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A Survey of Properties of Concrete Aggregates from Different Sources Near Metro-Manila

by

Yoshihide Yamao, Dr. Eng. *
Marte Sm. Gutierrez, M. S. **
Victor R. Macam, Jr. **
Dominador S. Pagbilao **
Bernardo A. Lejano **

ABSTRACT

The influence of aggregate properties on the performance of concrete is well documented in literature. It is important, therefore, that information regarding their properties be determined prior to mixing of concrete. This paper presents the results of tests performed to determine the physical properties of aggregates from different sources near Metro-Manila.

INTRODUCTION

Aggregate may be defined as granular materials, generally inert, such as sand, gravel, crushed rock or iron blast-furnace slag, used with cementing medium to form hydraulic-cement concrete or mortar [1].

Aggregates may be classified according to particle size as fine or coarse. Fine aggregates are those passing the 9.5-mm sieve, almost entirely passing the 4.75-mm sieve and predominantly retained on the 0.075-mm sieve. Coarse aggregates are those predominantly retained on the 4.75-mm sieve [1].

Another way is to classify them as natural or manufactured aggregates. Natural aggregates are those obtained from natural deposits of sand and gravel without altering their nature during production except by crushing, sizing, grading and washing. Manufactured aggregates are those artificially produced like air-cooled blast furnace slag.

Aggregates comprise 70-80 percent of the concrete mass. The influence of aggregate properties in the performance of concrete both in fresh and hardened state is well-documented in literature. Aggregate properties such as grading, shape, surface texture, specific gravity, strength and soundness are dominant factors in determining the proportion of materials in concrete mix. Eventually, these properties will influence the strength and performance of concrete structures [2].

*JICA Civil Engineering Expert, Technological University of the Philippines
**Civil Engineering Specialists, Integrated Research and Training Center, Technological University of the Philippines

It is therefore necessary that information regarding the properties of aggregates be made available to people involved in the manufacture of concrete. A good concrete mix design can be made from a knowledge of the properties of the aggregates and the application of established empirical relationships [3]. In the Philippines, these properties are usually determined using standard testing procedures specified in the American Society for Testing and Materials (ASTM) manuals. However, for small jobs, laboratory tests may not be practical because of primarily economic reasons.

The Integrated Research and Training Center in the Technological University of the Philippines is presently conducting a series of experimental studies on the design and manufacture of concrete in the Philippines. Part of this study is a survey of physical properties of fine and coarse aggregates from different sources which are commonly used in construction work in Metro-Manila. The testing methods and equipment used to determine these properties conform to the ASTM standard and the Japanese Industrial Standards (JIS). This paper presents the results of these tests. It is hoped that the results will be useful to contractors in their selection and proportioning of concrete mixes and as such help in the improvement of the concrete industry in the Philippines.

MATERIALS

There are several aggregates from different sources which are commonly used in concrete construction in Metro-Manila. For this study, six kinds of fine aggregates and ten kinds of coarse aggregates were chosen. The coarse aggregates were washed while the fine aggregates were allowed to pass the 4.75-mm sieve prior to testing. Table 1 is a list of the different aggregates with their corresponding visual description.

TESTING PROCEDURE

The testing procedures and equipment used in this experimental study conform to the ASTM standard and the Japanese Industrial Standard (JIS) for testing of concrete mineral aggregates. The properties that were determined were those directly related to the proportioning of materials for concrete mix.

Sieve Analysis (ASTM C-136, JIS A 1102)

A weighed sample of dry aggregates is separated through a series of sieves of progressively smaller openings for the determination of particle size distribution. The result of the test is presented in a graph. The fineness modulus (FM) which is an index of fineness or coarseness of the aggregates was calculated.

Specific Gravity and Absorption of Coarse Aggregates (ASTM C-127, JIS A 1110)

The sample is immersed in water for about 24 hours at room temperature. The specimen is removed from the water and rolled in a large absorbent cloth to remove all visible films of water on the surface of the particles in order to attain the saturated surface-dry (SSD) condition. The weights of the sample in air and in water are determined. Then, the sample is oven-dried to constant weight, cooled at room temperature and subsequently weighed in air.

Specific Gravity and Absorption of Fine Aggregate (ASTM C-128, JIS A 1109)

A sample of 500 grams of fine aggregate at saturated surface-dry condition is placed in a Chapman flask which is filled with water. The flask is rolled, inverted and agitated to remove the air bubbles. The flask is then immersed in a basin of water at a temperature of 20°C for 3 hours.

The total weight of the flask, sample and water is determined. The sample is then placed into a pan and dried to constant weight at a temperature of 110°C, cooled at room temperature and then weighed.

Unit Weight (ASTM C-29, JIS A 1104)

The sample at saturated surface-dry condition is placed in a calibrated cylindrical mold in three equal layers with each layer tamped 25 times with a rod. The mold is then leveled and weighed.

Los Angeles Abrasion (ASTM C-131, JIS A 1121)

The test sample, after it has been prepared for testing is placed in the Los Angeles machine together with the required steel balls. The machine is rotated at a speed of 33 rpm for 500 revolutions. The material is discharged from the machine and the sample is separated by wash sieving using 1.7-mm sieve. The materials that were retained is oven-dried to constant weight at a temperature of 110°C. It is then air-cooled at room temperature and subsequently weighed. The difference between the original weight and final weight, expressed as a percent of the original weight, is termed as the abrasion ratio.

Salt Content Determination of Fine Aggregates

A 200-gram sample is thoroughly mixed with 200 ml of distilled water in a beaker and is left to stand for three minutes. A salt determination paper is soaked for 30 seconds. The change in color of the paper is compared with a standard comparison sheet and salt content percentage is determined as stipulated at the said standard paper.

TEST RESULTS AND DISCUSSION

A summary of the results of the tests is presented in Tables 2 and 3 , and Figures 1 and 2. The values appearing in the tables are the mean of three tests.

Fine Aggregates

With regard to particle size distribution all grading curves of the sands are within the zone of acceptance stipulated at the ASTM manual (Figure 1). The fineness modulus ranges from 2.38 – 2.77 with Tarlac sand having the lowest value and Cavite sand having the highest value.

In terms of salt content, all sands have salt content of less than 0.02 percent except Cavite sand which has 0.10 percent. Thus, if Cavite sand is used in reinforced concrete structures it could have a corrosive effect on the reinforcing bars which could in turn affect the bond between the reinforcing bars and the concrete. A high salt content could also induce alkali-aggregate reaction.

The specific gravity values of the sands are clustered around 2.50 with Cavite sand having the lowest value of 2.38. The absorption values range from 2.83 – 3.80 percent except for Cavite sand which seemed to have an abnormal absorption value of 12.12 percent. This could be explained by the presence of lightweight aggregates and the abundance of pores within the particles as evidenced by the relative difficulty in the removal of air bubbles during the specific gravity test of Cavite sand.

Unit weight values of the sands fall within the range of 1248 – 1517 kg/cu.m., again with Cavite sand having the lowest value of 1248 kg/cu.m.

Table 2 and Figure 1 indicate the results of the tests on fine aggregates.

Coarse Aggregates

For the coarse aggregates, only Laguna ordinary gravel has a particle size distribution curve that is within the zone of acceptance (Figure 2). The Batangas, Montalban, Rizal ordinary gravels; and Batangas crushed gravel slightly protrude outside the zone of acceptance while the curves of the rest of the coarse aggregates show gaps in grading. At the outset, it seems that Laguna ordinary gravel on the basis of grading is suitable for concrete mix while the others need adjustment in grading. However, the use of aggregates with gaps in grading does not necessarily mean poor concrete as shown by some research works [4].

The specific gravity values of the coarse aggregates range from 2.47 – 2.86 with Batangas and Montalban crushed gravels having the highest values of 2.86. They also have relatively low absorption ratios of 1.74 percent and 0.84 percent respectively, while the others have absorption values ranging from 1.39 – 3.67 percent. The unit weight values of all the coarse aggregates range from 1568 – 1831 kg/cu.m.

Relatively, all aggregates have high resistance to degradation with Los Angeles abrasion ratio values ranging from 13.60 – 34.78 percent, well below the 50 percent maximum allowable value recommended by the ASTM. Bulacan ordinary gravel has the highest resistance to degradation with a Los Angeles abrasion value of 13.60 percent.

The results of tests on coarse aggregates are presented in Table 3 and Figure 2.

CONCLUSION

The results of the physical properties tests on ten coarse and six fine aggregates from different sources near Metro-Manila as presented in this paper show that all sands tested are suitable for concrete mix, except Cavite sand. Cavite sand exhibited poor qualities such as high salt content, high absorption, low specific gravity and low unit weight.

All the gravels tested appear to have properties suitable for concrete mix. An exception is with regard to particle-size distribution. It is shown that only Laguna ordinary gravel passes the criteria for particle-size distribution as specified in the ASTM. However, as mentioned earlier, the use of gap-graded aggregates does not necessarily mean poor concrete.

As pointed out above, for small jobs where testing of aggregates may not be practical a knowledge of properties of aggregates with the application of established empirical relationships, proportioning of materials could be ascertained. It is in this view that the results presented here could be useful and could form as a basis in proportioning materials in concrete mix.

However, it should be noted that the properties of the aggregates presented in this paper as determined from the tests performed do not constitute the sole basis in the selection of aggregates for concrete mix. Other factors such as cost, availability, and other physical or mechanical properties not included in this study should also be considered.

ACKNOWLEDGMENT

This experimental study was sponsored by the Japan International Cooperation Agency under the five-year JICA-IRTC project. The authors wish to thank Mr. Kazuo Tsuji of the Kumagai Gumi Corporation for his assistance in the procurement of the materials used in this study; Prof. Perla S. Roxas, Executive Director of IRTC for her moral support; and the students of the training course in Materials Engineering I being conducted at the Integrated Research and Training Center for their help in the testing of aggregates.

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Table 1. Visual Description of Aggregates

NAME/SOURCE			VISUAL DESCRIPTION
COARSE AGGREGATES	CRUSHED GRAVEL	ANGONO	Sub-angular to angular with some flat particles, color is dark gray
		BATANGAS	Sub-angular with some uncrushed particles, color is dark gray with dirty white particles
		BULACAN	Sub-rounded to rounded particles, color is grayish
		LAGUNA	Sub-angular to angular, color is a combination of dirty white and gray, surface is rough
		MONTALBAN	Sub-angular to angular, color is gray
	ORDINARY GRAVEL	BATANGAS	Sub-angular to angular, color is dark gray
		BULACAN	Sub-angular to sub-rounded, color is dark gray with mixture of brown particles
		LAGUNA	Predominantly angular, with rough texture, color is a combination of mocca & light gray
		MONTALBAN	Sub-rounded to rounded particles, color is a combination of gray, brown and dirty white
		RIZAL	Sub-angular to sub-rounded particles, color is grayish with some brownish particles
FINE AGGREGATES		BATANGAS	White and black particles, no deleterious materials, rough texture
		BULACAN	Predominantly white particles, no deleterious materials, rough texture
		CAVITE	Brownish gray particles, with deleterious materials like sea shells & fine particles
		PORAC	Grayish particles, smooth texture with fine particles
		RIZAL	White particles, rough texture, no deleterious materials
		TARLAC	White particles, rough texture with almost no fines and other deleterious materials

Table 2. Physical Properties of Fine Aggregates

NAME/SOURCE	UNIT WEIGHT kg/cu.m.	SPECIFIC GRAVITY	ABSORPTION %	SALT CONTENT %
BATANGAS SAND	1468	2.62	3.80	<0.02
BULACAN SAND	1508	2.52	3.30	<0.02
CAVITE SAND	1284	2.16	12.12	0.10
PORAC SAND	1517	2.50	2.83	<0.02
RIZAL SAND	1362	2.50	3.10	<0.02
TARLAC SAND	1428	2.40	3.76	<0.02

Table 3. Physical Properties of Coarse Aggregates

	NAME/SOURCE	UNIT WEIGHT kg/cu.m.	SPECIFIC GRAVITY	ABSORPTION %	LOS ANGELES ABRASION RATIO %
CRUSHED GRAVEL	ANGONO	1594	2.67	2.77	17.51
	BATANGAS	1791	2.86	1.74	15.53
	BULACAN	1831	2.77	1.39	18.85
	LAGUNA	1568	2.47	3.44	34.78
	MONTALBAN	1739	2.86	0.86	18.90
ORDINARY GRAVEL	BATANGAS	1806	2.77	1.42	16.48
	BULACAN	1804	2.77	1.67	13.60
	LAGUNA	1577	2.53	3.66	26.90
	MONTALBAN	1688	2.78	1.41	22.70
	RIZAL	1685	2.64	2.86	20.20

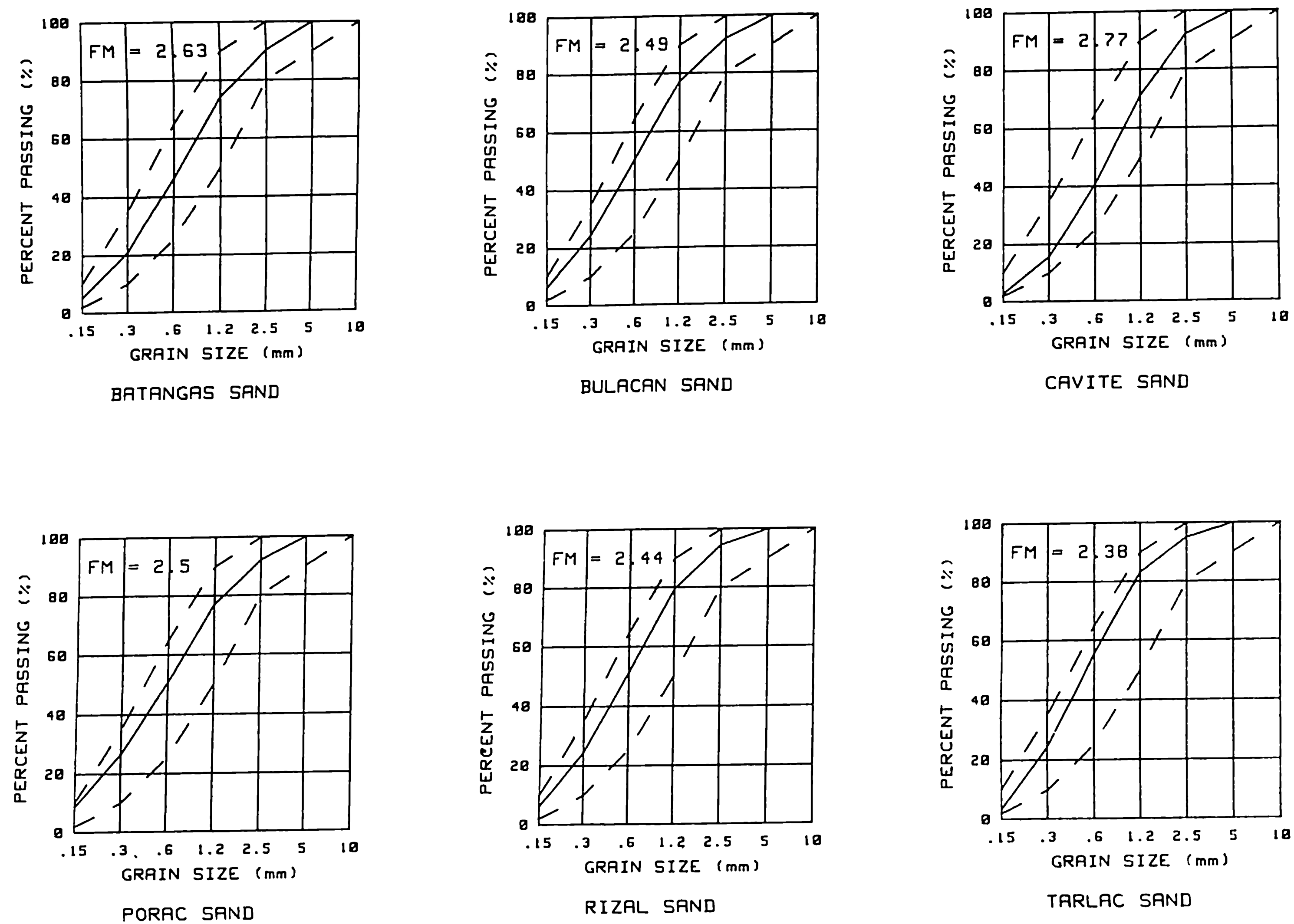

Figure 1. Grain-Size Distribution Curves of Fine Aggregates

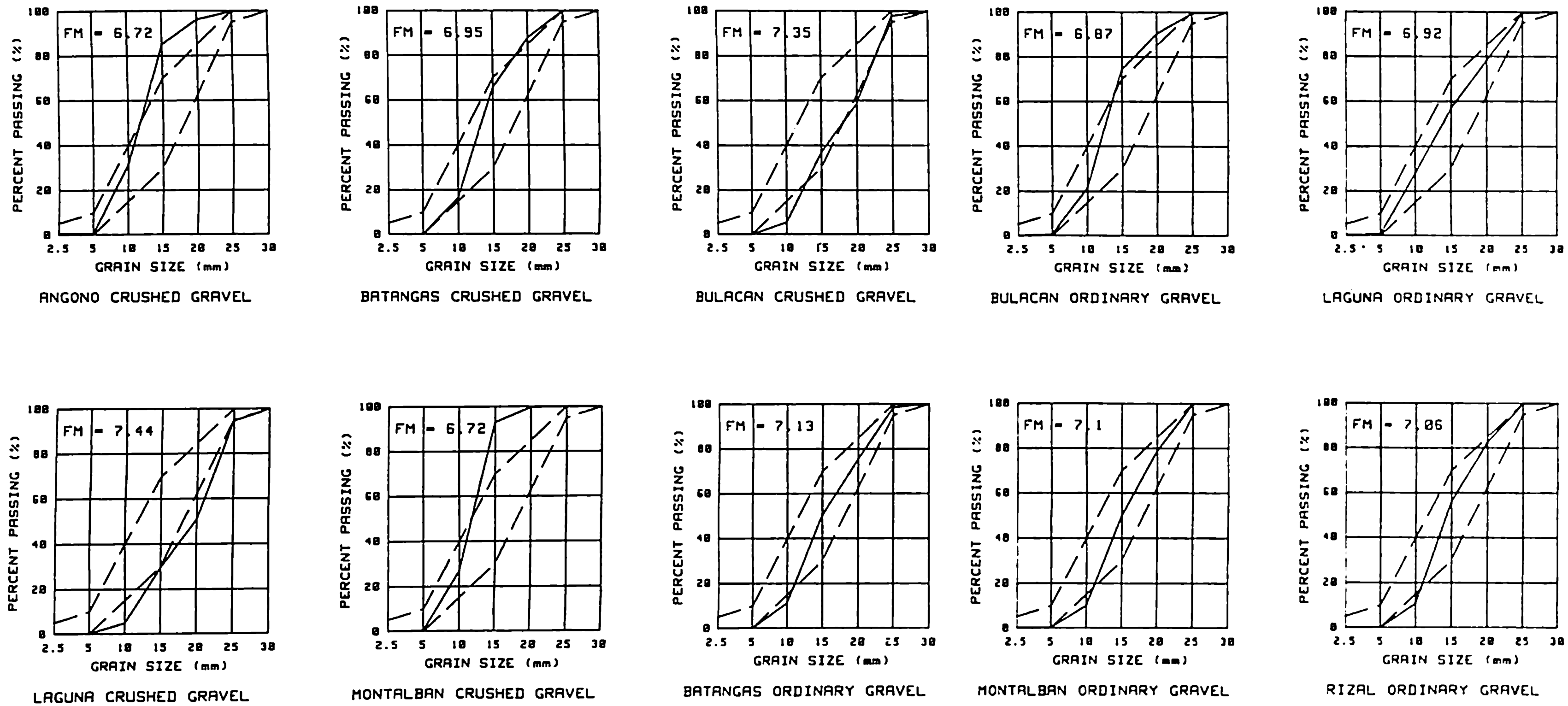

Figure 2. Grain-Size Distribution Curves of Coarse Aggregates