UTILIZATION OF CRUMB RUBBER TIRE AND RICE HULL FOR CONCRETE PAVING BLOCKS

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APPROVAL SHEET

In partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES (M.S.E.S.)**, this thesis entitled **"UTILIZATION OF CRUMB RUBBER TIRE AND RICE HULL FOR CONCRETE PAVING BLOCKS"**, has been prepared, examined, evaluated and submitted by **ENGR. JULIE CAFINO JUMAWAN**, who is hereby recommended for Oral Examination.

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ABSTRACT

This study intends to reuse the tires and rice hull as ingredients in the concrete mixture to produce a concrete paving blocks. The materials used in this study were the following: water, cement, sand, gravel, crumb rubber tire and rice hull. The instruments used were the concrete block molder, slump cone, tamping rod, sieves, weighing scale, thermometer, oven and Hydraulic Compressive Testing Machine. Concrete mixture used was 1:2:4 by weight and a water-cement ratio of 0.60. A total of four (4) mixtures were cast which consist of 0% replacement (control) and three (3) rubcrete mixtures replacing the sand with 2.5%, 5% and 7.5% of crumb rubber tire by weight. Rice hull was used as admixture which is 5% by weight of cement. Laboratory tests were conducted in determining the density, unit weight, water absorption, compressive and flexural strength of the concrete block. Test result indicates that among of these properties, only the water absorption and compressive strength are significant to each other. This means as the capacity of the concrete paver block to absorb water increases, its compressive strength decreases. It was concluded that the concrete paver blocks in this study can be used for pavement purposes for garage, parking area, patio, walkways, foot path, waiting sheds, gardens and other landscaping need in school and other public places. It can be used also for masonry wall, retaining wall, and other exterior or interior walls.

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CHAPTER I

THE PROBLEM AND ITS SCOPE

Introduction

One of today's major problems and which will continue to do so in the future is the environmental pollution due to rubber tire wastes. The biggest problem with disposing old tires is that they contain chemicals and heavy metals that leach into the environment as the tires break down. Some of these chemicals, according to the California Integrated Waste Management Board (1996) are carcinogenic and mutagenic (case cancer and gene mutations). Another major concern is the intrusion into groundwater, if toxic substance gets into any water in the soil and possibly transport them to other locations, will potentially harm any living organism that come in contact with the poisoned water. Some disposal sites have allowed old tires by burning them up, either by open or controlled combustion. These processes not only release harmful chemicals into the air, but they are also extremely dangerous that could affect ozone layers. These combustion sites put a health and safety risk not only to the environment, but to the workers as well.

Another valuable material to be used is rice hull or rice husk is an agricultural waste material that is produced all over the world. It is generated during milling and mostly used as a fuel in the boilers to produce energy through direct burning. About 75% of this husk is a volatile organic matter and the rest 25% of the weight of this husk gets converted into ash during the burning process and is known as rice hush ash (RHA). Normally, rice husk will be burned in open air or land fill but both approaches emit large quantity of carbon dioxide to the atmosphere which is a great threat to the environment. Burning the rice hull causes damage to the land and the surrounding area in which it is dumped.

In the advent of the Philippine Green Building Code, PD 1096 in adopting an environmental friendly building material while minimizing the negative impact on human health and the environment, this study intends to use crumb rubber tire and rice hull as ingredients in developing construction material for pavement. The researcher investigates the physical and mechanical properties of crumb rubber tires and rice hull in concrete paving block mixtures through laboratory testing.

Theoretical Background

This research is based upon the theories of Hooke's Law and Mohr-Coulomb Theory. The modern theory of elastic generalizes Hooke's Law that the strain (deformation) of an elastic object or material is proportional to the stress applied to it. Mohr-Coulomb Theory is a mathematical model describing the response of brittle material such as concrete, or rubber piles, to shear stress as well as normal stress.

Theoretical Framework of the Study

This study is anchored on the strength and failure of the materials as shown in Figure 1.

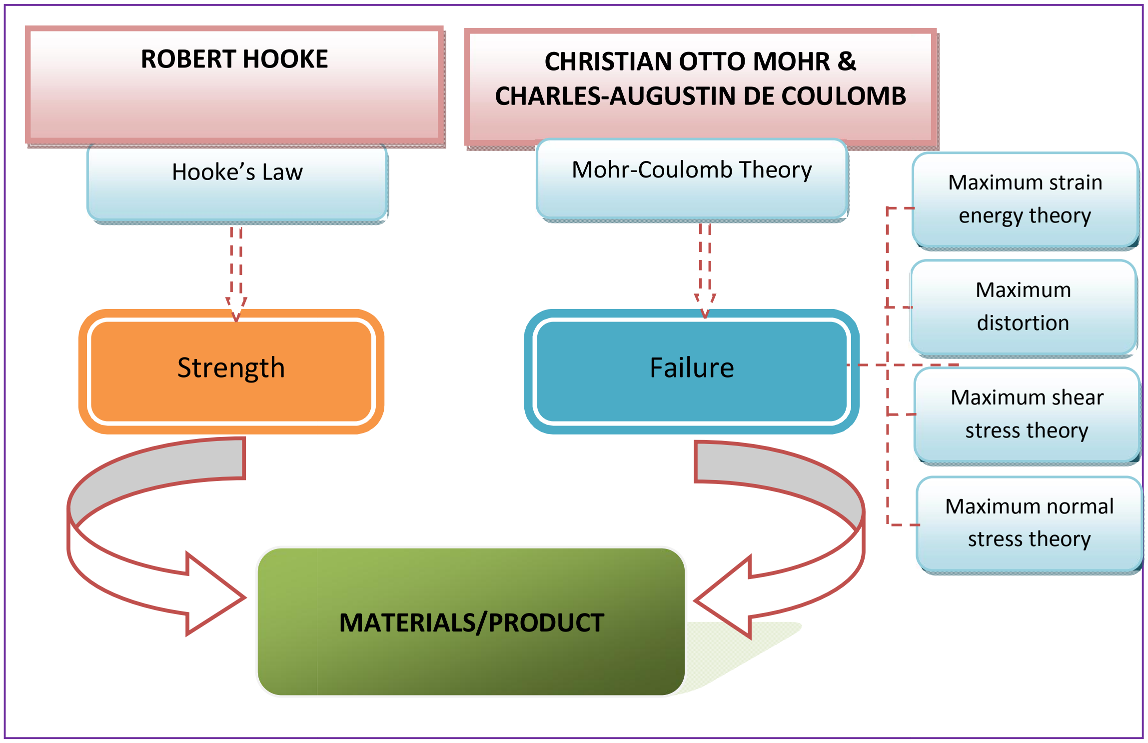

Figure 1. Theoretical Framework of the Study

The strength of materials refers to the ability of the material to withstand an applied load without failure or plastic deformation. Stresses are the load applied to a mechanical member which induces internal forces within the member. The stresses acting on the material cause deformation of the material in various manners. Strain is the deformation of the material. The applied loads may be axial (tensile or compressive), or rotational (strength shear). The strength of a material is not the only criterion that must be considered in designing structures. To a lesser degree, such properties as hardness, toughness, ductility determines the selection of a material. These properties are determined by making tests on the materials and comparing the results with established standards. To assess the load capacity of the structural member, the stresses and strains that develop within a mechanical member must be calculated. The relationship of stress-strain was first postulated by Robert Hooke in 1678, that stress is proportional to strain (Hooke's Law). But this proportionality will end at the proportional limit. Beyond this point, the stress is no longer proportionality to the strain. This assumption places an upper limit on the usable stress a material may carry (Singer and Pytel, 1987).

In structural engineering, Mohr-Coulomb Theory used to determine failure load in brittle materials such as concrete and similar materials. The Mohr–Coulomb theory is named in honor of Charles-Augustin de Coulomb and Christian Otto Mohr. Failure means either yielding (resulting in excessive permanent deformation) or actual rupture, whichever occurs first. Various theories of failure have been proposed, from the behavior of a material subjected to simple tension or compression tests, the point at which failure will occur under any type of combine loading.

There are four failure load theories: maximum shear stress theory, maximum normal stress theory, maximum strain energy theory, and maximum distortion energy theory. Out of these four theories of failure, the maximum normal stress theory is only applicable for brittle materials, and the remaining three theories are applicable for ductile materials. Of the latter three, the distortion energy theory provides most accurate results in majority of the stress conditions.

Maximum shear stress theory postulates that failure will occur if the magnitude of the maximum shear stress in the part exceeds the shear strength of the material determined from uniaxial testing. Maximum normal stress theory, on the other hand, proposes that failure will occur if the maximum normal stress in the part exceeds the ultimate tensile stress of the material as determined from uniaxial testing. For brittle materials, the maximum tensile stress should be less than or equal to ultimate tensile stress divided by factor of safety. The magnitude of the maximum compressive stress should be less than ultimate compressive stress divided by factor of safety.

Meanwhile, the maximum strain energy theory states that the failure will occur when the strain energy per unit volume due to the applied stresses in a part equals the strain energy per unit volume at the yield point in uniaxial testing. Likewise, the maximum distortion energy theory implies that failure will occur when the distortion energy per unit volume due to the applied stresses in a part equals the distortion energy per unit volume at the yield point in uniaxial testing. The total elastic energy due to strain can be divided into two parts: one part causes change in volume, and the other part causes change in shape. Distortion energy is the amount of energy that is needed to change the shape (Singer and Pytel, 1987).

Review of Related Literature

The researcher gathered the following information from both local and foreign sources which are relevant to this research study.

Green Building Code

Green Building Code which is a referral code of the PD 1096 otherwise known as the National Building Code of the Philippines as the concept of adopting measures and practices that promote resource management efficiency and location sustainability while minimizing the negative impact of buildings on human health and the environment. Proper and careful selection of environmentally sustainable building materials is the easiest way for architects, engineers, planners to begin incorporating sustainable design principles in buildings.

Concrete blocks

Small Industries Services Institute Manual, 2003 defines cement concrete paving blocks as precast solid products made out of cement concrete. The product is made in various sizes and shapes viz. rectangular, square and round blocks of different dimensions with designs for interlocking of adjacent blocks. The raw materials required for manufacture of the product are portland cement and aggregates which are available locally in every part of the country.

Cement concrete paving blocks find applications in pavements, footpaths, gardens, passenger waiting sheds, bus-stops, industry and other public places. The product is commonly used in urban areas for the above applications. Hence, the unit may be set up in urban and semi-urban areas, near the market.

A lot of face-lift is being given to roads, and footpaths along the roadside. Concrete paving blocks are ideal materials on the footpaths for easy laying, better look and finish. The process of manufacture of cement concrete paving blocks involves the following steps: a) Proportioning b) Mixing c) Compacting d) Curing e) Drying. A concrete mix of 1:2:4 (cement: sand: stone chips) by volume may be used for cement concrete paving blocks with water to cement ratio of 0.62. The concrete mix should not be richer than 1:6 by volume of cement to combined aggregates before mixing. Fineness modules of combined aggregates should be in the range of 3.6 to 4.0. All the raw materials are placed in a concrete mixer and the mixer is rotated for 15 minutes. The prepared mix is discharged from the mixer and consumed in the next 30 minutes. Vibrating table may be used for compacting the concrete mix in the moulds of desired sizes and shapes. After compacting, the blocks are demoulded and kept for 24 hours in a shelter away from direct sun and winds. The blocks thus hardened are cured with water to permit complete moisturisation for 14 to 21 days. Water in the curing tanks is changed every 3 to 4 days. After curing, the blocks are dried in natural atmosphere and sent for use.

Rice Hull

Rice hull or husk is the outer covering of the rice grain which is removed during the process of milling. It constitutes 20 to 25% of the rice grain that is harvested from the field making it one of the most abundant agricultural residues of the country (Orge and Abon, 2012).

As long as rice remains to be the staple food of the Filipinos, rice hull, being the by product of milling, will be continuously produced in the country. In 2011, an estimated amount of 3.7 million metric tons of rice hull was generated based on the palay production data of the Bureau of Agricultural Statistics. At a heating value of 14 GJ/ton, this is equivalent to around 52 million GJ of energy or equivalent to 8.7 million barrels of oil. The energy obtained from agricultural residues like rice hull is a form of renewable energy and, in principle, utilizing this energy does not add carbon dioxide (a greenhouse gas) to the atmospheric environment, in contrast to fossil fuels. If not properly utilized, however, rice hull will create growing problems of space and pollution in the environment. The continuous pressure of producing more and more rice to feed the country's increasing population, coupled with the development and introduction of high yielding rice varieties and other yield-enhancing technologies, signals an increase in the amount of rice hull generated annually. Thus, it may worsen the disposal problem that most rice millers already experience. Aside from generating dust which causes respiratory problems and skin irritation, rice hull that are dumped in open fields and left to decompose generate methane which is a more potent greenhouse gas than carbon dioxide. Hence, finding ways that would help increase the use and value of rice hull is beneficial not only in terms of providing additional income opportunities for farmers but also in protecting our environment (Orge and Abon, 2012).

Belonio (2005) states that voluminous amount of rice husks can be found in areas predominantly in rice producing regions, such as the Central Luzon, Western Visayas, Bicol, Cagayan Valley, and Central Mindanao. About 2 million metric tons of rice husks (Table 1) are produced annually.

Table 1

Rice Husks Annual Production by Region

Region	Metric Tons
CAR	39,064
Ilocos	168,125
Cagayan Valley	203,793
Central Luzon	341, 191
Southern Tagalog	203, 504
Bicol	149, 098
Western Visayas	255,000
Central Visayas	38,004
Eastern Visayas	85,225
Western Mindanao	74,812
Northern Mindanao	78,019
Southern Mindanao	133,328
Central Mindanao	163,683

Many countries attempt to utilize rice hulls. To date the results have been partially successful. However, with changing conditions, new techniques and more intensive research, it is highly possible that uses for this waste product may yet be found that will turn a present liability into a future asset. It has been impossible to obtain any accurate figures on what percentage of the available hulls are at present being economically utilized, but it seems safe to assume that it is less than 25 percent. Of the known potential uses, both past and present, the most significant are the following: use as fuel; use in fertilizers; use as a feed; use as insulating material; use as a filler in plastics and refractory materials; use in manufacture of furfural; use as an industrial cleaning agent; use of rice hulls and rice hull ash in lightweight concrete blocks (Hough and Barr, 1956).

Physical Properties of the Concrete Blocks

Unit Weight

Unit weight is defined as a weight of a given volume. It is thus a density measurement and also known as bulk density. The unit weight effectively measures the volume that the graded aggregate will occupy in a concrete and includes both the solid aggregate particles and the voids between them. The unit weight is simply measured by filling a container of known volume and weighing it (ASTM C 29). Clearly, however, the degree of compaction will change the amount of void space and hence the value of the unit weight. Since the weight of the aggregate is dependent on the moisture content of the aggregate, a constant moisture content is required. Oven-dry aggregate is used in ASTM C 29. The unit weight of the coarse aggregate is required for the volume method proportioning. The void space that must be filled with mortar can be calculated using the unit weight. The unit weight in kg/m^3 is equal to the weight of aggregate in a 1 m^3 of volume (MIndness, et al, 2003).

Water Absorption

Water absorption capacity is the maximum amount of water that a sample can absorb. It can be calculated by the following equation:

$$Absorption\ (\%) = \left(\frac{A - B}{B}\right)\ x\ 100 \qquad equation\ 1$$

where: A = wet mass in kg

B = dry mass in kg

Water absorption is due to the presence of voids. If the sample has more voids it will absorb more water and reduces the load carrying capacity.

Mechanical Properties of the Concrete Blocks

Compressive Strength

Compressive strength is the ability of concrete to resist loads which tend to compress it. It is calculated by the failure load divided with the cross sectional area resisting the load. It is recorded in pounds per square inch (psi) in English units and mega Pascal (MPa) in SI units.

$$Stress = \frac{Force, F}{Area, A} \qquad equation\ 2$$

The compressive strength of concrete, fc’, is determined by testing to failure 28-day-old 6-in.diameter by 12-in. concrete cylinders at a specified rate of loading. For the 28-day period, the cylinders are usually kept under water or in a room with constant temperature and 100% humidity. Although concretes are available with 28-day ultimate strengths from 2500 psi up to as high as 10,000 psi to 20,000 psi, most of the concretes used fall into the 3000-psi to 7000-psi range. For ordinary applications, 3000-psi and 4000-psi concretes are used, whereas for prestressed construction, 5000-psi and 6000-psi strengths are common. The values obtained for the compressive strength of concretes, as determined by testing, are to a considerable degree dependent on the sizes and shapes of the test units and the manner in which they are loaded (McCormac and Brown, 2014). Based on the materials manual of the Department of Public Works and Highways (DPWH) the following are the compressive strength of concrete: Class A is 20.7 MPa (3000psi) and Class B is 16.5MPa (2400).

From the National Structural Code of the Philippines (NSCP), 2010, concrete in an area presented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85% of fc' and if no single core is less than 75% of fc'.

Flexural Strength

Flexural strength or bend strength is also known as modulus of rupture or transverse rupture strength which is a property of a material defined as the stress in a material just before it yields in a flexure test. In the flexural test most commonly employed, a " standard" plain concrete beam of a square or rectangular cross-section is simply supported and subjected to third-points loading until failure. Assuming a linear stress distribution across the cross-section, the theoretical maximum tensile stress reached in the extreme fibre is termed the modulus of rupture (Menon, 2009).

The theoretical maximum tensile strength, or modulus of rupture, R, is then calculated from the simple beam bending formula for third point loading.

$$R = \frac{Pl}{bd^2} \qquad equation\ 3$$

where: P=maximum total load

l =span length

b = specimen width

d= specimen depth

It holds only if the beam breaks between the two interior loading (i.e. in the middle third of the beam). If the beam breaks outside these points by not more than 5% of the span length, the equation is replaced by

$$R = \frac{3Pa}{2bd^2} \qquad equation\ 4$$

where *a* is the average distance between the point of fracture and the nearest support. The results of the tests where failure occurs even closer to the supports are discarded (Mindness, et al, 2003).

Concrete Mixture and Design Specifications

According to Fajardo (2000), concrete mixture proportion of cement, sand and gravel are the following: Class AA (1:1.5:3); Class A (1:2:4); Class B (1:2.5:5) and Class C (1:3:6).

In the specification for the Department of Public Works and Highways (PDWH), the cement content and the proportions of aggregate and water that will produce workable concrete having a slump of between 40 and 75mm if not vibrated or between 10 and 40mm if vibrated, the flexural strength should not be less than 3.8MPa (550psi) when tested by the Third-Point Method or 4.5 MPa (650psi) when tested by Mid-Point method at fourteen days in accordance with the American Association of State Highway and Traffic Official (AASHTO) T97 and T77, respectively or a compressive strength of 24.1 MPa (3500psi) for taken at 14days curing and tested in accordance with AASHTO T24.

According to the American Society for Testing and Materials (ASTM) there are two kinds of blocks: (1) Load Bearing Block (ASTM C-90)- a block capable of carrying super-imposed load which is used in exterior wall below grade and for unplastered exterior wall above grade that maybe exposed to weather with a minimum compressive strength of 5.5MPa individually and 6.9 average of three (3) units and (2) Non-Load bearing Block (ASTM C-129)- a block not capable of carrying super-imposed load. It has a minimum net area compressive strength of 3.35MPa for individual units and 4.14MPa average for three units.

Water-Cement Ratio

The ratio of the water to cement is the chief factor for determining concrete strength. The lower the water-cement ratio, the higher is the compressive strength. The practical range of the w/c ratio is from about 0.3 to over 0.8. For ordinary concrete, a water-cement ratio of 0.6 to 0.7 is considered normal. A lower w/c ratio of 0.4 is generally specified if a higher quality concrete is desired. A ratio of 0.3 is very stiff and a ratio of 0.8 makes a wet and fairly weak concrete (Anque, et al, 2016).

Slump Test

Slump test is the oldest and most widely used test of workability. The apparatus for this very simple test consist of hollow mold in the form of a frustum of cone. The mold is filled with concrete in three layers of equal volume, each layer is rodded 25 times with a 16mm (5/8 in) diameter steel rod. The mold is then lifted away vertically, and the slump is measured by determining the differences between the height of the mold and the height of the concrete over the original center of the base of the specimen. The maximum tie from first placement of concrete to lifting of the cone is 2.5 minutes. If the distinct shearing off of the concrete from side of the cone occurs, the test is disregarded and a new one carried out. If such shearing occurs consistently, this indicates that the test is not suitable for that particular concrete mix (Mindness, et al, 2003). Slump ranges from 50-150mm (Besavilla, 2013).

Review of Related Studies

The researcher presents the following studies, which contains facts and information needed in this research.

In the study of Ling, T.C. (2012), " Effects of Compaction Method and Rubber Content on the Properties of Concrete Paving Blocks" recycled waste tyre (crumb rubber) are used to replace sand by volume at the level of 0%, 10%, 20% and 30% in order to investigate how the soft rubber particles behave under plant-machine compaction method during the production of rubberized concrete paving blocks (RCPB). In the hardened stage, the physical properties as well as mechanical properties of RCPB including density ,compressive strength, bending strength and skid resistance were studied. The results showed that as a small proportion (~10%)

of soft rubber particles was included in the mixture, the particles easily distorted and filled the voids between the solid particles. This filling mechanism reduced the porosity of concrete mixtures and effectively developed an adequate adhesion between the particles, resulting in higher gain in strengths. On the contrary , as the rubber ratio increased more than 10%, which the deformability is more predominant than the filling mechanism, this results in higher total stress concentrations and rebound stress of rubber particles, thus, increasing the porosity and micro-cracks, resulting in loss in strengths. Nevertheless, the presence of rubber in concrete did not demonstrate brittle failure, but rather a ductile which had an ability to withstand post-failure loads. In comparison, the mechanical properties of plant-made RCPB performed better than that of corresponding manually-made RCPB. Therefore, plant-compaction method is recommended for future RCPB production and crumb rubber content used to replace sand by volume should be kept at or less than 10%.

Husain, M. and Shirule, P. (2015) utilize the " Reuse of Scrap Tyre as Partial Replacement of Fine aggregate in Concrete and its Impact on Properties of Concrete". The blends are prepared by replacing 0%, 3%, 6%, 9%, 12%, 15% and 18% of fine aggregates by fine rubber particle by weight. Results shows that the maximum compressive strength is 40.66 N/mm^2 at 6% replacement of fine scrap tire rubber aggregate and it is more than the compressive strength of traditional concrete.

" Rubber-Tire Particles as Concrete Aggregate" also studied by Eldin, N. et al (1993). He examines the potential of tire chips and crumb rubber as aggregate in

Portland-cement concrete. Results shows that the concrete mixtures did not demonstrate brittle failure, but rather a ductile, plastic failure, and had the ability to absorb a large amount of plastic energy under compressive and tensile loads.

Ganjian et.al (2009) investigates the performance of concrete mixtures incorporating 5%, 7.5% and 10% of discarded tyre rubber as aggregate and cement replacements in his study of the " Scrap-Tyre-Rubber Replacement for Aggregate and Filler in Concrete". The mechanical tests included compressive strength, tensile strength, flexural strength and modulus of elasticity. The durability tests included permeability and water absorption. The results showed that with up to 5% replacement, in each set, no major changes on concrete characteristics would occur, however, with further increase in replacement ratios considerable changes were observed.

Gammal, EL, et. al (2010) in his study "Compressive Strength of Concrete Utilizing Waste Tire Rubber" investigates the density and compressive strength of concrete with waste tire rubber as partial replacement of fine and coarse aggregate by weight using different percentages. Results shows that a significant reduction in the compressive strength of concrete utilizing waste tire than normal concrete. Concrete with rubber demonstrate a ductile, plastic failure rather than brittle failure.

Meanwhile, Toutanji, H.A. (1996) in "The Use of Rubber Tire Particles in Concrete to Replace Mineral Aggregates" states that concrete with rubber tire aggregate exhibited a ductile failure and underwent significant displacement before fracture. High toughness was displayed by specimens containing rubber tire chips as compared to control specimens.

Khalco, A. et. al (2008) in his research " Mechanical Properties of Concrete Containing a High Volume of Tire" investigates the feasibility of using elastic and flexible tire-rubber particles as aggregates in concrete. Results show that a decrease in brittle behaviour of concrete with increasing rubber content were observed using nonlinearity indices. The maximum toughness index, indicating the post failure strength of concrete occurs in concrete with 25% rubber content. Unlike plain concrete, failure in rubberized concrete occurs gently and uniformly and does not cause any separation in the specimen.

Vieira, R. et.al (2010) in " CompletelyRandom Experimental Design with Mixture and Process Variables for Optimization of Rubberized Concrete" , commented that the optimum condition in the rubberized concrete, considering the level of the variable studied is: 2.4 mm size of rubber, 2.5% rubber that replaced the aggregate, 16% of cement, 76% of aggregate and 8% of water. The optimum mixture conditions with 2.5% of rubber show a concrete value of compressive strength above 20 MPa, can generate concrete suitable for use in structures as well as pavement, curbs, walls and other applications in civil engineering.

Al-Tayeb and Abu Bakar (2012) uses 5%, 10% and 20% replacements by volume, for both sand and cement in his study of the "Effect of Partial Replacements of Sand and Cement by Waste Rubber on the Fracture Characteristics of Concrete". Each case had three unnotched and notched specimens of size 600 mm × 75 mm × 150 mm; notches were 50 mm and 75 mm deep. The specimens were subjected to three points bending test in a computer-aided universal testing machine, and the fracture characteristics such as G_{IC}, CMOD and G_f were analyzed. It was observed that, in all proportions, the replacement of sand by fine crumb and crumb rubber increased the fracture properties; the increase of fracture properties by crumb rubber was more than that by fine crumb rubber. However the cement replacement by powdered rubber could improve the fracture factors, only for 5% and 10% replacements.

In the **"**Experimental Study on Rubberized Concrete" of Natarajan, C. and Murugan, RB. (2004), they use crumb rubber to replace fine aggregates in concrete. They investigated the mechanical properties of concrete when crumb rubber is used as partial replacement of fine aggregate in different percentage (5%, 10%, 15%, 20% and 25%) by volume. Results gives an acceptable mechanical and durability properties such as compressive strength, split tensile strength, flexural strength, water absorption, sulphate resistance, acid resistance and chloride resistance up to 15% replacement. Hence 15% rubber content is to be considered as the optimum amount. Though the compressive strength of concrete is reduced, it has few desirable characteristics such as low density, high flexural strength, high durability etc. Crumb rubber added to concrete gives better resistance to acid and sulphate attack. These properties can be advantages of waste tire crumb rubber concrete in construction applications.

Faraz, MI. et al. (2015), also investigates the effects of replacement of 5% and 10% of coarse aggregates by rubber crumbs on Portland cement concrete in his study of "Effect of Crumb Rubber Material on Concrete Mix" The following are the results: a.)The addition of rubber crumb resulted in increase in workability. The increase in workability is in direct proportion to the amount of rubber crumb added. The average slumps of mix 1, mix 2 and mix 3 are obtained as 33.33, 36.33 and 38.33 mm, respectively; b.) The addition of rubber crumbs resulted in reduction in weight of concrete. The reduction in weight is in direct proportion to the amount of rubber crumb added. The average weights of mix 1, mix 2 and mix 3 are obtained as 8.6, 8.3 and 8.1 kgs., respectively; c.) The addition of rubber crumbs resulted in increase in compressive strength of concrete at first and then it reduces; d.) The average increase in compressive strength of mix 2 for 7, 14 and 28 days is obtained as 4%, 5.47% and 6.34%, respectively; e.) The average reduction in compressive strength of mix 2 for 7, 14 and 28 days is obtained as 6%, 10.16% and 7.04%, respectively.

Furthermore, Fopossi, Aime J. et.al. (2014) in the " Effects of Stabilizers on the Water Absorption of Compressed Earth Blocks Made From Mangu Soil" states that water absorption depends to the type of soil used and is related with the compressive strength and durability of the materials. The increase of the moisture content reduces the strength which is more related to the porosity of the material.

Unpublished study of Divinagracia, L., Fortuito, J & Gregana, P. (2011) in " Utilizing Scrap RubberTires as Partial Replacement to Coarse Aggregates for

Concrete Pavements" partially replaced the coarse aggregate with chipped scrap rubber tire by percentage of 10%, 20%, 30% and 40%. Results shows that 10% replacement of the natural coarse aggregates with chipped scrap rubber tire gives the maximum required strength based on ASTM Specification.

Su, H., et. al. (2015) studies the three groups of singly-sized rubber particle samples (3 mm, 0.5 mm and 0.3 mm) and one sample of continuous size grading (prepared by blending the three singly-sized samples to form the same particle distribution curve of sand) were used to replace 20% of the natural fine aggregate by volume. The reference concrete containing 100% sand was also prepared to compare its properties with those of the samples in terms of workability, fresh density, compressive strength, tensile splitting strength, flexural strength and water permeability. The experimental results demonstrated that the rubber particle size affects the concrete's workability and water permeability to a greater extent than the fresh density and strength. Concrete with rubber particles of larger size tends to have a higher workability and fresh density than that with smaller particle sizes. However, the rubber aggregates with smaller or continuously graded particle sizes are shown to have higher strengths and lower water permeability.

Moreover, the "Use of Rice Husks in Road Construction" of Patil, A.H. et. al. (2014) assessed the potentiality of rice husk as a good source of high technological materials in road construction. Results in their study show that the use of rice husk in road construction increases the strength, flexibility, durability etc. of the road. They concluded that the use of rice husk in road construction is an effective method compared to construction method of normal roads. Hence, this will solve many problems like collection of drain water on road surface in rainy season, flexibility of a rigid pavement etc.

Also, Ayite, Y et.al. (2017) in his study " Effect of Rice Husks Concrete Preformed Coffers and Brick Use on Building Structural Elements" highlights the preformed coffers (15 cm thick), hollow and solid bricks made from cement - rice husks, cement - rice husks - sand and sand –cement mixtures respectively, to determine their characteristics: density, surface weight, brick compressive strength and preformed coffer bending strength. These characteristics were used to calculate building structural elements (joist, beam, column and footing). The results show that the preformed coffers and bricks of rice husks concrete are lighter than those made of sand - cement mortar. The compressive or bending strengths of these elements are similar. The use of rice husks concrete preformed coffers reduces dimensions and reinforcing steels of building structural elements.

In addition, Ayitea, D. et.al. (2013) in his research "A Study on the Use of Hollow Rice Husk Blocks for Flooring" investigates the application of the composites of husks of rice in building. This study consisted in formulating a set of composites of husks of rice experimentally. For the composite obtained, a study of the thermal conductivity has been worked out. Some blocks for flooring have been manufactured and have been tested in simple compressive stress. The physical and mechanical properties of the blocks for flooring made with husks of rice have been compared to those of the blocks for flooring made of sand and cement.

Optimal resistance to compression of the blocks increases with the proportion of cement on the mixture cement and husks of rice. In addition, the coefficient of thermal conductivity of the composite cement-sand-husks of rice at relative humidity 8%, is quite low. Blocks for flooring in composite with rice husk are about 46 % lighter than those made of sand and cement.

The researcher's study differs with Ayitea's since rice husks/hulls are mixed with rubber tires, gravel, sand and cement.

Conceptual Framework of the Study

The schema of this study is shown in Figure 2. It shows how the researcher go over the entire study.

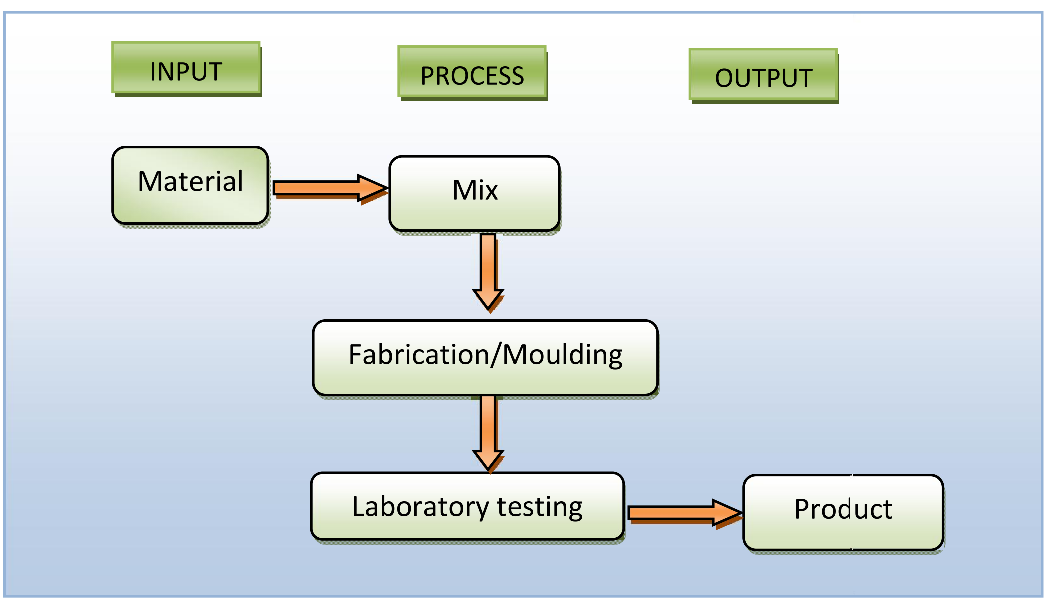

Figure 2. Conceptual framework of the study

The needed materials in this study were mixed and moulded. The moulded materials were tested in laboratory through testing machine. The test results of the product were compared to the specified standard of American Society for Testing and Materials (ASTM).

THE PROBLEM

Statement of the Problem

This study intends to reuse the tires and rice hull by incorporating them in the concrete mixture to produce a concrete paving blocks. The researcher sought answers to the following questions:

1. What are the effects of the crumb rubber as it partially replaced the sand by 2.5%, 5% and 7.5% by weight and addition of rice hull by weight of cement on the physical properties of the concrete paver blocks in terms of:
    a. density;
    b. unit weight;
    c. water absorption?

2. What are the effects of the crumb rubber as it partially replaced the sand by 2.5%, 5% and 7.5% by weight and addition of rice hull by weight of cement on the mechanical properties of the concrete paver blocks in terms of:
    a. compressive strength; and
    b. flexural strength?

Significance of the Study

The application of the waste tires in concrete construction is an environmental friendly technology, which can benefit the following:

Engineers and Developers

Using the idea of waste rubber tire as a construction material, engineers and developers may find creative ways to help not just by reducing the environmental problem but also in reducing the construction cost without reducing the effectiveness of the final product.

Environmentalists

This study helps the environmentalists in protecting the environment because incorporating waste rubber tire aggregates to concrete can lessen the extensive increase of rubber garbage in the surroundings. Through this, people and the environment will be safe from the hazardous effect of improper disposal of waste rubber tires.

Students and Educators

The result of this study will give idea to students and educators on how to utilize scrap materials that would benefit the environment and construction industry. This study would encourage future researchers to look further than what they see now and find alternatives to utilize waste materials.

Community

The findings of the study will help reduce the environmental issues associated with mining of aggregates and that of the misusing waste rubber tire.

Scope and Limitation of the Study

This study fabricated a concrete paver block using a crumb rubber tire and rice hull. The fine aggregates were partially replaced by 2.5%, 5% and 7.5% by weight of the crumb rubber tire. The additive used was rice hull which is 5% by weight of cement. The aggregates (sand and coarse) and crumb rubber were washed and air dried for about seven (7days) or one (1) week to get the dirt and other foreign matter that might affect the strength of the concrete mixture. Concrete mixture used is 1:2:4 by weight method. The physical properties of concrete paver blocks were tested in terms of density, unit weight and water absorption based on American Society for Testing and Materials (ASTM) Standard. The mechanical properties of the concrete paver blocks were tested in terms compressive strength and flexural strength using the Hydraulic Compressive Testing Machine.

This research are limited to lack of equipment to carry out some tests on the concrete paver blocks mixes like skid resistance, toughness, durability, modulus of elasticity, and permeability.

RESEARCH METHODOLOGY

This part of the study is composed of research method, research equipment and instruments, materials and methods, and statistical treatment of data.

Research Method

In this research, a laboratory tests were used in determining the physical and mechanical properties of the concrete block for paving purposes based on the standards of American Society for Testing and Materials (ASTM).

Research Equipment and Instrument

The instruments used in this study were the following laboratory equipment: concrete block molder, slump cone, tamping rod, sieves, weighing scale, thermometer oven, Hydraulic Compressive Testing Machine, and other apparatus needed in the study.

Materials and Methods

Materials

The materials used in this study were the following: water, cement, sand, gravel, crumb rubber tire and rice hull. The water used in this study was a potable drinking water as mixing water of concrete. Cement used was Type 1 Portland Cement, which is commercially available with a specific gravity of 3.15. The aggregates (sand and gravel) were taken from rivers that are commercially available in Siaton, Negros Oriental. The crumb rubber tire was taken from the recapping services of Dauin, Negros Oriental, see Appendix E page 94. These are obtained during the retreading process. Rice hull was taken from one of the rice mills of Zamboanguita, Negros Oriental.

Fine aggregates used in this study were natural sand passing 2.00 mm (#10 sieve). It was washed and air dried for about 7 days before using it in the concrete mixture. See Figure 3.

Figure 3. Fine aggregates

In Figure 4, the coarse aggregate used in this study were crushed gravel with nominal maximum size of ¾ inch or approximately 20 mm. It was washed and air dried for about 7 days before using it in the concrete mixture.

Figure 4. Coarse aggregates

The crumb rubber tire in Figure 5, was sieved at 2.0 mm (#10) sieve and was used as partial replacement for fine aggregates. It was washed and air dried for about 7 days before using it in the concrete mixture.

Figure 5. Crumb rubber tire

The rice hull in Figure 6, was sieved at 2.0 mm (#10) sieve and was used as additives in the concrete mixture.

Figure 6. Rice hull

Mixture Design and Proportioning

In this study, the concrete mixture for all paving blocks was 1:2:4 (1cement:2sand:4gravel) by weight with a water-cement ratio of 0.60. A total of four (4) mixtures were cast which consist of one control mixture (0% replacement) and three rubcrete mixtures. For rubberized concrete mixture, three different types of mixes were considered by replacing the fine aggregates with 2.5%, 5% and 7.5% of crumb rubber tire by weight. As admixture for every rubcrete mixtures, an addition of 5% of rice hull by weight of cement was used. See Appendix A for the detail computation of the concrete mixture.

Fabrication, Mixing and Curing of Concrete Paving Blocks

The workability of each mixture was tested through a slump test based on ASTM-C143 specification by using a slump cone. Slump cone has a standard dimension of 8 inches (bottom diameter) and 12 inches (high). See Appendix F.

The concrete paving blocks were fabricated in molds with internal dimensions of 50mm in thickness, 100mm in width, 200mm in length. There were five (5) samples for every mixture. The mixture were poured in the moulder into two layers of about equal depth and each layer was manually compacted using a rod. The concrete blocks were removed from the molds after 24 hours of casting and were cured at constant temperature for about 28 days until tested.

Laboratory Testing

The following tests were carried out to determine the physical properties (density, specific weight, and water absorption) and the mechanical properties (compressive strength and flexural strength) of the concrete paving blocks samples.

Physical properties of the concrete paving blocks

Density and unit weight. Five blocks for each mixtures were dried to a constant mass in an oven heated up to 110^{o}C in accordance to ASTM C642-97. The blocks were cooled at room temperature and weighted in kilograms. The volume were also measured in nearest cubic millimetres then converted to cubic meters. see Appendix F.

Water absorption. Five blocks for each mixtures were dried to a constant mass in an oven heated up to 110^{o}C in accordance to ASTM C642-97. The blocks were cooled at room temperature and weighted to determine its dry mass in kilograms. After weighing, all blocks were completely immersed in a clean water at room temperature for about 24 hours. Then, all blocks were removed from water, drained for about 1 minute and wiped with clothe. Then, the wet mass in kilograms for all blocks were immediately weighted.

Mechanical properties of the concrete paving blocks

Compressive strength. After 28 days of curing, the compressive strength of all concrete paver blocks were tested based on ASTM C39. The compressive strength was determined using the Hydraulic Compressive Testing Machine of New Bian Yek Commercial Incorporated (NBYCI) Batching Plant located at Camanjac, Dumaguete City, Negros Oriental.

Flexural strength. After curing the samples for 28 days, the flexural strength of all concrete paver blocks were tested based on ASTM C78-84. The flexural strength was determined using simple beam with third-point loading. This test was conducted at New Bian Yek Commercial Incorporated (NBYCI) Batching Plant located at Camanjac, Dumaguete City, Negros Oriental.

Statistical Treatment of Data

Statistical tools are used to solve for the mean or average data of each mixture of the concrete paver blocks for its physical and mechanical properties. Interpretation of data uses Analysis of Variance or ANOVA (One –Way) method generated from a statistical computer program to determine the significant difference of all data mixtures. The equation used for the computation of the mean or average of the sample is shown below.

$$mean\ or\ average,\ \bar{x} = \frac{\sum x}{N} \qquad equation\ 5$$

.

where: $\bar{x}$ = mean or average of the samples

$\sum x$ = Sum of samples

N = Number of samples

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DEFINITION OF TERMS

For the purpose of this study, the following words are defined.

ACI .Stand for American Concrete Institute (ACI). It is an international leading authority for the development and distribution of based standards for concrete design, construction and materials.

ASTM. Stand for American Society for Testing and Materials. It is an international standards organization that develops and publishes a technical standards for materials, products, systems and services.

Compressive Strength. It is also term as compression strength. It is a capacity of a material or structure to withstand loads tending to reduce size. It is the opposite of tensile strength, which withstands loads tending to elongate. It has a unit of pound-force per square inch (psi) in US Customary units or megapascals (MPa) in SI units.

Concrete Mixture Design. It is the suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

Crumb rubber. It is a by-product of retreading discarded tire into a new tire that can be used by most vehicles.

Curing. The process of maintaining moisture and temperature conditions of concrete for hydration reaction to normally so that concrete develops hardened properties over time.

Flexural strength. It is known as modulus of rupture, bend strength or fracture strength. It is also define as a material's ability to resist deformation under load.

Load Bearing Block. A block capable of carrying super-imposed load

Rice hulls (or **rice husks**). Are the hard protecting coverings of grains of rice.

Scrap tire. Any tire that has been removed from its original use

CHAPTER 2
PRESENTATION, ANALYSIS AND INTERPRETATION DATA

The overall test results of the physical and mechanical properties of concrete blocks of all samples containing crumb rubber tire and rice hull are shown in Table 1. Each of these results represents the average of five (5) samples.

Table 2

Test Results of the Physical and Mechanical Properties of the Concrete Blocks

Percentage Replacement of Crumb Rubber Tire plus 5% Rice Hull	**Physical Properties**			**Mechanical Properties**	
	Density (kg/m^3)	Unit Weight (kN/m^3)	Water Absorption (%)	Average Compressive Strength, (MPa)	Average Flexural Strength, (MPa)
0% (control)	1960	19.228	8.781	47.328	4.698
2.5%	2053.20	20.142	9.578	28.776	2.740
5.0%	2063.40	20.242	9.784	25.985	3.208
7.5%	2081.20	20.417	10.998	18.411	3.282

Table 2 shows the best results of the physical and mechanical properties of the concrete blocks. As the content of the crumb rubber increases in the concrete mixture, the physical properties of concrete paver blocks increase while their mechanical property decreases. Since the density and unit weight is directly proportional to each other, only the relationship of the density, water absorption, compressive strength and flexural strength were taken. The significant differences of the mixture of all samples were measured using ANOVA, see Appendix B page 70 for the computations.

Result shows that every sample mixtures with crumb rubber up to 7.5% by weight of sand differs significantly on its density, water absorption and flexural strength from the control (0%) sample yet have no significant difference on its compressive strength. Furthermore, Table 2 also shows that water absorption and compressive strength of all samples are inversely proportional to each other. This means that the difference of percentage (%) composition of crumb rubber tire in the concrete mix affects the water absorption and compressive strength of the block. As the water absorption increases, the compressive strength decreases. Increase in water absorption is because of the increase in voids in the blocks associated by the increase of the crumb rubber plus the rice hull. Thus, sample contains more voids absorbs more water and reduces the compressive strength. This result conforms to the study of Fopossi, Aime J. Et. al. (2014).

For detail discussion of the results of the physical and mechanical properties of the concrete paver blocks, a graphical presentations of its density, unit weight, water absorption, average compressive strength and average flexural strength are shown in Figure 7, Figure 8, Figure 9, Figure 10 and Figure 13 respectively.

Concrete Paver Block Density

The effects of the crumb rubber replacement and addition of rice hull on the concrete paver block density are shown in Figure 7.

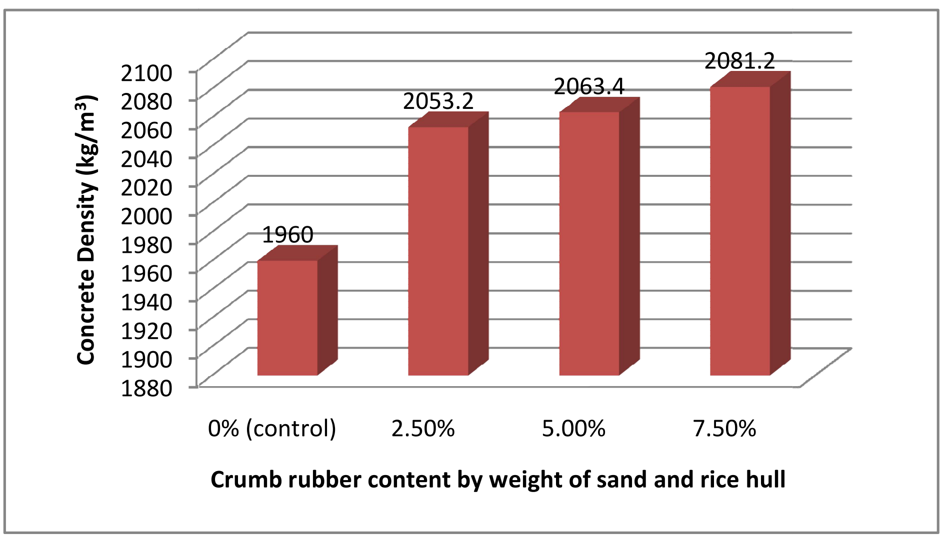

Figure 7. Density of Concrete Blocks with or without Crumb Rubber and Rice Hull

Figure 7, shows the density of concrete blocks with or without crumb rubber and rice hull. Here it could be seen that the control (0%) concrete samples has a lower density compare to samples with crumb rubber. Although, the density of the crumb rubber is very much lesser than the sand (see Table 4, Appendix A page 62), but the weight of the rice hull added in the concrete mixtures as the crumb rubber replaced the sand greatly affects the density. It was also observed that the density of the concrete samples increases ranging from 4.76% to 6.18% as crumb rubber replace the sand by 2.5% to 7.5% with an addition of 5% of rice hull by weight of cement, see Appendix C page 77 for the detailed computations.

Concrete Paver Block Unit Weight

Results of the replacement of crumb rubber to sand and addition of rice hull on the concrete paver block on its unit weight are shown in Figure 8.

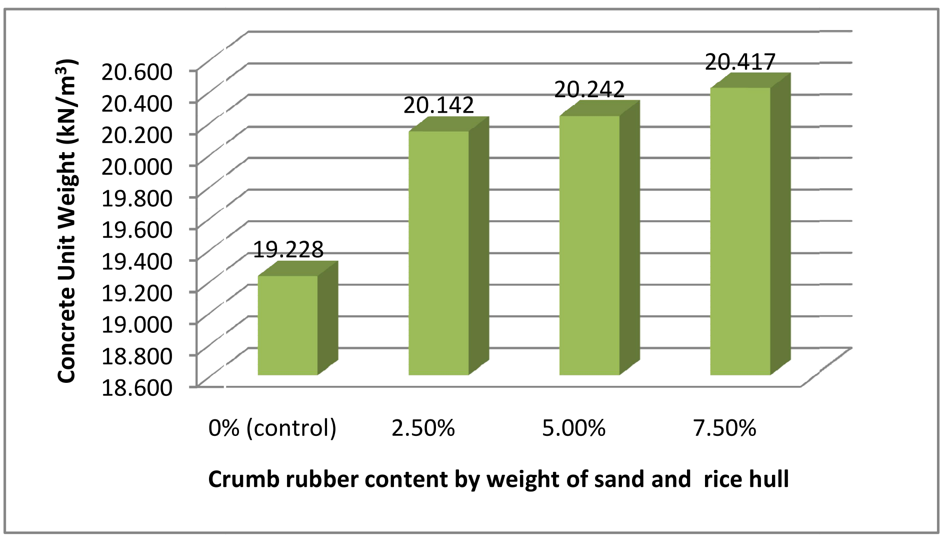

Figure 8. Unit Weight of Blocks With or Without Crumb Rubber and Rice Hull

Figure 8, shows the unit weight of concrete blocks with or without crumb rubber tire with rice hull. Here it could be seen that the unit weight of the concrete block with crumb rubber and rice hull in the concrete mixtures increases compare to control (0%) samples. This means that unit weight are directly proportional to the density of the block. As the mass per volume of the block increases, the weight per volume of the block also increases.

Concrete Paver Block Water Absorption

The rate of water absorption of the control concrete blocks and concrete blocks with crumb rubber and rice hull are shown in Figure 9.

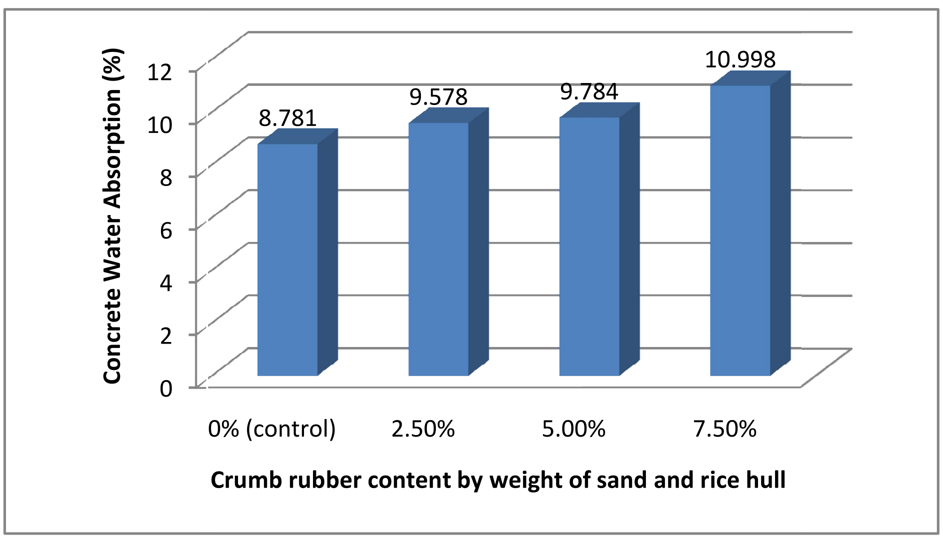

Figure 9. Water Absorption of Blocks With or Without Crumb Rubber and Rice Hull

Figure 9, shows the absorption of concrete blocks with or without crumb rubber tire and rice hull. Here it could be seen that the water absorption rate of concrete mixtures containing rubber and rice hull increases with the increase in the percentage of crumb rubber content. The increase of the absorption of the blocks with crumb rubber and rice hull ranged from 9% to 25.25% compared to the control (0%) blocks concrete mixture, see Appendix C page 78 for the computations. The increase of the amount of crumb rubber and rice hull of the concrete blocks increases the void spaces allowing the concrete blocks absorb more water than the control blocks (0%).

Concrete Paver Block Compressive Strength

The results of the compressive strength of concrete paver blocks with or without crumb rubber and rice hull are shown in Figure 10.

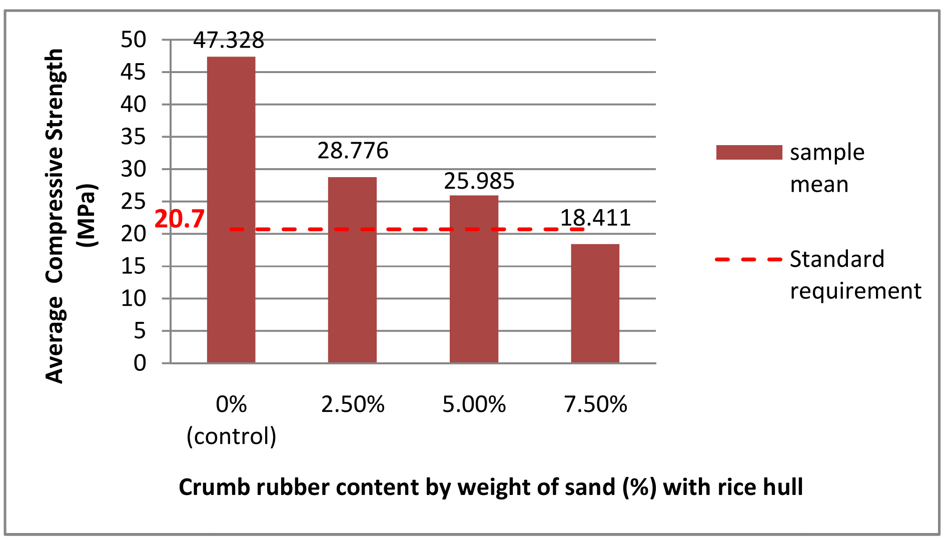

Figure 10. Average compressive strength of blocks with or without crumb rubber and rice hull

Figure 10, shows the average compressive strength of concrete blocks with or without crumb rubber tire and rice hull. Here it could be seen that the values presented shows a reduction of the compressive strength of the concrete paver blocks with an increase in crumb rubber content and addition of rice hull compare to control (0%) concrete paver blocks. Only the control sample passed the required compressive strength of Class A mixture for a 28-day old concrete which is 3000Psi or 20.7MPa.

The reduction of the compressive strength was reduced to 39.20%, 45.10% and 60.24% when using 2.5%, 5.0% and 7.5% respectively, of crumb rubber as replacement of sand by weight and addition of 5% rice hull by weight of cement in the concrete mixture compared to control mixture. See Appendix C page 78 for the computations.

Although, the compressive strength of the rubcrete blocks in this study decreases compare to control concrete blocks, yet all samples still passed or structurally adequate to the required compressive strength. Since, all concrete paver blocks average compressive strengths are above the 85% of 3000 Psi which is 2550Psi or 17.586MPa and the individual concrete paver blocks compressive strengths are also above the 75% of 3000 Psi which is 2250MPa or 15.517MPa, see Figure 11 and Figure 12. This is based on National Structural Code of the Philippines (NSCP, 2010), concrete shall be considered structurally adequate if the average of three cores is equal to at least 85% of fc' and if no single core is less than 75% of fc'.

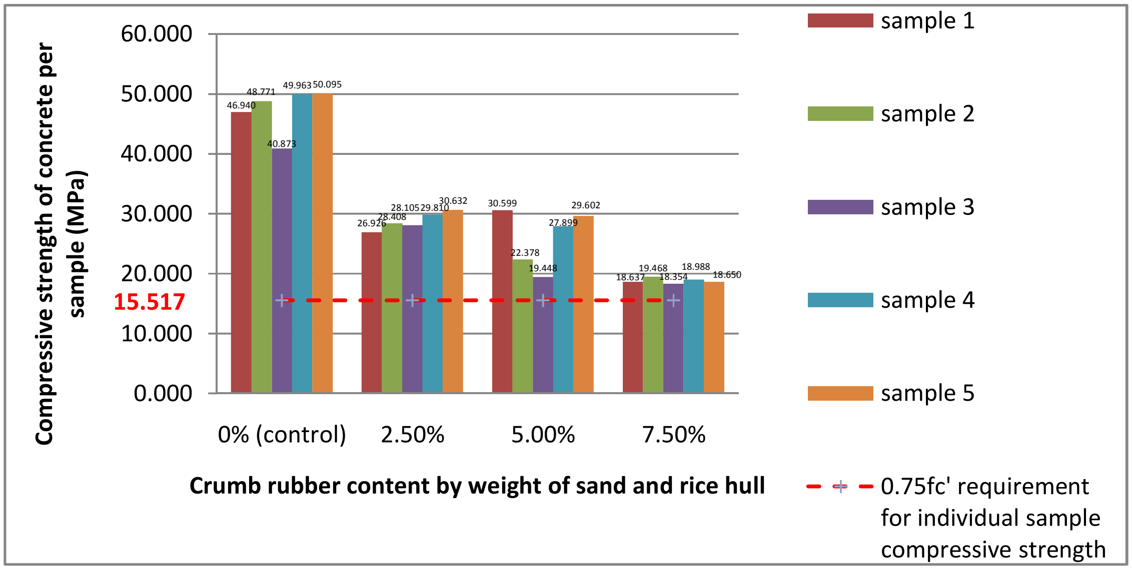

Figure 11. Individual Compressive Strength of Concrete Paver Blocks With or Without Crumb Rubber and Rice Hull Compared to the Standard

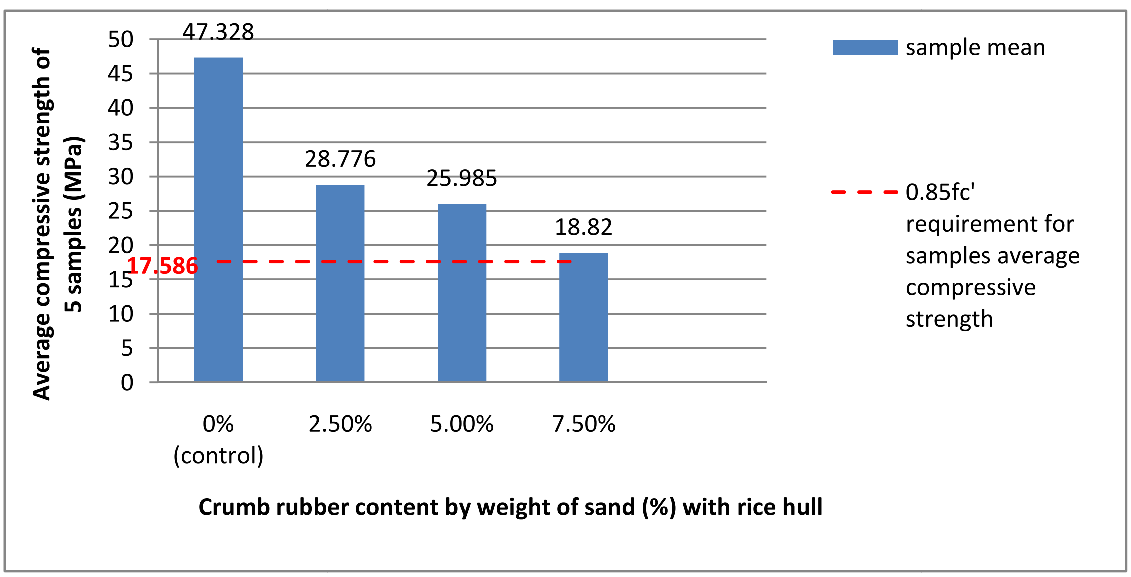

Figure 12. Average Compressive Strength of Concrete Paver Blocks With or Without Crumb Rubber and Rice Hull Compared to the Standard

Concrete Paver Block Flexural Strength

The result of the flexural strength of the concrete paver blocks with or without crumb rubber and rice hull is shown in Figure 13.

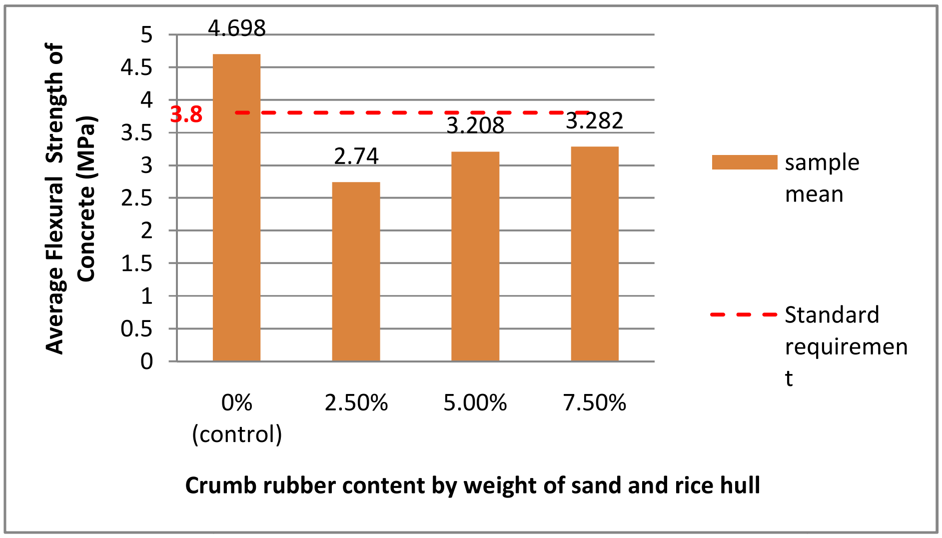

Figure 13. Average Flexural Strength of Blocks With or Without Crumb Rubber and Rice Hull

Figure 13, shows the flexural strength of concrete blocks with or without crumb rubber and rice hull. Here it could be seen that there was a reduction in the flexural strength of concrete paver blocks with crumb rubber and rice hull in the concrete mixtures. Only the control sample passed the required standard of the Department of Public Works and Highways (DPWH) for the flexural strength of concrete pavement tested by the Third-point Method which is 3.8MPa. The reduction of the flexural strength was reduced to 41.68%, 31.72% and 30.14% when using 2.5%, 5.0% and 7.5% respectively, of crumb rubber as replacement of sand by weight and addition of 5% rice hull by weight of cement in the concrete mixture compared to control mixture. See Appendix C page 86 for the computations.

Results also show that, as the amount of crumb rubber in the mix increases, the flexural strength increases. This is because of the flexibility of the rubber to resist the flexural stress applied during the testing of the concrete blocks.

Cost Estimates of the Samples of Concrete Paver Block

In this study, four (4) mixtures were used, 0% as the control mixture, 2.5%, 5% and 7.5% replacement of sand by crumb rubber tire by weight with addition of 5% of rice hull by weight of cement. Each mixture casted five (5) samples for each laboratory test of water absorption, compressive strength and flexural strength tests. Thus, a total of sixty (60) samples of concrete paver blocks were moulded. The total estimated cost for the preparation, hauling, fabrication, and laboratory testing of these sixty (60) samples is Nineteen Thousand One Hundred Eighty Seven Pesos & 50/100 (Php19,187.50), see Appendix D page 88 for the detailed computations.

In addition, the cost per piece of concrete paver blocks per mixture is shown in Table 3 below.

Table 3

Cost Estimates of each Sample of each Mixture of Concrete Paver Blocks

Samples containing different percentage of crumb rubber and 5% of rice hull	Cost per piece of concrete paver block (Php)
0% (control)	155.100
2.5%	155.097
5.0%	155.089
7.5%	155.084

From the above table, the cost per block of the concrete paver with 0% (control), 2.5%, 5.0% and 7.5% crumb rubber rubber plus 5% rice hull are Php155.10; Php155.097; Php 155.089; and Php 155.084 respectively.

It was observed that as the crumb rubber contents increases in the sample mixture plus 5% of rice hull, the cost per block decreases. However, comparing their cost to the 0% (control) sample, the difference of the cost was very minimal or equal. See Appendix D pages 89-93 for the detailed computations.

CHAPTER 3

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATION

This chapter presents the summary findings, the conclusion and the recommendations.

Summary of Findings

This paper presented the effects of the crumb rubber as it partially replaced the sand by 2.5%, 5% and 7.5% by weight and addition of 5% rice hull by weight of cement on the physical properties and mechanical properties of the concrete paver blocks compared to the control (0%) samples. The following are the findings:

1. Concrete paver blocks in this study casted with crumb rubber and rice hull show an increase of its physical properties (density, unit weight and water absorption) while decreases its mechanical properties (compressive and flexural) compared to the control samples. Every sample mixtures differs significantly on its density, water absorption and flexural strength from the control (0%) sample yet have no significant difference on its compressive strength. Furthermore, water absorption and compressive strength of all samples are inversely proportional to each other. This means that the difference of percentage (%) composition of crumb rubber tire in the concrete mix affects the water absorption and compressive

strength of the block. As the water absorption increases, the compressive strength decreases. Increase in water absorption is because of the increase in voids in the blocks associated by the increase of the crumb rubber plus the rice hull. Thus, sample contains more voids absorbs more water and reduces the compressive strength. This result conforms to the study of Fopossi, Aime J. Et. al. (2014).

2. Concrete paver blocks casted with crumb rubber and rice hull shows a reduction in the compressive strength compared to the control samples. The reduction of the compressive strength ranged from 39.20% to 61.10%. Only the control sample passed the required compressive strength of Class A mixture for a 28-day old concrete which is 3000Psi or 20.7MPa.

Although, the compressive strength of the rubcrete blocks in this study decreases compare to control samples, yet all blocks still passed or structurally adequate to the required strength of Class A mixture. Since the concrete paver blocks average compressive strengths are above the 75% of 3000 Psi which is 2250MPa or 15.517MPa and also the average compressive strengths of the concrete blocks are above the 85% of 3000 Psi which is 2550Psi or 17.586MPa

3. Concrete paver blocks casted with crumb rubber and rice hull shows a reduction in the flexural strength compared to the control samples. The reduction of the flexural strength was reduced to 41.68%, 31.72% and 30.14% when using 2.5%, 5.0% and 7.5% respectively compared to the control mixture.

Only the control sample passed the required standard of the Department of Public Works and Highways (DPWH) for the flexural strength of concrete pavement tested by the Third-point Method which is 3.8MPa.

Results also show that as the amount of crumb rubber in the mix increases, the flexural strength increases. This is because of the flexibility of the rubber to resist the flexural stress applied during the testing of the concrete blocks. Compare to the DPWH standard, the flexural stress of rubcretes increases ranging about 72% to 86.4%.

4. The total samples used in this study are sixty (60) samples which have a total cost of Nineteen Thousand One Hundred Eighty Seven Pesos & 50/100 (Php19,187.50). The said costs include the preparation, hauling, fabrication, and laboratory testing of all samples.

The cost per block of the concrete paver with 0% (control), 2.5%, 5.0% and 7.5% crumb rubber rubber plus 5% rice hull are Php155.10; Php155.097; Php 155.089; and Php 155.084 respectively.

It was observed that as the crumb rubber contents increases in the sample mixture plus 5% of rice hull, the cost per block decreases. However, comparing their cost to the 0% (control) sample, the difference of the cost was very minimal or equal.

CONCLUSIONS

Based on the results, the following conclusions are drawn:

1. Concrete paver blocks in this study casted with crumb rubber and rice hull are good in absorbing the water. This property of blocks shows a big help in absorbing a portion of storm water runoff through the pavement surface and allows the water infiltrates to the soil.

2. Concrete paver blocks in this study casted with crumb rubber and rice hull passed the standard set by the American Society for Testing and Material (ASTM) for masonry block specifications. It can be used for masonry wall, retaining wall and other exterior and interior wall. However, it cannot be used for road pavements since fails to meet the require standard of Department of Public Works and Highways (DPWH) for road purposes.

3. Concrete paver blocks in this study casted with crumb rubber and rice hull can be used also for parking area, garage, patio, walkways, footpath, waiting sheds, bus stops, gardens and other landscaping need.

4. It was concluded in this study that water absorption is inversely proportional to its compressive strength. Despite the reduction of the compressive and flexural strength of the concrete paver blocks with rubber and rice hull compare to the normal concrete but the possibility of recycling these products to concrete paver mixtures is a great help in reducing the disposal of rubber and burning rice hull in our locality.

RECOMMENDATIONS

It is recommended that the design mix of 1:2:4 with water-cement ratio of 0.60 and a content of crumb rubber up to 7.5% by weight of sand and additional of 5% rice hull by weight of cement used in the fabrication of the concrete paver blocks in this study will be used for the following to reduce the amount of scrap rubber tire found anywhere:

- parking area
- playground
- garage, patio, walkways, footpath
- waiting sheds
- gardens
- landscaping need in school and other public places
- masonry wall, retaining wall, and other exterior or interior walls.

Moreover, the mixture of concrete paver blocks samples with 2.5% replacement of sand with crumb rubber tire is the best recommended among the samples of rubcrete mixtures, since, it has the higher compressive strength among others. Although, this mixture has the higher cost per sample of concrete paver block but the differences of the cost compared to other samples of rubcrete mixtures are very minimal.

Also, further studies should be continued in the following areas:

1. To test bagasse ash or rice hull ash as concrete admixture with different ratios to overcome the reduction of the strength of concrete resulting the replacement of sand by rubber.

2. To test the size and percentage replacement of crumb rubber to sand and rice hull used in this study to concrete hollow blocks (CHB).

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APPENDICES

APPENDIX A

DESIGN MIX COMPUTATIONS

CALCULATIONS ON THE DENSITY OF EACH RAW MATERIAL

Table 4. Summary of the Density of the Raw Material

Material	Dry Density (kg/m^3)
Cement	1427
Sand	1304
Gravel	1381
Crumb Rubber	418
Rice Hull	399

$Volume\ of\ molder\ of\ concrete\ blocks$

$$Thickness, t = 50mm \quad = 0.05m$$
$$Width, W = 100mm \quad = 0.10m$$
$$Lenght, L = 200mm \quad = 0.20m$$
$$Volume, V = 0.05x0.1x0.2 = 0.001m^3$$

1. $\text{Mean weight of molder, W} = \ 0.294 \text{ kgs (considering 5 molders)}$

2..Mean weight of molder with raw materials in kilograms (considering 5 molders)

a. $Mean\ weight\ of\ molder\ with\ cement = 1.721kgs$
b. $Mean\ weight\ of\ molder\ with\ dry\ sand = 1.598kgs$
c. $Mean\ weight\ of\ molder\ with\ gravel = 1.675kgs$
d. $Mean\ weight\ of\ molder\ with\ crumb\ rubber = 0.712kgs$
e. $Mean\ weight\ of\ molder\ with\ rice\ hull = 0.693kgs$

2. Mean weight of each material in kilograms

a. $Mean\ weight\ of\ cement = Weight\ of\ molder\ with\ cement - weight\ of\ molder$
$$= 1.721 - 0.294 = 1.427kgs$$
b. $Mean\ weight\ of\ sand = Weight\ of\ molder\ with\ sand - weight\ of\ molder$
$$= 1.598 - 0.294 = 1.304kgs$$
c. $Mean\ weight\ of\ gravel = Weight\ of\ molder\ with\ gravel - weight\ of\ molder$
$$= 1.675 - 0.294 = 1.381kgs$$
d. $Mean\ weight\ of\ crumbrubber = Weight\ of\ molder\ with\ crumbrubber - weightofmolder$
$$= 0.712 - 0.294 = 0.418kgs$$
e. $Mean\ weight\ of\ rice\ hull = Weight\ of\ molder\ with\ rice\ hull - weight\ of\ molder$
$$= 0.693 - 0.294 = 0.399kgs$$

3. Weight per volume of each materials

a. $Density\ of\ cement = \frac{mean\ weight\ of cement}{volume\ of\ molder} = \frac{1.427}{0.001} = 1427\frac{kg}{m^3}$

b. $Density\ of\ sand = \frac{mean\ weight\ of sand}{volume\ of\ molder} = \frac{1.304}{0.001} = 1304\frac{kg}{m^3}$

c. $Density\ of\ gravel = \frac{mean\ weight\ of gravel}{volume\ of\ molder} = \frac{1.381}{0.001} = 1381\frac{kg}{m^3}$

d. $Density\ of\ crumb\ rubber = \frac{mean\ weight\ of crumb\ rubber}{volume\ of\ molder} = \frac{0.418}{0.001} = 418\frac{kg}{m^3}$

e. $Density\ of\ rice\ hull = \frac{mean\ weight\ of\ rice\ hull}{volume\ of\ molder} = \frac{0.399}{0.001} = 399\frac{kg}{m^3}$

COMPUTATIONS ON EQUIVALENT VOLUME OF CONCRETE FOR 1 BAG OF CEMENT

$$For\ Class\ A\ Mixture = 1:2:4$$

Weight of the materials per bag:

$$Cement = 1\ bag \qquad = 40kg \qquad = 0.0283m^3$$

$$Sand \quad = 2\ x\ 0.0283\ x\ 1304 = 73.806\ kg$$

$$Gravel \quad = 4\ x\ 0.0283\ x\ 1381 = 156.33\ kg$$

$$Water \ = 0.60\ x\ 40 \qquad = 24kg$$

Total weight of concrete ingredients, W= 40 +73.806 + 156.33 + 24 = 294.136 kg

Volume of concrete blocks per sample

$$Thickness, t = 50mm \qquad = 0.05m$$

$$Width, W \quad = 100mm \qquad = 0.10m$$

$$Lenght, L \quad = 200mm \qquad = 0.20m$$

$$Volume, V \quad = 0.05x0.1x0.2 = 0.001m^3$$

Density of concrete, ρ_c = 24000kg/m^3

$$Volume\ of\ concrete\ per\ one\ bag\ of\ cement, V_{bag} = \frac{294.136}{2400} = 0.123m^3$$

$$No.of\ bags\ of\ cement\ required\ per\ sample\ of\ concrete\ block = \frac{0.001}{0.123}$$

$$= 0.00813\ bags$$

Design mixture for one sample:

$$Weight\ of\ cement \quad = \ 0.00813\ x\ 40 \qquad = 0.3252kg$$

$$Wieght\ of\ sand \quad = \frac{73.806}{0.123}\ x\ 0.001 \qquad = 0.60\ kg$$

$$Wieght\ of\ gravel \quad = \frac{156.33}{0.123}\ x\ 0.001 \qquad = 1.271\ kg$$

$$Weight\ of\ water \quad = 0.3252\ (0.60) \qquad = \ 0.195kg$$

DESIGN MIX COMPUTATIONS FOR CONCRETE BLOCKS FOR FIVE (5) SAMPLES

Table 5. Summary of Design Mixture for five (5) concrete blocks

Materials	Weight of materials for each percentage replacements of crumb rubber by weight of sand (kgs)			
	0%	2.5%	5%	7.5%
Cement	1.626	1.626	1.626	1.626
Sand	3.000	2.925	2.85	2.775
Gravel	6.355	6.355	6.355	6.355
Crumb rubber	0	0.075	0.15	0.225
Rice hull	0	0.0813	0.0813	0.0813
Water	0.976	0.976	0.976	0.976
Total weight	11.957	12.038	12.038	12.038
Mean weight of each sample	**2.391**	**2.408**	**2.408**	**2.408**

Volume of concrete blocks per sample

$$Thickness, t = 50mm \qquad = 0.05m$$

$$Width, W \quad = 100mm \qquad = 0.10m$$

$$Lenght, L \quad = 200mm \qquad = 0.20m$$

$$Volume, V \quad = 0.05x0.1x0.2 = 0.001m^3$$

FOR ABSORPTION TEST

Volume of concrete blocks

$$Volume, V \quad = 0.001\ x\ 5 = 0.005m^3$$

a. Plain Concrete

$$Weight\ of\ cement \quad = 5\ x\ 0.00813\ x\ 40 \qquad = 1.626kg$$

$$Wieght\ of\ sand \quad = 5\ x\frac{73.806}{0.123}\ x\ 0.001 \qquad = 3.0\ kg$$

$$Wieght\ of\ gravel \quad = 5\ x\frac{156.33}{0.123}\ x\ 0.001 \qquad = 6.355\ kg$$

$$Weight\ of\ water \quad = 1.626\ (0.60) \qquad = \ 0.976k$$

b. 2.5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement = 5\ x\ 0.00813\ x\ 40 = 1.626kg$$

$$Wieght\ of\ sand = 3.0 - (0.025x3.0) = 2.925kg$$

$$Wieght\ of\ gravel = 5\ x\frac{156.33}{0.123}\ x\ 0.001 = 6.355\ kg$$

$$Weight\ of\ crumb\ rubber = 0.025(3.0) = 0.075kg$$

$$Weight\ of\ rice\ hull = 0.05\ (1.626) = 0.0813\ kg$$

$$Weight\ of\ water = 1.626\ (0.60) = 0.976kg$$

c. 5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement = 5\ x\ 0.00813\ x\ 40 = 1.626kg$$

$$Wieght\ of\ sand = 3.0 - (0.05x3.0) = 2.85kg$$

$$Wieght\ of\ gravel = 5\ x\frac{156.33}{0.123}\ x\ 0.001 = 6.355\ kg$$

$$Weight\ of\ crumb\ rubber = 0.05(3.0) = 0.15kg$$

$$Weight\ of\ rice\ hull = 0.05\ (1.626) = 0.0813\ kg$$

$$Weight\ of\ water = 1.626\ (0.60) = 0.976kg$$

d. 7. 5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement = 5\ x\ 0.00813\ x\ 40 = 1.626kg$$

$$Wieght\ of\ sand = 3.0 - (0.075x3.0) = 2.775kg$$

$$Wieght\ of\ gravel = 5\ x\frac{156.33}{0.123}\ x\ 0.001 = 6.355kg$$

$$Weight\ of\ crumb\ rubber = 0.075(3.0) = 0.225kg$$

$$Weight\ of\ rice\ hull = 0.05\ (1.626) = 0.0813\ kg$$

$$Weight\ of\ water = 1.626(0.60) = 0.976kg$$

FOR COMPRESSIVE STRENGTH TEST

Volume of concrete blocks

$$Volume, V \quad = 0.001\ x\ 5 = 0.005m^3$$

a. Plain Concrete

$$Weight\ of\ cement \quad = 5\ x\ 0.00813\ x\ 40 \quad = 1.626kg$$

$$Wieght\ of\ sand \quad = 5\ x \frac{73.806}{0.123}\ x\ 0.001 \quad = 3.0\ kg$$

$$Wieght\ of\ gravel \quad = 5\ x \frac{156.33}{0.123}\ x\ 0.001 \quad = 6.355\ kg$$

$$Weight\ of\ water \quad = 1.626\ (0.60) \quad = \ 0.976kg$$

b. 2.5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement \quad = 5\ x\ 0.00813\ x\ 40 \quad = 1.626kg$$

$$Wieght\ of\ sand \quad = 3.0 - (0.025x3.0) \quad = \ 2.925kg$$

$$Wieght\ of\ gravel \quad = 5\ x \frac{156.33}{0.123}\ x\ 0.001 \quad = 6.355\ kg$$

$$Weight\ of\ crumb\ rubber \quad = 0.025(3.04) \quad = \ 0.075kg$$

$$Weight\ of\ rice\ hull \quad = 0.05\ (1.626) \quad = \ 0.0813\ \ kg$$

$$Weight\ of\ water \quad = 1.626\ (0.60) \quad = \ 0.976kg$$

c. 5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement \quad = 5\ x\ 0.00813\ x\ 40 \quad = 1.626kg$$

$$Wieght\ of\ sand \quad = 3.0 - (0.05x3.0) \quad = \ 2.85kg$$

$$Wieght\ of\ gravel \quad = 5\ x \frac{156.33}{0.123}\ x\ 0.001 \quad = 6.355\ kg$$

$$Weight\ of\ crumb\ rubber \quad = 0.05(3.0) \quad = \ 0.15kg$$

$$Weight\ of\ rice\ hull \quad = 0.05\ (1.626) \quad = \ 0.0813\ \ kg$$

$$Weight\ of\ water \quad = 1.626\ (0.60) \quad = \ 0.976kg$$

d.7. 5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement = 5\ x\ 0.00813\ x\ 40 = 1.626kg$$

$$Wieght\ of\ sand = 3.0 - (0.075x3.0) = 2.775kg$$

$$Wieght\ of\ gravel = 5\ x\frac{156.33}{0.123}\ x\ 0.001 = 6.355kg$$

$$Weight\ of\ crumb\ rubber = 0.075(3.0) = 0.225kg$$

$$Weight\ of\ rice\ hull = 0.05\ (1.626) = 0.0813\ kg$$

$$Weight\ of\ water = 1.626(0.60) = 0.976kg$$

<u>FOR FLEXURAL STRENGTH TEST</u>

Volume of concrete blocks

$$Volume, V = 0.001\ x\ 5 = 0.005m^3$$

a. Plain Concrete

$$Weight\ of\ cement = 5\ x\ 0.00813\ x\ 40 = 1.626kg$$

$$Wieght\ of\ sand = 5\ x\frac{73.806}{0.123}\ x\ 0.001 = 3.0\ kg$$

$$Wieght\ of\ gravel = 5\ x\frac{156.33}{0.123}\ x\ 0.001 = 6.355\ kg$$

$$Weight\ of\ water = 1.626\ (0.60) = 0.976kg$$

b. 2.5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement = 5\ x\ 0.00813\ x\ 40 = 1.626kg$$

$$Wieght\ of\ sand = 3.0 - (0.025x3.0) = 2.925kg$$

$$Wieght\ of\ gravel = 5\ x\frac{156.33}{0.123}\ x\ 0.001 = 6.355\ kg$$

$$Weight\ of\ crumb\ rubber = 0.025(3.04) = 0.075kg$$

$$Weight\ of\ rice\ hull = 0.05\ (1.626) = 0.0813\ kg$$

$$Weight\ of\ water \quad = 1.626\ (0.60) \quad = \ 0.976kg$$

c. 5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$`Weight\ of\ cement \quad = 5\ x\ 0.00813\ x\ 40 \quad = 1.626kg$$

$$Wieght\ of\ sand \quad = 3.0 - (0.05x3.0) \quad = \ 2.85kg$$

$$Wieght\ of\ gravel \quad = 5\ x\frac{156.33}{0.123}\ x\ 0.001 \quad = 6.355\ kg$$

$$Weight\ of\ crumb\ rubber \quad = 0.05(3.0) \quad = \ 0.15kg$$

$$Weight\ of\ rice\ hull \quad = 0.05\ (1.626) \quad = \ 0.0813\ \ kg$$

$$Weight\ of\ water \quad = 1.626\ (0.60) \quad = \ 0.976kg$$

d.7. 5% sand replacement of crumb rubber and addition of 5% rice hull by weight of cement

$$Weight\ of\ cement \quad = 5\ x\ 0.00813\ x\ 40 \quad = 1.626kg$$

$$Wieght\ of\ sand \quad = 3.0 - (0.075x3.0) \quad = \ 2.775kg$$

$$Wieght\ of\ gravel \quad = 5\ x\frac{156.33}{0.123}\ x\ 0.001 \quad = 6.355kg$$

$$Weight\ of\ crumb\ rubber \quad = 0.075(3.0) \quad = \ 0.225kg$$

$$Weight\ of\ rice\ hull \quad = 0.05\ (1.626) \quad = \ 0.0813\ kg$$

$$Weight\ of\ water \quad = 1.626(0.60) \quad = \ 0.976kg$$

APPENDIX B

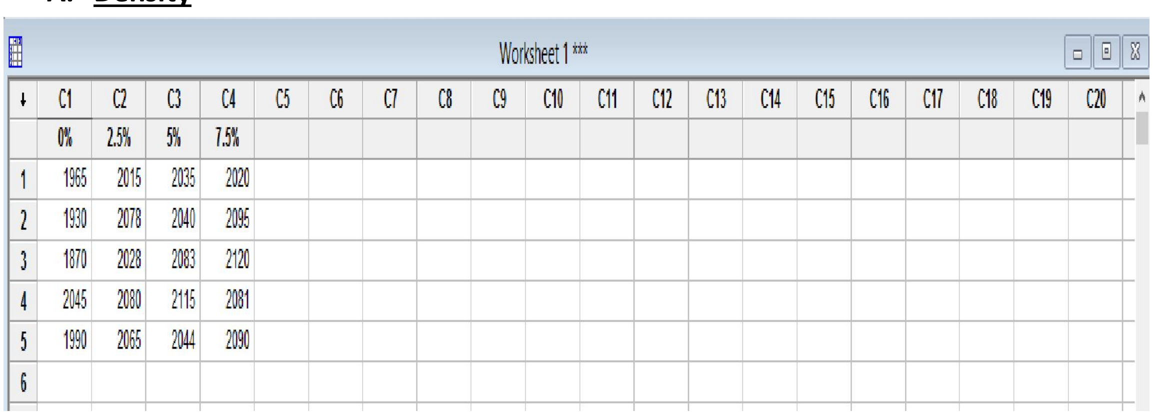
One-way ANOVA Computations

Summary of Data Mixture

Properties	No. of Samples	0% (control)	2.5%	5.0%	7.5%
Density	1	1965	2015	2035	2020
	2	1930	2078	2040	2095
	3	1870	2028	2083	2120
	4	2045	2080	2115	2081
	5	1990	2065	2044	2090
Water Absorption	1	8.397	9.677	9.828	11,634
	2	9.378	9.240	10.294	10.740
	3	9.626	9.911	9.938	11.085
	4	8.313	9.375	9.220	11.004
	5	8.191	9.685	9.638	10.526
Compressive Strength	1	46.940	26.927	30.60	18.637
	2	48.771	28.408	22.378	19.469
	3	40.873	28.105	19.448	18.354
	4	49.963	29.810	27.899	18.989
	5	50.095	30.632	29.602	18.650
Flexural Strength	1	3.432	2.94	2.808	3.588
	2	4.158	2.724	3.714	2.976
	3	4.512	2.868	2.862	2.682
	4	4.326	2.538	4.302	3.576
	5	5.796	2.628	2.352	3.588

Using ANOVA

A. Density



Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
	0%	2.5%	5%	7.5%																
1	1965	2015	2035	2020																
2	1930	2078	2040	2095																
3	1870	2028	2083	2120																
4	2045	2080	2115	2081																
5	1990	2065	2044	2090																
6																				

The p- value for 2.5%, 5%, and 7.5% against 0% are less than 0.05. These results indicate that the density of all samples containing different percentages of rubber differs significantly from the control (0%) sample.

B. Water Absorption

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
	0%	2.5%	5%	7.5%																
1	8.397	9.677	9.828	11.634																
2	9.378	9.240	10.294	10.740																
3	9.626	9.911	9.938	11.085																
4	8.313	9.375	9.220	11.004																
5	8.191	9.685	9.638	10.526																
6																				

The p- value for 2.5%, 5%, and 7.5% against 0% are less than 0.05. These results indicate that the water absorption of all samples containing different percentages of rubber differs significantly from the control (0%) sample.

C. Compressive Strength

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
	0%	2.5%	5%	7.5%																
1	46.940	26.927	30.600	18.637																
2	48.771	28.408	22.378	19.469																
3	40.873	28.105	19.448	18.354																
4	49.963	29.810	27.899	18.989																
5	50.095	30.632	29.602	18.650																
6																				

The p- value of all samples are greater than 0.05. These results indicate that the mean differences between the compressive strength of all samples are not significant or more or less equal.

D. Flexural Strength

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
	0%	2.5%	5%	7.5%																
1	3.432	2.940	2.808	3.588																
2	4.158	2.724	3.714	2.976																
3	4.512	2.868	2.862	2.682																
4	4.326	2.538	4.302	3.576																
5	5.796	2.628	2.352	3.588																
6																				

The p- value for 2.5%, 5%, and 7.5% against 0% are less than 0.05. These results indicate that the flexural strength of all samples containing different percentages of rubber differs significantly from the control (0%) sample.

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Welcome to Minitab, press F1 for help.

One-way ANOVA: 0%, 2.5%, 5%, 7.5%

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	3	44090	14697	7.58	0.002
Error	16	31013	1938		
Total	19	75103			

Means

Factor	N	Mean	StDev	95% CI
0%	5	1960.0	65.5	(1918.3, 2001.7)
2.5%	5	2053.2	29.9	(2011.5, 2094.9)
5%	5	2063.4	34.6	(2021.7, 2105.1)
7.5%	5	2081.2	37.1	(2039.5, 2122.9)

Pooled StDev = 44.0261

Dunnett Multiple Comparisons with a Control

Grouping Information Using the Dunnett Method and 95% Confidence

Factor	N	Mean	Grouping
0% (control)	5	1960.0	A
7.5%	5	2081.2	
5%	5	2063.4	
2.5%	5	2053.2	

Means not labeled with the letter A are significantly different from the contr
ol level mean.

Dunnett Simultaneous Tests for Level Mean - Control Mean

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
2.5% - 0%	93.2	27.8	(21.0, 165.4)	3.35	0.011
5% - 0%	103.4	27.8	(31.2, 175.6)	3.71	0.005
7.5% - 0%	121.2	27.8	(49.0, 193.4)	4.35	0.001

Individual confidence level = 98.04%

Interval Plot of 0%, 2.5%, ...

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	3	820635	273545	0.71	0.561
Error	16	6174691	385918		
Total	19	6995326			

Means

Factor	N	Mean	StDev	95% CI
0%C	5	430	858	(-159, 1019)
2.5%C	5	28.776	1.459	(-560.174, 617.727)
5%C	5	427	899	(-162, 1016)
7.5%C	5	18.820	0.427	(-570.131, 607.771)

Pooled StDev = 621.223

Dunnett Multiple Comparisons with a Control

Grouping Information Using the Dunnett Method and 95% Confidence

Factor	N	Mean	Grouping
0%C (control)	5	430	A
5%C	5	427	A
2.5%C	5	28.776	A
7.5%C	5	18.820	A

Means not labeled with the letter A are significantly different from the contr
ol level mean.

Dunnett Simultaneous Tests for Level Mean - Control Mean

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
2.5%C - 0%C	-402	393	(-1420, 617)	-1.02	0.620
5%C - 0%C	-3	393	(-1021, 1016)	-0.01	1.000
7.5%C - 0%C	-411	393	(-1430, 607)	-1.05	0.603

Individual confidence level = 98.04%

Interval Plot of 0%C, 2.5%C, ...

One-way ANOVA: 0%F, 2.5F, 5%F, 7.5%F

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	α = 0.05

Equal variances were assumed for the analysis.

One-way ANOVA: 0%W, 2.5W, 5%W, 7.5%W

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	3	12.610	4.2032	19.78	0.000
Error	16	3.399	0.2125		
Total	19	16.009			

Means

Factor	N	Mean	StDev	95% CI
0%W	5	8.781	0.668	(8.344, 9.218)
2.5W	5	9.578	0.268	(9.141, 10.015)
5%W	5	9.784	0.395	(9.347, 10.221)
7.5%W	5	10.998	0.419	(10.561, 11.435)

Pooled StDev = 0.460924

Dunnett Multiple Comparisons with a Control

Grouping Information Using the Dunnett Method and 95% Confidence

Factor	N	Mean	Grouping
0%W (control)	5	8.781	A
7.5%W	5	10.998	
5%W	5	9.784	
2.5W	5	9.578	

Means not labeled with the letter A are significantly different from the contr
ol level mean.

Dunnett Simultaneous Tests for Level Mean - Control Mean

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
2.5W - 0%W	0.797	0.292	(0.041, 1.552)	2.73	0.038
5%W - 0%W	1.003	0.292	(0.247, 1.758)	3.44	0.009
7.5%W - 0%W	2.217	0.292	(1.461, 2.973)	7.60	0.000

Individual confidence level = 98.04%

Interval Plot of 0%W, 2.5W, ...

One-way ANOVA: 0%C, 2.5%C, 5%C, 7.5%C

Method

APPENDIX C

Laboratory Tests Results

Table 6. Density and Unit Weight of Concrete Blocks

Percentage of crumb rubber as partially replacement of sand	No. of samples	Dry mass of concrete blocks (kg)	Volume of concrete blocks (m^3)	Density (kg/m^3)	Unit Weight (kN/m^3)
0%	1	1.965	0.001	1960.00	19.228
	2	1.930	0.001		
	3	1.870	0.001		
	4	2.045	0.001		
	5	1.990	0.001		
2.5%	1	2.015	0.001	2053.20	20.142
	2	2.078	0.001		
	3	2.028	0.001		
	4	2.080	0.001		
	5	2.06	0.001		
5.0%	1	2.035	0.001	2063.40	20.242
	2	2.040	0.001		
	3	2.083	0.001		
	4	2.115	0.001		
	5	2.044	0.001		
7.5%	1	2.020	0.001	2081.20	20.417
	2	2.095	0.001		
	3	2.120	0.001		
	4	2.081	0.001		
	5	2.090	0.001		

Solution:

$$\text{For 0\%,}\qquad \text{Density}, \rho = \left[\frac{\frac{1.965}{0.001}+\frac{1.930}{0.001}+\frac{1.870}{0.001}+\frac{2.045}{0.001}+\frac{1.990}{0.001}}{5}\right] = \frac{9800}{5} = 1960kg/m^3$$

$$\text{For 2.5\%, Density}, \rho = \left[\frac{\frac{2.015}{0.001}+\frac{2.078}{0.001}+\frac{2.028}{0.001}+\frac{2.080}{0.001}+\frac{2.065}{0.001}}{5}\right] = \frac{10266}{5} = 2053.20kg/m^3$$

$$\text{For 5\%,}\qquad \text{Density}, \rho = \left[\frac{\frac{2.035}{0.001}+\frac{2.040}{0.001}+\frac{2.083}{0.001}+\frac{2.115}{0.001}+\frac{2.044}{0.001}}{5}\right] = \frac{10317}{5} = 2063.40kg/m^3$$

$$\text{For 7.5\%, Density, } \rho = \left[\frac{\frac{2.020}{0.001}+\frac{2.095}{0.001}+\frac{2.120}{0.001}+\frac{2.081}{0.001}+\frac{2.090}{0.001}}{5}\right] = \frac{10406}{5} = 2081.20kg/m^3$$

Unit weight of Concrete Blocks

Note: *gravitational acceleration*, g = 9.81m/s^2

1Newton, N =1 kg m/s^2

1kiloNewton, kN =1000N

$$\text{For 0\% :} \quad \gamma = \frac{1960kg\,(9.81m/s^2)}{m^3} = \frac{19227.6N}{m^3} x \frac{1kN}{1000N} = 19.228kN/m^3$$

$$\text{For 2.5\%:} \quad \gamma = \frac{2035.20kg\,(9.81m/s^2)}{m^3} = \frac{20141.892N}{m^3} x \frac{1kN}{1000N} = 20.142kN/m^3$$

$$\text{For 5\%:} \quad \gamma = \frac{2063.40kg\,(9.81m/s^2)}{m^3} = \frac{20241.954N}{m^3} x \frac{1kN}{1000N} = 20.242kN/m^3$$

$$\text{For 7.5\%:} \quad \gamma = \frac{2081.20kg\,(9.81m/s^2)}{m^3} = \frac{20416.572N}{m^3} x \frac{1kN}{1000N} = 20.417kN/m^3$$

Percentage increase of the density of the samples with crumb rubber and rice hull compared to the control sample

$$\text{For 2.5\%,} \quad = \frac{2053.20 - 1960}{1960} x100 = 4.756\%$$

$$\text{For 5\%,} \quad = \frac{2063.40 - 1960}{1960} x100 = 5.276\%$$

$$\text{For 7.5\%,} \quad = \frac{2081.20 - 1960}{1960} x100 = 6.184\%$$

Percentage increase of the unit weight of the samples with crumb rubber and rice hull compared to the control sample

For 2.5%, $= \frac{20.142 - 19.228}{19.228} x100 = 4.753\%$

For 5%, $= \frac{20.242 - 19.228}{19.228} x100 = 5.274\%$

For 7.5%, $= \frac{20.417 - 19.228}{19.228} x100 = 6.184\%$

Table 7. Water Absorption of Concrete Blocks

Percentage of crumb rubber as partially replacement of sand	No. of samples	Dry mass of concrete blocks (kg)	Wet mass of concrete blocks (kg)	Water absorption rate (%)	Mean water absorption rate (%)
0% (control)	1	1.965	2.130	8.397	8.781
	2	1.930	2.111	9.378	
	3	1.870	2.050	9.626	
	4	2.045	2.215	8.313	
	5	1.990	2.153	8.191	
2.5%	1	2.015	2.210	9.677	9.578
	2	2.078	2.270	9.240	
	3	2.028	2.229	9.911	
	4	2.080	2.275	9.375	
	5	2.065	2.265	9.685	
5.0%	1	2.035	2.235	9.828	9.784
	2	2.040	2.250	10.294	
	3	2.083	2.290	9.938	
	4	2.115	2.310	9.220	
	5	2.044	2.241	9.638	
7.5%	1	2.020	2.255	11.634	10.998
	2	2.095	2.320	10.740	
	3	2.120	2.355	11.085	
	4	2.081	2.310	11.004	
	5	2.090	2.310	10.526	

Solution:

For 0%, $$\text{Sample 1, Water Absorption} = \frac{(2.130 - 1.965)}{1.965} \text{x} 100 = 8.397\%$$

$$\text{Sample 2, Water Absorption} = \frac{(2.111 - 1.930)}{1.930} \text{x} 100 = 9.378\%$$

$$\text{Sample 3, Water Absorption} = \frac{(2.050 - 1.870)}{1.870} \text{x} 100 = 9.626\%$$

$$\text{Sample 4, Water Absorption} = \frac{(2.215 - 2.045)}{2.045} \text{x} 100 = 8.313\%$$

$$\text{Sample 5, Water Absorption} = \frac{(2.153 - 1.990)}{1.990} x100 = 8.191\%$$

$$\text{Mean Water Absorption} = \frac{8.397 + 9.378 + 9.626 + 8.313 + 8.191}{5} = 8.781\%$$

For 2.5%,
$$\text{Sample 1, Water Absorption} = \frac{(2.210 - 2.015)}{2.015} x100 = 9.677\%$$

$$\text{Sample 2, Water Absorption} = \frac{(2.270 - 2.078)}{2.078} x100 = 9.240\%$$

$$\text{Sample 3, Water Absorption} = \frac{(2.229 - 2.028)}{2.028} x100 = 9.911\%$$

$$\text{Sample 4, Water Absorption} = \frac{(2.275 - 2.080)}{2.080} x100 = 9.375\%$$

$$\text{Sample 5, Water Absorption} = \frac{(2.265 - 2.065)}{2.065} x100 = 9.685\%$$

$$\text{Mean Water Absorption} = \frac{9.677 + 9.240 + 9.911 + 9.375 + 9.685}{5} = 9.578\%$$

For 5%,
$$\text{Sample 1, Water Absorption} = \frac{(2.235 - 2.035)}{2.035} x100 = 9.828\%$$

$$\text{Sample 2, Water Absorption} = \frac{(2.250 - 2.040)}{2.040} x100 = 10.294\%$$

$$\text{Sample 3, Water Absorption} = \frac{(2.290 - 2.083)}{2.083} x100 = 9.938\%$$

$$\text{Sample 4, Water Absorption} = \frac{(2.310 - 2.115)}{2.115} x100 = 9.220\%$$

$$\text{Sample 5, Water Absorption} = \frac{(2.241 - 2.044)}{2.044} x100 = 9.638\%$$

$$\text{Mean Water Absorption} = \frac{9.828 + 10.294 + 9.938 + 9.220 + 9638}{5} = 9.784\%$$

For 7.5%,
$$\text{Sample 1, Water Absorption} = \frac{(2.255 - 2.020)}{2.020} x100 = 11.634\%$$

$$\text{Sample 2, Water Absorption} = \frac{(2.320 - 2.095)}{2.095} x100 = 10.740\%$$

$$\text{Sample 3, Water Absorption} = \frac{(2.355 - 2.120)}{2.120} \text{x100} = 11.085\%$$

$$\text{Sample 4, Water Absorption} = \frac{(2.310 - 2.081)}{2.081} \text{x100} = 11.004\%$$

$$\text{Sample 5, Water Absorption} = \frac{(2.310 - 2.090)}{2.090} \text{x100} = 10.526\%$$

$$\text{Mean Water Absorption} = \frac{11.634 + 10.740 + 11.085 + 11.004 + 10.526}{5} = 10.998\%$$

Percentage increase of the water absorption of the samples with crumb rubber and rice hull compared to the control sample

$$\text{For 2.5\%,} \quad = \frac{9.578 - 8.781}{8.781} x100 = 9.076\%$$

$$\text{For 5\%,} \quad = \frac{9.784 - 8.781}{8.781} x100 = 11.422\%$$

$$\text{For 7.5\%,} \quad = \frac{10.998 - 8.781}{8.781} x100 = 25.248\%$$

===

.WORKSHEET FOR COMPRESSIVE STRENGTH TEST

Date : January 3, 2018
Project : Utilization of crumb rubber tire for concrete paving blocks
Sample by : Julie C. Jumawan
City/Province : Dumaguete City, Negros Oriental
Type of sample : Blocks

Summary of Compressive Strength Tests Results

Percentage of crumb rubber as partially replacement of sand	No. of samples	Actual Load (kN)	Compressive strength (MPa)	Mean Compressive strength (MPa)
0%	1	938.79	46.940	47.328
	2	975.42	48.771	
	3	817.45	40.873	
	4	999.25	49.963	
	5	1001.90	50.095	
2.5%	1	538.53	26.927	28.776
	2	568.16	28.408	
	3	562.09	28.105	
	4	596.20	29.810	
	5	612.64	30.632	
5.0%	1	611.99	30.600	25.985
	2	447.56	22.378	
	3	388.96	19.448	
	4	557.98	27.899	
	5	592.04	29.602	
7.5%	1	372.73	18.637	18.820
	2	389.37	19.469	
	3	367.07	18.354	
	4	379.77	18.989	
	5	373.009	18.650	

Remarks: The herein test results represents only from the sample submitted.

Tested by: Ernesto E. Sy Jr.
Assistant Manager

Solution

For 0%

$$\text{Mean Compressive Strength} = \frac{46.940 + 48.771 + 40.873 + 49.963 + 50.095}{5}$$
$$= 47.328\text{MPa}$$

For 2.5%

$$\text{Mean Compressive Strength} = \frac{26.927 + 28.408 + 28.105 + 29.810 + 30.632}{5}$$
$$= 28.776\text{MPa}$$

For 5%

$$\text{Mean Compressive Strength} = \frac{30.600 + 22.378 + 19.448 + 27.899 + 29.602}{5}$$
$$= 25.985\text{MPa}$$

For 7.5%

$$\text{Mean Compressive Strength} = \frac{18.637 + 19.469 + 18.354 + 18.989 + 18.650}{5}$$
$$= 18.820\text{MPa}$$

Percentage reduction of the compressive strength of the samples with crumb rubber and rice hull compared to the control sample

$$\text{For 2.5\%}, \; = \frac{47.328 - 28.776}{47.328} x100 = 39.199\%$$

$$\text{For 5\%}, \qquad = \frac{47.328 - 25.985}{47.328} x100 = 45.096\%$$

$$\text{For 7.5\%}, \qquad = \frac{47.328 - 18.820}{47.328} x100 = 60.235\%$$

WORKSHEET FOR FLEXURAL TEST

Date : January 3, 2018
Project : Utilization of crumb rubber tire for concrete paving blocks
Sample by : Julie C. Jumawan
City/Province : Dumaguete City, Negros Oriental
Type of sample : Blocks

Summary of Flexural Strength Tests Results

Percentage of crumb rubber as partially replacement of sand	No. of samples	Actual Load (kN)	Modulus of Rupture (MPa)	Average Flexural Strength (MPa)
0%	1	5.72	3.432	4.698
	2	6.93	4.158	
	3	7.52	4.512	
	4	7.21	4.326	
	5	9.66	5.796	
2.5%	1	4.9	2.94	2.740
	2	4.54	2.724	
	3	4.78	2.868	
	4	4.23	2.538	
	5	4.38	2.628	
5.0%	1	4.68	2.808	3.208
	2	6.19	3.714	
	3	4.77	2.862	
	4	7.17	4.302	
	5	3.92	2.352	
7.5%	1	5.98	3.588	3.282
	2	4.96	2.976	
	3	4.47	2.682	
	4	5.96	3.576	
	5	5.98	3.588	

Tested by: Ernesto E. Sy Jr.
Assistant Manager

Solution:

$$\text{For } 0\% \text{ Mean Flexural Strength} = \frac{3.432 + 4.158 + 4.512 + 4.326 + 5.796}{5} = 4.698\text{MPa}$$

$$\text{For } 2.5\% \text{ Mean Flexural Strength} = \frac{2.940 + 2.724 + 2.868 + 2.538 + 2.628}{5}$$
$$= 2.740\text{MPa}$$

$$\text{For } 5\% \text{ Mean Flexural Strength} = \frac{2.808 + 3.714 + 2.862 + 4.302 + 2.352}{5} = 3.208\text{MPa}$$

$$\text{For } 7.5\% \text{ Mean Flexural Strength} = \frac{3.588 + 2.976 + 2.682 + 3.576 + 3.588}{5}$$
$$= 3.282\text{MPa}$$

Percentage reduction of the flexural strength of the samples with crumb rubber and rice hull compared to the control sample

$$\text{For } 2.5\%, \quad = \frac{4.698 - 2.740}{4.698} x100 = 41.677\%$$

$$\text{For } 5\%, \quad = \frac{4.698 - 3.208}{4.698} x100 = 31.716\%$$

$$\text{For } 7.5\%, \quad = \frac{4.698 - 3.282}{4.698} x100 = 30.140\%$$

APPENDIX D

Cost Estimates Computations

TOTAL COST ESTIMATES OF THE STUDY FOR ALL SAMPLES (60 PIECES)

MATERIALS				
ITEM	UNIT	QUANTITY	UNIT COST (Php)	TOTAL COST
Portland Cement, Type 1	Bag	1	225.00	225.00
Sand	cu.m.	0.04	750.00	30.00
Fine Gravel	cu.m.	0.08	850.00	68.00
Crumb Rubber Tire	Sack	1	100.00	100.00
Rice Hull	Sack	1	50.00	50.00
½" thk. Marine Plywood	Pc	1	400.00	400.00
2" x4" Coco Lumber	Pc	4	160.00	640.00
Assorted CW Nails	Kg	1	50.00	50.00
Plastic " Trapal"	m	10	15.00	150.00
			TOTAL MATERIAL COSTS	**1,737.50**

LABOR				
TYPE OF WORKER/PERSONNEL	NO. OF WORKER	NO. OF DAY	RATE/DAY (Php)	TOTAL COST
Skilled Worker (Carpenter)	2	2	350.00	1,400.00
Laborer	4	6	200.00	4,800.00
			TOTAL LABOR COSTS	**6,200.00**

EQUIPMENT/APPARATUS RENTAL				
TYPE OF EQUIPMENT	NO. OF EQUIPMENT	NO. OF DAY	RATE/DAY (PhP)	TOTAL COST (PhP)
Hydraulic Compressive Testing Machine	1	1	6,000.00	6,000.00
Weighing Scale (Digital)	1	3	500.00	1,500.00
Oven	1	2	1,000.00	2,000.00
Sieve	2	1	500.00	1,000.00
Slump Cone	1	1	250.00	250.00
Thermometer	1	2	250.00	500.00
			TOTAL EQUIPMENT/APPARATUS COSTS	**11,250.00**

GRAND TOTAL	**19,187.50**

ESTIMATED COST PER CONCRETE PAVER BLOCKS FOR 0% (CONTROL)

MATERIALS				
ITEM	UNIT	QUANTITY	UNIT COST (Php)	TOTAL COST
Portland Cement, Type 1	Kg	0.326	6.00	1.96
Sand	Kg	0.600	0.60	0.36
Fine Gravel	Kg	1.271	0.65	0.83
½" thk. Marine Plywood	Pc	0.034	400	13.60
Assorted CW Nails	Kg	0.017	50.00	0.85
TOTAL MATERIAL COSTS				**17.60**

LABOR				
TYPE OF WORKER/PERSONNEL	NO. OF WORKER	NO. OF DAY	RATE/DAY (Php)	TOTAL COST
Skilled Worker (Carpenter)	2	0.25	350.00	87.50
Laborer	4	0.25	200.00	50.00
TOTAL LABOR COSTS				**137.50**

GRAND TOTAL	**155.10**

ESTIMATED COST PER CONCRETE PAVER BLOCKS FOR 2.5% REPLACEMENT OF CRUMB RUBBER TIRE

MATERIALS				
ITEM	UNIT	QUANTITY	UNIT COST (Php)	TOTAL COST
Portland Cement, Type 1	Kg	0.326	6.00	1.96
Sand	Kg	0.585	0.60	0.35
Fine Gravel	Kg	1.271	0.65	0.83
Crumb Rubber Tire	Kg	0.015	0.25	0.004
Rice Hull	Kg	0.017	0.15	0.003
½" thk. Marine Plywood	Pc	0.034	400	13.60
Assorted CW Nails	Kg	0.017	50.00	0.85
			TOTAL MATERIAL COSTS	**17.597**

LABOR				
TYPE OF WORKER/PERSONNEL	NO. OF WORKER	NO. OF DAY	RATE/DAY (Php)	TOTAL COST
Skilled Worker (Carpenter)	2	0.25	350.00	87.50
Laborer	4	0.25	200.00	50.00
			TOTAL LABOR COSTS	**137.50**

GRAND TOTAL	**155.097**

ESTIMATED COST PER CONCRETE PAVER BLOCKS FOR 5% REPLACEMENT OF CRUMB RUBBER TIRE

MATERIALS				
ITEM	UNIT	QUANTITY	UNIT COST (Php)	TOTAL COST
Portland Cement, Type 1	Kg	0.326	6.00	1.96
Sand	Kg	0.57	0.60	0.342
Fine Gravel	Kg	1.271	0.65	0.83
Crumb Rubber Tire	Kg	0.03	0.25	0.008
Rice Hull	Kg	0.017	0.15	0.003
½" thk. Marine Plywood	Pc	0.034	400	13.60
Assorted CW Nails	Kg	0.017	50.00	0.85
			TOTAL MATERIAL COSTS	**17.593**

LABOR				
TYPE OF WORKER/PERSONNEL	NO. OF WORKER	NO. OF DAY	RATE/DAY (Php)	TOTAL COST
Skilled Worker (Carpenter)	2	0.25	350.00	87.50
Laborer	4	0.25	200.00	50.00
			TOTAL LABOR COSTS	**137.50**

GRAND TOTAL	**155.089**

ESTIMATED COST PER CONCRETE PAVER BLOCKS FOR 7.5% REPLACEMENT OF CRUMB RUBBER TIRE

MATERIALS				
ITEM	UNIT	QUANTITY	UNIT COST (Php)	TOTAL COST
Portland Cement, Type 1	Kg	0.326	6.00	1.96
Sand	Kg	0.551	0.60	0.33
Fine Gravel	Kg	1.271	0.65	0.83
Crumb Rubber Tire	Kg	0.045	0.25	0.011
Rice Hull	Kg	0.017	0.15	0.003
½" thk. Marine Plywood	Pc	0.034	400	13.60
Assorted CW Nails	Kg	0.017	50.00	0.85
TOTAL MATERIAL COSTS				**17.584**

LABOR				
TYPE OF WORKER/PERSONNEL	NO. OF WORKER	NO. OF DAY	RATE/DAY (Php)	TOTAL COST
Skilled Worker (Carpenter)	2	0.25	350.00	87.50
Laborer	4	0.25	200.00	50.00
TOTAL LABOR COSTS				**137.50**

GRAND TOTAL	**155.084**

APPENDIX E

Dauin, Negros Oriental Recapping Services

Stockpile Crumb Rubber at Dauin, Negros Oriental Recapping Establishment

APPENDIX F

Research Documentations

Fig.D1. Preparation of Aggregates

Fig.D2. Sieving of Aggregates

Fig.D3. Sieving of Crumb Rubber

Fig.D4. Sieving of Rice Hull

Figure 5. Washing of Aggregates

Figure F6. Washing of Crumb Rubber

Figure F7. Preparation of Wooden Molds

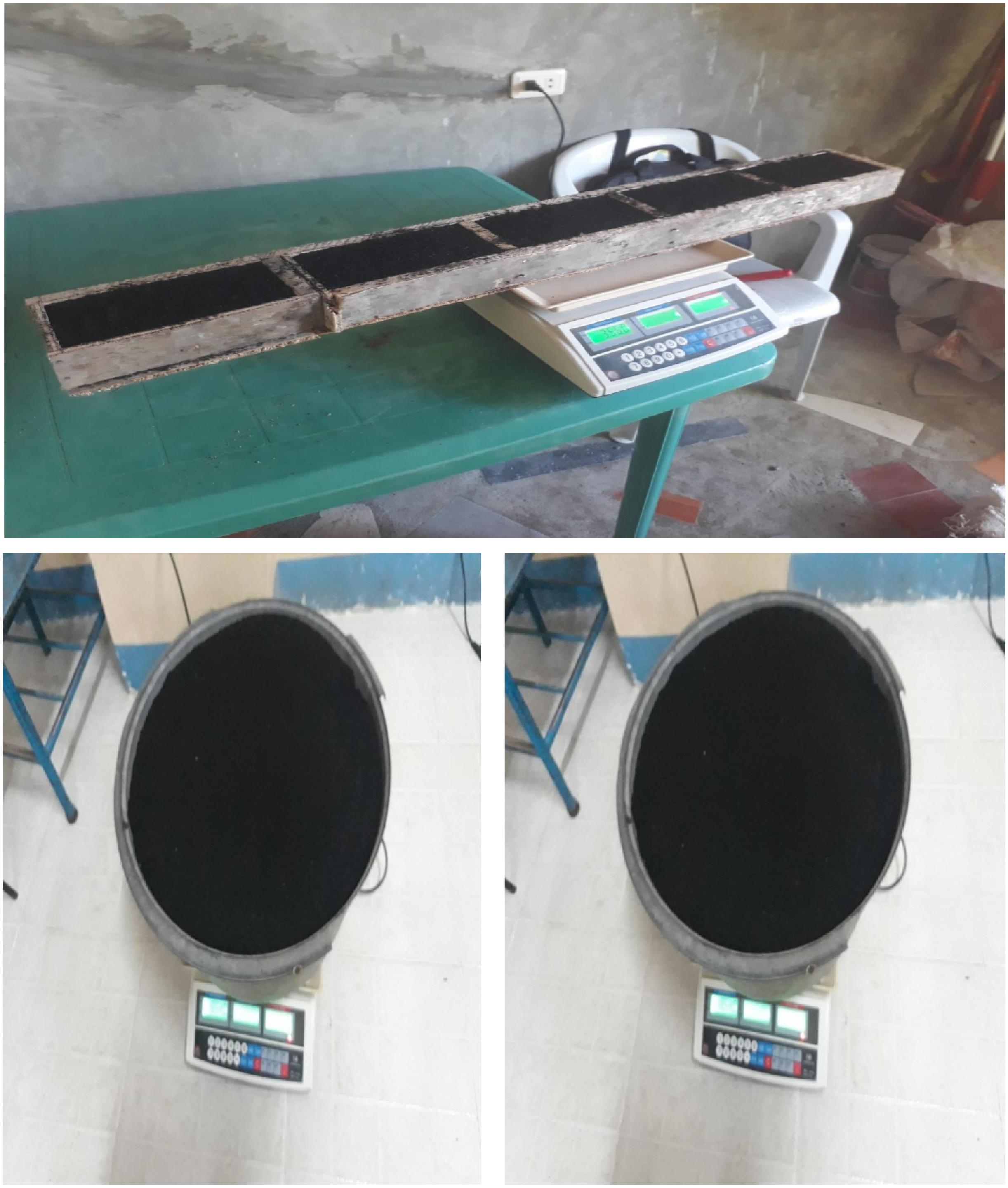

Figure F8. Weighing of Crumb Rubber

Figure F9. Weighing of Cement

Figure F10. Weighing of Rice Hull

Figure F11 Weighing of Aggregates

Figure F12. Mixing of Raw Materials

Figure F13. Slump Testing of Mixtures

Figure F14. Placing and Labelling of Mixtures on the Moulders

Figure F15. Removal of Samples from the Moulders

Figure F16. Weighing of Samples

Figure F17. Oven Testing of Samples

Figure F18. Curing of Samples at Day 1

Figure F19. Curing of Samples at Day 28

Figure F20. Compressive Testing of Samples

Figure F21. Flexural Testing of Samples

CURRICULUM VITAE

ST. PAUL UNIVERSITY DUMAGUETE
6200 Dumaguete City
Philippines

GRADUATE SCHOOL

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PERSONAL BACKGROUND

Name : Julie C. Jumawan

Date of Birth : July 01, 1979

Place of Birth : Siquijor, Siquijor

Present Address : Magsaysay Street, Poblacion, Zamboanguita, Negros Oriental

Civil Status : Married

Spouse : Irismay Traces Jumawan

Children : Jaesha Risse Traces Jumawan
Justnin Jule Traces Jumawan

Parents : Father : Felimon Pactol Jumawan
: Mother : Carmolina Cafino Jumawan

EDUCATIONAL BACKGROUND

Master's Degree : Master of Science Environmental Studies (Candidate)
St. Paul University Dumaguete
Dumaguete City, Negros Oriental
2018

Tertiary Education : Bachelor of Science in Civil Engineering
Negros Oriental State University (NORSU)
Dumaguete City, Negros Oriental
2001

Secondary Education : Décor Carmeli Academy
Zamboanguita, Negros Oriental
1996

Elementary Education :Zamboanga East Central School
Zamboanga City, Zamboanga Del Sur
1992

RECORD OF SERVICE

Municipal Engineer
Municipal Engineering Office
LGU-Zamboanguita
Zamboanguita, Negros Oriental
(2008 - present)

Engineering Assistant
Municipal Engineering Office
LGU-Zamboanguita
Zamboanguita, Negros Oriental
(2005 - 2008)

Field Engineer
Municipal Engineering Office
LGU-Zamboanguita
Zamboanguita, Negros Oriental
(2002 - 2005)

MEMBERSHIP

Philippine Institute of Civil Engineer
Member, 2001 – present

Philippine Association of Building Officials
Member, 2008 - present

Local Building Official Association – Negros Oriental Chapter
Member, 2008 – present

City and Municipal Engineers Association of the Philippines
Member, 2008 – present
Occupational Safety and Health Network Negros Oriental-7, Inc.
Member 2014-present

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TRAININGS AND SEMINARS

Seminar-Workshop on ROLL IT Program Stakeholders
Department of Trade and Industry and Department of Public Works and Highway
Dumaguete City
February 8, 2018

Seminar-Workshop on the Formulation of the Local Road Network Development
Plan (LRNDP)
Department of Interior and Local Government (DILG), Dumaguete City
November 22-23, 2017

Seminar on Safe Closure of Open and Controlled Dumpsites and Establishment of a Categorized Sanitary Landfill
Environment and Natural Resources Division (ENRD), Bayawan City
September 26-27, 2017

International Seminar on Earthquake Engineering
Philippine Institute of Civil Engineer, Inc., Dumaguete City
August 16, 2017

Seminar-Workshop on the Formulation of Local Climate Change Action Plan
Department of Interior and Local Government (DILG), Talisay City
March 14-16, 2017

Training of Trainers (TOT) on Occupational Safety and Health
Department of Labor and Employment (DOLE), Dumaguete City
March 1-3, 2017

Seminar on State of Nature Assessment 2016-Philippine Contribution to Climate Change: Carbon Sources and Sinks/Green Convergence
Department of Environment and Natural Resources, Dumaguete City
August 9, 2016

Seminar on Green Building Referral Code Multi-Stakeholder Consultation
Department of Public Works and Highway, Cebu City
February 10, 2015

Construction Safety Training
Department of Labor and Employment, Dumaguete City
October 27-31, 2014

Seminar-Workshop on Revised Structural Code of the Philippines
Association of Structural Code of the Philippines, Dumaguete City
October 9-11, 2014

Roll-out Training on Thematic Environment Management System
Department of Social Welfare and Development-KALAHI-CIDDS, Lapu-lapu City,
May 27-30, 2014

Training/Seminar-Workshop on Construction Materials Quality Control
Department of Social Welfare and Development-KALAHI-CIDDS, Cebu City
June 21-25, 2013