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ENGLISH VERSION……………………….

Experimental Study of the Semicircular Bending Test for Estimating the Flexural Strength of Concrete Mixtures for Pavements

Estudio Experimental de la Prueba de Flexión Semicircular para Estimar la Resistencia a la Flexión de Mezclas de Concreto para Pavimentos

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Abstract
The feasibility of using the Semicircular Bending (SCB) test to control the quality of concrete for application in pavements was investigated. Two concrete mixtures incorporating high-strength cement with specified compressive strengths of 30 MPa and 40 MPa were manufactured. The results of the SCB test were correlated with those of the flexural strength of standardized beams and the compressive strength of cylinders. A statistical analysis of the goodness of fit of all the empirical models obtained was conducted to study the degree of association between the variables. Power models were the most appropriate to relate the mechanical properties studied, with Pearson's correlation coefficients higher than 0.93. These equations can feed the database of levels 1 and 2 of the Mechanistic-Empirical (ME) design method for concrete pavements. Models with unique values that allow quick calculations with good precision were also found. The results show that the SCB test is a promising option when estimating the flexural strength of concrete for use in pavement, as well as carrying out its control and quality assurance.

Keywords: Concrete; modulus of rupture; semi-circular bending test; SCB; flexural strength; compressive strength.

Resumen
Se investigó la factibilidad de utilizar el ensayo de flexión de vigas Semicirculares (SCB, del inglés Semi Circular Bending Test) para monitorear y controlar la calidad del hormigón para su aplicación en pavimentos. Se fabricaron dos mezclas de hormigón con resistencias a la compresión especificadas de 30 MPa y 40 MPa incorporando cemento de alta resistencia. Los resultados del ensayo SCB se correlacionaron con la resistencia a la flexión de vigas estandarizadas y la resistencia a la compresión de cilindros. Se realizó un análisis estadístico de bondad de ajuste de todos los modelos empíricos obtenidos para estudiar el grado de asociación entre las variables. El modelo de correlación potencial resultó ser el más apropiado para relacionar las propiedades mecánicas estudiadas, con coeficientes de correlación de Pearson superiores a 0,93. Estas ecuaciones pueden ser utilizadas para alimentar la base de datos de los niveles 1 y 2 del método de diseño Mecanicista-Empirico (ME) para pavimentos de concreto. También se hallaron modelos con valores únicos que permiten cálculos rápidos con buena precisión. Los resultados muestran que el ensayo SCB es una opción promisoria a la hora de estimar la resistencia a flexión del hormigón para uso en pavimento, así como para realizar su control y aseguramiento de calidad.

Palabras clave: Hormigón; concreto; módulo de ruptura; ensayo de viga semicircular; SCB; resistencia a la flexión; resistencia a la compresión.

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1. Introduction

The most recent pavement design methods are based on Mechanistic-Empirical (ME) design principles that allow the estimation of pavement responses in terms of stresses, deformations, and deflections due to the imposition of traffic loads and the climatic conditions to which they are exposed and the use of these responses to calculate incremental damage over time (AASHTO, 2008). The ME design method considers three levels of precision in its input data. One of its main features is the possibility of using site-specific, regional, or default values related to levels 1, 2, and 3, respectively (Sabih and Tarefder, 2018). The structural response of a pavement depends on the level of design used. It is related to the mechanical properties of its constituent materials, which must be accurately and adequately characterized to improve the design precision. In the case of concrete pavement, the modulus of rupture (MOR) or flexural strength of concrete is one of the most important properties to measure because it has a significant effect on the potential for fatigue cracking of the slabs, transverse cracking, faulting of joints and impacts roughness (Sabih and Tarefder, 2016).

Level 1 is the most accurate based on concrete laboratory test data. The MOR of concrete can be obtained directly by applying the direct tension test. However, it presents challenges inherent to the loading mechanism, such as the adequate grip of the test specimen, the eccentricity of the load and the stress concentration at the ends of the specimen causing its fracture (Alhussainy et al., 2019); (Resan et al., 2020); (Sarfarazi et al., 2016); or indirectly by applying alternative tests such as the flexural bending test ASTM C78 (ASTM International C78/C78M, 2016)) and ASTM C293 (ASTM International C293/C293M, 2016) and the splitting tensile test (ASTM International C496/C496M, 2011), but the sensitivity to the procedures of preparation, handling and curing of the specimens produces variability of their results (National Ready Mixed Concrete Association, 2000). In addition, when the flexural bending test is used, standardized beams with typical dimensions of 150 by 150 mm in section and 600 mm in length are manufactured, configuring a heavy specimen exceeding 32 kg (assuming a concrete density of 2400 kg/m3) that can be damaged during handling and transport, as well as causing harm to the personnel who handle it.

Level 2 includes the default values based on correlation models, and level 3 corresponds to the design method's default values, the lowest precision. Flexural strength tests are not used to implement these design levels, so the MOR is obtained indirectly by estimating the compressive strength (fc') and converted using the proposed empirical equations. The above indicates that a pre-established relationship between compressive and flexural strength can be developed to evaluate concrete more conveniently and reliably. According to the National Ready Mixed Concrete Association (National Ready Mixed Concrete Association, 2000), flexural strength ranges from 10 to 15% of compressive strength depending on the mix ratio, type, size, and volume of coarse aggregates used. The Argentine Concrete Pavement Manual indicates that the compressive strength of concrete for pavements ranges from 7.14 to 8.30 times the flexural strength (ICPA, 2014). To apply levels 2 and 3 of the ME design method, the National Cooperative Highway Research Program (NCHRP 1-37A, 2004) recommends estimating the MOR of concrete as 0.79 fc´0.5 in MPa (9.5 fc´0.5 in psi). Other research and codes of standards have proposed various and numerous empirical correlation equations that relate the compressive strength and flexural strength of concrete. The ACI code (ACI 318, 2019) specifies the MOR as 0.62 fc´0.5. The New Zeland estándar NZS 3101 Concrete Structures Standard. Part 1:The Design of Concrete Structures, 2006 (NZS3101, 2006) suggests using Equation 0.60 fc´0.5 to calculate flexural strength. (Bhanja and Sengupta, 2005) proposed the MOR as 0.271 fc´0.81.

However, these equations give different results for the same material, creating uncertainty when estimating strength. A previous study concluded that, for a wide range of concrete strengths (35 to 100 MPa), these empirical relationships considerably underestimate the flexural strength and have a limited range of analysis of compressive strength values (Ahmed et al., 2014).

The considerations mentioned for design levels 1, 2, and 3 of the ME design methods suggest the need to investigate alternative methods in the laboratory to measure the flexural strength of concrete, which provides advantages and benefits over the tests currently being carried out. In addition, they can be implemented for monitoring, quality control, and acceptance or rejection of concrete for pavements. A previous study analyzed the possibility of implementing specimens of a smaller beam size than the standard ones in the laboratory and in the field to estimate the flexural strength of concrete and recommend changes in the AASHTO standards (Tanesi et al., 2013). The use of beams with a size of 102 x 102 x 356 mm with an approximate weight of 8.5 kg with a concrete density of 2400 kg/m3 was reported. It was concluded that using beams with smaller dimensions is a viable alternative to estimate the flexural strength of concrete and that the specimens are more accessible and safer for testing personnel to handle. However, a correction is required for its application so as not to underdesign the pavement structure. In recent years, the Semicircular Bending (SCB) test has gained more attention due to its simplicity, repeatability, and the good sensitivity of the results (Saha and Biligiri, 2015); (Zhang et al., 2017). The *test mode guarantees the application of pure tension on the underside of the specimen (mode I), allowing the flexural strength to be estimated by applying direct tension (Nsengiyumva and Kim, 2019); (Xiongzhou et al., 2021), which could better reflect the cracking mode of a concrete pavement when subjected to traffic-induced stresses. The test specimen can be manufactured in the laboratory or on-site or taken directly from the pavement (Lu et al., 2020). It is cut into discs, and later, it is again cut into two equal parts, resulting in two semicircular specimens. This simple way of obtaining the specimen results in more test samples that are easy to handle and store (Lu et al., 2021). Another advantage associated with the test specimen is that there is less concrete waste compared to standardized beams. The SCB test has been used in rock mechanics (Huang et al., 2020); (Kataoka et al., 2015); (Rashidi Moghaddam et al., 2018); (Wang, 2018) and for the characterization of the tensile strength and fracture resistance of asphalt mixtures (Chen and Solaimanian, 2019); (Du et al., 2021); (Jahanbakhsh et al., 2019); (Wang et al., 2021) but its use for the characterization of the mechanical properties of concrete has been limited.*

Given the variability in estimating the actual tensile strength of concrete reflected in the wide range proposed by the different equations obtained, this study proposes to evaluate the feasibility of applying the SCB test to measure flexural strength or MOR and properly correlate it with the flexural strength in beams and the compressive strength of cylinders of concrete for pavements and to be used in the control, quality assurance and acceptance or rejection of a concrete mix. To achieve this, an experimental study was carried out to characterize two concrete mixtures with 30 and 40 MPa strengths under cylindrical compression. The results obtained provide valuable evidence on the possible implementation of the SCB test to measure the MOR of concrete and propose empirical models that relate this property to the flexural strength measured in beams and the compressive strength measured in cylinders, which can be used to feed the database of levels 1 and 2 of the ME design method for concrete pavements. These models were statistically analyzed to determine their performance and goodness of fit.

On the other hand, these models could be used with more excellent reliability, at least locally, because they use materials from the region and thus reduce the uncertainty of the results by using empirical equations proposed in the literature with other types of specimens and tests. Furthermore, there is a need for more evidence of proposed correlation models that consider the results obtained through SCB specimen testing to analyze concrete's flexural and tensile strength for pavements.

2. Materials

2.1 Cement and mixing water

High-strength pozzolanic Portland cement with a 3.0 g/cm3 density was used for all study mixtures. The main characteristics of this cement are that it presents high initial and final strengths, high protection of steels, less heat of hydration, and inhibition of the harmful alkali/aggregate reaction. For the manufacture of the mixtures, it was decided to use tap water, as accepted by the NCh 1498 standard (INN, 2012).

2.2 Aggregates

The coarse and fine aggregates come from the crushing of river material. Sieve sizes separated the aggregates to reproduce best the gradation used to manufacture the concrete mixtures, as shown in (Figure 1). The distribution of the aggregate sizes is presented in (Table 1), and the physical properties measured in the laboratory are shown in (Table 2).

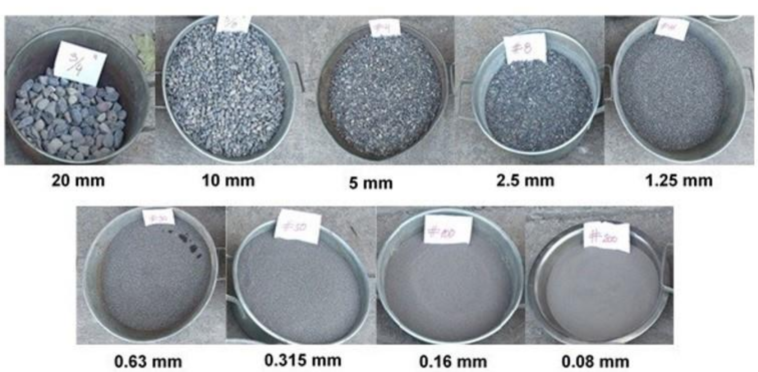

Figure 1. *Coarse and fine aggregates.*

Table 1. *Aggregate gradation.*

Sieve size (mm)	25	20	10	5	2.5	1.25	0.63	0.315	0.16	0.08
% passing	100	97	65	45	41	29	19	9	3	-

Table 2. Physical properties of aggregates.

Property	Sand	Gravel
Bulk density - Rodded	1.662	1.582
Bulk density - Loose	1.536	1.447
Bulk Specific Gravity SSD - Gs_{ssd}	2.668	2.558
Bulk Specific Gravity (dry) - Gs	2.618	2.504
Absorption (%)	2.62	2.18

3. Experimental Methods

3.1 Concrete mixing and curing procedure

Two concrete mixtures with different specified strengths were manufactured (G30 and G40), corresponding to mixtures with strengths measured in 30 MPa and 40 MPa cylinders, respectively. The concrete mixtures were dosed according to what is indicated by NCh 170 (INN, 2016), and the modified Faury method was used to obtain the proportions of the materials, the results of which are presented in (Table 3). The specimens made with the study mixtures were cured using an impermeable membrane and stored at a controlled temperature of 23 ± 2 °C until the test day, according to NCh1017 (INN, 2009a).

Table 3. *Mix proportions for concrete mixtures.*

		Materials (kg/m^3)			
Mix type	**w/c ratio**	**Cement**	**Water**	**Sand**	**Gravel**
G30	0.48	361.6	175.0	795.3	988.4
G40	0.43	403.3	175.0	758.8	988.4

3.2 Test methods for hardened concrete

Tests of cylinders' compressive strength, beams' flexural strength, and semicircular specimens' flexural strength were carried out. (Figure 2) shows the configuration of the specimens used in this research. All mixtures were tested at a controlled temperature of 20 ± 2 °C.

(a) (b) (c)

Figure 2. *Test setup for hardened concrete: (a) compressive strength, (b) flexural strength of beam, and (c) flexural strength of semicircular specimens.*

3.2.1 Compressive strength

Compressive strength tests were carried out according to NCh 1037 (INN, 2009b) using cylinders 150 mm in diameter by 300 mm in height. Three replicates were tested to calculate the compressive strength average. The tests were conducted in a servo-controlled compression machine with a speed of 0.35 N/m2/s and 7, 14, and 28 days after curing the specimens. The database for compressive strength consists of testing a total of 18 specimens for the two study mixes.

3.2.2 Beam flexural strength

The standard NCh 1038 (INN, 2009c) was used to measure the flexural strength of prismatic specimens of 150 mm by 150 mm in section and 600 mm in length. The tests were carried out in a universal machine applying load in the central third of the specimens at a speed of 0.016 N/m2/s with curing periods of 7, 14, and 28 days. Two replicas per mix were fabricated to measure the concrete's flexural strength, testing 12 specimens. This number of replicas is justified because the mixtures were prepared in a properly controlled environment, which promotes a relatively continuous and homogeneous material.

3.2.3 Bending strength of semicircular specimens (SCB)

Concrete cylinders of 150 mm diameter and 300 mm height were manufactured and cut into discs of 50 ±3 mm thickness. These discs were cut in half to obtain the SCB specimens. (Figure 3) shows the geometry of the SCB specimen. The dimensions used are higher than those indicated by (Kuruppu et al., 2014), who recommend a minimum diameter and thickness of 76 mm and 30 mm, respectively.

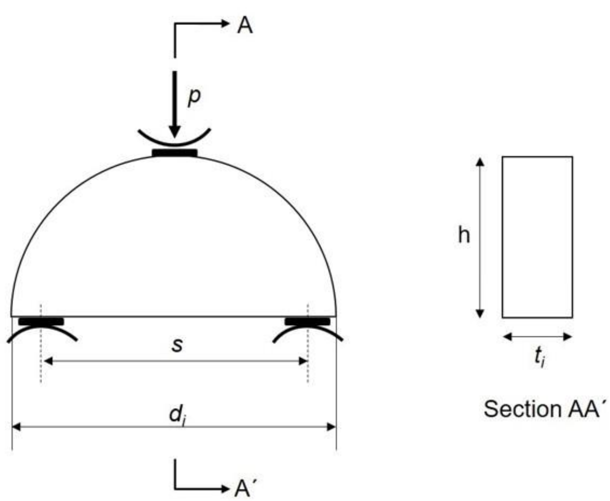

Figure 3. *SCB specimen geometry (di diameter of specimen, s distance between the two supporting cylindrical rollers, p monotonically increasing compressive load, ti thickness, and h high of specimen).*

The principle of this test consists of generating a bending load at three points in the test specimen by applying a compression force at the central point of the curvature of the semicircle, producing pure tension on the underside. Prepared SCB specimens were tested for a 5 mm/min loading rate. The specimen is placed on fixed supports spaced 120 mm apart. The tests were carried out 7, 14, and 28 days after the specimens were cured. A cylinder was made for each study mixture and curing period, obtaining a total of 10 semicircular specimens and a total of 60 test specimens. According to the utilized standard, the maximum bending tensile stress supported by the specimen is calculated using (Equation 1). It is also indicated that the results obtained in the SCB test are valid as long as the crack occurs in a zone ± 15 mm from the center of the load point, as shown in (Figure 4).

$$\sigma_{max} = \frac{4.263 \times p_{max}}{d_i \times t_i} \quad (1)$$

Where: σmax is the maximum bending tensile stress in MPa; pmax is the maximum force to produce the failure in N; di is the diameter of the specimen in mm; and it is the thickness of the specimen in mm.

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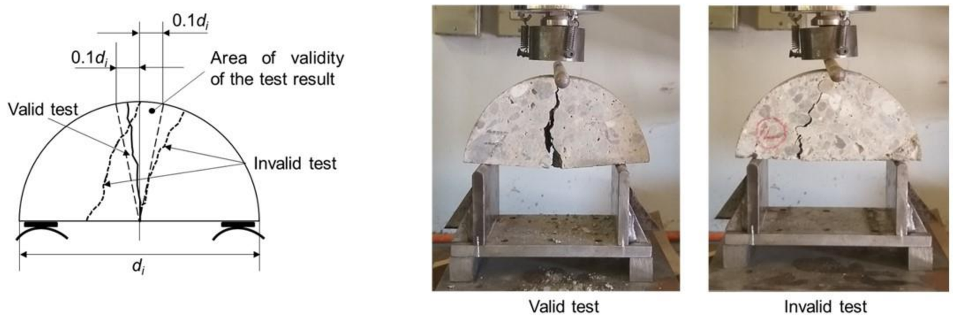

Figure 4. *SCB bending test validity zone.*

4. Results and Discussion

4.1 Properties of hardened concrete

The measured results of the compressive strength of the cylinder, the flexural strength of the beams, and the flexural strength of the semicircular specimens are presented in (Table 4).

Table 4. *Properties of hardened concrete*

Mix Type	Age (Days)	Flexural strength (Beam)			Flexural strength (SCB)			Compressive strength (Cylinder)		
		Mean	SD	%CV	Mean	SD	%CV	Mean	SD	%CV
G30	7	4,06	0,10	2,40	3,62	0,234	6,47	38,55	2,149	5,57
	14	4,44	0,16	3,57	3,89	0,127	3,27	40,87	1,516	3,71
	28	4,95	0,65	13,15	4,23	0,317	7,49	44,54	1,911	4,29
G40	7	4,34	0,05	1,22	4,07	0,321	7,87	42,80	3,965	9,26
	14	4,59	0,17	3,73	4,23	0,207	4,89	44,96	0,990	2,20
	28	5,41	0,03	0,51	4,71	0,209	4,45	49,23	0,349	0,71

SD = Standard Deviation
CV = Coefficient of Variation

The coefficient of variation (CV) values for the properties measured in the laboratory show a low variability in the data, mostly yielding values less than 10%, indicating homogeneity in the results. Higher strengths were obtained with the G40 mixture than the G30 mixture for all measured strengths. The literature indicates that the water/cement ratio (w/c) significantly impacts most properties of hardened concrete, particularly concrete strength and durability (Ayanlere et al., 2023). The w/c ratio affects the interfacial transition zone between the concrete and the aggregate, which controls the strength of the concrete (Wang et al., 2020). Reducing the w/c ratio increases the bond between the concrete materials, increasing their strength. Conversely, an increase in w/c ratio decreases the strength of the concrete. The results obtained in this research are consistent with the literature. The G40 mixes manufactured with a lower w/c ratio showed higher values of the measured resistances compared to the G30 mixes.

The SCB flexural strength values were obtained from the average of the valid tests (n), which ranged from 50% to 60% of the total of the specimens obtained for each cylinder, as seen in the boxplot of (Figure 5).

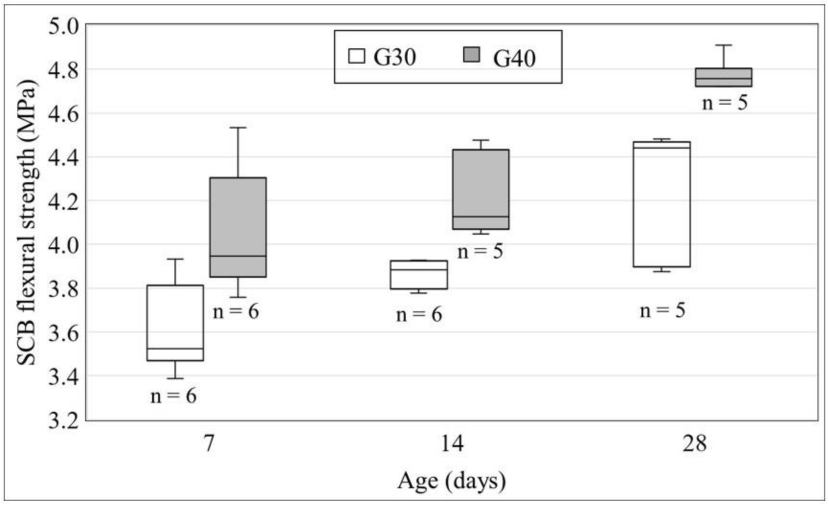

Figure 5. *Boxplot for SCB flexural strength.*

4.2 Regression analysis between strength properties of concretes

Compressive and flexural strength data were used to develop relationships between these concrete properties. A regression analysis was carried out, the main objective of which was to determine if it is possible to propose one of these models that adequately fits the experimental data and allows for predicting the flexural strength in standardized beams and the compressive strength of concrete based on its flexural strength measured in semicircular specimens applying the SCB test, regardless of the type of mixture manufactured. Statistical procedures were used to evaluate the goodness of fit and the performance of the proposed models. Pearson coefficient correlation (r), coefficient of determination (R2), Sum Square Error (SSE), Root Mean Square Error (RMSE), and the Mean Magnitude of the Relative Error (MMRE) of the predicted value concerning the experimental values were calculated. The lower the SSE and RMSE values are, the better the model is with its predictions. Values closer to zero indicate a better fit. According to (Ardiansyah et al. 2018), when the value of the MMRE indicator is less than 0.25, the model can be considered sufficiently accurate. (Equation 2) (Equation 3) and (Equation 4) describe these indicators. The percentage relative error (RE) was calculated using (Equation 5) to measure the measurement uncertainty for each model studied in this investigation.

$$SSE = \sum_{i=1}^{i=n}(x_i^* - x_i)^2 \tag{2}$$

$$RMSE = \sqrt{\sum_{i=1}^{i=n}\frac{(x_i^* - x_i)^2}{n}} \tag{3}$$

$$MMRE = \frac{1}{n} \times \sum_{i=1}^{i=n}\left(\frac{|x_i - x_i^*|}{x_i}\right) \tag{4}$$

$$RE\ (\%) = \frac{|x_i^* - x_i|}{x_i} \times 100 \tag{5}$$

*Where xi is the experimental value observed for each data i, x*i is the estimated value for each data i, and n is the total number of data.*

4.2.1 Relationship between compressive strength and SCB flexural strength

Three models were considered: the unique factor model, power model, and square root model, which are common in different country codes or recommendations. In this research, the three models that represent the two concrete mixtures studied are presented.

(Figure 6) shows the results of the compressive and SCB flexural strengths and their ratio for the different concrete curing periods. Error bars represent the standard deviation of the data. It can be seen that the ratio values are similar for the two mixtures, indicating independence of the curing time and the water/cement ratio. The average ratios found for the G30 and G40 mixtures were 10.55 and 10.53, respectively, with 10.54 being a representative value for both mixtures analyzed. The above suggests that one strength can be estimated from the laboratory measurement of the other using the unique factor model, as fc´=10,54 fs SCB

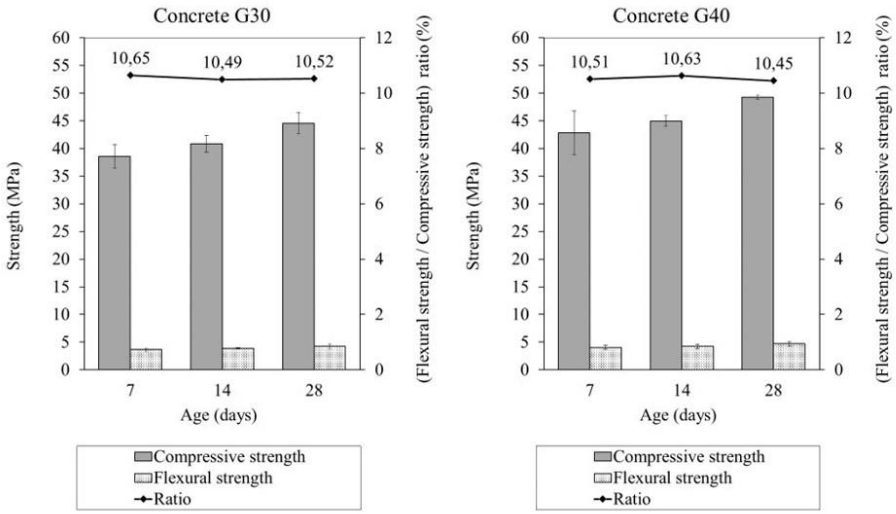

Figure 6. *Relationship between compressive and SCB flexural strengths*

(Table 5) shows the statistical indicators of the analyzed models. All the models present Pearson's correlation coefficients (r) higher than 0.95 and close to 1, indicating a strong positive association between the variables. (Table 6) compares the experimental data with the models developed for both concrete mixtures, and (Figure 7ª) and (Figure7b) present the fit of the proposed models. From a global data analysis, the power model is the most appropriate because it adequately represents the relationship between the variables showing the lowest values of SSE and RMSE. The normality (chi-square normality test), homoscedasticity (studentized Breusch-Pagan test), and independence (Durbin-Watson test) of this model were verified, obtaining p-values of 0.3999, 0.8051, and 0.2483 respectively, higher than the significance level of 0.05.

Table 5. *Regression models for the relationship of compressive strength and SCB flexural strength.*

Model	Equation	*r*	R^2	SSE	RMSE	MMRE
Power	$f_c^{'} = 11.317 f_{s\,SCB}^{\ 0.9499}$	0.998	0.995	0.316	0.229	0.004
Square root	$f_c^{'} = 21.395\sqrt{f_{s\,SCB}}$	0.997	0.995	15.629	1.614	0.031
Unique factor	$f_c^{'} = 10{,}54 f_{s\,SCB}$	0.998	0.995	0.510	0.292	0.006

Table 6. *Model comparison (f'c vs. fs SCB).*

Mix type	Age (days)	Experimental data (MPa)		Predicted compressive strength (MPa) (Model)		
		$f_{s\,SCB}$	$f'c$	Unique factor	Power	Square root
G30	7	3.62	38.55	38.17	38.42	40.71
	14	3.89	40.87	41.05	41.17	42.22
	28	4.23	44.54	44.61	44.56	44.01
G40	7	4.07	42.80	42.91	42.95	43.17
	14	4.23	44.96	44.60	44.55	44.01
	28	4.71	49.23	49.64	49.32	46.43

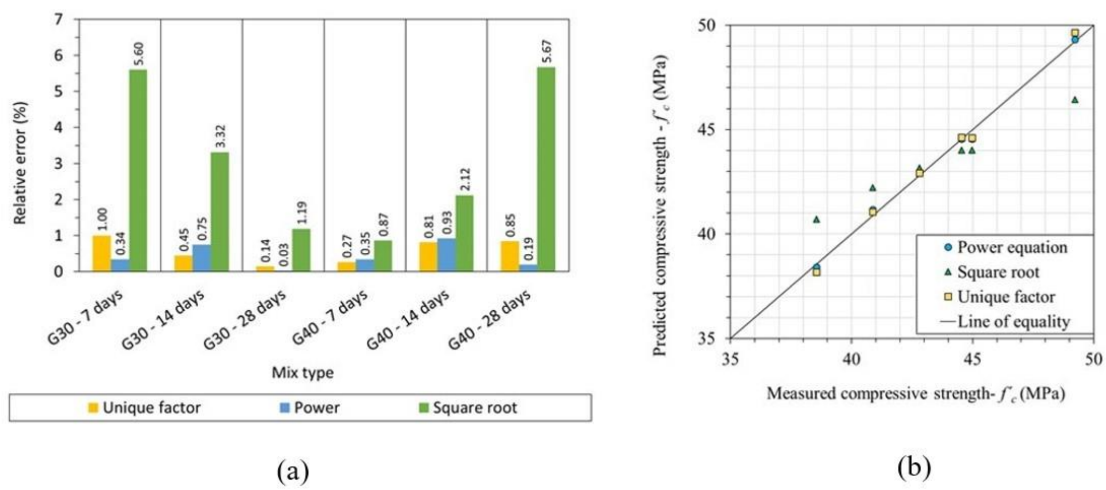

Figure 7. *Compressive strength prediction accuracy using regression models: (a) percentage relative error and (b) experimental compressive strength vs predicted compressive strength.*

On the other hand, it can be observed that the square root model presents the highest percentage of relative error, and the prediction values are the furthest from the equity line, suggesting that it is not an adequate model to predict the strength properties of concrete in this research. The above agrees with the results reported by (Ahmed et al., 2014), who indicated that the power model is more appropriate than the square root model to correlate compressive and flexural strengths.

4.3.1 Relationship between flexural strengths (Beam/SCB)

Unique factors and potential models were analyzed to establish a possible correlation between the variables. (Figure 8) shows the flexural strength results for beams and SCB specimens and their ratios for the studied curing periods. Error bars represent the standard deviation of the data. It can be observed that the beam/SCB flexural strength ratio shows a slight increase with the age of the specimens, tending to similar values at 28 days of curing. Despite the above, the averages obtained for the G30 and G40 mixtures are 1.14 and 1.10, respectively, with the average value being 1,12, representing the two study mixtures. Therefore, the empirical Equation that indicates the relationship between these properties can be stated as follows: fs beam=1.1213fs SCB.

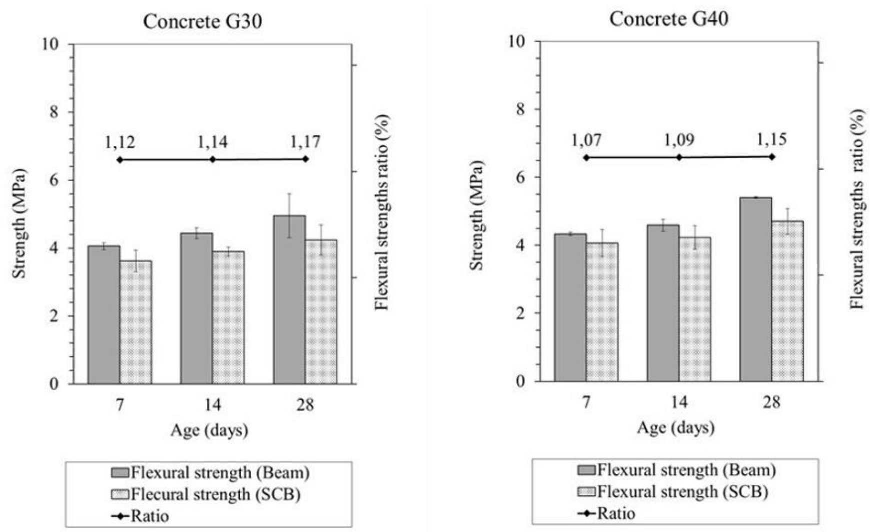

Figure 8. *Relationship between flexural strengths of beams and SCB specimens.*

(Table 7) presents the regression equations obtained for this study and the corresponding statistical analysis. It can be seen that the Pearson correlation coefficient values are higher than 0.93 for all the models analyzed, indicating a solid positive relationship and a good fit between the variables. In addition, they can be considered sufficiently accurate and reliable as they present MMRE values lower than 0.25. (Table 8) compares the experimental data with the two models developed for both concrete mixtures. According to (Figure 9ª) and (Figure 9b), both models can accurately predict the flexural strength measured in beams using semicircular beams.

Table 7. *Regression models for the relationship between flexural strengths.*

Model	Equation	r	R^2	SSE	RMSE	MMRE
Power	$f_{s\,beam} = 0.9975 f_{s\,SCB}^{\;1.0823}$	0.940	0.884	0.129	0.147	0.028
Unique factor	$f_{s\,beam} = 1.1213 f_{s\,SCB}$	0.943	0.888	0.138	0.152	0.028

Table 8. *Model comparison (fs beam vs fs SCB).*

Mix type	Age (days)	Experimental data (MPa)		Predicted compressive strength (MPa) (Model)	
		$f_{s\,SCB}$	$f_{s\,beam}$	Unique factor	Power
G30	7	3.62	4.06	4.06	4.02
	14	3.89	4.44	4.37	4.35
	28	4.23	4.95	4.75	4.75
G40	7	4.07	4.34	4.57	4.56
	14	4.23	4.59	4.74	4.75
	28	4.71	5.41	5.28	5.34

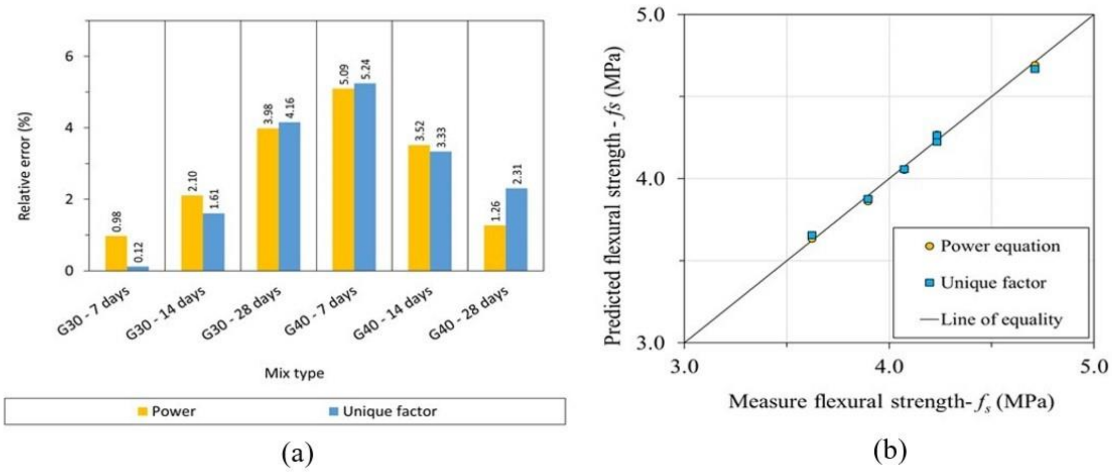

Figure 9. *Beam flexural strength prediction accuracy using regression models: (a) percentage relative error and (b) experimental flexural strength vs predicted flexural strength.*

Three critical data diagnostic checks (normality, homoscedasticity, and independence) were performed to validate the use of the power model. The results show p-values of 0.8445, 0.8859, and 0.7432 applying the Pearson chi-square normality (normality), studentized Breusch-Pagan (homoscedasticity), and Durbin-Watson (independence) tests, respectively. For all cases, the p-value is more significant than a significance level of 0.05, indicating that the residuals have a normal distribution, constant variance, and independence.

5. Conclusions and recommendations

An experimental laboratory study was carried out to determine the feasibility of using the SCB test to estimate the flexural strength measured in beams and the compressive strength of cylinders by obtaining correlation models. According to the results and the discussion, the following conclusions can be drawn:

- *The statistical analyses of the goodness of fit and performance of the proposed models demonstrated the feasibility of using the SCB test to measure and estimate the flexural strength of concrete and relate it to the flexural strength of beams and the compressive strength of cylinders. These models could feed levels 1 and 2 of the ME design method of concrete pavement.*
- *Pearson's correlation coefficients (r) higher than 0.93 were obtained for all the models analyzed, indicating a positive association between the variables. It was found that the power model is the most appropriate to relate the compressive strength of concrete with its flexural strength measured in semicircular specimens. In the case of the relationship of the flexural strength of concrete, the two proposed models, unique factor and power, are suitable to predict the flexural strength in beams from the results obtained from flexural tests of semicircular beams.*
- *According to the unique factor models, the beam flexural strength and cylindrical compressive strength are 1.12 and 10.5 times greater than the flexural strength measured in the SCB test. These coefficients allow calculating some related variables quickly and with a good approximation.*
- *Both the application of the SCB test and obtaining the specimens are simple and present competitive advantages with the standardized beam currently regulated and typically used. The semicircular specimens are smaller and lighter, allowing more samples to be analyzed. These advantages facilitate the logistics of obtaining the test specimens, their handling, and testing. This test is promising for quality control of concrete mixtures for pavements.*
- *It is of utmost importance to carry out more tests to correlate the compressive strengths and flexural strengths of beams and SCB beams. This will significantly strengthen the database, allowing the correlations to be adjusted, giving them greater reliability and certainty.*
- *Further studies that include more water/cement ratios, greater ranges of concrete strengths, and different types of cement, including additives and other gradations, are recommended. These studies will strengthen the models proposed in this research, calibrate their use in a broader range of applications, or propose other models that fit better. Further investigation of the effect of SCB thickness on the mechanical properties of hardened concrete and its repeatability, in addition to its relationship to maximum aggregate size, is required, especially when the maximum aggregate size may be as large as 37.5mm.*

• Finally, it is recommended to vigorously investigate some of the factors that could influence the validity and variability of the SCB test, such as irregularities in the cut of the specimens, the presence of larger aggregates compared to the dimensions of the specimen that could influence its fracture, and the possible segregation of the specimens resulting from the cylinder ends.

6. Disclosure statement

The authors reported no potential conflict of interest.

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