EVALUATION OF WASTE PAPER FOR FIBERCEMENT PANEL

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Bachelor of Science in Civil Engineering

Presented by:

Jennylyn Abenojar

Brian Abarientos

Krystel Collante

Ben Jhon Pasiga

Jorge Thompson

Kiezel Zacarias

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APPROVAL SHEET

In partial fulfillment of the requirements for the degree, Bachelor of Science in Civil Engineering this thesis entitled **"Evaluation of Waste Paper for Fiber-cement Panel",** has been prepared and submitted by **Jennylyn Abenojar, Brian Abarientos, Krystel Collante, Ben Jhon Pasiga, Jorge Thompson, and Kiezel Zacarias**, are hereby recommended for Oral Examination.

____

ENGR. RHONNIE ESTORES
Adviser

Approved by the Committee on Oral Examination with a grade of ________

____

ENGR. HADJI PEEJAY ARANDA
Chairman

____

DR. LEIZL FALLARNA
Member

____

ENGR. EDGARDO PEÑA, JR.
Member

____

ENGR. ALFREDO LUPIG
Member

Accepted and approved in partial fulfillment of the requirement for the **DEGREE OF BACHELOR OF SCIENCE IN CIVIL ENGINEERING**

Date: __________________

____

ENGR. ALLAN B. BENOGSUDAN, MS CE
CE/SE Department Head

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ABSTRACT

Title: AN EVALUATION OF FIBERCEMENT PANEL USING WASTE PAPER

Researchers: Jennylyn Abenojar
Brian Abarientos
Krystel Collante
Ben Jhon Pasiga
Jorge Thompson
Kiezel Zacarias

Adviser: Engr. Rhonnie Estores

School: Technological Institute of the Philippines, QC

Date: October 2oo8

Degree: Bachelor of Science in Civil Engineering

Shelter is the most compelling element of humankind. It is essential for full human development in providing a sense of stability, security and confidence. However, sky rocketing costs of building and construction material results to a growing problem of homelessness and inadequate shelter. For this reason, the use of composite and other construction materials that is not as expensive as wood will be able to alleviate the rising cost of construction materials. Recycling and using of indigenous materials as constructions aggregate are plus factors in bringing down the cost of building houses.

Findings and Conclusion

From gathered data's of the conducted test for classification and investigation of mix proportions of paper, cement and sand to work in a panel, shows that the material in application for a fiber-cement sheets did not conform to the standard specification. However, a suitable application can be practical for plasterworks, ornamentation, decorative moldings on ceiling and walls.

The optimum proportion for the mixture is 40% paper, 50% cement and 10% sand, 2:2 ½:1/2 ratio is obtained in terms of volume and has been accepted from the preliminary tests. Adding sand to each designed mix proportions of paper and cement provides a more stiff, hard or rigid material, fire retardant, and also termite resistant.

Recommendations

Based from the findings and conclusions, the following are suggestion for recommendations: (1)An equipment to be used must be improvised, such as a mixer with a blade at the bottom to provide a well mixed product. (2) Waste paper product in mixture with cement and sand is a recommendable additive for decorative moldings on ceilings and walls. Mix proportion can be 60% paper; 30% cement and 10% sand; 50% paper; 40% cement and 10% sand and 40% paper; 50% cement and 10% sand.

A further study must be conducted to develop a mix design to meet the Standard Specification for Flat Non-Asbestos Fiber cement Sheet, Roofing and Siding Shingles, and Clapboards. And test for resistance to decay and insects, acoustical properties, and thermal insulating properties must be established.

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CHAPTER I

THE PROBLEM AND ITS SETTING

Introduction

With a rapidly growing population and lack of adequate disposal sites, solid waste has become a major problem for most medium to large-size cities. When Philippine President Gloria Macapagal-Arroyo took office in January 2001, the first act she signed into law dealt with solid waste management. In recent years, inadequate solid waste management systems have posed serious health risks particularly in densely populated areas. In Manila, for example, the closure of the largest disposal site in 2000 combined with the inadequate capacity at other sites resulted in the disposal of tons of waste along city streets, empty lots, and in the waterways and bays in and around the city. *(http://www.environcorp.com/img/media/SWM_Philippines_Paper.pdf)*

Shelter is also the most compelling element of humankind. It is essential for full human development in providing a sense of stability, security and confidence. However, sky rocketing costs of building and construction material results to a growing problem of homelessness and inadequate shelter.

For this reason, innovative materials and technologies have been studied here and abroad to develop low cost infrastructures from cheap materials such as residual wastes.

Background of the Study

From qualitative waste survey of residents, commercial businesses, government institutions, and schools as performed in 2000 reported a collection rate of 0.4 kilograms per person per day (kg/p/day). A rate of 0.5 kg/p/day is generally considered an accurate estimate for solid waste generation for many rural communities of the Philippines. Composition of solid waste in

Manila consists of 53.7% Putrescibles, 20.7% other inert, , 12.9% paper, 5.8% of metals, 3.5% glass, 1.6% plastics , and 1.8% of textiles.

On the other hand, incomplete empirical studies and countless unsystematic real world observations, categories for recycling system shows that paper and plant debris makes up 50% of the total discards that are recyclable.

Since wastepaper are largely produced almost everywhere and reusing them into a building material could be very useful that is relatively inexpensive to make, malleable in its form and environmentally benign. This includes heaps of junk mail, newspapers, magazines, cardboards, catalogs, and any kind. It is principally wood cellulose, which is considered a fibrous material. Hence, cellulose is the second abundant material on earth after rock. It is the main component of plant cell walls, and the basic building block for many textiles and for paper. Cellulose is a natural polymer, a long chain of linked sugar molecules made by the linking of smaller molecules. The links in the cellulose chain are a type of sugar: β-D-glucose. The cellulose chain bristles with polar – OH groups. These groups form many hydrogen bonds with OH groups on adjacent chains, bundling the chains together. The chains also pack regularly in places to form hard, stable crystalline regions that give the bundled chains even more stability and strength. This hydrogen bonding forms the basis of Paper-cement's strength. Coating these fibers with Portland cement creates a matrix, which encases the fibers for extra strength. *(http://livinginpaper.com/mixes.htm)*

There are various types of paper as being added with different chemicals, treated with dyes, and bleach that contaminates soil and plant life which are extremely persistent in soil and cannot be broken down by bacteria. For this reason, encasing this fibrous material with cement obtains a material good for insulating, sound absorption quality, flame and fungus retardant, bug and rodent resistant. Since it is relatively light and more flexible than earth, rock or concrete, it is potentially an ideal material for earthquake-prone areas. *(http://livinginpaper.com/mixes.htm)*

The mixture of paper and cement is a material made by pulping waste paper by soaking it in water until fully saturated and softened to break them into fine fibers. It also contains various additives commonly sand and cement, then pressed into forms to fabricate panels. The form holds the mix into desired shape until it set. But form can be removed to expose as much surface area of the block to the air for drying. Forms can be built from just about anything depending on the desired shape of the finished product. Common materials are wood, sheet of metal, alone or in combination. Interlocking plastic dividers are also used. *(http://livinginpaper.com/forms.htm)*

Cement is absorbed by the paper fibers, ensuring that it is evenly distributed throughout the mix, and any excess water simply evaporates or squeezes out. Alternative binders can either be alone or in combination with Portland cement which includes fly ash, bottom ash, rice hull ash, plaster of Paris and lime. There may be others. Fly ash is ash left over from burning coal, caught in giant filters from smokestacks of power plants. Bottom ash is heavier than fly ash so it sinks to the bottom of the furnace. Rice hull ash is burned in power plants in areas of the country where rice is grown. Plaster of Paris is a variety of calcined gypsum. Before Portland cement was discovered, lime was used as a binder, mortar and plaster. Romans used it in their stone construction. *(http://livinginpaper.com/mixes.htm)*

Like any other mixture, variation of mix proportions of paper to cement, admixtures and curing procedures results in tradeoffs in its properties. Best mixture is the one which best fits the application. This type of mixture is also called Fibre-cement or Paper-cement since main component is fibers extracted from paper. It is also an industrial version of Paper Mache.

Fiber-cement or shortened form of “Fibrous Cement” has been used as a building material for nearly 100 years and widely used in Australia. It is a building material made of compressed fibers cemented into rigid sheets used to manufacture roofing, ceramic tile, backer board, decorative facades, fire walls, and other building. In appearance, Fibre-cement most often consists of overlapping horizontal boards, imitating wooden cladding, clapboard and imitation shingles. It is also utilized as a substitute for timber fascias and barge boards in high fire areas. Fibers involved were almost always asbestos based and, in some cases, mixed with formaldehyde in their fiber cement formulations having potentially unsafe or hazardous additives. *(http://en.wikipedia.org/wiki/Fiber_cement_siding)*

Wood shows traditional look of classic structures, since paper is cellulose and made from wood can therefore be an alternative material to wood. But wood requires significant maintenance. Without regular and sometimes costly maintenance, wood and wood-based products will split, swell, deteriorate and become brittle. Furthermore, the growth of internal mold and fungus in wood will foster decay that can go unnoticed until the damage requires expensive replacement. Termites and woodpeckers are wood's natural enemies and can plague homeowners with costly repairs for the lifetime of the home. However, when properly installed and protected, last for decades and so does Fibre-cement or Paper-cement. But on the other hand, paper and cement will deteriorate at a much slower rate than wood.

Fiber-cement from waste paper can be formed in many different ways and be used in diverse application in building construction. It takes about fifteen trees to make a ton of paper, meaning millions of trees are used once and then buried in landfill each year. Using this will greatly benefit communities and landfill space. It will save trees and other construction resources.

Most application used for this type of mixture is formed into bricks or blocks of any size to build walls and houses, others are being poured like cement made into a monolithic wall, in filled between poles or studs like light-weight straw clay, shaped into large, reinforced panels, mortared, drilled, hammered, nailed, used as plaster and more. It is widely used in New Mexico as pioneered by Mike McCain and Barry J. Fuller, they called it Papercrete construction. But only Portland Cement part of concrete is being used in the mix. The potential of Papercrete construction is enormous for do-it-yourself builder, though still untested in many areas and environments. And research for Papercrete is still completely experimental even if several houses and structure have been built, since long term performances aren't known yet. And no real insulation tests have been performed, plus Papercrete soak up water like a sponge but excrete it again so they must be protected from moisture and weather.

From research undertakings, discovered its potential for being high in resistance to fire. As each individual grain of sand embedded in the matrix of fibrous cement is surrounded by insulating air pockets wherein oxygen doesn't have a chance to penetrate and combustion cannot be sustained. It will take a long time for heat to flow; the wall will take all day to warm up and all night to cool down. However, no building product can be completely guaranteed against fire, nor can a non-combustible building product guarantee that a home will not be damaged by fire.

This study, Fibre-cement from waste paper is an experimental study in fabricating panels as related to the studies and methods from Papercrete Construction and Fibre-cement. Instead of forming it into bricks and blocks for building walls, mixture of paper and cement is formed into sheets in use for aesthetic panels or partitions. An investigation for this study presents different mix proportions of sand, cement and paper. Also, includes observations describing each sample as subjected to test conditions, investigation of mixture's weaknesses as for the desired use in application, and trial approach for mixture's reinforcement.

Statement of the Problem

This research study aims to determine if waste paper can be used to fabricate a Fibre-cement Panel. The following questions must be satisfied:

1. How waste paper would be feasible to alternate Fibre-cement?
2. What mix makes the most suitable proportion for a Fibre-cement?
3. What are the effects of adding sand in different paper-to-cement ratio?
4. What are the advantages and disadvantages of using waste paper for Fibre-cement?

Objectives

1. To present an alternative material for Fiber cement using waste paper.
2. To determine the suitable mix proportion that is suited for a Fiber-cement.
3. To compare the effect of adding sand in different paper-to-cement ratio.
4. To evaluate the advantage and disadvantages of using waste paper for Fibre-cement.

Significance of the Study

Chronic shortages of housing in urban and non-urban areas are increasing due to high costs of building materials. The poorest sector of the community is the most affected since they can't at least afford construction materials. This research aims to present a material that is alternative to Fibre-cement using waste paper.

In other country such as New Mexico, has used this mixture of paper and cement as a do-it-yourself project forming them into bricks or blocks and layer them to build residential houses. However, no study or application has been made in forming this mixture into a panel in comparison to Fibre-cement.

The study may serve economic benefit for construction builders as a do-it-yourself project for residential use and in diverting waste papers through reuse or recovery for a very useful building material.

From performed experiments and laboratory tests of different proportions of mixture. Will encourage a new knowledge to conduct similar studies in use of different application or expand the study of using waste paper as an alternative material for Fibre-cement.

Definition of Terms

For better understanding and appreciation, the following terms are operationally defined. (The definitions used in this research are in accordance with ASTM – Designation: D 9.)

Aggregate - is a granular material such as sand, gravel, crushed stones and iron blast-furnace slag, and when uses with cementing medium forms hydraulic cement concrete of mortar.

Allowable properties – mechanical properties of materials as prepared for design use. Allowable properties of wood are identified with stress-grade descriptions and reflect the orthotropic structure of wood; Often considered synonymous with allowable unit stresses, working stresses and design stresses.

Board foot – a nit of measurement represented by a board 1 ft long, 1 ft wide, and 1 in. thick. Abbreviation ft. b.m.; bd.ft., fmb. In finished or surfaced lumber, the board-foot measure is based on the nominal size. In practice, the work unit is 1000 board feet. Abbreviation M bd. ft.

Cellulose – the carbohydrate that is the principal constituent of wood and forms the structural framework of the wood cells.

Cement – a substance which sets and hardens independently and bind other materials together

Concrete – a building material of sand and gravel bonded with cement into a hard substance; use in making bridges and rod surfaces, etc.

Dense – (1) term used in stress grading of certain softwood species to signify a high specific gravity. (2) a visual estimate of high specific gravity. To be classified as dense, the softwood species shall average on one end or the other of each piece, not less than six annual rings per inch and one-third or more latewood. Pieces not less than four rings per inch shall be accepted as dense if they average one-half or more latewood.

Durability – a general term for permanence or resistance o deterioration. Frequently used in referring the degree of resistance of a species of wood to attack by wood-destroying fungi under conditions that favors such attack. In this connection the term 'decay resistance' is more specific.

Fibre-cement – a composite material made of sand, cement and cellulose fibers.

Fibre-cement siding – a building material used to cover the exterior of a building in both commercial and domestic applications.

Fire retardant – having or providing comparatively low flammability or flame spread properties.

Hardness – a term relating to the capacity of wood to withstand denting and abrasion; for purposes of comparison, hardness in wood is often measured as the load in pounds required embedding a 0.444-in. ball to one-half its diameter.

Low-cost housing – affordable housing for the poor or low-income individuals and families.

Moisture content – the amount of water contained in the wood, usually expressed as a percentage of the mass of the oven dry wood.

Moulding – a specially worked wood member used mostly for decoration but often serves a useful purpose in other ways; generally worked from lumber of strip size; may be a plane surface but often curved or patterned.

Papier-Mâché - term that has been applied to innumerable three-dimensional objects having a paper core; spelled many ways, ranging from the French papier-mâché to the Anglicized paper mache, papier machie, etc; literally means masticated paper, but it is also used to describe objects made of very different types of paper constructions, including paper pulp applied, cast or extruded into a molded form, paper strips adhered together over a molded form, and paper sheets adhered together and pressed between molded forms

Plaster of Paris - a white powdery slightly hydrated calcium sulfate $CaSO_4 \cdot ½H_2O$ or $2CaSO_4 \cdot H_2O$ made by calcining gypsum and used chiefly for casts and molds in the form of a quick-setting paste with water; also known as chalk

Portland cement – ordinary cement used widely in construction industry (for foundation, columns, beams) serves as binding agent.

Putrescibles – liable to decay or spoil or become putrid; includes animal, fruit and vegetable debris; cooked food; manures; offal and sewage sludge

Shrinkage – reduction in dimensions due to lowering the moisture content below the fiber saturation point.

Slurry – a thin mixture of liquid, especially water, and any of several finely divided substances, such as cement, plaster of Paris, or clay particles

Specific gravity – as applied to wood, the ratio of the oven dry weight of a sample to the weight of a volume of water equal to the volume of the sample at some specific moisture content, as green, air-dry, or oven dry.

Strength – (1) the ability of a member to sustain stress without failure. (2) In a specific mode of test, the maximum stress sustained by a member loaded to failure. (3) The capacity to sustain the application of force without breaking or yielding.

Scope and Limitations

This experimental research focuses on the viability of Fibre-cement from waste paper. Since mixture is broad in range and uses. The study relates to suitable mix from different proportions of sand, cement, and paper to fabricate an alternative material for a Fibre-cement Panel.

The main materials to be use in this study are newspapers, Portland cement and sand. Papers were soaked in water for days to soften and break them into fine fibres using a chopper or a blender, then mix together in different proportions of sand and cement. As stated in the previous chapter, the material being used is related to the studies and methods of developing Papercrete construction by Barry J. Fuller and its successor. They develop a brick or block material of this mixture in use for building walls, while this study investigates on its viability to flat sheets Fiber-cement in use for aesthetic panels or partitions.

Research delimits test only to the facilities provided in the laboratory where series of experiments are conducted. Only Strength and rigidity of basic elements employed in various construction systems has been examined and evaluated accordingly to the American Standard for Testing Materials, (ASTM). No cost analysis has been covered in the production of the material since this research is projected for do-it-yourself purpose.

Research Paradigm

The main purpose of this research is to distinguish the most excellent proportion in combination of Portland cement, sand as fine aggregate, and recycled paper which will be viable to produce a panel that is: economical, environment friendly, lightweight, fire proof, and durable.

This study applies input – process – output model as shown in Figure 1. Experiments are performed and results of tests and observation to its physical and mechanical properties are evaluated.

The input of the study focuses on designed proportions of paper in composition with Portland cement, and sand that best suits for a non-load bearing panel. Materials and equipment are needed, since waste papers must be well blended into fine fibers in different mix proportion with cement and sand, and then poured into different forms.

The process of the study base from input mentioned uses experimental and testing procedures on the following properties: Compressive Strength, Bending, Water content and Impact Test.

Based from the process, output generates an application for a design mixture of waste paper slurry, Portland cement, and sand that is viable for a non-load bearing wall panel.

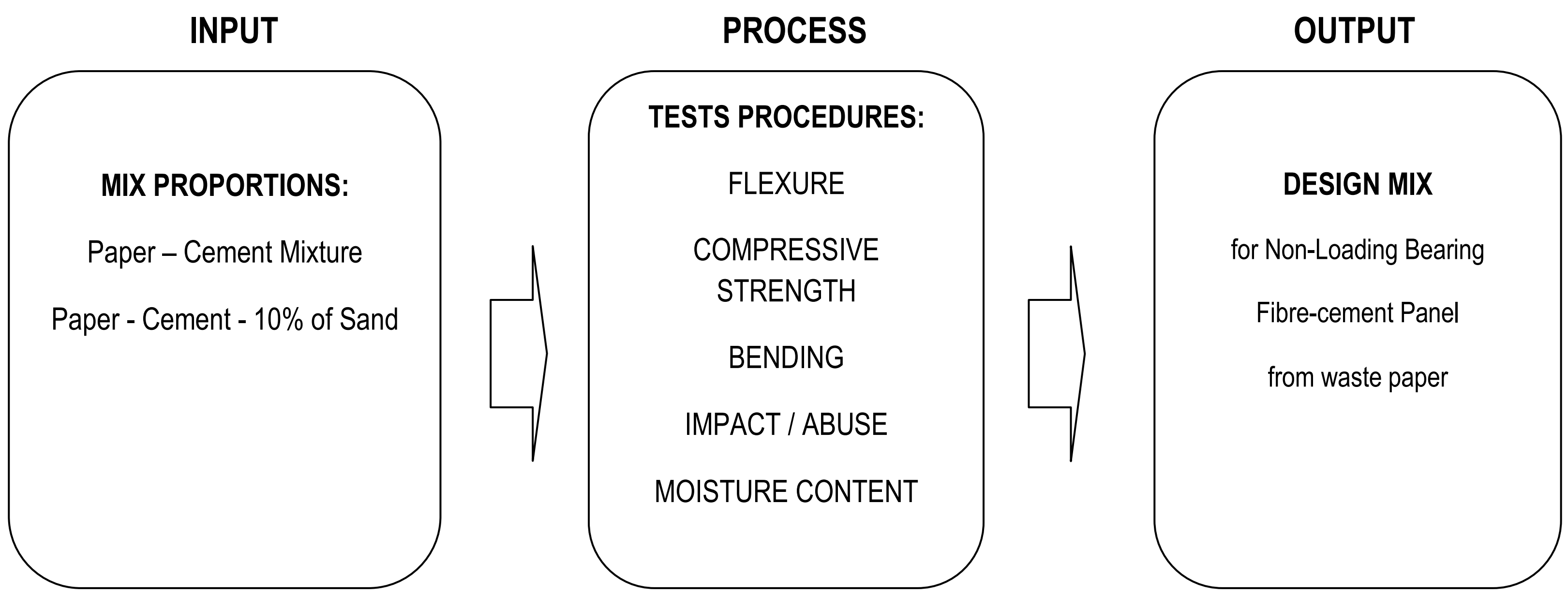

Figure 1. **Research Paradigm**

CHAPTER II

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents the different related studies regarding Fiber-cement Panel, which was found significant to our research.

Review of Related Studies

During a hundred year period between the mid-eighteenth and nineteenth centuries, a major industry flourished in England: that of Japanned *Papier-Mâché*. This industry had its origins in both architectural ornamentation and japanned tin ware. The development of japanned papier-mâché led to an unparalleled trade that resulted in the manufacture of many articles of furniture. The technological development of papier-mâché from a composite of simple components created in the ancient Orient, to an extremely hard and water-resistant material that workable enough to be turned on a lathe and strong enough to build an entire village.

The origin of papier-mâché is at least as ancient as the invention of paper itself. Paper was developed in China during the Han Dynasty, c. 202 B.C.- 220 A.D.,6 and it is consequently not surprising that the earliest use of paper to make three-dimensional objects occurred there. Artifacts, such as helmets and pot lids, attributed to this dynasty, were made of what has been described as Papier-Mache.

Pasteboard also had its origins in the ancient East, and early examples exist from Tibet. One of the oldest surviving artifacts made of this lightweight but strong material is a falcon's coffin from Persia, and it is interesting to note that even today Papier-mâché is recommended for coffins (albeit for humans) as outlined in a 20th century American patent. The first commercial pasteboard was produced in Europe around 1580, and European recipes for making papier-mâché date to the mid-1600's.[10] However, innovations in their respective technologies didn't undergo much development in the West until the early 18th century.

In England, the commercial application of papier-mâché seems to have been preceded by a similar material used for ornamental attachments on architecture and furniture. During the early 18th century, a revolution in architectural ornamentation eliminated the necessity of carving plaster or wood in situ through development of an inexpensive material that could be made in a mold and applied when convenient. While the initial composition consisted of inorganic and resinous solids mixed with binder and referred to as "compo"[11], a later version, called fibrous slab, combined plaster with vegetable matter such as hay, straw, nettles and bark. Eventually the plaster was replaced completely by fibers and other organic material including leaves of pineapple, aloe, and cacao plants; peat and bog asphodel; horse dung; and fibers of hemp, flax, and cane. Such material was recommended, and apparently used, for houses, bridges, and railroad wheels, among other things.

Slab appears to have been supplanted by papier-mâché as an architectural material in the mid-18th century by one of its chief manufacturers, a Mr. Wilton. He supposedly employed two French women who chewed paper - hence the French origin of the term. This pre-machine method of macerating pulp is said to have developed in France in 1740 and was promoted in England by paperhangers interested in extending their expertise to ceiling decoration. It was also referred to as paper stucco and pasteboard stucco. Wilton's recipe was applied not only to architecture but also to mirror frames and chair "knees". As a ceiling ornament, paper stucco fell into disuse with the advent of stamped tin ware.

At about the same time, during the mid-18th century, a japanned of tin ware, John Baskerville, experimented with paper panels (a derivative of pasteboard) as a base for Japan ware. Japan ware was an English imitation of Oriental lacquer. True lacquer comes from the resin of a tree of the sumac family indigenous to the Orient, and in the East this resin dries quickly upon exposure to sunlight. It was applied to a base of wood or leather, or occasionally paper. Since the lacquer did not set properly in the English climate, its effect had to be duplicated by various varnishes in a process referred to as "japanning." An example was "tar varnish" or "Jewish pitch", which was a mixture of asphaltum, amber, linseed oil and rosin in turpentine. This might be covered, for added protection or higher gloss by an alcohol based "spirit varnish", or a copal resin in linseed oil. Because these materials dried slowly, the Japanese hastened the process with frequent "stovings". Since the exposure to heat would crack and warp wood, other bases were sought. Tinned iron was successful, but paper provided a cheaper and lighter alternative. While recipes for using paper pulp are extant, the variations in density and homogeneity of this substrate provided a poor surface for varnishing.

In the late 18th century, Baskerville's apprentice, Henry Clay, succeeded in his predecessor's endeavor to develop an appropriate paper support by patenting a method of making hand-pressed or hand-smoothed paper panels which were heat-resistant. Ten sheets of unsized rag paper were pasted on both sides with a mixture of cooked glue and flour. They were then pressed into a metal mold and smoothed to remove air bubbles. The edges were trimmed and the sheets were drenched with linseed oil for waterproofing and the ensemble was dried at 1000F.20 The result was a rigid material that could be worked like wood. The use of paper panels came to be known as the "best" Papier-Mache as opposed to the common papier-mâché made from pulp.

In the early 19th century, there was a shift from the time-consuming process of hand-pressing individual sheets into a mold to the manufacture of paper maker's panels or blanks, which could be sold to furniture makers and were well suited for trays.21 However, hand-smoothed panels continued to be preferred by japanners since they were smoother and more solid than the papermaker's panels. The firm of Jennens and Bettridge, which purchased Clay's old shop in 1816, made thicker panels by layering 120 sheets together at a time, enabling production of larger and stronger items, such as the Smithsonian chair. However, these panels could take days to dry, or required even more stovings. In 1847 Theodore Hyla Jennens was issued a patent that marked the next major development in the papier-mâché industry. He developed a technique whereby dry panels could be softened with steam to enable manipulation into a heated metal mold. A counter mold was then screwed into position and the steam-molded panels were dried by heat. The result was a hard, pre-shaped product of even thickness. By reducing the number of steps and amount of time required to mold furniture, Jennens revolutionized the process and opened the door to mass-production.

The firm of Jennens and Bettridge also improved methods of japanning and decoration that are pertinent to the Smithsonian chair. In 1825 they received a patent for improvements in the process of mother-of-pearl decoration. Their process by-passed the need for skilled craftsmen to inlay decoration. The pearl pieces were ground and polished by workers to a thickness of 0.2-0.4 mm. These thin sheets of material were then stenciled with asphaltum and dipped in hydrochloric acid. The acid dissolved all the shell not protected by the asphaltum, leaving pearl pieces corresponding in size and shape to the stencil pattern. The pieces were adhered to the prepared japanned surface immediately after the object was varnished, using the tacky varnish as the adhesive. The areas of decoration were then repeatedly coated with varnish and polished until the surface was completely smooth, giving the appearance of intricate inlay by craftsmen of consummate skill.24 What appears to most 20th century eyes to be excellent craftsmanship is in reality a labor saving method of decorating industrially mass-produced objects. Gilding and painting were often applied after the pearl. "Bright" gold was applied principally by water gilding an area larger than the intended figure, and the pattern was then stopped out by asphaltum painted on with very fine brushes. The excess gold was washed away with cotton mops, and the asphaltum was removed by turpentine, exposing the desired pattern.25 The final step was “sprigging" or delineating details such as feathers or flower petals.26

By the mid-19th century, the technology of varnishes was also undergoing dramatic changes that fostered increased and more standardized “assembly line" production of japanned furniture. Alcohol based spirit varnishes were gradually being augmented with or replaced by fixed oil varnishes that were easier to use and far more durable. The industrial processing of resins promoted the widespread use of higher quality coatings, which were consequently no longer restricted to expensive furniture. As a result, even mass-produced furniture could be finished with highly decorative and durable finishes.

Ironically, Jennens and Bettridge's achievements in the mid-19th century were followed within several years by a decline in the demand for japanned furniture in England. As decoration became more bizarre and garish, objects evolved into more elaborate and impractical forms, moving from the simple trays and snuffboxes of early days to the piano cases and bedroom set shown in the Great Exhibition of 1851. Such over-popularization eventually destroyed the novelty of the material, and, coupled with a change in clothing fashions that necessitated heavier furniture, led to the demise of the firm in 1864.

(http://www.si.edu/MCI/downloads/RELACT/papier_mache.pdf)

Papercrete was as well developed in the late 1920’s by an unspecified man who supposedly patented it but was unable to make money because the process was so easy that anyone could do it, and many did.

In 1976, John Hall was an art student majoring in sculpture conducted an experiment with Papier Mache' by adding gypsum plaster to the mix. This worked pretty well, but the set time was about fifteen minutes, so the mix had to be quickly poured into a mold. He casted small test triangles and found that it was strong, light, and flame proof. The drawback was the quick set time, so he experimented with Portland cement instead of the gypsum. He made a molded 3' triangle from paper pulp, cement and a wooden 4' diameter geodesic frame, covered with cardboard and burlap then applied his mix. John Hall had a hard time using a cement mixer to pulp large amounts of paper just to provide the needed material for his doghouse, so he decided to stop his experimentations at that time. (*http://www.starship-enterprises.net/Papercrete/Workshop/history.html)*

A few years ago Mike McCain from Sun City, New Mexico, an inventor and builder located in Colorado experimented with shredded recycled paper, sandy dirt and cement to produce and amazing product he calls fibrous cement. Eric Patterson, a printer by trade in Silver City, New Mexico, developed and patented what he terms Padobe from just newspapers and cement. Since the process was so easy that anyone could do it, they encourage anyone to experiment with this material. Then a third force in Papercrete advancement is Sean Sands, a retired physician who is experimenting with wood chips, sawdust, cement and adobe. Sean and Mike constructed experimental domed shelters at a community in New Mexico in 1998, and both are continuing to build and experiment, with Mike offering workshops and private construction in the Western US. *(http://www.northcoast.com/~tms/papercrete.html)*

McCain is credited with designing the "3rd world tow behind Papercrete mixer" which uses a car or truck rear end to drive a blender type mixer that will mix about a yard of Papercrete in a short time. This mixer was made Papercrete practical for the owner builder. Since that time several different style mixers have been made by various people, with varying results. Sun City, New Mexico is the hotbed of Papercrete experimentation today. (*http://www.starship-enterprises.net/Papercrete/Workshop/history.html)*

Papercrete have drawbacks, and since it is still completely experimental (several houses and structures have been built in the last few years) the long term performance results aren't known. And no real insulation tests have been performed, plus Papercrete blocks soak up water like a sponge (but release it again) so they must be protected from moisture and weather. All that being said, it still has enormous potential as an ultra low cost building material or as a partial replacement of costly, commercial building products. (*http://www.starship-enterprises.net/Papercrete/Workshop/history.html)*

Those researches are very timely nowadays because one of the major concerns of the Philippine government is on how to provide more affordable materials needed to construct a decent and low-cost housing unit for the Filipino people. The clamor of the mass for affordable construction materials like wall panels is ever increasing. Most of the residential houses offered today are from the initiatives of private developers but sad to say at prices that are not affordable for low-income earners.

CHAPTER III

METHODS OF RESEARCH AND PROCEDURES

Research Method

Method of research for this study is experimental in investigating the viability of waste paper for a Fibre-cement Panel. Hence, this research covers only the physical and mechanical properties.

The study involves two phases for laboratory experiment. Phase I determines strength of different mix proportions of the material: paper, cement and sand or other additives. Phase II is for the Panel Construction and testing as based from the first stage taking the most suitable mixture and putting them to work in a Panel.

A 6"x6"x1/2 inch tile with variations of different proportion of paper-to-cement and paper-cement-sand mixture has been prepared for observations and trials. Ratio ranges from 40% to 80% of paper to cement 50% to 20% and a ratio having a baseline of 10% sand to varying amount of paper and cement.

Observations of every laboratory experiments are the major tool for data gathering in description of physical or mechanical properties of every proportions being made. And in order to quantify the performance of every specimen, the researchers used standardized testing procedures to ensure validity of tests. And consulted or referred to a group of people who had already been connected to this study and currently using this kind of material as building material for residential construction.

Project Design

The design of the project starts from preparing the main materials by stripping, soaking and grinding newspapers into cellulose and providing forms for specimens with different proportions of mixture. Trials from small samples 6”x6”x1/8” has been made to be examined for preliminary tests, batch of specimen consists of two different mixture ranging from 40% - 90% of paper to cement ratio, then a baseline mixture of 10% sand. By this trials characteristic of each mix proportion is being observed, resistance in surface abuse and nail through and pull test to determine mix proportion that will be suited to work in a panel. When mix proportions are identified, it will be tested for Water Absorption or Moisture Content, Density and Flexural Strength. Results then shall be evaluated to ASTM C1186 – 91. If the outcome conforms to the standard specification for Flat non-asbestos Fiber-cement Sheets, the mixture of the specimen must be accepted. Figure 2 shows a representation of these project undertakings.

Since research is related to the studies and methods from Papercrete Construction. The material is applied as bricks and blocks for building walls. An investigation has also been conducted for different mix proportions for flexural and compressive test to verify strength capacity meets its standard specification. But then, preparation for the material requires ample amount for series of mix proportions, specimens are then subjected for multiple testing. Hence, broken samples from Flexural Test of rectangular specimens 21”x6”x6” having different mix proportions are cut into cubical specimen 6”x6”x6” to test for Compressive Strength.

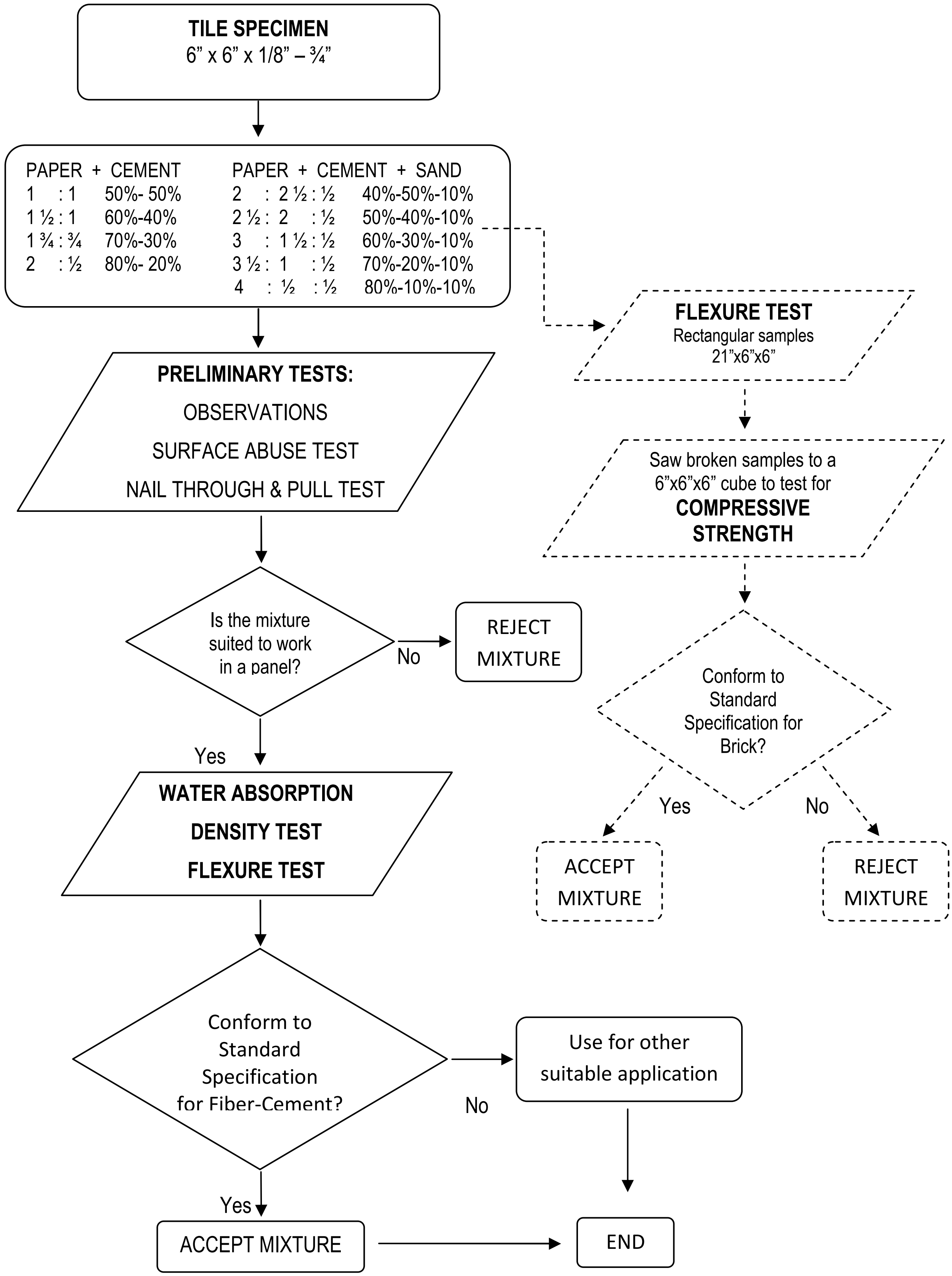

Figure 2. Project Design

Research Development

Development of this research has been conducted with assistance and references from group of people whom presently using this material as paper blocks in constructing their own residential houses. But for this case, the material is applied for non-load bearing sheath panel.

Materials such as newspapers and scrap ply boards were taken from neighbors and friends. Collected newspapers were stripped and soaked in water for days, then grinded into slurry to extract its fibers. Preparation for slurry needs an equipment to supply large amount for each designed mix proportion of specimens. Improvised equipment or machine could be a drill with a blade at its end or a pressure washer. But since there was no available equipment and too expensive to provide, a blender is used for preparing slurry. It took a lot of time to provide ample amount of drained slurry for every specimen to make.

Specimens were designed into two batch of mix proportion. Paper to cement mixture, then paper to cement mixture with baseline of 10% of sand. Mix together and compressed well into different forms provided from scrap ply boards. After 28 days of curing, specimens' dimensions and weight were recorded in preparation for various tests. Broken samples from flexural test are sawn to cubical specimen for compressive strength test. The other half has been submerged into water for observation and compression also. Tile samples for preliminary test have dimensions of 6" x 6" x 1/8" subjected for observation, surface abuse test, and nail through and pull test.

From preliminary test results, mixture that best suited for a panel is accepted to provide specimen for flexural test. It is then evaluated if the mix proportion and the use of paper in developing Flat Fibre-cement Panel is feasible. Evaluation is also conducted for the material in use for bricks or blocks for building walls.

An illustration of this research development is shown in Figure 3.

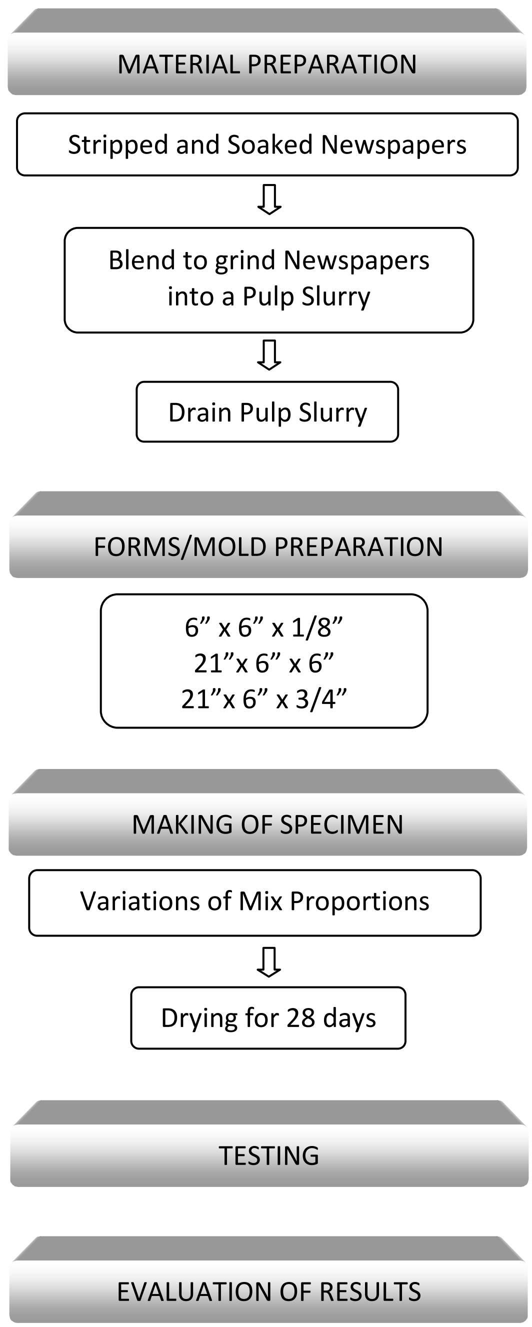

Figure 3. Research Development

<u>Operation and Testing Procedures</u>

This illustrates operation and procedures for tests conducted for this research. Laboratory Tests conforms to ASTM as suited to the available equipment.

I. Material Preparation

A. Slurry Production

<u>Materials / Apparatus:</u>

Newspapers

Blender

<u>Procedure:</u>

1. Strip newspapers to soak in water for 3 days or at least overnight.
2. Grind soaked newspapers into slurry by using a blender.

B. Forms

<u>Materials:</u>

Scrap ply boards

Hammer & nails

Steel tape

<u>Procedures:</u>

From scrap ply boards, form moulds for every specimen to be used for several tests. (21”x6”x6” rectangular forms; 6”x6”x3/4” or 1/8” tile forms; 3’x1.5’x3/4” and ¼” panel forms)

C. Making the Specimen

MIX PROPORTIONS OF SPECIMEN BY PERCENTAGE / VOLUME

Table 1. First Batch Mix Proportions

PAPER		**CEMENT**	
40%	2	60%	3
50%	1	50%	1
60%	1 1/2	40%	1
70%	1 3/4	30%	3/4
80%	2	20%	1/2

Table 2. Second Batch Mix Proportions

PAPER		**CEMENT**		**SAND**	
40%	2	50%	2 1/2	10%	1/2
50%	2 1/2	40%	2	10%	1/2
60%	3	30%	1 1/2	10%	1/2
70%	3 1/2	20%	1	10%	1/2
80%	4	10%	1/2	10%	1/2

Materials / Tools:

Pulp slurry (Paper) | Forms/Molds | Pail

Cement | Shovel or Trowel | Weight Scale

Sand (Vista) | Plastering tool | Tamping Rod

Procedures:

1. Measure amounts of pulp slurry, cement and sand to be mixed for each mix proportions.
2. A measured amount for a specimen is then mixed, adding water to make the mixture workable.
3. Pour the mixture into forms.

4. Rod each layer, from bottom layer throughout its entire depth. Distribute the strokes uniformly across the cross section of the mold ensuring that mixture is well compressed.
5. Trowel off top surface, flush with top of mold to finish. Then dry for 28 days.

II. Water Absorption / Moisture Content

This test is made to determine the tendency of the mixture to absorb water and uniformity of the product.

Procedure:

1. Prepare mix proportion of specimen.
2. A measured amount for specimen is then mixed and weighed.
3. Dry specimen for 48 $\pm$ 8 h and weigh on a scale of an accuracy of 0.5% of specimen mass.

Calculation and Report:

Water absorption, mass% = [(Ws – Wd)/Wd] x 100

(Source: ASTM C1186 – 91, Standard Specification for Flat Non-Asbestos Fiber cement Sheets. Vol. 04.05 Fiber Cement Products, 1984)

III. Density Test

The uniformity of density results are used for quality control assurance.

Procedure:

1. Prepare test specimen from the flexural test or a specimen of equivalent dimension
2. Determine volume of the specimen by any method capable of giving a result accurate within 2% of the results obtained by water displacement method.

3. Determine the mass by drying out the test specimen until the difference between two consecutive weighings, at intervals not less than two hours, is less than 0.1% by mass.

Calculation and Report:

Calculate and report the density of the specimen in kilograms per cubic meter (kg/m^3) using the equations:

Density = W / V

Where:

W = dry mass of specimen, Kg

V = volume, m^3

(Source: ASTM C1186 – 91, Standard Specification for Flat Non-Asbestos Fiber cement Sheets. Vol. 04.05 Fiber Cement Products, 1984)

IV. Flexural Strength Test

This method gives the flexural properties, principally strength and stiffness, of structural panels. These properties are of primary importance in most structural uses of panels whether in construction for floors, wall sheathing, roof decking, concrete form, or various space plane structures.

Apparatus:

Universal Testing Machine

Procedure:

1. *Preparation of Test specimens, (Flat Sheets)* – Cut a pair of specimens, each 6 ± 1/16 in. (152 ± 1.6 mm) in width and 12 ± 1/16 in. (305 ± 1.6 mm) in length, from the interior area of each sample sheet in such a manner that no edge of specimen is less that 3 in. (76 mm) from the original edges of the sheet. The longer dimension of one of the

specimens of each pair shall be parallel to the length of the sheet (that is, parallel with the fiber lay), and the other shall be at right angles to it.

Preparation of Test specimens, (Roofing Shingles, Siding Shingles and Clapboards) – Cut a single specimen 6 ± 1/16 in. (152 ± 1.6 mm) in width and 12 ± 1/16 in. (305 ± 1.6 mm) in length from each unit. Cut one half of the specimens in such a manner that the 12 in. (305 mm) dimension of each specimen is parallel to one edge of the shingle or clapboard unit; cut half of the specimens at right angles thereto.

Note: Alternate test specimen dimensions and span may be used provided that the ratio of the test span to specimen thickness is not less than 18, and that the actual span used be reported.

2. Determine flexural strength of each specimen by placing the underside of the specimen on supports that cannot exert longitudinal constraints [rocker-type bearing edges, rollers, etc. with a 1/8 in (3.2 mm) minimum radius and a ½ in. (12.7 mm) maximum radius and apply the load at mid-span through a similar edge bearing against the finished surface of the specimen. The test span shall be 10 ± 1/16 in. (254 ± 1.6 mm) and the load line and support shall be parallel.
3. Increase the load until result in failure of the specimen between five and thirty seconds.

Calculation and Report:

Calculate flexural strength of specimen by the following equation:

$$R = 3\,PL / 2\,bd^2$$

Where: R = flexural strength, MPa

P = maximum load, N

L = length of span, mm

b = width of specimen, mm

d = average thickness, mm

The average flexural strength of the specimen pair shall be the arithmetic mean value of each pair.

Table 3

FLEXURAL STRENGTH REQUIREMENT FOR FLAT NON-ASBESTOS FIBER-CEMENT SHEETS

Grade	Wet Strength, psi (MPa) min	Equilibrium Strength, psi (MPa) min
I	580 (4)	580 (4)
II	1015 (7)	1450 (10)
III	1885 (13)	2320 (16)
IV	2610 (18)	3190 (22)

(Source: ASTM C1186 – 91, Standard Specification for Flat Non-Asbestos Fiber cement Sheets. Vol. 04.05 Fiber Cement Products, 1984)

V. Compression Test

Compressive strength is a measure of the concrete's ability to resist loads which tend to crush it.

Test Specimen:

Saw broken samples of flexural test for a 6" x 6" x 21" in. specimen into cubical specimen having 6" x 6" x 6" in. dimension.

Apparatus:

Universal Testing Machine

Procedure:

1. Center the specimen on the lower platen of the testing machine.

2. Carefully align the axis of the specimen with the center of thrust of the spherically seated upper platen.
3. Bring the upper platen to bear on the specimen, adjusting the load to obtain uniform seating of the specimen.
4. Apply the load at the prescribed loading rate until the specimen fails. Record the maximum load (KN). Note type of failure and appearance of specimen.

(Source: ASTM C1186 – 91, Standard Specification for Flat Non-Asbestos Fiber cement Sheets. Vol. 04.05 Fiber Cement Products, 1984)

VI. Surface Abuse Test

This test is made to determine resistance of specimen for impact or surface abuse.

Apparatus:

Supports: steel rollers, two, on a rigid base

Impact instrument: Tamping Rod (7.5 kg / 73.55 N)

Test Specimen:

Tile Samples of 6” x 6” x 1/8 – 3/4”

Procedure:

1. Test specimen by having a first drop of 1 in. (25 mm) using the tamping rod.
2. Increase drops by 1 in (25 mm) increments until a height of 10 in. (250 mm) is reached.
3. Then use a 2 in. (50 mm) increment until compete failure occurs or until a 6 in. (150 mm) deflection is reached.

(Source: ASTM C1186 – 91, Standard Specification for Flat Non-Asbestos Fiber cement Sheets. Vol. 04.05 Fiber Cement Products, 1984)

CHAPTER IV

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

In this chapter, presents the data gathered from the experimentation. All data presented represents mix proportions that passed preliminary testing from tile samples of 6” x 6” x 1/8” – ¾” as shown in Table 4. Preliminary test includes observation of texture and characteristic of each designed mix proportions; nail through and pull test; and test for resistance in impact or surface abuse. The results were able to determine the optimum mix that resulted in the development of a functional Fibre-cement from waste paper.

Table 4. PRELIMINARY TEST

MIX PROPORTIONS	OBSERVATION	NAIL THROUGH / PULL TEST	SURFACE ABUSE TEST
Paper-Cement Ratio 1:1 ½ (40% - 60%)	powdery and flaky, rigid, non resistant to termites	dusty, just like wood when nailed	slightly scratched
1:1 (50% - 50%)	powdery and flaky, rigid, non resistant to termites	dusty, just like wood when nailed	slightly scratched
1 ½:1 (60%-40%)	powdery and flaky, rigid, non resistant to termites	Cracks and breaks	easily scratched
1 ¾:3/4 (70%-30%) 2 : ½ (80%-20%)	powdery and flaky, rigid, non resistant to termites	Easily breaks	easily scratched

Continued…

MIX PROPORTIONS	OBSERVATION	NAIL THROUGH / PULL TEST	SURFACE ABUSE TEST
Paper-Cement-Sand Ratio 2 : 2 ½ : ½ (40%-50%-10%)	Flaky, dusty, hard	Marks surface with a hole, flakes up the surface when pulled	Hardly dented
2 ½ : 2 : ½ (50%-40%-10%)	Flaky, dusty, hard	Marks surface with a hole, flakes up the surface when pulled	Slightly scratched
3 : 1 ½ : ½ (60%-30%-10%)	Flaky, dusty, moderately hard	Marks surface with a hole, flakes up the surface when pulled	Slightly scratched
3 ½ : 1 : ½ (70%-20%-10%)	Flaky, dusty, easily breaks	Cracks when nailed	Easily scratched
4 : ½ : ½ (80%-10%-10%)	Flaky, dusty, easily breaks	Cracks when nailed	Easily scratched

Table 5 shows the variation of water content of the fiber cement product using waste paper for ratio of 3: 1 ½: ½ and 2 ½:2:1/2 paper-cement-sand mixture. It proves here that paper absorbs as much water like sponge and yet exudes the water it soaked up.

Table 5. WATER ABSORPTION / MOISTURE CONTENT

FOR MIX PROPROTIONS OF PAPER-CEMENT-SAND

MIX PROPORTION **Paper:Cement: Sand**	**3 : 1 ½ : ½** **60% : 30% : 10%**	**2 ½ : 2 : ½** **50% : 40% : 10%**
Wet Mixture, g	114.2	112.9
Dry Mixture, g	61.3	77.2
Water content, w%	86.3	46.24

Table 6 shows the mass per unit volume of different mix proportions of paper-cement-sand, having ratio of 3:1 ½:1/2; 2 ½:2:1/2; and 2:2 ½:1/2 expressed in kilograms per cubic meter (kg.m^3). Data's were taken from rectangular specimen having dimension of 21"x6"x6".

Table 6. DENSITY FOR MIX PROPROTIONS OF PAPER-CEMENT-SAND

MIX PROPORTION **Paper: Cement: Sand**	**3 : 1 ½ : ½** **60% : 30% : 10%**	**2 ½ : 2 : ½** **50% : 40% : 10%**	**2 : 2 ½ : ½** **40% : 50% : 10%**
Weight, kg	1.75	1.9	3.5
Length, in.	21	21	21
Width, in.	6	6	6
Height, in.	¾	¾	¾
Volume, m^3	2.4	2.4	2.4
Density, kg/ m^3	0.73	0.79	1.09

Table 7 presents results from Flexural Strength Test of specimen having 21"x6"3/4", showing the average breaking load obtained by loading equally and simultaneously at both one third points of the test span.

Table 7. FLEXURAL STRENGTH TEST (FLAT SHEET FIBRE-CEMENT)

Sample Specimen	*(Paper - Cement - Sand)*		
	3 : 1 1/2 : 1/2	2 1/2 : 2 : 1/2	2 : 2 1/2 : 1/2
	60% - 30% - 10%	50% - 40% - 10%	40% - 50% - 10%
Date of Mixture	21-Sep-08	21-Sep-08	21-Sep-08
Date of Test	25-Sep-08	25-Sep-08	25-Sep-08
Concrete Age Tested, in days	4	4	4
Cure History	exposed to open air		
Width, b (in.)	6	6	6
Height, d (in.)	3/4	3/4	1
Length, L (in.)	21	21	21
Maximum Applied Load, P (in Kg)	6	22	40
(N)	58.86	215.82	392.4
Flexural Strength, $S = 3PL/2\ bd^2$	0.85	3.12	3.19

From test results presented in Table 7 for sample specimen with different mix proportions of Paper-cement-sand were illustrated in Figure 4 showing the range of its flexural strength.

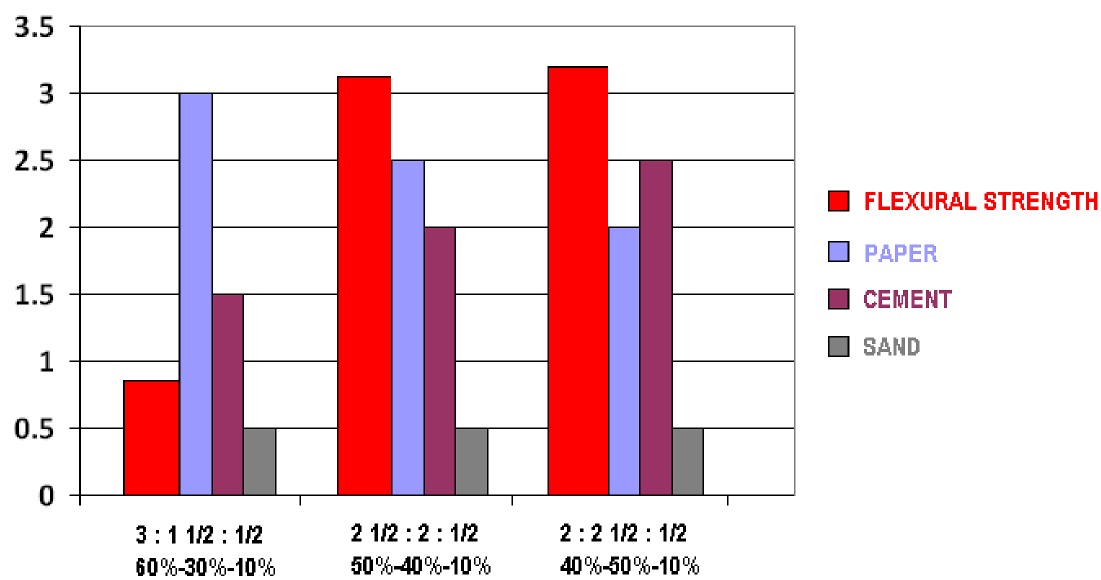

Figure 4. FLEXURAL STRENGTH TEST (Flat Sheet Fibre-Cement)

Table 8. FLEXURAL STRENGTH TEST (Rectangular specimen 21"x6"x6")

Sample Specimen	*(Paper - Cement)*				*(Paper - Cement - 10% Sand)*				
	2 : 1/2 80%- 20%	1 3/4 : 3/4 70% - 30%	1 1/2 : 1 60% - 40%	1 : 1 50% - 50%	4 : 1/2 : 1/2 80% - 10%- 10%	3 1/2 : 1 : 1/2 70% - 20% - 10%	3 : 1 1/2 : 1/2 60% - 30% - 10%	2 1/2 : 2 : 1/2 50% - 40% - 10%	2 : 2 1/2 : 1/2 40% - 50% - 10%
Date of Mixture	27-Jul-08	27-Jul-08	27-Jul-08	26-Jul-08	21-Jul-08	21-Jul-08	21-Jul-08	26-Jul-08	10-Aug-08
Date of Test	2-Sep-08	2-Sep-08	2-Sep-08	2-Sep-08	2-Sep-08	2-Sep-08	2-Sep-08	16-Sep-08	16-Sep-08
Concrete Age Tested, in days	36	36	36	37	42	42	42	51	36
Cure History	air dry								
Width, w in mm	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
Height, h in mm	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
Length, L in mm	533.4	533.4	533.4	533.4	533.4	533.4	533.4	533.4	533.4
Cross-sectional Area, L x w in mm^2	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16
Weight, Kg	9	10.4	12	13.2	15.2	14.6	16	13.6	14.5
Maximum Applied Load, P in KN	9.75	10.04	11	12.37	12.78	13.47	13.21	11.6	10.77
Flexural Strength, S = P/A in MPa	0.120	0.124	0.135	0.152	0.157	0.166	0.163	0.143	0.132

Table 8 shows flexural strength test results for rectangular specimen 21"x6"x6" having series of mix proportions of paper-cement and paper-cement-sand. Thus represents highest stress experienced within each specimen at its moment rupture.

Table 9. COMPRESSIVE STRENGTH TEST (Cubical specimen 6”x6”x6”)

Sample Specimen	*(Paper - Cement)*				*(Paper - Cement - 10% Sand)*				
	2 : 1/2	1 3/4 : 3/4	1 1/2 : 1	1 : 1	4 : 1/2 : 1/2	3 1/2 : 1 : 1/2	3 : 1 1/2 : 1/2	2 1/2 : 2 : 1/2	2 : 2 1/2 : 1/2
	80%- 20%	70% - 30%	60% - 40%	50% - 50%	80% - 10%- 10%	70% - 20% - 10%	60% - 30% - 10%	50% - 40% - 10%	40% - 50% - 10%
Date of Mixture	27-Jul-08	27-Jul-08	27-Jul-08	26-Jul-08	21-Jul-08	21-Jul-08	21-Jul-08	26-Jul-08	10-Aug-08
Date of Test	2-Sep-08	16-Sep-08	26-Sep-08	2-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08
Concrete Age Tested, in days	36	50	60	37	66	66	66	61	46
Cure History	air dry								
Width, w	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
Height, h	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
Length, L	533.4	533.4	533.4	533.4	533.4	533.4	533.4	533.4	533.4
Cross-sectional Area, L x w	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16
Weight, kg	2.98	2.15	3.4	3.6	4.4	4	4.5	4	4
Maximum Applied Load, P	66.08	61.86	45.98	68.6	63.62	51.24	62.59	50.33	77.53
Compressive Strength, MPa	3.060	2.75	2.11	2.990	2.81	2.25	2.78	2.18	3.45

Table 9 represents Compression test results of different variations of mix proportions of paper-cement and paper-cement-sand. This shows the compressive strength of each designed mixture of a cubical specimen subjected to air drying only.

Table 10. **COMPRESSIVE STRENGTH TEST (Cubical specimen 6"x6"x6")**

Sample Specimen	*(Paper - Cement)*				*(Paper - Cement - 10% Sand)*				
	2 : 1/2	1 3/4 : 3/4	1 1/2 : 1	1 : 1	4 : 1/2 : 1/2	3 1/2 : 1 : 1/2	3 : 1 1/2 : 1/2	2 1/2 : 2 : 1/2	2 : 2 1/2 : 1/2
	80%- 20%	70% - 30%	60% - 40%	50% - 50%	80% - 10%- 10%	70% - 20% - 10%	60% - 30% - 10%	50% - 40% - 10%	40% - 50% - 10%
Date of Mixture	27-Jul-08	27-Jul-08	27-Jul-08	26-Jul-08	21-Jul-08	21-Jul-08	21-Jul-08	26-Jul-08	10-Aug-08
Date of Test	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08	26-Sep-08
Concrete Age Tested, in days	60	60	60	61	66	66	66	61	46
Cure History	submerged to water								
Width, w	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
Height, h	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
Length, L	533.4	533.4	533.4	533.4	533.4	533.4	533.4	533.4	533.4
Cross-sectional Area, L x w	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16	81290.16
Weight, kg	4	3.95	4.4	5	5.4	5.4	5.4	5.1	5
Maximum Applied Load, P	26.39	18.84	36.33	65	53.82	44.71	54.88	34.36	45.98
Compressive Strength, MPa	1.16	0.83	1.6	2.87	2.3	1.96	2.44	1.47	2.11

Table 10 represents Compression test results of different variations of mix proportions of paper-cement and paper-cement-sand. This shows the compressive strength of each designed mixture of a cubical specimen submerged in the water.

CHAPTER V

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Findings

From gathered data's of the conducted test for classification and investigation of mix proportions of paper, cement and sand to alternate Fiber-cement are the following:

1. As base from the physical requirement test result for flexural strength did not conform to the Standard Specification for Flat Asbestos-Cement Sheets as stated in the ASTM C220 – 91. However, a suitable application can be practical for plasterworks, ornamentation, decorative moldings on ceiling and walls. But if desired to apply for a wall panel, a building blocks or bricks should be used.

2. The optimum proportion for the mixture is 40% paper, 50% cement and 10% sand, this ratio is obtained in terms of volume and has been accepted from the preliminary tests and had shown utmost strength test result in comparison with other mix proportions.

3. The addition of sand and greater amount of cement makes the mixture more abrasive resistant, stiff, hard or rigid and termite resistant yet slows down drying time and more denser.

4. Fabrication of this material requires ample amount of pulp slurry and fibers from waste paper must be extracted at its finest. For this reason, a well-bonded composite of paper, cement and sand is fabricated. Thus, a mixer shall be provided or improvised but the research conducted had only used a blender since stability and viability of the mixture with

respect to its application is only being covered for the study. But as to its cost advantages and its practicality in comparison with the other materials used for decorative moldings, only with the availability of the equipment, since commercialized molding in the country has been religiously used, its cost might seem lesser in value.

Conclusions

The result of the experiments shows the following conclusion:

1. Waste paper product in mixture with cement and sand is a recommendable additive for decorative moldings on ceilings and walls. Mix proportion can be 60% paper; 30% cement and 10% sand; 50% paper; 40% cement and 10% sand and 40% paper; 50% cement and 10% sand.

2. Sufficient amount of pulp slurry is needed in the mix, therefore a designed mixer shall be improvised to extract most fibers of waste papers and be well mixed with sand and cement. A blender will not be able to come up the amount of pulp slurry for massive production.

3. Use of waste papers which are largely produced almost everywhere will greatly benefit the environment by reducing paper waste materials and the community by providing a lesser cost of material that they can provide by themselves as a do-it-yourself project.

4. Since the design of the design of mix proportions focused only to paper-cement-sand, using cement only as binder while sand as an additive. And like any other mixture with variation of mix proportion of paper to cement, admixtures and curing procedures results in

tradeoffs in its properties. Best mixture is the one which best fits the application hence; this study is completely experimental to test other available additives in mixture of different proportions of paper and cement. Borax or chalk can be an alternative for 10% sand.

Recommendations

Based from the findings and conclusions stated, the following are suggestion for recommendations:

1. Molds for fabrication must be designed to provide a composite, well bonded and well finished at its surface. Molds or forms must be made not of wood but rather from metal, a steel channel could be used.

2. An equipment to be used must be improvised, such as a mixer with a blade at the bottom to grind waste paper into slurry for a well mixed product.

3. After the specimen or samples are set and dry, remove it from molds and daily sprinkle with water for a curing of 28 days. A can with fine holes at the bottom can be used as sprinkler.

4. For future study, a test for resistance to decay and insects, acoustical properties, and thermal insulating properties must be established.

5. A further study must be conducted to develop a mix design to meet the Standard Specification for Flat Non-Asbestos Fiber cement Sheet, Roofing and Siding Shingles, and Clapboards.

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http://www.papercreters.com/

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http://www.livinginpaper.com/

Kelly & Rosana Hart - DREAM GREEN HOMES Your Source for Alternative Home Plans:

http://www.dreamgreenhomes.com/

http://www.greenhomebuilding.com/

Kat Ehrhorn - EARTH DOME

http://www.domes.blogspot.com/

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http://www.oikos.com/library/papercrete/fibrous.html

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By Gordon Solberg

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http://products.construction.com/portal/server.pt/gateway/PTARGS_0_2_493_204_249_43/http%3B/205.142.52.224/swts_content_files/151414/223420.pdf

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By Dr D E Gooding and Dr T H Thomas

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APPENDIX A

LETTER OF REQUEST

APPENDIX B

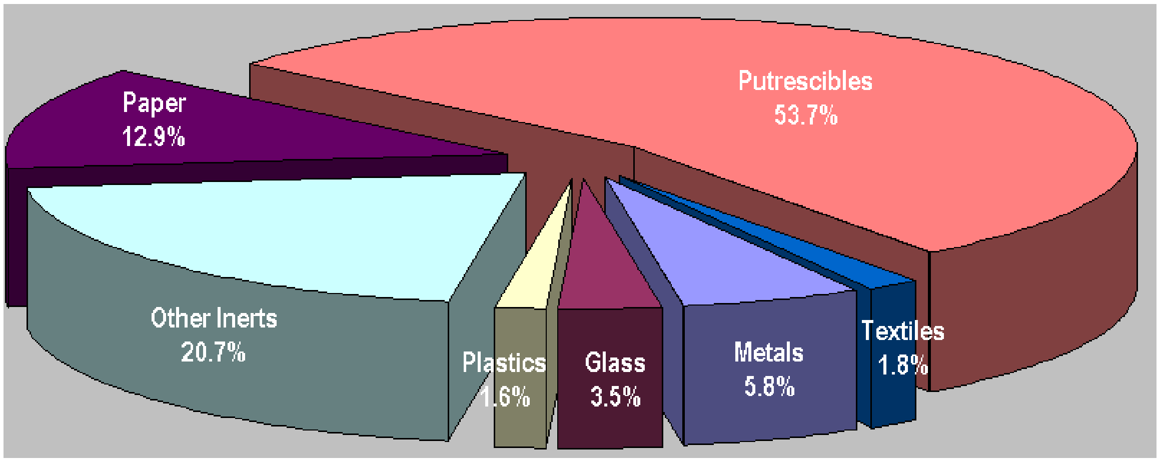
ASTM PROCEDURES

APPENDIX C

CONSULTATIONS W/ PAPERCRETERS

APPENDIX D

PHOTO GALLERY

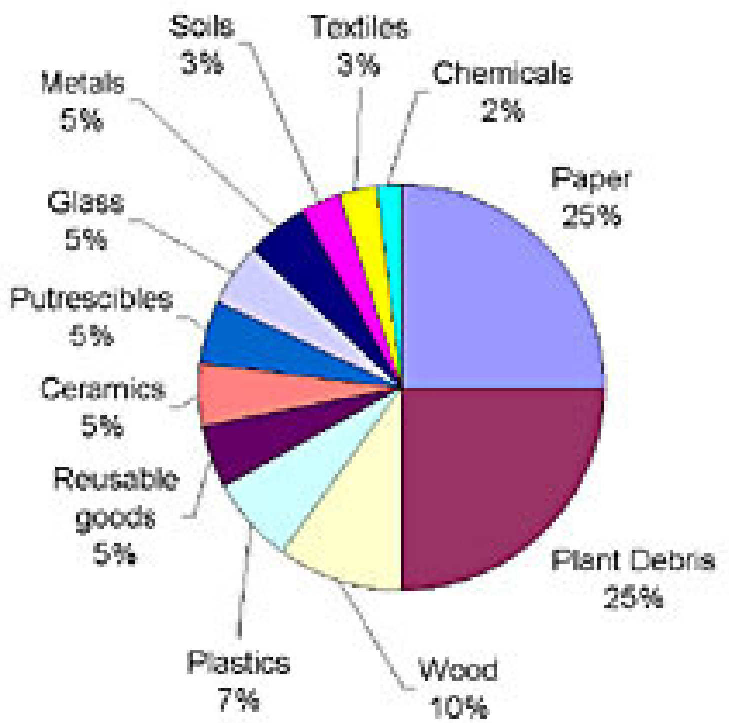


Composition of Solid Waste in Manila

(http://www.environcorp.com/img/media/SWM_Philippines_Paper.pdf)

Percentage of Recyclables in Discards

- 25% Paper
- 25% Plant Debris
- 10 % Wood
- 7% Plastics
- 5% Reusable goods
- 5% Ceramics
- 5% Putrescibles
- 5% Glass
- 5% Metals
- 3% Soils
- 3% Textiles
- 2% Chemicals



Excerpted from Total Recycling: Realistic Ways to Approach the Ideal.

(http://www.grrn.org/zerowaste/twelve_categories.html)

MATERIAL PREPARATION












SLURRY PRODUCTION

FORMS

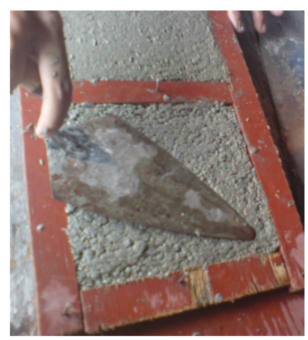
 

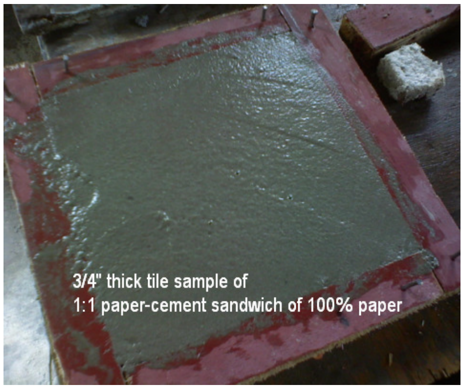
SAMPLE PREPARATION

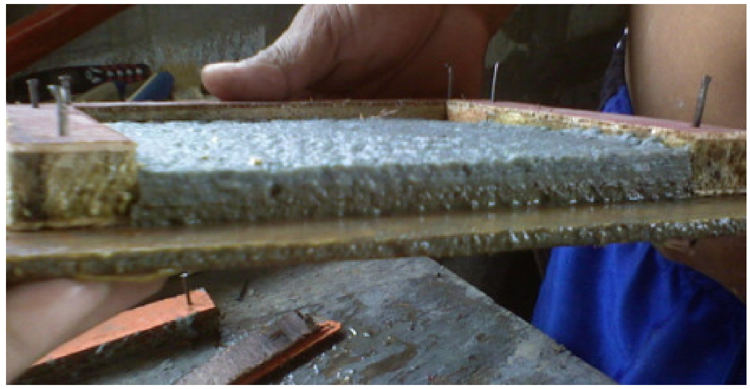


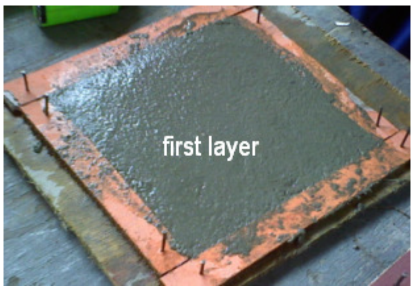






3/4" thick tile sample of
1:1 paper-cement sandwich of 100% paper

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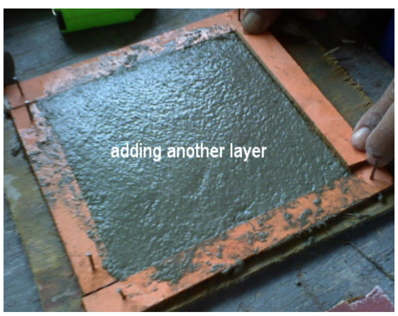
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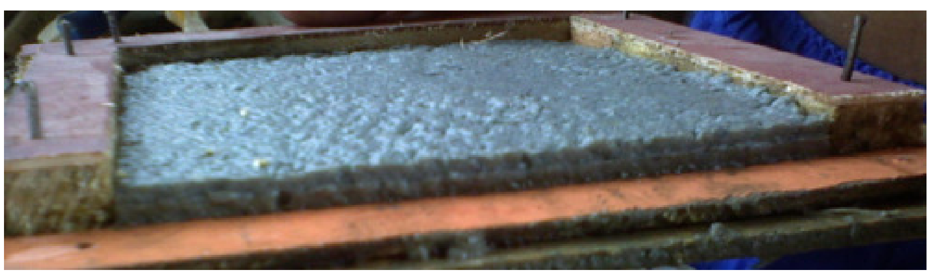

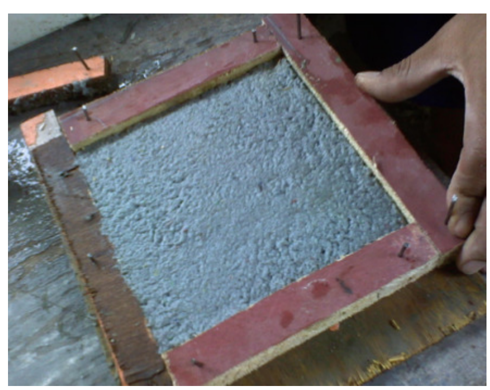


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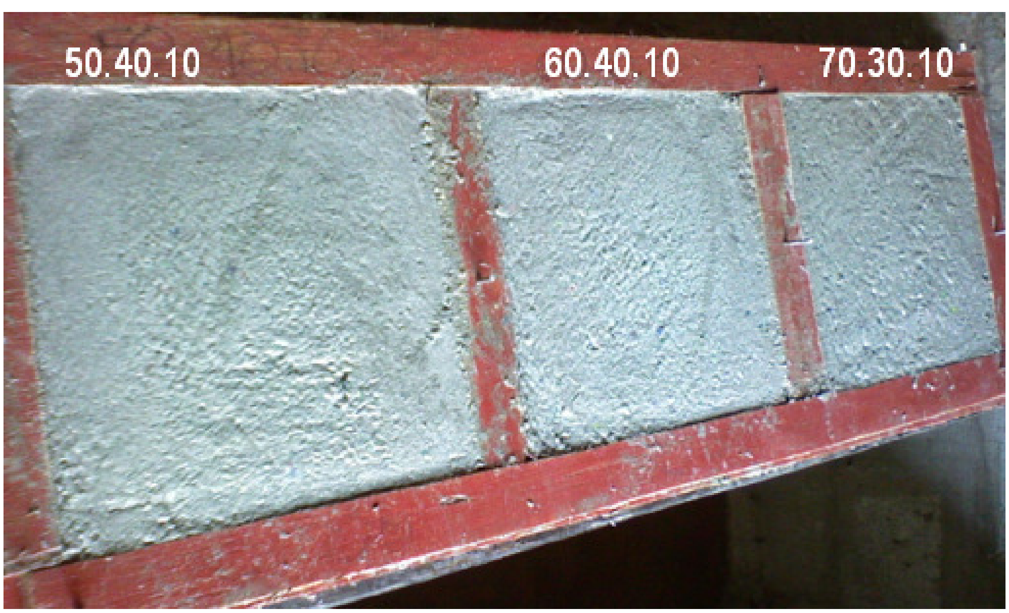
7:3


8.2
5.4.1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60.40.10
70.30.10


50% PAPER
50% CEMNT


50% PAPER
50% CEMNT


50% PAPER


50% PAPER
50% CEMENT

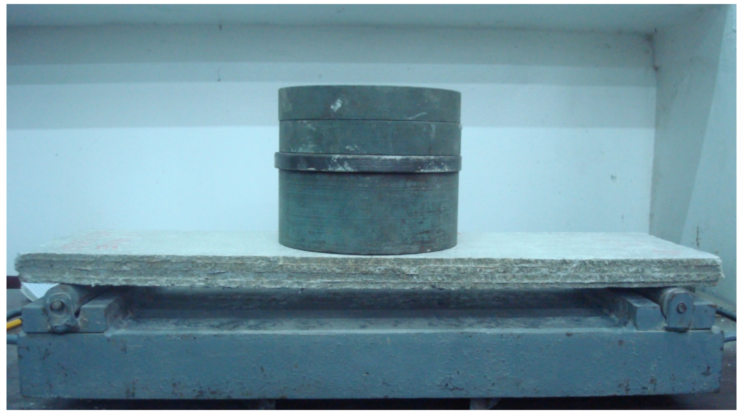

40.40.20
50.40.10
40.50.10







TEST PROCEDURES

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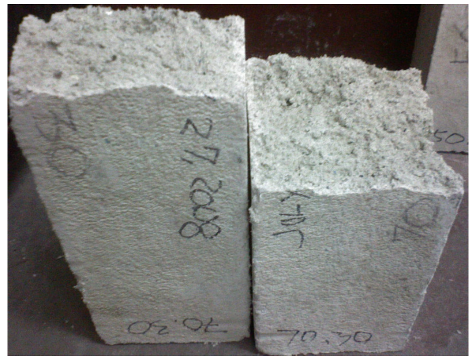
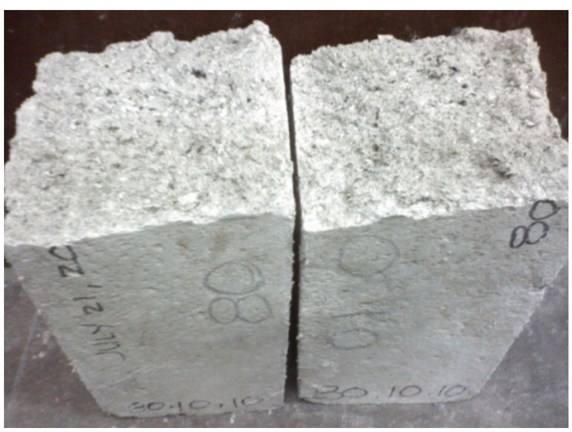
TEST SPECIMEN

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JULY 21
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JULY 21, 2008
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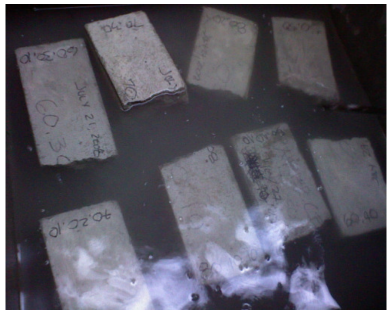


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60.40.10


60.40

APPENDIX E

CURRICULUM VITAE

JENNYLYN BRACERO ABENOJAR

B39 L3 Marjoram St. Robinsons Homes East, Antipolo City
jenabenojar@yahoo.com
639-4021 | 0908-6883788

EDUCATIONAL BACKGROUND:

College Education:	Technological Institute of the Philippines, TIP Bachelor of Science in Civil Engineering #938 Aurora Blvd., Cubao, Quezon City 2002 – 2008
	Rizal Technological Institute of the Philippines, RTU Bachelor of Science in Chemistry Boni, Mandaluyong City 2000 - 2002
Secondary Education:	Antipolo Lady of Lourdes School, ALLS Circumferential Road, Antipolo City 1998 – 2000
	Our Lady of Perpetual Help School, OLPHS (Kiddie) Santolan, Pasig City 1997 - 1998
	Roosevelt Memorial High Scholl, RMHS 10TH Avenue, Cubao, Quezon City 1996 - 1997
Primary Education:	Belarmino Elementary School Proj. 4, Quezon City 1991 – 1996

TRAININGS & SEMINARS ATTENDED:

Computer Aided Drafting
Dec 2007 – Mar 2008

RoomWorX Computer Assistant
July 2005 - 2006

PERSONAL DATA:

Nickname:	Jen-jen, Jenny
Sex:	Female
Date of Birth:	11 August 1983
Place of Birth:	Tacloban City
Age:	24
Civil Status:	Single
Weight:	110 lbs.
Height:	5' 4"
Nationality:	Filipino
Father's Name:	Engr. Romarico P. Abenojar
Mother's Name:	Lina B. Abenojar

BRIAN PALISOC ABARIENTOS
319 U.Vidanes St.,Quisao Pililla,Rizal
www.brianabarientos@yahoo.com

EDUCATIONAL BACKGROUND:

College Education:	Technological Institute of the Philippines, TIP #938 Aurora Blvd, Cubao, Quezon City Bachelor of Science in Civil Engineering 2001-2008
Secondary Education:	Tanay National High School Tanay, Rizal 1997-2000
Primary Education:	Quisao Elementary School Pililla, Rizal 1991-1996

TRAININGS & SEMINARS ATTENDED:

Philippine Institute of Civil Engineers
"SANITARY ENGINEERING: A Vital Component in a livable Environment"
Technological Institute of the Philippines, Quiapo, Manila
September 26, 2002

Technological Institute of The Philippines
Civil and Sanitary Engineering Students Educational Tour and Seminar
San Roque Power Corporation
San Miguel, Pangasinan
August 24, 2007

PERSONAL DATA:

Nickname:	Brian
Sex:	Male
Date of Birth:	April 27, 1983
Place of Birth:	Pililla, Rizal
Age:	22
Civil Status:	Married
Weight:	180 lbs.
Height:	5'4".
Nationality:	Filipino
Father's Name:	Celso G. Abarientos
Mother's Name:	Elsa P. Abarientos
Spouse:	Ana Marie Rizalyne P. Abarientos

KRYSTEL M. COLLANTE
50-A St. Mary St., Cubao, Quezon City
krystel_collante@yahoo.com.ph
0926-6709634

EDUCATIONAL BACKGROUND:

College Education:	Technological Institute of the Philippines, TIP Bachelor of Science in Civil Engineering #938 Aurora Blvd., Cubao, Quezon City 2003 – 2008
Secondary Education:	Tarlac College of Agriculture, Science Curriculum, TCA Romulo High Way, Camiling, Tarlac 1999 - 2003
Primary Education:	Cat-Nag Elementary School Catagudingan San Clemente, Tarlac 1993 – 1999

TRAININGS & SEMINARS ATTENDED:

Reinforced Concrete Works
February14, 2008

PERSONAL DATA:

Nickname:	Kryz, Kitel
Sex:	Female
Date of Birth:	17 March 1986
Place of Birth:	Tarlac City
Age:	22
Civil Status:	Single
Weight:	102 lbs.
Height:	5’ 6”
Nationality:	Filipino
Father’s Name:	Pedrito L. Collante
Mother’s Name:	Nancy M. Collante

BEN JHON P. PASIGA
#2160 Sitio matarik Camarin Caloocan City
bj_knightz018@yahoo.com
0928-7182911

EDUCATIONAL BACKGROUND:

College Education:	Technological Institute of the Philippines, TIP #938 Aurora Blvd, Cubao, Quezon City Bachelor of Science in Civil Engineering 2001-2008
Secondary Education:	Camarin High School Cadena de amor Area B.Camarin Caloocan City 1995-2000
Primary Education:	Camarin Elementary School Camarin Caloocan City, Metro Mnl. 1990-1996

TRAININGS & SEMINARS ATTENDED:

Reinforced Concrete Works
February14, 2008

PERSONAL DATA:

Nickname:	bj, banjo
Sex:	Male
Date of Birth:	January 18, 1982
Place of Birth:	Baao Camarines Sur
Age:	26
Civil Status:	Single
Weight:	140 lbs.
Height:	5'4”
Nationality:	Filipino
Father’s Name:	Ruben M. Pasiga
Mother’s Name:	Rosemarie P. Pasiga

JORGE G. THOMPSON, JR
39 C2 E Hermosa St. San Roque Pateros MM.
www.jjworld@yahoo.com
0921-9528165

EDUCATIONAL BACKGROUND:

College Education:	Technological Institute of the Philippines,TIP #938 Aurora Blvd, Cubao, Quezon City Bachelor of Science in Civil Engineering 2005-2008
Secondary Education:	Matnog National High School Gadgaron Matnog Sorsogon 1999-2003
Primary Education:	Matnog Central School Caloocan, Matnog, Sorsogon. 1993-1999

TRAININGS & SEMINARS ATTENDED:

Reinforced Concrete Works
February14, 2008

PERSONAL DATA:

Nickname:	JJ
Sex:	Male
Date of Birth:	January 14,1986
Place of Birth:	Naga Camarines Sur
Age:	22
Civil Status:	Single
Weight:	115 lbs.
Height:	5'6".
Nationality:	Filipino
Father's Name:	Jorge G. Thompson Sr.
Mother's Name:	Teresita G. Gabelo

KIEZEL ZACARIAS

11 B Concepcion Townhouse E. Santos St. Concepcion, Marikina City
freaky_kiezel@yahoo.com
0908-2059129

EDUCATIONAL BACKGROUND:

College Education:	Technological Institute of the Philippines, TIP #938 Aurora Blvd, Cubao, Quezon City Bachelor of Science in Civil Engineering 2003-2009
Secondary Education:	Regent Christian Academy Marikina City 1998-2002
Primary Education:	Richland Montessori School Quezon City 1992-1998

TRAININGS & SEMINARS ATTENDED:

Reinforced Concrete Works
February14, 2008

PERSONAL DATA:

Nickname:	Khaye
Sex:	Female
Date of Birth:	Dec. 4, 1985
Place of Birth:	Manila
Age:	22
Civil Status:	Single
Weight:	120 lbs.
Height:	5’6”
Nationality:	Filipino
Father’s Name:	Engr. Ricardo Zacarias
Mother’s Name:	Ma. Isabel Zacarias