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Study of the importance of core cylinders in the monitoring of the compressive strength of the concrete

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Abstract. The fulfillment of the resistance to the compression as a fundamental property of the concrete, during the process of execution of a work, constitutes great work for all the factors that intervene in the constructive process. The same concrete cannot be suitable for all structures, many times when using the same mixture, failures can occur with relevant damage. This situation frequently occurs at construction sites and resources must be allocated to repair structures to guarantee their useful life. This research aims to focus on the importance of performing compressive strength tests and taking enough samples for reliable results. For this purpose, 36 concrete test samples were taken from different structural elements of work according to the requirements of the standard. Subsequently, the laboratory tests were carried out at 7, 14, 28, and 56 days with a control cylinder, to analyze the behavior of each sample according to the concrete specifications requested for the different types of structures. From the results obtained, we could observe the differences in the percentages achieved by each of the samples and the type of failure presented, in turn, the importance of the control cylinder, for the monitoring of the strength of the concrete.

1. Introduction

Concrete is the most used construction material in the world, manufactured by man, occupies the second place after the water in its use, more than six thousand tons are produced annually, for its manufacture raw materials are used as cement, sand, and aggregates, the aggregates are inert and rigid materials that form a granular skeleton, constitute approximately 65% to 75% of the total volume of concrete, besides, water, additives that represent the remaining volume. New materials have been incorporated into the concrete, among them minerals, chemicals, fiber; therefore, the concrete is a heterogeneous product and its mechanical behavior [1].

In concrete setting times, several influencing factors affect this process such as water-cement ratio, cement type, chemical additives, additive addition time, mixing, and temperature, which is one of the most influential in the development of the resistance of the mixture, the resistance increases at high temperatures and must be kept uniform in the setting process to avoid fractures by a thermal shock, because in curing times there is a release of heat energy that can generate losses of heat.

To meet the technical requirements related to the situation in which the concrete was used, it is necessary to define some properties related to its cool and hardened state and it is, therefore, necessary



that of the appropriate proportion of its components [1]. It is increasingly important to determine the resistance to the impact load and in turn to determine the strength properties of cement-based materials at an experimental level before they can be considered for use in construction [2].

A lot of times specialized machinery and tools are needed when performing the emptying and a skilled workforce for the sampling of the cylinders, which is very involved in the result, making it necessary to use a control cylinder which will serve to corroborate the strength in case the required strength is not achieved after testing at 7, 14 and 28 days is not able to obtain the required strength.

Cylindrical cores for compression tests at 56 days are extracted with a probe equipped with diamond drills when the concrete has acquired sufficient strength so that during the cut the adhesion between the aggregate and the paste is not lost. In all cases, the concrete must have at least 14 days of placement.

The extraction must be done perpendicular to the surface, taking care that in the area there are no joints, nor are they near the edge. The compressive strength obtained when testing a tell-tale shall be corrected concerning the last test performed, and account shall be taken of the differences between the tell-tales and test-pieces in aspects such as age, dimensions, the state of saturation at the time of the test, the presence of reinforcing steel inside and the fact that the controls are subjected to the aggressive extraction process. Differences associated with material properties, such as exudation, should also be corrected. [3] by carrying out a correct sampling and paying attention to the mixtures of the concrete and the cycles through which it passes.

Various causes can motivate the evaluation of the concrete in the structure. In works under construction, it may be due to low results of resistance to compression obtained in the test pieces at the age of 28 days; in finished works, it may be associated with the presence of pathologies in the structure, to the change of use (an increase of the load), among others. [3], resistance is often influential on surface wettability.

Concrete surfaces are one of the substrates on which the mortar coating can be applied, which is widely used in the building. Frequently, when there are incompatibilities between the substrate and the mortar, the durability of the coating system can be compromised, causing pathological manifestations such as detachments and displacements [4].

Compressive strength can be defined as the maximum measured strength of a concrete specimen under axial compression load and is expressed as force per unit cross-sectional area [5], a more in-depth study of the influence of the addition of minerals is necessary to find the conditions where the auto compaction and the compressive strength of a mixture are simultaneously improved by looking for correlations between these [6].

The requirements to perform the test for resistance to simple compression of the test pieces are The height/diameter ratio from 2.5 to 3.0, Diameter greater than 10 times the maximum grain size of the rock (Diameter not less than 50 mm -Tolerance of the test piece faces). Such requirements are important because in some cases they are very difficult to achieve or make the trial very costly [7].

The most widely used aggregates in the world come from natural deposits formed in riverbeds or floodplains and are relatively inexpensive as they generally do not require any industrial process. However, some regions lack rivers, where source rocks are extracted which give rise to aggregates directly from the Earth's crust, using explosives and/or excavating machines; these rocks are subsequently fragmented by mechanized crushing. Such aggregates are called shredded aggregates and require a screening and grading process for particulates [8]. For more than 70 years in American practice, the most widely used test for concrete has been the standard cylinder compression test. The

test method is relatively easy to perform in terms of sampling, specimen preparation, and force determination, when performed correctly, this test has a low variation of resistance within the laboratory, and therefore easily lends itself to be used as a standard. The compressive force thus obtained is modified by specified factors and used to verify the nominal forces of structural members. This force value is therefore an essential parameter in design codes.

The test is mainly used as a basis for quality control to ensure that project requirements are secured. It is not intended to determine the strength on the ground of the concrete, since none of the effects of placement, compaction, or curing are considered. Traditionally, a certain measure of the strength of the concrete in the structure has been obtained using in situ cured cylinders. These supposedly heal on-site under the same conditions as the concrete in the structure. However, the measured strength of the cylinders cured in situ is often significantly different from the strength on the ground because it is difficult, and often impossible, to have an identical indentation, compaction, and have the same curing conditions for concrete in cylinders as for concrete in structures. In-situ cured specimens are also prone to errors due to incorrect address or inadequate storage, which can generate inaccurate data for critical operations.

The purpose of on-site testing is to estimate concrete characteristics in the structure. The desired characteristic is very often compressive force. To estimate strength, it is necessary to have a known link between the in-situ test result and the strength of the concrete. For a running construction, this link is generally established empirically in the laboratory [9], Axial compression strength is the greatest of the strengths of concrete and its most appreciated mechanical attribute; however, stress resistance is also important as it is required to predict cracks in this material [10].

The materials as aggregates are made granulometry, to determine that they are suitable in the preparation of the mixture; another topic is the composition, in percentage, of the different sizes of aggregate in a sample, this proportion is usually indicated from larger to a smaller size, by a figure representing, by weight, the partial percentage of each size that passed or was retained in the different sieves that are compulsorily used for such measurement.

The granulometry and maximum size of the aggregate affect the relative proportions of the same in the designs of mixtures, as well as the requirements of water and cement, impacting the resistance, workability, pumping capacity, economy, porosity, shrinkage, and durability of the concrete. It is known that all classical methods of mixing design such as Fuller, Bolomey, O'Reilly, etc., are based on the granulometry of aggregates [11]. The addition of fine materials improves concrete strength providing the workability must be controlled. [12].

The objective of this study is to demonstrate the methodological process to determine the resistance of a mixture, through tests of resistance to compression, which will be carried out according to what is established by the ASTM C39 Standard, considering all the factors involved in the process from sampling to the test where the resistance reaches at least 100%. which are analyzed at different times, in the case of non-compliance, a control cylinder is tested at 56 days of age to corroborate the strength of the structure, essay of great importance, and that gives a part of tranquility in the work that is being carried out.

2. Experimental procedure

The concrete mixture was initially prepared, in a mixing truck with a drum from 70 to 100 rpm and at a speed from 6 to 18 rpm. This mixture was designed with a resistance of 4000 psi, it was sent to the discharge, which was made 30 minutes after the preparation of the mixture, 6 samples are taken from each structure, 2 samples during the discharge process, one at the start and the other sample after 15 minutes, and then tested in the laboratory to test their resistance at the age of 7, 14, 28 and 56 days. Two samples were tested per age and the average obtained from the two samples was the result of resistance.

In the case of two of the samples where the required strength was not achieved, samples of hardened concrete were taken and extracted directly from the structure, this was done 56 days after the first sampling, to corroborate compliance.

For the compression test of the concrete, the mixture was prepared with a resistance of 4000 psi, then cylindrical test specimens of 6" X 12" were molded, the curing process is performed according to the ASTM C31 standard, finally, they were stored in the field until the concrete reached a solid-state, at a temperature of 24 C, and transported to the laboratory for the next 48 hours; other properties of fresh concrete were tested such as temperature, settlement, density, and air content, the settling test was conducted following ASTM C 139, in the laboratory the cylinders were subjected to the compression strength test, analyzing their percentage of advance according to the age of the concrete, and the type of fractures or faults that they presented at the time of testing, This was performed per the ASTM C39 standard test for compressive strength of cylindrical specimens of concrete. After obtaining the results released by the certified laboratory, we were able to observe that several of the samples did not meet their required resistance at 28 days, therefore, it is necessary to analyze the control cylinder at 56 days; The results obtained show several types of failures, among which we find the transverse failure one of the most common in this type of tests.

2.1 Materials and Methods

Various types of materials were used for the samples taken fine sand, coarse sand of different sizes, Structural Cement, water, and additive required for the type of concrete of 4000 psi that was produced. Among the tests carried out, the settlement was considered, which was carried out using the Abrams cone method.

For the materials used as fine and coarse sand are performed the granulometry and absorption density tests, with which we obtain that they are suitable materials, to achieve the required strength compliance 4000 psi. See Table 1 granulometry and 2 characterizations for fine agglomeration, see Table 3 coarse aggregate granulometry and Table 4 characterization for coarse agglomeration.

Table 1. Fine sand granulometry used.

Sieve	Mass		Percentage		Limits NTC 174. 2018	
	Withheld	Percentage	Ret	Percentage	Min	Max
Inches	(g)	(%)	Withheld	Accumulated	Pass (%)	
1/2"		0.0%	0.0%		100.0%	100%
3/8"	3.9	0.3%	0.3%		99.7%	100%
N° 4	63.9	5.20%	5.6%		94.4%	95%
N° 8	92.5	7.6%	13.2%		86.8%	80%
N° 16	84.0	6.9%	20.1%		79.9%	85%
N° 30	158.4	13.0%	33.1%		66.9%	25%
N° 50	404.9	33.4%	66.5%		33.5%	5%
N° 100	309.8	25.5%	92.0%		8.0%	0%
N° 200	57.6	4.7%	96.8%		3.2%	0%
Mondo	0.1	0.0%	96.8%		3.2%	3%
Masa						
Total	1174.8	96.8%				

Table 2. Density and absorption of the fine aggregate.

MASS OF THE SAMPLE SSS, Mass (g)	503.4	503.4
MASS OF THE DRY SAMPLE, MS (g)	495.8	495.8
PYCNOMETER MASS WITH SAMPLE AND WATER (g)	974.5	974.5
PYCNOMETER MASS FILLED WITH WATER (g)	663.4	663.4
NOMINAL DENSITY (g/cm ³),23 C	2.68	2.68
BULK DENSITY (g/cm ³),23 C	2.57	2.57
DENSITY SSS (g/cm ³),23 C	2.61	2.61
PERCENTAGE OF ABSORPTION (%)	1.5	1.5

Table 3. Granulometry of coarse sand used.

Sieve	Mass Withheld (g)	Percentage Withheld (%)	Percentage		Limits NTC 174. 2018	
			Ret Accumulated (%)	Pass (%)	Min	Max
1 1/2"			0.0%	100%	100%	100%
1"	89.4	1.6%	1.6%	98.4%	100%	100%
3/4"	741.9	13.1%	14.7%	85.3%	90%	100%
1/2"	2381.7	42.0%	56.7%	43.3%	20%	55%
3/8"	1131.9	20.0%	76.6%	23.4%	0%	15%
N°4	1443.0	20.2%	96.8%	3.2%	0%	5%
N°8	18.1	0.3%	97.1%	2.9%	0%	0%
N°16	3.0	0.1%	97.2%	2.8%	0%	0%
N°30	3.8	0.1%	97.2%	2.8%	0%	0%
N°50	5.2	0.1%	97.3%	2.7%	0%	0%
N°100	7.2	0.1%	97.5%	2.5%	0%	0%
N°200	9.3	0.2%	97.5%	2.4%	0%	0%
Mondo	134.5	2.4%	100.0%	0.0%		
Masa Total	5669.0	100.2%				

Table 4. Density and absorption of coarse aggregate

MASS OF THE DRY SAMPLE, MS (g)	3371.5
MASS OF THE SATURATED AND SUPERFICIALLY DRY SAMPLE (g)	3496.5
SAMPLE MASS IMMERSSED IN WATER (g)	2113.5
NOMINAL DENSITY (g/cm ³),23 C	2.67
BULK DENSITY (g/cm ³),23 C	2.43
SATURATED AND SUPERFICIALLY DRY DENSITY (g/cm ³) 23C	2.52
PERCENTAGE OF ABSORPTION (%)	3.7

The fine and coarse aggregate is always baked to constant mass at a temperature of $110 \pm 5^\circ\text{C}$ before being immersed in water for 24 hours. After this, calculations were made to determine the unit mass values of the aggregates. The results are presented in Table 5.

Table 5. Determination of the unit mass of the aggregates used.

COMPACT UNIT MASS BY TAMPING	
	SAND
SAMPLE MASS + MOULD (g)	6550
MOLD MASS (g)	1800
NET MASS OF SAMPLE (g)	4750
MOLD VOLUME (cm ³)	2807
UNIT LOOSE MASS (kg/m ³)	1690
	UNIT LOOSE MASS
SAMPLE MASS + MOULD (g)	6100
MOLD MASS (g)	1800
NET MASS OF SAMPLE (g)	4300
MOLD VOLUME (cm ³)	2807
UNIT LOOSE MASS (kg/m ³)	1530

2.2 Methodology

2.2.1. Settlement test.

To the newly mixed concrete on site, the respective samples were taken to verify the fulfillment of their design parameters. In this way, to verify its consistency condition, the settling test was carried out in a fresh state. To analyze the manageability of the concrete it is necessary to be governed under the ASTM C31, this is fundamental at the time of the acceptance or rejection of the mixture. The results for this trial were favorable, meeting a settlement value of 5 ± 1 .

Figure 2 illustrates the procedure carried out for conducting the settling test for the concrete prepared for this investigation.



Figure2. Illustration of the settlement test procedure.

2.2.2. Compressive strength tests:

The samples were carried out in a certified laboratory, with the respective tests of compressive strength. The test machine, properly calibrated and certified by the laboratory, was used and the tests were carried out according to the ASTM C39 standard

3. Analysis of Results

After submitting the cylinders to the tests of resistance to compression, it is evident in sample 1 of Table 6 that after 14 days their resistance reaches 102 %, this resistance is average of the % obtained, in the two cylinders tested. No further tests are performed for these samples because the required strength is achieved.

In sample 2 of Table 7, we can show that trials are performed until the age of 28 days when the mixture reaches 113% of the resistance. In samples 3 and 4 of Table 8 and 9 respectively, the control cylinder was tested, at 7, 14, and 28 days, yielding resistances below 100%, so we used the control cylinder and analyzed at the age of 56 days, and check the resistance.

After analyzing the control, it is observed that the resistance is achieved with 128% for sample 3 and 103% for sample 4, demonstrating the importance of the control cylinder test, and in turn giving complete reliability to the structure.

Tabl3 6. Resistance 14 days

SAMPLE	1		
Dimension	6"x12"		
Age	psi	%	%
7	2.79	69	70
7	2.81	71	
14	3.6	100	102
14	4.17	105	

Table 7. Resistance 28 days

SAMPLE	2		
Dimension	6"x12"		
Age	psi	%	%
7	2.81	71	73
7	2.86	74	
14	3.12	78	84
14	3.55	89	
28	4.6	115	113
28	4.37	110	

Table 8. Resistance for control cylinder

SAMPLE 3			
Dimension	6"x12"		
Age	psi	%	%
7	1.5	40	41
7	1.9	42	
14	1.9	42	45
14	2.2	47	
28	3.55	89	88
28	3.44	86	
56	4.68	125	128
56	5.41	131	

Table 9. Resistance for control cylinder

SAMPLE 4			
Dimension	6"x12"		
Age	psi	%	%
7	2.2	47	45
7	1.9	42	
14	3.12	78	84
14	3.55	89	
28	3.6	90	91
28	3.62	91	
56	4.47	107	103
56	3.93	98	

4. Conclusions and Recommendations

From the results of this research, we can conclude the importance of compressive strength. In each of the samples taken, we show the evolution of resistance for the days. Two of the four samples failed to reach their maximum percentage at 28 days, having the need to make use of a witness cylinder of hardened concrete, to have the follow-up of the behavior, and checking that, when 56 days, achieved a positive result, achieving the required resistance. Laboratory tests represent a cost subject to regulatory procedures that ensure their full application and compliance with specifications.

Concrete is a product developed technically and under strict quality controls. If we carry out the tests with poor sample management, the results will give rise to doubts that will not benefit the structure in terms of quality and durability; and it is precisely this that leads us to carry out tests with witnesses, which are of great help in decision-making, with their analysis and review give continuity to the constructive process.

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References

- [1] J. F. Moretti, C. R. Minussi, J. L. Akasaki, C. F. Fioriti, J. L. P. Melges, and M. M. Tashima, "Previsão do módulo de elasticidade e da resistência à compressão de corpos de prova de concreto por meio de redes neurais artificiais," *Acta Sci. - Technol.*, vol. 38, no. 1, pp. 65–70, 2016, doi: 10.4025/actascitechnol.v38i1.27194.
- [2] S. K. Sateshkumar, P. O. Awoyera, T. Kandasamy, S. Nagaraj, P. Murugesan, and B. Ponnusamy, "Impact resistance of high strength chopped basalt fibre-reinforced concrete," *Rev. la Constr.*, vol. 17, no. 2, pp. 240–249, 2018, doi: 10.7764/RDLC.17.2.240.
- [3] A. F. Domínguez and J. J. H. Albear, "Factores de corrección a la resistencia a compresión de testigos de hormigón. Análisis crítico de las normas cubanas e internacionales," *Inf. la Constr.*, vol. 69, no. 547, pp. 1–9, 2017, doi: 10.3989/id53723.
- [4] E. Cappelari, C. Giodani, S. T. H. Dapper, and A. B. Masuero, "Influence of concretes compressive strength on superficial wettability," *Rev. Mater.*, vol. 25, no. 1, 2020, doi: 10.1590/s1517-707620200001.0907.
- [5] R. Chaupis and M. Angel, "UNIVERSIDAD SAN PEDRO FACULTAD DE INGENIERIA Resistencia a compresión de un concreto $f'c = 210 \text{ kg/cm}^2$ al sustituir al cemento en 4 %, 6 % y 8 % por cascara de huevo," 2019.
- [6] J. A. Correa-Yepes, N. Rojas-Reyes, and J. I. Tobón, "Effect of fly ash and silica fume on rheology, compressive strength and self-compacting in cement mixtures," *DYNA*, vol. 85, no. 206, pp. 59–68, 2018, doi: 10.15446/dyna.v85n206.68960.
- [7] M. Galván-Ceballos and I. A. Restrepo, "Resistance correlation with compression uniaxial effective humidity and porous rocks," *Dyna*, vol. 83, no. 198, pp. 9–15, 2016, doi: 10.15446/dyna.v83n198.53151.
- [8] Abazid, Mohammad, Hüseyin Gökçekuş, and Tahir Celik. "Implementation of TQM and the Integration of BIM in the Construction Management Sector in Saudi Arabia Validated with Hybridized Emerging Harris Hawks Optimization (HHO)." (2021).
- [9] M. Antonio, "RESISTENCIA A LA COMPRESIÓN ULTRASONIDO Marco Antonio Céspedes García," p. 112, 2003.
- [10] E. I. Moreno and J. Varela-rivera, "Resistencia a Tensión Del Concreto Tensile Strength of Concrete With High Absorption Limestone Aggregate," vol. 8, 2016, [Online]. Available: <http://www.scielo.org.mx/pdf/ccid/v8n1/2007-3011-ccid-8-01-00035.pdf>.
- [11] J. Toirac Corral, "Caracterización granulométrica de las plantas productoras de arena en la República Dominicana, su impacto en la calidad y costo del hormigón," *Cienc. Soc.*, vol. 37, no. 3, pp. 293–334, 2012, doi: 10.22206/cys.2012.v37i3.pp293-334.
- [12] A. Alfeehan, M. Mohammed, M. Jasim, U. Fadehl, and F. Habeeb, "Utilizing industrial metal wastes in one-way ribbed reinforced concrete panels," *Rev. Ing. Constr.*, vol. 35, no. 3, pp. 246–256, 2020, doi: 10.4067/S0718-50732020000300246.