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Powdered Shell Wastes as Partial Substitute for Masonry Cement Mortar in Binder, Tiles and Bricks Production

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***Abstract* – The study was conducted to investigate the utilization of different powdered shell wastes blended with Portland cement for masonry cement mortar as binder for blocks laying construction, and for the production of concrete tiles and bricks. The experimental research design was used and statistically tested using the mean, frequency, t-test, ranking, and the Analysis of Variance (ANOVA).**

Results show that aquatic animal shells (oyster, mussel, and mollusk) when transformed into powder can be utilized as partial substitute for Portland cement in masonry cement mortar as evidenced by its similar physical, chemical and mechanical properties, especially its workability, specific gravity, and compressive strength.

The compressive strength of samples under the 9 experimental treatments and the control mix designs using the t-test reveals no significant difference. The three best technology options for powdered shell as partial substitute for Portland cement is the use of 15% mussel shell powder or 15 % oyster shell powder or 10 % oyster shell powder.

Thus, it is recommended for the cement industry and local government units with abundant source of shells to adopt through laws the innovative technology to recycle shell wastes in order to conserve mountain forest (as source of cement) and to lower cement production cost.

Keywords - investigate; utilization; wastes; analysis; experimental.

1.0. INTRODUCTION

Accordingly, to become a "Green," environmentally conscious society, current and future generations have to make a commitment to actively reuse, reduce, recycle, rethink, redesign, and re-imagine the way they live and produce things in order to cultivate change. It is now the time that learning communities can take the lead to educate communities on ways to "Go Green" in order to limit the impacts of waste and pollution in the environment and the quality of life for all humans (International Technology and Engineering Educators Association, 2010)[1].

Among the common wastes that can be possibly used for green technology are the aquatic animal shell wastes (World Organization for Animal Health, 2010)[2]. These wastes include shells that are disposed from households, markets and farms.

In Harrisburg, Texas alone, up to 20,000 tonnes of shells is stored in limestone-capped stockpiles at the Cape Foulwind quarry for between four and six months (New York Times, 2008)[3]. As reported by Mazik, Burdon & Elliott (2005)[4], during the Seafood-waste disposal at sea – a scientific review at the University of Hull, Cottingham Road Hull HU6 7RX, United Kingdom, the disposal of seafood processing waste including shells is a worldwide problem.

In the Philippines, several coastal islands produce most of the different types of shell wastes that are disposed from households, sea shores, markets and farms. It includes shells of Tahong {Perna viridis) or mussel shell, Kuhol ((Helix pomatia) or mollusk shell, and Talaba (Crassostrea gigas) or oyster shell are considered wastes and are normally dumped in open garbage areas or back to the aquatic system. As the waste shells are being reused / recycled, waste materials in the environment are decreased. Vectors of diseases that swarm waste areas will be diminished and thus safeguard public health (Solidum, J.N., et al, 2011)[5].

Figure 1: Shells of Mussel, Mollusk and Oyster

In other countries, seashell is a common alternative to crushed limestone in coastal areas. They can be easily crushed or ground into gravel for walkways, aggregate in concrete mixes or drainage bases under masonry or other construction. (http://www.ehow.com/info_crushed-limestone-substitutes.html)[6].

Today, blended hydraulic cements are one of the technologies being used in the construction by intimately blending two or more types of cementitious material. Primary blending materials are Portland cement, ground granulated blast-furnace slag, fly ash, natural pozzolan, and silica fume. These cements are commonly used in the same manner as Portland cements. Blended hydraulic cements conform to the requirements of American Society for Testing and Materials (ASTM) C595 or C1157.

Thus, this study is purposely done to investigate the utilization of different powdered shell wastes blended with Portland cement for "masonry cement mortar" as binder for blocks laying construction, and for the production of concrete tiles and bricks. It also intends to establish a comprehensive data analysis that may serve as baseline information for the suitability of the materials.

2.0. HYPOTHESIS

The hypotheses of the study were as follows:

1. There is no significant difference in the compressive strengths of masonry cement mortars in terms of the three curing period.
2. There is no significant difference in the compressive strengths of masonry cement mortars in the experimental treatment mix designs.
3. There is no interaction effect between the curing period and the experimental treatment mix designs in the compressive strengths of masonry cement mortars.
4. There is no significant difference in the compressive strengths of masonry cement mortars in the individual experimental treatment mix design and control mix design.

3.0. RELATED LITERATURE

3.1. Solid Waste Management

Solid waste management is a polite term for garbage management. As long as humans have been living in settled communities, solid waste, or garbage, has been an issue, and modern societies generate far more solid waste than early humans ever did. Daily life in industrialized nations can generate several pounds of solid waste per consumer, not only directly in the home, but indirectly in factories that manufacture goods purchased by consumers. (Mazik, Burdon & Elliott, 2005)[4].

3.2. Studies on Shell Wastes Utilization

Arroyo et al. (2005)[7] conducted a study on the feasibility of a mollusk shell–based adhesive as a substitute for mortar**.** The mollusks shell-based adhesive was made from combining powdered mollusks shells and tackifier in an elastomer and toluene mixture. (DOST Report, Bicutan, 2005)[8].

In southern coast of Korea, enormous amount of oyster-shell waste has been illegally disposed at oyster farm sites along the sea shore. To seek for a possibility to recycle the waste as construction materials, chemical and mechanical characteristics of crushed oyster-shell were investigated. The experimental results demonstrate that oyster-shells can be resources of pure calcareous materials and effective in replacement of sand, indicating promising reusable construction materials (Gil-Lim Y. et. al., 2002)[9].

3.3. Portland Cement

Today, Portland cement is the most widely used building material in the world with about 1.56 billion tonnes (1.72 billion tons) produced each year. Annual global production of Portland cement concrete hovers around 3.8 million cubic meters (5 billion cubic yards) per year. In the U.S., rigid pavements are the largest single use of Portland cement and Portland cement concrete. (http://my.safaribooksonline.com/book/construction-engineering)[10].

3.4. Workability

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration), and can be modified by adding chemical admixtures. (http://my.safaribooksonline.com/book/construction-engineering)[10].

3.5. Curing

In all but the least critical applications, care needs to be taken to properly cure concrete, and achieve best strength and hardness. This happens after the concrete has been placed. Cement requires a moist, controlled environment to gain strength and harden fully. The cement paste hardens over time, initially setting and becoming rigid though very weak, and gaining in strength in the days and weeks following. In around 3 weeks, over 90% of the final strength is typically reached, though it may continue to strengthen for decades(http://my.safaribooksonline.com/book/construction-engineering)[10].

3.6. Specific Gravity of Materials

The term specific gravity refers to the ratio of the density of a solid or liquid to the density of water at 4 degrees Celsius (CIO Midmarket Resources, 2013)[11].

4.0. METHODOLOGY

4.1. Research Method

The experimental research was used in the development of the experimental study which is directed towards the application of technological innovation, technology transfer and efficiency. It is a collection of data by manipulation and controlled testing to understand causal processes. (Explorable.com, 2012)[12].

Experimental method of research is the only method of research which can truly test hypothesis concerning cause and effect relationship. It also represents the most valid approach to the solution of problems, both practical and theoretical (Gay & Airasian, 2003)[13].

Good (2003)[14] adds that experimental method of research is a method involving the control or manipulation of conditions for the purpose of studying the relative effects of various treatments applied to members of samples.

4.2. Data Gathering Procedure

4.2.1. Preparation of Pulverized Shells

The raw materials from aquatic shell wastes were gathered in sacks directly from the Province of Isabela, Cavite and wet market of Cubao, Quezon City selling shell products from Bacoor, Cavite which are grounded into powdered form using the shell grinder and furnace from the laboratory of the Bureau of Research and Standard, Department of Public Works and Highways (DPWH), EDSA, Quezon City. The powdered shells were prepared by sieving using Sieve No**.** 10 (200 mm) to meet the cement standard size and oven dried for at least 18 hours or

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to a constant weight. The oven-dried samples were placed in a tightly sealed container to maintain its conditions. Cement used was a known Portland cement brand.

Figure 2: Powdered Shells

4.2.2. Physical, Chemical and Mechanical Observation and Testing of Powdered Shells

The DPWH-Bureau of Research and Standards Chemical Laboratory was utilized in the conduct of physical, chemical and mechanical observation and testing of powdered shells and Portland cement.

Figure 3: Laboratory Testing of Powdered Shells

Figure 4: Laboratory Testing of Portland Cement

4.2.3. Mixing and Preparation of Masonry Cement Mortar

The component materials were proportioned in a way as indicated in ASTM C 188/ C 109 M-95 for 18 samples per mix design per type of shell (ASTM, 2012)[15].

Table 1 Standard Mix Design

Materials	Number of Specimens	
	6	9
Portland Cement, g	500	740
Sand, g	1,375	2,035
Water, ml (Portland)	242	359

The pulverized shells were first incorporated with cement and then mixed thoroughly. It was then added with the other materials (i.e. sand and water) and thoroughly mixed in a mechanical mixer to achieve the proper consistency of the concrete mixture to avoid voids which decreases the compressive strength of concrete. Flow test was conducted to ensure consistency of the concrete paste that affect the strength of specimen to be molded. Data for the average diameter of the mortar and the number of tamps are presented in Table 2 per layer for the molding of test samples. Tamping pattern is based on the ASTM Standards.

Table 2 Tamping Requirements

Average Diameter of the Mortar Paste, cm	Number of Tamps Per Layer
16.9 and below	20
17.0 to 19.9	15
20.0 to 20.9	10
21.0 and above	5

The mortar paste was placed into the molds in two layers. It was tampered in every layer. The specimen was removed from the storage and scraped off the excess mortar in the mold to smoothen surface. The mortar specimen was removed from the mold and was labeled per specimen. The mortar specimen was placed in the curing tank for curing. The water in the curing tank was maintained to a temperature of 20 + 3 degrees Celsius.

Ninety-six samples (24 samples each for 4 mix design) with 5 cm dia. X 10 cm. height of cylinder are prepared for compressive strength test. Table 3 shows the different blended aquatic shells: oyster, mussel, and molusk shells combined with Portland Cement, sand, and water in varying curing periods- 3, 7, and 28 days respectively. Concentrations for aquatic shells and Portland cement vary for the three trials while keeping the concentrations of sand and water constant. Concentrations are as follows: A – (5% : 95%), 2.75, 0.6; B - (10 % : 90 %), 2.75, 0.6; and C - (15 % : 85 %), 2.75, 0.6.

Figure 5: Mixing and Preparation of Masonry Cement Mortar

4.2.4. Curing and Compression Testing

After curing the concrete mix for 24 hours, it was then removed from the mold and place into the lime-saturated water solution until it will be ready for curing at an standard age of 3, 7, and 28 days.

On the intended day of curing, the specimens were placed in a compression machine (Universal Testing Machine) to determine the compressive strength. Two trials with three replications were used and the average of the three trials was recorded.

Figure 6: Compression Testing

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4.3. Production

4.3.1. Production of Masonry Cement Mortar as Binder

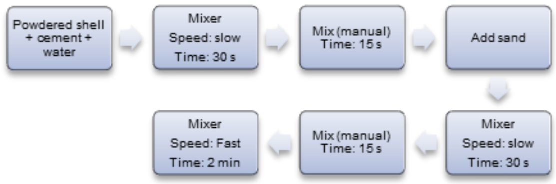

Figure 7. Process in the Production of Masonry Cement Mortar as Binder

Prepare the mixer and place the powdered shell and cement in the mixing bowl and add water. Record the time water was added. Set the speed of the mixing to slow and mix the cement paste for 30 seconds. Remove the mixing bowl from the mixer. Using a mixing spoon, scrape off the paste adhering to the side of the mixing bowl and also from the paddle, and mix the paste manually for not more than 15 seconds. Add the sand into the paste and place the mixing bowl back to the mixer. Set the speed of the mixing to slow and mix the cement paste for 30 seconds. Remove the mixing bowl from the mixer. Using a mixing spoon, scrape off the paste adhering to the side of the mixing bowl and also from the paddle, and mixed the paste manually for not more than 15 seconds. Replace the mixing bowl to the mixer and mixed the mortar paste for 2 minutes with the speed set to "fast" then it is ready for use as block binder.

4.3.2. Production of Masonry Cement Mortar as Tiles and Bricks

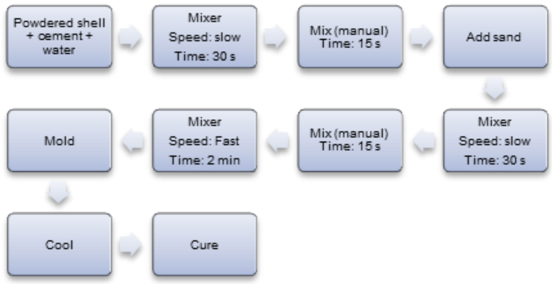

Figure 8. Process in the Production of Masonry Cement Mortar as Tiles and Bricks

The procedure for the production of Masonry mortar as binder, tiles and bricks is the same as that of the preparation of the sample specimen.

4.2.7. Product

Figure 9: Product of Masonry Cement Mortar

4.4. Statistical Treatment of Data

To interpret the data gathered, the following statistical tools were utilized:

a. *Weighted Mean.* It was used in getting the average of the pretest and posttest scores of the experimental group and control group. It was also applied in analyzing evaluation of the modules by the teachers and students. The formula used is taken from the book of Levin (2010).

$$\bar{X} = \frac{\Sigma x}{n}$$

Where:
Σ = summation
n= total number of scores in a set

b. Two-Way Analysis of Variance (ANOVA) with Replications. It is a statistical method of making simultaneous comparisons to determine the significant difference between two or more compressive strength. It is a statistical method that yields values that can be tested to determine whether a significant relation exists between variables. Where there is only a single observation for each combination of the nominal variables, there are only two null hypotheses: that the means of observations grouped by the other factor are the same. It is impossible to test the null hypothesis of no interaction. Testing the two null hypotheses about the main effects requires assumption that there is no interaction.

c. T-test for Independent Sample Means. It was utilized to determine the significant difference between the pretest and posttest scores of the experimental and control groups.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2}{N_1 + N_2 - 2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

5.0. RESULTS AND DISCUSSIONS

The presentation of data was based on the outlined statement of the problem of the study. The tables were also used to illustrate the findings of the study.

5.1. Characteristics of the Test Materials: Oyster, Mussel, Mollusk Shells and Portland Cement.

Based on observations and tests conducted by the researcher, the following were the results regarding the physical, chemical, and mechanical properties of oyster, mussel, mollusk shells and Portland cement.

5.1.1. Physical Properties

Oyster shell consists of two parts - sheet phase layer and porous bulky layer. Sheet phase layer is oriented to the growth direction of oyster shell and porous bulky layer is between sheet phase layers. The sheet layers are oriented to each sheet direction and the sheets of bulky layers wrap the 5–15 mm pores with non-orientation. Except these two layers, there are two small parts, the growth stem and the parasite. The growth stem is the starting point of oyster shell's growth and the parasite lives on the outside of oyster-shell. Both have white gray colors.

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Mussel shells are almost always wedge shaped or asymmetrical in shape. As shown, the shells are usually much longer and wider. They come in two halves that close and inside contain the mussel meat. These halves are hinged to open and close and stay connected in the center with a hinge. The two sides are called "valves" and are closed by a ligament. The shells are dark colored, usually blue or brown on the outside. Inside, a mussel show is lighter colored, silver. The shells often have a pearl glow on the inside.

Mollusk shell looks like a thinner spherical shell. It has a fracture thickness with crystals. The crystals are deposited in layers that vary in thickness. They have just one shell that varies in size and shape.

Portland cement is a combination of calcium, silicon, aluminum, and iron. Generally, raw materials consist of combinations of limestone, shells or chalk. The size of the cement after the process is about 5-inch size (125-mm), then to 3/4-inch (19 mm). Once the raw materials arrive at the cement plant, the materials are proportioned to create cement with a specific chemical composition.

5.1.2. Specific Gravity

In the result of the experiment as presented in Table 10 using the laboratory procedure, the powdered shell wastes are comparable with the specific gravity of Portland cement. Thus, they can be combined together to produce another material such as masonry cement mortar.

Table 3 Specific Gravity of Materials

Portland Cement	Powdered Oyster Shells	Powdered Mussel Shells	Powdered Mollusk Shells
3.15	3.09	3.01	3.03

5.1.3. Fineness of Materials

Normally, fineness of cement improves the workability of a concrete mix. It can be seen that fineness is a vital property of cement and has to be carefully controlled. This is why powdered shell wastes must conform with the fineness of cement to produce uniform distribution of hydration and development of strength. This can be obtained through sieving using sieve number 200. As a result of the test conducted at DPWH-BRS, the researcher obtained the required fineness of powdered shell wastes as shown in Table 11 below.

Table 4 Fineness Materials (No. 200 Passing Percentage)

Mix Design	Powdered Shell				Portland Cement	
	No. 200 Passing %	Oyster (g)	Mussel (g)	Mollusk (g)	No. 200 Passing %	Wt. (g.)
1	5	37	37	37	95	703
2	10	74	74	74	90	666
3	15	111	111	111	85	629

5.1.4. Chemical Properties of Materials

As a result of the chemical testing conducted by the researcher at the DPWH-BRS, Chemical Laboratory, it was found out that the different materials have mostly common in composition as presented in Table 12 below.

Table 5 Chemical Composition/Properties of Materials

Portland Cement	Chemical Name	Powdered Oyster Shells	Powdered Mussel Shells	Powdered Mollusk Shells
CaO	Calcium oxides	CaO	CaO	CaO
SiO_2	Silicon oxides	SiO_2	SiO_2	SiO_2
Al_2O_3	Aluminum oxides	Al_2O_3	Al_2O_3	Al_2O_3
Fe_2O_3	Iron oxides	Fe_2O_3	Fe_2O_3	Fe_2O_3
	Other minerals	Other minerals	Other minerals	Other minerals

5.1.5. Mechanical Properties of Materials

The following tests conducted at DPWH-BRS explain the mechanical properties of the different materials used in the study.

5.1.5.1. Flow test

The mortar flow test utilizes a specially designed table that repeatedly raises and drops a known quantity of mortar 25 times. During the test, the mortar will spread or flow to form a circular mass (shaped like a pancake), and the diameter of the mass is measured and compared to the initial size. The increase in size is expressed as a percentage of the initial size; for most mortars the required flow is 110%. The flow test is repeated, using a fresh batch of mortar each time, until the desired flow is achieved. The quantity of water needed to achieve flow is recorded, and this mortar is then tested for compressive strength.

5.1.5.2. Compressive Strength Test

The compressive strength of concrete including masonry mortar is the most common performance measure used in designing buildings and structures. It can be measured in terms of the curing period. In this study, the masonry cement mortar as a material for block binder and as tiles and bricks was tested using the ASTM requirements using the allowable compressive strength in Mega Pascal (MPA) as follows: For 3 days curing period, the allowable compressive strength is 12 MPa; for 7 days, it is 19 MPa, and for 28 days is 28 MPa.

5.1.5.3 Compressive Strengths of Masonry Cement Mortar Under Experimental Treatment and Control Mix Design

Based on the compressive strength test conducted at DPWH-BRS, the following data were gathered. Table 13, shows the comparison of the results

of compressive strength of masonry mortars using different mix designs and with replications for the experimental treatment and control group in 3, 7, and 28 days curing period.

Table 6 Compressive Strengths of Masonry Cement Mortars under Experimental Treatment and Control Mix Design

Experimental Treatments	Mix Design	Number of Trials/ Replications	Compressive Strength (Mpa)		
			3 days	7 days	28 days
A	5% Oy + 95% PC + Sand + H2O	6/18	23.57	28.59	37.59
B	5% Mu + 95% PC + Sand + H2O	6/18	23.47	28.34	38.33
C	5% Mo + 95% PC + Sand + H2O	6/18	24.95	28.73	39.54
D	10% Oy + 95% PC + Sand + H2O	6/18	18.08	23.56	32.34
E	10% Mu + 95% PC + Sand + H2O	6/18	21.76	26.55	34.24
F	10% Mo + 95% PC + Sand + H2O	6/18	21.41	27.31	36.71
G	15% Oy + 95% PC + Sand + H2O	6/18	15.65	19.62	28.79
H	15% Mu + 95% PC + Sand + H2O	6/18	19.69	23.39	32.37
I	15% Mo + 95% PC + Sand + H2O	6/18	20.54	24.00	33.46
Control	100% PC + Sand + H2O	6/18	26.28	31.60	43.04
Specification/Allowable Compressive Strength (ASTM)			12.00	19.00	28.00

Oy - Powdered Oyster Shell   Mo - Powdered Mollusk Shell

Mu - Powdered Mussel Shell   PC - Portland Cement

It can be seen from Table 13 that all the compressive strengths for the experimental treatment and control mix designs passed the allowable compressive strengths in 3, 7, and 28 days curing period as prescribed by ASTM. The compressive strengths of the control mix design in 3, 7, 28 days curing period are higher than the compressive strengths of the experimental treatment mix designs. As the shell powder compositions in the experimental treatment increases, the compressive strengths of the different mix designs are fast approaching the allowable compressive strength compared to the control mix design. These results are brought about by the gradual increase of powdered shell per mix design.

5.1.5.4. Test for Tw0-Way ANOVA

To test the difference in the compressive strengths, the statistical treatment of Two-Way ANOVA with replications was conducted. Table 14 reveals the result of the test.

Table 7 - Difference of Compressive Strengths of Masonry Cement Mortars in Terms of Curing

Source of Variation	SS	df	MS	F		
				T	C	I
Main Effect of C (Column)	890.82	2	445.41	6.01	121.58	Sig.
Main Effect of R (Row)	5,827.04	2	2,913.52	6.01	795.26	Sig.
Interaction Effect	13,447.78	4	3,361.94	4.58	917.66	Sig.
Within	65.94	18	3.66			
Total	20,231.58	26				

I- Interpretation   Sig.- Significant
T- Tabular   C- Computed

5.1.5.5. *Difference of Compressive Strengths of Masonry Cement Mortars in Terms of Curing*

As a result, the computed F-value (column) of 121.58 is higher than the tabular F-value of 3.55 at .01 level of significance with 2 and 18 degrees of freedom, the null hypothesis is rejected in lieu of the research hypothesis, which means that there is a significant difference in the compressive strengths of the three groups of masonry mortar in 3, 7, and 28 days curing period. Thus, the compressive strengths of the masonry cement mortar are dependent in every curing period. Once the masonry cement mortar passed the first curing period which is the 3 days curing period, the masonry cement mortar is capable enough to be used as binder, tiles and bricks. If it fails at 3 days curing period, further testing is required up to 28 days curing period.

5.1.5.6. Difference of Compressive Strengths of Masonry Cement Mortars in Terms of Experimental Treatment Mix Design

For the computed F-value (row) of 795.26, it is also higher than the tabular F-value of 3.55 at .05 level of significance with 2 and 18 degrees of freedom. In this regard, the null hypothesis is also rejected in lieu of the research hypothesis, thus there is a significant difference in the compressive strength of the masonry mortars in terms of the experimental treatment mix design. Thus, the compressive strengths of the masonry cement mortar are dependent with the mix designs. In the study, it determines the best mix designs as technology options using powdered shell as partial substitute for Portland cement in masonry cement mortar to be used as binder, tiles and bricks.

5.1.5.7. Interaction Effect Between Curing Period and Experimental Treatment Mix Designs in the Compressive Strengths of Masonry Cement Mortars

Based on the computed F-value (interaction) of 917.66, which is greater than the tabular F-value of 2.93 at .01 level of significance with 4 and 18 degrees of freedom, the null hypothesis is rejected as the interaction effect is present. It is to be concluded that there is an interaction effect between the curing period and mix design. Also, the compressive strengths of the different mix design are approaching the allowable compressive strength as the percent mix of powdered shell and days of curing period increases. Thus, the best technology options using powdered shells as partial substitute for Portland cement in masonry cement mortar to be used as binder, tiles and bricks, are dependent on the mix proportion and curing period of masonry cement mortar.

5.1.5.8. Effect of the Compressive Strengths of Masonry Cement Mortars on the Curing Period of Experimental Treatment and Control Mix Designs

In general, the compressive strengths of masonry cement mortars in the experimental treatment mix design from 5% to 15% proportion of powdered shell wastes compared to the control mix design in 3, 7 and 28 days curing period were not significant. It means that, in terms of compressive strengths all the experimental treatment mix designs were comparable to the control mix design.

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5.2. Best Technology Options for Masonry Cement Mortar

Table 8 - Best Technology Options for Masonry Cement Mortar

ET	Curing Period	Mean	Computed t-value	Critical t-value	Decision	I	Rank
A	3 Days	23.57	2.20	3.17	Accept	NS	18
	7 Days	28.59	0.71	3.17	Accept	NS	12
	28 Days	37.59	0.51	3.17	Accept	NS	4
B	3 Days	18.18	2.99	3.17	Accept	NS	26
	7 Days	23.56	2.24	3.17	Accept	NS	19
	28 Days	32.34	1.12	3.17	Accept	NS	8
C	3 Days	15.65	2.84	3.17	Accept	NS	27
	7 Days	19.62	2.99	3.17	Accept	NS	25
	28 Days	28.79	1.58	3.17	Accept	NS	10
D	3 Days	23.47	2.28	3.17	Accept	NS	20
	7 Days	28.34	0.78	3.17	Accept	NS	13
	28 Days	38.33	0.42	3.17	Accept	NS	3
E	3 Days	21.76	3.07	3.17	Accept	NS	22
	7 Days	26.55	1.31	3.17	Accept	NS	14
	28 Days	34.24	0.89	3.17	Accept	NS	5
F	3 Days	19.69	3.09	3.17	Accept	NS	24
	7 Days	23.39	2.28	3.17	Accept	NS	21
	28 Days	32.37	1.12	3.17	Accept	NS	7
G	3 Days	24.95	0.97	3.17	Accept	NS	16
	7 Days	28.73	0.67	3.17	Accept	NS	11
	28 Days	39.54	0.31	3.17	Accept	NS	2
H	3 Days	26.28	3.11	3.17	Accept	NS	15
	7 Days	31.60	1.08	3.17	Accept	NS	9
	28 Days	43.04	0.60	3.17	Accept	NS	1
I	3 Days	20.54	3.14	3.17	Accept	NS	23
	7 Days	24.00	2.11	3.17	Accept	NS	17
	28 Days	33.46	0.98	3.17	Accept	NS	6

ET- Experimental Treatment
I- Interpretation
NS- Not Significant

Based on the compressive strengths of the 9 experimental treatments, the three best technology options for masonry mortar as binder, tiles and bricks production are the following.

Experimental treatment H with compressive strength of 43.04 MPa, using 15 percent mussel shell powder as partial substitute for Portland cement in masonry cement mortar at 28 days curing period rank number 1.

Experimental treatment G got the second highest rank with compressive strength of 39.54 MPa, using 15 percent oyster shell powder as partial substitute for Portland cement masonry cement mortar at 28 days curing period.

The third technology option for masonry cement mortar is experimental treatment D with 38.33 MPa compressive strength using 10 percent oyster shell powder as partial substitute for Portland cement in masonry cement mortar at 28 days curing period.

It shows in the ranking that mix designs that were cured at 28 days were rank higher in terms of compressive strength. This happens because of the properties of the materials especially Portland cement when mix with concrete such as masonry cement mortar, the compressive strength increases during the curing period.

6.0. CONCLUSIONS

Based on the results of the study, the researcher concludes:

1. That the aquatic animal shells when transformed to powder can be used as partial substitute to Portland cement either per single type of shell or a mixture of different types of shell powder. This was further concluded by the study conducted by Arroyo et al. (2005) regarding the feasibility of a mollusk shell–based adhesive as a substitute for mortar. The results showed no significant difference between the control mean and the treatment means. Thus, a mollusks shell-based adhesive can be substitute for commercial mortar.
2. That all the 9 experimental treatment mix designs can be adopted in the production of masonry cement mortar as binder and for the production of tiles and bricks.
3. That there is a difference of the compressive strengths of masonry cement mortars (9 experimental treatment mix designs) due to curing period using ANOVA test of hypothesis.
4. That there is a difference of the compressive strengths of masonry cement mortars (9 experimental treatment mix designs) due to the different mix designs using ANOVA test of hypothesis.
5. That there is a difference of the compressive strengths of masonry cement mortars (9 experimental treatments) due to the interaction effect between the different curing periods and the different mix designs using ANOVA test of hypothesis.
6. That the best technology options for masonry cement mortar are experimental treatment H, G, and D.

7.0. RECOMMENDATIONS

Based on the findings and conclusions, it is recommended for the private sector, especially cement industry, and local government units with abundant source of shells to adopt through laws the innovative technology in order to conserve mountain forest (as source of cement) and to lower cement production cost. As to the physical, chemical and mechanical properties of the materials, it is recommended to adopt the process to other type of shells and other recycled materials as substitute for Portland cement and always consider testing, curing and mix design of the materials.

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