Mindanao Journal of Science and Technology Vol.13 (2015) 109-131

Chicken Feathers as Substitute for Fine Aggregates in Concrete

Gil P. Manginsay[1] and Ruth Guinita-Cabahug[2]*
[1]MSU – Iligan Institute of Technology
Iligan City, Philippines

[2]College of Engineering and Architecture
Mindanao University of Science and Technology
Cagayan de Oro City, 9000 Philippines
* *ruth_gc@yahoo.com*

Date received: June 24, 2015
Revision accepted: August 1, 2015

Abstract

An experimental investigation aimed to determine the viability of chicken feathers as substitute for fine aggregates for concrete was conducted. Chicken feathers collected from slaughter houses (waste material) were utilized after previous studies conducted revealed that chicken feathers posses good durability and resistance to degradation because of the extensive cross-linking and strong covalent bonding within its structure. In the investigation conducted, the chicken feathers content ranged from 5% to 50% of the total volume of fine aggregates. The aggregate-cement ratio was 1:6. Cement was held constant with varying water-cement ratio in every mixture. Specimens were grouped according to their number of days of curing as follows; 7, 14, and 28 days. The results affirmed that the compressive strengths of the specimens are inversely proportional to the level of feathers that were added. The specimen with 5% feathers, cured in 28 days, yielded a compressive strength of 12.61 Mpa. This value met the Type S mortar cement of ASTM C270-91 standard specification that covers mortars for use in the construction of non-reinforced and reinforced unit structures. The rest of the compressive strength results of the specimens satisfied the minimum compressive strengths of the Types N and O mortar cement of ASTM C270-91 standard which are 5.2 and 2.4 MPa respectively.

Keywords: concrete substitute, chicken feathers, alternative concrete

1. Introduction

One of the major problems in the Philippines is waste disposal. Despite of the government's program, the Republic Act No. 9003 or known as "Ecological Solid Waste Management Act of 2000", still tremendous volume of solid wastes are generated and collected daily. The major factors contributing to such problem, among others, are: 1) rapid increase of the country's population; 2) people's lack of knowledge of the program and 3) people's lack of concern of the program.

Atienza's (2011) report stated that there are several factors that could have contributed to the failure of the previous policies to fully address the problems on waste management. While the intentions of these policies are good, it failed to get the cooperation of the community and various stake holders because the laws were all "command and control" in nature. The rapid population growth, urbanization and modernization in the country have resulted in the significant increase of waste generated especially in urban cities. The lack of infrastructure for efficient transportation especially in the provinces and inner areas of cities and barangays could have contributed in the inefficient implementation and effective monitoring of waste management program.

Considering that the Philippines dressed a total of about 5,470,740,000 kilograms of chicken for the period 1991-2002 (Chang, 2004), one can just imagine the magnitude of waste that had been generated.

Adapted from Acda (2010), "Chicken feathers are waste products of the poultry industry. Billions of kilograms of waste feathers are generated each year by poultry processing plants, creating a serious solid waste problem (Parkinson 1998; Schmidt 1998). The Philippine poultry industry produced about 40 million broiler chickens annually (USDA FAS 2005). These chickens generate about six million kilograms of waste feathers annually when the birds are processed in commercial dressing plants.

The National Meat Inspection Service (NMIS) (2014) posted the Accredited Poultry Dressing Plants in the entire country. In Misamis Oriental, there are nine (9) still recognized poultry dressing plants.

The report of Palabao (2011) declared that in 2010, AnakCiano, Inc. (ACI) in Brgy. Mahon, Tagoloan, Misamis Oriental, had a total of 15 million birds, of which two (2) million were raised in company owned commercial farms. The remaining birds are grown by 60 commercial farmers with average capacity of 40,000 birds and another 4,000 backyard farmers with an average capacity of 500 birds under the auspices of ACI's foundation arm, the Anak Tering Foundation, Inc. In 2011, ACI probably increased its production to 20 million birds. Most of the farms are located in the provinces of Bukidnon and Misamis Oriental.

San Miguel Foods, Inc. inked an agreement with North Star Asia Holdings Corp. to build a P120-million poultry processing facility in El Salvador, Misamis Oriental. The plant could process 30,000 chickens daily or 10.8 million annually (CDO.Com, 2014).

The above mentioned dressing plants alone can process 30.8 million chickens annually. If we equate this figure to the report of Acda (2010) that 40 million broiler chickens can generate 6 million kilograms of feathers, 30.8 million broiler chickens could have 4.62 million kilograms of feathers annually. This volume of chicken feathers will significantly grow through the contribution of other poultry dressing plants and local chicken dressers nearby. Burning such waste can create air pollution and could be hazardous to the environment.

Literatures say that another major problem that the nation is facing is the depletion of its natural resources due, but not limited, to the following; 1) abused within decades by human activities; and 2) rapid increase of population which proportionally requires for greater need of natural resources. Forests are denuded due to logging and quarrying activities.

Aggregates and forest products are some of the major construction materials utilized in the construction industries. But there is a scarcity of supply of these commodities. Supply and demand principle dictates that when demand increases while supply decreases, price will increase.

Mostrales, *et. al.* (1991) stated that "housing problems and inadequate shelters are the effects of high population growth, diminishing resources, scarcity and rising cost of conventional building materials, and poor affordability". In this situation, introduction of alternative construction materials made from available resources matched with appropriate method and technology is needed.

This condition implies the need to explore alternative materials that can be utilized in construction industries. Thus, chicken feather wastes are considered.

The structure and properties of chicken feather barbs makes them unique fibers preferable for several applications. The presence of hollow honeycomb structures, their low density, high flexibility and possible structural interaction with other fibers when made into products such as textiles provides them unique properties unlike any other natural or synthetic fibers (Reddy and Yang, 2007).

According to Kock (2006), keratin of chicken feathers shows good durability and resistance to degradation because of the extensive cross-linking and strong covalent bonding within its structure. On the other hand, Hong and Wool [2005] found out that the strengths of chicken feather fibers ranged from 41 to 130 MPa. Moreover, the calculated strength from experimentally fracture energy data for a feather fiber reinforced composite had a strength results of 94 to 187 MPa. As stated in the foregoing, chicken feathers have the potential for an alternative material for use in the construction industry. This study explored the possibility of using chicken feathers as alternative material in concrete mixture.

2. Methodology

This study used the pre-experimental method, particularly the Post-test Only Research Design, with test specimens of concrete blocks whose mixture composed of cement, fine aggregates and chicken feathers. Chicken feathers replaced certain volume of fine aggregates by weight at different level of percentage with constant volume of cement to all mixes. One mix of specimen that contained cement and pure fine aggregates only, was used as the basis for obtaining proportions of the different batches of mixes containing chicken feathers. The mix with cement and pure fine aggregates served as the control mix for comparison purposes.

2.1 Sampling Method

The chicken feathers were mixed as weight-for-weight replacement of fine aggregate at six specific replacement levels. The replacement levels used were 5%, 10%, 20%, 30%, 40% and 50%.

Each batch of mix contained six 2-inch cubes of concrete specimens that were cast using one size and one type of moulds or forms. The uniform inside measurement of the moulds is 5.08 x 5.08 x 5.08 centimeters (approximately 2” x 2” x 2”). The specimens were demoulded right after sufficient manual compaction.

The specimens were then divided into three groups of 14 specimens in each according to the number of days of curing. The distributions in each level of percent of feathers to the specimens are presented in Table 1.

Table 1. Number of specimen in every percent of feathers

Group	Number of Specimen in Every Percent of Feathers							Total No. of Specimens
	0%	5%	10%	20%	30%	40%	50%	
7 days	2	2	2	2	2	2	2	14
14 days	2	2	2	2	2	2	2	14
28 days	2	2	2	2	2	2	2	14

The specimens were cured through total water immersion for 7, 14 and 28 days respectively. Then, each series of 2-inch mortar cubes was tested for their compressive strength.

The equipment used for testing of samples is a computerized Versa Tester Machine of the College of Engineering in MSU-Iligan Institute of Technology.

2.2 Samples Used in the Test

The cement used in the study is a Type 1P – Portland-pozzolan-cement manufactured by Lafarge Iligan Incorporated in Iligan City. This type of cement is an intimate and uniform blend of portland cement or portland blast-furnace slag cement and fine pozzolan produced either by inter grinding portland cement clinker and pozzolan or by blending portland cement or portland blast- furnace slag cement and finely divided pozzolan in which the pozzolan constituent is between 15 and 40 percent by weight of the portland-pozzolan-cement.

The fine aggregate was bought from a CHB maker in Barangay Santiago, Iligan City. The fine aggregate was quarried from the river bank of Barangay Hinaplanon, Iligan City. Chicken feathers used were those from common 45-day old broiler chickens. The chicken feathers were collected from different chicken dressers in Iligan City Wet Market. The water used for the mixtures came from the water supply line of MSU-IIT in Iligan City.

2.3 Methods for Preparation of Chicken Feathers

The collected chicken feathers were thoroughly washed and dried under the heat of the sun for about five days. Tin snip was employed to reduce the length of the feathers because some parts were hard to cut down like the quill and the shaft. The reduced lengths of the feathers were measured approximately 1 centimeter. About 6 kilograms of cut feathers were prepared.

The unit weight of the cut feathers was determined using the standard method of unit weight determination for fine aggregates, and it was found out to be 0.33 grams/cm^3. The absorption also was determined to be 41.36%.

2.4 Methods for Sampling and Investigating the Physical Characteristics of Aggregate

Some of the standard methods of sampling and testing for the acceptability of the aggregate were used, to wit:

a. ASTM Designation 128-88 - Test for Specific Gravity and Absorption of Fine

b. ASTM Designation C 136 Test for Sieve Analysis of Aggregate

2.5 Mortar Mix Proportioning

There were 42 specimens needed for this study. The size of each specimen is 5. 08 x 5.08 x 5.08 centimeters or has a volume of 131.10 cm^3. For each batch of mix, 6 samples were made. The component of the first batch of mixture were cement, fine aggregate, and water only and the rest of the mixture composed of cement, fine aggregates, chicken feathers and water of different percentage level.

The first six specimens that were moulded containing 0% chicken feathers yielded a total volume of 786.6 cm^3 fine aggregates or its equivalent weight of 2,021.6 grams. For a batch mixed with 5% chicken feathers needs 747.3 cm^3 (1,920.6 grams) of fine aggregates and 39.3 cm^3 (13 grams) of chicken feathers since the specific gravity of fine aggregate used is 2.57 g/cm^3 and the unit weight of the chicken feathers is 0.33 g/cm^3. The relative density (specific gravity) of cement as studied by Kurtis is 3.15 g/cm^3 (Kurtis).

Kurtis' study result on the specific gravity of portland cement is similar to the result of the study of Caltrans that the typical specific gravity of Portland cement will vary from 3.05 to 3.20 with an average of 3.15. Specific gravity does not influence concrete quality and is used to determine concrete unit weights (California Department of Transportation, 2013).

As examples on the calculation of the sample materials are shown as follows:

For specimens without feathers;

Vol. of fine aggregates	= 786.6 cm^3
Weight of fine aggregates	= 786.6 cm^3 * 2.57 g/cm^3
	= 2,021.6 grams

For specimens with 5% feathers;

Vol. of fine aggregates	= 786.6 cm^3 * 0.95
	= 747.3 cm^3
Vol. of feathers	= 786.6 cm^3 * 0.05
	= 39.3 cm^3
Weight of fine aggregates	= 747.3 cm^3 * 2.57 g/ cm^3
	= 1,920.6 grams
Weight of feathers	= 39.3 cm^3 * 0.33 g/ cm^3
	= 13 grams

The cement-aggregate ratio used in this study is 1:6. It means that there will be 1 part of cement for every 6 parts of aggregates measured by weight. From the foregoing examples, each mix needs 131.1 cm^3 (412.965 g) of cement. Since chicken feathers was treated as aggregates to replace sand (fine aggregates), therefore the volume of cement is held constant to all the mixes of specimens regardless of the feathers percentage level.

As example on the calculation of the volume of cement is shown as follows:

Vol. of fine aggregates	= 786.6 cm^3
Vol. of cement	= 786.6 cm^3 / 6
	= 131.1 cm^3
Weight of cement	= 131.1 cm^3 * 3.15 g/cm^3
	= 412.965 grams

The water-cement ratio varies at every batch of mix. The amount of water required for every batch of mix was for the hydration of cement and that the water-cement mix can coat the surfaces of every particle of aggregates and every fiber of feathers plus the amount of water absorbed by the fine aggregates and the chicken feathers. As investigated, the absorption of fine aggregate is 4.35% and of the chicken feathers is 41.36%. Table 2 shows the distribution of water for each mix with the water-cement ratios graphical representation with respect to the level of chicken feathers.

Table 2. Quantity of each component for every batch

% Feathers	Vol. of sand m3	Wt. of sand (grams)	Vol. of feathers m3	Wt. of feathers (grams)	Wt. of Cement (grams)	Wt. of water (grams)	Cement-sand ratio
0	786.6	2021.562	0	0	412.965	220*	1:6
5	747.27	1920.4839	39.33	12.9789	412.965	240*	1:6
10	707.94	1819.4058	78.66	25.9578	412.965	260*	1:6
20	629.28	1617.2496	157.32	51.9156	412.965	300*	1:6
30	550.62	1415.0934	235.98	77.8734	412.965	340*	1:6
40	471.96	1212.9372	314.64	103.8312	412.965	380*	1:6
50	393.3	1010.781	393.3	129.789	412.965	420*	1:6

(Values with * are results from trial and adjustment processes)

2.6 Experimental Test Procedure (Procedure in Making Specimens)

The required amount of dry raw materials of the specimens were prepared, that corresponds to the volume of the batch to be mixed. All the raw materials were dry-mixed thoroughly in the mixing bowl. Then water was gradually added as mixing of the materials continued until the desired consistency was attained. The mixing of materials lasted up to more or less 5 minutes, enough for the feathers and the aggregates to absorb water.

As a simple test for the cohesiveness of the mixture, no excess water should be visible when a lump of concrete is squeezed in the hand, and if the sample is rubbed quickly on a smooth round metal bar or tube (2 to 4 cm in diameter) a slight film or paste should be brought to the surface.

The mould was placed on the ½” x 8” x 8” steel plate which served as the rigid base for tamping. One-half of the volume of mould was filled with mortar mix and evenly tamped slightly the surface with 5/8” Ø x 6” long steel tamper. The remaining mix was placed into the mould to overflow then ram down for 2 to 3 times using the ¼” x 2” x 10” steel plate tamper.

The pallet was placed against the top of the mould to cover it and brought everything to upside down then unlock the mould. Then stored the specimens in a shelter to air dry for 24 hours without disturbing and exposing to sunlight.

After more or less 24 hours, the specimens was cured in the curing tank by immersion as to the required 7, 14, and 28 days at a temperature of approximately $27^0C - 30^0C$. Changing of water was done at least every four days. After curing, the specimens was air-dried for 7 days before testing. Generally, a period of 7 to 15 days of drying will bring the blocks to the desired degree of dryness to complete their initial shrinkage. After this, the blocks are ready for use in the construction work (Glass & Ceramics Division, 2011)

The specimens were tested accordingly from 14, 21, and 35 days of age and consequently from 0% to 50% level of feathers. The result of every test was then recorded.

2.7 Statistical Methods and Analysis

Analysis of Variance (ANOVA) test - provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes *t*-test to more than two groups. Doing multiple two-sample t-tests would result in an increased chance of committing a type I error. For this reason, ANOVAs are useful in comparing three, or more means. The ANOVA test is a particular form of statistical hypothesis testing heavily used in the analysis of experimental data. The F-test is used for comparisons of the components of the total deviation in ANOVA; statistical significance is tested for by comparing the F-test statistic

$$F = \frac{variance\ between\ treatments}{variance\ within\ treatments}$$

$$F = \frac{MS_{Treaments}}{MS_{Error}} = \frac{SS_{Treatments}\ \ (I-1)}{SS_{Error}\ \ (n_T - I)}$$

where:

MS is mean square

I = number of treatments and

n_T= total number of cases

to the F-distribution with $I - 1$, $n_T - I$ degrees of freedom.

The Two-Way Analysis of Variance was employed in finding the significant differences of compressive strengths in relation to the feather level, the number of curing days of concrete block and the significant difference of the interaction between the chicken feather level and number of days of curing was also determined.

There are three sets of hypothesis with the two-way ANOVA. The null hypotheses for each of the sets are given below.

> H_{01} : The means of the compressive strengths in relation to the feather level are equal.
>
> H_{02}: The means of the compressive strengths in the number of curing days of concrete block are equal.
>
> H_{03}: There is no interaction between the chicken feather level and number of days of curing.

The two independent variables are fine aggreagtes and chicken feathers. The idea is that the fine aggregates and the chicken feathers affect the compressive strenghts of concrete block. The fine aggregates and the chicken featehrs will have two or more levels within it, and their degrees of freedom for each of them is one less than the number of levels.

Multiple Comparison Procedures are commonly used in an analysis of variance after obtaining a significant ANOVA F-test. The significant ANOVA result suggests rejecting the global null hypothesis H_0 that the means are the same across the groups being compared. Multiple comparison procedures are then used to determine which means differ.

3. Results and Discussions

All specimens were then cured, after storing, through total immersion into the water to complete the hydration process. The specimens were grouped into 3 according to the number of days of curing (i.e.7 days group, 14 days group and 28 days group). Each group constituted fourteen (14) samples with seven (7) classifications according to their feather content. It means that every two (2) samples were classified to have the same level of feathers. The curing temperature of the water in the curing tank should be maintained at 27-30°C (CIVCAL Team).

3.1 Weight Reduction of Concrete Blocks at Various Mixtures

Table 3 shows that by replacing fine aggregates with chicken feathers, the weight of the mortar specimens reduced. The weight reduction might be affected by the different densities of chicken feathers and fine aggregates which are 0.33 g/cm^3 and 2.57 g/cm^3 respectively.

Table 3. Average weight reduction of concrete blocks at various feather mixtures (%)

% Feather	7 Days	14 Days	28 Days
0	0	0	0
5	8.13	9.15	7.56
10	12.22	11.79	13.67
20	20.08	24.90	19.33
30	29.75	28.35	26.72
40	35.90	36.21	37.11
50	48.59	44.04	44.08

3.2 Compressive Strengths of Concrete Blocks Mixed with Chicken Feathers

Compressive strength test is a one-time method test in every specimen, meaning, the specimen being tested will come to be destructed and could not be utilized to another test or use. There were two replicates of specimen in every level that were subjected for testing. The aim of these replications is to give reliable average results in every level of mixture.
The experiment yielded the following results shown in Table 4 below with its graphical illustration in Figure 1.

It can be noted in Figure 2 below that the increase in compressive strengths of specimens is relative to the increase of the numbers of days of curing. Alawode, *et al.*, (2011) stressed that the compressive strength was observed to increase with age; after casting the concrete mixes, the compressive strength increases as the number of curing day increases.

Table 4. Average compressive strengths of specimens at different mixtures vis-à-vis number of days

Percent of Feathers by Weight	Compressive Strength in MPa		
	7 Days	14 Days	28 Days
0	17.54	19.58	20.61
5	11.385	12.12	12.61
10	8.045	8.79	8.89
20	6.795	6.885	6.945
30	6.105	6.15	6.19
40	5.685	5.745	5.77
50	5.465	5.61	5.665

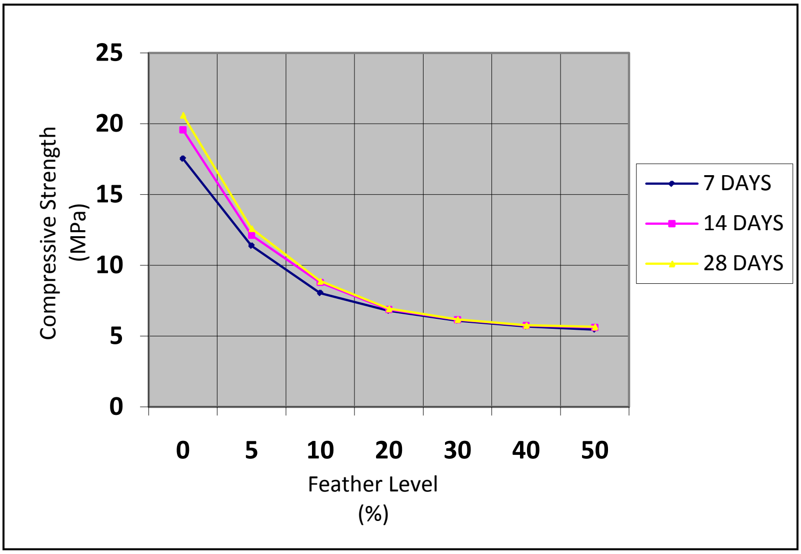

Figure 1. Compressive strengths of specimens at various levels of mixtures

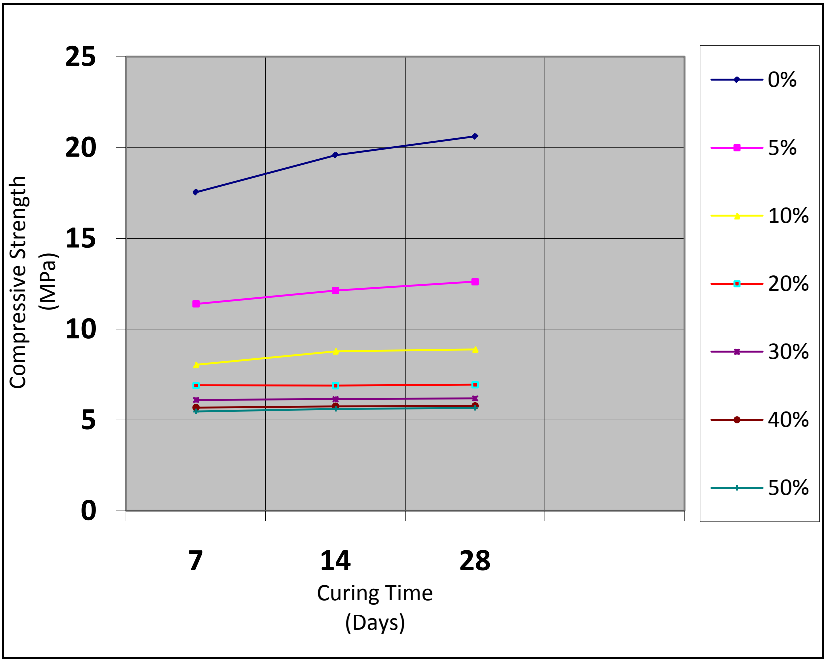

Figure 2. Compressive strengths of specimens at various curing time

In Table 4, the compressive strength of the specimen with 5% feathers at 28 days curing, met the minimum compressive strength of 12.4 MPA for the type S mortar cement of ASTM C270-91 standard specification that covers mortars for use in the construction of non-reinforced and reinforced unit structures. Moreover, the rest of the compressive strength results of the specimens satisfied the minimum compressive strengths of 5.2 and 2.4 MPa respectively for the types N and O mortar cement of ASTM C270-91 standard.

On the other hand, National Ready Mixed Concrete Association (NRMCA) (2003) notes that concrete compressive strength requirements can vary from 2500 psi (17 MPa) for residential concrete to 4000 psi (28 MPa) and higher in commercial structures. Hence the results of the tests did not meet the specified concrete requirements as far as the statement of the National Ready Mixed Concrete Association (NRMCA) is concerned.

As shown in Figure 2, the compressive strength results of the specimens, with feather levels from 5% to 50%, are comparable to the required compressive strength for load bearing CMU (Concrete Masonry Unit) by the ASTM and DPWH.

Banaag (2006) quoted that the “ASTM C129 requires the minimum average compressive strength of hollow non-loadbearing CMU to be 4.14 MPa, or a minimum individual compressive strength of 3.45 MPa (ASTM 2003). And the DPWH Item 704 requires a minimum average compressive strength of 6.9 MPa, or a minimum individual compressive strength of 5.5 MPa for hollow load-bearing CMU (DPWH 2000)”.

The study by Rosario (2010) shows the compressive strength results of S2 (building block) with 20% CFM (Chicken Feather Materials) is 5 Mpa and S3 (building block) with 30% CFM is 5.66 Mpa The results of Rosario (2010) are more or less similar to the results at 50% level of feathers as shown in Table 4 which is 5.465 MPa.,5.61 MPa.,5.665 MPa. at the ages of 14, 21, and 35 days respectively. But the ratio of cement-aggregate and other details of Rosario’s study were not known by the researcher.

The decrease of compressive strengths as shown in Figure 2 might be affected by some contributory factors such as: Fine aggregate – Chicken Feather Ratio, Cement-Aggregate Ratio, and Water-Cement Ratio. Specifically, the decrease in compressive strength with increasing amount of chicken feathers may be attributed to the absorption of water by the chicken feathers such that when the concrete block dries up, it creates pores resulting to weak points.

3.3 Fine Aggregate – Chicken Feathers Ratio

There were seven assortments of mixtures of specimens that were prepared. One of which was without feather content, a mixture of pure fine aggregates, cement and water only. The fine aggregates of the other six mixtures were gradually substituted by chicken feathers in different levels of percentages (i.e. 5%, 10%, 20%, 30%, 40%, and 50%). The specimens with 0% feather content have the highest compressive strengths. As the feathers replaces fine aggregates in increasing manner, the compressive strength decreases. Therefore, the varying ratios of fine aggregate with respect to the chicken feathers affected the compressive strength of the specimens as shown in Figure 3. It indicates that the compressive strengths of the specimens are inversely proportional to the increase of the feather levels.

Adapted from the study of Acda (2010), the feather-cement composites (board), that feather content at levels of 5% to 10% using water-cement ratio of 0.60 and 15% to 20% using water-cement ratio of 0.80 allowed proper mat formation and consolidation. The stiffness (MOE= modulus of elasticity) and flexural strength (MOR=modulus of rapture) of boards decreased significantly with increasing quantities of feather.

The decreasing compressive strength results also may be affected by the densities of aggregates and chicken feathers. Fine aggregates used in this study, as experimented, have an average density of 2.57 g/cm^3 while that of the feathers according to Kock ranges from 1-1.2 g/cm^3. Kock (2006) added that Hong and Wool (2005) reported a value of 0.8 g/cm^3 and Barone and Schmidt (2005) reported a value of 0.89 g/cm^3 (Kock , 2006).

Evidently, Kock (2006) stressed that “CFM (Chicken Feather Materials) inclusion in a composite could potentially lower composite density, whereas the density of a typical composite with synthetic reinforcing increases as fiber content increases (Hong and Wool, 2005). Thus, substantial savings, in terms of transportation and construction costs, could be derived from the use of lightweight composites containing CFM”.

In addition Espino said that for a given mix proportions, type of aggregate and water-cement ratio, the compressive strength of the mortar decreases as the density decreases (Espino, 1966). Apparently, as the volume of fine aggregates decreases, due to the substitution of chicken feathers, the density of the specimen decreases because chicken feathers is less dense compared to fine aggregates thus resulting to the decrease in compressive strength of the specimen.

3.4 Cement-Aggregate Ratio

The cement-aggregate ratio of the mix is 1:6. The volume of cement is held constant in all mixtures at different level of feather-aggregate ratio. With the presence of feathers that gradually replaced fine aggregates, the resulting volume of the mixtures increased because the specific weight of feathers is lower compared to that of fine aggregates.

According to Merrit (1976), “Cement served as the binder of the aggregates, and with cement content increasing, the strength is also increasing”. Thus, the resulting compressive strength gradually decreases, as shown in Figure 2, as the feather level increases unless the quantity of cement is increased. In this study the normal behavior of cement in the concrete with regards to cement-aggregate ratio is altered by the increasing presence of the quantity of feathers.

3.5 Water-Cement Ratio

During the sampling procedures, it has been observed that the increase of water content in each succeeding mixtures, from 0% to 50% level of chicken feathers, is proportional to the increase of the chicken feather levels even if the quantity of fine aggregates decreases. The increase of water content in every mix, upon the addition of chicken feathers and even the decrease of fine aggregates, was due to the water absorbed by the chicken feathers and the water needed for the cement paste that could fill up the interstices between solid particles (i.e. fine aggregates and feather fibers) in the mix. It should be remembered that the absorption of chicken feather is 41.36% which is very much higher compared to the fine aggregates used which is 4.35%.

Fajardo (2000) mentioned that the purpose of mixing concrete is to select an optimum proportion of cement, water, and aggregates, to produce a concrete that is workable, strong, durable, and economical. The proportion that will be finally adopted in concrete mixing has to be established by actual trial and adjustment processes to attain the desired strength and quality of concrete required. Laboratory tests showed that the water-cement content ratio is the most important consideration in mixing because it determines not only the strength and durability of the concrete but also the workability of the mixture.

Therefore, the water content in each mixture is one of the contributory factors in the decrease of the compressive strength of the specimen with the increasing feather levels.

3.6 Analysis of Variance of Specimen Strength

Table 5 shows that the test is significant in the treatment which is the percent mixture of chicken feathers in specimen, number of days of curing, and the interaction between percent mixture of chicken feather and number of days of curing, since the significant p-value is less than 0.05. Hence, we can say that we are 95% confident that at least one of the mean of compressive strength of specimen is significantly different due to the percentage of chicken feather mixed in specimen. Similarly, at least one of the mean of compressive strength of specimen is significantly different due to the number of days of curing. The same with the interaction between percent mixture of chicken feather and number of days of curing, at least one of the mean of compressive strength of specimen is significantly different. We can say that the compressive strength of the specimen will differ due to the percentage mixture of chicken feathers and the number of days of curing. Since, we aim to know the comparison of compressive strength between the control specimen, 0% mixture, and with the 6 different percentages of chicken feathers mixed in specimen, the 5%, 10%, 20%, 30%, 40%, and 50%, we perform the multiple comparisons test and it is shown in Table 6.

Table 5. Two-way analysis of variance of the strength of specimen

Source of Variation	Sum of Squares	df	Mean Square	F	Sig. (p-value)
Intercept	3532.101	1	3532.101	16980.000	0.000
%Mixtures	894.898	6	149.15	717.082	0.000
No. of Days	4.779	2	2.389	11.487	0.000
%Mixtures *No. of Days	7.44	12	0.62	2.981	0.014
Error	4.368	21	0.208		
Total	4443.585	42			

Table 6. Multiple comparison of means of different percent of mixtures vs. control variable . multiple comparisons (scheffe)

	%Mixture	Means of Different %Mixture (J)	Mean Difference (I-J)	Std. Error	Sig.
Control 0% (Mean= 19.243) (I)	5%	12.038	7.205	0.2633	0.000
	10%	8.575	10.668	0.2633	0.000
	20%	6.875	12.368	0.2633	0.000
	30%	6.148	13.095	0.2633	0.000
	40%	5.733	13.510	0.2633	0.000
	50%	5.580	13.663	0.2633	0.000

Table 6 shows that the compressive strength of control specimen with 0% chicken feather mixture is significantly different from the compressive strength of specimen with chicken feathers, 5% mixtures to 50% mixtures. Furthermore, the mean difference between the mean compressive strength of control specimen and the mean compressive strength of specimen with chicken feathers is positive difference, and it implies that control specimen is compressively stronger than specimen with chicken feathers. Table 7 presents the groupings of different percentage mixtures that have the same compressive strength.

Table 7. Means for groups in homogeneous subsets

%Mixture	No. of Samples	Subset				
		1	2	3	4	5
50%	6	5.580				
40%	6	5.733				
30%	6	6.148	6.148			
20%	6		6.875			
10%	6			8.575		
5%	6				12.038	
Control	6					19.243
Sig.		0.5974	0.3132	1.00	1.00	1.00

The results show that 30%, 40% and 50% chicken feather mixtures in specimen have the same compressive strength, with the strength of 5.5 to 6 MPA. Also, 20% and 30% mixtures have the same compressive strength, with the strength 6+ MPa. Meanwhile, 5% and 10% mixtures has different compressive strength, their strength is 12 MPa and 8.5 MPa respectively. Lastly, the specimen with 0% mixtures of chicken feathers has the greatest compressive strength, with the strength of approximately 19 MPa.

Viability of Concrete Blocks Mixed with Chicken Feathers for Concrete Application

The results in Table 4 show the average compressive strengths of the specimens at different level of mixtures evidently suggests for the acceptability of concrete block mixed with chicken feathers for concrete application based on the ASTM C129 standard specification for non-load bearing Concrete Masonry Units.

Results shown in Table 4 as evidenced in this proposal, is coupled with the ASTM and DPWH standard requirements for the minimum compressive strengths for concrete masonry units as stated by Banaag (2006).

4. Conclusion and Recommendations

The following conclusions were drawn based on the results of the experiment, to wit:

A. Processes in Making Concrete Block Mixed with Chicken Feathers;

1. The increase of water-cement ratio is proportional to the increase of the quantity of feathers. This can be attributed to the fact that the effective surface area of chicken feathers is bigger than the sand and as such require more amount of water to be mixed with the constant weight of cement to form a cohesive and workable mixture.

2. The quality of concrete block mixed with feathers is relative to the water-cement chemical reaction since fast water evaporation will result to inadequate water-cement hydration.

3. The quality of concrete block mixed with feathers is dependent on the cohesiveness among aggregate particles of the specimens as these will bring to disintegration when minimal force acted upon on them.
4. The quality of the concrete block is relative to its number of curing days since the longer the curing period, the stronger is the specimen would be.

B. Compressive Strengths of Concrete Block Mixed with Chicken Feathers

1. The mixture of the concrete block without feathers could be utilized as mortar for masonry units since their compressive strengths are even higher than what is specified by ASTM C270 which is 17.2 MPa.

2. The compressive strength of concrete block with chicken feathers is inversely proportional to the feather level. This might be attributed to the absorption of water that when dried up, creates pores that leaves weak points”

C. Viability of Concrete Block Mixed with Chicken Feathers for Concrete Application

1. Concrete blocks mixed with chicken feathers are viable for concrete application, particularly for non-load bearing structural member such as walls and fences.

Recommendations

1. The use of chicken feathers for concrete application is favorably recommended.

2. Recommendation for further study may consider the following:

   2.1 Feathers of ducks, ostrich, etc.
   2.2 Use of feathers as additives rather than as replacement of fine aggregates
   2.3 In-depth study on chicken feathers for concrete hollow-block application and load-bearing structural member
   2.4 Properties of chicken feathers

5. References

Acda, M.N., (December 2010). Waste Chicken Feather as Reinforcementin Cement-Bonded Composites. Philippine Journal of Science, pp. 139, 161, 163, 164-165

ACI, (1980). Manual Of Concrete Practice Part 1, p. 207-7 from https://law.resource.org/pub/us/cfr/ibr/001/aci.manual.1.1980.pdf

Alawode, O., and Idowu, O.I., (2011). Water-Cement Ratios on the Compressive Strength and Workability of Concrete and Lateritic Concrete Mixes. The Pacific Journal of Science and Technology, 12, 101 from http://www.akam aiuniversity.us/PJST12_2_99.pdf

Atienza, V.A., (2011). Review of the waste Management System in the Philippines: Initiatives to promote Waste Segregation and recycling through Good Governance, An Interim Report, 66,77 from http://www.ide.go.jp/Japanese/Publish/Downloa d/Report/2010/pdf/2010_431_05.pdf

Building Materials & Technology Promotion Council (BMTPC). Techno Economic Feasibility Report On Concrete Hollow & Solid Block, 9, from http://www.bmtpc.org/DataFiles/CMS/file/02_Concrete%20Hollow%20&%20Solid % 20Bl k1

Banaag, V. F. E., Cañada, A. L. C., Meñes, M.O., Saldivar, K.Q., and Lo, D.S., (2006). "Bagasse as an alternative aggregate in hollow CMU", Symposium on Infrastructure Development and the Environment, pp. 2,3

Caltrans (California Department of Transportation), (2013). Concrete Technology Manual, p.1.2,2.8, from www.dot.ca.gov/hq/esc/.../manuals/OSCCompleteManuals/ CTM2013.pdf

CDO Dev.Com, (2010). Progress Watch : Cagayan de Oro and Misamis Oriental, San Miguel Foods to Build P120 Million Poultry Processing Facility in Mis Or. From http://www.cdodev.com/2010/12/14/san-miguel-foods-to-build-p120-million-poultry-processing-facility-in-misor/#comments

Cement Concrete & Aggregates Australia, (2004). Concrete Basics A Guide to Concrete Practice, 6,23, from http://www.concrete.net.au/publications/pdf /concretebasics.pdf

Chang, H.S., (2004). Cross-Sector Comparisons of Poultry Production in the Philippines, Working Paper Series, 6, pp. 66,71, from http://ageconsearch .umn.edu/bitstream/12896/1/ wp040012.pdf

CIVCAL Team, Virtual Building and Construction Environment: Making Test Cubes From Fresh Concrete) from http://www.cityu.edu.hk/CIVCAL/design/labexp/te stcube/ testcube5.html

Concrete Manual, (2003). Mix Design, 312(2) from http://www.dot.state.m n.us/materials manuals/concrete/Chapter3.pdf

Concrete Portland Cement Association, (2013): Role of Portland Cement, from http://www.cement.org/tech/cement_role.asp

Davis, Harmer E., Troxell, George Earl, and Wiskocil Clement T., “The Testing and Inspection of Engineering Materials”,New York: McGraw-Hill Book Company, Inc., Third Edition, 1964, pp. 21, 414-415, 67

Dietz, A.G.H., (1982). Plastics in Building: Past, Present, Future, Plastic in Material and Structural Engineering. Richard A. Bares ed. New York: Elsiever Scientific Publishing Co., p. 689

Dunn, L.E., (2013). Concrete Technology Manual, 9, From http://www.dot.c a.gov/hq/esc/construction/manuals/OSCCompleteManuals/CTM2013.pdf

Espino, E.I., (1966). An Investigation Into The Relation Between The Strength And Density Of Normal Concrete, Thesis, 17

Fajardo, Jr. M.B., (2000). Simplified Construction Estimate. (2000 Ed.), Quezon City: 5138 Trading, p. 41

Fajardo, Jr. M.B., (2000). Simplified Methods on Building Construction. (2000 Ed.), Quezon City: 5138 Trading, p. 243

Farlex, Inc. The Free Dictionary, 2014 from http://www.thefreedictionary.com/conventional

Glass & Ceramics Division, (2011). Project profile on cement concrete hollow blocks, pp. 4,5, from http://www.dcmsme.gov.in/reports/glass/HollowConcreteBlocks.pdf

Highway (Transportation) Research Board, (1958). Chemical Reactions of Aggregates in Concrete, Special Report No. 31, p. 1-12

Kock, J.W., (2006). Physical And Mechanical Properties Of Chicken Feather Materials, Thesis, pp. 4, 13-15, 19, 66-67

Kurtis, K., Tests on Portland Cement, from http://people.ce.gatech.edu/~kk92/testskek.pdf

Lee, S.M. (ed.). Handbook of Composite Reinforcements. USA: VCH Publishers Inc.

Lerado, B.L., (1994). Concrete Hollow Block. Module, 1, p. 2

Mehta, P.K. and Monteiro, P.J.M., (2006). CONCRETE-Microstructure, Properties & Materials. McGraw Hill

Meritt, F.S., (1976). Concrete: Factors Affecting Strength. Standard Handbook for Civil Engineers.(2nd ed.). New York: McGraw-Hill Book Co., p. 9

Mostrales, D., Trinidad, A. G., Empig, V. E., and Dimamay, M. S., (1991). The Introduction of Micro-Concrete Roofing Technology In Mindanao (Philippines), Iligan City: MSU-IIT, 1, 5.

National Meat Inspection Service (NMIS), Department of Agriculture (2014). Meat Establishment, Accredited Poultry Dressing Plant. Retrieved on February 14, 2014, from http://nmis.gov.ph/index.php/meat-establishment/5-accredited-poultry-dressing-plant-pdp

National Ready Mixed Concrete Association (NRMCA), (2003). Concrete in Practice What, why & how?. *CIP 35- Testing Compressive Strength of Concrete.* Retrieved February 8, 2014, from http://www.nrmca.org/aboutconcrete/cips/35p.pdf

Neville, A.M., (1977). Properties of Concrete. London: Pitman Publishing Limited, 103-112, 182-185.

Palabao, J., (2011). AnakCiano, Inc: A company with infinite potentials. *Business Week Mindanao.* Retrieved on February 14, 2015, from http://www.businessweekmindanao.com/2011/06/29/anakciano-inc-a-company-with-infinite-potentials/

Perenchio, W. F., and Klieger, P., (1976). Further Laboratory Studies of Portland-Pozzolan Cements, PCA Research and Development Bulletin, Ser. 1536, pp. 7-8

Reddy, N., and Yang, Y., (2007). Structure and Properties of Chicken Feather Barbs as Natural Protein Fibers. Polymers and the Environment, 15, pp. 81–87; doi: 10.1007/s10924-007-0054-7

Rosario, W.R.D., (2010). Potential Use of Chicken Feather Materials (CFM) as a Component for Building Blocks, Unpublished Research.

Tejano, E.A., (1985). State of the Art of Coconut Coir Dust and Husk Utilization. Philippine Journal of Coconut Studies, p. 6

U.S. Department of Transportation Federal Highway Administration. Portland Cement Concrete Testing Manual, Publication Number: FHWA-PD-91-013, 8 http://isddc.dot.gov/OLPFiles/FHWA/013716.pdf

Winter, G.H., and Nilson, A.H., (1964). Concrete and Reinforcing Steel: Design of Concrete Structures. McGraw-Hill, Inc., p. 8