Original Article

Correlation Analysis between Different Core Diameters and Standard Cylinder Strength in Concrete Assessment

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Abstract - One of the most important things to do before the assessment of the compressive strength of concrete in its original place in existing structures is the selection of the most appropriate diamond core diameter, because the use of undersized cores can lead to underestimated strength values. Thus, the focus of this paper is to investigate the influence of 2-inch, 3-inch, and 4-inch nominal diameter core diamonds on the measured compressive strength of concrete slabs prepared in the district of El Tambo, Huancayo. In order to perform an adequate analysis, a concrete slab with a target design strength (f'c) of 210 kg/cm² was cast, and different cores were extracted from it. It was also necessary to prepare standard 4"x8" cylindrical specimens from the same mix, so a reference could be obtained. After waiting for 28 days, different compressive strength tests were performed. The Results obtained from these tests showed that the smaller diamond cores, which means the ones of 2-inch and 3-inch, yielded average strengths that were significantly lower than the design strength (158.09 kg/cm² and 187.73 kg/cm², respectively). In contrast, the 4-inch cores, which are the biggest one, exhibited a higher average strength (350.27 kg/cm ²), and this exceeds both the design strength and the average reference cylinder strength. After adequate analyses, strong correlations were found between core strengths and reference cylinder strengths for all the diameters studied. In addition, quadratic regression models consistently gave the best fit (highest R²), particularly for 2-inch (R²≈0.96) and 3-inch (R²≈0.94) cores. Later, the derived quadratic models, such as y = -0.0024x² + 2.4811x - 282.62, were employed for predicting equivalent cylinder strength ('y') from the 4-inch core strength ('x'); these models offer a robust method for strength correction. To conclude, it can be argued that the core diameter has a significant impact when measuring strength, with smaller diameters giving lower results. Also, the developed quadratic models are recommended for accurately estimating concrete strength, especially when utilizing 2-inch and 3-inch cores.

Keywords - Core, Concrete, Compressive strength, Strength, Testing, Cylinder.

1. Introduction

With the increasing demand for reinforced concrete buildings in the construction sector, these structures naturally experience wear and deterioration over time. Therefore, it is necessary to characterize the material primarily in terms of compressive strength, while minimizing structural damage as much as possible [1, 2]. As a consequence, ensuring the quality of the concrete has become an essential practice to guarantee structural safety and integrity [3-5]. Among available methodologies, codes, and standards, testing on extracted cores is the most reliable method for determining the actual in-place concrete strength [6]. Consequently, core extraction and testing are a widely employed technique for this in situ verification [1, 7]. However, the reliability of the results obtained from these tests can be affected by various factors. Among the most influential are the core diameter,

slenderness ratio (Height/Diameter, H/D), the sample's moisture condition, the drilling direction relative to casting, the presence of steel reinforcement (rebar), and the concrete strength level itself [8]. Previous research suggests that compressive strength measurements from larger diameter cores (e.g., 100 mm and 75 mm) tend to yield more consistent and representative results when comparing the results with those obtained from smaller diameter cores (such as 50 mm) [9]. This variability has direct and critical implications because an inaccurate estimation of strength can lead to structural safety assessments that are mistaken, and of course, this situation ends up influencing decisions regarding rehabilitation, strengthening, or demolition. Therefore, it is fundamental to optimize the interpretation of core test results, including quantifying the influence of key variables such as diameter, to determine the main characteristic of concrete,

which is its compressive strength. Factors like core size, its slenderness ratio, and moisture condition affect not only the measured strength value but also the representativeness of the sample with respect to the entire structure. Appropriate diameter selection and the correct application of correction factors are essential for reducing uncertainty in structural assessment [10]. This study specifically focuses on analyzing in detail the effect of core diameter on the measured compressive strength, aiming to establish more rigorous adjustment criteria or predictive models that enable more reliable and representative estimations [11]. On the other hand, another investigation [12] regarding the specimen geometry, the compressive strength of the diamond core was used to determine conversion factors for diameters of 50, 75, and 100 mm, within a Height-to-Diameter (L/D) ratio range of 0.6 to 1.0, using correlation coefficients (R^2) of 0.987, 0.955, and 0.964, respectively.

Furthermore, [13] compressive strength is influenced by specimen size. In general, the conventional strength obtained from molded specimens is higher than that of in-situ extracted cores; however, this difference tends to diminish as concrete strength increases. For cylinders with dimensions of $\phi 75 \times 150$ mm and $\phi 100 \times 200$ mm, the correction factors relative to the standard specimen range from 0.76 to 0.88 for compressive strengths between 20 and 60 MPa.

In practice, the extraction of diamond cores is generally carried out without the presence of reinforcing steel, as its inclusion would introduce an additional factor that could influence the evaluation of compressive strength [14]. The guide UNE-EN 13791:2020 [15, 16], for specimens with a diameter between 50 and 75 mm, provides a better account of specimens and characterizes the resistance in situ. In function of the dispersion. The ultimate objective is to provide tools that enhance the processes for structural safety assessment of existing structures, with the least margin of compromising the safety of the structure, and for application in concrete slab elements.

2. Materials and Methods

The methodology for this research involved casting a concrete slab with a target design compressive strength of 210 kg/cm², following the specifications of standard NTP 339.059 [17], in the district of El Tambo, Huancayo. Diamond-drilled cores with nominal diameters of 2", 3", and 4" were extracted from this slab, with the extraction process shown in Figure 1 a-c. Concurrently, standard cylindrical specimens measuring 4" in diameter by 8" in height (4"x8"), prepared using the same concrete mix design, were fabricated in the laboratory to serve as the reference (control) strength (see Figure 2). Subsequently, the compressive strength of both the extracted cores and the standard cylindrical specimens was evaluated. Finally, these results were compared to determine the optimal correction factors applicable to the different core diameters.

Fig. 1 Diamond core extraction process (a) Core drilling equipment in operation, (b) Close-up of the diamond core bit, and (c) An extracted diamond core sample.

Fig. 2 Standard cylindrical specimens measuring 4" in diameter by 8" in height

2.1. Diamond Cores

According to the standard NTP 339.059, the approach by which the diamond cores that are used for determining the compressive strength of concrete should be obtained by drilling perpendicular to the horizontal surface. In addition, the extraction of these diamond cores must occur at a minimum distance of 150 mm from the formed joints or the edges of a cast concrete unit. By doing this, the existing joints and damaged surfaces can be avoided. Indeed, when these diamond cores are extracted from slabs, they must possess sufficient dimensions to ensure that the concrete sample is free from fractures, spalls, voids, or other significant damage [18].

In order to determine the extraction locations, the priority was given to the areas where the concrete sections are intact, which means they are free from fractures, cracks, erosion, or other characteristic defects [19]. The primary purpose of performing the diamond core testing is to determine the structural compressive strength. Generally, cores should have a minimum diameter of 94 mm (3.7"). While smaller diameters, around 50 mm, may occasionally be permitted [6], this can lead to reduced sensitivity related to the Length-to-Diameter (L/D) ratio. It is also common practice to use a core

diameter not less than twice the nominal maximum size of the coarse aggregate [20].

Concerning the length of diamond cores, NTP 339.059 [17] suggests that the Length-to-Diameter ratio (L/D) should ideally be between 1.9 and 2.1 (1.9 ≤ L/D ≤ 2.1).

However, if the extracted core's L/D ratio exceeds this range, the specimen length should be reduced (typically by sawing) to fall within it or meet testing requirements. Conversely, for cores with an L/D ratio below 1.75, strength correction factors must be applied [20]. Consequently, the standard provides the following correction factors based on the L/D ratio, as specified in Table 1.

Table 1. Strength correction factors based on the specimen length-to-diameter (L/D) ratio

Length/Diameter (L/D) Ratio	Strength Correction Factor
1.75	0.98
1.5	0.96
1.25	0.93
1	0.87

Situations where the application of diamond core testing is particularly useful include: when the in situ strength of concrete elements is deemed insufficient based on other tests or calculations; when irregularities are suspected or known to have occurred during the construction process; potential deficiencies in curing procedures; cases of premature load application; structural assessment after a fire event; evaluation of aged structures; absence of reliable documentation verifying the original concrete strength; among other circumstances requiring direct strength verification [22].

On the other hand, both the sample and the testing machine must be of the type that allows the speed of a specific load to be reached. The margin of error for the loads must not exceed ± 1.0 % the indicated load. This applies to test samples in a wet state, ASTM C39/C39M.

2.2. Mix Design

In order to attain the appropriate proportions of the concrete constituents (cement, aggregates, and water) and thereby achieve the desired properties in terms of strength, durability, and workability, a specific mix design was developed. The design of this mix aimed to have a plastic consistency that had a required slump within the range of 3" to 4" (as indicated in Figure 3).

Furthermore, the nominal maximum size of the aggregate (NMSA) was ¾ inch, and the target air content was 2%. All these features were a must because this mix was designed to achieve a compressive strength of 210 kg/cm². Table 2 summarizes the mix proportions per cubic meter.

Table 2. Concrete mix design proportioning

Component	Quantity	Unit
Cement	375.16	kg/m^3
Effective Water	163.79	L/m^3
Fine Aggregate (moist)	1300.07	kg/m^3
Coarse Aggregate (moist)	437.15	kg/m^3
TOTAL	2276.18	kg/m^3

Concrete slump standard

- - ◆ - Polynomic (SLUMP (mm))　　■　SLUMP (mm)

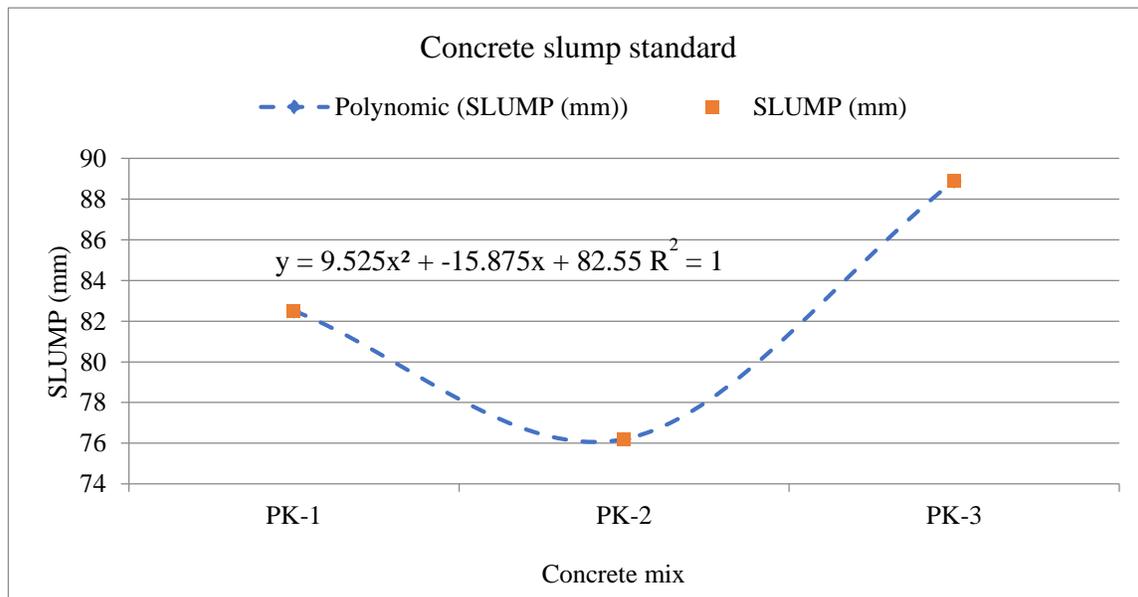$y = 9.525x^2 + -15.875x + 82.55 \ R^2 = 1$

Fig. 3 Measured slump values for concrete mixes PK-1, PK-2, and PK-3, showing a quadratic relationship

2.3. Slump

Slump is the indicator of concrete that shows how fluid and consistent it is. It is also a crucial parameter in the design of a mix, and it is often guided by principles like those in ACI 211 [23]. For the purposes of this study, the target slump range was determined to be 3" to 4" (76.2 mm to 101.6 mm), which is the characteristic of a plastic concrete consistency.

Later, the verification tests were conducted in order to be sure that the produced concrete mixes met this requirement. The measured slump values for the different trial mixes (PK-1, PK-2, PK-3) are presented in Table 3.

Table 3. Measured slump for the concrete mix designs

Mix ID	Slump (mm)
PK-1	82.55
PK-2	76.20
PK-3	88.90

Figure 3 graphically presents these slump results. It shows the measured slump for concrete mix PK-1 was 82.55 mm, while mix PK-3 yielded a slump of 88.90 mm.

2.4. Research Design and Sampling

A correlational research design is employed in this study, so the degree of relationship between variables could be determined (although without assigning dependent or independent roles at the beginning). The main focus was to do the analysis of the relationship between the compressive strength results obtained from extracted diamond cores and the standard cylindrical specimens.

The primary test specimen used in this paper was a concrete slab cast specifically made for this research in the district of El Tambo. The slab utilized concrete with a target compressive strength (f'c) of 210 kg/cm² and a nominal maximum aggregate size (NMSA) of 3/4 inch.

The concrete made for the purposes of this study had a minimum curing period of 28 days prior to the extraction of the core, so representative strength development could be guaranteed (Figure 4 illustrates the slab post-coring).

Fig. 4 Concrete slab (f'c = 210 kg/cm ²) after core extraction

In this study, the sampling technique employed was a non-probabilistic purposive one. The sample that was analyzed consisted of forty-five (45) diamond cores that were extracted from the slab, and another fifteen (15) standard 4" x 8" cylindrical specimens cast from the same concrete batch. The cores were extracted according to the different diameters that were studied in this investigation (2", 3", and 4"), and all specimens (cores and cylinders) were also tested after a minimum of 28 days had passed. The distribution of test specimens is detailed in Table 4. Plots, it is important to mention that this sample size was considered to be adequate for performing both descriptive and inferential statistical analyses, which aimed at deriving strength correction factors.

Table 4. Distribution of test specimens

Concrete Type	Diamond Cores		
	2"	3"	4"
Concreto de f'c: 210 kg/cm2 con TMN de agregado de 3/4"	15	15	15
Concreto de f'c: 210 kg/cm2 con TMN de agregado de 3/4"	Standard Cylinders 4" x 8"		
	15		

2.5. Data Analysis

To model the relationship between core strength and reference strength, it was necessary to employ and evaluate diverse mathematical correlation models, as listed in Table 5. The model providing the best fit to the experimental data, determined by the highest coefficient of determination (R^2), was selected. For these correlation equations, the dependent variable 'Y' represents the concrete compressive strength (typically the reference cylinder strength), and the independent variable 'X' represents the strength value obtained from the diamond cores of a specific diameter (2", 3", or 4").

Table 5. Correlation models considered

Correlation Type	Mathematical Equation
Linear	$y = \beta_1 + \beta_2 * x$
Quadratic	$y = \beta_1 + \beta_2 * x + \beta_3 * x^2$
Power Law	$y = a * x^b$
Logarithmic	$y = a * b^x$
Logarithmic	$y = a + b * \log(x)$

Furthermore, validity refers to the quality of an instrument to accurately measure what it is intended to evaluate (see Figure 5). That is, it demonstrates effectiveness in obtaining results related to the capacity, behavior, performance, or other aspects intended to be measured.

In this study, the primary instrument (considered here as the overall methodology and procedure based on NTP 339.059 for core extraction and testing) was validated through expert judgment.

Instrument Validation Form

I. General Information

Date	24/01/2024
Instrument to Validate	Diamond Core Extraction NTP 339.059
Research Title	Diamond Core Diameters and Concrete Compressive Strength in Slabs

ii. Instrument Validation Criteria

Instructions for Expert: Review each criterion below regarding the instrument/procedure and mark (x) the corresponding rating:

1	D=Deficient	Less than 30% of indicators achivied
2	R=Fair	Between 30% and 70% of the indicator achievied
3	B=Good	More than 70% of indicators achivied

Criteria	Indicators / Description	D (1)	R (2)	B (3)	Observation
RELEVANCE	The evaluated elements correspond to the stated research objectives.			X	
COHERENCE	Aligns with the variable, dimensions, and indicators intended for measurement.			X	
CONGRUENCE	Is consistent with the current progress of science and technology.		X		
SUFFICIENCY	Provides adequate scope/detail to measure the indicators.		X		
OBJECTIVITY	Relies on observable and verifiable actions/measurements.			X	
CONSISTENCY	Reflects the theoretical dimensions of the variable.			X	
ORGANIZACIÓN	Logically sequenced and structured.			X	
CLARITY	Descriptions/instructions are in clear and understandable language.			X	
OPPORTUNITY	The procedure is applied/relevant at the appropriate stage.		X		
STRUCTURE	The procedure includes well-defined instructions and response options.			X	
TOTAL		0	6	21	

III. Validity Coefficient

$$\frac{D+R+B}{30} = 0.90$$

Coefficient Range	Validity Level
0.40 o más	Very Good
0.30 a 0.39	Good
0.20 a 0.29	Deficient
0 a 0.19	Insufficient

Fig. 5 Instrument validation form (expert judgment)

3. Results

3.1. Strength and Correlation for 2-inch Diamond Cores

The results comparing the compressive strength of the 2-inch (50.79 mm) diameter diamond cores and the standard cylindrical reference specimens are shown in Figure 6. The average height of these extracted 2-inch cores was 104.44 mm. The analysis of the 2-inch core data indicates that the maximum measured compressive strength was 186.21 kg/cm² (obtained from specimen M3), representing approximately 89% of the target design strength of 210 kg/cm². Likewise, the average compressive strength across all 2-inch cores was 158.09 kg/cm², and this result is lower than the target design strength. In Figure 6, the strength values for each individual 2-inch core as well as its corresponding reference cylinder specimen are shown.
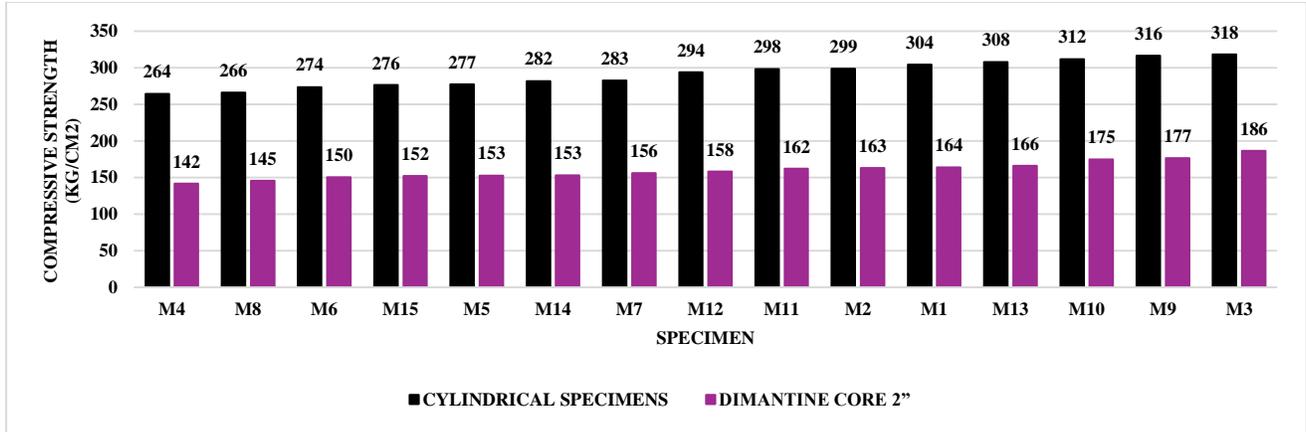
Fig. 6 Comparison of compressive strength between reference cylindrical specimens and 2-inch diamond cores

Figure 7 exposes the results of various correlation models that were adjusted to the compressive strength data, and this picture shows the strength of 2-inch diamond cores (x-axis) against the strength of the 4"x8" reference cylindrical specimens (y-axis). In Figure 7(a), the linear correlation analysis shows the data points that generally follow an increasing trend. The resulting coefficient of determination of this correlation model (R^2) is 0.9215, and this result indicates a strong linear relationship between the 2-inch core strength and the cylinder strength.

When evaluating the quadratic correlation of the model (Figure 7(b)), it provides results that fit better to the data, with dispersed points showing a clear ascending trend and also giving a higher coefficient of determination (R^2) of 0.962. This value suggests a very strong, near-perfect quadratic relationship for this dataset. Furthermore, Figures 7(c), 7(d), and 7(e) examine exponential, logarithmic, and power-law (potential) correlations, respectively.

The corresponding R^2 values obtained were 0.9074 (exponential), 0.9356 (logarithmic), and 0.9246 (power-law). These values also indicate strong to very strong correlations between the 2-inch core and cylinder strengths, although the quadratic model (Figure 7(b)) exhibited the highest R^2 value among all tested models.

(a)

(b)

(c)

(d)
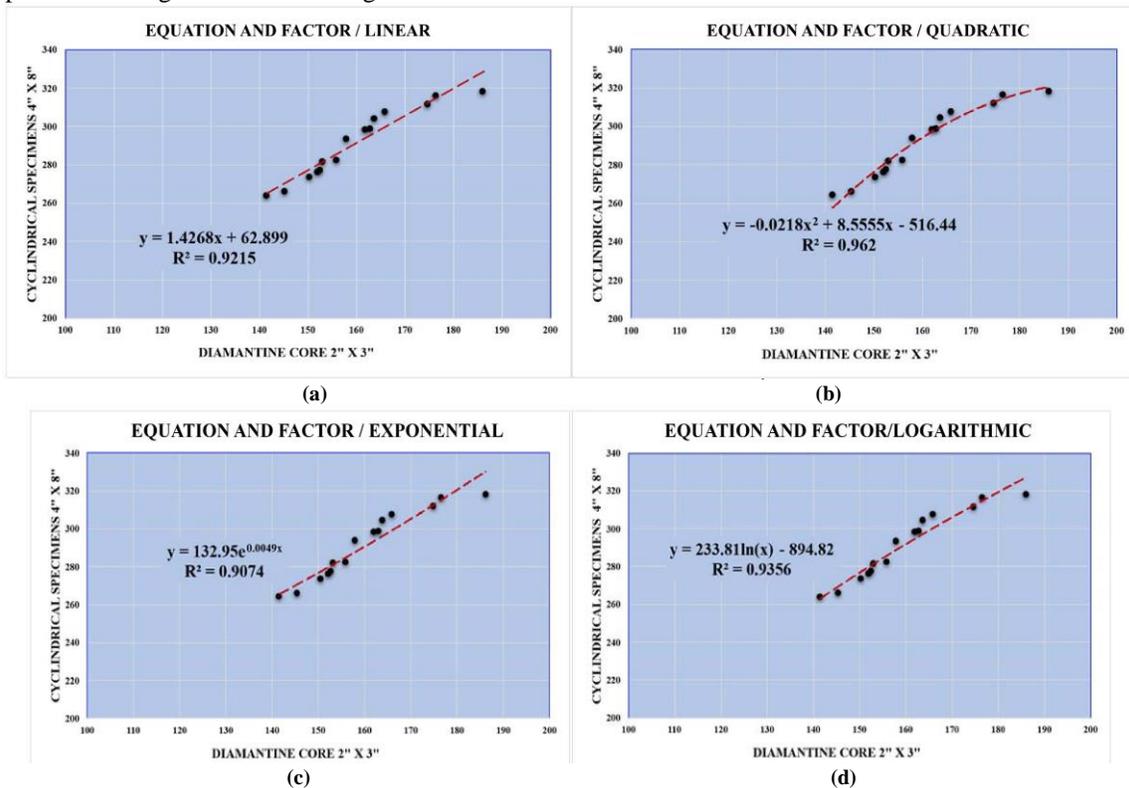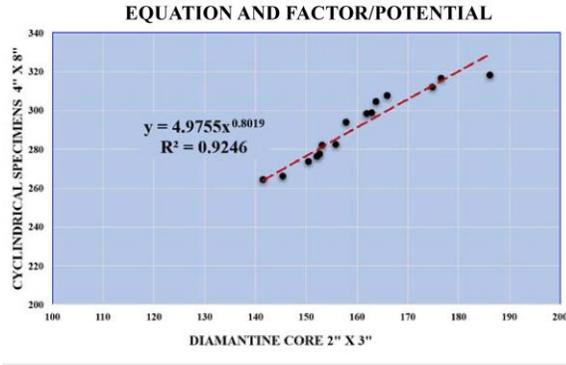
(e)

Fig. 7 Correlation models fitted to 2-inch diamond core strength vs. reference cylinder strength: (a) Linear, (b) Quadratic, (c) Exponential, (d)Logarithmic, and (e) Power-Law (Potential).

3.2. Strength and Correlation for 3-inch Diamond Cores

The results comparing the compressive strength of the 3-inch diameter diamond cores and the standard cylindrical reference specimens are presented in Figure 8. Analysis of the data for the 3-inch cores shows that specimen M10 yielded the highest measured compressive strength, reaching 220 kg/cm². This value represents approximately 105% of the target design strength (210 kg/cm²). Nonetheless, when looking at the average compressive strength across all tested 3-inch cores, it can be noticed that this average is 187.73 kg/cm², and this is still lower than the target design strength. Figure 8 also provides a visual comparison of the strength values for each individual 3-inch core and its corresponding reference cylinder specimen.
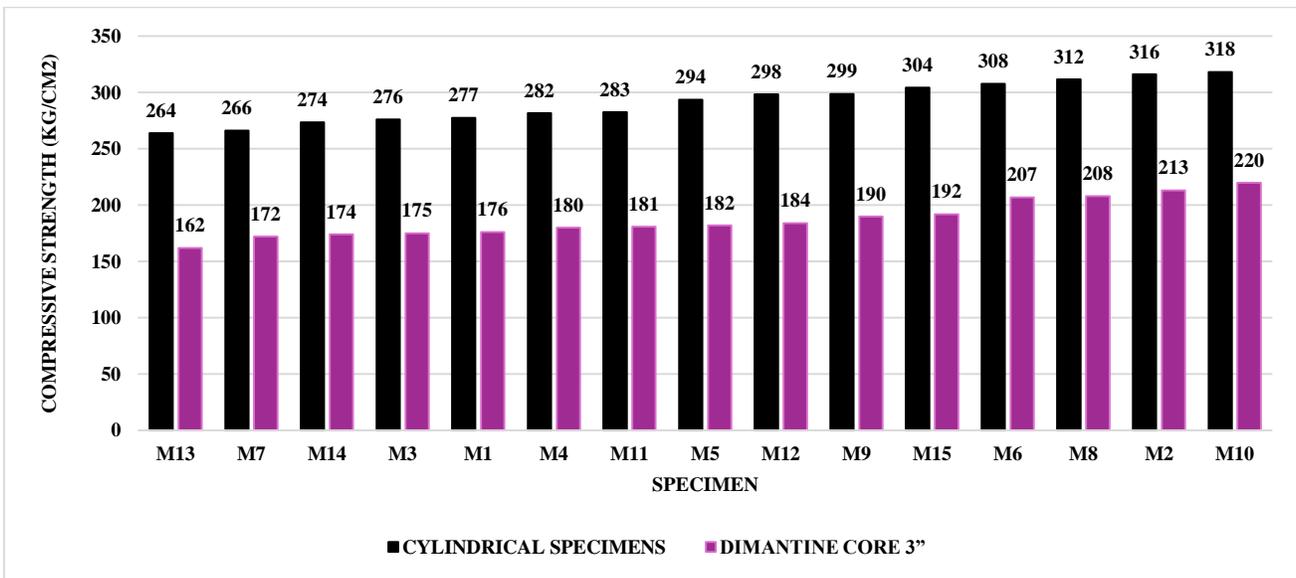

Fig. 8 Comparison of compressive strength between reference cylindrical specimens and 3-inch diamond cores

Figure 9 illustrates the application of various correlation models to the compressive strength data. The application of various correlation models pictures the relationship of the strength of 3-inch diamond cores (x-axis) against the strength of the 4"x8" reference cylindrical specimens (y-axis). Figures 9(a), 9(c), and 9(e) show the linear, exponential, and power-law (potential) correlations, respectively. Another thing to mention is that the coefficients of determination (R^2) obtained were 0.9025 (linear), 0.8927 (exponential), and 0.9069 (power-law). These R^2 values indicate a strong relationship between the 3-inch core strength and the reference cylinder strength for these models.

Furthermore, the quadratic correlation, shown in Figure 9(b), exhibits a clear increasing trend and also causes a higher coefficient of determination (R^2) of 0.9352. Thus, these results suggest that there is a very strong relationship between these two variables, and this delivers a better adjustment than the linear, exponential, or power-law models for this dataset. The logarithmic correlation presented in Figure 9(d) also shows an increasing trend with a strong R^2 value of 0.9148, indicating a very strong relationship between the variables according to this model as well. Overall, the quadratic model provided the best fit based on the highest R^2 value.

(a)   (b)

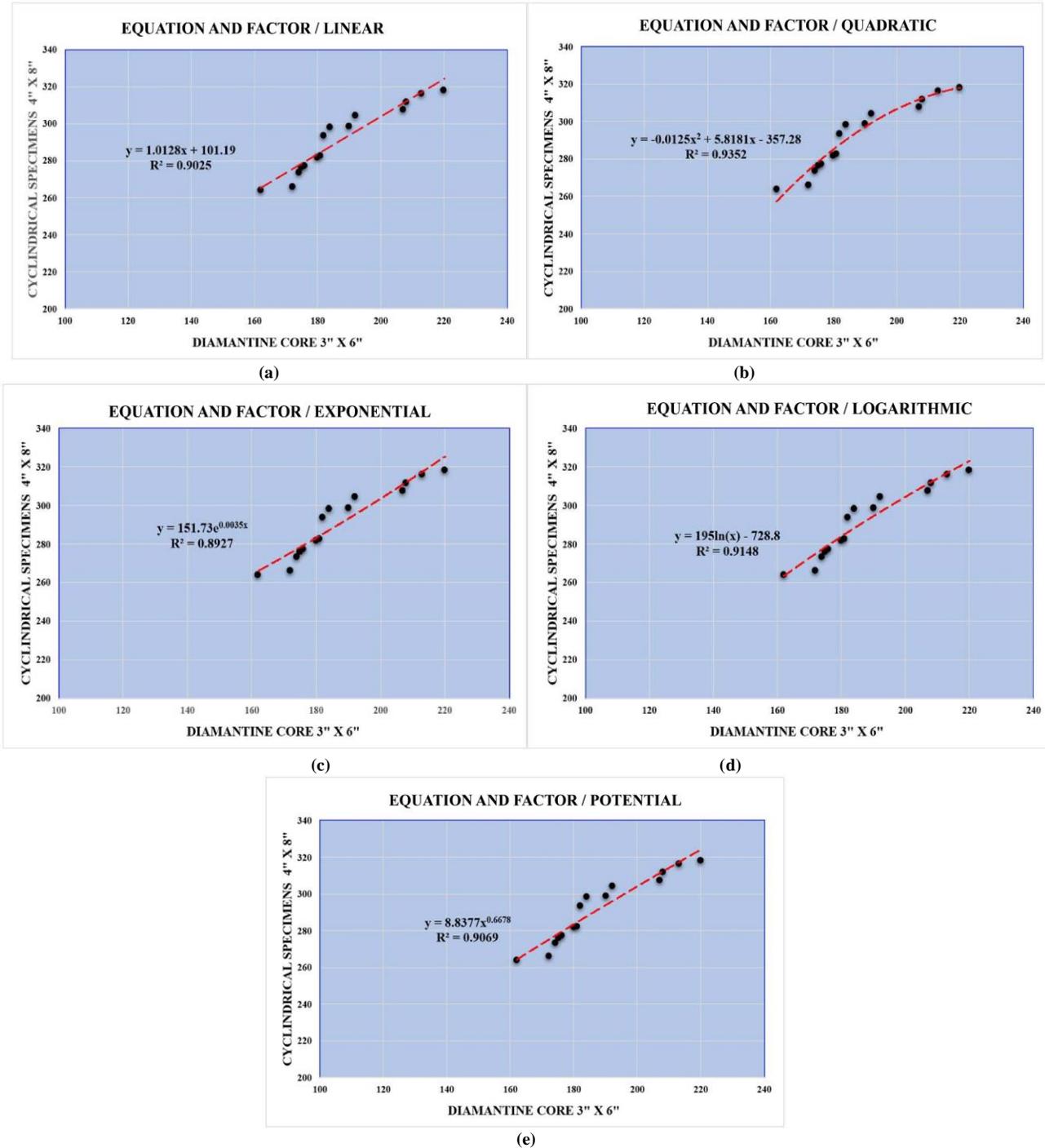(c)   (d)

(e)

Fig. 9 Correlation models fitted to 3-inch diamond core strength vs. reference cylinder strength: (A) Linear, (B) Quadratic, (C) Exponential, (D) Logarithmic, (E) Power-Law (Potential)

3.3. Strength and Correlation for 4-inch Diamond Cores

The results comparing the compressive strength of the 4-inch diameter diamond cores and the standard cylindrical reference specimens are exhibited in Figure 10. It can be observed that specimen M8 yielded the highest compressive strength among the extracted 4-inch cores, reaching a value of 396 kg/cm². This maximum measured strength represents approximately 188% of the target design strength (210 kg/cm²). Additionally, the average compressive strength calculated across all tested 4-inch cores was 350.27 kg/cm², a value significantly greater than the target design strength. In Figure 10, a visual comparison of the strength values for each individual 4-inch core against its corresponding reference cylinder specimen is shown.
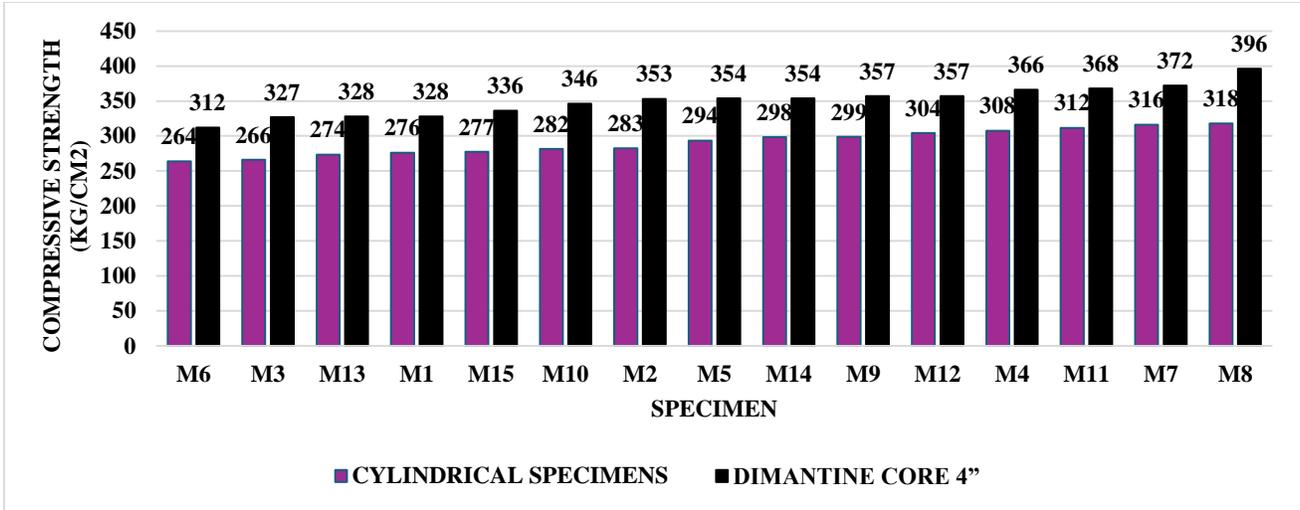
Fig. 10 Comparison of Compressive Strength between Reference Cylindrical Specimens and 4-inch Diamond Cores.

Figure 11 unveils the different results obtained after applying various correlation models to the compressive strength data from the 4-inch cores, giving a graphical representation of the core strength (x-axis) against the strength of the 4"x8" reference cylindrical specimens (y-axis). The linear (Figure 11(a)), exponential (Figure 11(c)), and logarithmic (Figure 11(d)) correlation models all showed similar positive trends. Besides, the coefficients of determination (R²) obtained in these models were 0.8888 (linear), 0.8817 (exponential), and 0.8925 (logarithmic), respectively. These values acquired in these particular models

indicate a clear, strong relationship between the 4-inch core strength and the reference cylinder strength. Furthermore, the quadratic correlation (Figure 11(b)) and the power-law (potential) correlation (Figure 11(e)) also exhibited clear ascending trends. In addition, the quadratic model had an R² of 0.8949, while the power-law model yielded an R² of 0.8899. These results also represent strong correlations between the variables. Comparing all models, the logarithmic (R²=0.8925) and quadratic (R²=0.8949) correlations provided slightly better fits to this dataset than the other models tested.

(a)

(b)

(c)

(d)
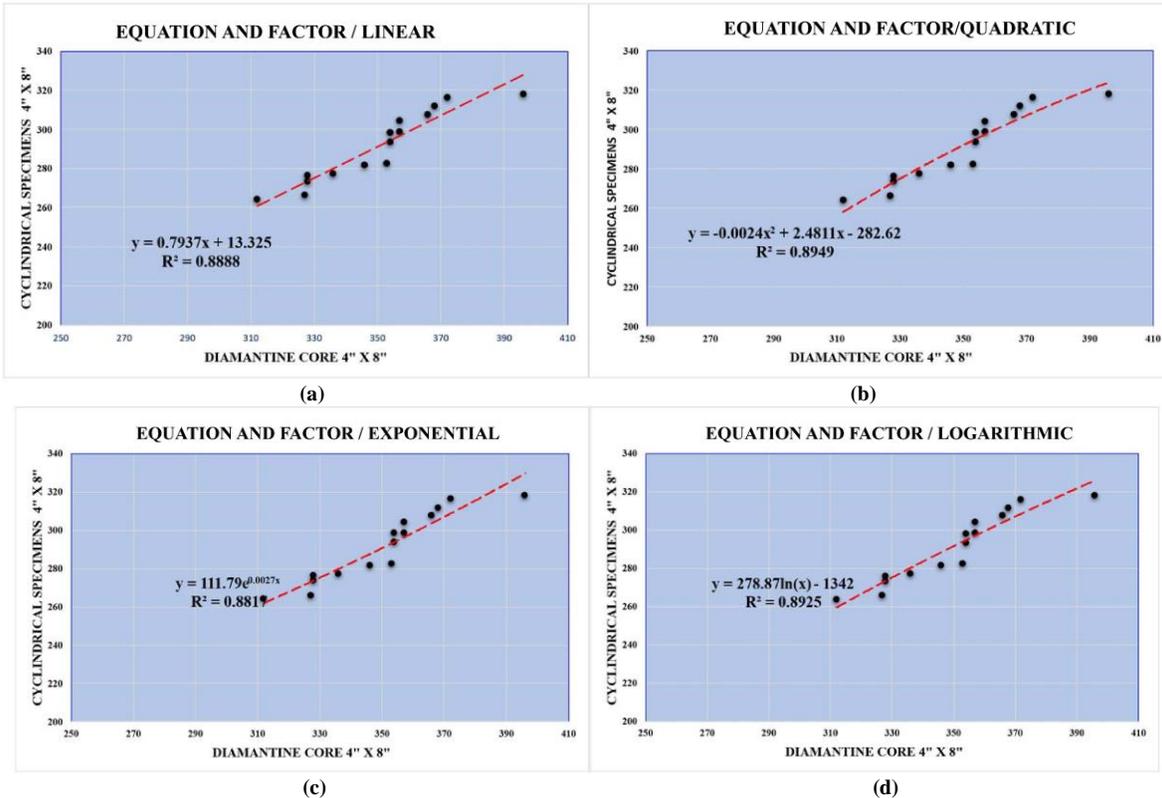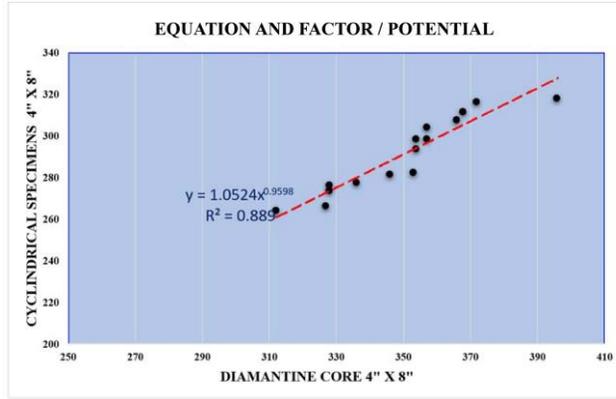
(e)
Fig. 11 Correlation models fitted to 4-inch diamond core strength vs. reference cylinder strength: (a) Linear, (b) Quadratic, (c) Exponential, (d) Logarithmic, and (e)Power-Law (Potential).

3.4. Strength Prediction Models and Corrected Values

Table 6 presents the predicted compressive strengths of the reference cylindrical specimens, calculated using the best-fit correlation equations previously established for each diamond core diameter (2", 3", and 4"). These equations serve as the models to estimate the standard cylinder strength based on the measured strength of the extracted cores.

Specifically, the predicted strength ('y') corresponding to the measured 2-inch diamond core strength ('x') was calculated using the quadratic equation identified as the best fit in Figure 7(b): $y = -0.0218x^2 + 8.5555x - 516.44$. In the case of the 3-inch diamond cores, the corresponding best-fit quadratic equation from Figure 9(b) was used, which is: $y = -0.0125x^2 + 5.8181x - 357.28$. Finally, for the 4-inch diamond cores, the predicted strength was determined by using the best-fit quadratic equation identified in Figure 11(b), that is: $y = -0.0024x^2 + 2.4811x - 282.62$. All the results acquired after the application of these equations to the measured core strengths are detailed in Table 6.

Table 6. Predicted reference cylinder strengths based on measured core strengths and correlation equations

Measured 2" Core Strength (Kg/cm²)	Measured 3" Core Strength (Kg/cm²)	Measured 4" Core Strength (Kg/cm²)	Predicted Cylinder Strength from 2" Core (Kg/cm²)	Predicted Cylinder Strength from 3" Core (Kg/cm²)	Predicted Cylinder Strength from 4" Core (Kg/cm²)
142	162	312	258	257	258
145	172	327	265	273	272
150	174	328	276	277	273
152	175	328	280	278	273
153	176	336	282	279	280
153	180	346	282	284	289
156	181	353	287	286	294
158	182	354	291	287	295
162	184	354	297	290	295
163	190	357	298	297	297
164	192	357	300	299	297
166	207	366	303	311	304
175	208	368	313	312	305
177	213	372	315	315	308
186	220	396	320	317	324

3.5. Hypothesis Testing

Table 7 shows the comparison of the influence of 2", 3", and 4" diameter diamond core samples on the compressive strength of concrete in slabs, Tambo district – Huancayo.

Table 7. Influence of diamond diameters on compressive strength

	2" diameter diamond cores	3" diameter diamond cores	4" diameter diamond cores
Normality test (Normality assessment using the Anderson-Darling statistic)	The experimental values of the diameters in the compressive strength follow a normal distribution.	The experimental values of the diameters in the compressive strength follow a normal distribution.	The experimental values of the diameters in the compressive strength follow a normal distribution.
Test of variances (Fisher statistic)	The p-value (0.150) is greater than the significance level α (0.05), or the probability of committing the error 0.05. The results of the experiment on the concrete compressive strength specimens exhibit equality of variances.	The p-value (0.814) is higher than the significance level α (0.05), or the probability of committing the error 0.05. The results of the experiment on the specimens in the compressive strength of the concrete exhibit equality of variations.	The p-value (0.528) is greater than the significance level α (0.05), or the probability of committing the error 0.05. The results of the experiment on the concrete compressive strength specimens exhibit equality of variances.
Test of equality of means (Student's t-test)	The p-value of the student's t-test, which is 0.000, is less than the significance level α. This means that the two-treatment means are different.	The p-value of the student's t-test, which is 0.000, is less than the significance level α. This means that the two-treatment means are different.	The p-value of the student's t-test, which is 0.000, is less than the significance level α. This means that the two-treatment means are different.

In the treatment of these results, numerical autocorrelation tests of the residuals were performed for each group of diamond diameters. Using the Durbin-Watson criterion, it was identified that each group tends to approach the value of 2, as shown in Table 8. This is related to the fact that the values are independent and there were no influences from external factors during the testing of each sample.

Table 8. Analysis of the residuals for each diamond core diameter

Diamond cores 2" (Kg/cm2)	Diamond cores 3" (Kg/cm2)	Diamond nuclei 4" (Kg/cm2)
-11.60	-16.13	-12.38
-13.16	-10.39	-15.32
18.77	4.98	8.99
0.25	5.52	5.88
-20.03	-18.90	-18.09
17.27	23.99	23.02
25.89	23.82	25.27
19.72	28.68	21.70
-14.29	-9.20	-10.09
-20.53	-21.27	-27.03
3.86	1.01	1.04
-25.28	-25.93	-25.69
16.14	8.15	14.52
-10.85	-11.40	-9.09
13.85	17.07	17.26

Zone of no autocorrelation	2.10	1.77	1.88
Upper area	2.639		
Lower area	1.361		

4. Discussion

All the results gained in this investigation allow us to confirm that the diameter of extracted concrete cores significantly influences the measured compressive strength, and this is a critical factor for the accurate assessment of in situ concrete properties [24, 25]. Thus, the inaccurate estimations that arise from non-representative sampling activities can compromise the structural evaluations [15], since the reduction factors to be used may be affected, varying between 0.76 and 0.88 [13].

A clear trend related to the core diameter could be noticed in this study. The results shown in Figures 6 and 8, indicated that the average compressive strengths measured for the 2-inch (158.09 kg/cm ²) and 3-inch (187.73 kg/cm ²) diameter cores were remarkably lower compared to not only the average strength of the 4-inch cores (350.27 kg/cm ²), but also the target design strength (210 kg/cm ²).

This finding aligns with previous results of existing literature [26], which suggests that smaller diameter cores tend to generate lower apparent strength values. This situation might happen due to factors like a higher proportion of damaged material near the cut surface or increased influence of aggregate size relative to the core diameter. Furthermore, this is why the European standard for these considerations requires that more samples be taken so that the material can be better characterized [15].

In contrast, the results attained from the 4-inch diameter cores exhibited significantly higher average strength, which even exceeded the target design strength [14]. After examining the correlation between the core strength and the reference 4"x8" cylinder strength, the results showed that the 4-inch cores had a strong relationship, with the best-fit quadratic and logarithmic models, generating coefficients of determination (R²) of approximately 0.895 and 0.893, respectively (Figure 11(b), 11(d)). This strong correlation, as distinguished in the case of the 4-inch cores, is consistent with previous findings presented by S. Suzuki et al. [27], who reported an R² value of 0.89 when they made comparisons between 4-inch cores with cylindrical specimens. The results of this preceding study increase the reliability of this core size for strength assessment [12].

A critical observation noticed across all core diameters (Figures 7, 9, and 11) was that the quadratic correlation models consistently provided the best or near-best fit (highest R²) to associate the core strength with the reference cylinder strength, particularly for the 2-inch (R²=0.962) and 3-inch (R²=0.935) cores. This critical observation also suggests that a simple linear correction factor may not fully capture the relationship, especially for smaller diameter cores, because the strength reduction appears more pronounced and potentially non-linear. The implication is that applying a non-linear (e.g.,

quadratic) correction model, derived empirically as done in this study, may lead to more accurate estimations of the equivalent standard cylinder strength when testing smaller, non-standard core diameters. This refinement is crucial for improving the reliability of structural evaluations based on core testing.

Similarly, to ensure the reliability of the tested samples, statistical analyses were performed for each sample as well as for the group to which it belongs. Among its particularities, the Durbin Watson test helps to clarify that during the probe breaking test, the compressive strength values were not contaminated by external factors (calibration, humidity, press speed) [13].

5. Conclusion

Based on the results of this investigation evaluating the influence of diamond core diameter on measured compressive strength, the following conclusions are drawn:

- Core diameter significantly affects measured compressive strength. Strengths obtained from 2-inch and 3-inch diameter cores were consistently and significantly lower than both the strengths of the standard 4"x8" reference cylindrical specimens and the target design strength (210 kg/cm ²).
- Conversely, the 4-inch diameter cores yielded average compressive strengths (350.27 kg/cm ²) that exceeded the target design strength and were generally higher than the corresponding reference cylinder strengths.
- Quadratic regression models consistently provided the best statistical fit (highest coefficient of determination, R²) for correlating measured core strength to the reference cylinder strength across all diameters tested. The fit was particularly strong for the 2-inch (R² ≈ 0.96) and 3-inch (R² ≈ 0.94) cores, indicating a pronounced non-linear relationship. A strong correlation (R² ≈ 0.90) was also observed for the 4-inch cores.
- The empirically derived quadratic equations, such as $y = -0.0024x^2 + 2.4811x - 282.62$ for the 4-inch cores (where 'x' is core strength and 'y' is predicted cylinder strength), serve as effective prediction models or correction methods, in this case, for concrete slabs, however, this model is conditioned by the proposed resistance, characteristics of the aggregates in the mix design, degree of calibration of the testing machines, and environmental conditions. These models are particularly valuable for this study since they allow estimating equivalent standard cylinder strength from the results obtained when using smaller, non-standard core diameters (2" and 3").

The utilization of the specific quadratic models developed in this study is strongly recommended, particularly for correcting strength values obtained from 2-inch and 3-inch cores. These specific quadratic models permit a better capture

of the observed strength relationship, a feature that simple linear factors do not possess. Consequently, the use of these specific quadratic models potentially leads to more accurate assessments of in situ concrete strength.

Acknowledgments

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