Mechanical Test of Concrete with Aggregates Hauled from Strategic Quarry Sites in Ilocos Sur

Franklyn T. Amistad, MSCE

Abstract

This study aimed to conduct a mechanical test of concrete with aggregates hauledfrom the strategic quarry sites in Ilocos Sur. There were three samples for each of the source of aggregates for the mechanical tests using the Universal Testing Machine. The compressive strength of cylinder concrete is below the allowable compressive ultimate strength set by the ASTM which is 3252 psi for 41- day old sample and 3186 psi for 37 days specimen. For the concrete hollow block samples, the compressive strength was above the allowable value set by the Philippine Trade Standard Specification of 350 psi. The flexural stress was above the 15 percent of 3000 psi which is 525 psi. Based on the findings the F-value of the different mechanical test is very much below the tabular F-value of 7.71 at 5 percent level of significance. With these findings, the researcher recommends that the physical test should be conducted to determine the cleanliness of the earth material and the other physical properties of the aggregates. The economic aspects shall be considered when choosing the source of aggregates and when producing concrete hollow blocks to maintain a higher compressive/crushing strength.

Introduction

Background of the Study

Aggregates are as important as cement to fonn a concrete that is very useful in the construction of roads and buildings. These materials are granular material ingredients of cement and bituminous mixes. The same materials constitute about 85% of concrete and about 95% of bituminous mixes, by weight. With these characteristics, it is necessary for the material engineer to exercise a responsible selection of these materials to acquire a sturdy and durable mixture.

Concrete is a result of a hardened product of carefully proportioned mixture of aggregates, cement, and water. In order to be useful in construction the product must meet minimum compressive and flexure strength requirements which are determined through a mechanical test; and to check the strength of the concrete used for bridges, buildings, and other structures where the principal stresses are compressive. Cylinder samples are obtained and tested in compression. In concrete pavements where stresses are bending, beam samples are tested to determine flexural strength. In this study, the standard specification from the American Society for Testing and Materials (ASTM) will be used as a minimum compressive strength of 3000 pound per square inches (psi) and a minimum flexural strength of 525 psi. The compressive or crushing strength for concrete hollow blocks of 350 psi for individual and 300 psi for an average of 5 samples is based on the Philippine Trade Standard Specification. In this research, two strategic sources of aggregates were considered such as those hauled from the Banaoang river quany site located in Santa, Ilocos Sur and Amburayan river quany site in Tagudin, Ilocos Sur. Mechanical test was conducted to determine the compressive stress and flexural stress of the sample specimens with aggregates hauled from the two quany sites. The results of this study may provide the material engineers empirical information that will guide them, and the contractor to be more selective of aggregates that would make projects stronger and more durable.

Objectives of the Study

This study generally focused on the mechanical test such as the compressive and flexural strength of concrete with aggregates hauled from strategic quany sites in Ilocos Sur.

The study, specifically, had the following objectives:

1. To determine the compressive strength of concrete with aggregates hauled from Banaoang river and Amburayan river quany sites;
2. To determine the compressive of concrete hollow blocks with different source of aggregates;
3. To determine the flexural strength of concrete with aggregates from Banaoang river and Amburayan river quarry sites;
4. Compare the compressive strength of concrete cylinder samples between the source of aggregates;
5. Compare the compressive strength of concrete hollow blocks samples between the source of aggregates; and
6. Compare the flexural strength of beam concrete samples between the source of aggregates.

Methodology

The researcher made use of the exploratory investigation method of research. Aggregates were gathered from the two strategic quarry sites in Ilocos Sur located in Banaoang River in Santa and from the Amburayan River in Tagudin, Ilocos Sur. The location map is shown in Figure I. The researcher and the Civil Engineering students enrolled in Construction Materials and Testing at the University of Northern Philippines College of Engineering formulated the samples for both the compressive and flexure tests. The mixture ratio of 1:2:3 (coarse aggregates) was used for both the concrete cylinder and the beam concrete with 6"x 12" and 6"x 8x18 dimensions, respectively (see Figure 2 and 5). The process in the preparation of the samples for both compressive and flexure tests was followed. On the other hand, 45 pieces of 4-inche concrete hollow blocks were formulated out of one bag of cement. (see Figure 4). There were three samples for each type of test for the different quarry sites. Sample specimens were brought to Baguio City following safety measures and tested in a Universal Testing Machine (UTM) in BIP Geotechnical and Materials Testing Engineers, Baguio City for the Compressive Strength and at the College of Engineering, Saint Louis University, Baguio City for the flexural test. For the concrete cylinder and concrete hollow blocks, compression was used to determine the compressive strength while the concrete beam was tested in the same machine for mid point loading.

Figure 1. Location map of the strategic quarry sites in Ilocos Sur

Figure 2
The researcher mixing the aggregates for the concrete cylinders and concrete beams for the compressive strength and flexure tests, respectively.

Figure 3
The students helpethe researcher in the formulation of the concrete hollow blocks.

Figure 4
The students help the researcher in the formulation of the concrete cylinder and concrete beam for compressive and flexure tests, respectively

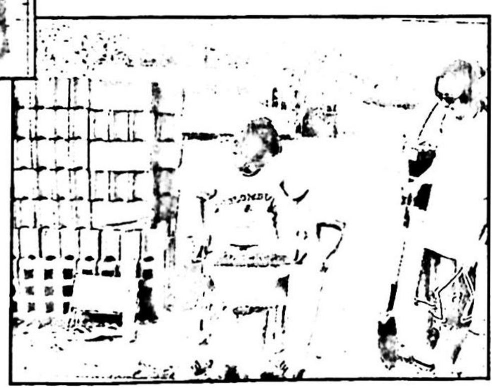

Figure 5
The researcher preparing the sample concrete hollow blocks.

Review of Related Literature

Approximately three-fourth of the volume of the conventional concrete is occupied by aggregates sand, gravel, crushed rock or air-cooled blast-furnace slag. It is inevitable that a constituent occupied such large percentage of the mass should contribute important properties to both the plastic and the hardened product. Additionally, in order to develop special light weight, thermal-insulating, or radiation-shielding characteristic, aggregates manufactured specially to develop these in properties of concrete are often employed (Legg, 1956).

On the study entitled "Waste Fibers in Cement-stabilized Recycled Aggregate Base Course Material", the ultimate tensile strengths for the 28-day specimens are plotted versus dry density in the 7-day results that these data show that the split tensile strength strongly depends on density; the 28-day tensile strength increased form 190 KPa (28 psi) at a dry density of 1712 kg/m(107 pc£) to almost 1335 KPa (194 psi) at a dry density of 2010 kg/m^3 (125 pct). For the same type and amount of fiber, the strength generally increased with an increase in density. These data indicated that there is a slight increase in strength as a result of an increase in cement for specimens with no fibers. In general, however, there was a decrease in the tensile strength of specimens with fibers relative to the control specimens (Cavey et.al., 1995).

The compressive strength of the cylinder specimens fonnulated from aggregates hauled from Calaba, Bangued, Abra varies from that of Banaoang, Santa, Ilocos Sur when considered three samples each. Two cylinder specimens formulated from aggregates from Calaba, Bangued, Abra surpassed the 3000 psi, a required compressive strength of concrete according to ASTM C 109 for 28 day old specimen with values 3003 psi and 3042 psi. Only one sample from Banaoang Santa, Ilocos Sur with compressive strength of 3107 psi surpasses the 3000 psi for 28 days (Tordil et. al., 2008).

In the study conducted in 1995 on the determination of the crushing strength of the concrete hollow blocks (CHB) samples manufactured in Ilocos Sur, the manufacturers produced varied numbers of CHB from each different commercial size (4", 5", and 6") from the different source of aggregates. Based on the result of this study, out of 137 samples, only two (2) surpassed the allowable crushing strength required by the Philippine Trade Standards Specification for concrete hollow blocks (PTS 661-09:1968) for non-load bearing which is 350 psi for individual and 300 psi for an average of 5 CHBs. Thus, the samples were generally below the allowed crushing strength (Amistad et. al., 1996).

Basic Concepts

When aggregates and/or inert materials are bond together into a conglomerate mass using Portland cement and water, they will be formed into concrete, mortar or plaster. About seventy-five percent (75%) of the total mass of concrete are aggregates that would densely pack the materials for a better strength of concrete, water resistance, and economy of concrete.

Fine and coarse aggregates are the two classifications of natural aggregates. Fine aggregates is generally the product of natural disintegration of silica bearing or calcium-bearing rock. Fine aggregates or sand are those that pass the no. 4 sieve and predominantly retained by a no. 200 (74 micron) sieve. It is also manufactured by large pieces of aggregate by crushing, grinding or rolling. Coarse aggregate is the portion of aggregates that is retained on no. 4 (4.76 mm) sieve. These aggregates are the natural gravel deposits, which are formed by water, wind or glacial action. Sometimes the coarse aggregates are manufactured by crushing rock, stone, boulder and large cobblestones to attain the desired dimensions of the materials. The conditions for maximum size of coarse aggregates shall easily fit into the forms and in between reinforcing bars and it should not be larger than one-fifth (1/5) of the narrowest dimension of the fonns or one-third (1/3) the depth of the slab nor three-fourths (3/4) of the minimum distance between reinforcing bars..

The five sources of aggregates are the following: recycled concrete, sand, gravel, and crushed gravel, crushed stone, air-cooled blast-furnace slag and crushed hydraulic-cement concrete.

The following are the procedures in the preparation of materials and compressive strength tests of specimen such as cylinder and concrete hollow blocks, and the flexure strength tests of beam concrete.

Compressive Strength Tests of Cylinder

1. Molding of specimen. Place the thoroughly-mixed sample in the cylindrical mold in 3 layers of approximately equal volume. In placing the concrete, move the scoop around the edge of molder to insure symmetrical distribution of concrete. Tamp each layer with 25 strokes using a tamping rod. The rod should penetrate the entire depth of the layer being tamped. Tap sides of the mold if voids are left by tamping rod. After the top layer had been rodded, strike-off the surface with a trowel and cover with a plate or damp material to prevent evaporation.

2. After 24 hours, remove the specimen from the mold and cure until time of test Curing means to store the specimen sample in a moist condition at the temperature range of 18 to 24°C. The specimen should not be exposed to running water to avoid so much void due to the so much water content.

3. Before testing, the ends of the specimen should be capped with suitable material such as gypsum plaster filler to make ends approximately at right angles to the axis of the sample cylinder. The cap shall be thin as possible.

4. Determine the average diameter of the cylinder sample considering the diameters of the two ends. Measure also the height of the sample cylinder.

5. Place the sample cylinder to the working table of the testing machine (Universal Testing Machine). Center the same specimen by aligning carefully with the center of spherically-seated blocks of the middle platen. As the block is brought to bear on top of specimen, rotate gently movable portion to obtain a uniform seating.

6. Apply load at a constant rate within the range of 20 to S0 psi per second. Increase load until specimen fails.

7. Record the maximum load carried by the specimen.

Compressive Strength Test of Concrete Hollow Block

According to the Philippine Trade Standard Specification for Concrete Hollow Blocks, the following are the procedures in conducting compressive strength test of concrete hollow block. Measure the dimension of each unit then cap the bearing surface with gypsum plaster filler to a thickness of not more than 3 mm. (1/8 inch). Allow the cap to solidify fo a minimum of 2 hours before testing. Set the specimen concrete hollow blocks on the lower bearing block and center it beneath the upper bearing block. The upper bearing should be firmly attached at the center of the sensitive platen of the universal testing machine. Apply the load at a uniform rate until failure occurs. Record the maximum load, then calculate the compressive strength by dividing the maximum load by the gross cross-sectional area of the unit in square centimeters. The gross area of the unit is the total area of the section perpendicular to the direction of the load including the areas within the cells, and re-entrant spaces.

Flexure Strength Tests of Beam Concrete

1. Molding of specimen. Place the thoroughly-mixed sample in the mold, with its long axis horizontal, in layers approximately 3 inches in depth. Tamp each layer S0 times per sq. ft. of area. The top layer should slightly overfill the mold. After each layer had been rodded, spade the concrete along the sides and ends of the mold with a trowel. After the rodding and spading operations on the top layer are completed, strike-off the surface with a straight-edge and finish with a wooden float. Cover the top with damp material.

2. After 24 hours, remove specimen from the mold and cure until time of test, same as in compression specimen such as cylinder.

3. Testing specimen by simple beam with third-point loading or mid-point loading depending on the available type of testing in the testing centers. In testing the specimen, it should be in the same position as when molded. Center the bearing blocks, bring the load-applying blocks in contact with the upper surface at the third points between support or mid-point of the beam. Apply the load at 150 psi per min. Increase the load until the specimen fails. Record the maximum load carried by the specimen.

Operational Definition of Terms

Aggregates refer to the inert granular material such as fine and coarse aggregates or crushed stone, which with the water and Portland cement, are common ingredients of concrete.

Allowable Compressive Crushing Strength refers to the allowable ratio of the force to the cross-sectional area of the sample where the stress is being applied.

Coarse aggregate refers to particles greater than 0.19 inch (4.75 mm), but generally range between 3/8 and 1.5 inches (9.5 mm to 37.5 mm) in diameter. There are four kinds of coarse aggregate, namely: limestone or calcium-bearing material; basalts, granite and related igneous rocks; sandstone and quartzites; and rock, such as opal and cleft composed of mainly of amorphous silicone oxide

Compressive/crushing strength refers to the amount of stress developed when an external force tends to press or shorten a body.

Concrete refers to **a** construction material that consists of cement (commonly Portland cement) as well as other cementation materials such as fly ash and slag cement, aggregate and chemical admixtures.

Fine aggregates refer to the natural sand or crushed stone with most particles passing through a 3/8-inch (9.5-mm) sieve.

Flexural-Strength refers to the outer fiber stress developed when material is loaded as a single supported beam and deflected to **a** certain value of strain.

Mechanical properties refer to the aggregates strength, hardness, toughness, elasticity, plasticity, brittleness and ductility and malleability used as measurements of how concrete behaves under a load. These properties are described in terms of the types of force or stress that the concrete must withstand and how these are resisted.

Results and Discussion

Table 1 presents the compressive strength of concrete cylinder samples with aggregates hauled from the strategic quarry sites in Ilocos Sur. The table shows that the compressive stress of samples with aggregates from Banaoang River, Santa, Ilocos Sur is below the allowable compressive strength of a concrete cylinder of 3186 psi. This is 106.2% of the 3000 psi for 28-day samples. Only samples with aggregates from Amburayan River, Tagudin, Ilocos Sur attained a compressive strength that surpassed the allowable value of 3252 psi for 41 days sample which is 108.4 % of the 3000 psi. Samples were tested in a Universal Testing Machine (UTM) as shown in Figure 6.

Table 1. Compressive Strength of Concrete Cylinder with Aggregates Hauled from the Strategic Quarry Sites in Ilocos Sur

Concrete Cylinder Sample	Banaoang River, Santa, Ilocos Sur Quarry Site		**Amburayan River, Tagudin, Ilocos Sur Quarry Site**	
	Age (days)	**Compressive Stress (psi)**	**Age (days).**	**Compressive Stress (psi)**
1	37	3136.64	41	4091.31
2	37	2118.39	41	2609.63
3	37	2892.61	41	2798.82

Concrete hollow blocks were subject to compression on the UTM as shown in Figure 7. Table 2 reveals the compressive or crushing strength of 4-inches concrete hollow blocks with aggregates from the strategic quarry sites in Ilocos Sur. Based on the findings as shown on Table 2, the samples surpassed allowable compressive/crushing strength set by the Philippine Trade Standard Specifications which is 350 psi for individual and 300 psi for an average of 5 samples for non-load bearing structures. When the ASTM specification is used with the allowable value of 400 psi, the compressive strength of the samples that are depicted on the table are considered safe. This means that the samples formulated can resist load in compression.

Table 2. Compressive/ Crushing Strength of Concrete Hollow Blocks with Aggregates Hauled from the Strategic Quarry Sites in Ilocos Sur

Concrete Beam Sample	Banaoang River, Santa, Ilocos Sur Quarry Site		Amburayan River, Tagudin, Ilocos Sur Quarry Site	
	Age (days)	Compressive Stress psi)	Age (t.days)	Compressive Stress (psi)
I	62	496.54	42	475.03
2	62	440.37	42	488.38
3	62	544.85	42	544.71

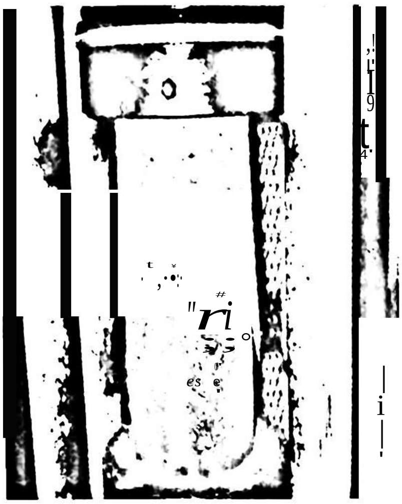

Figure 6
Sample concrete cylinder is subjected to compression tests using the Universal Testing Machine (UTM).

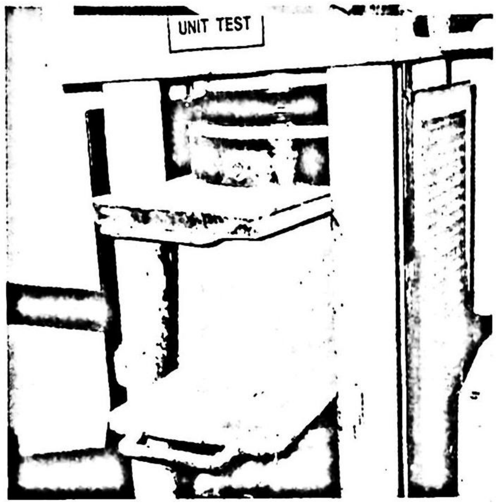

Figure 7
Compression load is being applied to concrete hollow blocks using Universal Testing Machine (UTM) to determine the compressive strength of the CHB samples.

The samples for flexure test are 6x 8"x 18" concrete beam.. The flexural strength of beam concrete samples are presented on Table 3. It is shown that two samples with aggregates hauled from Banaoang River, Santa, Ilocos Sur have higher strength than that of the allowable flexural strength for 37-day samples of 555 psi. Meanwhile, of the values of the flexural stress of samples with aggregates from Amburayan River, Tagudin, Ilocos Sur as shown on the table, only one exceeded the allowable flexural strength of 545 psi. for 41-day old. Samples.

Table 3. Flexural Strength of Beam Concrete with Aggregates Hauled from the Strategic Quarry Sites in Ilocos Sur

Beam Concrete Sample	Banaoang River, Santa, Ilocos Sur Quarry Site		Amburayan River, Tagudin, Ilocos Sur Quarry Site	
	Age (t,day)	Flexural Stress (psi)	Age (t.days)	Flexural Stress (psi)
1	37	681.5	41	532.15
2	37	601.75	41	448.05
3	37	455.3	41	568.4

Tables 4, 5 and 6 present the analysis of variance (ANOVA) on the compressive strength of cylinder by source of aggregates, compressive strength/crushing strength of 4 inches concrete hollow blocks by source of aggregates, and flexural strength of beam concrete samples by source of aggregates, respectively. It is noticed on Tables 4 and 5 that the F-value of 0.65532 and 0.0849, respectively, are very much lower than the tabular F-value at 5 percent level of significance which is equal to 7.71. This means that there are no significant differences between the compressive strength of concrete cylinder and the source of aggregates. Likewise, there are no significant differences between the compressive/crushing strength of 4 inches CHB and the source of aggregates.

Table 4. ANOVA Table on the Compressive Strength of Concrete Cylinder by Source of Aggregates

Variation	Sum of Square	d,	MSS	F
Between Source of Aggregates	304,707.256	1	304,707.256	
Between Samples	1,865,833.064	4	466,458.265	**0.65532**
Total	2,170,540.32			
	Taos =7.71			

Table 5. ANOVA Table on the Compressive Strength of 4-inche Concrete Hollow Blocks by Source of Aggregates

Variation	Sum of Suare	d,	MSS	F
Between Source of Aggregates	116.073	1	116.073	
Between Samples	5,468.3318	4	1,367.0829	
	5,584.4048			**0.0849**
Total	To0.0s =7.71			

The ANOVA table on the flexural strength of specimen beam concrete by source of aggregates is shown on Table 6.

The table shows that the computed F-value of 0.7085 is very much lower than the tabular F-value at 5 percent level of significance of 7.71. This indicates that there were no significant differences between the flexural strength of beam concrete and the source of aggregates.

Table 6. ANOVA Table on the Flexural Strength of Beam Concrete by Source of Aggregates

Variation	Sum of Square	d,	MSS	F
Between Source of Aggregates	6013.5067	I	6013.5067	
Between Samples	33,948.3667	4	8,487.0916	0.7085
Total	39,961.8734			
	Tacos =7.71			

Conclusions and Recommendations

I. The water quality of the quarry site should be detennined to find out if the chemical properties of the impurities on the aggregates affect the compressive and flexural strengths of the concrete mixed with the earth materials such as aggregates.

2. Producing 45 pieces of CHB from one bag of cement is lower than that of the actual nwnber pf CHB produced by manufacturers. However these CHBs are stronger and more durable. Hence, other researchers should conduct a study on the possibility of producing lesser but stronger CHBs from one bag of cement with higher return of investment.

3. The mechanical properties of aggregates from the strategic quarry sites in Ilocos Sur should be compared with other sources of aggregates for construction like that of the Pinatubo aggregates for low cost construction projects in the Philippines.

4. Engineers, contractors, pennittees, Local Government Units (LGUs) and non-governmental organizations should exercise moral obligation to monitor the restrictive use of aggregates in their respective localities. Thus, they shall be an instrument for social orderliness in using clean aggregates for better quality of concrete and more durable structures.

5. Other researchers should consider ecological economics and environmental analyses of the different mechanical tests of the aggregates for each project especially for buildings, roads and bridges. Studies on the electrochemical techniques should be conducted to repair/reinforce concrete projects or improve the mechanical properties of aggregates to increase the quality and life span of the projects.

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