Respuestas, 25 (S2), January - April 2020,, pp. 46-52, ISSN 0122-820X - E ISSN: 2422-5053

Respuestas
Journal of Engineering Sciences

RESPUESTAS

Original Article https://doi.org/10.22463/0122820X.1832

Concrete slump with partial replacement of cementitious material by fly ash and hydrated lime

Asentamiento en concretos con reemplazo parcial de material cementante por ceniza volante y cal hidratada

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How to cite: O. Hurtado-Figueroa, C. Bonilla-Granados, J.A Cardenas-Gutierrez "Concrete slump with partial replacement of cementitious material by fly ash and hydrated lime". *Respuestas,* vol. 25, no. S2, pp. 46-52, 2020.

Received on September 25, 2019; Approved on December 10, 2019

Keywords:

Cementitious material,
Concrete mixes,
Slump

ABSTRACT

It was determined the settlement, with the help of the Abrams Cone, of 3 mixtures of conventional concrete with weight differences in the incorporated cementitious material whose variation contemplates the 300, 350 and 400 Kg/m3 for each mixture. The classification of the materials used for the elaboration of the concrete mixtures was made by means of the standardized methods in the Colombian Technical Norms and the Tests of the National Institute of Roads. Based on the conventional mixtures elaborated, an equal number of experimental mixtures were carried out that counted as a common characteristic the replacement of 40% of the weight of the cementitious material by 70% of fly ash, residual material of the Termoelectrica Termotasajero located in the municipality of San Cayetano Cúcuta Colombia and 30% of hydrated lime coming from the Municipality of Malaga in the department of Santander of the same country. The experimental mixtures, in addition to their variable in the weight of the incorporated cementitious material, had an additional variable which consisted of the % of water in relation to the weight of the cementitious material with which its reveniment was evaluated with the inclusion of 60, 65 and 70% of the weight of the material by water. After a comparative analysis of the data from the mixtures, the viability of including fly ash and hydrated lime in mixtures that include 350 and 400 kg of cementitious material per m3, together with 65 and 70% of water in relation to the weight of the same material, was concluded.

Palabras clave:

Asentamiento,
Material cementante,
Mezclas de concreto

RESUMEN

Se determinó el asentamiento, con la ayuda del Cono de Abrams, de 3 mezclas de concreto convencional con diferencias de pesos en el material cementante incorporado cuya variación contemplo los 300, 350 y 400 Kg/m3 para cada mezcla. La clasificación de los materiales utilizados para la elaboración de las mezclas de concreto fue realizado mediante los métodos estandarizados en las Normas Técnicas Colombianas y los Ensayos del Instituto Nacional de Vías. Con base en las mezclas convencionales elaboradas, se realizaron igual número de mezclas experimentales que contaron como característica en común el reemplazo del 40% del peso del material cementante por un 70% de ceniza volante, material residuo de la Termoelectrica Termotasajero ubicada en el municipio de San Cayetano Cúcuta-Colombia y un 30% de cal hidratada proveniente del Municipio de Málaga en el departamento de Santander del mismo país. Las mezclas experimentales además de su variable en el peso de material cementante incorporado contaron con una variable adicional la cual consistió en el % de agua con relación al peso del material cementante con los cuales se evaluó su revenimiento con la inclusión del 60, 65 y 70% del peso del material por agua. Luego del análisis comparativo de los datos arrojados por las mezclas se concluyó la viabilidad de la inclusión de la ceniza volante y la cal hidratada en las mezclas que contemplen 350 y 400 Kg de material cementante por m3, junto al 65 y 70% de agua con relación al peso del mismo material.

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Introduction

Since its invention, concrete has been the essential construction material in civil engineering works due to its versatility and economy, a characteristic that makes it the most common construction material [1]. Today, it is considered the second most used material after water, with almost three tons used annually by each person on earth [2].

The economic growth of most countries leads to significant percentages of their domestic budget being allocated for planning and execution of infrastructure works, activities that considerably increase the demand for construction materials[3]. In recent decades, the increase in the use of concrete has led to an excessive consumption of natural stone aggregates (NSA), which constitute approximately 70% of the total volume of the mixture [4-5], a characteristic that ratifies the classification of this industry as one of the productive areas with the greatest environmental impact [6] due to the incessant exploitation of natural resources (NR) necessary for the development of a large part of its processes.

This constructive activity that is increasing in parallel with the growing world population, which, according to UN studies, is estimated at approximately 9700 million inhabitants in the next 30 years [7], awakens the alarms of the different sectors, especially the environmentalist, who incessantly seek joint solutions to solve the ecological crisis that is approaching. Fortunately, the scientific sector in recent years has been developing research projects aimed at mitigating the use of NR and the reduction or elimination of polluting residues in the processes inherent in the development of the various civil engineering works. Thus, the implementation of ecological materials with low environmental impact in engineering works becomes the premise for professionals in this field, who have the task of innovating designs, techniques and construction materials in their next construction works [8].

The investigations carried out on concrete, which focus on the materials that compose it, have promoted the use of non-conventional materials in partial or total replacement of both its NSA and the cementitious material (CM) [9]. Research results that lead to the evolution of concrete leading to the status of sustainable material respectful of ecosystems in the interest of environmental protection and the conservation of NR [10].

Concrete production is a multi-stage process with many important factors[11], which in addition to continuing with the objective of the construction industry to ensure the well-being of the inhabitants by reducing CO2 emissions and reducing the use of NR [12], must be concerned with maintaining the physicochemical characteristics and mechanical properties that position it as a reliable material for use in various construction projects. The flagship property of concrete is its resistance to compressive stresses, a characteristic that provides reliability for its application in engineering works, as well as its runoff or slump property that makes more efficient the workability of the mixture for disposal in projects that require some type of special condition in its pouring or final strength.

The physicochemical properties and the particle size of the non-conventional material that is intended to replace those traditionally used in the elaboration of concrete mixtures, are a key piece for initiating the development of research. This is how the component to be replaced, fine NSA, coarse NSA, water and CM are identified, together with their % of substitution [13].

Fly ash (FA), a by-product of the combustion of coal and hydrated lime (HL), are among the most studied materials in the different investigations for the partial substitution of CM in concrete mixtures [14] due to their physicochemical characteristics that make them viable to substitute CM in percentage terms.

The present research work shows the data obtained in the Slump test of three types of experimental mixtures (EM) whose variable (1) consisted in the weight of CM used for the elaboration of 1m3 of concrete (300, 350 and 400Kg). And as a variable (2) the % of the ratio water cementitious material (R-w/cm), (60, 65 and 70%) was contemplated. The EM presented as a common characteristic the partial replacement in weight of the CM in 40%, by FA and HL. The results obtained were tabulated and compared with those obtained in conventional concrete mixtures (CCM) that were initially carried out as a comparative review. It was concluded that a % increase in the a/mc ratio is necessary to improve the workability of EM.

Respuestas, 25 (S2), pp. 46-52, 2020, ISSN 0122-820X - E ISSN: 2422-5053

Materials and methods

An experimental investigation was carried out which began with the analysis and classification of the materials implemented in the elaboration of the CCM. Was used CM Portland type 1 for general use, marketed by the cement company CEMEX. As described in the Colombian Technical Regulations (NTC), the CM was classified under the standards indicated in NTC30 [15]. Its chemical analysis was proposed with NTC321 [16]. Its physical and mechanical specifications were analyzed with NTC121 [17]. The NSA was collected from Transmateriales S.A located in the city of Cúcuta-Colombia. Following the NTC77 [18] standards, the particle sizes were identified. Their unit mass and the voids between particles were catalogued by NTC92 [19]. With the accomplishment of the Test 230 of the National Institute of Ways (INV-E230) [20] the indexes of elongation and flattening of the thick NSA were determined, its density and absorption was indicated by the standards captured in the NTC176 [21], while its % of wear to the abrasion was defined by the NTC98 [22]. The NTC237 [23] was implemented to collect data corresponding to the density and absorption of the fine NSA. The FA by-product of the combustion of coal was granted by the thermoelectric Termotasajero located in the Municipality of San Cayetano-Cúcuta. Its physicochemical analysis was recovered from previous investigations carried out on this type of material [14]. The HL was brought from the Municipality of Malaga in the department of Santander-Colombia. Its type S classification was compared according to the standards indicated in NTC4019 [24]. The mixing water had the specifications detailed in NTC3459 [25]. Analyzed and classified the materials, we proceeded to the elaboration of 3 designs of mixtures of CCM whose weight of CM for the projection of 1m3 of concrete determined its variable (1) 300, 350 and 400Kg. As variable (2) was indicated the % of the Rw/cm, 60, 65 and 70%. Each one of the designs of mixtures was verified by means of the settlement test according to the parameters described in NTC396 [26]. The data from the trials served as a comparative basis for subsequent comparison with EM.

For the confection of the EM, 40% of the weight of the CM was replaced by FA and LH to the 3 designs of CCM, common characteristic between the EM. The lime constituted 30% of the weight of the replaced CM and the FA the remaining 70%. The Rw/cm ratio in EM was the same as that used for CCM. As in the CCM, the slump of the EM was verified by the same test carried out in the materials laboratories of the Francisco de Paula Santander-Cúcuta University. The data produced by the designs of the CCM and EM were tabulated and compared demonstrating the influence of the Rw/cm in the slump of the EM in comparison with the CCM.

Sieve	Mass (g)	% Retained	% Accumulated retained	% Pass
3/8"	0	0	0	100
No 4	125.5	6.403	6.403	93.60
No 8	256.9	13.107	19.510	80.49
No 16	446.3	22.770	42.281	57.72
No 30	392.4	20.020	62.301	37.70
No 50	371.4	18.949	81.250	18.75
No 100	255.4	13.031	94.281	5.72
No 200	96.5	4.923	99.204	0.80
Fund	15.6	0.796	100	0

Source. Authors

Table I. Fine aggregate granulometry

Sieve	Size (mm)	Retained soil mass	% Retained	% Accumulated retained	% Pass
1"	25.40	0	0	0	100
3/4"	19.00	0	0	0	100
1/2"	12.70	1396	21.183	21.813	78.188
3/8"	9.50	2053	32.078	53.891	46.109
No 4	4.76	1769	27.641	81.531	18.469
No 8	2.38	960	15	96.531	3.469
No 16	1.19	214	3.344	99.875	0.125

Source. Authors

Table II. Coarse aggregate granulometry

Density	Kg/m^3
Cementitious Material	2546.04
Natural Stone Aggregates	2661.37
Water	100
Volume of air used	2%

Source. Authors

Table III. Materials densities for 1m3 of concrete

Results

Design of Experimental Mixes

The CCMs were initially identified as CCM/300, CCM/350 and CCM/400 according to the weight of the CM used, this being its variable (1). For variable (2), each recognised mixture was transcribed with the % value of the incorporated Rw/cm. Thus, for CCM/300, CCM/300-60, CCM/300-65 and CCM/300-70 were established corresponding to its Rw/cm. The same descriptive process was used for the other mixtures. Once the CCM had been unidentified, the design of the EM was proceeded. For the design of the EM, 40% of the CM weight incorporated in the CCM was replaced by FA and HL, this being the common variable among the EM. The distribution of the FA / HL ratio in relation to the % of the replaced CM is 30% for the HL and the remaining 70% for the FA.
The Rw/cm in the EM was similar to that described in the

CCM, so the EM were marked as EM/300-60, EM/300-65 and EM/300-70, with the same reference for the other EM.

CCM	Rw/cm	liters /m³	% Volume		Kg/m³			
		Water	Air	NSA/m³	Total NSA	NSA Coarse	NSA Fine	CM
CCM/300-60	0.60	180	2%	66.72%	1775.59	887.79	887.79	300
CCM/300-65	0.65	195	2%	65.22%	1735.67	867.83	867.83	300
CCM/300-70	0.70	210	2%	64.47%	1715.71	857.85	857.85	300
CCM/350-60	0.6	210	2%	63.25%	1683.40	841.70	841.70	350
CCM/350-65	0.65	227.5	2%	61.50%	1636.83	818.41	818.41	350
CCM/350-70	0.7	245	2%	59.75%	1590.25	795.13	795.13	350
CCM/400-60	0.6	240	2%	58.29%	1551.29	775.65	775.65	400
CCM/400-65	0.65	260	2%	56.29%	1498.07	749.03	749.03	400
CCM/400-70	0.7	280	2%	54.29%	1444.84	722.42	722.42	400

Source. Authors

Table IV. Design of Conventional Mixes

EM	Rw/cm	liters/m³	% Volume		Kg/m³					
		Water	Air	NSA/m³	Total NSA	NSA Coarse	NSA Fine	CM	FA	HL
EM/300-60	0.60	180	2%	66.72%	1775.59	887.79	887.79	180	84	36
EM/300-65	0.65	195	2%	65.22%	1735.67	867.83	867.83	180	84	36
EM/300-70	0.70	210	2%	64.47%	1715.71	857.85	857.85	180	84	36
EM/350-60	0.6	210	2%	63.25%	1683.40	841.70	841.70	210	98	42
EM/350-65	0.65	227.5	2%	61.50%	1636.83	818.41	818.41	210	98	42
EM/350-70	0.7	245	2%	59.75%	1590.25	795.13	795.13	210	98	42
EM/400-60	0.6	240	2%	58.29%	1551.29	775.65	775.65	240	112	48
EM/400-65	0.65	260	2%	56.29%	1498.07	749.03	749.03	240	112	48
EM/400-70	0.7	280	2%	54.29%	1444.84	722.42	722.42	240	112	48

Source. Authors

Table V. Design of Experimental Mixes

Slump test CCM and EM

After the designs of mixtures, CCM and EM, the slump tests were carried out. The Abrams cone was used for the test under the procedure described in NTC396.

Mix	Slump (cm)
CCM/300-60	3.5
CCM/300-65	4.3
CCM/300-70	5.4
CCM/350-60	6.2
CCM/350-65	6.5
CCM/350-70	7.3
CCM/400-60	8
CCM/400-65	9.5
CCM/400-70	11

Source. Authors

Table VI. Conventional Mixes Slumps

Mix	Slump (cm)
EM/300-60	1
EM/300-65	2.5
EM/300-70	5.1
EM/350-60	1
EM/350-65	9.8
EM/350-70	10.5
EM/400-60	8.5
EM/400-65	18
EM/400-70	19

Source. Authors

Table VII. Experimental Mixes Slumps

Comparison of Slumps CCM/300 vs EM/300

In this comparison it is evident that the behavior in the increase of the slump that presents the CCM by means of the gradual increase of the Rw/cm averages 1cm by % of addition. While the average increase of the EM is 2 cm. The % increase in Rw/cm between EM/300-60 and EM/300-70 doubled the increase in their settlement relative to CCM.

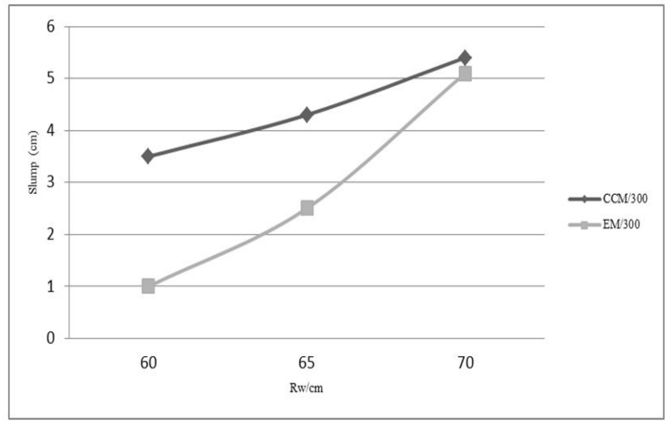

Figure 1. Slumps CCM-EM/300

Source. Authors

Comparison of Slumps CCM/350 vs EM/350

There is a significant difference in the results compared between the mixes /300-60, with the result given by the CCM/300-60 being higher. Mixture EM/350-65 and EM/350-70 outperform of the CCM comparing them.

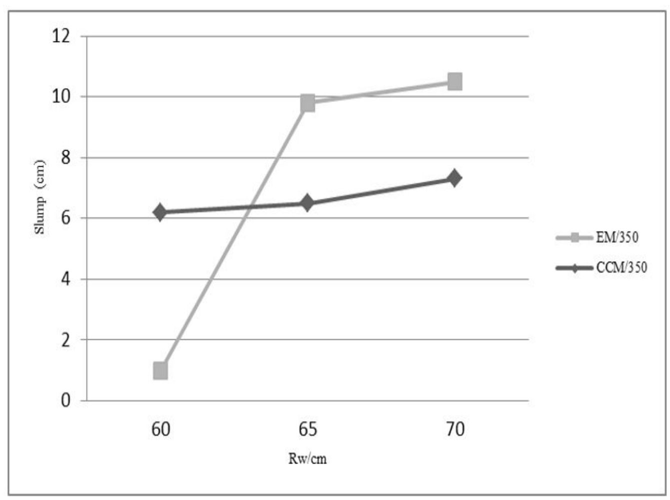

Figure 2. Slumps CCM-EM/350

Source. Authors

Comparison of Slumps CCM/400 vs EM/400

In the latter comparison, the differential gap between the EM with Rw/cm (65 and 70) exceeds 8 cm between the comparative CCM. The /400-60 mixtures presented a minimum settlement difference.

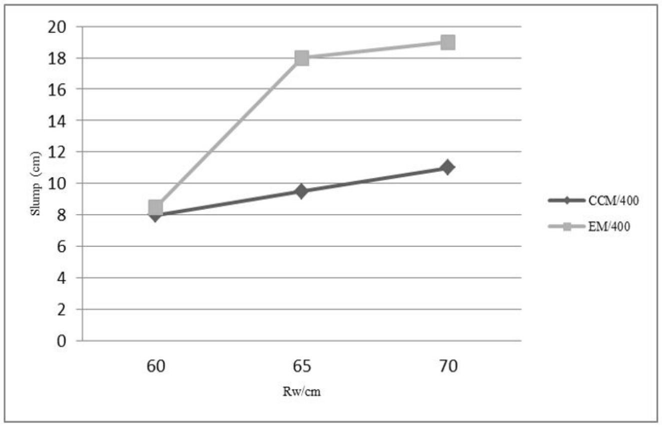

Figure 3. Slumps CCM-EM/400

Source. Authors

Conclusions

The Rw/cm 60 put in advantage the slump of the CCM/300 in relation to the EM/300, in turn, the Rw/cm 70 in the same mixtures did not present major difference, the comparative results between the mixtures urge the CCM. In the comparison between the CCM and EM/350, the Rw/cm 60 continued with the superiority of the slump of the CCM over the EM, while in the Rw/cm 70 the significant increase in the slump of the EM compared to the CCM was evidenced. In the CCM and EM/400 a particular result was observed in the slump obtained by the mixtures with the Rw/cm 60 indicating a minimum superiority of the EM over the CCM, the other Rw/cm indicated the considerable advantage of the results thrown by the EM. The amount of cement incorporated in the mixtures significantly influences their slump, a characteristic evident in Figures 2 and 3 compared to Figure 1. The increase of the CM together with the Rw/cm 65 and 70 expressed an important increase in the slump of the EM/400. The results confirm the viability of FA and HL in concrete mixes whose CM weight ranges from 350 to 400Kg with Rw/cm of 65 and 70%.

References

[1] J. Khalaf and Z. Huang, "The bond behaviour of reinforced concrete members at elevated temperatures," Fire Saf. J., vol. 103, no. August 2017, pp. 19–33, 2019.

[2] C. Zheng, C. Lou, G. Du, X. Li, Z. Liu, and L. Li, "Mechanical properties of recycled concrete with demolished waste concrete aggregate and clay brick aggregate," Results Phys., vol. 9, no. April, pp. 1317–1322, 2018.

[3] N. K. Bui, T. Satomi, and H. Takahashi, "Improvement of mechanical properties of recycled aggregate concrete basing on a new combination method between recycled aggregate and natural aggregate," Constr. Build. Mater., vol. 148, pp. 376–385, 2017.

[4] C. Zhou and Z. Chen, "Mechanical properties of recycled concrete made with different types of coarse aggregate," Constr. Build. Mater., vol. 134, pp. 497–506, 2017.

[5] A. Gholampour and T. Ozbakkaloglu, "Time-dependent and long-term mechanical properties of concretes incorporating different grades of coarse recycled concrete aggregates," Eng. Struct., vol. 157, no. December 2017, pp. 224–234, 2018.

[6] N. Tošić, S. Marinković, T. Dašić, and M. Stanić, "Multicriteria optimization of natural and recycled aggregate concrete for structural use," J. Clean. Prod., vol. 87, no. 1, pp. 766–776, 2015.

[7] O. Hurtado-Figueroa and J. Cardenas-gutierrez, "Substitution of Natural Stony Material Aggregates in Conventional 17 . 5 Mpa Non-Structural Concrete Mixtures by Means of Percentage Addition of Hospital Solid Waste," Contemp. Eng. Sci., vol. 11, no. 100, pp. 4995–5004, 2018.

[8] Hurtado-Figueroa, O; Cardenas-Gutierrez, JA "Resistance to compression of conventional concrete alleviated through partial substitution of coarse aggregate for expanded polystyrene Resistance to compression of conventional concrete alleviated through partial substitution of coarse aggregate for expa," IOP Conf. Ser. J. Phys., no. 1126, p. 012040, 2018.

[9] Patiño-Murillo, JA; Gutierrez-Sandoval, YC; Leal-Santafe, JI; Castro-Maldonado, JJ; Hurtado-Figueroa, O "Estudio Del Comportamiento de Muestras de Mortero Natural Sometidas a Esfuerzo de Compresión Performance of Natural Mortar Samples Subject to Compression Strength Tests," Lámpsakos, no. 20, pp. 22–28, 2018.

[10] Q. Peng, L. Wang, and Q. Lu, "Influence of recycled coarse aggregate replacement percentage on fatigue performance of recycled aggregate concrete," Constr. Build. Mater., vol. 169, pp. 347–353, 2018.

[11] R. Howes, M. N. s. Hadi, and W. South, "Concrete strength reduction due to over compaction," Constr. Build. Mater., vol. 197, pp. 725–733, 2019.

[12] O. Damdelen, "Investigation of 30% recycled coarse aggregate content in sustainable concrete mixes," Constr. Build. Mater., vol. 184, pp. 408–418, 2018.

[13] Hurtado-Figueroa, O; Cardenas-Gutierrez, JA and Rojas-Suarez, JP, "Determination of the quality of coarse aggregates for the elaboration of concrete mixes from 3 water sources in the City of Cucuta-Colombia Determination of the quality of coarse aggregates for the elaboration of concrete mixes from 3 water sources in the," IOP Conf. Ser. J. Phys., no. 1126, p. 012041, 2018.

[14] Hurtado-Figueroa, O; Cardenas-Gutierres, JA; Prada-Botia G, "Verification of compression resistance between a conventional concrete and its addition of 5 , 10 and 15 % in volume of fly ash replacing fine aggregate Verification of compression resistance between a conventional concrete and its addition of 5 , 10 and," IOP Conf. Ser. J. Phys., no. 1126, p. 012037, 2018.

[15] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1966 Cemento pórtland. clasificación y nomenclatura. NTC30 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[16] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1982 Ingeniería civil y arquitectura. Cemento pórtland. especificaciones químicas. NTC321 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[17] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1982 Ingeniería civil y arquitectura. Cemento Pórtland. especificaciones físicas y mecánicas NTC121 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[18] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 2007 Concretos. Método de ensayo para el analisis por tamizado de los agregados finos y gruesos. NTC77 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[19] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1995 Ingeniería civil y arquitectura. Determinación de la masa unitaria y los vacíos entre partículas de agregados. NTC92 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

Respuestas, 25 (S2), pp. 46-52, 2020, ISSN 0122-820X - E ISSN: 2422-5053

[20] Ensayos del Instituto Nacional de Vias (INV E) 2007 Indice de aplanamiento y de alargamientode los agregados para carreteras. INV E230 (Colombia: Instituto Nacional de Vias)

[21] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1995 Ingeniería civil y arquitectura. Método de ensayo para determinar ladensidad y la absorción del agregado grueso. NTC176 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[22] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1995 Ingeniería civil y arquitectura. Determinación de la resistencia al desgaste de agregados gruesos hasta de 37,5 mm, utilizando la máquina de los ángeles. NTC98 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[23] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1995 Ingeniería civil y arquitectura. Método para determinar la densidad y la absorción del agregado fino. NTC237 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[24] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 2004 Cal hidratada para mampostería. NTC4019 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[25] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1995 Concretos. Agua para la elaboración de concreto. NTC3459 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)

[26] Instituto Colombiano de Normas Tecnicas y Certificacion (ICONTEC) 1992 Ingeniería civil y arquitectura. Método de ensayo para determinar el asentamiento del concreto. NTC396 (Colombia: Instituto Colombiano de Normas Tecnicas y Certificacion)