EFFECT OF THE ADDITION OF WASTEPAPER TO CONCRETE MIX

by

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Thesis submitted in fulfilment of the requirements for the degree of Master of Science

AUGUST 2009

ACKNOWLEDGMENTS

In the name of Allah, The Most Beneficent and The Most Merciful.

I am greatly indebted to Assoc. Prof. Ir. Dr. Abdul Naser Abdul Ghani, Research Supervisor, for providing invaluable information, guidance as well as advice on this research.

I would like to acknowledge the help of Barry Fuller from *Living in Paper* in giving me some of his papercrete recipes and tips.

My appreciation is also extended to Joyce Plath from www.joyceplath.com for encouraging me to try other methods and recipes in making papercrete when earlier trial mixes did not work out.

I wish to acknowledge the aid, advice, and assistance received from the following individuals; Mr. Khalid, Mr. Idris, and Ms. Diana from the School of Housing, Building, and Planning technicians.

Last, but certainly not least, to my family; *abah*, *mama*, brothers, and sisters for their support, concern, and of course for their love to me, while doing this study.

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KESAN PENAMBAHAN KERTAS TERBUANG DALAM CAMPURAN KONKRIT

ABSTRAK

Penyelidikan ini melaporkan keputusan kajian ke atas penggunaan kertas terbuang sebagai bahan tambah dalam campuran konkrit dan pada masa yang sama ia harus memastikan keputusan yang dihasilkan mempunyai kekuatan mekanikal yang baik. Pada peringkat awal eksperimen, didapati penambahan kertas terbuang telah mengurangkan kekuatan mekanikal konkrit. Keputusan percubaan ini juga menunjukkan peningkatan nisbah air kepada simen setiap kali kertas ditambah. Dengan penambahan sebanyak 25% kertas, kekuatan mekanikal konkrit menurun dengan mendadak. Campuran konkrit yang mengandungi kertas disediakan dan ciri – ciri kekuatan asas seperti kekuatan mampatan, kekuatan tegangan memutus, kekuatan lenturan, halaju denyutan ultrabunyi, pengkarbonan, resapan air, dan berat ditentukan dan dibandingkan dengan campuran kawalan. Empat campuran konkrit yang mengandungi bahan terbuang yang dijadikan sebagai bahan tambah kepada konkrit itu adalah 0%, 5%, 10%, dan 15% telah disediakan dengan nisbah 1:2:3 berdasarkan berat terhadap simen kepada pasir kepada batu. Saiz maksimum batu adalah 20 mm. Kajian mendapati bahawa kandungan kertas terbuang sehingga 5% di dalam campuran konkrit boleh diterima bagi menghasilkan kekuatan konkrit untuk aplikasi struktur. Kajian ini juga mendapati kekuatan tegangan memutus meningkat kepada 3.5% hasil daripada penambahan 5% kertas terbuang.

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ABSTRACT

This research reports on the results of an investigation of utilization of wastepaper as additional materials in concrete mixes, for which it must be assured that the resulting concrete has the proper mechanical strength. In preliminary works on the subject, it was found that the addition of wastepaper reduces the mechanical strength of concrete. The test results also revealed that as the content of the paper increased the water to cement ratio for the mix was also increased. With the addition of 25% wastepaper in proportion to the amount of cement, the mechanical strength decreases significantly. Concrete mixes containing various contents of the paper were prepared and basic strength characteristics such as compressive strength, splitting tensile, flexural, ultrasonic pulse velocity, carbonation, water absorption, and unit weight were determined and compared with the controlled mix. Four concrete mixes containing the wastepaper, which are controlled mix, 5%, 10%, 15% as an additional materials to concrete were prepared with ratios of 1:2:3 by weight of cement, sand, and gravel respectively. It was found that wastepaper content of up to 5% in concrete mix can produce acceptable concrete strength for structural applications. It was also found that concrete tensile strength increased by 3.5% as a result of the 5% wastepaper addition.

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Malaysia is facing a serious challenge in disposing of waste in the many landfills throughout the country that are near or at capacity, which results in high disposal costs and potential environmental problems by the increasing of domestic and industrial waste (Chandravathani, 2006). At the same time, Malaysia is also facing a grave environmental issue where some of landfills have been operated without leachate treatment (BERNAMA, 2006).

Malaysia produces 6.5 millions tonnes of wastes a year and with the increasing rate of 5% per year, the wastes will reach 27,000 tonnes per day by 2014 and this had cost the government RM 400 millions in 2003 for waste management (AWAM, 2008). In 2005, Penang alone generated 84,823 tonnes of wastepaper and cardboard and within that large number, only 5% has gone through recycling process (UNDP, 2008), and land filling is the only disposal method being employed which consumes a relatively large area of land.

Civil engineers have been challenged to convert solid waste to useful building and construction materials. Utilization of waste materials for construction will not only solve waste problems but also provide a new resource for construction purposes. This research describes the potential technologies for the development of building materials utilizing wastepaper.

Wastepaper has been used as building materials for decades, especially in cementitious matrices, and since then a number of researches have been conducted to develop the mechanical properties of the composite such as compressive, tensile, flexural strength. The advantages of using wastepaper in concrete are low cost and low density although it has poor mechanical properties (Soroushian, 1994; Decard et al., 2001). Another interest in the use of wastepaper is for making low cost construction materials for houses and in the last few years have seen thorough effort in the development and usage of wastepaper in cement-based composites (Fördös, 1988; Modry, 2001; Decard et al., 2001). Most of the published works on recycling of papers are on paper mill (Bai et al., 2003; Chin et al., 1998; Chun et al., 2006; Gallardo and Adajar, 2006; Kraus et al., 2003; Naik et al., 2004), or to manufacture board (Fuwape et al., 2007; Okino, 2000; Uraki et al., 2002).

1.2 Research Objectives

The objectives of this research are as follow:

1. To evaluate the effect of the addition of wastepaper to concrete mix.
2. To study the effect of wastepaper on the strength of concrete.
3. To develop mixture proportions for concrete containing wastepaper.

1.3 Scope of Research

Literature review, paper processing, and laboratory tests are the main scopes of this research. Waste material in this research is bound with Ordinary Portland Cement (OPC) and aggregates (fine and coarse). The mentioned waste material is wastepaper (old newspaper and waste office paper). Paper processing involves the process of soaking the wastepaper in water and mechanical pulping where the wastepaper is then blended using the ordinary kitchen blender. Furthermore, laboratory tests include the physical properties of wastepaper (moisture content, specific gravity, and water absorption) and the properties of wastepaper concrete (compressive strength, splitting tensile strength, flexural strength, water absorption, unit weight, direct ultrasonic pulse velocity (UPV) measurement, and carbonation test).

1.4 Significance of Research

The use of wastepaper in concrete could become an economical and profitable substitute to landfills, incinerator or other use options. Its physical and mechanical properties presented in this research shows that it has a potential as a building material which may offer significant savings in the amount of binds and aggregates consumed in the construction. This also could make wastepaper cement composites as an immediate and important area for potential cost savings for housing and means to reduce building costs. Wastepaper concrete is environmental friendly, which means that the energy consumption to produce them is very small, suitable for noise reduction, and much less expensive than other man-made fibres (Fuller et al., 2006).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Fibres are not directly usable in engineering applications because of their small cross-sectional dimensions. Therefore, fibre-reinforced composite materials that consist of fibres are embedded in or bonded to a matrix with different interfaces between them and both fibres and matrix preserve their physical and chemical characteristics but cannot be achieved with either of the constituents acting alone (Johnston, 2001). The purpose of reinforcement in cement-based composites is to improve resistance against crack spread by the control of crack opening and spread (Balaguru and Shah, 1992). Fibres are the principal load-carrying members while the surrounding matrix acts as a load transfer medium between fibres and protect fibres from environmental damages. Fibres occupy small volume fraction in a composite and share the portion of the load acting on a composite.

A product that is derived from renewable resources but would biodegrade is considered a bioproduct. Composites containing biofibres are expected to be biodegradable. However, composites containing biofibres are being used in many engineering applications in structural and non-structural assemblies. One important use of the mechanical properties of natural fibres is tensile reinforcing and volume filler within the matrix of a composite material. In recent years there has been considerable research into developing natural fibre cement and concrete. Natural fibre has the advantage of low density, low cost, and low energy demand during manufacture even though they have poor mechanical properties compared with man-made fibres. Another aspect of interest in the use of natural fibre is for making low cost construction materials for buildings, infrastructure, transportation, industrial, and consumer applications (Evans, 1986).

Cellulose fibres can be obtained from plants such as bamboo but trees are the major source for the fibres evaluated in fibre-reinforced cement and concrete (Coutts, 1994; Mohr et al., 2005). The fibres are obtained from various wood species by mechanical and chemical pulping or the combination of both (Naik et al, 2003; Chun and Naik, 2005; Algin and Turgut, 2008). Another source of cellulose fibre is wastepaper.

This chapter describes the results of previous works on the use of wastepaper for cement-based composites. Wastepaper is available in relatively large quantities around the world. In the United States of America, there are quite a numbers of houses built wholly with wastepaper. Some of the houses have been built for decades and still in good condition up till today without any major problems (Fuller et al. 2006).

2.2 Reported Laboratory Studies on Wastepaper

Thomas et al. (1987) investigated the use of cellulose fibres, reclaimed from wastewater from paper recycling, as reinforcement in cementitious building products. The experimental program is based on the development of a material composed of Portland cement mixed with sludge produced by the treatment of wastewater from a paper recycling plant. During the mixing process, the fibres tend to coalesce and this problem is overcome by introducing the cement into the sludge prior to chemical or mechanical dewatering, followed by vibrating, and pressure dewatering of the cement/sludge slurry. Figure 2.1 shows that the Phase II material has a compressive strength higher than Phase I material.

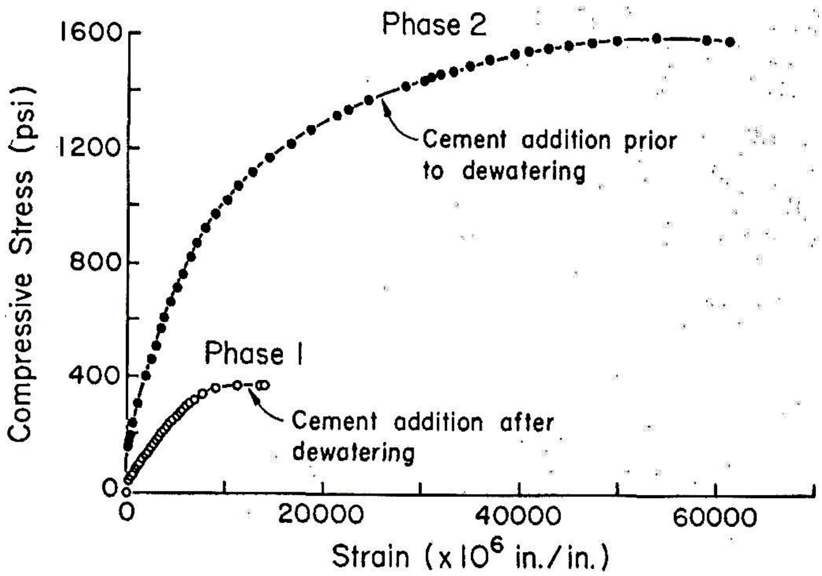


Figure 2.1: Stress-strain behavior of Phase I and Phase II materials in compression (Thomas et al., 1987).

In Coutts (1991), the investigation in on commercial wastepaper which contained recycled magazines, newsprint, and other waste material derived from wood pulp fibres as fibre reinforcement of plaster products. The main constituents were *P. radiata* and mixed eucalypt kraft pulps. The matrix was prepared from commercially available plaster of Paris. The wastepaper fibre-reinforced plaster (WFRP) was prepared using the slurry/vacuum-dewatering technique. The flexural strength, fracture toughness, and density were determined and displayed in Table 2.1.

Table 2.1 Properties of wastepaper reinforced plaster products (Coutts, 1991)

Fibre (wt %)	Flexural strength (MPa)	Fracture toughness (kj m^{-2})	Density (g cm^{-3})
2	12.9 ± 1.9	0.18 ± 0.01	1.66 ± 0.04
4	11.8 ± 0.5	0.31 ± 0.04	1.60 ± 0.02
6	12.2 ± 0.8	0.41 ± 0.02	1.56 ± 0.02
8	15.2 ± 1.0	0.67 ± 0.07	1.50 ± 0.02
10	17.3 ± 0.9	0.92 ± 0.08	1.46 ± 0.02
12	16.7 ± 1.8	1.03 ± 0.11	1.42 ± 0.02
14	18.4 ± 1.8	1.27 ± 0.15	1.37 ± 0.02
16	16.9 ± 1.8	1.24 ± 0.19	1.34 ± 0.02

Soroushian et al. (1994) investigated recycled magazine paper together with virgin cellulose fibre as reinforcement of thin cement. The slurry-dewatering method followed by pressing was used to manufacture the products. Eleven variables were investigated namely recycled magazine fibre source, fibre mass fraction, fibre beating level, substitution level of virgin fibres with recycled ones, sand/binder ratio, maximum particle size of sand, silica/fume binder ratio, flocculating agent/binder ratio, vacuum level, compaction pressure, and curing condition. Figure 2.2 shows the experimental load-deflection curves. Recycled fibres were observed to produce composites with desirable load-deflection characteristics when compared with virgin fibres composite.

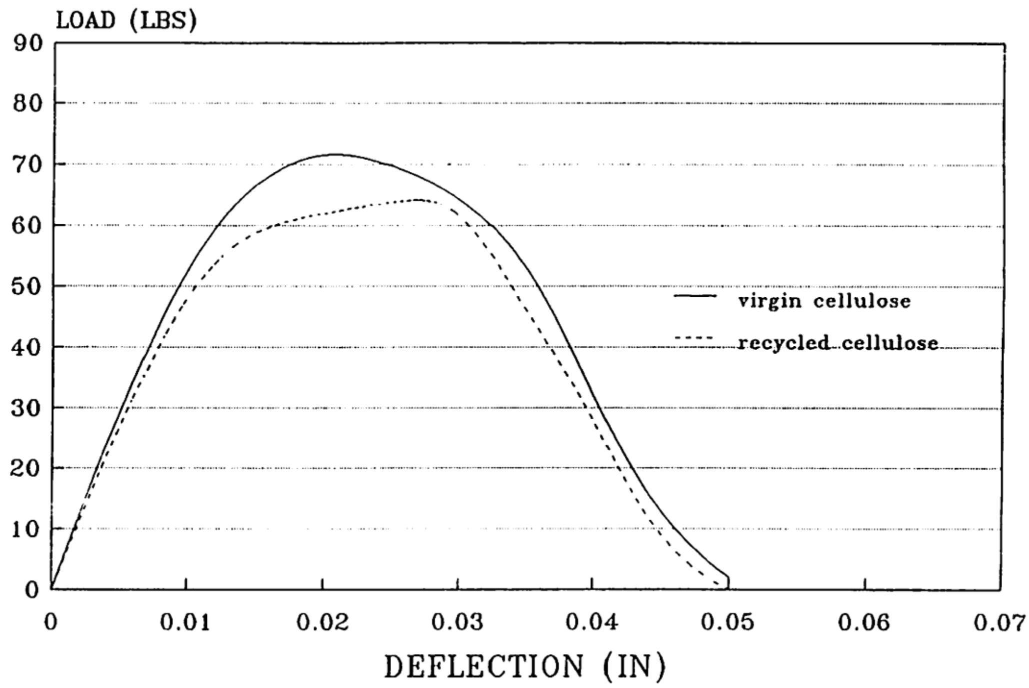


Figure 2.2: Typical load-deflection curves (Soroushian et al., 1994).

Later, Soroushian et al. (1995) investigated two types of recycled fibres which were fibre “a” and “b”; fibre “a” is made of mixed paper with approximately 90% magazine and 10% newsprint, whereas fibre “b” is produced from almost 100% magazine paper. Eleven variables were investigated namely recycled magazine fibre source, fibre mass fraction, fibre beating level, substitution level of virgin fibres with recycled ones, sand/binder ratio, maximum particle size of sand, silica/fume binder ratio, flocculating agent/binder ratio, vacuum level, compaction pressure, and curing condition. Each factor was considered at two levels in a fractional factorial design of experiments (Table 2.2). Table 2.3 shows the optimized composite performance. It was found that optimum composites were obtained using 8% total fiber mass fraction, 50% substitution level of virgin with recycled fibers, and refinement (beating) of fibers of 540.

Table 2.2 Proportioning and processing variables (Soroushian et al., 1995)

Variable	Low level	High level	Notes
Fiber source	"a"	"b"	Dry processed fibers from two source
Fiber mass fraction	5 percent	8 percent	
Fiber beating level	As received	Beaten	CSF after beating 520
Fiber substitution level	50 percent	100 percent	Half or all fibers recycled
Sand binder	0.25	0.75	Binder = cement + silica fume
Sand maximum size	50 μm	600 μm	
Silica fume binder	0	0.1	
Flocculating: Agent/binder	0.002	0.006	Acrylamide acrylate polymer
Vacuum level	127 mm	254 mm	Of mercury
Compaction pressure	0.7 MPa	1.4 MPa	
Curing condition	Moist	Steam	

1 MPa = 144 psi; 1 μm = 4 x 10^{-5} in.; 1 mm = 0.039 in.

Table 2.3 Optimization experimental program (Soroushian et al., 1995)

	Variables			Flexural performance		
Experiment no.	Fiber mass fraction, percent	Fiber substitution level, percent	Fiber refinement level*	Strength, MPa Mean, 95 percent Con. Int.	Toughness, N-mm Mean, 95 percent Con. Int.	Intitial stiffness, N/mm Mean, 95 percent Con. Int.
1	12	75	12.5(500)	13.10 (0.24)	85.985 (±16.5)	286.84 (±31.4)
2	8	50	20(480)	13.99 (0.18)	97.971 (±22.9)	159.57 (±43.0)
3	16	50	20(480)	7.71 (0.30)	31.83 (±3.23)	28.808 (±14.3)
4	8	100	5(490)	7.61 (0.4)	26.119 (±0.66)	243.62 (±34.2)
5	16	100	20(410)	6.00 (0.38)	8.901 (±1.15)	92.172 (±25.4)
6	12	75	12.5(500)	10.24 (0.16)	84.657 (±21.8)	251.71 (±36.0)
7	12	75	12.5(500)	12.17 (0.21)	88.429 (±15.1)	254.04 (±28.9)
8	16	100	5(490)	6.284 (0.17)	15.655 (±0.38)	66.597 (±12.7)
9	12	75	12.5(500)	11.437 (0.16)	101.11 (±15.0)	140.10 (±30.3)
10	8	50	5(570)	13.219 (0.26)	88.984 (±7.42)	159.28 (±36.4)
11	16	50	5(570)	6.738 (±0.17)	88.689 (±4.04)	31.408 (±6.06)
12	8	100	20(410)	10.159 (±0.28)	116.58 (±5.49)	69.741 (±15.7)

* Minutes of beating at 3000 rpm (Canadian Standard Freeness).

Springer et al. (1996) research was about developing a thick moulded pulp block from mixed wastepaper (Table 2.4). The sizes of mould used to produce blocks were 200 x 100 x 50 mm. The blocks were moulded using a heated platen press and an aluminium mould, fitted with porous brass plates on top and bottom for water removal. The demoulded blocks were then coated with Goodyear SBR (Styrene

Butadine Rubber) Latex and were immersed for one min. Table 2.5 shows the results at different applied pressures. Springer et al. (1996) found that modulus elasticity and bending tensile strength were highly dependent on the density and the percent age of old newspaper composition of the block.

Table 2.4 Eco-Block furnish by weight (Springer et al., 1996)

Wastepaper	%
Old newsprint	60
Old corrugated (occ)	15
Magazines	15
Paperboard	10

Table 2.5 Resulting densities, modulus of elasticity, and tensile strength at different applied pressures (Springer et al., 1996)

Measure	Number of samples	Applied pressures (kPa)	Density (g/cm^3)	Modulus of Elasticity (kPa)	Tensile maximum (kPa)
Mean	5	689.5	0.64	1.6×10^5	7.2×10^3
Standard deviation	-	-	0.02	1.6×10^4	7×10^2
Mean	6	413.7	0.52	1.3×10^5	5.4×10^3
Standard deviation	-	-	0.01	9.4×10^3	3.2×10^2
Mean	6	137.9	0.44	6.2×10^4	2.4×10^3
Standard deviation	-	-	0.03	5.9×10^3	2.6×10^2

Soroushian (1996) investigated the effects of weathering on the performance of recycled wastepaper (magazine) fiber-cement composites through accelerated aging tests simulating natural aging conditions. Wood fibers in thin-sheet cement products were manufactured by the slurry-dewatering technique where fibers and other solid ingredients (cement, silica sand, silica fume, and admixtures) were dispersed into slurry with high solid content. The excess water was removed using a vacuum under pressure, and compaction and curing using high-pressure steam curing. It was found that aging leads to a minor increase in flexural strength, a major drop in flexural toughness, and an increase in flexural stiffness (Figure 2.3).

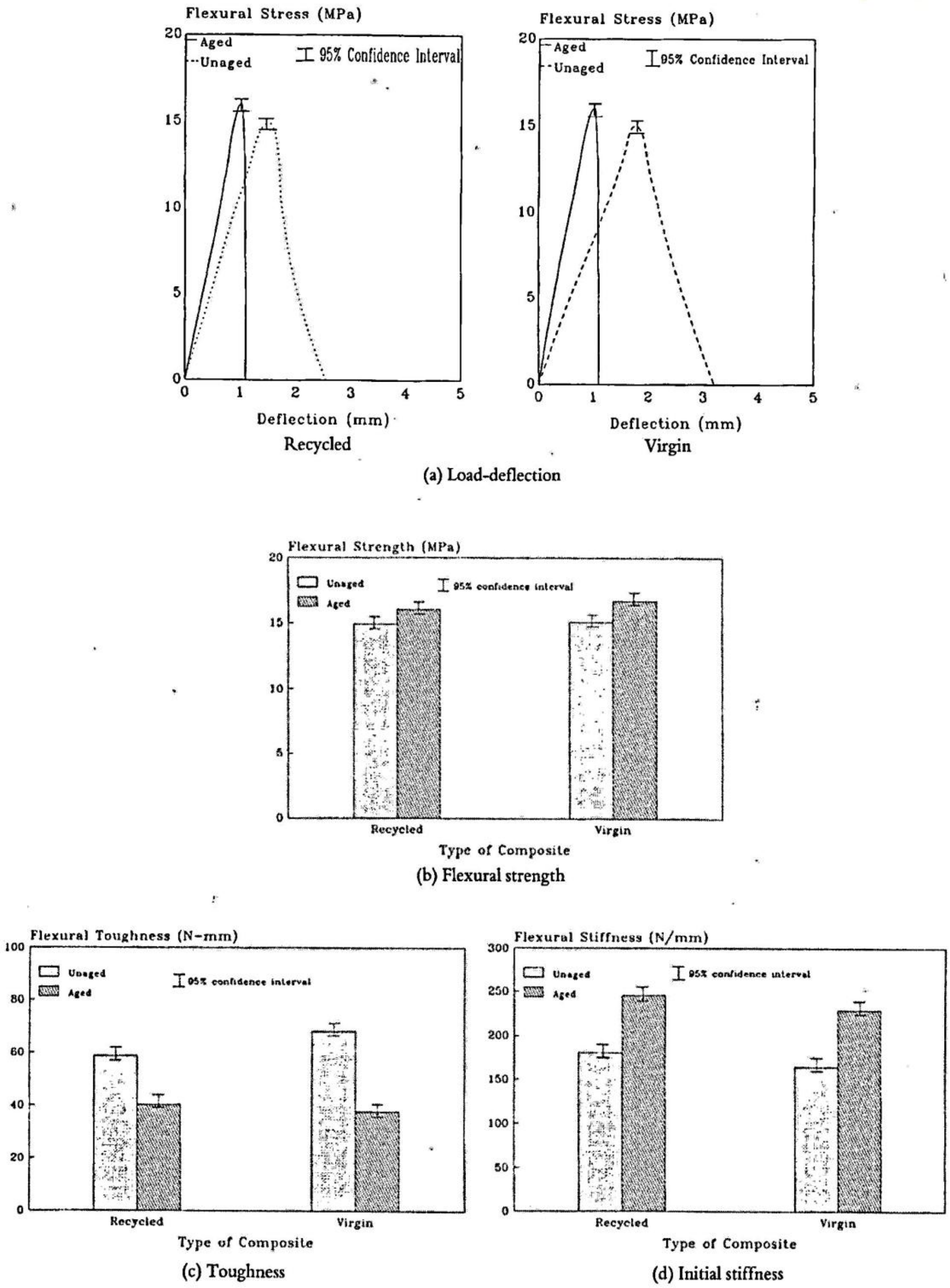


Figure 2.3: Effect of repeated wetting and drying with carbonation on flexural behavior (Soroushian et al, 1996).

Okino et al. (2000) investigated shredded newspaper, mixed magazine, and white office wastepapers which are bonded with urea-formaldehyde (UF) and tannin para-formaldehyde (TP) adhesives both at 8% and 12% of resin solid contents to produce low-density boards. The results of the physical and mechanical properties for each binder are shown in Table 2.6. It was concluded that white office wastepaper and newspaper of UF and TP-bonded boards at 12% resin level demonstrated better mechanical properties than magazine of TP-bonded boards.

Table 2.6 Physical and mechanical properties (Okino et al., 2000)

Treatment				Properties				
Type of paper[a]	Type of resin[b]	Resin level (%)	Density (g/cm^3)	MOE[c] (GPa)	MOR[d] (MPa)	IB[e] (kPa)	Swelling (%)	
							2 h	24 h
N	UF	8	0.57	1.0	4.9	49	35	137
N	UF	12	0.55	1.7	6.6	98	26	130
N	TP	8	0.54	1.2	4.0	29	37	163
N	TP	12	0.55	1.0	5.7	69	29	143
M	UF	8	0.52	1.1	2.7	39	19	123
M	UF	12	0.54	1.5	3.8	71	14	104
M	TP	8	0.50	0.8	2.3	10	26	149
M	TP	12	0.58	1.0	3.5	88	19	111
W	UF	8	0.52	1.4	3.8	108	10	38
W	UF	12	0.55	2.0	5.3	137	9	49
W	TP	8	0.52	1.4	3.9	88	10	37
W	TP	12	0.57	1.7	4.4	117	11	39
LD-1[f]	–	–	–	0.5	3.0	100	–	–
LD-2[g]	–	–	–	1.0	5.0	150	–	–

[a] N = newspaper, M = mixed magazine, and W = office wastepaper.
[b] UF = urea-formaldehyde, and TP = tannin-paraformaldehyde.
[c] MOE = modulus of elasticity in static bending.
[d] MOR = modulus of rupture in static bending.
[e] IB = internal bond.
[f] LD-1 = low-density grade-1. Requirements for grades of particleboard according to ANSI A208 (1993).
[g] LD-2 = low-density grade-2. Requirements for grades of particleboard according to ANSI A208 (1993).

Modry (2001) investigated the use of paper labels from beer bottles and beer mats as a constituent of concrete. In the concrete mix, Portland cement CEM II/A and quartz sand were used with 40% by volume of the mix being repulped paper. From the concrete mix, hollow concrete blocks of size 450 x 250 x 110 mm were manufactured. This type of samples was used in the application of concrete non-load bearing partition walls. The engineering properties of blocks were compressive strength (1.84 MPa), water absorption (25.65% by weight), water absorption due to capillary action (4.48), water vapour permeability (2.6 x 10^{-6} kg/m/h/Pa), and thermal conductivity (0.35 W/m/K). From the assessment of the properties of the hollow blocks with waste paper, Modry (2001) concluded that such products can be used as blocks in non-load bearing partition walls.

In Soroushian et al. (2003), an investigation on mixed plastic and paper waste products was conducted. Concrete mixes containing various contents of waste were prepared with basic strength characteristics such as 1 to 2 in. (25 to 50 mm) slump (after fiber addition), 3 to 8% air content, and 4000 psi (27.8 MPa) minimum compressive strength. The control mix consisted of Type I Portland cement, crushed limestone of 1 in. (25.4 mm) maximum size as coarse aggregate, and natural sand as fine aggregate. Additionally, air-entraining and water reducing admixtures were also used. The mixture comprised of water, cement, coarse aggregate, and fine aggregate at the weight ratio of 0.45:1.00:3.16:2.74. The amount of various virgin and recycled discrete reinforcement systems considered in this investigation are presented in Table 2.7. The work indicated that discrete reinforcement systems derived from waste can give positive reinforcing effects in concrete (Figure 2.4).

Table 2.7 Properties of virgin and recycled discrete reinforcement system (Soroushian et al. 2003)

Discrete reinforcement	Aspect ratio	Bulk specific gravity	Dosage in concrete		Volume %	Mixture identification
			lb/yd^3	kg/m^3		
Virgin cellulose	200	1.5	1.5	0.9	0.06	cell 1.5
			2.5	1.5	0.1	cell 2.5
Recycled paper	200	1.5	1.5	0.9	0.06	paper 1.5
			2.5	1.5	0.1	paper 2.5
Virgin polypropylene	150	1.2	1.5	0.9	0.075	poly 1.5
			3.0	1.8	0.15	poly 3.0
Recycled plastic (melt-processed)	11.1	0.8	1.4	0.9	0.1	plmp 1.5
			2.5	1.5	0.19	plmp 2.5
Recycled plastic (automotive shredded residue)	1.65	1.0	34	20.0	2	plasr 34
Recycled (shredded)	3.70	1.0	17	10.0	1	plsh 17
			34	20.0	2	plsh 34

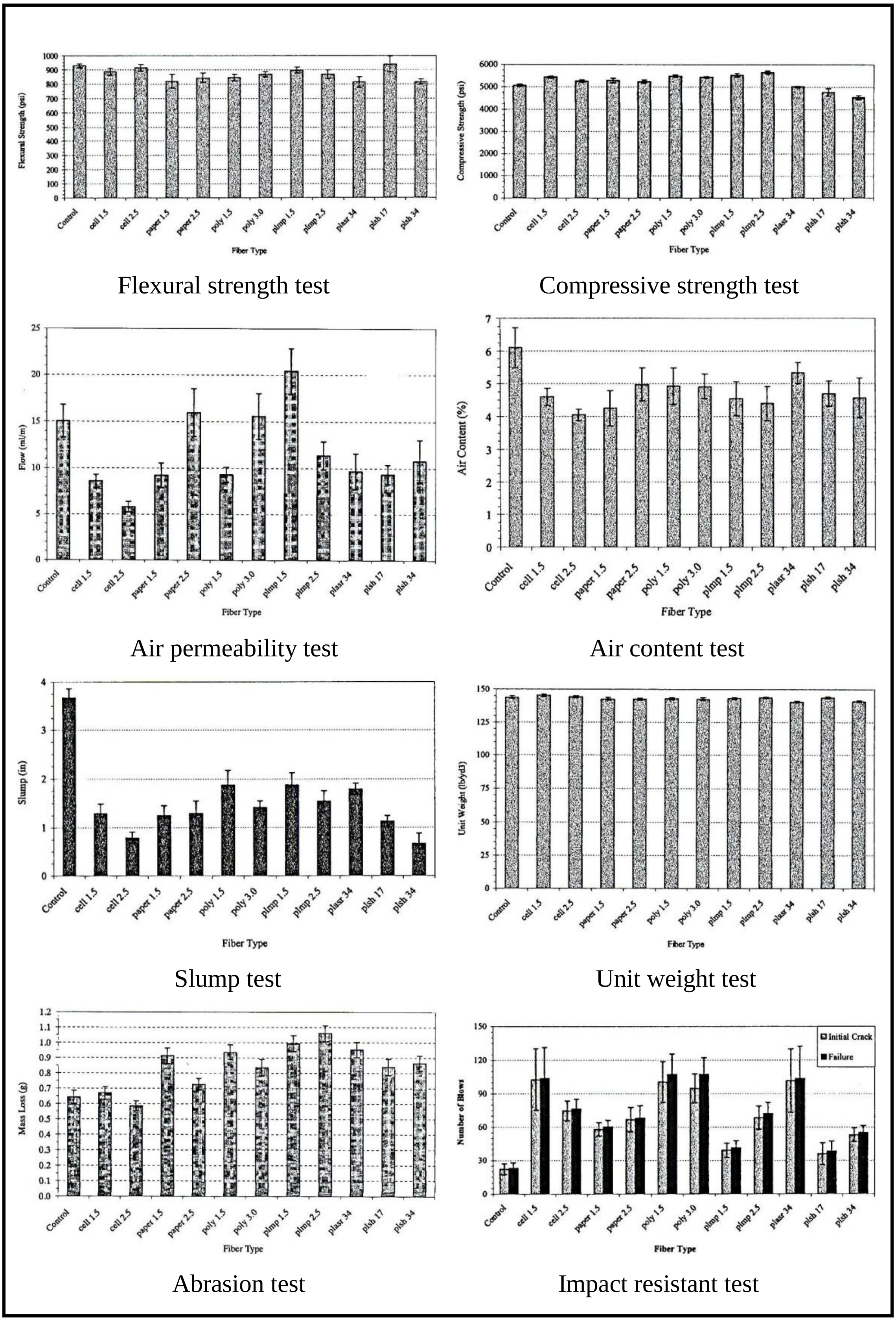


Figure 2.4: Effect of waste materials on concrete mix (Soroushian et al. 2003).

In Fuller et al. (2006), the investigation conducted was on wastepaper concrete (papercrete) which consists only of Portland cement in the mix along with other admixtures. In this study, only two mixtures were taken into consideration namely paper:cement (1:2) and paper:cement:sand (1:1:5). The criteria used for the selection were based on low cost of production and ease of fabrications. It was concluded from the stress-strain graph that papercrete is a ductile material which can sustain large deformation (Figure 2.5), given that since the steel bar was driven into papercrete blocks, pull-out test results (Table 2.8) vary considerably from one to another cause by a few factors as perpendicular and bar wrinkles or folds and as for the creep test the deformations were not very high (Table 2.9).

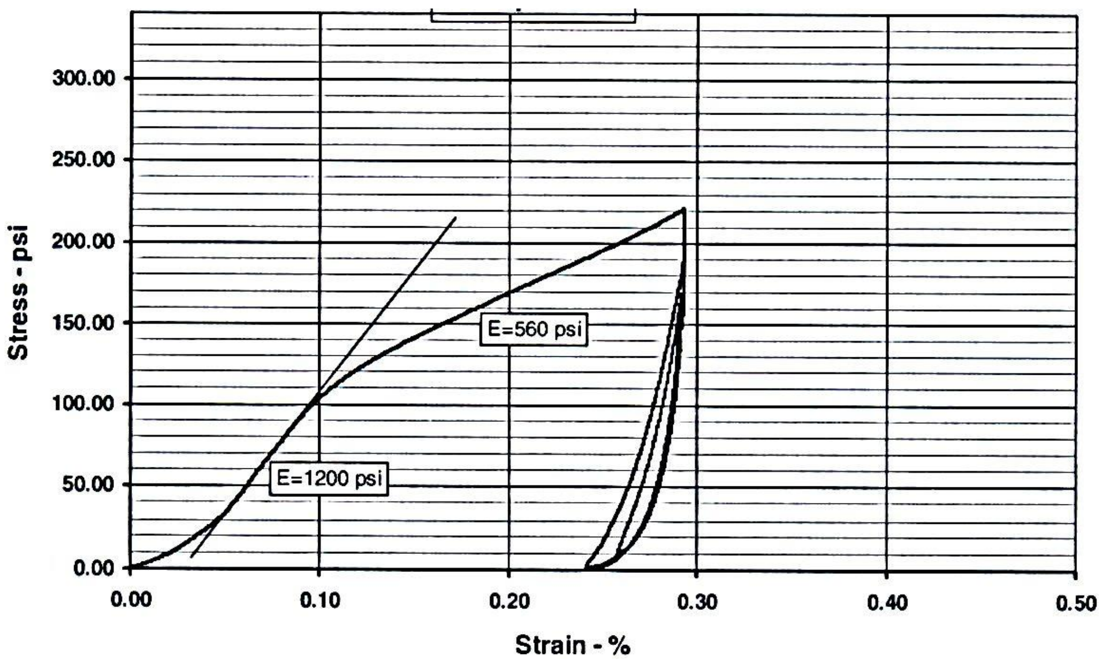


Figure 2.5: Stress vs. Strain graph (Fuller et al., 2006).

Table 2.8 Pull-out Test (Fuller et al., 2006)

Group	Sample	Type	P_{max} (lb)
1	1	Single	60.4
1	2	Single	47.0
2	3	Double	258.0
2	4	Double	130.0
2	5	Double	694.0

Table 2.9 Creep Test Results (Fuller et al., 2006)

Sample No.	Contact Area (in^2)	Load (lb)	Stress (psi)	Deformation due to creep (inch)
2.1	9	307.5	34.17	0.0108
2.2	9	307.5	34.17	0.0282
2.3	9	307.5	34.17	0.0177
4.1	9	307.5	34.17	0.0774
4.2	9	307.5	34.17	0.0831
4.3	9	307.5	34.17	0.0471

Fuwape et al. (2007) investigated technical properties of three layered cement-bonded boards (CBBs) made from wastepaper and sawdust. The CBBs were produced at three density levels of 1000, 1200 and 1300 kg/m^3 and at four cement/particle ratios of 2.0:1, 2.5:1, 3.0:1 and 3.5:1 on a weight to weight basis. The technical properties assessed were modulus of rupture (MOR), modulus of elasticity (MOE), water absorption (WA) and thickness swelling (TS). The MOR values ranged from 4.85 to 11.69 MPa and MOE values ranged from 2.80 to 5.57 GPa. The mean values of WA and TS after 24 h of water soaking the CBBs ranged from 18.18% to 40.49% and 3.55% to 12.13%, respectively. MOR and MOE of the CBBs increased with the increase in board density but MOR decreased with the increase in cement/particle ratio. WA and TS decreased with the increase in board density and cement/particle ratio. The researchers suggested that CBBs produced from wastepaper and sawdust at cement/particle ratios of 3.0:1 and 3.5:1 are suitable for building construction such as panelling, ceiling, and partitioning.

2.3 Critical Summary

Most of the discussed literature reviews and researches are mainly about the production of cement board or to be exact the use of wastepaper in fibre-reinforced cement or mortar. Moreover it also includes the wastepaper utilization from wastewater from paper mill. Almost all studies used Portland cement as a binder except Okino et al. (2000) which used wastepaper bonded with urea-formaldehyde (UF) and tannin para-formaldehyde (TP) adhesives. There are only few discussions and studies on utilization of wastepaper in fibre-reinforced concrete. The amount and the effect of wastepaper in concrete mixes are also limited to only the direct mix of cement and paper only. There are also very few or no reported study on the effect of carbonation on wastepaper concrete. Carbonation *per se* does not cause deterioration of concrete but it has an important effect as it can cause corrosion of embedded steel by reducing the concrete pH. For these reasons, this research thrust towards finding the necessary engineering properties for the utilization of wastepaper in concrete for future reference.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

The focus of this research is to identify relevant engineering properties, particularly strength of paper based concrete. The outline of this research is presented in Figure 3.1. As the flow of research shows, this research is mainly focused on laboratory tests and investigations. Preliminary design mixes were conducted to decide the most suitable amount of wastepaper to be mixed with concrete.

Literature Review

⇩

Preliminary laboratory test (wastepaper)
- Specific gravity test
- Moisture content
- Water absorption test

⇩

Laboratory test (hardened concrete)
- Compressive strength
- Splitting tensile
- Flexural strength
- Water absorption
- Unit weight
- Ultrasonic pulse velocity (UPV)
- Carbonation

⇩

Results and Analysis

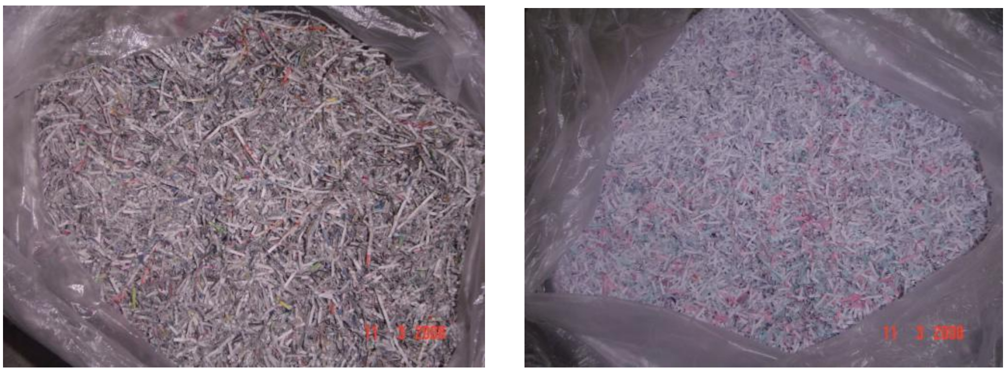
Figure 3.1: Research flow.

3.2 Wastepaper Processing

In this research, two different types of wastepaper are selected because these papers are easily obtained or collected. Those wastepapers are office papers and newspaper. Before these wastepapers are mixed with cement (Ordinary Portland Cement – OPC), it has undergone several processes, which are:

i. Shredding the papers

This is a very easy process where both types of papers were shredded separately with a shredder machine. The size of the shredded papers is 17 x 2 mm.



A B

Plate 3.1: Shredded papers; (A) newspaper and (B) office papers

Plate 3.2: Shredder machine

ii. Pulping the papers

Both types of papers were submerged in water separately for 1, 24, 48 and 72 hours. This method was used to determine the required time to soften the papers. The softer the papers are the lesser the time required to pulp the papers. After 48 hours, the papers were just soft enough to be blended. Papers were then blended with water using driller and after that with a kitchen blender. The original driller arm was replaced with a modified arm along with a sharp blade. The size of the blade is 6.35 mm (2.5 in.) in length. With driller, it took 10 min to get a semi-pulped paper while using kitchen blender, it took less than 1 min to get a creamy look or paste-like pulp.

A B

Plate 3.3: Pulping the papers using; (A) driller and (B) kitchen blender

A B

Plate 3.4: Equipment to pulp papers; (A) driller and (B) arm with sharp blade

A B

Plate 3.5: Results of pulped papers using; (A) driller and (B) kitchen blender

iii. Water absorption test

To determine the effect of water absorption of the mixes. This test is based on BS 1881: Part 122: 1983. The weights of papers were recorded after being dried for 24 hours. The papers were then submerged in water for 24 hours. The papers were removed from the water and the excessive water was then removed from the surface and their weights were measured.

Table 3.1: Water content in office paper and newspaper

Type of Paper	Type of Form	Oven-dry weight (kg)	Wet weight (kg)	Absorption (%)
Office paper	Shred	0.0935	0.307	228
	Pulp	0.0937	0.709	657
Newspaper	Shred	0.0907	0.363	300
	Pulp	0.0910	0.955	949

In pulped form, papers contained more water than the shredded form. Smaller surface area will contain water more easily than large surface area. From Table 3.1, there are differences in water content in both papers. The initial weight for both papers before oven-dry was 0.1 kg. Though the weights were the same but since newspaper is lighter than office paper, the former had more paper in quantity and this had contributed to the large amount of water content.

3.3 Experimental Program

This experimental program was designed to study the mechanical and physical properties of paper concrete incorporating wastepaper. The matrix consisted of concrete with different percentages of wastepaper. For this study, the mechanical properties of wastepaper concrete specimens are measured in the terms of:

i. Compressive strength tested according to BS 1881:Part 116:1983
ii. Tensile strength tested according to BS 1881:Part 117:1983
iii. Flexural strength tested according to BS 1881:Part 118:1983

The physical properties of wastepaper concrete specimens were measured in terms of:

i. Water absorption test according to BS 1881:Part 114:1983
ii. Ultrasonic non-destructive test according to BS 1881:Part 203:1986

The experimental program was outlined into eight stages:

i. Preparation of material
ii. Apparatus
iii. Preliminary design
iv. Mix proportion and mix design
v. Specimen preparation

vi. Curing of specimens

vii. Testing

3.4 Preparation of Material

3.4.1 Cement

Ordinary Portland Cement (OPC) conform to the MS 522: Part 1:2003 or BS 12: 1991 was used. OPC has medium rate of hardening and it is suitable for most types of works. The finer cement gains strength more quickly.

A B

Plate 3.6: Ordinary Portland Cement (OPC); (A) overall and (B) close up

3.4.2 Fine Aggregate

River sand was used as fine aggregate. The river sand particle size used is passing 5 mm sieving and Figure 3.2 shows the size distribution of river sand.

A B

Plate 3.7: River sand; (A) overall and (B) close up

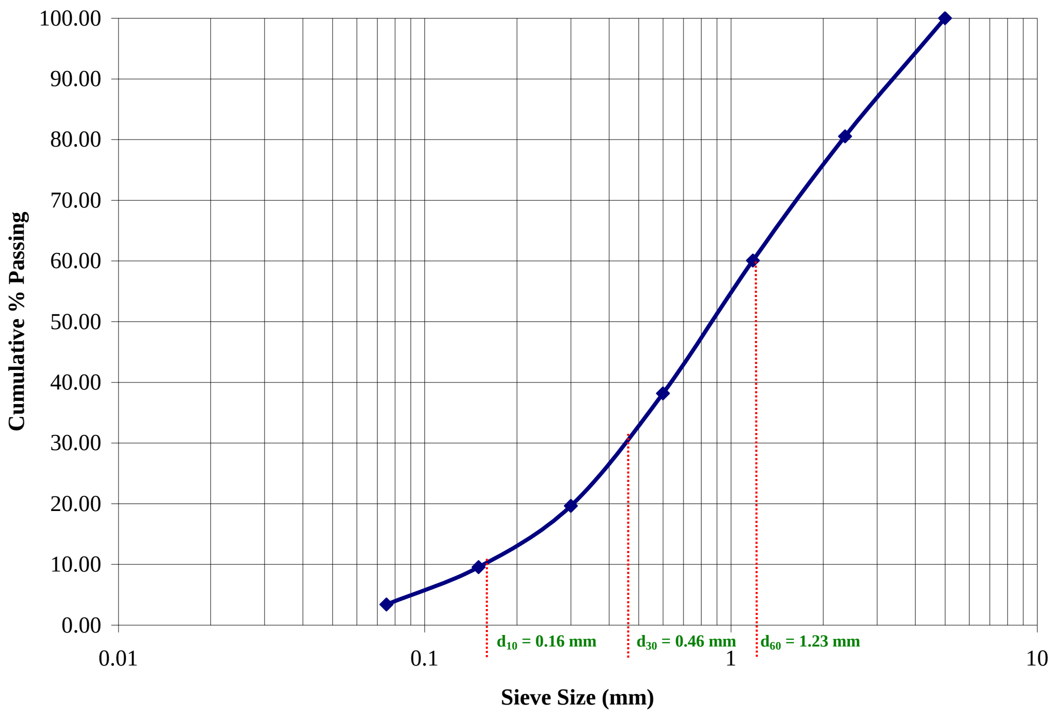


Figure 3.2: Particle size distribution curve for river sand used in this research.