Empirical Analysis of the Compressive Strengths of Composite Materials: The Case of Rice Straw and Cement

John Arvin R. Manaloto[1]
jrmanaloto@up.edu.ph

Abstract

In the Philippines, rice straw is an agricultural waste product which is disposed through incineration. Using it as a composite material in green building construction can reduce cost and environmental hazards caused by crop burning. A fiber (rice straw) reinforced concrete, through proper mixing and proportion of its design, can achieve good strength and insulation properties. This study focuses on determining the effectiveness of rice straw/stalk with cement as an alternative eco-friendly and light building material. Moreover, this study aims to determine the effects of using various percentages of chopped rice straw in different concrete mixtures to optimize the compressive strength of the composite material. The rice straw samples used for this study came from Barangay Salvacion, Tabaco, Albay. The samples were dried in various drying durations of five days, eight days and 10 days and then cured in water for 24 hours. Afterward, concrete cylinder samples using steel molds were prepared for compressive strength determination. In the concrete mixes, different proportions were prepared by replacing the coarse aggregates with 25 percent, 50 percent and 100 percent rice straw. In the course of mixing the composite materials, water retardant and foaming agent admixtures were also introduced. The samples were cured for one day, three days, seven days, 14 days, and 28 days for compressive strength determinations. The results show that the compressive strength is inversely proportional with the rice straw content of concrete. The sample with 100 percent rice straw replacement attained a compressive strength value of 266.00 psi on the 28th day of curing while the zero percent rice straw attained 1,526.00 psi. The compressive strength value was found to be reduced by at most 82.56 percent. Using 100 percent rice straw as aggregates decreased the mixtures' workability resulting to a higher concrete water demand but also made it lighter with decreased density, hence making it lightweight. An air entraining admixture was mixed with plasticizer to help increase the workability of the concrete mixture.

Keywords: Rice Straw, Low-cost Materials, Eco-friendly, Sustainable Material, Lightweight Concrete

I. Introduction

The ever-present need to improve the present condition of building and construction materials in the country calls for the innovative use of composite materials; these are manufactured through the combination of traditional materials with strong fibers that act as reinforcing fillers.

One example of a composite building material is the cement-bonded type, which can be formed into bricks or blocks as substitute to the commonly-used hollowed blocks made from cement and concrete mixture. Organic fillers such as agro-industrial waste products rich in cellulosic materials are found to be good substitute for cement, if mixed in the right proportions.

In the Philippines, two of the many agricultural waste products are rice straw and rice plant residues. Almost all rice straw accumulated after harvest is incinerated and disposed, leaving some areas in the field accumulating nutrients while the others are depleted of them. Rice straws have no market value; hence, using them to manufacture composite products can prove to be beneficial not only to the manufacturers who would be spending less on the acquisition of raw materials, but also the farmers who could generate another source of income from their waste product.

Previous studies suggest that rice straw has mechanical properties that can prove advantageous as a building material. It is reported to increase the tensile modulus of the material. Moreover, it presents other mechanical properties such as its being flame-retardant and resistant to bacterial decomposition.

A. Problem Statement

The recent growth of our country's construction industry requires large amount of concrete production. These massive development processes include extraction of raw materials such as cement and aggregates which are major components of concrete, and these materials are about to be depleted soon from its various sources. The arising problem to shortage of supply of the said materials requires an innovative solution. Exploring or finding alternative green building material solution is necessary. This study will explore the possibility of utilizing agricultural waste product as substitute to traditional construction materials.

[1] John Arvin R. Manaloto is an Assistant Professor of the UP College of Architecture - Building Science Studio Laboratory. He graduated with Bachelor of Science Degrees in Geodetic Engineering and Civil Engineering from the Institute of Civil Engineering, UP College of Engineering and Bachelor of Science in Sanitary Engineering from the National University. He completed his Master's Degree in Civil Engineering (M.S.C.E.-Structural Engineering) at the National Graduate School of Engineering, UP College of Engineering. He is a PhD-Candidate in Civil Engineering (Ph.D.C.E.-Geotechnical Engineering) at the NGSE, UP College of Engineering.

B. Objectives

The objective of this study was to determine the most efficient composite material to be used as replacement to traditional materials for building and construction. Specifically, the researcher would like to answer these following questions:

1. What type of composite can offer the highest resistance versus natural occurrences and/or disasters?
2. How can we cope with the limitations of construction materials (especially cement) in production?
3. What are the efficiency and compressive strength of the rice straw and cement composite material compared to local commercial material?
4. What is the effect of various percentage and proportion of chopped rice straw on the material?

C. Significance of the Study

The study can serve as a baseline data for engineers and architects to conduct a more in-depth study on composite materials. The potential of the study, if given due attention, is huge in terms of its impact on the current state of building and construction in the country.

If proven feasible for a bigger market, manufacturers can then use the results obtained by engineers and architects to alter their current products. The raw material used, which is rice straw, can appeal to them in terms of its low cost and abundance in the market. On the other hand, the appeal of producing composite materials instead of traditional building materials lies in the acceptance of the consumers of the said good.

Upon mass production of composite materials, the consumers can benefit from a potential decrease in the price of traditional building materials because of the introduction of a new viable competitor. Moreover, the introduction of composite materials can prove to be beneficial because of its relatively low cost, with roughly the same or even better quality with that of the ones conventionally used.

Rice hull or straw is an agricultural residue, which is usually treated as waste product without much use. Farmers can benefit from the production of rice hull composite bodies since the raw material is their waste product hence they gain another source of income without altering their production process.

Developing an alternative green building material can provide various advantages that may improve the building function performance, develop products that are eco-friendly to the environment, and benefit even on the economic aspect of the users.

D. Scope and Limitations

1. The study focuses on determining the effectiveness of rice straw/stalk as an alternative light material, traditionally paired with cement, used in construction.
2. The study involves an experiment that will help the researcher in determining the compressive strength and sustainability of the materials to be tested using a controlled specimen.
3. The measurement of strength of the samples (or their resistance to breakage) will only be done through the measurement of the compressive strength in accordance with ASTM C39. Statistical calculations will not be included in the analyses.
4. The researcher did not include any key factors in the study other than the said variables to be used in determining the study's efficiency.
5. The cost efficiency of the composite material produced is not included in this study. This study will only focus on the sample's compressive strength and its lightweight characteristic.

II. Review of Related Literature

A. Conventional Building Materials

Traditional materials include plastics, ceramics, and metals. Low-density materials like plastics are easily fabricated and joined but have short-term chemical resistance and lack thermal stability, as well as have poor mechanical properties, and moderate resistance to environmental degradation, especially the photo-chemical effects of sunlight. Ceramics, on the other hand, may have low or high density. They are resistant to most form of degradation and have high thermal stability; however, they are brittle and difficult to fabricate and shape. Metals have medium to high density. Through alloying, metals may have good thermal stability and resistance. They are moderately easy to shape and join and they have useful mechanical properties that make them suitable and preferred as engineering materials (Harris, 1999).

Conventional materials have advantages and disadvantages, and the combination of these materials into composite materials is designed to take advantage of the conventional materials' intrinsic characteristics and eliminate the disadvantages. Figure 1 shows the composite materials resulting from the combination of two conventional materials.

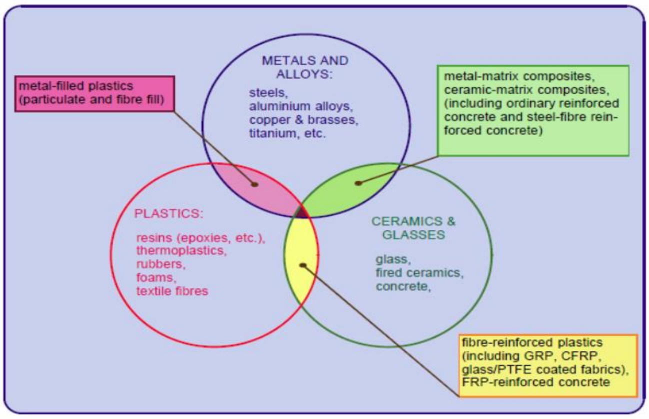

Figure 1. Relationship between classes of engineering materials, showing the evolution of composites.
Source: Harris (1999).

B. Composite Materials

Composite materials are "engineered or naturally-occurring materials made from two or more constituent materials with significantly different physical or chemical properties," wherein the added materials may or may not remain distinct at a microscopic level (ASHLAND, 2011). End users can benefit from the composite because they are extremely durable, lightweight, energy-saving, and flexible in design. These materials result from reinforcing traditional materials with other engineering materials, so as to create materials with better specifications and range. The reinforcing materials are usually strong fibers such as glass fibers, carbon fibers, silicon carbide, alumina and alumina/silica compounds and organic fibers (Harris, 1999).

Glass fibers are strong inorganic fibers but lack the rigidity because of their molecular structure. Carbon fibers, on the other hand, are high-tensile strength materials that are inherently expensive. Silicon carbide (continuous silicon carbide monofilaments) is composed of thick fibers which are generally of importance to manufacturers of metal and ceramic composites; however, it is reactive towards oxygen. Alumina and alumina/silica compounds are used mainly for metal composites because of their chemical inertness, high-temperature stability, and ability to form a good bond with alloys. Organic fibers are used where improvements in strength and rigidity is required (Harris, 1999).

Composite materials can also be classified as eco-friendly materials, which are defined to describe products that do the least possible damage to the environment, while serving the same purpose as their counterpart materials. Eco-friendly materials, known to come from renewable sources, are biodegradable, reusable/recyclable, and durable. They also aid in energy efficiency of the buildings or infrastructures they are used in, reduce air, land and water pollution, and make use of waste product as their raw material (Mhaskar, 2013).

C. Cement-Bonded Composite Materials

Cement-bonded composite materials are those "made from wood or other ligno-cellulosic raw materials bonded with inorganic binders such as cement, chemical additives and water and pressed under regulated pressure" (Adedeji & Ayaji, 2008).

They are usually produced by combining strands, particles or fibers of wood with cement and formed into panels, bricks, tiles, and other construction materials.

In comparison to concrete, composites have lower energy consumption in terms of its manufacturing process. This is clearly shown in Figure 2.

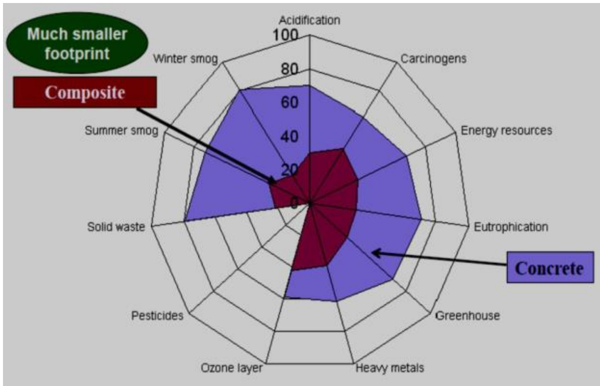

Figure 2. Energy consumed in the production of composites and concrete.
Source: ASHLAND (2011).

The area shaded in maroon representing the energy consumption for the production of composites has a much smaller scope than that of concrete, represented by the purple area. This gives conclusive evidence that the production of composites leaves a much smaller footprint as compared to the production of traditional concrete. This can be attributed to the addition of organic or inorganic fillers.

Agricultural by-products have been used in building materials for some time, ranging in applications from wood panels to roof tiles. Vegetable fibers, which are in abundance in most developing countries, are suitable reinforcement materials for brittle matrix despite their poor durability performance. Adequate mixture design may be the key to finding the most suitable composite properties for building materials. Waste fibers added at eight percent mass resulted in a decrease in the fracture strength of the corresponding traditional material by 18 MPa. However, at 12 percent waste fiber, there is a reasonable increase in toughness at about 1.20 kJ/m^2 (Rabi et al., 2009).

Upon fiber reinforcement, a building material's mechanical properties are improved, which would otherwise be unsuitable for practical applications. One vital improvement achieved through fiber reinforcement is the post-cracking toughness, which may allow for the "large-scale construction use of such composites" (Rabi et al., 2009).

D. Microstructure of Rice Straw Fibers

Storage environment of the rice straw fibers can cause undesirable impurities. Mold formation during its storage can result harm to the fibers. The skin of the straw particles may have smoother surface due to presence of molds. Unfortunately, this property has an adverse effect on the pull-out resistance of fibers. Roughness of the fiber is required to contribute to better adhesion with the binder matrix (cement, lime, etc.) and consequently better mechanical resistance (Bouasker et al., 2014). In order to avoid any damage, it is highly recommended to treat the fibers in order to eliminate molds before insertion in the fiber reinforced composite.

Table 1. Physical Properties of Rice Straw Fibers.

Rice Straw Variety	Bulk Density (kg/m³)	Porosity (%)	Moisture Content (%)
Long Grain	166.29	83.2	6.58
Short Grain	162.03	85.28	6.92
Cascara de Arroz	177.23	80.29	6.82
Japonica	194.48	71.21	6.89

Source: Zhang, Ghaly, & Li (2012).

E. Properties of Different Straw Fiber Cement Composites

The differences of the straw fiber-cement composites in their physical and mechanical properties by different pretreatment methods, fiber content and fiber length were investigated by Ding, Tian, and Ge in 2019. The results of the study showed that the hemicellulose content in straw decreases greatly in three pretreatment methods (cold water, four percent NaOH, and hot alkali) and the effect of straw on retarding time of cement is weakened. The most favorable order of the three kinds of straw as cement additives is wheat > corn > rice.

The main components of crop straw are cellulose, hemicellulose and lignin. When straws are added to cement's cementitious materials, alkaline environment caused by cement hydration will cause chemical erosion of straw, dissolve monosaccharide, oligosaccharide, starch and other substances, and the cement retard finally (Ding, Tian, & Ge, 2019).

Straw fibers were pretreated by soaking the straw with three solvents: cold water, four percent NaOH solution, hot alkali (60.00°C, 4.00 percent NaOH solution), soaking time was 24 hours, and the pretreatment methods were investigated.

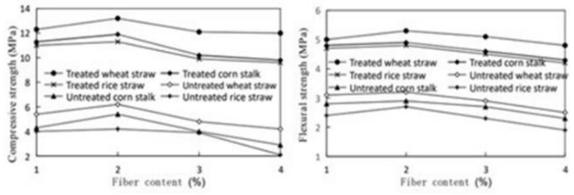

Figure 3. Effect of straw fiber content on compressive strength and flexural strength of straw fiber reinforced cementitious composites.
Source: Ding, Tian, & Ge (2019).

Figure 3 shows the effects of three kinds of pretreated and untreated straw fibers on the compressive strength and flexural strength of straw fiber-cement composites. The strength of the three kinds of straw fiber increases first and then decreases when the content of the three kinds of straw fiber increases from one percent to four percent, and the compressive strength and flexural strength reach the maximum when the content of the three kinds of straw fiber is two percent.

It can also be seen from Figure 3 that the mechanical properties of straw fiber-cement composites differ greatly before and after pretreatment. The pretreatment can significantly improve the compressive strength and flexural strength of straw fiber cement composites. This is due to the removal of fiber carbohydrates after thermal-alkali immersion, the influence of carbohydrates on cement hydration is greatly weakened. In addition, the waxy layer on the surface of straw fiber can be partly or completely eliminated after soaking with hot alkali, and the rough surface can be exposed, which increases the mechanical adhesive force between the cement paste and the surface of straw fiber, and reduces the effect on the adhesive strength of the straw fiber-cement interface (Ding, Tian, & Ge, 2019).

Moreover, Figure 3 shows that the mechanical strength of rice straw is obviously worse than that of the corn and wheat straw, and the order is rice < corn < wheat. This is because the cellulose content of rice straw after pretreatment is lower than that of corn and wheat, and the interfacial bonding probability between rice straw and cement is low, so the strength of the composite is not improved.

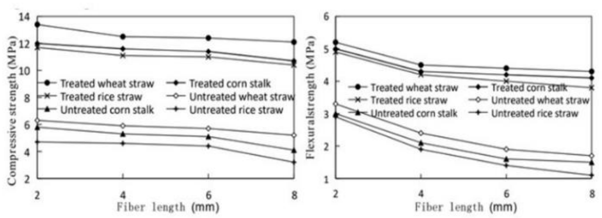

Figure 4. Effect of fiber length on compressive strength and flexural strength of straw fiber reinforced cementitious composites.
Source: Ding, Tian, & Ge (2019).

Figure 4 presents that when the fiber length changes from two millimeters to eight millimeters, the compressive strength and flexural strength of the cement-based composite material tend to decrease with the increase of the fiber length. This is because the short fibers have favorable dispersibility in the cement slurry and are easy to mix with the cement. At the same time, short fibers can block part of the capillary channel in the matrix, and the water retention performance is excellent. The cement matrix is not easy to be separated, so that the cement is more hydrated. The two-millimeter-long fiber has the best effect on the mechanical properties of the composite.

When three methods are used to pretreat wheat straw, corn stover and rice straw, the content of extracts by hot alkali treatment are high, and the sugar substances in straw are more fully dissolved. The pretreated straw fiber can improve the compressive strength, flexural strength, dry density and water absorption of the straw fiber-cement composite. The wheat straw can improve the performance of the composite better than corn straw and rice straw. Adding straw fiber into cement's cementitious materials can improve the physical and mechanical properties effectively, and the addition of straw fiber can greatly help to reduce the density of building materials and obtain lighter building materials (Ding, Tian, & Ge, 2019).

III. Methodology

The main objective of the research is to produce an efficient and eco-friendly building light material available on a neighborhood scale out of rice straw/stalk fibers which are considered as one of the agro-wastes.

The researcher adopted an experimental design as the study will focus on testing cement-bonded composite materials made of rice straw, sand, water, and cement. Upon gathering related literature of this study, the researcher devised an approach to determine the materials needed and its specification.

A. Material Sample Preparation:

The rice straw samples used for this study were delivered from Barangay Salvacion, Tabaco, Albay. Upon receiving the samples at UP Diliman College of Architecture Complex, the samples were initially weighed and separated into three different drying samples; they are five days, eight days and 10 days of various drying day samples. After dividing the rice straw into three parts, weighing per set was done in preparatory for a 24-hour soaking.

Figure 5. Arrival of Samples from Albay

Figure 6. Initial Weighing of Samples.

Figure 7. Separation of Samples into Three Sets.

Figure 8. Preparation of Samples for Soaking.

Figure 9. Containers Used for Soaking Samples.

Figure 10. Soaking of Sample for 24 hrs.

After soaking overnight, the rice straw was washed from impurities. The washed samples were set aside to drain water before weighing. After obtaining the weight, the samples were brought to the roof deck area of the Building 3 of the UP College of Architecture for initial drying.

Figure 11. Washing of Soaked Sample.

Figure 12. Initial Weighing Before Drying.

Figure 13. Preparation for Drying.

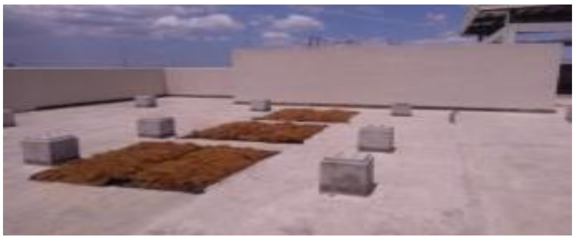

Figure 14. Drying of Samples.

Figure 15. Storing of Samples

Samples were weighed daily to determine their moisture content. Rice straw samples were sun-dried daily for six hours until they reach their corresponding drying days. Average daily temperature monitoring was also measured during morning, noon time and afternoon at five days apiece. After the drying duration of the three sets (five days, eight days and 10 days), the final weighing per set was done before the cutting and shredding of rice straw.

Figure 16. Daily drying.

Figure 17. Daily weight monitoring.

Figure 18. Temperature monitoring.

Figure 19. Final Weighing of Samples.

The cutting length of rice straw is about 1.5-2.5 cm. per set and the final weighing of cut rice straw was done before packing and having them labeled for the materials testing and laboratory.

Figure 20. Cutting/Chopping of Samples.

Figure 21. Chopped Samples.

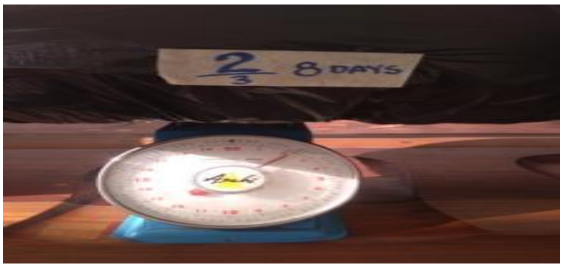

Figure 22. Final Weighing of Samples.

Figure 23. Samples Ready for Laboratory Testing.

Table 2. Daily Sun-dried Sample Weight.

No. of Days	Set A (5 Days)	Set B (8 Days)	Set C (10 Days)
Day 0	5 ½ Kgs.	5 ¾ Kgs.	5 ¾ Kgs.
Day 1	14 Kgs.	14 ¼ Kgs.	14 ¼ Kgs.
Day 2	9 ¼ Kgs.	9 Kgs.	8 ½ Kgs.
Day 3	5 ½ Kgs.	5 ¼ Kgs.	5 Kgs.
Day 4	2 ¾ Kgs.	2 ¾ Kgs.	2 ¾ Kgs.
Day 5	2 5/8 Kgs.	2 ¾ Kgs.	2 5/8 Kgs.
Day 6	-	2 ¾ Kgs.	2 ¾ Kgs.
Day 7	-	2 ½ Kgs.	2 3/8 Kgs.
Day 8	-	2 3/8 Kgs.	2 3/8 Kgs.
Day 9	-	-	2 ½ Kgs.
Day 10	-	-	2 ½ Kgs.

Table 3. Temperature Monitoring.

Set A		Set B		Set C	
Day 1	38.8°C	Day 4	41.4°C	Day 6	35.6°C
Day 2	38.3°C	Day 5	43.1°C	Day 7	36.0°C
Day 3	41.5°C	Day 6	34.7°C	Day 8	38.1°C
Day 4	41.4°C	Day 7	41.6°C	Day 9	42.5°C
Day 5	41.2°C	Day 8	42.1°C	Day 10	46.6°C

Composite can be easily adapted to suit special needs of users by modifying design parameters such as mix proportion, water/cement ratio and types of additives. The concrete cylinders used herein were produced using steel manual molds. The common sample size is 150 x 300 mm. These units are made of cementitious mixes that are placed into steel molds, compacted, then demolded and cured. The materials used were:

1.) Ordinary Portland Cement (OPC) from the local market.
2.) Fine aggregate siliceous sand with a maximum size of five millimeters, well graded and free from impurities.
3.) Coarse aggregates free of impurities with nominal maximum of size of 10 mm.
4.) Chopped rice straw with a length ranging 1.5- 2.5 cm.
5.) Natural fresh drinking water (distilled water) free of impurities.

The combinations of the dry materials were then mixed with a constant amount of water. In the course of mixing the composite materials, additional admixtures were introduced namely, a water retardant and a foaming agent. The mixture is then poured onto cylinder molds and allowed to dry for 24 hours before the experimentation proper. The cylinder molds were designed to produce standard-sized concrete cylinders (150 x 300 mm).

The second trial for each sample was also done accordingly, making another set of four concrete cylinder, total to eight concrete cylinders.

B. Experimental Objectives:

The objective of this research is primarily to study the effects of using various percentages of chopped rice straw in different concrete mixture for the purpose of optimizing the composite material's compressive strength.

C. Laboratory Testing Procedures:

1. Materials were proportioned according to volume (m^3), one cement, three sand, 1 3/8 aggregate and then weighed to measure the exact weight;
2. A theoretical volume of 0.025 m^3 was used as basis for the computations of cement, aggregates, and sand;
3. A cement factor of 10 bags per cubic meter was initially computed using a 0.025 m^3 volume;
4. Other materials like sand, aggregates and rice straw/stalk were proportioned using the volume of cement occupied as guide; hence, 1: 3: 1 means, one volume of cement + three volume of sand + one volume of aggregates, and then weighed;
5. In the course of mixing the composite materials, additional admixtures were introduced namely, Isofoam and Isoflow 771;
6. Concrete are the same with the other batch used as comparison. Flow or slump are measured again after 30 minutes to determine consistency retention;
7. Density were also measured using a container of known volume (in this case, container used for measuring air content was used);
8. From the actual density measured, yield of concrete is determined by dividing the actual weight of all materials to the measured density;
9. From the actual yield measured, the exact cement factor per cubic meter is computed. Actual weight of aggregates, sand and other components are also adjusted in the actual concrete mix design.

D. Parameters:

The main consideration of the parameters for this study is preparing and testing the number of mixes: rice straw content and the ratio between fine and coarse aggregates.

Slump Tests

Figure 24. Initial test (0 percent Rice Straw).

Figure 25. After 30 minutes (0 percent Rice Straw).

Figure 26. Initial test (25 percent Rice Straw).

Figure 27. After 30 minutes (25 percent Rice Straw).

Figure 28. Initial test (50 percent Rice Straw).

Figure 29. After 30 minutes (50 percent Rice Straw).

Figure 30. Initial test (50 percent Rice Straw).

Figure 31. After 30 minutes (50 percent Rice Straw).

E. **Composite Samples Casting and Curing**:

Coarse and fine aggregates were batched by volumes with the desired amount. Cement was added by weight using only whole bags of 50 kg to ensure the uniform proportions of the mix. The chopped rice straw was added to the mixture according to the quantities previously stated. The dry mixes were batched outdoors in a rotating power-driven resolving mixer before adding water. The cylinder samples were molded and de-molded immediately after compaction. The samples were cured for the period of one day, three days, seven days, 14 days, and 28 days to gain sufficient strength.

Table 4. Sample Specimen Subject for Laboratory Testing.

Curing Time	24 Hours	3 Days	7 Days	14 Days	28 Days	Total Number of Samples
Rice Straw Content:	0%	0%	0%	0%	0%	5
	25%	25%	25%	25%	25%	5
	50%	50%	50%	50%	50%	5
	100%	100%	100%	100%	100%	5

Table 5. Sample Test Specimen Data.

INTERNAL TRIALS: RICE STALK WITH OPC		1:3:1 (100% 10mm Agg)	1:3:1 (75% 10mm Agg + 25% R. Straw)	1:3:1 (50% 10mm Agg + 50% R. Straw)	1:3:1 (100% R. Straw)
		1/7/2019	1/7/2019	2/7/2019	2/7/2019
Materials:	Source:	0.025 m³	0.025 m³	0.025 m³	0.025 m³
Cement, OPC, kg	APO OPC	10.0	10.0	10.0	10.0
20/10 mm Aggregates, kg	Limestone	10.0	7.5	5.0	-
Rice Stalk, kg	UP	-	0.41	0.71	1.67
Sand, kg	Vibro	30.0	30.0	30.0	30.0
Designed Water, L	Local	5.0	5.0	5.0	5.0
Admixture1, Isofoam, ml	Cemex	0.025	0.025	0.025	0.025
Admixture2, Isoflow 771, L	Cemex	0.10	0.10	0.10	0.10
Water-Cement Ratio		0.5	0.5	0.5	0.5
Adjustment, water, L		-1.2	-1.0	0	1.0
Total Weight of batched Materials, kg		53.8	52.41	51.21	47.17

Table 6. Concrete Properties.

FRESH CONCRETE PROPERTIES					
Concrete Water Demand	L/m³	119	118	147	162
Flow, Initial	mm	665	685	650	645
Flow, After 30 minutes	mm	550	545	500	450
Slump, 30 minutes	mm	-	-	-	220
Density, Yield, Relative Yield, & Air					
Weight of bucket with Concrete	kg	15.65	14.76	14.49	12.79
Weight of bucket	kg	3.89	3.89	3.89	3.89
Weight of Concrete	kg	11.76	10.87	10.6	8.9
Volume of bucket	m³	0.007	0.007	0.007	0.007
Density (Unit Weight of Concrete)	kg/m³	1680	1553	1514	1271
Yield		0.032	0.034	0.034	0.037
Cement Factor (CF)	kg/m³	312	296	296	270
Air	%	28.0	32.0	35.0	40.0
HARDENED CONCRETE PROPERTIES					
Compressive Strength					
24 hours	psi	257	88	70	0
2 days	psi	736	293	195	0
3 days	psi	941	497	337	17
7 days	psi	1,074	665	408	53
14 days	psi	1,260	834	532	160
28 days	psi	1526	1127	603	266

F. **Compressive Strength of Cylindrical Composite Samples**

The Unconfined Compressive Test (UCT) is a common performance measure used by engineers in designing buildings and other member structures. This test determines whether the concrete mix design meets the requirements of the specified strength in the job specification. The compressive strength of the concrete cylinders in this study was determined by using the compression machine normally a Universal Testing Machine (UTM) commonly used by testing industries nowadays. The sample specimen size used was 15 cm x 30 cm. The concrete cylinder was subjected to compressive load on both faces of the specimen until the material fails and a reading was recorded thereafter. Several tests and readings were taken after 24 hours, three days, seven days, 14 days, and up until it reaches its maximum strength on the 28th day. The said concrete testing was executed at Matest Laboratory Services, Inc. in Marikina City.

The determination of compressive strength of composite samples was done in accordance with specifications from ASTM C39 - Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. Listed below is the sequence of the aforementioned testing procedure:

1. Compression test of moist-cured specimen is made right after its removal from moist storage.
2. The specimen is tested in moist condition and is kept moist during the period between removal from moist storage and testing.
3. The specimen is then placed on the lower bearing block of the Compression Machine and is carefully aligned with the center of thrust of the spherically seated block. Prior to testing, the load indicator of the compression machine is set to zero.
4. The load is then applied on the specimen continuously without shock. The compressive load is applied until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern.
5. The maximum load read from the load indicator will now be used for the computation of the compressive strength.
6. The compressive strength of the specimen is determined by dividing the maximum load carried by the specimen during the test by the average cross-sectional area of the specimen.

Figure 32. Composite sample A.

Figure 33. Composite sample B.

Figure 34. Composite sample C.

Figure 35. Composite sample D.

IV. Results

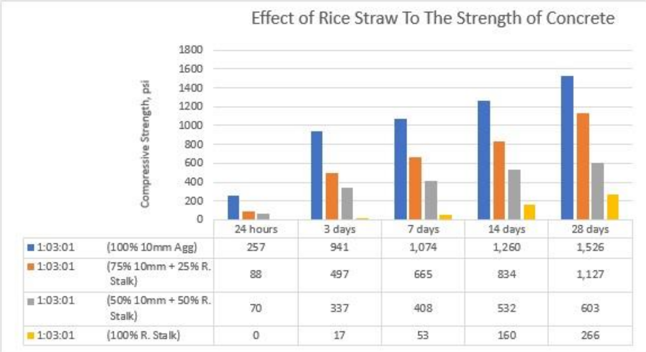

Figure 36. Effect of Rice Straw to the Strength of Concrete.

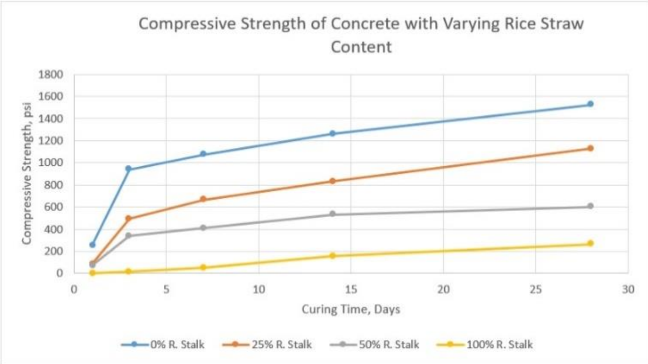

Figure 37. Compressive Strength of Concrete with Varying Rice Straw Content.

From the graph shown above, it is evident that the compressive strength is inversely proportional with the rice straw content of concrete. We can therefore see that there is a wide gap between the 100 percent rice straw and zero percent rice straw on the 28th day of curing. Based from Figure 37, the sample with 100 percent rice straw attained a compressive strength value of 266psi on the 28th day of curing while the zero percent rice straw attained 1526psi. The compressive strength value was found to be reduced by at most 82.56 percent.

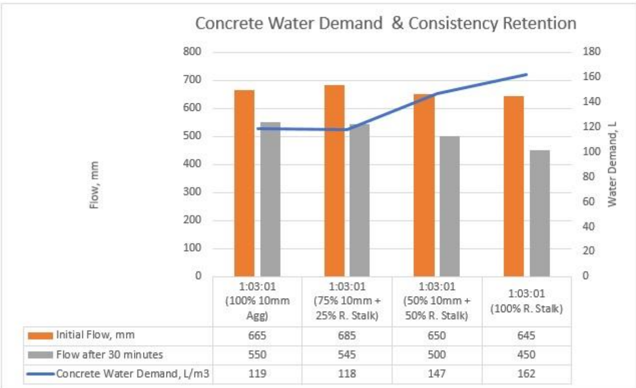

Figure 38. Concrete Water Demand and Concrete Consistency Retention.

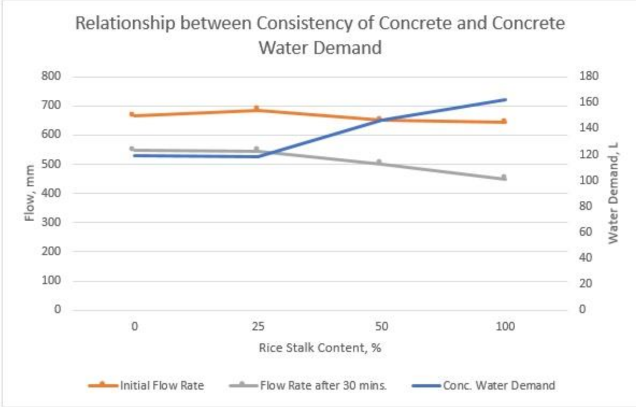

Figure 39. Relationship between Consistency of Concrete and Concrete Water Demand.

From Figure 39, the sample with 25 percent rice straw content required the least concrete water demand amounting to 118 liter/m^3 while the sample with 100 percent rice straw required a value of 162 liter/m^3. Based from the graph as shown, it is noticeable that the sample with 100 percent rice straw content requires greater amount of water. The rice straw content of the sample is directly proportional to the concrete water demand. The concrete water demand value also increased by at most 26.54 percent.

As a consequence of adding rice straw which is apparently lighter than the concrete mixture, the composite bodies end up to be more lightweight than traditional building materials. Higher percentages of organic filler result to a higher decrease in weight. This relationship can easily be seen in the Figure 40**.**

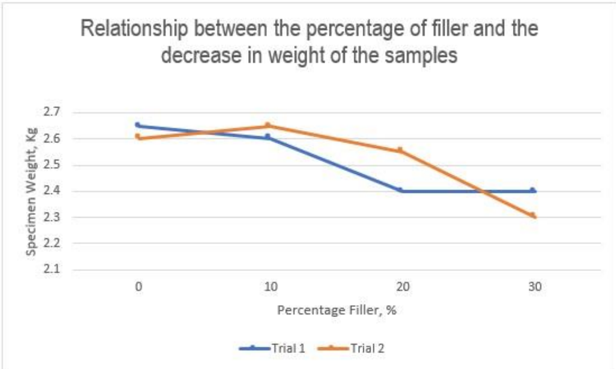

Figure 40: Relationship between the percentage of filler and the decrease in weight of the samples.

V. Analysis and Discussion

It was observed that severe segregation of concrete was experienced using 100 percent rice straw as aggregates and plasticizer admixture only, thus it was agreed to introduce an air entrain type of admixture to address the issue. Air entrain admixture combined with plasticizer makes concrete cohesive.

Since using rice straw as component to concrete will affect concrete strength, it was concluded to focus the use of rice straw to the manufacture of lightweight concrete. All trial mixes above were developed to check the effect of rice straw to density and strength of lightweight concrete.

It was also observed during the trials that water demand of concrete increases with the increase of rice straw addition. The increase in water demand affected the strength of concrete. The higher the water demand, the lower is the concrete strength (Figures 39 and 40).

Density of concrete decreases with the increase of rice straw. More rice straw, concrete density becomes lighter. Consistency retention or concrete's ability to maintain its flow is one of the requirements of concrete workability. We can observe from Figure 40 that workability is also affected with the increase in the use of rice straw. More rice straw in concrete lowers consistency retention.

VI. Conclusion and Recommendation

The quantity of rice straw in concrete mixture affects several concrete properties. Using 100 percent rice straw as aggregates decreased the mixtures' workability resulting to a higher concrete water demand. An air entraining admixture was mixed with plasticizer to help increase the workability of the concrete mixture. The rice straw proportion also affects the strength of concrete. Lower concrete strength value was obtained as the quantity of rice straw increased as well as the increase in concrete water demand. Since rice straw weighs less than aggregates, using 100 percent rice straw as aggregates produced a lower density of concrete. Another factor that contributed to getting a lower density of concrete is the air content of the concrete mixture. An increase in the rice straw proportion also increases its air content.

The use of rice straw/stalk as an alternative material for making concrete should be further developed to check if it can be used for massive structural elemental purposes. The study conducted merely focused on the use of rice straw/stalk in the production of lightweight concrete where it was found to have very excellent value. Control of water maybe the key factor of using rice straw/stalk for structural purposes. Stringent used of other admixtures can be experimented on for further enhancement in succeeding studies.

Additional tests can be further developed for concrete composite materials as the case of rice straw and cement for both the flexural and tensile strengths. ASTM C78 or the Standard Test Method for Flexural Strength of Concrete specifically uses a simple beam with third point loading. The result of this test is expressed as modulus of rupture in MPa or psi. Correspondingly, ASTM C496 or the Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete specimens uses a cylinder which splits across its vertical diameter. This test determines the load at which the concrete members may crack. These tests will further enhance and aid in the understanding of knowledge to fully investigate the effect of rice straw to the strength and behavior of concrete mix designs.

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