ANALYSIS OF THE STRENGTH AND EFFICIENCY OF CONCRETE MADE WITH DOMESTIC WASTEWATER FROM W. T. P. SALITRE - BOGOTÁ D. C.

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ABSTRACT

The research project analyzes the results of the Compression Strength of concrete specimens designed for 21 MPa and 28 MPa using the A.C.I. (American Concrete Institute) method, the aggregates fulfill the requirements of the CTN - 174 (Colombian Technical Standard), Type HER Cement- (High Early Resistance), due to the CTN 121 was used, the mixing water comes from the Wastewater Treatment Plant (WTP) Salitre and drinking water from the Aqueduct of Bogota. Six different dosages of mixing water were carried out for each of the established designs; starting with 100% treated wastewater and reaching up to 75% treated wastewater with 25% potable water, the samples were identified and labeled respectively. For each of the six dosages, nine specimens were prepared and were tested at seven, fourteen and twenty-eight days, respectively. The results were compared to the standard specimen identified for each design; however, there are differences in the strength results between the standard specimen and the dosages; these are less significant as the percentage of potable water increases.

Keywords: compression strength, hydraulic concrete, wastewater, physicochemical composition.

1. INTRODUCTION

This research represents a new vision in the elaboration of concrete and allows the optimization of potable water in this process. The use of treated domestic wastewater from the W.T.P. Salitre of the city of Bogotá as mixing water is the first step towards the development of sustainable projects and the production of ecological and environmentally friendly concrete. This technology opens a window towards the regulation of the use of treated domestic wastewater, mainly from the W.T.P. Salitre - Bogota as mixing water, with the potential to be extended to the entire national territory, making Colombia an innovative reference worldwide.

After water, concrete is the second most used material in the world [1], during the month of January 2020 about 475, 800 m³ of ready-mixed concrete was consumed in Colombia [2] and according to the last report presented by UNESCO in the report "Water and Climate Change" [3], where it makes a strong call to the rational and efficient use of water resources, the consumption of fresh water increases annually by 1%, caused mainly by population growth, economic development and changes in consumption patterns.

To carry out the concrete manufacturing process, a minimum water content of 40% of the cement volume is necessary, mainly in the hydration and workability process of the mixture; therefore, only a part of the water used in this process reacts chemically to hydrate the cement, the rest evaporates over time [4].

By means of a detailed characterization of the physicochemical composition of the water obtained from the W.T.P. Salitre, the significant parameters required by the CTN-3459 and ASTM-C39 (American Society of Testing Materials) Standards, which the mixing water must fulfill, are determined. According to this process, it is possible to compare the results obtained for the ultimate strength of concrete made with treated wastewater from the Salitre WWTP and concrete made with treated water from the Aguas Claras DWTP (Drinking Water Treatment Plant), issuing a favorable concept for the use of this new technology and becoming a reference in future projects.

Concretes elaborated with treated wastewater from the W.T.P. of the Savannah Sugar Mill - Nigeria, show efficiency and significant increase in the concrete curing time, as well as a greater resistance to compression, according to the results obtained, considering the physicochemical analysis made to the water samples, where it is characterized with a high degree of acidity. Additionally, cracks and impurities appeared inside the cylinders, which are visible and are caused by the mixing water [5].

Based on previous experiences, concrete was made with steel slag to substitute in different percentages (40% and 60%) the fine and coarse aggregate. Domestic wastewater was used and a wetland was constructed using Canna Indica plants, which are effective for the elimination of organic matter [6], cultured bacteria were added to the wastewater to generate spores, and finally a preparation of wastewater + cultured bacteria + urea + calcium dihydrate was made to replace the mixing water. A standard concrete sample was made using potable water and natural basalt aggregates with a design of 25 MPa called C1. One sample substituted potable water with treated wastewater C2, another sample used wastewater with bacteria culture C3 and finally a sample was prepared using 50% natural basalt aggregates with 50% steel slag aggregate, and mix water using treated wastewater preparation with bacterial culture C4. All concrete mixtures fulfilled the compression tests performed at 28 days, with a decrease between 3% and 4% of the strength of the C2 sample compared to the other samples, however, the results were considered satisfactory [7].

2. STATE OF THE ART

Water is one of the most important elements in the elaboration of concrete and the strength, workability and properties of the hardened mixture depend on it [8]. The moment in which the water comes into contact with the cement, then initiates the hydration and hardening process of the concrete through a process of chemical and physical reactions that allow the change of state for the mixture [9].

[10], they analyzed the effects on the strength of simple concrete made with treated wastewater from the W.T.P. Cañaveralejo. They performed a detailed characterization of the mixing water and found satisfactory parameters with those required by CTN 3459, except for the concentration levels of COD and BOD, which were 11 and 6 times higher than the maximum values allowed by the regulation. They used the ACI 211.1 method to perform different mix designs (DAR, DAP, DARR and D50/R50), the results obtained during the first seven (7) days of setting of the strengths of the four samples were very similar, after fourteen (14) days there was a small gap between the DAP, D50/R50 samples in relation to the DAR and DARR samples, the former being higher in comparison to the latter. Finally, the results obtained at twenty-eight (28) days determined that the resistances reached by the designs with wastewater (DAR and DARR) were 88.9% and 90.2% in relation to the DAP design, these values are lower than the requirements of the Colombian Seismic Resistant Construction Regulation (NSR-10), however, the results obtained with the D50/R50 designs are close to the minimum allowed, considering a greater analysis and control in the future use of treated wastewater from the W.T.P. Cañaveralejo as mixing water for concrete.

[11], based their research on the chemical characteristics of cement as the main component in the strength of concrete that is why, tests were performed under the requirements of ASTM-C150 (2004). The mixing water used was taken from Lorstan Province WWTP and Ekbatan WWTP in Iran. Physicochemical characterization tests were performed following the parameters of the APHA standard (Standard Method for the Examination of Water and Wastewater, New York - USA 1992) and the behavior of compression strength, setting times, slump, tensile strength, water absorption of concrete mixtures, electrical resistivity, resistance of concrete to rapid freezing and thawing and electronic scanning were analyzed. Microscopy (SEM) tests were combined with energy dispersive X-ray spectroscopy (EDX) for the sixty-three (63) triplicate concrete samples. The results obtained from the tests determined the feasibility of treated domestic wastewater as mixing water in the production of concrete. However, the initial setting time of the samples made with treated domestic wastewater was longer than the samples made with potable water. There was a noticeable difference in the Compression Strength tests performed on the concrete made with potable water and the concrete made with the WWTP water. The water absorption and electrical surface resistance tests showed similarity between the concrete samples made with WWTP water and potable water. The results of compression strength of concrete made with treated wastewater, and subjected to rapid freezing and thawing, determined that at 21 days it was 10.11% lower than concrete made with potable water.

[12], studied the effect of wastewater on the properties of concrete, in order to find the possibility of using treated wastewater in the manufacture of concrete. Five (5) different dosages of mixing water were carried out, replacing potable water with treated wastewater. The percentages were defined by the weight of the mixing water, according to the established design. The first dosage was 100% potable water TW (Standard Mix), the second was 100% treated tertiary wastewater TTWW, curing with potable water, the third dosage was 100% treated tertiary wastewater TTWW and curing with treated tertiary wastewater TTWW, the fourth dosage was 100% treated secondary wastewater STWW and curing with potable water, and finally the fifth dosage was 100% treated secondary wastewater STWW and curing with treated secondary wastewater STWW. Compression strength, flexural strength, chloride penetration resistance, carbonation resistance and abrasion resistance tests were performed. The test results showed that the concrete samples made with TTWW tertiary treated wastewater were satisfactory and presented acceptable properties under varying conditions. In order to that, the use of tertiary treated wastewater in concrete manufacturing will enable the efficient use of wastewater and reduce freshwater consumption in the construction industry. In addition to the fact of making sustainable constructions considering the mechanical properties obtained, which were similar to the samples made with potable water. The compression strength of concrete made with treated tertiary wastewater TTWW, and cured with the same water, is in the range of 85 to 94% of concrete made with potable water.

Researchers Gadzama, E., Ekele, OJ, Anametemfiok, VE and Abubakar, AU [5], analyzed the effects on the properties of normal strength concrete using wastewater from SAVANNAH Sugar Factory as mixing water. They made a standard mix using ACI 211.1 method with a ratio of 1: 2: 4: 0.56 and designed for a Compression Strength of 25 MPa, dosed the mixing water in three percentages 100% wastewater, 75% wastewater and 100% potable water. The wastewater characterization tests determined high concentrations of metallic elements in comparison to the levels present in drinking water, as well as the presence of zinc, lead and sodium, which were found to be within the WHO parameters; however, the wastewater showed an acid pH, which is outside the tolerable parameters. There was a significant increase in the setting times of the mixes that used wastewater, as the dosage of the mixing water changed, as well as the setting time. The results of compression strength obtained at 28 days did not fulfill the requirements of the research, the data obtained ranged between 83% and 91%, however, the strength obtained from the samples failed at 90 days presented a compression strength higher than the design strength.

[13], studied the effects of wastewater use on the properties of high strength concrete. For this purpose, they used water from three (3) different car wash stations in Muscat City. Then, they performed physicochemical characterization of the water, the results of pH, DTS, Chloride, Hardness, Alkalinity and Sulfates yielded values higher than those of potable water. However, they were within ASTM parameters, therefore they concluded that the selected water could be used without restriction in the mix design. Four (4) different dosages were carried out: 100% wastewater, 75% wastewater, 50% wastewater and 100% potable water. Once the concrete samples were made and cured, the required tests were performed at 7 and 28. All the tests fulfilled the ASTM requirements; however, there were differences in the compression strength between the samples made with the 100% wastewater and 75% wastewater dosages compared to the 50% wastewater dosages and the 100% potable water standard sample, which were superior. In the case of the tensile tests, the standard sample (100% drinking water) presented the lowest value in the design, the value obtained by the 75% wastewater sample being higher. Although the results of Compression Strength of the different samples do not have a major difference between them, the major contribution of this research is the suggestion of further analysis of the behavior of the structures made with wastewater from the selected car wash stations and how they can influence the stability and durability of concrete exposed to prolonged time.

[14], evaluated structural concrete made with biologically treated water as an alternative to the use of potable water. The mixing water was taken from the Phytoremediation Plant by Artificial Wetlands and the Activated Sludge plant. The concentrations of the main water parameters (chloride concentration, sulfate, alkalinity, total solids, organic matter and pH) were evaluated. The aggregates were tested (specific weight and absorption of both fine and coarse aggregates), and the ACI 211.1 method was used for the mix design. A standard mix was made, followed by tests on the concrete in its fresh state (slump), air content using the pressure method, setting time according to density and yield. Specimens of 4" x 8" were used. The cylinders were tested at 7, 14 and 28 days to determine their properties. Three cylinders were made from each mix, and the capillary absorption test was performed to check the durability of the mix, the capacity and speed of the water absorbed by the concrete. The main conclusion is the feasibility of using water treated by activated sludge processes and artificial wetlands as mixing water in concrete designs, considering that all the tests performed yielded optimum results and were in accordance with the requirements of the standards applied. The safety of the results is related to the proper physicochemical characteristics of the water used in the designs.

[15], analyzed the use of industrial wastewater in the production of concrete, using wastewater from seven (7) different plants and a sample of drinking water as a standard sample. The collected water came from the dairy, food, and construction materials industries, and others. The difference in this research is that the authors did not perform the physicochemical characterization of the water; however, the authors recommend it for future projects. It is worth mentioning that they carried out Compression Strength tests by raising the temperature, starting at room temperature 25°C and reaching up to 150°C. The main conclusions reached by the authors were that the concrete made with wastewater from the construction industry had higher resistance than the standard sample, obtaining 42% better results, suggesting the use of this water as mixing water. The tests carried out with wastewater from dairy plants had low results of compression strength. However, the wastewater from tuber factories reached a maximum strength of 92% compared to the standard sample, the requirements of the applied regulations suggest positive results higher than 90%, so the authors recommend its use. As the temperature of the standard sample increased, its compression strength increased.

Other studies reflect the feasibility of using wastewater in the production of concrete, as in [16] where concrete samples were tested with different amounts of cement and super plasticizer admixture produced with both potable water and treated wastewater and cured with treated wastewater before chlorination and in [18] where an experimental and statistical study was carried out on the feasibility of using concrete wash water in the production of fresh concrete.

3. MATERIALS

3.1 Aggregates

The selection of fine and coarse aggregates was based on the characterization and results of the laboratory tests carried out, using the requirements of standards CTN-174, INV-E - 500 and NSR-10. Materials with a low absorption percentage were selected, in order to not affect the slump and the workability of the mix, these were supplied by the "Planta de Agregados Argos - Planta Saldaña - Municipality of Saldaña" and the following tests were carried out:

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Table-1. Characterization of the fine aggregate. Source: authors

CHARACTERISTIC	TEST STANDARD	SPECIFICATION CTN 174 or INV. E 500 INFERIOR LIMIT	SPECIFICATION CTN 174 or INV. E 500 SUPERIOR LIMIT	RESULT
Apparent density (Kg/M3)	CTN-237	-	-	**2618.26**
Loose unit mass (Kg/M3)	CTN-92	-	-	**1470.66**
Fine module	CTN-77	2.3	3.1	**2.88**
Absorption (%)	CTN-237	-	4	**1.140**
Sieving material #200 (%)*	CTN-78	-	3	**2.98**
Clay lumps and crumbly particles (%)	CTN-589	-	3	**0.41**
Sanitation-sodium sulfate (%)	CTN-126	-	10	**4.10**
Organic matter (Gardner color scale)	CTN-127	-	M. Patron	**1.00**
Light particles (%)	CTN-130	-	0.5	**0.16**
Sand equivalent (%)	INV-E 133	60	-	**68.86**

Table-2. characterization of the thick aggregate. Source: authors.

CHARACTERISTIC	TEST STANDARD	SPECIFICATION CTN 174 or INV. E 500 INFERIOR LIMIT	SPECIFICATION CTN 174 or INV. E 500 SUPERIOR LIMIT	RESULT
Elongation index (%)	CTN-237	-	-	**2615.5**
Apparent density (Kg/M3)	CTN-92	-	-	**1497.5**
Loose unit mass (Kg/M3)	CTN-237	-	-	**1.17**
Fractured faces (2 faces) (%)	CTN-78	0	1	**0.40**
Absorption (%)	CTN-78	0	0.25	**0.070**
Sieving material #200(%)*	CTN-589	0	12	**1.30**
Clay lumps and crumbly particles (%)	CTN-126	0	40	**6.00**
Abrasion-wear Los Ángeles machine (%)	CTN-127	0	0.5	**0.00**
Light particles (%)	INV E-230	0	25	**18.70**
Sodium sulfate sanitation (%)	INV E-230	0	25	**16.20**
Flattening index (%)	INV E-240	-	10	**0.70**
Flat elongated particles 5:1 (%)	INV E-227	60	-	**79.30**

3.2 Cement

The classification of cement is mainly defined by the physical requirements and its performance; the main objective is to guarantee the durability of the concrete and the stability of the works CTN - 121 [17], for this reason, Structural Cement MAX Type HER (High Early Resistances) by Argos S.A. brand was used; its density is 3.11 g/cm³. The main advantage of HER type cement is that it provides initial better strengths and greater durability to concrete structures.

3.3. Water Mixture

Table-3. Characterization of the water mixture. Source: authors.

PARAMETER	UNITIES	RESULT TREATED WASTEWATER	RESULT DRINKING WATER
Alkalinity	(mg-$CaCO_3$/l)	274.3	200
pH	(pm)	7.46	7
Temperature	°C	19.16	20
DBO_5	(mg-O_2/l)	231	6.5
DQO	(mg-O_2/l)	599	45
SSF	(mg/l)	0.81	0
Turbidity	(NTU)	190	2
SSD		4.59	0

The characterization of the water mixture was done following the parameters of the CTN-3459 [19].

4. METHODOLOGY

4.1 Mix Design

After the characterization tests on the aggregates, cement and mixing water, the design was carried out for

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21 MPa and 28 MPa compression strength and a slump of 4" using the ACI 211-1 Method [20].

Table-4. Mixture design 21 MPa. Source: authors.

DESCRIPTION	W (WEIGHT Kg)
MAX Structural cement	360 Kg
Thick aggregate ½"	825 Kg
River sand	1008 Kg
Water for mixture	169 L

Table-5. Mixture design 28 MPa. Source: authors.

DESCRIPTION	W (WEIGHT Kg)
MAX Structural cement	430 Kg
Thick aggregate ½"	766 Kg
River sand	936 Kg
Water for mixture	194 L

4.2 Mixing Water Dosing

Based on the mix design of numeral 4.1, six (6) different mixing water dosages were made for each design (according to Tables 6 and 7), replacing potable water with treated wastewater from the Salitre WWTP and combining it with potable water in the proportions described in Tables 6 and 7.

Table-6. Mixing water dosing 21 MPa. Source: authors

Test No.	% Residual water	% Drinking water	Vol. Design water	Vol. Residual wáter	Vol. Drinking water
MP01	0.0%	100.0%	169L	0 L	169 L
JF01	100.0%	0.0%	169L	169 L	0 L
JF02	95.0%	5.0%	169L	161 L	8 L
JF03	90.0%	10.0%	169L	152 L	17 L
JF04	85.0%	15.0%	169L	144 L	25 L
JF05	80.0%	20.0%	169L	135 L	34 L
JF06	75.0%	25.0%	169L	127 L	42 L

Table-7. Mixing water dosing 28 MPa. Source: authors

Test No.	% Residual water	% Drinking water	Vol. Design water	Vol. Residual wáter	Vol. Drinking water
MP01	0.0%	100.0%	194L	0 L	194 L
LMO 1	100.0%	0.0%	194L	194 L	0 L
LMO 2	95.0%	5.0%	194L	184 L	10 L
LMO 3	90.0%	10.0%	194L	174 L	19 L
LMO 4	85.0%	15.0%	194L	164 L	29 L
LMO 5	80.0%	20.0%	194L	155 L	39 L
LMO 6	75.0%	25.0%	194L	145 L	48 L

4.3 Preparation of Cylinders

Using the mix designs of numeral 4.1 and the mixing water dosages of numeral 4.2, nine (9) 6 "x12" cylinders were made for each of the dosages. The cylinders were prepared and cured following the recommendations described in CTN-1377 [21] and CTN-396 [22] for slump measurement.

Figure-1. Elaboration of the cylinders. Source: authors.

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Figure-2. Curing the specimens. Source: authors.

5. RESULTS AND DISCUSSIONS

According to the requirements of CTN-673 [23], numeral 7. Procedure, Table-2. Age of test specimens, the period determined to perform the Compression Strength tests was determined in seven (7), fourteen (14) and twenty-eight (28) days. The nine (9) cylinders were divided into the number of tests to be performed, in order to fail three (3) cylinders for each stipulated period; complying to the requirements of the Colombian Seismic Resistant Code NSR-10, numerals C.5.6.2.4 and C.5.6.3.3.

Figure-3. Test compression resistance. Source: authors.

Figure-4. Shear fracture. Source: authors.

Table-8. Resistance tests 21 MPa. Source: authors.

	7 Days	14 Days	28 Days
MP01	13.4 MPa	19.0 MPa	**22.4 MPa**
JF01	11.0 MPa	15.7 MPa	18.4 MPa
JF02	11.2 MPa	15.9 MPa	18.7 MPa
JF03	11.4 MPa	16.2 MPa	19.0 MPa
JF04	11.7 MPa	16.6 MPa	19.6 MPa
JF05	12.6 MPa	17.9 MPa	**21.1 MPa**
JF06	12.8 MPa	18.1 MPa	**21.3 MPa**

Table-9. Resistance tests 28 MPa. Source: authors.

	7 Days	14 Days	28 Days
MP01	19.1 MPa	25.3 MPa	**29.4 MPa**
LM01	14.1 MPa	18.4 MPa	21.6 MPa
LM02	14.8 MPa	19.8 MPa	22.8 MPa
LM03	15.5 MPa	20.1 MPa	23.9 MPa
LM04	16.3 MPa	21.3 MPa	25.0 MPa
LM05	16.8 MPa	22.3 MPa	25.9 MPa
LM06	18.2 MPa	24.4 MPa	**28.0 MPa**

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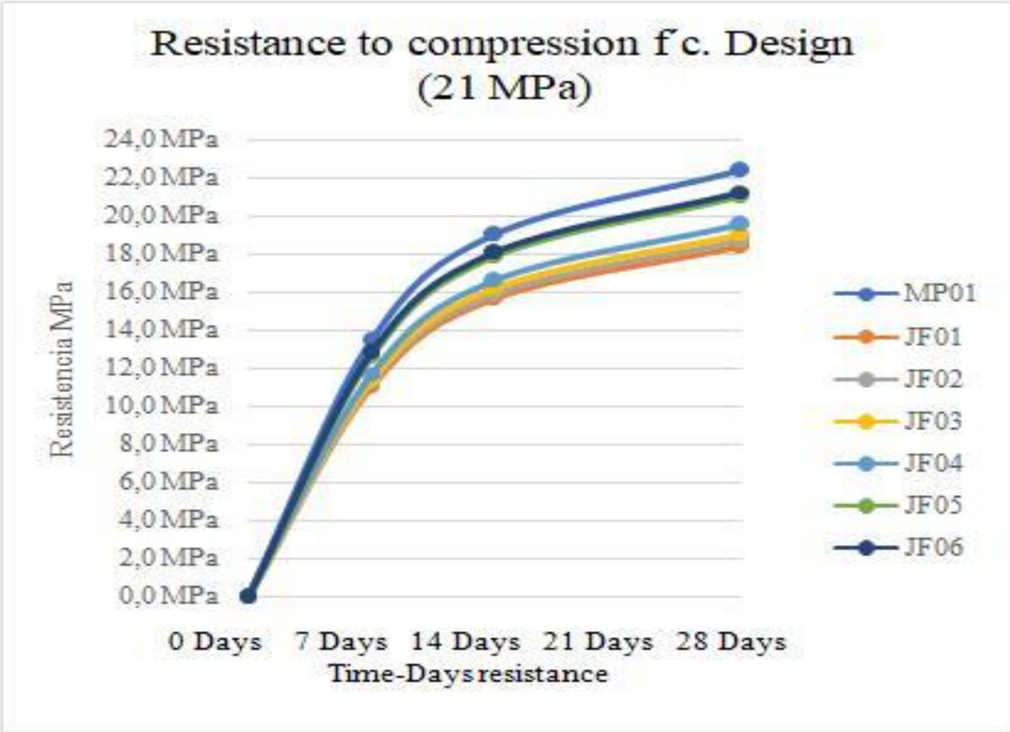

Figure-5. Resistance to 21 MPa dosages. Source: authors.

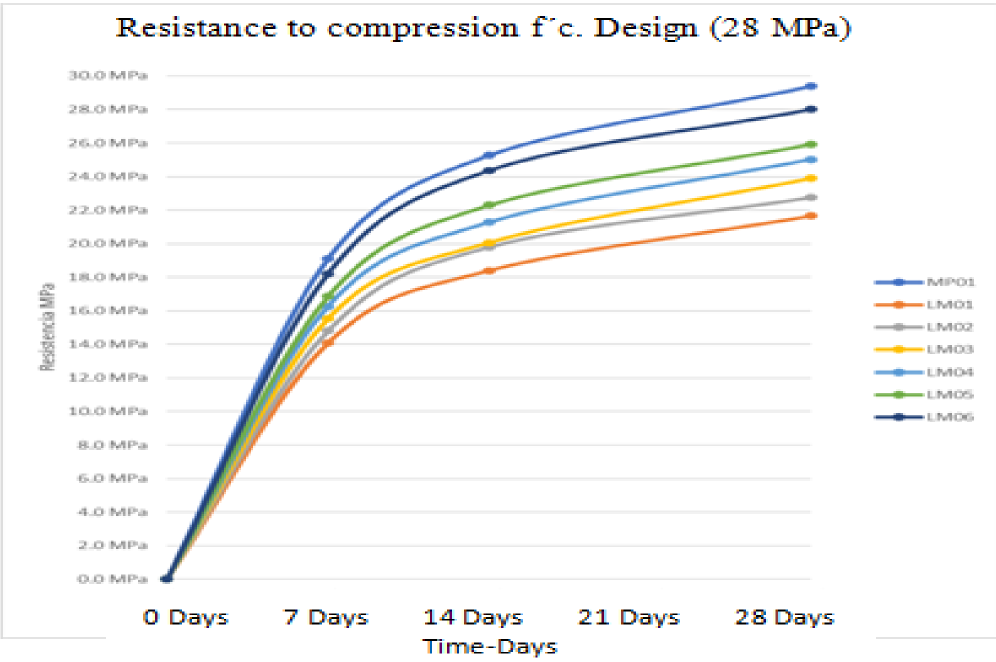

Figure-6. Resistance to 28 MPa dosages. Source: authors.

5.1 Analysis of Results

5.1.1 Aggregates

Tables 1 and 2 show the quality of the fine and coarse aggregates. These materials have a low absorption percentage, which allows maintaining a constant W/C (Water/Cement) ratio; therefore, taking into account the mixing water as a variable, it should be controlled. They are very clean materials, with low concentration of organic matter and very low presence of clay lumps, which guarantees an excellent performance of the mix.

5.1.2 HER cement

Undoubtedly, HER cement is designed to achieve better strengths at early ages and throughout the course of the designed structure, due to its chemical composition

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(higher C3S content, it reduces the amount of cement used per m3 designed and also the volume of water used in the mix.

5.1.3 Mixed water

Chemical tests performed on treated domestic wastewater from the Salitre WWTP in Bogotá, D.C., show significant factors that affect the physicochemical composition of the mixed water, due to high concentrations of BOD5, COD, turbidity, odor, among others. According to CTN-3459, these concentrations exceed the maximum allowed for use as mixing water. However, considering the treatment flow of the Salitre WWTP (4 m3/s), the use of this water as mixing water can contribute to the decontamination process of the water sources in Bogotá.

5.1.4 Compression test results

The Colombian Seismic Resistant Code NSR-10 in Title C, numeral C.5.6.3.3.3 establishes the acceptance criteria for mix designs.

a) The arithmetic average of three consecutive strength tests must be equal or greater than the design f'c.

b) No strength result shall be less than the design f'c by more than 3.5 MPa.

The test results for the failed specimens, the arithmetic average of each dosage and the acceptance parameters according to NSR-10 are included in Annex 1.

For the 21 MPa mix design, dosages JF-05 and JF-06 fulfilled the two parameters required by NSR-10 and the mix designs of these dosages are considered accepted; specimens JF-01, JF-02, JF-03 and JF-04 only met parameter 2 stipulated in NSR-10, for this reason, the mix designs are not considered accepted.

For the 28 MPa mix design, sample LM-06 fulfilled the two parameters described by NSR-10, samples LM-01, LM-02 and LM-03 did not meet any NSR-10 parameter, and therefore, the mix designs made for these mix designs are not accepted. Samples LM-04 and LM-05 only fulfilled the second parameter of NSR-10. For this reason, these are not considered acceptable as mix designs.

Samples JF-01 and LM-01, which were made with 100% domestic wastewater, presented percentages of strength loss compared to the standard sample of 82% and 74%, respectively. This is mainly due to the high levels of BOD5 and COD present in the water, a significant difference can be observed in the resistance results between the standard sample and the dosages, this difference decreases as the percentage of potable water in the mixture increases.

The percentage loss of resistance was calculated using formula 1.

$$\%Loss\ resistance = \frac{\text{Dosage resistance}}{\text{Pattern sample resistance}} * 100 \qquad (1)$$

Table-10. Loss of resistance in dosages. Source: authors.

21 Mpa			28 Mpa		
Sample	**Resistance obtained**	**Loss of resistance (%)**	**Sample**	**Resistance obtained**	**Loss of resistance (%)**
MP01	22.4 MPa	**100%**	**MP01**	29.4 MPa	**100%**
JF01	18.4 MPa	**82%**	**LM01**	21.6 MPa	**74%**
JF02	18.7 MPa	**84%**	**LM02**	22.8 MPa	**77%**
JF03	19.0 MPa	**85%**	**LM03**	23.9 MPa	**81%**
JF04	19.6 MPa	**87%**	**LM04**	25.0 MPa	**85%**
JF05	21.1 MPa	**94%**	**LM05**	25.9 MPa	**88%**
JF06	21.3 MPa	**95%**	**LM06**	28.0 MPa	**95%**

6. CONCLUSIONS

Samples JF-05 and JF-06, for the 21 MPa design and sample LM-06 designed for 28 MPa, were the only ones that complied with the parameters described in the Colombian seismic-resistant code NSR-10.

It is suggested to carry out a research that gives continuity to this project with the purpose of performing concrete durability, flexural strength and modulus of elasticity tests. Thus, it will be possible to know more properties of the concrete made with domestic wastewater from the Salitre WWTP in Bogota.

The high concentration levels of BOD5 and COD present in the domestic wastewater from the Salitre WWTP affected substantially the strength behavior of the concrete samples. However, with the entry into operation of PHASE II of the Salitre WWTP, further investigations can be carried out.

The use of HER type structural cement generated higher strengths at all testing times; at seven days, strengths between 65% and 70% of the design were achieved, and tests at fourteen days yielded strengths between 85% and 90% of the design. Additionally, during the preparation process, the workability of the mix was improved and the W/C ratio decreased.

The results obtained in this research project showed better results than those obtained by Calderón Linares, A. S., & Burbano Cerón, M. J. [10], who worked with wastewater from the PTAR Cañaveralejo. The characterization tests performed on the wastewater from the two treatment plants did not show significant differences.

The use of structural cement and the selection of aggregates with low absorption percentage reduced the volume of mixing water, which meant that the designs were more efficient and better results could be obtained.

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