Coal Fly Ash as Cement Replacement on Mortar Mixed with Mangima Stone and Conventional Fine Aggregates

Ruel R. Cabahug*, Jovyline L. Ape, April Mae G. Curiba,
Vanessa Jane D. Egama, Mea C. Mabano and Ritchelle Marie A. Uy
College of Engineering and Architecture
University of Science and Technology of Southern Philippines
Cagayan de Oro City, 9000 Philippines
**ruel_cabahug2@yahoo.com*

Date received: August15, 2017
Revision accepted: November 10, 2017

Abstract

A study was conducted to investigate the characteristics of fly ash as cement replacement on mortar mixed with Mangima stone and conventional fine aggregates. Since many studies have established that coal fly ash and Mangima stone can be a good substitute for concrete aggregates, the researchers decided to create a new experiment to show the combination of the two materials on a mortar mixture. Several design mixtures were evaluated to compare the test findings. The quality tests of the Mangima stone with conventional fine aggregates and cement with different proportions of fly ash included the following: specific gravity (SSD) and absorption test and sieve analysis (gradation test). It also presents the results of the investigation carried out to evaluate the compressive strength of 1:3 mortar mixes in which conventional fine aggregates was replaced with 50% Mangima stone fine sand by weight which was further modified by partially replacing cement with six percentage ratios i.e.0%, 20%, 40%, 60%, 80% and 100% of coal fly ash. The compressive strength was determined by three (3) trials at 7, 14 and 28 days of age. Test results revealed that the combined use of Mangima stone and conventional fine aggregates exhibited that fly ash can only be utilized as cement replacement on mortar by 20% which attained the type S mortar.

Keywords: compressive strength, specific gravity, Mangima stone, fly ash, Portland cement

1. Introduction

The economical construction in the present days needs a rapid development to facilitate the demand of the construction industry. It is beneficial to research on materials in a particular place to be used as an alternative material in the construction today.

On several areas in Mindanao, Philippines, there are normally occurring Mangima stones especially in the province of Bukidnon. Mangima stone got its name from a place where it was discovered. Mangima stone is a metamorphic rock, which forms through recrystallization of pre-existing rocks under high temperature and pressure. During metamorphosis, the rock remains completely solid, and pressure is often anisotropic, which leads to preferred orientation of newly formed minerals.

A Mangima stone (*Phyllite schist*) has several varieties that can be extracted, but the properties of these materials are very similar except that they vary mostly in color. These stones have become very popular in the building sectors because of its finishing effects. Most of its uses are for decorative tiles, roofing shingles or wall finishings with its varying natural colors. Extraction and production of Mangima stones for finishing materials became a lucrative business, especially in the urbanized centers. Production of desired cuts such as brick sizes have been established thereby Mangima stone wastes are also piling up in the work yards. Such increasingly vast wastage of Mangima stones encourages one to think of how to utilize the waste products of the Mangima stone industry. With this reason, several studies were formulated to utilize the unused Mangima stone cuttings as an alternative aggregate in the construction industry. While such waste can be useful for the concrete science, utilization of Mangima wastes can provide a great benefit to supply the construction industry with aggregate materials, while preventing the environmental impact by making more sustainable use of these wastes (Tomkeieff, 1983, Schmid *et al.*, 2007).

Several studies have been conducted on the use of Mangima stone as alternative aggregate for concrete. These studies proved that Mangima stone could be used as a coarse aggregate (Cabahug *et al.*, 2011). Mangima stone was also found to be a potential alternative as fine aggregate in mortar and concrete preparations (Galgao *et al*., 2013 and Donghil *et al.*, 2016).

The study of Eduria *et al.,* (2016) used Mangima stone as fine aggregate for mortar preparation including its utilization for Ferro cement application. Their findings revealed that 50% Mangima fine aggregates were able to obtain compressive strength higher than the conventional aggregates. Their study became the basis of this research undertaking taking into consideration the addition of fly ash material in the optimum design mixture obtained.

Aside from the studies conducted to evaluate whether Mangima stone can be an efficient alternative aggregate in construction industries, fly ash has undergone several types of research and has been broadly used in concrete applications over the last half-century. Fly ash is the product of the combustion of pulverized coal in the thermal power plants. According to the American Cement Institute (ACI), fly ash is defined as the finely divided residue that results from the combustion of ground or powdered coal, and that is transported by flue gasses from the combustion zone to the particle removal system.

Moreover, Bouzoubaa *et al.*, (2001) studied the mechanical properties of concrete and physical properties of high volume fly ash cement and mortars. The use of the high volume fly ash cement improves the resistance of the concrete to the chloride ion penetration. The study investigates the potential of fly ash as a cement replacement in concrete. The objective is to reduce the amount of ordinary Portland cement needed in building construction to achieve economic construction and sustainable development through the preservation of the environment.

Fly ash is typically used as either an addition or as a cement replacement. The use of fly ash can also increase the long-term strength and durability of concrete; this is the reason why many researchers are investigating the use of higher volumes of fly ash to a specific application. It does not only extend technical advantages to the properties of cement mortar but also contributes to the environmental pollution control.

Several studies have been conducted on the use of fly ash to concrete mixture. The study of Mittal *et al.* (2005) and Ahmed and Jamkar (2012) shows that there is an increase on the compressive strength of the concrete mixture with the addition of fly ash to the design mixture. Yijin *et al.* (2004) studied that the addition of ultra-fine fly ash (UFA) to cement paste, mortar, and concrete can improve their fluidity, but some coarse fly ash can't reduce water.

Recent researches have provided adequate support for the assertion that gives the researchers an idea to conduct an experimental investigation through the physical and chemical property of the fly ash mix with concrete and the characteristics of Mangima stone as a fine aggregate by using the proportion of their mortar mixture.

This study proposes to determine the compressive strength of blending Mangima stone and conventional fine aggregates with different levels of percentage of fly ash to Portland cement in mortar mixture and also the researchers will determine if the addition of fly ash to the cement proportion will increase the compressive strength compared to the standard mortar mixture.

This study aims to determine the compressive strength of mortar with the different levels of percentage of fly ash as cement replacement and to determine the optimum mortar mixture of fly ash as a cement replacement in mortar mixed with Mangima stone and conventional fine aggregates.

2. Methodology

2.1 Collection of Materials

Mangima stone was collected at Manolo Fortich, Bukidnon. The Mangima stone was crushed manually by using a hammer until it achieved its desired sizes for fine aggregates as shown in Figure 1. To determine the size of the aggregates it has undergone sieve analysis (gradation test) and specific gravity and absorption test. Fly ash was collected at STEAG State Power Inc. The fly ash was dried, transported and its specific gravity was determined.

Figure 1. Crushed Mangima stone collected from Manolo Fortich, Bukidnon

2.2 Specific Gravity and Absorption Test for Fine Aggregates

The standard fine aggregate specific gravity and absorption test was according to American Association of State Highway Transportation Officials (AASHTO) T84 (2016) and American Society for Testing and

Materials (ASTM) C128 (1992) the specific gravity and absorption for fine aggregate.

2.3 Specific Gravity for Hydraulic Cement

This test method covers the determination of the density of hydraulic cement which was ASTM C188 (2015).

2.4Sieve Analysis (Gradation Test)

The standard fine aggregate sieve analysis test was according to AASHTO T27 (2014).

2.5 Design of Cement Mortar

The design mix control emphasized on the quality test of fine aggregates or sand using Mangima stone aggregate as partial replacement of conventional fine aggregates, acquired normal weight and grading requirements of fine aggregates. Mangima stone aggregate undergone manual pounding. It was clean, inert, free of organic and deleterious substances, and relatively free of silt and clay.

The ranges of mix proportions for common mortar applications were a cement-sand ratio of 1:3 with varying water/cement ratio. The water content of the mixture was the main factor affecting workability of concrete whereby increased in water content result in higher workability of a mix. The higher the sand content, the higher the required water contents to maintain the same workability. The moisture content of the aggregate was considered in the calculation of required water. The quantities of materials were preferably determined by weight. The mixed must be as stiff as possible, provided it does not prevent full penetration of the mesh. Usually, the slump of fresh mortar does not exceed 50 mm (2 inches).

All mortar mixtures were proportioned using the ASTM C270 (2014) standard specification for mortar for unit masonry. The design of mortar mix used in this study had an aggregate with a fixed percentage content of 50% Mangima fine aggregate and 50% conventional aggregate. The design mix with the constant proportion of aggregate with varying contents of Portland cement and fly ash was as follows: 100% Portland cement with 0% fly ash, 80% Portland cement with 20% fly ash, 60% Portland cement with 40% fly ash, 40% Portland cement with 60% fly ash, 20% Portland cement with 80% fly ash and 0 % Portland cement with 100% fly ash.

The total volume of new material for fine aggregates used in producing mortar cube specimen was 2-inch (50 mm.) cube mold. The design mix had been an ideal tool for controlling the required materials needed in making mortar cube specimen and gave an exact volume required in cement, fine aggregates and water for each mixture. There were three (3) mortar cube specimens for every design mix.

2.6 Making of Mortar Cubes Specimen

Mortar cube specimens were prepared using the procedures of ASTM C305 (2014) which is the Standard Practice for mechanical mixing ofh Cement pastes and mortars of plastic consistency.

3. Results and Discussion

The compressive strength of the mortar cube samples in which the proportion of Mangima stone fine aggregates and conventional sand were constant with the varying proportions of cement and fly ash. After the determination of the compressive strength, the researchers then classified the mortar type of each mortar cube samples based on the standards and specifications set by the ASTM.

3.1 Determination of Physical Properties of Aggregates

Physical properties of Mangima stone fine aggregates with conventional sand involved laboratory tests: absorption test, specific gravity test and sieve analysis (gradation test). Laboratory tests of physical properties of Mangima stone fine aggregates with conventional sand were important factors in the determination of the workability and compatibility of aggregate.

3.2 Specific Gravity Absorption Test of Aggregates

Table 1 shows the laboratory results of the specific gravity and absorption of the 50 % Mangima stone fine aggregates with 50 % conventional sand. The specific gravity (relative density) of an aggregate is the ratio of its mass to the mass of an equal absolute volume of water used in certain computations for mixture proportioning and control, such as the volume occupied by the aggregate in the absolute volume method of mix design. The specific gravity (relative density) of an aggregate was determined on an oven-dry basis (SSD) basis.

Table 1. Test report on specific gravity and absorption of 50% Mangima stone + 50% conventional sand

Fine Aggregate	Trial No.1	Trial No. 2	Average
A. Weight of Sample in Air (SSD), g	500	500	500
B. Weight of Pycnometer with water, g	717.2	716	716.6
C. Weight of Pycnometer with sample & water, g	1029	1027	1028
D. Weight of Sample in air (Oven Dry), g	444	432	438
E. Bulk Specific Gravity (Oven Dry)	2.36	2.29	2.32
F. Bulk Specific Gravity (SSD)	2.66	2.65	2.65
G. Absorption	12.61	15.74	14.18

The laboratory results showed that from the two (2) trials, the average bulk specific gravity on saturated surface-dry basis resulted in 2.65 and the bulk specific gravity on oven-dry basis resulted in 2.32. The standard acceptable range of specific gravity values of the fine aggregates ranges 2.4 to 2.9, and it showed that the bulk specific gravity on saturated surface-dry basis passed, but the bulk specific gravity on oven-dry basis failed to reach the minimum specific gravity value by 0.08.

The laboratory result also showed that from two (2) trials, the average percentage of absorption was 14.18 % and it failed within the general range of absorption values for water-free fine aggregates range 2% to 6%. The percentage of absorption of Mangima stone with conventional fine aggregates was relatively high compared to conventional fine aggregates only due to its water-free characteristics as completely dry stone. Thus there is a need for adjustments for water requirements when blended with other materials in making of mortar.

3.3 Sieve Analysis (Gradation Test)

The sieve analysis determined the gradation (the distribution of aggregate particles, by size, within a given sample) for verification specifications. The gradation data was used by the researchers to determine the relationships between various fine aggregate and fine aggregate blends, particularly when the Mangima stone fine aggregates was blended with the conventional fine aggregates and predict trends during the making of mortar cube samples. Being used in conjunction with other tests, the sieve analysis was an excellent basis for the quality control and quality acceptance of the Mangima stone fine aggregates.

The researchers used standard sieve sizes and determined the cumulative mass retained, and mass was passing on each sieve sizes and calculated the cumulative percentage retained and percentage passing on different sieve sizes.

Another purpose of conducting the sieve analysis or gradation test was to determine the fineness modulus of Mangima stone fine aggregates. Fineness modulus (FM) of fine aggregate was one of the bases of the researchers to determine if the Mangima stone fine aggregate was graded appropriately compared with the conventional fine aggregates. Aggregates of the same fineness modulus required the same quantity of water to produce a mix of the same consistency and give a mortar of the same strength. The fineness modulus (FM) was the total of percentages retained on each specified sieve (except sieve No. 200) divided by 100. After determining the percentage passing through different sieve sizes, the fineness modulus of Mangima stone fine aggregates was then calculated to be 2.8 which conform to specified range requirement of 2.3 to 3.1. Therefore, the Mangima stone was graded to achieve the same particle distribution as the conventional fine aggregates (see Table 2).

Table 2. Test report on Sieve Analysis (Gradation Test) of Mangima Stone Fine Aggregate

Sieve Size	Mass Retained (g)	Mass Passing (g)	Retained (%)	Cumulative Sand Retained (%)	Percent Passing (%)		Remarks
					Actual	Specs	
9.5 mm (3/8 in)	0	500	0	0	100	100	Passed
4.75 mm (No. 4)	4	496	0.8	0.8	99.2	95-100	Passed
2.36 mm (No. 8)	115	381	23	23.8	76.2	80-100	Failed
1.18 mm (No. 16)	95	286	19	42.8	57.2	45-80	Passed
0.600 mm (No.30)	80	206	16	58.8	41.2	25-60	Passed
0.300 mm (No. 50)	57	149	11.4	70.2	29.8	5-30	Passed
0.150 mm (No. 100)	66	83	13.2	83.4	16.6	0-10	Failed
0.075 mm (No. 200)	75	8	15	98.4	1.6	0-3	Passed
PAN	8	-	1.6	100			
Total	500						
Fineness Modulus	2.8						

3.4 Specific Gravity of Hydraulic Cement with and without Fly Ash

Table 3 shows the laboratory results of the specific gravity of the different percentage of cement and fly ash. This test method covered the determination of the density of hydraulic cement which was ASTM C188 (2015). Its particular usefulness was in connection with the design and control of concrete mixtures. The density of hydraulic cement is defined as the mass of a unit volume of the solids.

Table 3. Test report on specific gravity of cement

Cement Proportion	Specific Gravity
1. 0% Fly Ash + 100% Cement	3.13
2. 20% Fly Ash + 80% Cement	3.01
3. 40% Fly Ash + 60% Cement	2.99
4. 60% Fly Ash + 40% Cement	2.91
5. 80% Fly Ash + 20% Cement	2.82
6. 100% Fly Ash + 0% Cement	2.72

If the specific gravity of cement is greater than 3.19 then, the cement was either not finely minced as per the industry standard, or was excessively moisturized which affects the mix bonding. Fly ash as cement replacement level increased, the specific gravity decreased the demand for water content.

3.5 Compressive Strength

The compressive strength was the common performance measure used in determining the durability and strength properties of mortar samples. It was performed in conformance with the ASTM C 270 (2014).

Table 4 shows the laboratory results of the compressive strength of mortars having different percentages of fly ash with the constant proportion of 50% Mangima stone and 50% conventional sand. The compressive strength of mortar cube samples was the basis of the researchers in classifying the mortar type of the samples. Three samples of each of the design mixes (100% Portland Cement + 0% Fly Ash, 80% Portland Cement + 20% Fly Ash, 60% Portland Cement + 40% Fly Ash, 40% Portland Cement + 60% Fly Ash, 20% Portland Cement + 80% Fly Ash, 0% Portland Cement + 100% Fly Ash) were tested on the compression testing machine after 7, 14, and 28 curing days. The load was applied on each of the mortar cube samples until it breaks and then recorded the reading. The greater the compressive load that the mortar cube can withstand, the greater the compressive strength it can acquire. The compressive strength of the 2" x 2" x 2" mortar cube samples was calculated by dividing the applied load to the cross-sectional area and recorded regarding Mpa units.

Table 4. Test result of comprehensive strength of mortar cubes sample

Sample	Date Molded	Date Tested	Age (Days)	Ultimate Load (Kn)			Compressive Strength (Mpa)
				Trial A	Trial B	Trial C	
50% Mangima Stone Fine Agg. + 50 % Con.sand + 100% PC + 0% Fly Ash	11/18/2016	11/25/2016	7	40	40	34.5	13.4
	11/18/2016	12/02/2016	14	38	30.5	35	14.8
	11/18/2016	12/16/2016	28	41.5	45	39.5	16.3
50% Mangima Stone Fine Agg. + 50 % Con.sand + 80% PC + 20% Fly Ash	11/18/2016	11/25/2016	7	35.5	35.5	19	12.3
	11/18/2016	12/02/2016	14	32.5	34	29	12.7
	11/18/2016	12/16/2016	28	43	43	43	16.7
50% Mangima Stone Fine Agg. + 50 % Con.sand + 60% PC + 40% Fly Ash	11/18/2017	11/25/2016	7	21	22.5	22.5	8.9
	11/18/2018	12/02/2016	14	23.5	37.5	28	11.5
	11/18/2019	12/16/2016	28	34	32	29	12.3
50% Mangima Stone Fine Agg. + 50 % Con.sand + 40% PC + 60% Fly Ash	11/18/2020	11/26/2016	7	10	12	12	4.4
	11/18/2021	12/03/2016	14	19	18	10	6.1
	11/18/2022	12/17/2016	28	13	19	18	6.5
50% Mangima Stone Fine Agg. + 50 % Con.sand + 20% PC + 80% Fly Ash	11/19/2022	11/26/2016	7	5	5	6	1.9
	11/19/2023	12/03/2016	14	10	8	8	2.1
	11/19/2024	12/17/2016	28	8	3	4	3.4
50% Mangima Stone Fine Agg. + 50 % Con.sand + 0% PC + Fly Ash	11/19/2025	11/26/2016	7	0	0	0	0
	11/19/2026	11/26/2016	14	0	0	0	0
	11/19/2027	12/03/2016	28	0	0	0	0

The mortar cube samples were specified in accordance to ASTM C 270 in which the classification of mortar type depended on the compressive strength of mortar cube samples on the 28^{th} day of curing of which the mortar type may be classified into M, S, N, and O.

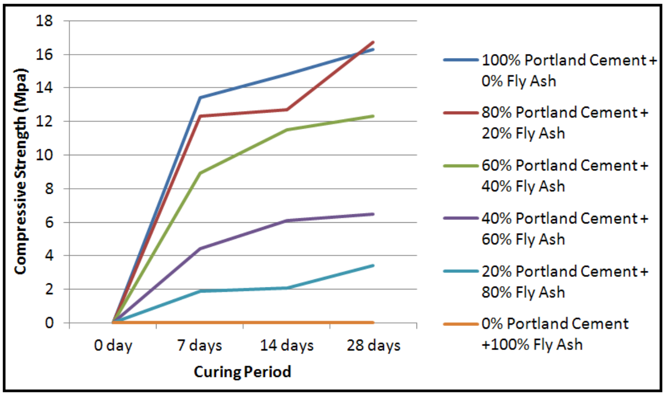

Figure 3. The compressive strength of specimen

Type S mortar achieved high tensile bond strengths, about the highest that mortars obtained. It was used for structures subject to normal compressive loads, requiring high flexural bond strength with a minimum compressive strength of 12.41 Mpa (1800 psi). Type N mortars a general-purpose mortar for above grade structures. This medium- strength mortar represents the best compromise among strength, workability, and economy. It has a minimum compressive strength of 5.2 Mpa (750 psi). Type O is a high-lime, low strength mortar. It is used in non-load-bearing structures and has a minimum compressive strength of 2.41 Mpa (359 psi).

In Table 5, the results of compressive strength of mortar cube samples after 28 days of curing shows that all of the mortar cubes with a constant proportion of Mangima stone fine aggregates and conventional fine aggregates (sand) with different percentage of Portland cement and Fly ash produced a different type of mortar. The mortar cube sample with the percentage of 0% and 20% fly ash produced type S mortar and 40% and 60% fly ash shows a type N mortar sample. The 80% fly ash produced type O mortar and the 100% fly ash did not pass any mortar type classification because it failed to obtain specimens.

Table 5. The classification of mortar based on a the achieved compressive strength of the specimen

Percent Proportion of Cement in Mortar	Compressive Strength (MPa)			Mortar Type
	7 days	14 days	28 days	
100% Portland Cement + 0% Fly Ash	13.4	14.8	16.3	S
80% Portland Cement + 20% Fly Ash	12.3	12.7	16.7	S
60% Portland Cement + 40% Fly Ash	8.9	11.5	12.3	N
40% Portland Cement + 60% Fly Ash	4.4	6.1	6.5	N
20% Portland Cement + 80% Fly Ash	1.9	2.1	3.4	O
0% Portland Cement +100% Fly Ash	0	0	0	-

4. Conclusions and Recommendations

From this study, the results show the physical properties of the aggregate. The fineness modulus of Mangima stone passed its standard requirement as fine aggregates. From the test of specific gravity and absorption test, the constant proportion of 50% Mangima stone with 50% conventional sand shows a great absorptive property as an aggregate. It has exceeded the standard absorption of aggregate for concrete mixing which affects the bonding strength of cement which is the same with the absorption of water to the cement. The combined aggregates have higher moisture content than the standard value for fine aggregate. Also, the replacement of cement by fly ash reduces the water demand for a mortar mixture. Higher fly ash contents yield higher water reductions.

The specimen with the highest compressive strength was from the 80% Portland cement with 20% fly ash on a constant proportion of Mangima aggregates and conventional sand. There was a small increase of compressive strength based on the mixture with no replacement of fly ash on its 28 days of curing. The addition of fly ash with more than 20% can cause the decrease in the compressive strength of the mortar. The specimen with the mixture of 40%, 60% and 80% replacement of fly ash showed decreased strength based on 28 days of curing. The mixture with the 100% replacement of fly ash showed no compressive strength on its 7, 14, and 28 days of curing. Based on this result, fly ash can only be utilized as cement replacement on mortar by 20%.

The researchers give the following recommendations based on the study conducted: (1) it is also recommended to utilize the proportion of 20% class fly ash with Mangima stone and conventional sand as an aggregate; (2) having found out that 50% Mangima stone aggregates is the optimum design mix it is recommended to use mechanical crusher in crushing Mangima stone to obtain the desired particles sizes for the fine aggregates for practical applications; and (3) conduct further study of combining fly ash and Mangima stone for concrete hollow blocks (CHB) fabrication or ferrocement applications.

5. References

AASHTO T27, (2014). Standard Method of test for Sieve Analysis of Fine and Coarse Aggregates. American Association of State Highway Transportation Officials.

AASHTO T84, (2016). Standard Method of Specific Gravity and Absorption of Fine Aggregate, from https://quizlet.com/86928038/aashto-t-84-astm-bc128standard-method-of-specific-gravity-and-absorption-of-fine-aggregate-flash-cards/.

Ahmed, I., and Jamkar, S.S., (2012). Effects of Fly Ash on Properties of Concrete., Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684 Volume 4, Issue 2, PP 01-05.

ASTM C128, (1992). Standard Method of Test For Fineness of Hydraulic Cement by the no. 100 (150-Micrometer) and 200 (75-Micrometer) Sieves (ASTM C184-90), from http://standards.globalspec.com/std/596048/aashto-t128 .

ASTM C188, (2015). Standard Test Method for Density of Hydraulic Cement, from https://www.astm.org/Standards/c188.htm.

ASTM C305, (2014). Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency, fromhttp://www.astm.org/Standards/C305.htm.

ASTM C270, (2014). Standard Specification for Mortar for Unit Masonry. Retrieve from https://www.astm.org/Standards/C270.htm .

Bouzoubaa, N., Zhang, M.H., and Malhotra, V. M., (2001). Mechanical Properties and Durability of Concrete Made With High-Volume Fly Ash Blended Cements Using a Coarse Fly Ash. Cement and Concrete Research. Vol. 31, pp 1393-1402.

Cabahug, R.R., Cabahug, R.G., Lamberte, JC.L., and Neri, A.C., (2011) Mangima-Stone-as Alternative-Coarse-Aggregate-in-Concrete. Mindanao Journal of Science and Technology Vol. 9 pp. 19-28, from http://cdo.ustp.edu.ph/mjst/wp-content/uploads/2014/02/2.

Donghil, C.C., Go, K.B., Nalipongnit, K.A.P., Pontillas, M.P., and Sabay, B.K.A., (2016). Mangima Stone (Phyllite Schist) as Partial Sand Replacement in the Production of Nonload Bearing Concrete Hollow Blocks, [Thesis]. College of Engineering and Architecture, Mindanao University of Science and Technology.

Eduria, J., Niones, J.M., Fernandez, J., Gutierrez, C.M., and Solano, J.A. (2016). An Investigation on Using Mangima Stone Aggregates For Ferrocement Application, [Thesis]. College of Engineering and Architecture, Mindanao University of Science and Technology.

Galgao, P. O. Magalos, J. D., Poserio, J. And Ymbong, J.J., (2013). Phyllite Schist as an Alternative to Fine Aggregates: Evaluation for Application in Compressive Structural Members, [Thesis]. College of Engineering and Architecture, Mindanao University of Science and Technology.

Mittal, A., Kaisare, M.B., and Shet ti, R. (2005). Experimental study on Use of Fly Ash in Concrete, from file:///C:/Users/Acer/Desktop/thesis/july29experimental_study_on_use_of_fly_ash_in_concrete_by_mr_amit_mittal_136.pdf.

Schmid, R., Fuentes, D., Harte, B., and Davis, E. (2007). A Systematic Nomenclature for Metamorphic Rocks, from http://books.google.com.ph/.

Tomkieff, S. I., Walton, E.K, Randall, B.A.O., Battery, M.H., and Tomkeieff, O., (1983). Dictionary of Petrology. New York: Wiley, from http://books.google.com.ph/.

Yijin, L., Shiqiong, Z., Jian, Y., and Yingli, G., (2004). The effect of fly ash on the fluidity of cement paste, mortar, and concrete. International Workshop on Sustainable Development and Concrete Technology, Beijing, China.