

# Mangima Stone as Alternative Coarse Aggregate in Concrete

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## Abstract

*A study was conducted to investigate the characteristics of concrete mixed with Mangima stone as alternative aggregates. Several design mixtures were evaluated to compare the test findings. The quality tests of the Mangima aggregates included the following: abrasion test, unit weight (kg.cu.m), specific gravity (SSD), absorption test and sieve analysis (gradation test). Concrete specimen samples were tested for compression tests. The study concluded that the Mangima stone can be a suitable alternative material for coarse aggregates to produce structural concrete because results showed that compressive strength of the concrete blended with Mangima aggregates attained higher strength capacity than the conventional (basalt) aggregates.*

*Keywords:* Phyllite schists; Mangima stone; concrete; aggregates; alternative aggregates

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## 1. Introduction

The demand of aggregates for the construction industry is rapidly increasing due to the decreasing resources of basalt aggregates. It is demanded that other alternative materials should be considered to supplement the increasing demand of the construction industry.

Mangima stones (*Phyllite schist*) is normally occurring on several areas of Mindanao, Philippines especially in the province of Bukidnon. Several varieties can be extracted but the properties of these materials are very similar except that they vary mostly on color. Mangima stones have become very popular with 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, this study was formulated to utilize the unused Mangima stone cuttings as an alternative substitute for coarse aggregates 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.

Mangima stone got its name from a place where it was discovered and extracted. This is in Mangima, Manolo Fortich, Bukidnon, Philippines. The geologic name of Mangima stone is “*phyllite schist*”. Schist, Phyllite and Phyllite Schist are the three kinds of Mangima stones. This stone is a non-metallic, naturally occurring, solid, inorganic and have an orderly internal crystal structures (Tomkeieff, 1983, Schmid *et al.*, 2007). Figure 1 shows an example of a Mangima Stone.

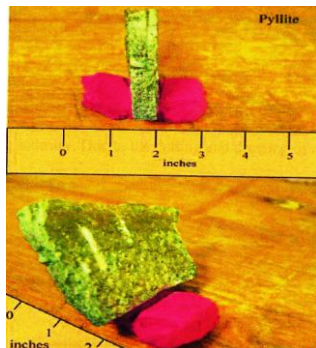


Figure 1. Mangima stone (Phyllite schist)

Table 1 provides the directory of small-scale mining in the province of Bukidnon, Philippines as of June 2010. The Mining Act of 1995 defines small-scale mining as those operating 20 hectares or below. Thus, every concessionaire can only acquire a maximum of 20 hectares to mine for Mangima stones.

Table 1. Directory of small-scale mining, province of Bukidnon as of June 2010

Location of mine	Allowed volume (m <sup>3</sup> )	Area (has)	Minerals commodity
Kiliog, Libona	50,000	20	Phyllite Schist
Dalirig, Manolo Fortich,	-	20	Phyllite Schist
Maluko, Manolo Fortich,	20,000	20	Phyllite Schist
Maluko, Manolo Fortich,	12,000	20	Phyllite Schist
Maluko, Manolo Fortich,	6,000	20	Phyllite Schist
Impakebel, Maluko	3,000	10	Phyllite Schist
Kiabo, Malitbog, Bukidnon	0	19.7	Phyllite Schist
Maluko, Manolo Fortich,	15,000	2.86	Phyllite Schist
Sayawan, Impasug-ong,	50,000	11	Phyllite Schist
Maluko, Manolo Fortich,	18,000	6	Phyllite Schist
Impakebel, Maluko, Bukidnon	50,000	20	Phyllite Schist
Siloo, Malitbog, Bukidnon	3,000	20	Phyllite Schist
Mindagat, Malitbog,	50,000	20	Phyllite Schist
Gata, Sayawan, Impasug-ong	50,000	8	Phyllite Schist
Maluko, Manolo Fortich,	50,000	20	Phyllite Schist

Source: Mines and Geosciences Bureau (DENR-10)

Libona, Manolo Fortich, Malitbog, and Impasug-ong are the areas in the province of Bukidnon, Philippines where Mangima Stones are extracted and quarried (Obsioma, 2010). A tenement control map and topography (contour) of the places in Region 10, where the location of Phyllite Schist in certain areas of the Province of Bukidnon and Cagayan de Oro City are shown in Figure 2.



Figure 2. Location of phyllite schist (Mangima stone) in Cagayan de Oro City and province of Bukidnon. (Source: BENRO X, Local EPM, 1999)

This study focused on Mangima stones as alternative coarse aggregates for structural concrete and to determine if the Mangima stones can be used as alternative aggregate materials for concrete. It aimed to utilize the Mangima stone as alternative coarse aggregates in the concrete. The objectives included the following: (1) to determine the physical properties of Mangima stone; (2) to utilize the Mangima stone wastes as alternative coarse aggregates in concrete; and (3) to determine the compressive strength of concrete cylindrical specimens of; a) 100% conventional (basalt) aggregate; b) 25% Mangima aggregate plus 75% conventional (basalt) aggregates; c) 50% Mangima aggregate plus 50% conventional (basalt) aggregate aggregates; and d) 100% replacement of Mangima aggregates.

## **2. Methodology**

Mangima stones were collected from the source and were graded according to the requirements of coarse aggregate for concrete mixture. The graded aggregates were subjected to physical characteristics tests such as specific gravity and absorption tests.

Concrete mixtures of different proportions were molded using the following proportions of Mangima aggregates: 25%, 50%, 75% and 100%. The concrete mixtures were rodded and were cured using moist curing method of which concrete specimen were tested for compressive strength at the age of 7, 14 and 28 days. A total of thirty six (36) specimen samples were prepared to represent three (3) samples for age 7, 14, and 28 days respectively. Another twelve (12) specimens of concrete were molded to represent the basalt aggregate concrete which served as the control specimen of this study. The concrete preparation procedure was in accordance with ASTM/ACI codes as provided in the DPWH Standard Specifications for Roads and Highways (2004).

## **3. Results and Discussion**

The data results of the Mangima stones for quality tests were compared to the basalt aggregates. While the compressive tests for concrete cylindrical specimen were compared to that of conventional concrete. Table 2 shows the quality tests of coarse aggregates for Mangima aggregates (MA) and

Table 2. The test report of quality control on four mixtures

Mixtures	Quality tests				Abrasion (%)
	Specific gravity (SSD)	Absorption (%)	Unit weight (Kg.cu.m)		
			Loose	Retained	
100% Conventional (basalt) Aggregate (CA)	2.68	1.79	1505	1691	31
A - 100% Mangima Aggregates (MA)	2.86	0.95	1437	1685	41
D - 75% MA + 25% CA	2.64	1.59	1440	1652	41
B - 50% MA + 50% CA	2.79	1.42	1508	1630	33
C - 25% MA + 75% CA	2.74	1.49	1454	1610	29

conventional (basalt) aggregate(CA). The results reveal that aggregates have higher percentage in abrasion loss. This can be attributed to the natural characteristics of Mangima stone which is flaky.

### 3.1 Abrasion Test

The abrasion resistance of coarse aggregates depends on the properties, size and grading of the materials prior for testing. The toughness and abrasion resistance of aggregates is very important for determining the hardness, impact, or degradation of coarse aggregates. In Table 2, results of abrasion test of Mangima aggregates show that 100% Mangima aggregates and the mixture blended with 75% Mangima aggregate + 25% basalt aggregate have the same result of 41% abrasion losses. The results indicate that more Mangima aggregates contained in a mixture, will result to higher abrasion loss.

### 3.2 Unit Weight on Coarse Aggregates

In Figure 3, the graphical representation of unit weight of the aggregates is shown. The comparison of loose aggregates and retained aggregates has shown disparity in unit weights of the aggregates. This characteristic is noted as an attribute for the Mangima stone aggregates.

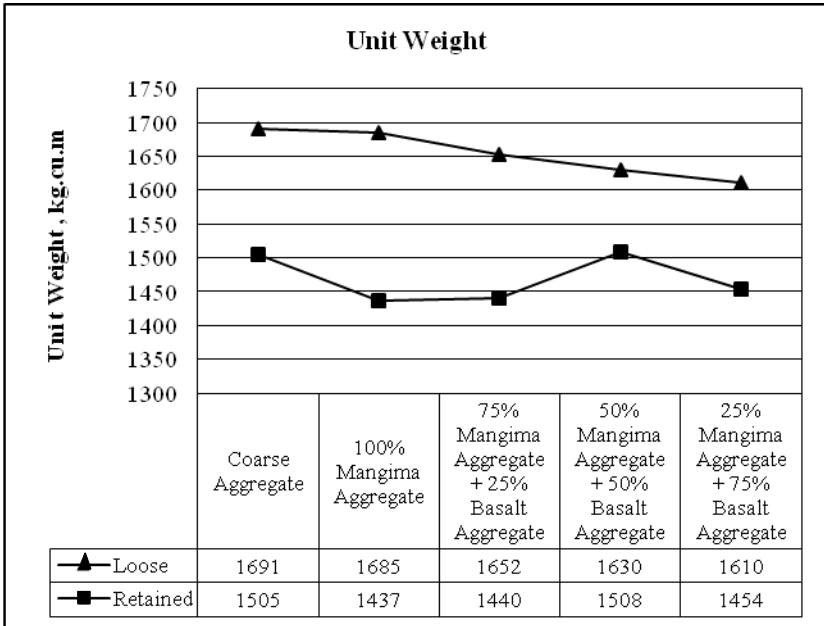


Figure. 3. Unit Weight (Loose and Rodded) of aggregate samples.

### 3.3 Specific Gravity on Coarse Aggregates

The specific gravity of Mangima aggregates is higher than that of basalt aggregates. However, the relationships showed inconsistencies when specific gravity is dependent on the aggregate shape, properties and quality. Table 2 shows the ranges of specific gravity is 2.5 to 2.7, more than 2.7 is good quality as a construction materials.

### 3.4 Absorption test on Coarse Aggregate

The absorption of aggregates results revealed that aggregates blended with Mangima aggregates are more permeable as compared to basalt aggregates. This is the typical characteristics found in the Mangima aggregates. Table 2 also shows that basalt aggregates have an absorption of 1.79 while Mangima aggregates ranges from 0.95 to 1.59.

### 3.5 Gradation Test (Sieve Analysis)

Table 3 shows the test report on Sieve Analysis (Gradation Test) of aggregate samples. Sieve size of the aggregate is very important to quantify the required size of aggregates needed to be used.

Table 3. Test report on sieve analysis

Sieve size, mm	Cumulative % passing			
	100 MA	75 MA+25BA	50 MA+50BA	25 MA+75BA
37.5 mm	100	100	-	100
25.0 mm	99	98	100	99
19.0 mm	67	76	84	94
12.5 mm	13	15	20	27
9.50 mm	7	6	5	7
4.75 mm	2	1	0	1
0.075 mm	0	0	0	0

### 3.6 Compressive Strength

Table 4 presents the average data result of compressive strength of the Mangima aggregate concrete mixtures. The results reveal that all the concrete samples passed the required standards after 28 days curing.

Table 4. Test results on average concrete cylindrical specimens

Ordinary mixture		Waste Mangima Stone Mixture (%)		
No. of days of curing	Strength (min.), <i>psi</i>	No. of days of curing	Sample identification	Strength, <i>psi</i>
7 Days	2,100	7 Days	A	1,969.35
			B	2,524.15
			C	3,048.58
			D	2,200.42
14 Days	2,550	14 Days	A	2,632.42
			B	3,100.60
			C	3472.93
			D	2,735.72
28 Days	3,000	28 Days	A	3086.53
			B	3,168.12
			C	3,787.48
			D	3,258.90

The average strength capacity of the Mangima aggregate concrete mixtures and the ordinary concrete mixtures are presented in Figure 4. Results show that all the Mangima concrete samples have strength capacity higher than the conventional concrete. This study provides a very interesting result when the compressive strength capacity of each sample passed the desired requirement.

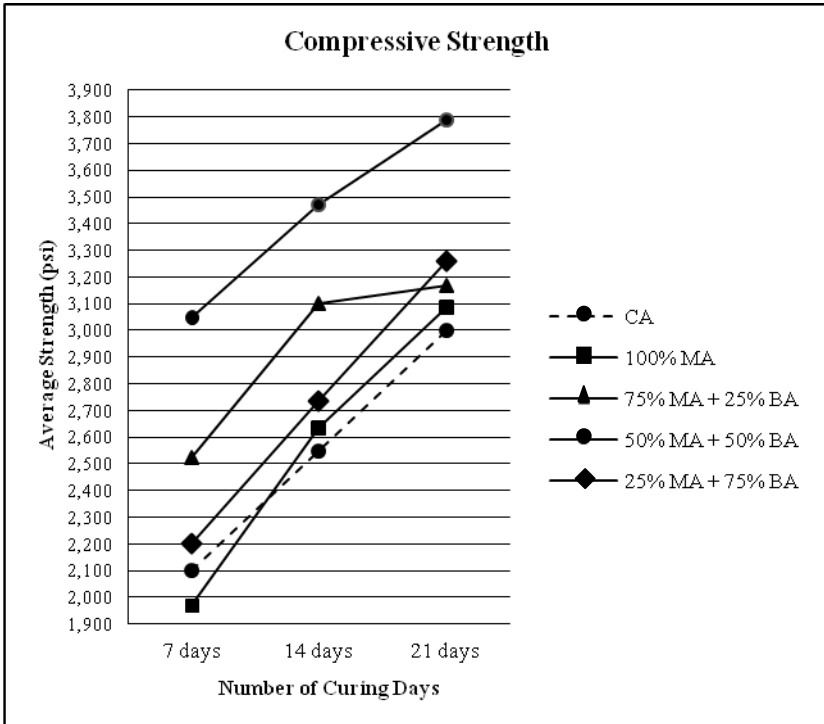


Figure. 4. Compressive strength of different sample

To compare the increase of compressive strength attained by each design mixture, the percentage values of the differences in compressive strengths were computed. This is shown in Table 5. Based on the conventional concrete mixture of 3,000 psi, all of the designed mixtures obtained greater strength. The 25% Mangima aggregate blended with 75% basalt aggregates has the optimum strength among the other design mixtures.

Table 5. Percentage increase of compressive strengths against the conventional concrete

Designed mixture	Compressive strength (psi)	% increase
100% Mangima aggregates	3,086.53	2.8 %
75% Mang Agg + 25% Basalt agg.	3,168.12	5.6%
50% Mang Agg + 50% Basalt agg.	3,258.90	8.6%
25% Mang Agg + 75% Basalt agg.	3,787.48	26.0%
100% Basalt aggregates	3,000.00	-



This further suggests that blending 25% of Mangima aggregates will produce up to 26% increase of compressive strength concrete. Such findings made this study interesting because while the physical attributes of the aggregate suggested unsatisfactory characteristics such as gradation, the concrete specimen possessed a different characteristics. It is noted that as a concrete specimen with Mangima aggregates, it becomes a different material such that the designed mixture of 25% Mangima aggregate + 75% Basalt aggregate is the best mixture that can provide the optimum compressive strength.

#### **4. Conclusion and Recommendation**

This study provides good evidence that Mangima stone can be used as an alternative material to replace basalt aggregate up to 100%. With the varied design mix proportions, it is concluded that the mixture of 25% Mangima aggregate + 75% Basalt aggregate yielded the highest compressive strength with 26% strength higher than the conventional basalt concrete. This study has presented results that provide viability of Mangima stone for concrete material.

This study serves as a preliminary undertaking to investigate the characteristics of concrete using Mangima stones as alternative aggregate. Results showed a good potential that Mangima stones can be used as aggregates with higher compressive strength capacity concrete, surpassing the conventional basalt aggregates concrete. It is recommended that further studies be conducted using the Mangima aggregates in concrete mixtures to optimize structural use of the material to areas where availability and abundance occur. It is suggested that a study to investigate the use of crushed Mangima stones for fine sand in concrete mixture be undertaken to further understand the characteristics of concrete with this kind of material.

#### **5. Acknowledgement**

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