Utilization of Residual Chicken Bones as an Alternative Partial Replacement of Cement in Concrete Hollow Blocks

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Abstract

Concrete hollow blocks (CHBs) are frequently employed as construction materials for the construction of interior and exterior walls. To make a CHB, the construction industries use cement, aggregates, sand, and water. Cement undergoes a process of solidification, forming a strong connection with other materials to effectively unify them. However, cement can also be a cause for environmental and health problems to the people because of carbon dioxide emissions. In this paper, the researchers utilize residual chicken bones as an alternate partial replacement of cement in CHBs. The assessment of the compressive strength of CHBs, with or without the incorporation of residual chicken bones is the main objective of this study. To determine the differences of the CHBs in terms of compressive strength, the samples have various percentages which are: 0%, 1%, 2%, and 3% of residual chicken bones that will partially replace the cement. With the use of oneway ANOVA, the concrete hollow blocks mixed with and without residual chicken bones were analyzed. After analyzing, the result of the concrete hollow blocks with residual chicken bones had higher compressive strength than the standard CHB, which it has significant difference. To confirm this, the concrete hollow blocks with 2% residual chicken bones has the highest compressive strength of all the samples. However, the inclusion of more than 2% of residual chicken bones in CHBs results in a decreasing of their compressive strength.

Keywords: chicken bones, concrete hollow blocks, partial replacement of cement, compressive strength, universal testing machine, American society for testing and materials, one-way ANOVA test

1. INTRODUCTION

Construction has been evolving and improving as time goes by, from households made from wood to concrete and now to steel. However, as time passes by, waste in construction projects has been overwhelming and excessive in which; repurposing various materials and integrating it with construction mediums has been the main target of researchers because of its great potential and effect on the environment. Furthermore, in the construction of any project, raw materials like cement, gravel, sand, and water play a vital role in making the structure sturdy. Moreover, the main use case of Concrete Hollow Blocks (CHB) in construction is to divide and generate walls to secure the structure. Concrete hollow Blocks are comprised of cement, fine or coarse aggregates, and water.

Residual Chicken Bones (RCB) are one of the common wastes in every food business in the world. There are numerous ways that can be done with residual chicken bones, one of which is that it can be a green waste where it improves the soil. The objective of this study is to explore the potential of residual chicken bones as an alternative for a portion of the cement used in production of CHBs. This will lessen the use of sand or gravel in the concrete mixer to create a CHB.

This gives emphasis on using chicken bones as partial cement replacement that would be mixed with other aggregates to make concrete hollow blocks. The data collection was conducted by gathering residual chicken bones in a small fast-food restaurant. The study was limited to residual chicken bones only. In addition, the type of chicken bone that was gathered were the drumsticks, radius, ulna, and humerus of the chicken. The study will not be conducted on chicken feathers or raw chicken bones. Furthermore, the American Society for Testing and Materials (ASTM) standards were observed in this study to follow to maintain the quality of concrete. Nevertheless, this paper was limited to residual chicken bones alone, and the study did not tackle chicken feathers or raw chicken bones. In addition, chicken infections and bone imperfections were not discussed in the paper.

CHBs are extensively employed in the construction of both interior and exterior walls. However, a significant challenge associated with their use and production pertains to the expenses incurred due to raw materials and the environmental impact stemming from extensive quarrying activities. This investigation centered on the utilization of leftover chicken bones as a substitute for a portion of the cement in production of concrete hollow blocks, with the aim of reducing the overall expenditure on raw materials required for CHB manufacturing. This study is focused on evaluating the feasibility of using residual chicken bones as an alternative partial replacement of cement in production of CHB.

2. METHODS

The researchers used the residual chicken bones because it is the most common waste food that can be found in fast food restaurants. The researchers collected the residual chicken bones in Wing Bites Kawit and Imus, Cavite. The methodology answered the research question of how many residual chicken bones are used in making CHBs that will partially substitute as the cement and the compressive strength of the CHBs mixed with RCB.

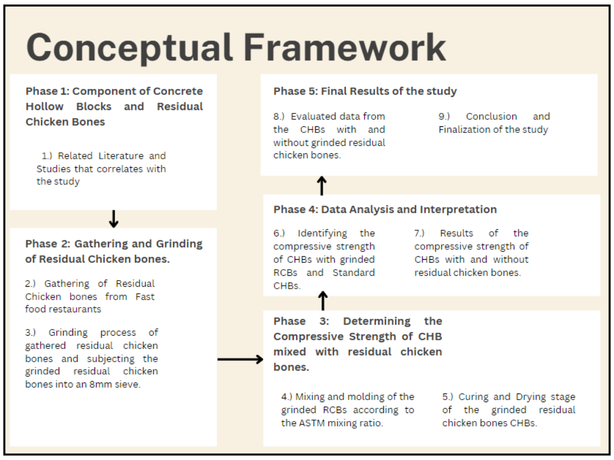


Figure 1.1

Figure 1.1 represents the conceptual framework of the study, it shows the phases and steps in utilizing residual chicken bones as an alternative partial replacement of cement in concrete hollow blocks. The first phase focuses on the component of CHBs and Residual Chicken bones. With the help of literature, studies, journals, books, etc. the researchers determined the advantages and disadvantages of compressive strength of cement and the partial replacement of cement. Therefore, the results of this phase were conducted in an experimental procedure. The researchers emphasize the *keywords: chicken bones, concrete hollow blocks, partial replacement of cement, compressive strength, universal testing machine (UTM), and American society for testing and materials.*

The second phase is gathering and grinding of residual chicken bones. In this phase, the researchers gathered residual chicken bones from fast food restaurants and household food leftovers then grinded it through an 8mm sieve. For the first step of this phase is gathering the residual chicken bones in specific fast-food restaurants located in Cavite which were Wing Bites (Kawit) and Wing Bites (Imus) and also gathering in the researcher's household food leftovers, can be seen in figure 1. The second step of this phase was grinding the gathered residual chicken bones. The grinded residual chicken bones were applied as an alternative partial replacement of cement by the weight percentage. The researchers put the grinded residual chicken bones into a container that represented 1% of the cement weight in the CHB. This allowed the researchers to check 1%, 2%, and 3% of residual chicken bones in the CHB.

The third phase is determining the compressive strength of CHB mixed with residual chicken bones. This phase determined the compressive strength of CHB mixed with residual chicken bones. In addition, this phase contains three (3) steps that focus on molding, hardening, and testing the concrete hollow blocks mixed with residual chicken bones. The first step is mixing and molding, where the grinded residual chicken bones were mixed with the partial replacement of cement. The second step is curing, the concrete mixed with grinded residual chicken bones were cured. This process lasted for twenty-eight (28) days, after the samples were dried up, it is ready for testing. The third step was testing the CHBs infused with residual chicken bones and standard CHBs with the use of Universal Testing Machine (UTM).

The fourth phase is data analysis and interpretation where in this phase was focused on data analysis and interpretation of the results from the previous phases. With the use of UTM, the data of the grinded residual chicken bones as an alternative partial replacement of cement in CHBs and standard CHB were determined. Furthermore, the statistical method employed to identify the compressive strength of both samples was the One-way ANOVA.

The fifth phase is final results of the study where the researchers evaluated the data from the statistical model used for this study. The researchers evaluated the compressive strength of the variables. In addition, this phase states the conclusion and recommendation for this study.

This study employed an experimental quantitative approach to ascertain the compressive strength of CHBs, utilizing the UTM. The data collected from CHBs mixed with residual chicken bones will undergo analysis and compared with the standard CHBs through the statistical method known as one-way ANOVA.

The study was conducted at three primary locations: D.V.S Construction in Kawit, Cavite; Fabrimetrics Phils., Inc., in Quezon City; and Precision Materials Testing Corporation, located in Imus City, Cavite. The researchers went to Fabrimetrics Phils., Inc. to grind the residual chicken bones. The production of CHBs took place at D.V.S Construction. To conduct sample testing, the 31 researchers went to Precision Materials Testing Corporation, where the researchers determined the compressive strength of the CHB utilizing the UTM.

According to phase 2, the researchers gathered the residual chicken bones in the specified fast-food restaurant and in their houses. Afterwards, the researchers processed the residual chicken bones by grinding them with a grinder and sieving them through an 8mm sieve for even distribution onto the CHBs. Phase 3 began by partially replacing 1%, 2%, and 3% of the cement with the grinded residual chicken bones. After doing so, the researchers began phase 4 and 5, which is analyzing and evaluating the compressive strength of the concrete hollow blocks mixed with the grinded residual chicken bones. With this, the researchers compared if the CHBs mixed with grinded residual chicken bones are better than the standard CHBs or not.

The data gathering instrument is a tool where and how the researchers collected their data. The instruments gathered from phase 1, were from the articles, research journals, and websites locally and internationally. For the second phase, the researchers used a grinder in order to grind the collected residual chicken bones into the 8mm sieve. Next was identifying the CHBs compressive strength through the experiment. The CHBs underwent molding, curing, and testing the CHBs mixed with residual chicken bones. With the use of the UTM, the researchers tested the compressive strength of the CHBs mixed with residual chicken bones and standard CHBs. The researchers also utilized a hollow block mixing machine for incorporating the grinded residual chicken bones, sieved to 8mm, into the concrete mix during the molding process. Afterwards, 32 curing and drying began. For the data analysis, the UTM and one-way ANOVA were used in order to determine the compressive strength of the two samples and to evaluate which is better.

The Analysis of variance or also known as the ANOVA is an example of the general linear model that is widely used for factorial designs. When the experimental settings may be divided into groups based on one or more factors, this is known as a factorial design. each with two layers or more, according to Henson, R. N. (2015). It is handled as a t-test for independent samples within multiple groups. The study of variances is used to know whether there are any appreciable differences between class means. Additionally, ANOVA is frequently used in experimental research to identify key factors that are investigated to demonstrate their significance in relation to selected parameters.

ANOVA Test

$F = MSB/MSW$

where:

F=Anova Coefficient

MSB=Mean sum of squares between the groups

MSW=Mean sum of squares within groups

3. RESULTS AND DISCUSSIONS

In the experimentation, there are 12 samples of CHBs vary in different percentages. The percentages used are the number of residual chicken bones in the CHB as a partial replacement of the cement. The results will determine whether the compressive strength (in MPa) of CHBs with residual chicken bones is better than the CHBs without residual chicken bones.

Table 4.1. Compressive Strength of CHBs @ 28 Days in MPa

	Control Sample			CHB with 1% of Residual Chicken Bones		
Compressive Strength @ 28 Days (in Mpa)	0.93	0.87	0.73	3.17	2.83	3.86
Sample	**1**	**2**	**3**	**4**	**5**	**6**
	CHB with 2% of Residual Chicken Bones			**CHB with 3% of Residual Chicken Bones**		
Compressive Strength @ 28 Days (in Mpa)	3.43	5.46	8.48	2.29	2.74	1.6
Sample	**7**	**8**	**9**	**10**	**11**	**12**

In Table 4.1, it shows that there are 1%, 2%, and 3% CHBs mixed with Residual Chicken Bones. Based on the references cited in Chapter 2, adding a cement alternative has the potential to enhance the compressive strength of concrete. Hence, as indicated by the data presented in Table 4.1, there was a noticeable rise in the compressive strength of CHBs when 1%, 2%, and 3% of residual chicken bones were added. In addition, the researchers used "Control Sample" as the CHB without residual chicken bones (0%) or Standard CHB.

Identified the weighted percentages of grinded residual chicken bones that will be used as an alternative partial replacement of cement in CHBs.

As depicted in table 4.1, the researchers utilized the ranges from 1% to 3% of residual chicken bones to determine if the CHBs mixed with residual chicken bones have better compressive strength than the standard CHBs. Furthermore, the researchers made a cardboard container to measure the weighted proportions of the grinded residual chicken bones. The researchers can stack the grinded residual chicken bones into the CHB, replacing 1% of the cement.

Identified the compressive strength of standard CHBs and the CHBs mixed with grinded residual chicken bones.

As depicted in table 4.1, the researchers were able to identify the compressive strength of the standard CHB and CHBs with different percentages of residual chicken bones. These CHB samples were made by the construction laborers of D.V.S Construction Firm. In addition, the skilled worker of Precision and Material Testing Corp (PMTC) gave the researchers the compressive strength of all CHB samples in terms of Psi with the use of their testing machine. However, the researchers will convert the unit Psi into the unit MPa and use it for all of the data in this study.

Figure 4.1. Compressive strength of the CHBs (in MPa) @ 28 days for the Control Sample

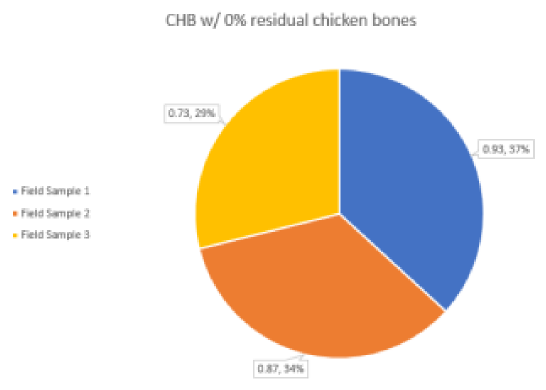


Figure 4.2. Compressive strength of the CHBs (in MPa) @ 28 days for the CHBs with 1% of Residual Chicken Bones

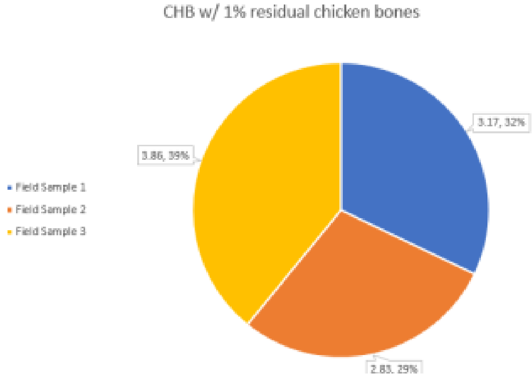


Figure 4.3. Compressive strength of the CHBs (in MPa) @ 28 days for the CHBs with 2% of Residual Chicken Bones

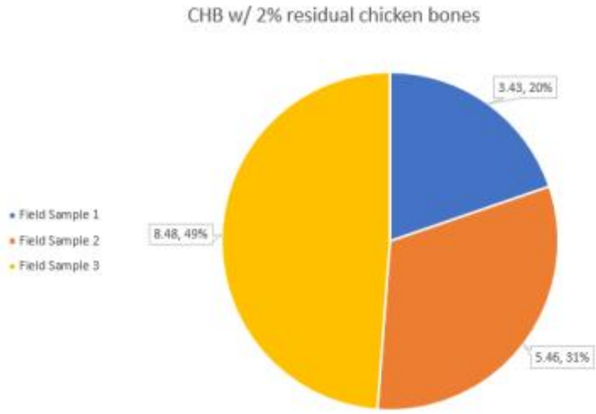
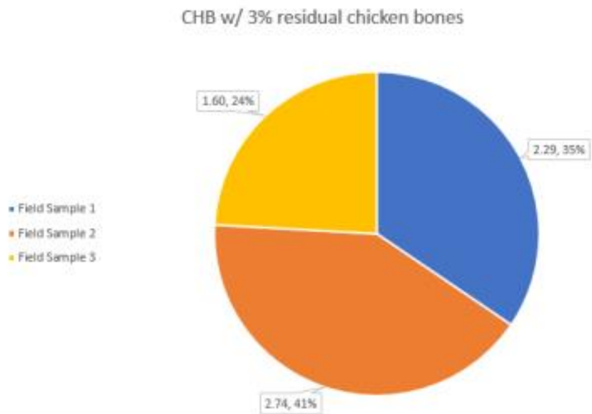


Figure 4.4. Compressive strength of the CHBs (in MPa) @ 28 days for the CHBs with 3% of Residual Chicken Bones



As you can see from the figures 4.1, 4.2, 4.3, and 4.4, the compressive strength of the CHBs are increasing in various percentages of residual chicken bones. With this, it proves that the CHBs mixed with residual chicken bones has better compressive strength than the standard CHBs. However, there are slight decrease of compressive strength shown in Figure 4.4. This is because at some point in increasing of percentage of residual chicken bones can lead to decreasing of the compressive strength of CHBs. Although there is a decrease in compressive strength of CHBs as seen in 3% of residual chicken bones, it is still shows a higher compressive strength than the standard CHB.

Used a statistical treatment that can determine if the CHBs with residual chicken bones can be used as an alternative partial replacement of cement for CHBs.

The researchers used a statistical treatment which is the One-Way ANOVA to determine if the grinded residual chicken bones can be used as the alternative partial replacement of cement for CHBs. In order to demonstrate if the standard CHB and the CHB mixed with different percentages of residual chicken bones had significant differences in their compressive strength or not, the researchers entered the compressive strengths of the samples to the one-way ANOVA in MS Excel. In addition, the researchers added bar graphs or figures to easily view the differences of each CHB sample. The results of the one-way ANOVA gave the researchers the following tables:

SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
CHB mixed with 0% of RCB	3	2.531034483	0.843678161	0.010479588		
CHB mixed with 1% of RCB	3	9.848275862	3.282758621	0.274292509		
CHB mixed with 2% of RCB	3	17.37931034	5.793103448	6.453460166		
CHB mixed with 3% of RCB	3	6.634482759	2.211494253	0.332239398		
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F-statistic***	***P-Value***	***F-Crit***
Between Groups	39.44565597	3	13.14855199	7.438571354	0.010595933	4.066181
Within Groups	14.14094332	8	1.767617915			
Total	53.58659929	11				
Significant @ 0.05 (p < 0.05) & Significant when F-statistic > F-crit						

Table 4.2 Data of all CHB Samples with different percentages of residual chicken bones using the one-way ANOVA.

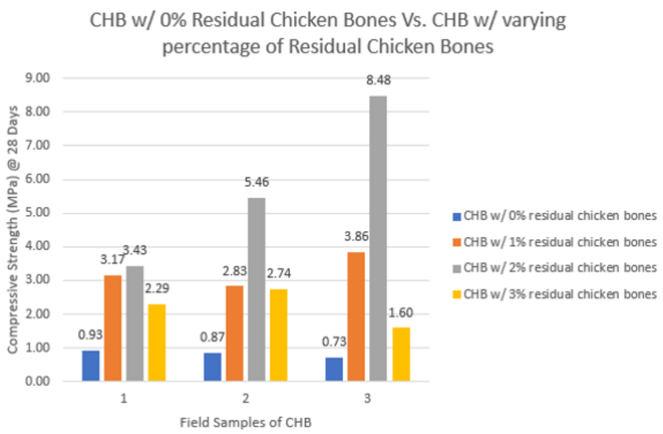


Figure 4.5 Compressive strength of all CHBs (in MPa) @ 28 days.

As you can see, In this figure it shows the similarity of table 4.2, figure 4.5 shows all of the compressive strength of each CHB sample at 28 days of curing. In addition, it shows that the CHB mixed with 2% of residual chicken bones has the highest compressive strength among the CHB samples. However, it also shows that the standard hollow blocks have the lowest compressive strength among the CHB samples.

In this figure shows that stacking a 1% residual chicken bones proved that it has an increase of compressive strength than the standard CHB. However, it also demonstrates a slight decrease in compressive strength when utilizing 3% of residual chicken bones. Therefore, the researchers can conclude that in order to achieve improved compressive strength compared to the standard CHB, the inclusion of residual chicken bones in CHBs should be limited to 2% or less.

With that being said, the researchers also proved that calcium silicate can strengthen the compressive strength of the concrete. Due to the calcium phosphate mixing with the other components, which are: cement, sand, and residual chicken bones, it creates calcium silicate where it improves the compressive strength of the concrete.

SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
CHB mixed with 0% of RCB	3	2.531034483	0.843678161	0.010479588		
CHB mixed with 1% of RCB	3	9.848275862	3.282758621	0.274292509		
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F-statistic***	***P-Value***	***F-Crit***
Between Groups	8.923670234	1	8.923670234	62.67236388	0.001378	7.708647
Within Groups	0.569544193	4	0.142386048			
Total	9.493214427	5				
Significant @ 0.05 (p < 0.05) & Significant when F-statistic > F-crit						

Table 4.3. Data of the standard CHB and CHB with 1% of residual chicken bones using the one-way ANOVA.

SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
CHB mixed with 0% of RCB	3	2.531034483	0.843678161	0.010479588		
CHB mixed with 2% of RCB	3	17.37931034	5.793103448	6.453460166		
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F-statistic***	***P-Value***	***F-Crit***
Between Groups	36.74521601	1	36.74521601	11.36929409	0.027996033	7.708647422
Within Groups	12.92787951	4	3.231969877			
Total	49.67309552	5				
Significant @ 0.05 (p < 0.05) & Significant when F-statistic > F-crit						

Table 4.4. Data of the standard CHB and CHB with 2% of residual chicken bones using the one-way ANOVA.

SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
CHB mixed with 0% of RCB	3	2.531034483	0.843678161	0.010479588		
CHB mixed with 3% of RCB	3	6.634482759	2.211494253	0.332239398		
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F-statistic***	***P-Value***	***F-Crit***
Between Groups	2.806381292	1	2.806381292	16.37715687	0.015515738	7.708647422
Within Groups	0.685437971	4	0.171359493			
Total	3.4918191263	5				
Significant @ 0.05 (p < 0.05) & Significant when F-statistic > F-crit						

Table 4.5. Data of the standard CHB and CHB with 3% of residual chicken bones using the one-way ANOVA.

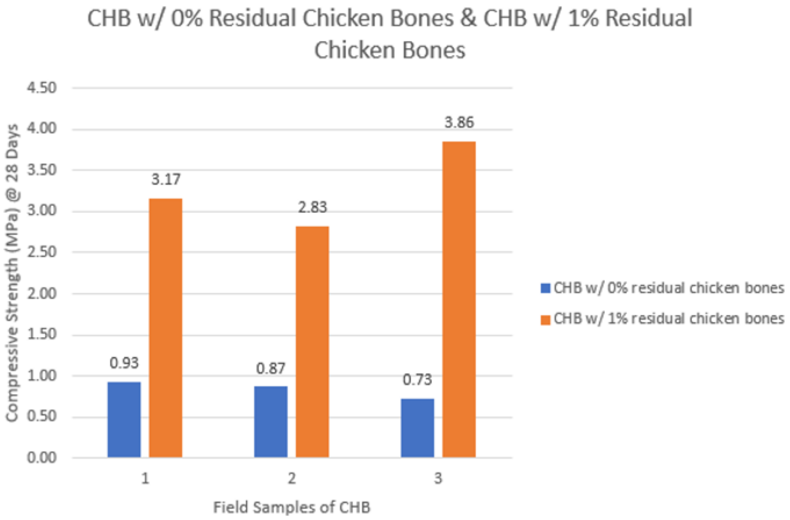


Figure 4.6. Compressive strength of 0% residual chicken bones CHBs & 1% residual chicken bones CHBs (in MPa) @ 28 days.

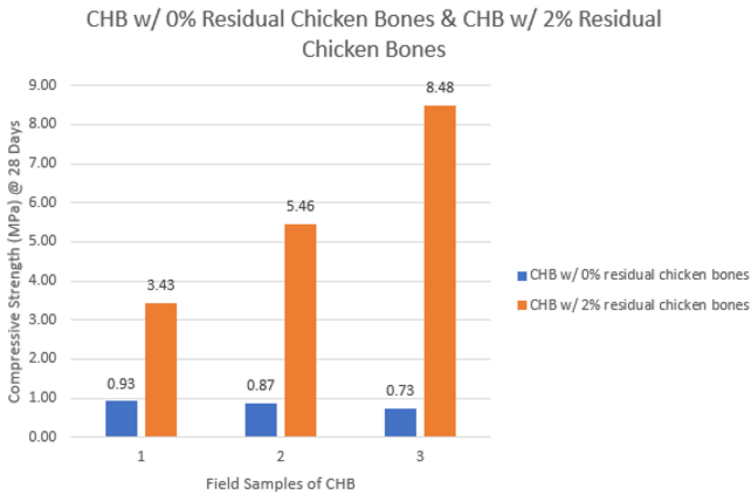


Figure 4.7. Compressive strength of 0% residual chicken bones CHBs & 2% residual chicken bones CHBs (in MPa) @ 28 days.

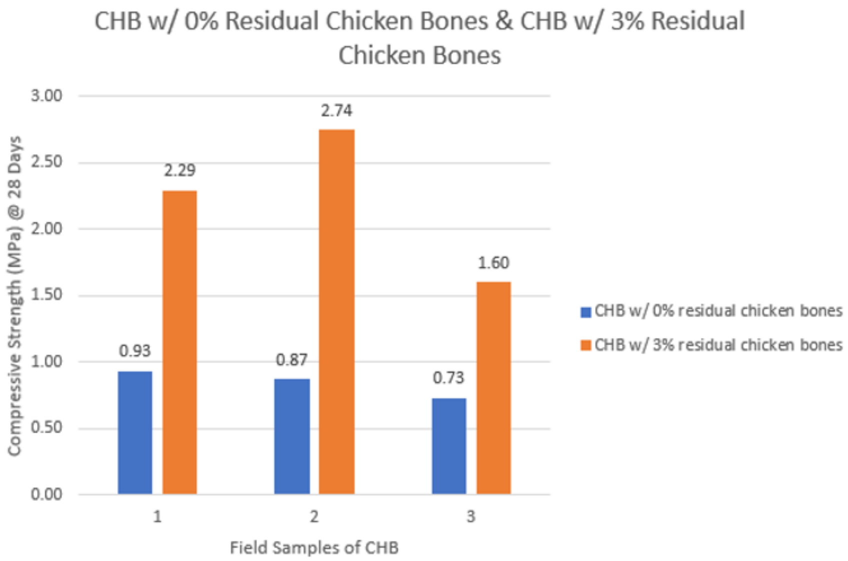


Figure 4.8. Compressive strength of 0% residual chicken bones CHBs & 3% residual chicken bones CHBs (in MPa) @ 28 days

As you can see in tables 4.3,4.4, and 4.5, the results of one-way ANOVA between standard CHB and CHBs with 1%, 2%, and 3% of residual chicken bones shows that there is a significant difference in terms of compressive strength. It also shows that the p-value of the samples are less than 0.05 and the F-statistics are greater than F-critical. In addition, the differences of the standard CHB and CHBs with 1%, 2%, and 3% of residual chicken bones can also be seen in Figures 4.6, 4.7, and 4.8. It shows that there is an increase in compressive strength in CHBs. However, adding more than 2% of residual chicken bones can slightly decrease the compressive strength of the CHB.

4. CONCLUSION

In the field of construction, CHBs are widely used for various purposes. CHBs are commonly used for commercial and residential buildings, internal partition and boundary walls, and thermal insulation on rooftops. In addition, it provides a durable and stable structure that can withstand the forces exerted on it. With this in mind, the researchers wanted to enhance the utilization of concrete hollow blocks through utilizing the residual chicken bones as an alternative partial replacement of cement that may increase its compressive strength. Therefore, the researchers conducted quantitative and experimental research between the CHBs mixed with residual chicken bones with different percentages and standard CHBs to determine which has better compressive strength. According to the experiment, it shows that the CHBs mixed with residual chicken bones have better compressive strength than the standard CHBs.

The researchers conducted experiments using a total of twelve CHB samples, which were grouped into four categories. Each of these groups comprised three CHB samples, with varying percentages of grinded residual chicken bones used as an alternative partial replacement of cement, the percentages are: 0%, 1%, 2%, and 3%. All of the results in compressive strength were in unit MPa. To assess the compressive strength of each sample, the researchers used UTM following the ASTM C140.

Within this study, the researchers used one-way ANOVA through MS Excel as a statistical treatment in order to identify the significant difference of the two variables which are CHBs mixed with residual chicken bones and standard CHBs. According to the results of one-way ANOVA, the p-value is less than the significant value and the F-statistic is greater than the F-critical, which proved that there is a significant difference of compressive strength between the two. It shows that the CHBs mixed with residual chicken bones have greater compressive strength than the standard CHBs. Therefore, the null hypotheses were rejected and the alternative hypotheses were accepted by the researchers. In addition, according to the results of one-way ANOVA, it shows that there was slight a decrease of compressive strength when increasing the percentages of residual chicken bones to the mixture. Also, it also shows that adding a portion of residual chicken bones to the mixture can increase the compressive strength of the CHBs.

Therefore, the researchers can say that CHBs mixed with residual chicken bones are more practical than the standard CHBs. However, this is only for the compressive strength of the CHBs. According to the ASTM standard, specifically, ASTM C90, the researchers' concrete hollow block mixed with residual chicken bones did not meet the requirement for compressive strength of CHBs. Therefore, the CHBs mixed with residual chicken bones cannot be used in carrying structural loads, but it can be considered and used as non-load bearing walls, which are partition walls or interior walls. With this in mind, the CHBs mixed with residual chicken bones met the compressive strength requirements for ASTM C129 which is for non-load bearing concrete masonry units. In spite of that, this study presented strong evidence in terms of compressive strength of CHBs when residual chicken bones were incorporated. In addition, it could also help the environment by recycling the residual chicken bones since the study shows that utilizing residual chicken bones can be an alternative partial replacement of cement in CHBs.

5. REFERENCES

Arora, R., Kumar, K., Saini, R., Sharma, K., Dixit, S., Dixit, A. K., & Taskaeva, N. (2022). Potential utilization of waste materials for the production of green concrete: A review. Materials Today: Proceedings.

ASTM C90. (2014). Standard Specification for Loadbearing Concrete Masonry Units. *Annual book of ASTM standards, United States*.

ASTM specifications for Concrete Masonry Units. NCMA. (2019, June 17). https://ncma.org/resource/astm-specifications-for-concrete-masonry-units/

Buch, S. H., & Bhat, D. M. (2015). Performance of Hollow Concrete Block Masonry Under Lateral Loads. Advances in Structural Engineering, 2435–2444. https://doi.org/10.1007/978-81-322-2187-6_186

Cabarle, K. (2022, July 6). *Cement Guaranteed Best Construction Material Philippines' prices - construct ph*. Construct PH - Building Dreams Together. https://constructph.com/cement-construction-material-philippines-prices/

Cabarle, K. (2023, April 27). *Gravel and sand guaranteed best construction material Philippine's prices - construct ph*. Construct PH - Building Dreams Together. https://constructph.com/gravel-and-sand-guaranteed-best-construction-material-philippines-prices/

Cansu, Ü., & Boran, G. (2015). Optimization of a multi-step procedure for isolation of chicken bone collagen. Korean Journal for Food Science of Animal Resources, 35(4), 431.

Cheng, F. U., Liu, Y., Chun-Wan, T., Lin, L., & Sakata, R. (2008). The development of angiotensin I-converting enzyme inhibitor derived from chicken bone protein., 79(1), 122–128. doi:10.1111/j.1740-0929.2007.00507.x

Dolores, A. J. S., Lasco, J. D., Bertiz, T. M., & Lamar, K. M. (2020). Compressive strength and bulk density of concrete hollow blocks (CHB) infused with low-density polyethylene (LDPE) pellets. Civil Engineering Journal, 6(10), 1932-1943.

Ganiron Jr, T. U. (2013). Sustainable Management of Waste Coconut Shells as Aggregates in Concrete Mixture. Journal of Engineering Science & Technology Review, 6(5).

Hakim S. Abdelgader, Mugahed Amran, Marzena Kurpińska, Mohammad A. Mosaberpanah, Gunasekaran Murali, Roman Fediuk, 10 - Cement kiln dust, Editor(s): Rafat Siddique, Rafik Belarbi, In Woodhead Publishing Series in Civil and Structural Engineering, Sustainable Concrete Made with Ashes and Dust from Different Sources, Woodhead Publishing, 2022, Pages 451-479, ISBN 9780128240502,https://doi.org/10.1016/B978-0-12-824050-2.00003-6.

Hanny, A., Islam, M., Sumdani, M., & Rashidi, N. (2019). The effects of sintering on the properties of epoxy composites reinforced with chicken bone-based hydroxyapatites. Polymer Testing, (), 105987–. Retrieved from doi:10.1016/j.polymertesting.2019.105987

Hasan, Muttaqin & Saidi, Taufiq & Sarana, David & Bunyamin,. (2021). The strength of hollow concrete block walls, reinforced hollow concrete block beams, and columns. Journal of King Saud University - Engineering Sciences. 10.1016/j.jksues.2021.01.008.

Henson, R. N. (2015). Analysis of variance (ANOVA). Brain Mapping: an encyclopedic reference, 1, 477-81.

Holmes, N., O'Malley, H., Cribbin, P., Mullen, H., & Keane, G. (2016). Performance of masonry blocks containing different proportions of incinator bottom ash. Sustainable Materials and Technologies, 8, 14–19.

Ignacio, P. L. C., Acierto, D. I. A., Camba, C. P. P., Gomez, R. V. L., & Ozaeta, M. I. M. (2020, April). A Comparative Study of Concrete Hollow Blocks with and Without Rice Husk Powder as Partial Replacement to Cement. In Journal of Physics: Conference Series (Vol. 1529, No. 3, p. 032045). IOP Publishing.

Isidore C. Ezema, Chapter 9 - Materials,Editor(s): Vivian W.Y. Tam, Khoa N. Le,Sustainable Construction Technologies,Butterworth-Heinemann, 2019, Pages 237-262, ISBN 9780128117491, https://doi.org/10.1016/B978-0-12-811749-1.00007-9.

Ismail, Z. Z., & AbdelKareem, H. N. (2015). Sustainable approach for recycling waste lamb and chicken bones for fluoride removal from water followed by reusing fluoride-bearing waste in concrete. Waste Management, 45, 66-75.

Jaya, R. P. (2020). Porous concrete pavement containing nanosilica from black rice husk ash. In New Materials in Civil Engineering (pp. 493-527). Butterworth-Heinemann.

Karade, S.R., Jamkar, S.S, and Duggal, A.K., (2013). Development of concrete using animal bones, Construction and Building Materials, Volume 48, February 2013, Pages 425-430.

Khan, K., Kilimci, F., & Kara (2021). Biomechanical tests: Applications and their reliability for the prediction of bone strength in broiler chicken. Anatomy Department, Veterinary Faculty. Retrieved from doi: 10.24880/maeuvfd.936262

Korean J Food Sci Anim Resour. 2015; 35(4): 431–440. Published online 2015 Aug 31. doi: 10.5851/kosfa.2015.35.4.431

Kotb, M., Assas, M., & Abd-Elrahman, H. (2010). Effect of grounded bone powder addition on the mechanical properties of cement mortar. Civil Engineering Department, UMM Al Qura University. Retrieved from doi:10.2495/DN100181

Lea, F. M. and Mason, . Thomas O. (2022, September 17). cement. Encyclopedia Britannica.

Maharishi University of Information Technology. (2019). Study of concrete properties using bone powder by partial replacement of cement. IRJET. Retrieved from https://www.irjet.net/archives/V6/i5/IRJET-V6I5514.pdf

Muszyński, S., et. al. (2018). Analysis of bone osteometry, mineralization, mechanical and histomorphometrical properties of tibiotarsus in broiler chickens demonstrates an influence of dietary chickpea seeds (Cicer arietinum L.) inclusion as a primary protein source. Plos One. Retrieved from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0208921

Muthulakshmi, S., Uma, S. G., & Hemalatha, G. (2021). Feasibility study on compost as partial replacement for fine aggregate in concrete. Materials Today: Proceedings, 46, 3775-3778.

Obianyo, et. al. (2020). Multivariate regression models for predicting the compressive strength of bone ash stabilized lateritic soil for sustainable building. Construction and Building Materials, 263(), 120677–. doi:10.1016/j.conbuildmat.2020.120677

Ostertagova, E., & Ostertag, O. (2013). Methodology and Application of One-way ANOVA. ResearchGate. Retrieved from file:///Users/myrtelletacay/Downloads/americanjournal.pdf

Ozioko, H. O., & Ohazurike, E. E. (2020). Effect of Fine Aggregate Types on the Compressive Strength of Concrete. Nigerian Journal of Engineering, 27(2).

Peter A. Claisse, Chapter 17 - Introduction to Cement and concrete, Editor(s): Peter A. Claisse, Civil Engineering Materials, Butterworth-Heinemann, 2016, Pages 155-162, ISBN 9780081002759, https://doi.org/10.1016/B978-0-08-100275-9.00017-6.

Sandle, T. (2016). Using bones and shells to make super-concrete. Digital Journal. Retrieved from https://www.digitaljournal.com/tech-science/using-bones-and-shells-to-make-super-concrete/article/466588

Singh, P., Mondal, T., Sharma, R., Mahalakshmi, N., & Gupta, M. (2018). Poultry waste management. Int. J. Curr. Microbiol. App. Sci, 7(08), 701-712.

Specification, C. (2003). Standard Specification for Nonloadbearing Concrete Masonry Units 1. *Changes*, *4*, 1-3.

Suhardjo, G. A. (2020). Animal Bone as Concrete Material. Binus University. Retrieved from https://civil-eng.binus.ac.id/2020/12/18/animal-bone-as-concrete-material/

Sutar, S. N., Patil, P. V., Chavan, R. V., & Maske, M. M. (2021). Study and Review of Ordinary Portland Cement. ASEAN Journal of Science and Engineering, 1(3), 153–160. https://doi.org/10.17509/AJSE.V1I3.37973

Tambunan, D. R., & Hidayat, A. (2021, August). Effect of Utilization of Bamboo Fiber and Gypsum Substitution as Cement Against Strong Concrete Press. In Journal of World Conference (JWC) (Vol. 3, No. 2, pp. 163-168).

Thorat, V.M., Papal, M., Kacha, V., Sarnobat, T., & Gaikwad, S. (2015). Hollow Concrete Blocks-A New Trend.

Tomas U. Ganiron Jr/Journal of Engineering Science and Technology Review 6 (5) (2013) 7-14

Vasoya, N. K., & Varia, H. R. (2015). Utilization of various waste materials in concrete a literature review. Int. J. Eng. Res. Technol, 4(4), 1122-1126.

Zhao, S., et. al. (2018). Standardizing compression testing for measuring the stiffness of human bone. Bone & Joint Research, 7(8), 524–538. Retrieved from doi:10.1302/2046-3758.78.bjr-2018-0025.r1