STUDY OF THE COMPRESSIVE STRENGTH OF CONCRETE WITH SELECTED SHELLS AS SUBSTITUTE TO FINE AGGREGATES

Dr. Corazon C. Corbal[1]

[1]Associate Professor, College of Engineering and Architecture,
Iloilo Science and Technology University, La Paz, Iloilo City
E-mail Address: corbalcorazon@yahoo.com

Abstract: **This study aimed to examine the effect of waste marine sea shell product in the compressive strength of concrete when used as substitute to fine aggregate.Specifically, this study aimed to determine the compressive strength of concrete when 5%, 10% and 15% of the volume of fine aggregate was substituted with three selected shells namely Capiz Shell, Scallop Shell and Green Shell. The study covered the determination of the physical properties of cement, coarse and fine aggregates that were used in determining the appropriate design of concrete mixture. Shell samples were taken from Estancia, Concepcion and Oton, Iloilo, while aggregates were taken from Jalaur River, Cabatuan, Iloilo. Laboratory tests were conducted at Western Institute of Technology CE Laboratory. A total of fifty-four (54) concrete cylinder samples were prepared and tested using the Universal Testing Machine. The average compressive strength of three concrete samples obtained during the tests was used in the analysis of comparing the compressive strength of concrete. The result showed that the three shells used as substitute to fine aggregates had met the minimum compressive strength requirement for 28 days when 5% of the volume of the fine aggregate was substituted with the three selected shells, but when 10% and 15% of the volume of fine aggregate were substituted with the three selected shells, only Capiz Shell and Green Shell met the required compressive strength of 3,000 psi required at 28 days.**

Keywords: **concrete, aggregate, compressive strength, shells, Capiz Shell, Scallop Shell, Green Shell.**

1. INTRODUCTION

"At their best, at their most creative, science and engineering are attributes of liberty—noble expressions of man's God-given right to investigate and explore the universe without fear of social or political or religious reprisals".

— David Sarnoff

Having more than 7,100 islands and a coastline which stretches over 36,289 kilometers., Philippines is a country known to be rich in marine resources all over the world. According to Green Peace, our country is a host to 2000 species of fish, 22 species of whales and dolphins, more than 900 species of seaweeds, 400 species of corals, and 5000 species of clams.

Among these 5000 species of clams are Capiz, Scallop and Green Shells which are common to the Philippines. In fact, along the coastal areas of Iloilo City and Iloilo province, farming of these shells has been one of the major sources of income.

After removing the flesh for food, most of these oyster shells are discarded along the coast or beside roadways where restaurants are located.

It has been a serious problem in the barangay since the accumulated shells dumped in the area produce foul odor and act as pollutants in both water and air, aggravating shoreline erosion, reducing fish propagation and preventing the growth of mangroves in the area.

According to the observation made by the local government unit in one community, there is an extensive shoreline erosion on the barangay for the past four decades. There is an average of 20-25 sacks dumped in the area daily. However, during peak season up to 40 sacks are discarded in the dumpsite. The dumping has started last 2016 but has already brought serious problem in the said barangay. It will be a great help to lessen the dumping of the shells in the area by creating a product in which the wastes shells can be utilized accordingly.

Since Portland Cement is a lime-based cement binder, several analyses show that Shells can also be used as substitute for lime in the production of concrete.

This study aimed to compare the compressive strength of concrete with shells as substitute to fine aggregates, determine the physical properties of cement and fine and coarse aggregates were determined, and appropriate design of concrete mixture was identified. The compressive strengths were then compared to know what cement-shell mixture was most likely have the best compressive strength in making concrete

Three (3) selected shells namely: Capiz Shell, Scallop Shell and Green Shell were used in this study. The three (3) selected shells are endemic shell species and abundant in Panay Island. Almost any time of the year, they can be harvested and that makes their shell readily available to collect, a significant advantage for this study since they are indigenous and voluminous

Windowpane oyster (*Placuna placenta*) also known as the Capiz Shell. Capiz shells are shells that are found in a province in the Philippines called Capiz. The shell is a flat, semi-transparent shell with a pearlescent appearance. These oysters are edible, but valued more for the shells are used as a raw material in many manufacturing industry. The Capiz shells are very important to the culture of the Capiz people; it is the way that the people in Capiz earn money. The shells are not endangered, so there are plenty of Capiz shells in the Philippines.

Capiz shells are earning worldwide recognition, and are used to make almost anything. The translucent Capiz shells are commonly used in window panes in the Philippines, India, and other Asian countries, as they are a cheaper alternative to glass and readily abundant. The primary exporter of products made from this shell is the Philippines where it is known locally as “kapis”, and is used in the manufacture of decorative items such as chandeliers and lampshades, and kitchen utensils such as mats, trays, and bowls.

Scallop shells (*Argopectenirradians*)

Scallops are a cosmopolitan family of bivalves, found in all of the world's oceans, though never in freshwater. They are one of very few groups of bivalves to be primarily "free-living"; many species are capable of rapidly swimming short distances and even of migrating some distance across the ocean floor. Many species of scallops are highly prized as a food source, and some are farmed as aquaculture. The word "scallop" is also applied to the meat of these bivalves when it is sold as seafood. The brightly colored, symmetrical, fan-shaped shells of scallops with their radiating and often fluted sculpture are valued by shell collectors, and have been used since ancient times as motifs in art, architecture and design.

Green Shell (*Mytilusedulis)* or mussel. Mussel is the common name used for members of several families of clams or bivalve mollusks, from saltwater and freshwater habitats. These groups have in common a shell whose outline is elongated and asymmetrical compared with other edible clams, which are often more or less rounded or oval.

This comparative study focuses on the compressive strength of concrete with shells as substitute to 5%, 10% and 15% volume of fine aggregates. With the traditional use of fine aggregates in cement mixtures, this study will test the compressive strength of concrete using other materials such as shells in making concrete. With this study, once effective and strong concrete out of cement-shell mixture will be identified, these shells can be frequently used in different industries and the people most especially will be able replicate the technique and make use of the availability and abundance of these shells in their locality.

Through this comparative study, materials’ engineers, structural designers and people in the academe and industries may know new techniques in making concrete and that other materials such as shells are possible and ideal as substitute to fine aggregates which are useful for various purposes.

Objectives of the Study

This study aimed to compare the compressive strength of concrete when 5%, 10%, and 15% of volume of fine aggregate is substituted with selected shells.

Specifically, this study aimed to:

1. determine the physical properties of cement, fine and coarse aggregates to be used in the appropriate design of concrete mixture.

2. determine the appropriate design of concrete mixture based on the properties of materials tested in (1).

3. test the compressive strength of concrete when 5%, 10% , and 15% of volume of fine aggregate is substituted with selected shells.

4. compare the compressive strength of concrete when 5%, 10% , and 15% of the volume fine aggregate was substituted with selected shells.

2. METHODOLOGY

This study includes the selection of shells abundant in a specific place, selection of aggregates, cement and the testing of physical properties of aggregates and cement in the laboratory, designing of concrete mixtures, preparation of trials mixes, and testing of the compressive strength of concrete cylinder samples.

Selection of Samples

Shells

The selection of shells used in this study were based on their abundance in the place where they were taken. These are (1) Capiz Shell from the Municipality of Oton, Iloilo, (2) Scallop Shell from Sand Bar Island in Gigantes Islands, Estancia, Iloilo and (3) Green Shell from the Municipality of Concepcion, Iloilo.

Five (5) kilograms of each raw shell samples were taken and washed in tap water and air dried for weeks approximately at room temperature. The shells were then broken into small pieces using rubber mallet for Capiz and Green Shell and using iron hammer for Scallop Shell. The broken small pieces of shells were then grinded using the rice grinder "bukbokan" to reduce sizes like that of the fine aggregates. It was then passed to sieve no.4 and retained on sieve no. 200.

Aggregates

Fine and coarse aggregates were taken from Jalaur River in Cabatuan, Iloilo. For laboratory use, a 500 kilograms sample of fine aggregates and 1,000 kilograms sample of coarse aggregates were used.

Fine Aggregate was passed through sieve number 4 and retained on sieve number 200 , while Coarse aggregate was passed through sieve number 3 and retained in sieve number 4. Sieve Analysis, Unit Weight and Absorption, and Specific Gravity tests were done for both fine and coarse aggregates.

Sieve Analysis

A sample of about 1,200 grams passing sieve number 4 and retained on sieve no. 200 was dried at a temperature of about 105^0C using oven with temperature control. It was then cooled to room temperature and weighed. The cooled sample of about 1000 grams was passed through a nested set of sieves. Material retained on each sieve was weighed using the triple beam balance and cumulative percentage passing each sieve on the basis of oven dried weight of the original sample was calculated.

Unit Weight

A 1000 gram sample was washed and dried to a temperature of 105^0C using oven with temperature control. A sample was then placed in the volumetric measuring device filling one-third of the measure, leveled and tamped 25 times which were evenly distributed over the surface. Next layer was then placed filling up to two thirds of the volumetric measure, and then overflowing. Each layer was leveled and tamped 25 times the same procedure as in the first layer. The top surface of the volumetric measure was then leveled off and net weight of the sample was obtained. The unit weight , in kg/m^3, was computed by dividing the net weight of the sample by the volume of the measure.

Specific Gravity and Absorption

A sample of about 1000 grams was soaked in water for 24 hours. It was then spread on a flat surface and stirred frequently until it approaches a free-flowing condition. From time to time the sample was placed in the conical mold in three equal layers, and the surface of each layer was tamped 25 times. The mold was then lifted up vertically until such time that the sample slumped upon removal of the mold. The condition indicated a surface-dry condition. While drying the sample, the weight of the pycnometer filled with 500 ml of water was obtained. A 500 grams sample in a surface-dry condition was then placed in the pycnometer. The pycnometer was then rolled on a flat surface to remove the bubbles.

When there were no more bubbles observed, the pycnometer was filled with water to a 500 ml mark and weighed. The sample was then removed from pycnometer and dried in the oven at a temperature of 105^0C for one day. It was then cooled to constant weight and oven-dried weight was obtained. Specific gravity was then computed by dividing the weight of the saturated surface dry sample with the weight of the pycnometer plus water plus sample multiplied by the sum of the weight of sample in SSD in air and the pycnometer and water. Absorption was also computed by dividing the difference of the weight of Saturated Surface Dry and Oven Dried sample with the weight of Oven-dried sample.

Testing of Coarse Aggregates

Specific Gravity and Absorption

A sample of about 5000 grams was soaked in water for 24 hours. It was then dried to surface-dry condition by wiping the sample with clean absorbent cloth. The sample in a surface-dry condition was then weighed and placed in a wire basket. The wire basket with sample was then submerged in water and weight of the submerged sample was obtained. The sample was then removed from wire basket and dried in the oven at a temperature of 105^0C for one day. It was then cooled to constant weight and oven-dried weight was obtained. Specific gravity was then computed by dividing the weight of the saturated surface dry sample with the difference in the weight of the SSD and water. Absorption was also computed by dividing the difference of the weight of Saturated Surface Dry and Oven Dried sample with the weight of Oven-dried sample.

Testing of Cement

Fineness Modulus

A 50 grams sample was placed on the No. 200 sieve with pan attached. Sieving was done continuously for about 5 minutes or until the residue looks clean and no more than 0.05 grams passes through in 1 minute of continuous sieving. The side of the sieve was then brushed thoroughly and the weight of the residue was obtained. Percent Fineness was then computed by dividing the weight of the residue with the original weight of the sample.

Time of Setting

A 500 grams sample cement paste of normal consistency was prepared. A cement pat was then formed on a glass plate with a diameter of 3 inches, ½ inch thick at the center with flat top and tapering to a thin edge. Then the pat was left to dry and after 30 minutes onwards it was placed in the Gilmore Apparatus to determine the time of setting. The initial and final time of setting was recorded when the pat bear without appreciable indentation the ¼ pound Gillmore needle and final set when the pat bear without appreciable indentation the 1 pound Gillmore needle, respectively.

Specific Gravity

A 64 grams sample of the cement was placed in a graduated glass flask containing a previously read volume of water-free kerosene. The increase in volume is recorded and the specific gravity is calculated by dividing the weight of sample by the increase in volume.

Design of Concrete Mixture

Using the results of laboratory tests performed on cement, fine and coarse aggregates, a design of concrete mixture was prepared. It was based on the Bureau of Public Highways Procedures and Standards' requirements for cement, water content, size of the aggregate and the desired strength.

The design of concrete mixture was based on the design strength of 3,000 pound per square inch (psi), maximum size of coarse aggregates of 1 and ½ inches, water-cement ratio of 0.57 3 inches slump, natural sand and fineness modulus of about 3.02.

An adjustment in percent of sand and net water content was applied for each 0.05 increase or decrease in water-cement ratio, for each 0.1 increase or decrease in fineness modulus of sand, and for each 1 inch increase or decrease in slump. The resulting design proportion with adjustments applied was one part cement, one point thirteen sand, one point 4 gravel and zero point fifty-one water (1:1.13:1.40 : 0.51). For a trial mix using concrete cylinder mold, the proportion by weight is 3.16 kilograms of cement, 3.56 kilograms of sand, 4.45 kilograms of gravel and 1.61 kilograms of water.

Molding and Curing of Specimen (concrete cylinder sample)

Using the 6 inches diameter and 12 inches high concrete cylinder mold, a 3.16 kilograms of cement, 3.56 kilograms of sand, 4.45 kilograms of gravel and 1.61 kilograms of water were weighed. Sand sample was then place in a volumetric cylinder measure and 5, 10 and 15 percent of its weight was computed. It was then placed in the graduated cylinder and substituted with the equivalent volume of shell. The materials were then mixed thoroughly and placed in the cylindrical mold in 3 layers of approximately equal volume.

Each layer was tamped 25 times evenly distributed over the surface using 16 mm diameter round bar. After the top layer had been rodded, the surface was leveled with a trowel and covered with a plate or damp material that prevented evaporation. After 24 hours it was removed from the mold and cured by ponding until the time of the test.

Six (6) concrete cylinder samples were prepared for each proportion. A total of 54 concrete cylinder samples were prepared.

Testing of Specimen (concrete cylinder sample)

After 14 and 28 days, the samples were taken from the pond and were prepared for testing. The specimen which is in the moist condition was placed on the working table of the Universal Testing Machine. The specimen was centered by aligning carefully with the center of spherically –seated block of the middle plated. As the block was brought to bear on top of specimen, it was rotated gently to obtain a uniform setting. A load then was applied at a constant rate within the range of 20 to 50 psi per second until specimen failed. The maximum load in Pounds (lbs) was then recorded. Compressive strength was computed by dividing the Maximum load with the Area of the Specimen.

For each proportion of 5%, 10% and 15% volume of fine aggregates substituted with shells, three concrete cylinder samples were tested after 14 and 28 days to determine the corresponding compressive strength using the Universal Testing Machine. The average compressive strength for each proportion was obtained and analyzed (refer to tables 1-7).

3. RESULTS AND DISCUSSION

This includes the result of compressive strength of concrete with 5%, 10%, and 15% volume of fine aggregate substituted with selected shells, worksheets for the laboratory test performed, and the report of test of results.

Table 1: Average Compressive Strength of Concrete after 14 days with 5%, 10% and 15% volume of fine Aggregate was substituted with Capiz, Scallop and Green Shell

Name of Shell	% of fine Aggregate substituted with shell	Average Compressive Strength (psi)	Percentage of the Design Strength (3,000 psi)
Capiz	5%	2,669.26	88.98
	10%	3,992.22	133.07
	15%	3,066.15	102.20
Scallop	5%	3,626.46	120.88
	10%	2,373.54	79.12
	15%	2,194.55	73.15
Green Shell	5%	3,190.66	106.36
	10%	3,859.92	128.66
	15%	4,249.02	141.63

The table showed the average compressive strength of concrete after 14 days with 5%, 10% and 15% of the volume of fine aggregate was substituted with Capiz, Scallop, and Green shell. At 5%, the result showed that the compressive strength is 2,669.26 psi or 88.98% of the design strength for Capiz, 3,626.46 psi or 120.88% of the design strength for Scallop and 3,190.66 psi or 106.36% of the design strength for Green Shell. At 10% volume of fine aggregate substituted with shell, the compressive strength is 3,992.22 psi or 133.07% of the design strength for Capiz Shell, 2,373.54 psi or 79.12 % of the design strength for Scallop Shell and 3,859.92 psi or 128.66% of the design strength for Green Shell. At

15%, the result showed that the compressive strength is 3,066.15 psi or 102.20% of the design strength for Capiz, 2,194.55 psi or 73.15% of the design strength for Scallop and 4,249.02 psi or 141.63% of the design strength for Green Shell. It can be observed that the compressive strength of Capiz Shell and Green Shell increases when the percentage of volume of fine aggregate increases, while for Scallop, it can be observed that the compressive strength decreases when the percentage of the volume of fine aggregate substituted with shell increases.

Table 2: Average Compressive Strength of Concrete after 28 days with 5%, 10% and 15% volume of fine Aggregate was substituted with Capiz, Scallop and Green Shell

Name of Shell	% of fine Aggregate substituted with shell	Average Compressive Strength (psi)	Percentage of the Design Strength (3,000 psi)
Capiz	5%	3,050.58	101.69
	10%	4,007.78	133.59
	15%	4,031.13	134.37
Scallop	5%	3,276.26	109.21
	10%	2,910.51	97.02
	15%	2,887.16	96.24
Green Shell	5%	3,852.14	128.40
	10%	4,926.07	164.20
	15%	4,420.23	147.34

The table showed the average compressive strength of concrete after 14 days with 5%, 10% and 15% of the volume of fine aggregate was substituted with Capiz, Scallop, and Green shell. At 5%, the result showed that the compressive strength is 3,050.58 psi or 101.69% of the design strength for Capiz, 3,276.26 psi or 109.21% of the design strength for Scallop and 3,852.14 psi or 128.40% of the design strength for Green Shell. At 10% volume of fine aggregate substituted with shell, the compressive strength is 4,007.78 psi or 133.59% of the design strength for Capiz Shell, 2,910.51 psi or 97.02 % of the design strength for Scallop Shell and 4,926.07 psi or 164.20% of the design strength for Green Shell. At 15%, the result showed that the compressive strength is 4,031.13 psi or 134.37% of the design strength for Capiz, 2,887.16 psi or 96.24% of the design strength for Scallop and 4,420.23 psi or 147.34% of the design strength for Green Shell. It can be noted that the compressive strength of Capiz Shell and Green Shell increases when the percentage of volume of fine aggregate increases, while for Scallop, it can be observed that the compressive strength decreases when the percentage of the volume of fine aggregate substituted with shell increases.

4. CONCLUSION

Based on the results, the following conclusions were drawn:

1. The Scallop shell is effective as substitute to fine aggregate at a smaller amount only.

2. That Capiz and Green Shells can be used as substitute to fine aggregate having a compressive strength of more than 100% of the design compressive strength, and that it increases when the percentage of volume of fine substituted with Capiz and Green Shells increases.

3. The compressive strength of Capiz and Green shells used as substitute to fine aggregate consistently increases from 14 to 28 days.

REFERENCES

[1] Jack, McCormac, 1986. Design of Reinforced Concrete, 2nd Edition, by Harper and Row, Publishers, Inc. New York

[2] ASEP, 2010, National Structural code of the Philippines, 6th Edition, by Association of Structural Engineers of the Philippines, Inc.

[3] Kelly et al. 2009, Use of Recycled Oyster Shells as Aggregate for Pervious Concrete

[4] Richardson and Fuller, 2013. Sea Shells Used as Partial Aggregate Replacement in Concrete: Structural Survey

[5] Etuk et al. 2012. Feasibility of Using Sea Shells' Ash as Admixture for Concrete