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# Abrasion Resistance of Coarse Aggregate and Compressive Strength of Concrete in Camarines Norte

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**RESEARCH ARTICLE**

**Abstract**

Concrete has been used for a long time in the field of construction. Coarse aggregate is a major concrete component, and its size can vary. Abrasion resistance is one of its properties, and depending on the source and size of the aggregate, it can impact concrete strength. Throughout the use of concrete, only the abrasion resistance of concrete is correlated to the strength of concrete. Thus, this study aims to create a mathematical relation between the abrasion resistance of coarse aggregates and the compressive strength of concrete, considering two nominal maximum sizes from different quarries in Camarines Norte. Experimental methods such as the Los Angeles Abrasion Test, Paired t-test Analysis, The One-Way Analysis of Variance, and Bivariate Correlation Analysis were employed to investigate the substantial correlation between the abrasion resistance of coarse aggregate and the compressive strength from three different quarries concerning ASTM and ACI standards governing concrete. The result shows that only Calabasa attained the standard abrasion resistance of coarse aggregate of 50% among the three quarries. Hence, only One-Way Analysis of Variance resulted in a significant relationship but not in Paired t-test Analysis and Bivariate Correlation.

**Keywords:** Abrasion Resistance; Coarse Aggregate; Concrete; Compressive Strength

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## 1 INTRODUCTION

Concrete has been used in construction for a long time due to its strength, durability, and versatility. It is typically composed of cement, water, and aggregates. Coarse aggregate occupies a large weight or volume, depending on the mix proportion adopted. The size of this type of aggregate ranges from 4.75 mm to 75.0 mm or No.4 to 3 in sieve. However, the properties of the raw materials used to make concrete, especially the coarse aggregates, can significantly impact the final strength and performance of the concrete mixture. While factors such as water/cement ratio, aggregate proportions, curing conditions, and temperature are well-known to influence concrete strength, the role of the abrasion resistance of coarse aggregates is often overlooked. Abrasion resistance is one of the properties of coarse aggregate, defined as the ability to resist being worn away by rubbing and friction or shattering upon impact. This could vary among coarse aggregates depending on the source or site from which it was gathered, and possibly the size of the aggregate. Coarse aggregates with poor abrasion resistance may be more susceptible to breakdown during concrete mixing, placing, and compacting. This can lead to a weaker interface transition zone between the aggregate and cement paste, compromising the overall strength and durability of the hardened concrete. Current design standards and guidelines for concrete mixtures, such as those provided by the American Concrete Institute (ACI), do not explicitly account for the abrasion resistance of coarse aggregates when determining mix proportions or strength requirements.

So, throughout the use of concrete, only the abrasion resistance of concrete is correlated to its strength. This gap in knowledge and practice highlights the need for research to establish a clearer, significant relationship between the abrasion resistance of coarse aggregate and the strength of concrete. According to Kozul and Darwin (1997), changes in coarse aggregate can change concrete's strength and other properties [1]. There is strong evidence that aggregate properties are a factor in the strength of concrete. Ezeldin and Aitcin (1991) compared concretes containing four coarse aggregate types with the same mix proportions [2]. They concluded that higher-strength coarse aggregate typically yields higher compressive strengths in high-strength concrete. Laplante (1991) also tested four different types of coarse concrete aggregate as a portion of a large testing program and compared the resulting abrasion resistance with the abrasion resistance of respective concrete [3]. The results show that different types of aggregate produce different values of abrasion resistance. Zhou, Bar, and Lyndon (1995) show that compressive strength increases with an increase in coarse aggregate size [4]. However, most of the studies disagree; Walker and Bloem (1960) and Bloem and Gaynor (1963) concluded that an increase in aggregate size results in a decrease in the compressive strength of concrete [5]. According to Wu, Parker, and Kandhal (1998), aggregates that lack adequate toughness and abrasion resistance may cause construction and performance problems [6]. Degradation occurring during production can affect the overall gradation and, thus, widen the gap between the properties of the laboratory-designed mix and the field-produced mix. Another form of deterioration imposed on concrete structures is surface abrasion. This mechanical wear can catalyze other forms of deterioration, such as cracking and corrosion of reinforcing steel.

The results of this study on relating the abrasion resistance of coarse aggregate to the strength of concrete may benefit various stakeholders. For the local community, it will provide additional knowledge about the properties of coarse aggregates sourced from nearby quarries, serving as a basis for selecting suitable aggregate sources. The Department of Public Works and Highways, a crucial governing body overseeing infrastructure development, can leverage the study's findings as an additional authoritative reference when evaluating and approving the use of coarse aggregates from specific quarries in public works projects of various scales. In the architectural and civil engineering fields, the research outcomes can contribute to developing optimized concrete mix designs that meet construction requirements by accounting for the abrasion resistance of coarse aggregates. For the researchers, this study is a practical application of the theories and principles they have learned, translating academic knowledge into real-world situations. Furthermore, future researchers can use this work as a reference for related studies, building upon the established relationship between coarse aggregate abrasion resistance and concrete strength.

This research focused on the relation of abrasion resistance of coarse aggregate gathered from different quarries to the compressive strength of concrete using different nominal maximum sizes with constant design strength. The coarse aggregates were gathered from various sources to represent the aggregates of Camarines Norte. These quarries were Brgy. Calabasa at Labo, Brgy. Dagotdotan at San Lorenzo Ruiz, and Brgy. Dogongan from Daet. They are relatively distant from each other and offered crushed aggregates used in this study to control the size. The fine aggregates used were bought from the nearest hardware store in the locality. To control the design strength and further investigate the difference in compressive strength results from said quarries, the design strength used for each quarry was 28 MPa, and the same fine aggregate was used for each mixture. In addition, two nominal maximum sizes were used as factors for abrasion resistance. These were one-inch (1") and three-fourth inch ($\frac{3}{4}$ inch), which were commonly used in construction. The nominal maximum size was also considered for compressive strength to secure the significant effect of size on abrasion.

This study used materials and equipment that were economical and available in the locality. The success of this study must benefit those who used aggregates from Camarines Norte. The primary objective of this study was to create a mathematical relation between the abrasion resistance of coarse aggregates and the compressive strength of concrete, considering two nominal maximum sizes from different quarries in Camarines Norte. To come up with this, specific objectives were as follows: (1) Identify the properties of coarse aggregates from different quarries in Camarines Norte in terms of (a) Specific Gravity, (b) Absorption, and (c) Gradation. (2) Identified the abrasion resistance of coarse aggregates from three different quarries, considering two (2) nominal maximum sizes. (3) Determined the significant difference in abrasion resistance of coarse aggregate between the two nominal maximum sizes. (4) Determined the significant difference in abrasion resistance of coarse aggregate between three (3) quarries. (5) Identified the compressive strength of concrete using coarse aggregate from three (3) different quarries, considering two (2) nominal maximum sizes. (6) Identified the significant relationship between coarse aggregate abrasion resistance and concrete compressive strength.

# 2 METHODOLOGY

## 2.1 Research Design

This study aimed to establish the correlation between coarse aggregates' abrasion resistance and concrete's compressive strength. This was achieved through an experimental research design using a two-by-three factorial design with replication. The two independent variables were the quarries and nominal maximum sizes. During the quarry selection phase, inputs from entities implementing construction projects and regulating quarry sites in the province were consulted. Additionally, quarry selection considered several factors, such as the abundance of materials, frequency of usage, and the distances of quarries from each other. The nominal maximum sizes were chosen based on the most frequently used nominal maximum size of aggregates. The dependent variable was the compressive strength of the concrete. Three quarry sites and two nominal maximum sizes of aggregates were considered in this study. The tests conducted were the Los Angeles Abrasion resistance test for coarse aggregates and the compressive strength of concrete test. Each set of specimens has three replications, resulting in 36 specimens.

## 2.2 Research Materials and Equipment

Coarse aggregates, Ordinary Portland Cement (Type 1), washed sand, and mixing water were used to prepare concrete specimens. The equipment apparatuses used were the Los Angeles abrasion machine, steel spheres, sieves, and balance to perform the abrasion resistance test. Concrete sample preparation used 4-inch diameter cylindrical concrete molds with a height of 8 inches, slump cone, tamping rods, mixing pan, and shovel. The compressive strength of concrete specimens was determined using a digital compression testing machine.

## 2.3 Research Procedure

The quarry selection phase involved consultation with the Department of Public Works and Highways to determine the quarry sites in the province with valid quarrying permits and the most frequently used sites. Site visitation was also conducted. ASTM D75 Standard Practice sampled and transported aggregates from stockpiles for Sampling of Aggregates. About 100kg of aggregate samples were collected from the three sites. Aggregates were tested to determine their specific gravity, absorption, gradation, and abrasion resistance. The determination of the specific gravity and absorption were guided by ASTM C 127 Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate, wherein the soil samples were soaked in water for 24 hours [7]. The water displacement method was used to calculate the specific gravity, and the absorption was calculated by determining the increase in the mass of aggregates after soaking. Gradation was determined using the ASTM C 136 Method for Sieve Analysis of Fine and Coarse Aggregates, wherein a standard set of sieves was used and plotted in a gradation chart [8].

The ASTM C 131 Standard Test Method for Resistance to the Gradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine determined the abrasion resistance [7]. In this test, the coarse aggregate was placed in the machine with steel balls and was rotated repeatedly. After this, the sample was sieved to determine the percent loss and abrasion resistance. The preparation and curing of concrete samples and the compressive strength test were employed by ASTM C 31 (Standard Test of a Making and Curing of Concrete Test Specimens) [9] and C 39 (Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens) [10], respectively. 4-in diameter cylindrical concrete samples were prepared and were cured for 14 days. The samples underwent a compressive strength test, and their compressive strengths were recorded for data analysis.

## 2.4 Data Analysis

A one-sigma limit was used to assess the acceptability of the average compressive strength and abrasion resistance results of replicated specimens. Paired sample t-test, conversely, determines the significant difference between the abrasion resistances of coarse aggregate from each quarry for each nominal maximum size. The significance level considered for this test was 0.05. One-way ANOVA was performed to determine the significant difference in abrasion resistance of coarse aggregate between different quarries; a 0.05 significance level was also used in this test. Lastly, the Pearson product-moment correlation was used to determine the significant relationship between coarse aggregate abrasion resistance and concrete compressive strength.

#### *2.4.1 Data Gathering*

The observation and data analysis conducted by the researcher in the water supplied by the Local Water Supplier gathered pertinent information that disclosed the problems and limitations. The pressure data in Figure 1 shows the water pressure and the flow rate of the water supply by the water supplier. The data collected are from the pressure gauge and the Flowmeter connected to the entrance of the CSPC Campus.

# 3 RESULTS AND DISCUSSIONS

## 3.1 Properties of Coarse Aggregate

#### *3.1.1 Specific Gravity*

Bulk-specific gravity and apparent-specific gravity differ in the ratio of the weight of aggregates to the weight of the same volume of water at a specified temperature. However, the two differ because the apparent specific gravity does not include the permeable pores in aggregate volume. As a result, the apparent specific gravity is higher than the bulk specific gravity. These parameters were used for the mixture computation of the concrete sample specimens. Table 1 shows the Bulk Specific Gravity of the aggregates from Brgy. Calabasa, Labo, Brgy. Dagotdotan, Daet, and Brgy. Dogongan and Daet were 2.541, 2.411, and 2.390, respectively. Their apparent specific gravity was also 2.645, 2.559, and 2.538, respectively.

**Table 1.** Specific Gravity of Coarse Aggregate

| Quarry | Bulk Specific Gravity | Apparent Specific Gravity |
|---|---|---|
| Calabasa | 2.541 | 2.645 |
| Dagotdotan | 2.411 | 2.559 |
| Dogongan | 2.390 | 2.538 |

According to ACI Education Bulletin E1 – 07 [11], the bulk specific gravity of a normal-weight aggregate used in concrete ranges from 2.3 to 2.9, and the results obtained are within this range.

#### *3.1.2 Absorption*

Absorption is the increase in weight of the aggregates due to the penetration of water into the pores. Absorption tests found that the absorption was 2.54%, 4.1%, and 4.212% for the aggregate samples from Brgy. Calabasa, Labo, Brgy. Dagotdotan, Daet, and Brgy. Dogongan, Daet, respectively. According to ACI Education Bulletin E1 – 07 [11], the absorption of normal weight aggregate ranges from 0.5-4%.

**Table 2.** Absorption of Coarse Aggregate

| Quarry | Absorption |
|---|---|
| Calabasa | 2.540 |
| Dagotdotan | 4.100 |
| Dogongan | 4.215 |

#### *3.1.3 Gradation*

The aggregates were controlled on two nominal maximum sizes and followed the ASTM C 136 [8] Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. In considering 1 inch as the nominal maximum size, the mass percent passing the 1 inch is 100%, corresponding to the maximum size and the nominal maximum size, and the value is permitted as indicated in the ASTM standard. 90% had passed the $\frac{3}{4}$ inch sieve, showing that 10% of the aggregates in the 1-inch sieve were retained in the $\frac{3}{4}$ inch sieve. 25% had passed the $\frac{1}{2}$ inch sieve, and 65% had retained. 15% was retained in the $\frac{3}{8}$ inch, and 10% had passed and retained on the No. 4 sieve. In considering $\frac{3}{4}$ inch as the nominal maximum size, the mass percent passing $\frac{3}{4}$ inch is 100%, and 10% was retained on the $\frac{1}{2}$ inch sieve. 90% had passed the $\frac{1}{2}$ inch sieve, and 50% had retained on the $\frac{3}{8}$inch sieve. The remaining 40% was retained on the No. 4 sieve. The laboratory results showed that the coarse aggregates passed the standard specification for grading, having a nominal maximum size of 1 inch or 25mm and $\frac{3}{4}$ inch or 19 mm. The size distribution of the aggregates is shown in Tables 3 and 4 for the nominal maximum size of one inch and $\frac{3}{4}$ inch.

**Table 3.** Size distribution of coarse aggregate with 1-inch nominal maximum size

| Sieve Size for No.67 Gradation (in) | Mass Retained | % of Mass Retained | Cumulative % of Mass Retained | % Passing |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 100 |
| $\frac{3}{4}$ | 250 | 10 | 10 | 90 |
| $\frac{1}{2}$ | 1625 | 65 | 75 | 25 |
| $\frac{3}{8}$ | 375 | 15 | 90 | 10 |
| No. 4 | 250 | 10 | 100 | 0 |
| No. 8 | 0 | 0 | 100 | 0 |
| **TOTAL** | **2500** | **FM** | | |

**Table 4.** Size distribution of coarse aggregate with ¾-inch nominal maximum size

| Sieve Size for No.67 Gradation (in) | Mass Retained | % of Mass Retained | Cumulative % of Mass Retained | % Passing |
|---|---|---|---|---|
| ¾ | 0 | 0 | 0 | |
| ½ | 250 | 10 | 10 | 90 |
| 3/8 | 1250 | 50 | 60 | 40 |
| No. 4 | 1000 | 40 | 100 | 0 |

| | | | | |
|---|---|---|---|---|
| No. 8 | 0 | 0 | 100 | 0 |
| **TOTAL** | **2500** | **FM** | | |

## 3.2 Abrasion Resistance of Coarse Aggregate

Following the abrasion test, Table 5 shows the different abrasion resistance of coarse aggregates from three quarries.

**Table 5. Abrasion Resistance of Coarse Aggregates**

| Quarry | Calabasa | Dagotdotan | Dogongan |
|---|---|---|---|
| 1 inch | 64.38 | 41.81 | 45.72 |
| | 58.13 | 49.24 | 46.5 |
| | 55.64 | 38.68 | 38.36 |
| ¾ inch | 53.25 | 42.86 | 46.95 |
| | 62.72 | 38.22 | 36.9 |
| | 51.19 | 35.5 | 39.45 |

The minimum abrasion resistance was approximately 50%, and results show that the abrasion resistance of coarse aggregate has a noticeable variation, as does the coarse aggregate from Brgy. Dagotdotan, Daet and Brgy. Dogongan and Daet failed to meet the standard abrasion resistance set by ASTM. The coarse aggregate from Brgy. Calabasa, Labo attained the highest abrasion resistance value, which is 64.38%, and the lowest was 35.5% from Brgy. Dagotdotan, Daet.

To assess the reliability of the results, a one-sigma limit (1s) was performed by ASTM C 670 [12] Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials. Herein, the one-sigma limit indicates the variability of the individual test results obtained under similar conditions. The standard deviation, which measures how widely the values are dispersed from the average, was also considered as the numerical index describing the characteristics of the sample.

**Table 6. One-Sigma Limit for Abrasion Resistance of Coarse Aggregate**

| Quarry | Sample | Abrasion Resistance | Standard Deviation | Range | Maximum | Remarks |
|---|---|---|---|---|---|---|
| Calabasa | 1 inch | 64.38 | 3.677 | 8.74 | 12.132 | Accept |
| | | 58.13 | | | | |
| | | 55.64 | | | | |
| | ¾ inch | 53.25 | 5.021 | 11.53 | 16.568 | Accept |
| | | 62.72 | | | | |
| | | 51.19 | | | | |
| Dagotdotan | 1 inch | 41.81 | 4.429 | 10.56 | 14.615 | Accept |
| | | 49.2 | | | | |
| | | 38.68 | | | | |
| | ¾ inch | 42.86 | 3.039 | 7.36 | 10.027 | Accept |
| | | 38.22 | | | | |
| | | 35.50 | | | | |
| Dogongan | 1 inch | 45.7 | 3.667 | 8.14 | 12.102 | Accept |
| | | 46.5 | | | | |
| | | 38.36 | | | | |
| | ¾ inch | 46.95 | 4.266 | 10.05 | 14.076 | Accept |

| |
|---|
| 36.90 |
| 39.45 |

In conformity with the same standard, the range of the group results was obtained and compared to the maximum acceptable range for the applicable system of causes and several test results, which is computed by attained by the product of the standard deviation and the multiplier of 1s stated in ASTM C 670 [12] Table 1. Maximum Acceptable Range. The researchers used 3.3 as the multiplier for the maximum acceptable range for the test results. The results should be accepted only if the range is less than the maximum acceptable range and rejected if not.

Table 6 shows the reliability assessment of results on abrasion resistance using a one-sigma limit. Through comparison, it can be observed that all the ranges for each group of results were less than the maximum acceptable range value. Therefore, all the individual results were considered acceptable.

## 3.3 Significant Difference of Abrasion Resistance of Coarse Aggregate Between Two Nominal Maximum Size.

Test results from abrasion resistance were tested through statistical analysis. A dependent t-test was performed on the data gathered to determine the significant difference in abrasion resistance between the two nominal maximum sizes. This study applied confidence intervals of 95% to determine if there is a significant relationship between the two variables.

Table 7 shows that all t-values on abrasion resistance, which are greater than 0.05, indicate that the nominal maximum size of coarse aggregates does not greatly affect their abrasion resistance.

**Table 7.** **Statistical result on Paired Samples t-test**

| | | Paired Differences | | | |
|---|---|---|---|---|---|
| | | 95% Confidence Interval of the Difference | | | |
| | | Upper | t | df | Sig. (2-tailed) |
| **Pair 1** | CALABASA1 – CALABASA2 | 23.25730 | .804 | 2 | .506 |
| **Pair 2** | DAGOTDOTAN1 – DAGOTDOTAN 2 | 19.59609 | 1.239 | 2 | .341 |
| **Pair 3** | DOGONGAN1 – DOGONGAN2 | 18.83456 | .444 | 2 | .701 |

## 3.4 Significant Difference of Abrasion Resistance of Coarse Aggregate Between Three Different Quarries

Test results from abrasion resistance were tested through statistical analysis. One-way ANOVA was performed on the data gathered to determine the significant difference in abrasion resistance between the three quarries. This study applied confidence intervals of 95% to determine if there is a significant relationship between the two variables.

Table 8 shows the p-value on abrasion resistance, which is less than 0.05, indicating that the abrasion resistance of coarse aggregates differs from each quarry site.

**Table 8.** Statistical result on One-Way Analysis of Variance (ANOVA) of Abrasion Resistance

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 103.080 | 2 | 515.540 | 22.401 | .000 |
| **Within Groups** | 345.216 | 15 | 23.014 | | |
| **Total** | 1376.296 | 17 | | | |

## 3.5 Compressive Strength of Concrete

**Table 9.** Compressive Strength of Concrete

| Quarry | Sample | Area | kN | Mpa | Mean |
|---|---|---|---|---|---|
| Calabasa | 1 inch | 8659 | 130.7 | 15.1 | 15.37 |
| | | 8659 | 113.9 | 13.1 | |
| | | 8247 | 147.8 | 17.9 | |
| | ¾ inch | 8659 | 165.4 | 19.1 | 17.73 |
| | | 8659 | 143.7 | 16.6 | |
| | | 8247 | 144.4 | 17.5 | |
| Dagotdotan | 1 inch | 8247 | 132.7 | 16.1 | 15.67 |
| | | 8247 | 126.1 | 15.3 | |
| | | 8247 | 129 | 15.6 | |
| | ¾ inch | 8247 | 149.2 | 18.1 | 16.57 |
| | | 8247 | 124.5 | 15.1 | |
| | | 8247 | 143.4 | 16.5 | |
| Dogongan | 1 inch | 8247 | 101.9 | 12.3 | 13.83 |
| | | 8247 | 126.3 | 15.3 | |
| | | 8247 | 115.3 | 13.9 | |
| | ¾ inch | 8247 | 156.5 | 18.9 | 18.13 |
| | | 8247 | 155 | 18.8 | |
| | | 8247 | 137.8 | 16.7 | |

Using ASTM C 670 [12] to assess the reliability of the results on compressive strength, a one-sigma limit (1s) was also performed. Table 10 shows the reliability assessment of results on compressive strength using one sigma limit. Through comparison, it can also be observed that all the ranges for each group of results were less than the maximum acceptable range value. Therefore, all the individual results were considered acceptable. For more details, see Appendix A.

**Table 10.** One-Sigma Limit for Compressive Strength of Concrete

| Quarry | Sample | Mpa | Standard Deviation | Range | Maximum | Remarks |
|---|---|---|---|---|---|---|
| Calabasa | 1 inch | 15.1 | 1.969 | 4.8 | 6.497 | Accept |
| | | 13.1 | | | | |
| | | 17.9 | | | | |
| | ¾ inch | 19.1 | 1.034 | 2.5 | 3.412 | 1 inch |
| | | 16.6 | | | | |
| | | 17.5 | | | | |
| Dagotdotan | 1 inch | 16.1 | 0.330 | 0.8 | 1.089 | ¾ inch |
| | | 15.3 | | | | |
| | | 15.6 | | | | |
| | ¾ inch | 18.1 | 1.226 | 3 | 4.045 | 1 inch |

| | | | | | | |
|---|---|---|---|---|---|---|
| Dogongan | 1 inch | 15.1<br>16.5<br>12.3<br>15.3<br>13.9 | 1.226 | 3 | 4.045 | ¾ inch |
| | ¾ inch | 18.9<br>18.8<br>16.7 | 1.014 | 2.2 | 3.347 | 1 inch |

## 3.6 Significant Relationship Between Abrasion Resistance of Coarse Aggregate and Compressive Strength of Concrete

**Table 11.** Statistical result on Correlatios

| | | Abrasion | Compressive |
|---|---|---|---|
| **Abrasion** | Pearson Correlation | 1 | -.007 |
| | Sig. (2-tailed) | | .989 |
| | Sum of Squares and Cross-products | 361.532 | -.486 |
| | Covariance | 72.306 | -.097 |
| | N | 6 | 6 |
| **Compressive** | Pearson Correlation | -.007 | 1 |
| | Sig. (2-tailed) | .989 | |
| | Sum of Squares and Cross-products | -.486 | 12.788 |
| | Covariance | -.097 | 2.558 |
| | N | 6 | 6 |

Test results from abrasion resistance and compressive strength were tested through statistical analysis. Bivariate Correlation (Pearson's) was performed on the data gathered to determine the significance between the coarse aggregate's abrasion resistance and the concrete's compressive strength. This study applied confidence intervals of 95% to determine if there is a significant relationship between the two variables. Table 12 shows Pearson's correlation between abrasion resistance and compressive strength, which is less than 0.05, indicating that the null hypothesis was accepted.

# 4 CONCLUSION AND RECOMMENDATIONS

Based on the results, it can be concluded that the specific gravity, absorption, and gradation were within the values suggested by the ACI and ASTM. However, among the three quarries, only the sample from Brgy. Calabasa has acceptable abrasion resistance, and the nominal maximum size does not affect the abrasion of the coarse aggregates. The abrasion resistance of the coarse aggregates between the three different quarries statistically showed a significant difference. Only the One-Way Analysis of Variance showed a significant relationship between a coarse aggregate's abrasion resistance and concrete's compressive strength. It's important to note that the Pearson's Correlation analysis revealed no significant relationship between the coarse aggregate's abrasion resistance and the concrete's compressive strength.

In addition to the conclusions drawn from this study, several recommendations can be made. Firstly, it is crucial to carefully test aggregate samples to ensure accurate results. The use of calibrated equipment to guarantee reliable quality material tests should also be prioritized. It is advisable to consider three or more nominal maximum sizes to achieve a more desirable relationship between the abrasion resistances of coarse aggregates. Additionally, round aggregate is recommended to obtain a more accurate abrasion resistance value. Furthermore, alternative curing methods for concrete specimens should be considered, and concrete admixtures should be minimized. Concrete specimens should be tested on their 28th day to attain maximum strength. Finally, using five or more replicates of sample specimens for every mix proportion is highly desirable to validate consistency and minimize errors in results.

## REFERENCES


[1] R. Kozul and D. Darwin, "Effects of aggregate type, size, and content on concrete strength and fracture energy," University of Kansas Center for Research, Inc., Tech. Rep., 1997.

[2] A. Ezeldin, P. Mehta, and P.-C. Aitcin, "Effect of Coarse Aggregate on the Behavior of Normal and High-Strength Concretes," *Cement, Concrete and Aggregates*, vol. 13, no. 2, p. 121, 1991. [Online]. Available: http://www.astm.org/doiLink.cgi?CCA10128J

[3] P. Laplante, P. Aitcin, and D. Vézina, "Abrasion Resistance of Concrete," *Journal of Materials in Civil Engineering*, vol. 3, no. 1, pp. 19–28, Feb. 1991. [Online]. Available: https://ascelibrary.org/doi/10.1061/%28ASCE%290899-1561%281991%293%3A1%2819%29

[4] F. Zhou, F. Lydon, and B. Barr, "Effect of coarse aggregate on elastic modulus and compressive strength of high performance concrete," *Cement and Concrete Research*, vol. 25, no. 1, pp. 177–186, Jan. 1995. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/000888469400125I

[5] S. Walker and D. Bloem, "Effects of Aggregate Size on Properties of Concrete," in *ACI Journal Proceedings*, vol. 57, 1960. [Online]. Available: http://www.concrete.org/Publications/ACIMaterialsJournal/ACIJournalSearch.aspx?m=details&ID=8021

[6] Y. Wu, F. Parker, Kandhal, and Ken, "Aggregate Toughness/Abrasion Resistance and Durability/Soundness Tests Related to Asphalt Concrete Performance in Pavements," Tech. Rep. Report No: NCAT Report No. 98-4, Mar. 1998. [Online]. Available: https://rosap.ntl.bts.gov/view/dot/13979

[7] C09 Committee, "Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine." [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C131-06

[8] ——, "Test Method for Sieve Analysis of Fine and Coarse Aggregates." [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C136-06

[9] ——, "Practice for Making and Curing Concrete Test Specimens in the Field." [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C31C31M-22

[10] ——, "Test Method for Compressive Strength of Cylindrical Concrete Specimens," aSTM C39/C39M-21. [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C39C39M-21

[11] American Concrete Institute, "Aggregates for Concrete," 2007. [Online]. Available: https://www.concrete.org/Portals/0/Files/PDF/E1_07.PDF

[12] C09 Committee, "Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials." [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C670-15

[13] A. C. I. Committee, "Guide to durable concrete." American Concrete Institute, 2001. [Online]. Available: https://www.concrete.org/publications/internationalconcreteabstractsportal/m/details/id/10785

[14] C. Nmai, D. Suchorski, and P. McDowell, "Aggregates for concrete (Developed by Committee E-701, Materials for concrete construction)," *ACI Education Bulletin E1-99, American Concrete Institute*, p. P9, 1999.

[15] C09 Committee, "Test Method for Bulk Density (Unit Weight) and Voids in Aggregate," aSTM C29/C29M-23. [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C29C29M-23

[16] C09 Committee, "Specification for Concrete Aggregates," aSTM C33/C33M-18. [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C33C33M-18

[17] C09 Committee, "Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate," aSTM C127-15. [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C127-15

[18] C09 Committee, "Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate." [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C128-01

[19] C09 Committee, "Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine." [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C535-16

[20] C09 Committee, "Practice for Reducing Samples of Aggregate to Testing Size." [Online]. Available: http://www.astm.org/cgi-bin/resolver.cgi?C702C702M-18

[21] Abdullahi, "Effect of aggregate type on Compressive strength of concrete," *International Journal of Civil and Structural Engineering*, vol. 2, no. 3, Feb. 2012. [Online]. Available: http://www.ipublishing.co.in/ijcserarticles/twelve/lpages/0203/jcserlpvol2issue300008.html

[22] D. Bloem and R. Gaynor, "Effects of Aggregate Properties on Strength of Concrete," *ACI Journal Proceedings*, vol. 60, no. 10, 1963. [Online]. Available: http://www.concrete.org/Publications/ACIMaterialsJournal/ACIJournalSearch.aspx?m=details&ID=7900

[23] A. F.A.O., O. Adegbesan, A. O.A, and S. Oderinde, "Comparison of the Compressive Strength of Concrete Produced using Sand from Different Sources," *International Journal of Academic Research in Business and Social Sciences*, vol. 5, Sep. 2015.

[24] A. Kılıç, C. Atiş, A. Teymen, O. Karahan, F. Özcan, C. Bilim, and M. Özdemir, "The influence of aggregate type on the strength and abrasion resistance of high strength concrete," *Cement and Concrete Composites*, vol. 30, no. 4, pp. 290–296, Apr. 2008. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0958946507000947

[25] J. Pena, "Comparative Study of the Abrasion Resistance," 2007.