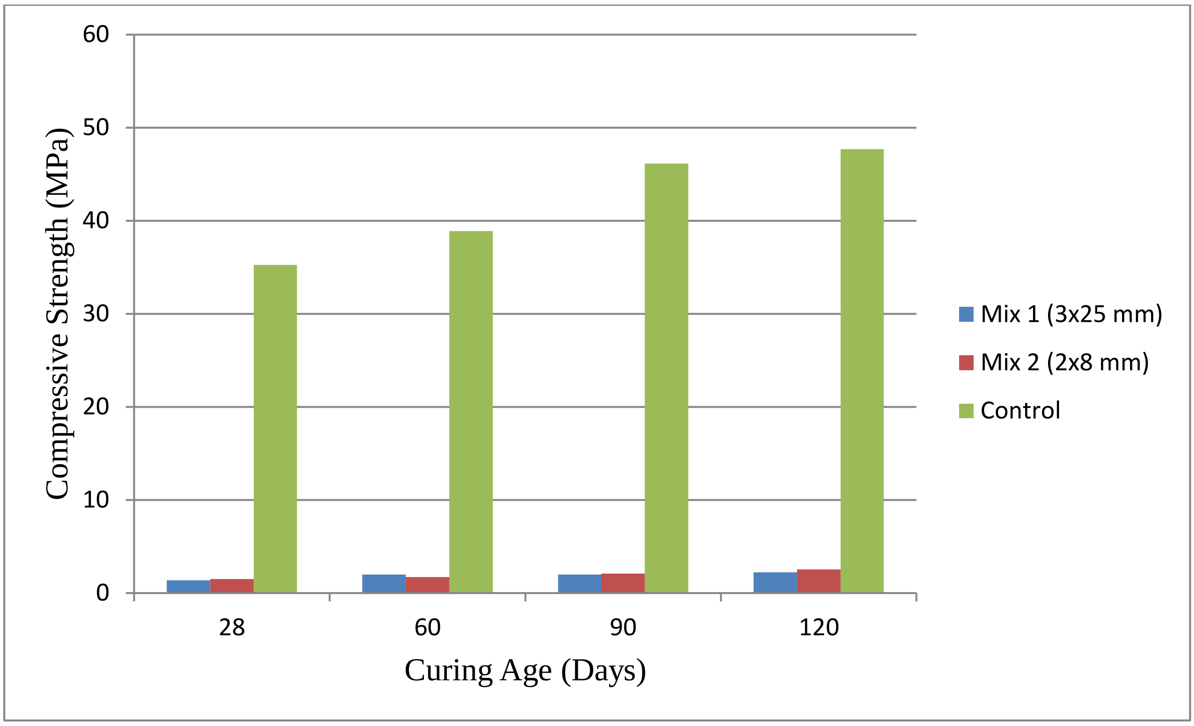

Figure 4.2: Compressive strength result for seal curing specimens up to 120 days

Figure 4.3: Before compression test

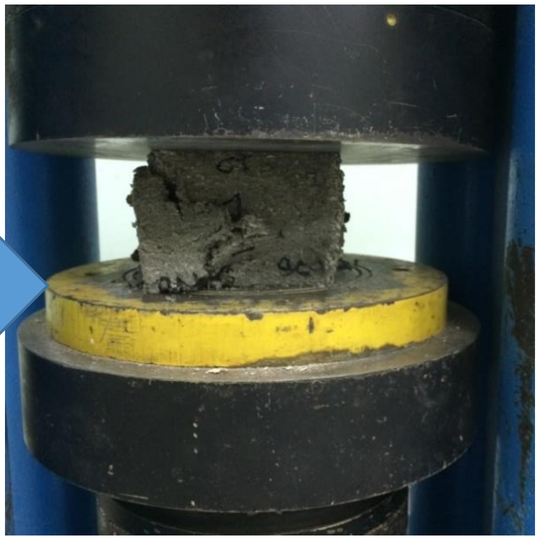

Figure 4.4: After compression test

4.3 EFFECT OF DIFFERENT SHREDDED SIMILI PAPER SIZE ON WATER ABSORPTION OF MORTAR

Water absorption test carried out after every curing process takes place. The specimens were dried first in the oven at 105ºC for 24 hours and then cooled in the desiccator. The weight of specimens was then recorded and submerged into the water tank for the test. From the Table 4.3 and Figure 4.5, the results show the percentage of water absorption for Mix 1, Mix 2 and control mix which subjected to air curing method. The specimens from Mix 2 were proved exhibited a lower percentage of water absorption than Mix 1 for all curing period.

The water absorption for Mix 1 is slightly higher about 3% than the Mix 2 at 28 days of curing but less about 2% than Mix 2 after 60 days curing. However, Mix 1 came back higher at the 90 and 120 days of curing compared to the Mix 2. From this data, it means that the Mix 1 which contains larger shredded size can absorb more water than Mix 2 which used a smaller size. It can summarise that the smaller size used in cement mortar produced a lower percentage of water absorption of the specimens. However, the used of paper in cement mortar is not particularly suitable as the specimens absorb too much water which can create an early failure to the mortar.

Table 4.3: Results of water absorption for air curing (%)

Curing Age	Mix 1	Mix 2	Control
28	56.38	53.91	7.14
60	54.73	56.38	7.53
90	53.46	52.11	7.46
120	54.92	51.64	8.11

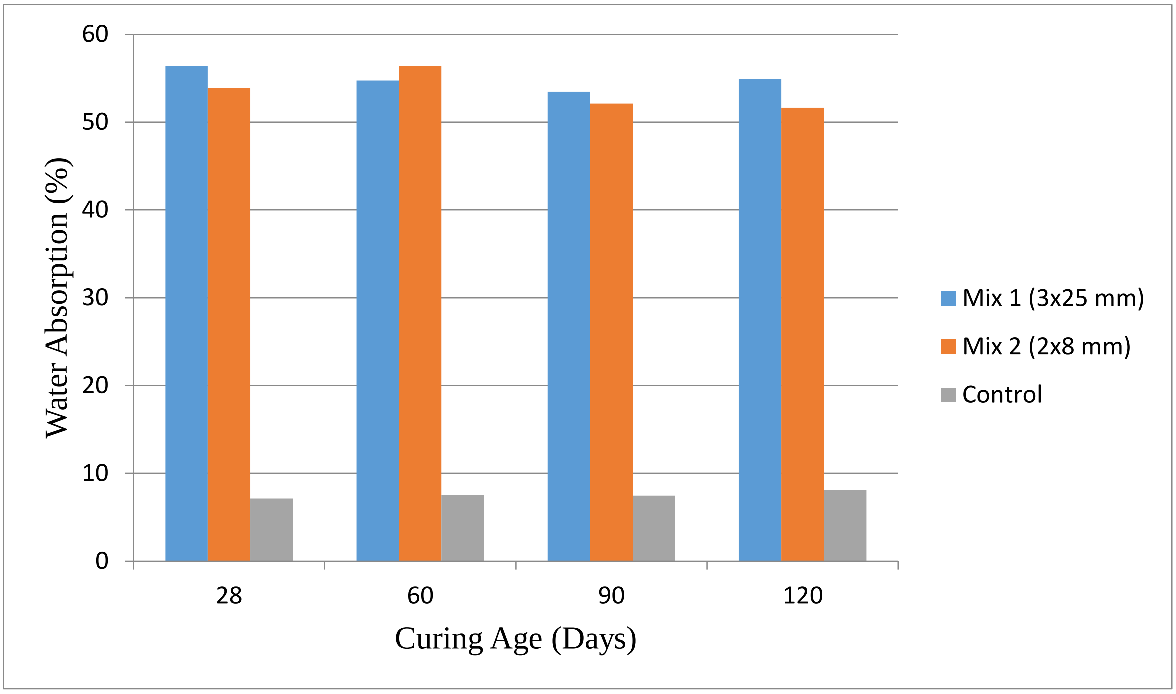

Figure 4.5: Water absorption result for air curing specimens up to 120 days

Table 4.4 and Figure 4.6 below shows the results of water absorption test for Mix 1, Mix 2 and control mix which were subjected to seal curing method. It indicates that the Mix 2 has lower percentage absorption of water compared to the Mix 1 at all curing ages of 28, 60, 90 and 120 days. For the 60 days duration, there is significantly different between these two mixes where Mix 2 absorbs water about 30% less than the Mix 1. The different of result due to the high of the initial relative weight of Mix 2 before dispersed into the water which consequences in lower water absorption as the water already contained in the specimens as the shredded paper used in the specimens is a water-absorbent material. Therefore, it can be best concluded that the Mix 2 can absorb less water as it contains the smaller size of shredded paper. Thus, the high percentage of water absorption of the specimen means that the specimen gives a lower performance which can result in an early failure.

Table 4.4: Resulrs of water absorption for seal curing (%)

Curing Age	Mix 1	Mix 2	Control
28	39.17	39.15	4.48
60	47.83	14.23	5.72
90	40.56	32.18	5.93
120	44.12	35.62	5.25

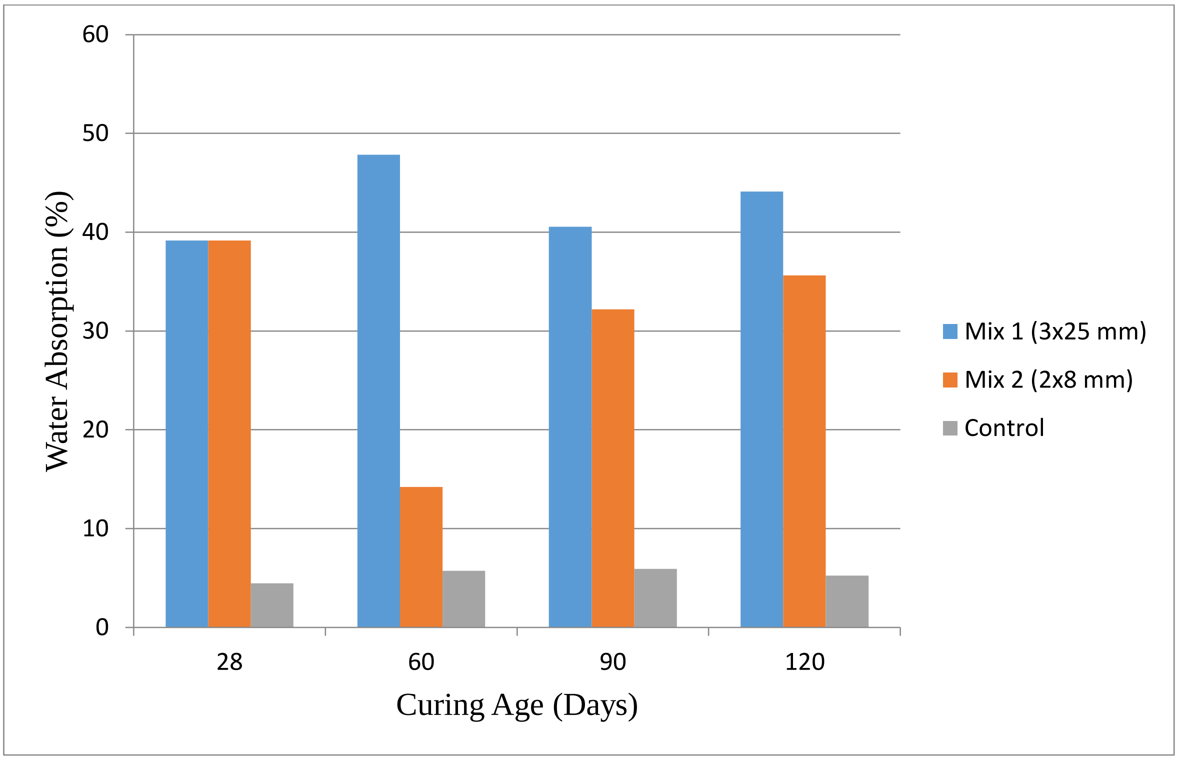

Figure 4.6: Water absorption result for seal curing specimens up to 120 days

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

In this final chapter, the conclusions were drawn to point out the objectives and outcomes of this research. A few recommendations were also added to study the effect of different shredded simili paper size on compressive strength of mortar as partial replacement of sand for the future study.

5.2 BRIEF CONCLUSION

The objectives of the study of the compressive strength and water absorption of mortar containing different shredded simile paper size after each test can be summarised as follows.

5.2.1 Effect of different shredded simili paper size as a partial replacement of sand on compressive strength of mortar

From the research that has been carried out, the smaller size of shredded paper contained in cement mortar gives a higher compressive strength of the specimens. This is because the smaller size of shredded paper can fill in the void in cement mortar which then make the specimen denser particles. Thus, it is able to produce higher compressive strength when subjected to a load on it. The duration of curing also affects the compressive strength. Increase in the length of curing gives more strength to the mortar. Between the two mixes, Mix 2 exhibits a better performance on compressive strength of mortar as it contained a smaller shredded paper size compared to the Mix 1.

5.2.2 Effect of different shredded simili paper size as a partial replacement of sand on water absorption of mortar

The shredded paper used in the cement mortar is a water-absorbent material, which results in a high percentage of water absorption when to undergo the water absorption test. The great excess of water will lead to the reduction of strength and performance of the specimens. During the water absorption test, the specimens have been affected by the organic residue (algae) when been submerged in water. Thus, the test has been carried slightly altered due the existence of this algae. From the results of the research conducted, Mix 2 is better than Mix 1 as it provides a less percentage of water absorption.

5.3 RECOMMENDATION

The following are some recommendations for the future study of this research.

i. The tests conducted in this research are compressive strength and water absorption. Further research by conducting thermal resistance test may also be carried out to check on its heat loss and thermal efficiency.
ii. Throughout this research, the only type of paper used is simili paper. A study and research on using a different kind of paper are essential to finding out what type of paper able to produce papercrete with a better performance.
iii. Use a different form of curing method is also recommended as the practice of seal curing method is practically unsuitable for this research.

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APPENDIX A

DATA OF COMPRESSIVE STRENGTH TEST

Compression Test on 100x100x100mm Cube for 28 Days of Curing.

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1352.4	958.8	3.49	36.98	48.120
	2	1355.0	966.2	4.58	42.77	55.892
	3	1354.8	961.5	3.76	33.14	47.536
Average				**3.94**	**37.63**	**50.516**
Sealed Curing	1	1361.0	1176.9	1.12	3.23	12.446
	2	1366.2	1244.1	1.58	4.41	14.924
	3	1362.9	1216.6	1.24	3.88	13.878
Average				**1.31**	**3.84**	**13.749**

Compression Test on 100x100x100mm Cube for 28 Days of Curing.

Paper Shredded Size**: 2x8 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1344.54	948.92	4.66	33.76	57.229
	2	1355.99	967.74	5.28	51.54	65.462
	3	1344.72	950.22	4.53	40.88	62.180
Average				**4.82**	**42.06**	**61.624**
Sealed Curing	1	1352.0	1161.2	1.48	4.47	14.820
	2	1348.9	1129.8	1.22	3.71	14.167
	3	1353.5	1194.5	1.76	5.14	16.046
Average				**1.49**	**4.44**	**15.011**

Compression Test on 100x100x100mm Cube for 60 Days of Curing.

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1340.7	953.9	6.42	55.78	70.900
	2	1344.3	952.8	5.26	53..36	67.271
	3	1354.5	944.0	4.84	34.74	47.453
Average				**5.51**	**47.96**	**61.875**
Sealed Curing	1	1367.91	1191.8	2.48	8.62	19.963
	2	1365.83	1113.5	1.72	7.40	19.143
	3	1369.07	1209.9	2.04	8.26	20.542
Average				**2.08**	**8.09**	**19.883**

Compression Test on 100x100x100mm Cube for 60 Days of Curing.

Paper Shredded Size: **2x8 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1364.45	970.7	6.22	47.68	88.644
	2	1364.22	971.4	7.04	62.48	102.535
	3	1372.95	973.8	8.68	75.86	99.186
Average				**7.31**	**62.01**	**96.788**
Sealed Curing	1	1354.0	1200.1	1.95	6.54	18.609
	2	1350.9	1233.1	1.77	6.84	18.749
	3	1355.5	1142.3	1.49	6.14	14.050
Average				**1.74**	**6.51**	**17.136**

<u>Compression Test on 100x100x100mm Cube for 90 Days of Curing.</u>

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1375.11	982.0	6.44	55.26	74.762
	2	1338.57	925.0	3.24	26.82	33.915
	3	1361.52	954.7	5.52	37.83	49.546
Average				**5.07**	**39.97**	**52.741**
Sealed Curing	1	1365.36	1154.62	1.884	8.436	19.662
	2	1367.81	1195.33	2.062	8.521	19.532
	3	1368.04	1206.02	2.464	8.683	20.047
Average				**1.905**	**8.547**	**19.747**

<u>Compression Test on 100x100x100mm Cube for 90 Days of Curing.</u>

Paper Shredded Size**: 2x8 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1366.42	972.52	7.36	61.024	98.166
	2	1367.04	972.84	7.88	64.898	99.548
	3	1367.28	973.44	8.62	74.332	101.761
Average				**7.953**	**66.751**	**99.825**
Sealed Curing	1	1352.02	1114.22	2.15	7.66	20.892
	2	1351.63	1114.18	1.97	7.42	20.248
	3	1352.76	1120.31	2.65	7.93	21.959
Average				**2.257**	**7.670**	**21.033**

Compression Test on 100x100x100mm Cube for 120 Days of Curing.

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1355.52	963.35	6.95	38.82	66.128
	2	1357.06	960.28	5.87	37.45	58.272
	3	1356.48	968.42	7.28	44.21	74.839
Average				**6.70**	**40.16**	**66.413**
Sealed Curing	1	1365.04	1244.32	3.86	8.816	22.462
	2	1361.62	1167.29	3.24	7.424	21.764
	3	1362.83	1212.86	3.72	7.962	22.326
Average				**3.607**	**8.067**	**22.184**

Compression Test on 100x100x100mm Cube for 120 Days of Curing.

Paper Shredded Size**: 2x8 mm**

Curing Type	Sample	Initial Weight (g)	Final Weight (g)	Max Load (kN)		
				Deform	First Crack	Final Reading
Air Curing	1	1366.82	971.54	9.26	75.223	109.672
	2	1366.40	971.48	8.76	68.984	108.155
	3	1365.24	971.25	8.63	66.420	105.322
Average				**8.883**	**70.209**	**107.716**
Sealed Curing	1	1362.22	1132.46	3.51	8.26	24.828
	2	1361.85	1134.30	3.97	8.64	28.411
	3	1362.98	1130.53	3.26	7.95	22.589
Average				**3.58**	**8.283**	**25.276**

APPENDIX B

DATA OF WATER ABSORPTION TEST

Water Absorption Test on 100x100x100mm Cube for 28 Days of Curing.

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	1	1362.52	938.14	1466.2	56.29
	2	1361.16	933.45	1460.8	56.49
	3	1362.08	937.21	1465.5	56.37
Average		**1361.92**	**936.27**	**1464.2**	**56.38**
Sealed Curing	1	1369.57	932.9	1321.0	41.60
	2	1356.63	944.2	1288.2	36.43
	3	1359.71	930.5	1297.7	39.48
Average		**1361.97**	**935.87**	**1302.3**	**39.17**

Water Absorption Test on 100x100x100mm Cube for 28 Days of Curing.

Paper Shredded Size: **2x8 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	1	1348.62	923.7	1452.2	57.22
	2	1342.15	926.0	1410.6	52.33
	3	1350.12	935.1	1422.9	52.17
Average		**1346.96**	**928.27**	**1428.6**	**53.91**
Sealed Curing	1	1356.11	918.28	1292.1	40.71
	2	1351.49	913.79	1266.7	38.62
	3	1346.50	914.46	1263.0	38.11
Average		**1351.37**	**915.51**	**1273.9**	**39.15**

<u>Water Absorption Test on 100x100x100mm Cube for 60 Days of Curing.</u>

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	**1**	1351.6	926.02	1431.6	54.60
	2	1365.4	931.39	1440.6	54.67
	3	1364.5	929.43	1440.0	54.93
Average		**1360.5**	**928.95**	**1437.4**	**54.73**
Sealed Curing	**1**	1372.62	921.0	1357.6	47.40
	2	1371.26	918.6	1354.9	47.50
	3	1372.19	911.8	1354.8	48.58
Average		**1372.02**	**917.1**	**1355.8**	**47.83**

<u>Water Absorption Test on 100x100x100mm Cube for 60 Days of Curing.</u>

Paper Shredded Size: **2x8 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	**1**	1366.2	935.9	1469.3	56.99
	2	1361.5	938.2	1463.0	55.94
	3	1356.6	934.0	1459.0	56.21
Average		**1361.4**	**936.0**	**1463.8**	**56.38**
Sealed Curing	**1**	1352.9	1111.5	1277.9	14.97
	2	1347.8	1110.0	1261.1	13.61
	3	1348.1	1108.6	1264.9	14.10
Average		**1349.6**	**1110.0**	**1268.0**	**14.23**

Water Absorption Test on 100x100x100mm Cube for 90 Days of Curing.

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	**1**	1379.67	942.9	1468.9	55.79
	2	1356.73	946.3	1444.1	52.60
	3	1359.61	953.2	1448.7	51.98
Average		**1365.34**	**947.5**	**1454.5**	**53.46**
Sealed Curing	**1**	1364.26	931.2	1305.6	40.21
	2	1365.62	928.8	1301.1	40.08
	3	1364.91	930.4	1315.3	41.39
Average		**1364.93**	**930.1**	**1307.3**	**40.56**

Water Absorption Test on 100x100x100mm Cube for 90 Days of Curing.

Paper Shredded Size: **2x8 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	**1**	1347.8	939.5	1438.2	53.08
	2	1345.9	935.6	1422.6	52.05
	3	1344.2	933.2	1411.0	51.20
Average		**1345.9**	**936.1**	**1423.9**	**52.11**
Sealed Curing	**1**	1365.1	961.3	1276.5	32.79
	2	1360.4	960.8	1264.4	31.99
	3	1358.5	960.6	1265.7	31.76
Average		**1361.3**	**960.9**	**1268.9**	**32.18**

Water Absorption Test on 100x100x100mm Cube for 120 Days of Curing.

Paper Shredded Size: **3x25 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	1	1359.75	945.8	1468.6	55.28
	2	1356.74	941.2	1452.5	54.32
	3	1358.18	942.4	1462.5	55.19
Average		**1358.22**	**943.13**	**1461.2**	**54.92**
Sealed Curing	1	1366.22	930.1	1344.8	44.59
	2	1365.84	929.8	1335.2	43.60
	3	1366.31	930.8	1341.9	44.17
Average		**1366.12**	**930.2**	**1340.6**	**44.12**

Water Absorption Test on 100x100x100mm Cube for 120 Days of Curing.

Paper Shredded Size: **2x8 mm**

Curing Type	Sample	Initial Weight (g)	Weight before dispersed (g)	Final Weight (g)	Absorption %
Air Curing	1	1347.25	927.8	1421.4	53.20
	2	1341.50	922.2	1382.8	49.95
	3	1349.22	930.1	1411.6	51.77
Average		**1345.99**	**926.7**	**1405.3**	**51.64**
Sealed Curing	1	1355.02	930.81	1290.4	38.63
	2	1350.95	928.26	1256.1	35.32
	3	1350.06	928.14	1233.6	32.91
Average		**1352.01**	**929.07**	**1260.0**	**35.62**