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Utilization of Shell Wastes for Locally-Based Cement Mortar and Bricks Production: Its Impact to the Community

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Abstract

Marine shell wastes have been popular as a recycled material for many type of construction due to its characteristics which resembles limestone that is similar to cement raw materials and if it is processed into shell ash cement, it can be substituted or blended with Portland cement for concrete works. The use of mussel and oyster shell ash cement as substitute for Portland cement will minimize the use of mountain forest and quarries as sources of Portland cement.

Thus, the study was conducted to evaluate the utilization of mussel and oyster shell ash cement blended with Portland cement for masonry cement mortar as block binder and for the production of concrete bricks. The study provides analysis for the suitability of the materials and its impact of production to the community. The multiple baseline design was used in the study.

Results show that when mussel and oyster shell wastes are transformed into an ash cement, it can be used as partial substitute for Portland cement in the production of locally-based masonry cement mortar as block binder and bricks production for the community at a mix ratio of 5%, 10%, and 15% of either mussel or oyster shell ash cement and 95%, 90%, and 85% Portland cement, respectively. This is evidenced by their chemical properties, specific gravity and mechanical properties especially compressive strength.

The production of the above-mentioned new technology will give impact to the community that will improve the quality of people's living conditions and its environment, encourage participation of women, and create responsible leaders in the community.

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1. Introduction

Today the mixtures of cement, sand and water have become popular in producing concrete bricks and masonry cement mortar as block binder almost in many construction applications. As lower cost alternatives to cement and to conserve our natural resources such as forest-mountains (source of cement), blended cements are increasingly being used by inter grinding Portland cement with another material. fly ash, blast-furnace slag, and condensed silica fume are all common components of blended cements and each of them results in a different type of blend with unique set of properties. Portland blast-furnace slag cement contains between 25 % and 70 % slag by mass of the finished cement complying with the American Society for Testing and Materials (ASTM) an international organization that sets standards for construction, design and engineering. Accordingly, blended cements are being both developed and used more and more frequently because it is cheaper, durable and more environment-friendly recycled materials (https://www.nrmca.org/aboutconcrete/cips/30p.pdf)[1].

Concrete bricks are load bearing, light weight and made from industrial by-products. It is manufactured in various colours and patterns. The type of finish is even an option; smooth, sandblasted, stone pattern, etc. The concrete used to produce the bricks can be anything from regular aggregate concrete to various mixtures of lightweight aggregates. Concrete brick deaden exterior noise, fire protection and improve the thermal mass qualities of exterior walls, thus improving energy bills (http://www.adbrimasonry.com.au/homeowner/bricks)[2].

Moreover, investigation on the possibility of using wastes and synthetic natural materials of different origin for concrete works began due to the finding of the discrimination of the use of natural resources. As a result, research on natural materials with cement based composites has been revived. Thus, rediscovery of concrete mixtures using indigenous materials prove to be the answer to the current search for low cost building structures.

Accordingly, marine shell wastes have gained wide acceptance in various type of construction due to the value added as well as opportunity to use as recycled materials and the quality it possessed. Further, since shells resembles limestone that is similar to the 80% limestone of the main raw materials used in the cement manufacturing process, it is therefore possible to substitute shell ash cement or blend with Portland cement. If substituted or blended, it will also minimize the use of manufactured cement, especially Portland cement. Thus, it is imperative to consider marine shell wastes as alternative materials for cement to mitigate environmental problems.

Accordingly, for the society to be environmentally conscious, the present and the coming generations should commit themselves and seriously involve in the recycle of things to better their lives. http://www.thrall.org/special/goinggreen.html[3].

In other countries, seashells such as mussel and oyster shells are common materials that can be pulverized into gravel for pathways, as an aggregate for concrete mixes and sub-base masonry for drainage systems. According to FitzGerald A. (2007)[4], shell waste constitutes a major financial and operational burden to the primary processing industry and has been identified as a limitation to the development of the sector in some regions. Further he emphasized that shellfish processors want simple, local, cost-effective outlets for shell including the utilization of shells as an aggregates which applications range from low value, bulk products to added value, niche products that require greater product development and placement.

In the Philippines, Tahong {Perna viridis) or mussel shell and Talaba (Crassostrea gigas) or oyster shell are the common shells that are disposed from households, restaurants, markets and along coastal areas such as Manila Bay, Cavite, Bulacan, Bataan, Pampanga and other parts of Luzon, Visayas and Mindanao (Mamon, S. J., 2017)[5].

2. Objectives of the Study

Therefore, this study was conducted to assess the utilization of ash cement of mussel shell and oyster shell blended with Portland cement for masonry cement mortar as binder and for the production of concrete bricks. It also intends to establish a comprehensive data analysis that may serve as baseline information for the suitability of the materials and its impact of production to the community.

2.1. Experimental hypotheses of the study

In line with the experimental study part of the research, the hypotheses tested 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 terms of the experimental mix designs.

3. There is no interaction effect between the curing period and the experimental mix designs in the compressive strengths of masonry cement mortars.

3. Materials and Methods

The following presents the research methods, materials, test method, standard procedures, population frame, description of respondents, instrument used, data gathering procedures, and the statistical treatment of data used by the researcher for the effective and efficient conduct of the experiment and analysis of respondents' perceptions on the impact of the study to the community.

3.1. Research method

The study used multiple baseline design. Multiple-baseline design is a type of single-case design used to study treatment effects across multiple participants, multiple behaviours, or multiple settings. Baselines are established by repeated observation. Interventions are then implemented at different times for the different participants, behaviours, or settings. Effects are demonstrated when changes are observed that coincide with the interventions (Ferron, J. and Scott, H., 2014)[6].

Multiple baseline design involve the use of concurrent observations to generate two or more baseline, the investigation has the opportunity to introduce intervention affecting only one set of observations, while using the other as a control (Thomas J. A., 2013)[7]. Thus, multiple baseline design used in the study involves experimental research and descriptive research. The experimental research was utilized in the experimental study part of the research which is a development of new technology and application, while descriptive research was used to determine the impact of the study to the community.

Part I: Experimental study

Costales and Zulueta (2013)[8] stated that experimental research seeks to answer question about causations. Researchers attribute the change in one variable to the effect of one or more variables. The variables causing changes in the subjects' responses or performance are independent variables and whose measurement can be made with any instrument, type-survey, test or observation.

3.2. Data gathering procedure

3.2.1. Preparation of mussel and oyster waste shell ash cement

The mussel and oyster waste shells were collected from wet market, households, restaurants and coastal areas of Cavite which were pulverized and furnace into ash cement at the laboratory of the Department of Public Works and Highways-Bureau of Research and Standard to meet the Portland cement sieve standard size.

3.2.2. Mixing and flow test of masonry cement mortar with shell ash cement

The mixture of materials was based on the table below as indicated in the ASTM C 188/ C 109 M-95 for 9 samples per trial per mix design of masonry cement mortar (ASTM, 2012)[9].

Table 1: Standard Mix Design.

Number of Specimens	Portland Cement with shell ash cement, g	Sand, g	Water, ml
9	740	2,035	359

The materials were thoroughly mixed in a mechanical mixer to achieve the proper consistency of the mixture and to avoid voids, which decreases its compressive strength and it was tested for its paste consistency using the mortar flow table.

3.2.3. Moulding and making of sample treatments

Following the tampering requirements based on the ASTM Standards, the two-layer mortar paste was tampered for every layer inside the moulds. This is to ensure uniform filling of the mould. Vibrate the moulds to remove entrapped air using table vibrator. Cover the specimen and stored in a cool place for 24 hours. Recover the specimen from the storage and the excess mortar was scraped off for fine surfaces and was labelled with sample treatment. The samples were cured in water tank with a temperature of 23 degree Celsius.

Thirty-nine samples with 3 replications were prepared for compressive strength test. Table 3 shows the different experimental treatment to be applied with a mixture ratio of shell ash: Portland cement, sand and water.

Table 2: Experimental Treatments.

Mussel Shells			
(Shell Ash Cement: Portland Cement), Sand, & Water	**3 days**	**7 days**	**28 days**
A (5 % : 95 %), 2.75, 0.6	Trial 1: 3 Replications	Trial 1: 3 Replications	Trial 1: 3 Replications
	Trial 2: 3 Replications	Trial 2: 3 Replications	Trial 2: 3 Replications
B (10 % : 90 %), 2.75, 0.6	Trial 1: 3 Replications	Trial 1: 3 Replications	Trial 1: 3 Replications
	Trial 2: 3 Replications	Trial 2: 3 Replications	Trial 2: 3 Replications
C (15 % : 85 %), 2.75, 0.6	Trial 1: 3 Replications	Trial 1: 3 Replications	Trial 1: 3 Replications
	Trial 2: 3 Replications	Trial 2: 3 Replications	Trial 2: 3 Replications
Oyster Shells			
(Shell Ash Cement: Portland Cement), Sand, & Water	**3 days**	**7 days**	**28 days**
D (5 % : 95 %), 2.75, 0.6	Trial 1: 3 Replications	Trial 1: 3 Replications	Trial 1: 3 Replications
	Trial 2: 3 Replications	Trial 2: 3 Replications	Trial 2: 3 Replications
E (10 % : 90 %), 2.75, 0.6	Trial 1: 3 Replications	Trial 1: 3 Replications	Trial 1: 3 Replications
	Trial 2: 3 Replications	Trial 2: 3 Replications	Trial 2: 3 Replications
F (15 % : 85 %), 2.75, 0.6	Trial 1: 3 Replications	Trial 1: 3 Replications	Trial 1: 3 Replications
	Trial 2: 3 Replications	Trial 2: 3 Replications	Trial 2: 3 Replications
Control			
Portland Cement, Sand, & Water	**3 days**	**7 days**	**28 days**
(100 % Portland Cement), 2.75, 0.6	Trial 1: 3 Replications	Trial 1: 3 Replications	Trial 1: 3 Replications
	Trial 2: 3 Replications	Trial 2: 3 Replications	Trial 2: 3 Replications

3.2.4. Curing

The samples were taken from the mould and soaked in water solution with saturated lime and subjected to curing at standard age of 3, 7, and 28 days.

3.2.5. Compressive strength test

Upon reaching the date of curing, the samples were tested in the UTM for the determination of its compressive strength. Two trials with three replications were used in every mix design and the mean compressive strength was noted.

3.2.6. Production of masonry cement mortar as binder and bricks production

Using the mixer machine, the process flow for Masonry cement mortar production is shown below.

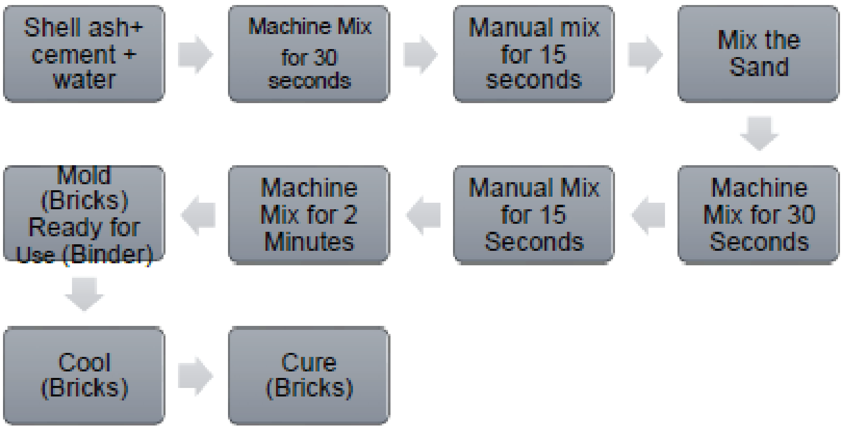

Figure 1: Production of Masonry Cement Mortar as Binder and for Bricks Production.

Place the mixer machine ready and pour the shell ash cement, Portland cement and water in the mixing container then machine mix for thirty seconds. Remove the mixing container from the mixer and mix manually with spoon for fifteen seconds. Collect all the paste including those adhering to the side of the mixing container and from the spoon, and mix all the paste manually within 15 seconds. Mix the sand into the paste inside the mixing container and return this to the mixer and machine mix for 30 seconds. After 30 seconds, remove the mixing container from the mixer and mix manually for 15 seconds. Return the mixing container to the mixer and machine mix for 2 minutes at fast speed then it is ready for use as block binder. For use as brick, the mixture shall be moulded, cooled and cured then ready for use as brick.

3.2.7. Statistical treatment of data

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

1. **Weighted Mean.** The weighted mean was used in computing the average of the compressive strength of mix design and control groups. Below is the formula used from the book of Ymas, S. (2012) [10].

$$\overline{x} = \frac{\Sigma x}{n}$$

Where: Σ = summation

$\overline{x}$ = weighted mean

n = total number of scores in a set

Two-Way Analysis of Variance (ANOVA) with Replications. This was used to determine the significant difference between two or more compressive strength with one measurement variable and two nominal variables, and each value of one nominal variable is found in combination with each value of the other nominal variable. It tests three null hypotheses: that the means of the measurement variable are equal for different values of the first nominal variable; that the means are equal for different values of the second nominal variable; and that there is no interaction (McDonald, J. H., 2014) [11].

Part II: Descriptive study

The descriptive research was used in the study regarding the perceptions of the stakeholders on the impact of the study in the community. This involved the collection of data that provide an account or description of individuals, groups or situations (Polit & Hungler, 2003)[12].

3.2.8. Population frame

The purposive sampling was utilized in determining the respondents of this study. The respondents totalling to 120 were the group samples' representatives that were the stakeholders and expected beneficiaries of the study who have the major concern on waste utilization and management. They are the officials from the local government units of Cavite who are among the producers of shell wastes of oysters and mussels. While the representatives from concerned public and private groups/sectors such as the students, faculty, Department of Public Works and Highways (DPWH), Department of Science and Technology (DOST), Department of Environment and Natural Resources (DENR), Holchims Company, Earth Day Network and its Partner Government Organizations and Non-Government Organizations were the groups or sectors with special concern or with major programs regarding waste utilization and management in the region. Table 5 presents the percentage distribution of respondents per stakeholders.

Table 3: Percentage Distribution of Respondents.

Stakeholders	No. of Respondents	Percentage (%)
Concerned Government Agencies (GA): DPWH, DENR, and DOST	30	25.00
Private Groups/Sectors (PGS): Earth Day Network and its Partner GOs and NGOs	20	16.67
Local Government Unit (LGU) of Province of Cavite	40	33.34
Concerned Faculty (CF)	10	8.32
Student Leaders (SL)	20	16.67
Total	**120**	**100**

Department of Public Works and Highways (DPWH). Ten of the respondents were the higher officials aware of the mandate of the government regarding the use of indigenous materials as partial substitute for cement, and employees of the DPWH-BRS in-charge of the laboratory testing of materials where the experimental portion of the study was conducted.

Department of Environment and Natural Resources (DENR). Ten of the respondents were the higher officials and employees of the DENR whose functions are on the implementation of programs and activities related to ecological solid waste management.

Department of Science and Technology (DOST). Another ten of the respondents were the higher executive officials and employees of the DOST tasked to implement projects on material recycling, utilization and management.

Earth Day Network and Partner GOs and NGOs. Also, twenty respondents were from the private sector with its partner GOs and NGOs such as the Department of Education, ABS-CBN and SM Foundations, whose mission is to broaden, diversify and mobilize environmental movement through a variety of education, public policy, and activism campaigns. It was already recognized leader in greening schools and environmental education curricula, promote and fund environmental education, green school facilities, and enable the shift to a carbon-neutral economy.

Local Government Unit of the Province of Cavite. Twenty of the respondents were the LGU officials and community leaders of the Province of Cavite City who were the expected beneficiaries of the study. They are among the major producers of sea shell wastes in the country.

Concerned Faculty. Ten members of the faculty of Rizal Technological University (RTU)-College of Engineering and Industrial Technological were also the respondents of the study. They are the faculty teaching engineering and environment subjects related to the study. Some of them were part-time faculty in other Universities and Colleges teaching similar subjects.

Student Leaders. Twenty student leaders of RTU were also the respondents of the study. They were actively involved in the promotion, implementation of programs and activities related to environmental awareness in the school, partner with other schools and in the community.

3.3. Description of the respondents

The subjects of this study were described according to the frequency and percentage distribution of respondents by age, gender and civil status in order to provide demographic background of the respondents.

3.3.1. Age

Table 4 shows the percentage and frequency distribution of respondents by age.

Table 4: Frequency and Percentage Distribution of Respondents by Age Group.

Age Group	Frequency	Percentage (%)
30 years old and below	13	10.83
31-40 years old	51	42.50
41-50 years old	34	28.33
51 and above	12	10.00
Total	**120**	**100**

The table shows that most of the respondents represent the 31-40 years of age bracket as shown by the frequency of 51 with an equivalent percentage of 42.50. Those who belong to 41-50 years of age group are second in rank with 28.33%. Third, is the group of the respondents with age range from 30 years old and below with 10.83 %, and the smallest group is the group age range from 51 years old and above with an equivalent of 10 %.

3.3.2. Gender

Table 5 shows the percentage and frequency distribution of respondents by gender.

Table 5: Frequency and Percentage Distribution of Respondents in Terms of Gender.

Gender	Frequency	Percentage (%)
Male	73	60.83
Female	47	39.17
Total	**120**	**100**

Majority of the respondents are males as exhibited by a frequency of 73 or 60.83 % and only 47 respondents or 39.17 % are females. This shows that most males are involve/represent the local government units, concerned government agencies, private sector, faculty and students in project decision making for the community especially in the program related to environment.

3.3.3. Civil status

Table 6 illustrates the percentage and frequency distribution of respondents by civil status.

Table 6: Frequency and Percentage Distribution of Respondents by Civil Status.

Civil Status	Frequency	Percentage (%)
Single	31	25.83
Married	61	50.83
Separated	04	03.34
Widow/Widower	24	20.00
Total	**120**	**100**

It is observed that majority of the respondents are married with 50.83 %. Next in rank are the respondents with singe status of 25.83 %, followed by respondents who are widow/widower with 20.00 %, and the least are those that separated from their spouses of 3.34%.

3.4. Research instrument

The researcher utilized the modified questionnaire which was patterned from the assessment material used by the Department of the Environment, Water, Heritage and the Arts, Australia in their study of Peoples' Performance entitled "Waste Technology and Innovation Study: Final Report, August, 2009"[13].

The questionnaires were presented and evaluated by authorities in the field of waste utilization and management and technology development. The content of the questionnaire includes the following criteria on the impact of the study to the community.

1. Consistency of the study with the Philippine Republic Act 9003, also known as the Ecological Solid Waste Management Act, that authorizes local government units (LGUs) to take charge of solid waste management programs in their respective area of responsibility-particularly requiring them to rely more on reuse and recycling of waste materials.

2. Development of innovative platform to drive and guide the production of novel technologies to new businesses and emerging infrastructure needs.

3. Employment opportunities for skilled and unskilled local labour- construction and operation including multiplier industries.

4. Acceptability of the study by the community (regional and local level) including perceived and real nuisances and convenience levels.

5. Enhancement of quality of people's living environment.

6. Creation of livelihood opportunities as sources of income generation.

7. Cost effectiveness in terms of technology development and production.

8. Availability and efficiency of resources (manpower, materials/ equipment and support services).

9. Participation of local community women in the project.

10. Creation of responsible leaders in the local community.

Aside from the questionnaire, products of masonry cement mortar for binder and bricks were used in the demonstration during the interview with the respondents.

3.4.1. Data gathering procedure

Before the distribution of the questionnaires, courtesy calls were conducted with the stakeholders to formally seek permission to undertake the study. Questionnaires were then administered to the identified sample respondents from the above mentioned agencies and groups. Research assistant was hired to facilitate the gathering of information for the immediate retrieval of the questionnaires.

3.4.2. Statistical treatment of data

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

1. **Frequency.** According to Webster (1981:221)[14], this refers to the number of recurrence of a given event (response) in a given time.
2. **Percentage**. Based from Guilford and Fruchter (1978:32)[15], percentage is measured using the formula:

$$P = \frac{n}{N} \times 100$$

   Where: P = Percentage

   n = Number of cases in

   particular group/

   occurrence of behaviour

   N = total number of cases

3. **Rating Scale**. The rating scale used is as follows:

Table 7: Rating Scale.

Rating	Verbal Interpretation (VI)
4.50 – 5.00	Very Effective (VE)
3.50 – 4.49	Effective (E)
2.50 – 3.49	Fairly Effective (FE)
1.50 – 2.49	Ineffective (IN)
1.00 – 1.49	Very Ineffective (VI)

4. Results and Discussion

The following are the results and discussions related to the data gathered from the experiment conducted at the DPWH-BRS, regarding various testing of materials used in the study, and the analysis of the perceptions of respondents regarding the impact of the study to the community.

4.1. Properties of test materials: Oyster and mussel shell ash cement, and portland cement

Based on the laboratory tests conducted by the researcher, the following were the results regarding the chemical and mechanical properties of test materials.

4.2. Chemical properties of test materials

The chemical test found out that the different test materials have common chemical composition as indicated in Table 12 below.

Table 8: Chemical Composition/Properties of Test Materials.

Common Chemicals Presence in the Test Materials		
Portland Cement	**Oyster Shell Ash Cement**	**Mussel Shell Ash Cement**
Calcium oxides	Calcium oxides	Calcium oxides
Silicon oxides	Silicon oxides	Silicon oxides
Aluminum oxides	Aluminum oxides	Aluminum oxides
iron oxides	iron oxides	iron oxides
	Other minerals	Other minerals

4.3. Mechanical properties of test materials

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

4.3.1. Specific gravity

As a result of the test for specific gravity of the test materials as shown, the specific gravity of Oyster and Mussel shell ash cements are comparable with the specific gravity of Portland cement. It shows that Oyster and Mussel shell ash cements can be mixed with Portland cement to develop a masonry cement mortar.

Table 9: Specific Gravity of Test Materials.

Portland Cement	Oyster Shell Ash Cement	Mussel Shell Ash Cement
3.150	3.092	3.011

4.3.2. Fineness of test materials

Basically, fineness of cement provides a better workability, homogeneity of hydration and development of strength in masonry cement mortar. Fineness of the test materials was obtained by sieving using #200 sieve. The results are shown in Table 10 below.

Table 10: Fineness of Test Materials (No. 200 Passing Percentage).

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

4.3.3. Compressive strength test

The most popular performance measure for masonry cement mortar use in structures is its compressive strength for a given curing period. It can be determined using the UTM considering the ASTM requirements for allowable compressive strength in Mega Pascal (MPA) as shown in Table 11 below:

Table 11: Allowable Compressive Strength.

3 Days	7 Days	28 Days
12 MPa	19 MPa	28 MPa

Thus, below are the results of the compressive strength of the masonry cement mortar with mussel and oyster shell ash cement.

1. **Compressive Strengths of Masonry Cement Mortar For Experimental and Control Mix Design**

   Table 12 shows the results of compressive strength of masonry cement mortars of different mix designs in 3, 7, and 28 days curing period for the experimental and control group.

   Base on Table 12, all the compressive strengths of the experimental and control mix designs passed the allowable compressive strengths for 3, 7, and 28 days curing period. However, the compressive strengths of the experimental mix designs are lower than the compressive strengths of the control mix design for

TABLE 12: Compressive Strengths of Masonry Cement Mortars for Experimental and Control Mix Design.

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

the given curing periods. The compressive strengths of the different experimental mix designs are gradually decreasing as the shell ash cement compositions increases.

The statistical treatment of Two-Way ANOVA with replications was applied to test the difference in the compressive strengths. The result reveals in Table 13 below.

TABLE 13: Difference of Compressive Strengths of Masonry Cement Mortars in Terms of Curing for Experimental Mix Design.

Source of Variation	SS	df	MS	F		
				Tabular	Computed	Interpretation
Main Effect of C (Column)	710.42	2	355.21	4.26	91.31	Significant
Main Effect of R (Row)	270.28	3	90.09	3.86	23.16	Significant
Interaction Effect	9.45	6	1.58	3.29	0.44	Not Significant
Within	35.04	9	3.89			
Total	1,025.20	20				

2. **Interpretation of difference of Compressive Strengths of Masonry Cement Mortars in Terms of Curing for Experimental Mix Design**

As a result, the computed F-value (column) of 91.31 is higher than the tabular F-value of 4.26 at.05 level of significance with 2 and 9 degrees of freedom. The null hypothesis is rejected in lieu of the experimental hypothesis. Thus, there is a significant difference in the compressive strengths of the experimental mix designs of masonry cement mortar in 3, 7, and 28 days curing period. It means that every curing period of the experimental mix design has an effect on the compressive strength of the masonry cement mortar. In this case, continuous sample testing for the compressive strength of masonry cement mortar should be conducted in every curing period to ensure its compliance with the ASTM standard.

3. **Interpretation of difference of Compressive Strengths of Masonry Cement Mortars in Terms of the Shell Ash Cement Ratio in the Experimental Mix Design**

   As shown in Table 14, the computed F-value (row) of 23.16 is greater than the tabular F-value of 3.86 at.05 level of significance with 3 and 9 degrees of freedom. In this regard, the null hypothesis is also rejected in lieu of the experimental hypothesis which means that there is a significant difference in the compressive strengths of the masonry cement mortars in terms of mix design. Thus, monitoring of the compressive strengths of the masonry cement mortar is vital in terms of shell ash cement mix proportion to comply with the standard.

4. **Interaction Effect between Curing Period and Experimental Mix Designs in the Compressive Strengths of Masonry Cement Mortars**

   Based on the computed F-value (interaction) of 0.44, which is below the tabular F-value of 3.29 at.05 level of significance with 6 and 9 degrees of freedom, the null hypothesis is accepted as the interaction effect is not present. Thus, there is no interaction effect between the curing period and mix design in the compressive strengths of the experimental mix designs of masonry cement mortars.

4.4. Extent of impact with respect to the production of masonry cement mortar and bricks in the community

Table 14 shows the extent of impact of locally-based masonry cement mortar and brick production in the community.

As to the impact of the production of masonry cement mortar and concrete bricks to the community, Table 15 reveals a total mean of 4.67 which means that the overall impact of the study to the community is very effective. That the study is consistent

Table 14: Extent of Impact with Respect to the Production of Masonry Cement Mortar and Bricks in the Community.

CRITERIA	WEIGHTED MEAN	
	Mn	V.I.
Consistency with the Philippine R. A. 9003...	4.73	VE
Development of innovative platform	4.80	VE
Employment opportunities....	4.77	VE
Acceptability of the new technology....	4.35	E
Enhancement of quality of people....	4.77	VE
Creation of livelihood opportunities....	4.78	VE
Cost effectiveness in terms of technology...	4.78	VE
Availability and efficiency of resources......	4.71	VE
Participation of local community women....	4.72	VE
Creation of responsible leaders...	4.32	E
TOTAL MEAN	4.67	VE

with the goal of Philippine Republic Act 9003, also known as the Ecological Solid Waste Management Act, that authorizes local government units (LGUs) to take charge of solid waste management programs in their respective area of responsibility-particularly requiring them to rely more on reuse and recycling of waste materials.

The study will develop innovative platform to drive and guide the production of novel technologies to new businesses and emerging infrastructure needs. It provides employment opportunities for skilled and unskilled local labor- construction and operation including multiplier industries. Furthermore, the study is acceptable to the community both local and regional in terms of its production at the community level including its perceived and real nuisances and convenience levels, thereby create livelihood opportunities as sources of income generation that will redound to the enhancement of quality of people's living condition.

Moreover, the production of masonry cement mortar and concrete bricks is cost effective in terms of technology utilization due to availability and efficiency of resources (manpower, materials/ equipment and support services) thus encourage the participation of women and create responsible leaders in the local community.

5. Conclusion and Recommendation

The following present the conclusions and recommendations of the study on the utilization of shell waste for locally-based cement mortar and bricks production, and its impact to the community.

5.1. Conclusions

1. That the mussel and oyster shell ash cement, based on its chemical and mechanical properties can be utilized as an alternative material for Portland cement in the production of locally-based masonry cement mortar and bricks production for the community at a mix ratio of 5%, 10% and 15% of either mussel or oyster shell ash cement and 95%, 90% and 85% Portland cement, respectively.
2. That due to significant difference of the compressive strength of the experimental mix designs in terms of its curing periods and mix proportions, there is a need for a regular quality monitoring of the compressive strengths of the products through random sampling to ensure its compliance with the ASTM standard.
3. That there is no interaction effect between the experimental mix designs and the curing periods, thus it safe to adapt the mix ratio as indicated in Conclusion 1.
4. That the study brought a positive impact to the community as evidenced by the supportive responses from the majority of the respondents.

5.2. Recommendations

Based on the findings and conclusions, the following recommendations are being put forward:

1. As to the chemical and mechanical properties of the materials, it is recommended to adapt the same process to other type of shells and similar materials for substitute to cement, thus contribute to the goal of the government to use indigenous materials for construction and to conserve mountain forest as source of cement and to lower production cost.
2. In adapting the generated technology on masonry cement mortar as block binder and bricks production, it is recommended for regular compressive strength test of sample as part of the monitoring and evaluation process to ensure compliance with the ASTM standard.

3. Another research should be studied for the development of locally-base shell waste cement manufacturing machine in support of the community masonry cement mortar as block binder and bricks production to be initially established in coastal barangays of the Province of Cavite.

4. For other local government units and their constituents or the community with abundant source of shells to establish the collection of shell wastes that can be negotiated with cement industry or they may develop their own local production of shell wastes which ash can be blended with cement for their consumption or start up business.

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