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Artigo Original

Reuse of glass in concrete: a study of the production and mechanical performance of resistance

Reutilização do vidro no concreto: um estudo da produção e do desempenho mecânico da resistência

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Abstract

The glass incorporated into the concrete contributes to the conservation of the environment, as it will have a correct destination and is an easily found material. This work had the objective of analyzing the mechanical performance of the concrete produced with glass waste from non-returnable packaging. Since glass is a residue that is easily found, it is justified to incorporate it into concrete in partial replacement of small aggregates, thus avoiding its disposal in landfills and also in an irregular way. The concrete produced was made with the addition of “51” and “Long Neck” ground glass. A standard trace of 25 MPa was defined, with partial substitutions of 5%, 15%, 25% and 35% in the small aggregate. The individual strengths of the test specimens were submitted to the Tukey test for statistical analysis and it was verified that the trait with the percentage of 35% substitution is statistically different from the other traits. The concrete had a mean Fck of 32,37 MPa, higher than the established minimum of 25 MPa. It can be concluded that the concrete with the use of ground glass presents technical feasibility for execution and contributes to the preservation of the environment.

Keywords: Ground glass; Reuse; Sustainability; Concrete; Resistance

Resumo

O vidro incorporado ao concreto contribui para a conservação do meio ambiente, pois terá uma destinação correta e é um material facilmente encontrado. Esse trabalho teve objetivo analisar o desempenho mecânico do concreto produzido com resíduos de vidro de embalagens não retornáveis. Sendo o vidro um resíduo que é facilmente encontrado, justifica-se sua incorporação ao concreto em substituição parcial de agregados miúdos, evitando assim a sua destinação em aterros sanitários e também de forma irregular. O concreto produzido foi confeccionado com adição de vidro moído de Garrafa de “51” e de “Long Neck”. Definiu-se um traço padrão de 25 MPa, com substituições parciais de 5%, 15%, 25% e 35% no agregado miúdo. As resistências individuais dos corpos de prova foram submetidas ao Teste de Tukey para análise estatística e foi verificado que o traço com o percentual de 35% de substituição é diferente estatisticamente dos demais traços. O concreto apresentou um Fck médio de 32,37 MPa, maior que o mínimo estabelecido de 25 MPa. Pode-se concluir que o concreto com a utilização do vidro moído apresenta viabilidade técnica para execução e contribui para a preservação do meio ambiente.

Palavras-chave: Vidro moído; Reutilização; Sustentabilidade; Concreto; Resistência

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1 Introduction

Concrete is a material that contains a mixture of aggregates, binder (cement and water). According to the magazine Concreto & Construções, the binder is the cement in the presence of water; the aggregate is any granular material (sand, gravel, pebbles, crushed rock, blast furnace slag, and construction and demolition waste), whose particle larger than 4.75 mm is considered to be large; otherwise, otherwise it is small (IBRACON, 2009).

Concrete is the main responsible for the compressive strength of the structures. This important characteristic, in addition to other factors, is also associated with its porosity, since the larger the water/cement ratio of the concrete, the greater the porosity, consequently the resistance decreases (GOMES, 2011).

Concrete is one of the materials most used in engineering works and is in constant study. Its great application is due to its durability, ease of taking on different forms and versatility, being therefore used in various forms, whether in structural or non structural parts. The possibility of incorporation of residues into cement-based mixtures is a contribution of the construction industry to the recycling of environmentally harmful residues, and may also improve the performance of materials with their addition (MARQUES, 2006). In order to produce concrete it is necessary to produce Portland cement, which according to data from the National Union of Cement Industry, in 2016 production and consumption was 57 million tons (SNIC, 2019).

Among the many innovations that arise for the confection of concrete, the addition of glass is a sustainable option, as it replaces aggregates in whole or in part. Many countries already use this material as a small aggregate, as is the case in Australia. According to resolution n° 307 of CONAMA (BRAZIL, 2002) glass is considered to belong to Class B, ie it is a recyclable product.

Australia is the country that most uses ground glass from recycling as an aggregate to produce concrete. The material comes to be used in rates of 10% to 20%, as a substitute for sand, for the construction of beams, pillars and slabs, as well as non-structuring elements - in this case at rates that can replace sand by up to 50% (CRENTSIL, 2001).

The use of glass incorporated in concrete contributes to the conservation of the environment, because the glass will have a correct destination and is an easily found material. Silva (2013) states that glass has many applications, and can be found easily in our daily life, in the enormous diversity of artifacts, in civil construction, in window frames or vertical elements.

Brazil produces an average of 800 thousand tons of glass per year, of which 220,000 tons / year are recycled, which corresponds to 27.6% of the total generated. The amount of glass discarded in the trash corresponds to 3% of the total (LÓPEZ, 2005).

The scrap of glass has much to contribute, because it is a recyclable material, with very low cost, and has in its composition, a great amount of silica and calcium oxide, being able to present pozolanic characteristics, improving the mechanical properties of the concrete (GOMES, 2011).

The scrap of glass comes from the discards that happen in the daily life of people can be originated from: containers, glasses, glass, among others, but it is necessary to give a correct destination for these types of waste avoiding so they are deposited in the environment, polluting and altering the natural landscape (SANTA-ELLA et al., 2014). Since glass is a residue that is easily found, its incorporation into concrete is justified as a partial replacement of small aggregates, thus avoiding its use in landfills and also in an irregular manner. The use of glass residues in the concrete will contribute to society as a whole, because in addition to reducing the amount of bottles discarded in the environment and soil irregularly, will reduce the use of natural resources, such as the small aggregate.

With the need to produce construction materials with additions of residues, the following problem arises: does the addition of glass in the concrete optimize its mechanical properties? The variable studied in the present work is classified in continuous quantitative (MEDRI, 2011), being the substitution content of the conventional small aggregate (river sand) by the recycled aggregate coming from glass of non-returnable containers in the contents of 5%, 15%, 25% and 35%. In this sense, this study aimed to describe the mechanical performance of concrete produced with glass residue from non-returnable packaging, as well as to reuse glass scrap in concrete production, produce concrete using glass as a small recycled aggregate, perform the axial compression strength test (NBR 5739/1994) and compare the data obtained to transform into information using statistical tools.

1.1 Concrete

Concrete is considered a civil construction material and is the result of the mixture of cement that is the binder, of small and large aggregates and water added in the right dose. According to Almeida (2002), the concrete must have sufficient plasticity for the handling, transport and launching operations in order to acquire cohesion and resistance over time due to the reactions that occur between binder and water. In this sense will be presented information about each concrete constituent material, such as: cement, large aggregates, small aggregates and water.

Portland cement was discovered in England around 1824 and industrial production began after 1850. It is a fine powder with binding properties, binders or binders, which hardens under the action of water. The cement is considered a binder because it has the function of joining materials, and it hydrates when mixing with water. When it hardens it has the characteristic of artificial rock. The more the cement is hydrated with water, as well as being immersed, that is, in the process of curing, maintains its properties. Among the different types of cement, the most common use in constructions are CPII E-32, CPII F32 and CPIII-40. CPV-ARI cement is also widely used in precast structures (BASTOS, 2006).

Aggregates are classified into small and large, which may originate naturally or artificially. The difference between them lies in the particle size of the particles. The granulometry is determined by characterization tests according to NBR norm NM: 248 (ABNT, 2003), where the material will be disposed in the mechanical agitator of sieves. The granules passing through the ABNT # 4 sieve (square mesh sieve with a nominal opening of 4.8 mm) are retained as an aggregate and are retained in the ABNT # 200 sieve (0.075 mm nominal mesh); and large aggregate are the grains that pass through the ABNT sieve with a nominal opening of 152 mm and are retained in the ABNT # 4 sieve (4.8 mm aperture).

Almost all natural waters are suitable for kneading. The water content of the fresh concrete is given by the water-cement factor (a/c), ie by the water-cement weight ratio. This ratio generally ranges between 0.3 and 0.6. The lower the water content, the greater the concrete strength and the lower the workability (ALMEIDA, 2002). The water cement factor is a very important parameter in the composition of the concrete, it is a relation between the water and cement weights, and it has influence in the resistance and durability of the concrete. If you increase the volume of water to be added to the concrete, that ratio increases.

1.2 Glass

Glass is an inorganic, homogeneous and amorphous substance obtained by cooling a mass based on silica (SiO2) or fused silicon oxide (SiO), which hardens by the continuous increase of viscosity until it reaches the stiffness condition, but without crystallization (PINTO, 2007).

The glasses have a varied chemical composition. What is common to all types of glass is silica, which is the base of the glass. Table 1 shows the chemical composition of different glasses, considering the most common types of glass.

Analyzing table 1 it is possible to verify that the containers have a chemical composition of 74% silica (SiO2), 1% alumina (Al2O3), 5% calcium oxide (CaO), 15% sodium oxide (Na2O) , 0% boron trioxide (B2 O3) and 4% magnesium oxide (MgO). One of the oldest materials used by man, the composition of glass has hardly changed in the last millennia: it consists basically of sand, lime and bark. Other materials included in its formulation may be considered secondary ingredients, although important because they facilitate the production process, reduce the melting temperature and add special properties, which differentiate one type of glass from another. Glass does not decompose in nature and can remain under the ground for thousands of years without presenting changes (CRQ, 2011).

1.3 Concrete produced with waste

Concern about the correct allocation of solid waste from construction, as well as the concern about the use of nonrenewable resources, means that priorities for use within the system emerge. These priorities include reducing waste in generating sources and reducing final disposal in the soil, maximizing reuse, selective collection and recycling (BORBA, 2016).

According to Adreoli et al. (2014), the difficulty of waste management has two components: the enormous amount of waste generated and its composition. Concrete is a composite, that is, it is formed by several materials with different characteristics. In light of this, innovations have emerged with the introduction of materials with partial substitutions of natural aggregates (pebbles, gravel and sand), but it is necessary to analyze their resistance to compression forces and determine how and where it should be applied.

Alves (2017) analyzed the concrete strength with the incorporation of asphalt pavement residues (RPA) and concluded that the concrete decreases the compressive strength and the reduction of this resistance is greater with the increase of the contents of these residues. It is not a viable alternative for concretes with structural purposes or requiring high resistance.

One can cite Silva Junior et al. (2016) who analyzed the incorporation of rubber tire residues (RBP) into the concrete traces, and found that increasing the partial replacement of sand with RBP leads to a reduction in workability and mechanical properties as it increases this replacement.

Other types of waste have also been evaluated in the incorporation to the concrete, as is the case of construction waste (RCC), in partial replacement of the aggregate. Santos et al. (2015) stated that it is possible to produce concrete with recycled aggregates at lower costs than those produced with natural aggregates, thus contributing to sustainability in civil construction and recommend

Table 1- Chemical composition of different types of glass

Type	Major Components %						Properties
	SiO_2	Al_2O_3	CaO	Na_2O	B_2O_3	MgO	
Fused Silica.	99						Very low thermal expansion, very high viscosity.
Borosilicate (pyrex)	81	2		4	12		Low thermal expansion, small ion exchange.
Containers	74	1	5	15		4	Easy workmanship, great durability.

Source: Van Vlack (1973)

greater technological control of the material used.

Given the possibility of the incorporation of residues in the concrete, it will be possible to analyze the use of the ground glass in partial replacement of the small aggregate.

2 Methodology

The research is classified as exploratory bibliographical and experimental. A bibliographic search was carried out in scientific articles in the Google Scholar databases, SciELO (Scientific Electronic Library Online), through the key words glass in concrete, glass reuse, resistance of concrete with glass and, in books, graduate work, stricto sensu and specific legislation. The experimental research was carried out in the Laboratory of Catholic Materials of Tocantins from January to May 2018.

A standard trace of 1: 1.97: 2.28: 0.516 (Cement: Tiny Aggregate: Aggregate Large: Water / cement factor) was considered. All the materials that were used in the concrete production were studied to obtain a correct dosage of the concrete and with the purpose of discovering the characteristics, since they could influence the quality of the concrete studied (CIRILO, 2016).

From this trait were made substitutions in the conventional aggregate (river sand) by the recycled aggregate coming from glass of non-returnable packages in the contents: 5%, 15%, 25% and 35% and mixed in concrete mixer, for the manufacture of concrete.

For each concrete trait were produced 6 (six) test bodies (cylindrical mold: 10 x 20 cm), and were submerged in water in the curing tank for concrete samples for 7 (seven) days, which were submitted to the axial compressive strength test in hydraulic press.

The materials used to make the concrete were coarse sand (small aggregate), cement CP III-E-32, crushed pebble, water and ground glass. The partial replacements of the small group were divided into control groups:

Trace 1 - T1 - 0% of substitution of the conventional aggregate by the recycling from glass of non-returnable packaging.

Trace 2 - T2 - 5% replacement of the conventional aggregate by recycling from non-returnable packaging glass.

Trace 3 - T3- 15% replacement of the conventional aggregate by recycling from non-returnable packaging glass.

Trace 4 - T4- 25% of substitution of the conventional aggregate by recycling from glass of non-returnable packaging.

Trace 5 - T5- 35% of substitution of the conventional aggregate by recycling from glass of non-returnable packaging.

The concrete used in this experiment was made with the addition of ground glass of "Bottle of 51" and "Long Neck Bottle". The tests were carried out in the Materials Laboratory of the Catholic Faculty of Tocantins, in Palmas-TO. The "51" and "Long Neck" glass bottles were collected in bars and on the streets, in the municipality of Palmas - TO, and in places where some event took place, for 4 months. In total, 250 bottles were collected and / or purchased.

The glass bottles, before being milled, went through the cleaning process for the removal of the label and existing residues, being washed in running water. The grinding of the glass was carried out to obtain a granulometry similar to that of the small aggregate and, therefore, be substituted in the strokes. The first equipment used for the glass milling process was the jaw crusher aiming to reduce the size of its "chips". Afterwards, another grinding was carried out in the ball mill, aiming the reduction of the glass shards until reaching a granulometry that the process under study required.

After the entire grinding process, the glass was sifted to make sure that the granulometry of the material was in agreement with that of the small aggregate. In this sense, the granulometric analysis of the crushed glass was carried out, where NBR NM: 248 (ABNT, 2003) was obeyed, considering as a small aggregate the grains passing through the sieve # 4 (nominal opening of 4.8 mm) and retained in the ABNT # 200 sieve (nominal opening of 0.075 mm).

After calculating the volume of materials to be used in the trace there was an unforeseen. The NBR asks that the aggregates be dry so that the concrete trace is made and, in the small aggregate, in case the sand that would be used in the trace was wet and the non-correction of this one, could cause unforeseen in the reduction of the concrete.

It was then decided to compensate for the water present in the sand. 2000 g of wet sand was weighed and this volume was dried on a heating plate on a zinc tray for 24 hours in a greenhouse until all the moisture evaporated. The dry material was weighed again, and it was then possible to verify the percentage of water present in that sand, to subtract that amount from the amount of water preset for the traces.

In this sense it was possible to verify that the percentage of water present in the sand was of 4.3%. The granulometric characterization of the large aggregate (crushed pebble) and kid (coarse sand) was performed according to NBR NM: 248 (ABNT, 2003), through the mechanical sieve agitator. The binder used was composite Portland cement, CP-II-E-32 (32 MPa at 28 days).

The concrete trait was defined by the case study carried out by Cirilo (2016), where an analysis of the influence of the partial replacement of the sand by the glass in concrete traces was carried out, using the Tukey Test. In this sense, Cirilo trait (2016) was used:

$$1 : 1{,}97 : 2{,}28 : 0{,}516$$

Where: Cement: Aggregate Tiny: Aggregate Large: Water/cement factor.

The concrete traces were rotated in the following way: With the concrete mixer already in operation, the large aggregate and half the water were initially mixed, mixing for one minute. Then the cement, the sand, the glass and, finally, the rest of the water were added. After the time of 4 minutes of concrete mixing it was removed from the concrete mixer to be molded in 10 cm x 20 cm test bodies.

A standard trace of 25 MPa was defined, and partial substitutions were made in the conventional aggregate (river sand) in the 5%, 15%, 25% and 35% factors. From this trait it was possible to calculate the volume of concrete to be rotated in the concrete mixer, considering that the trait was calculated for a cubic meter of concrete. Since 6 test specimens were defined for each trace, the volume of each cylindrical specimen 10cm x 20cm was calculated, and a loss coefficient of 20% was calculated for any setback. With the volume of the trace in hand it was possible to calculate the weight of each component of the trace and reach the following values:

Table 2- Reference Trait

Referential	
Material	Mass (kg)
Brita	15,201
Water	3,440
Sand	13,134
Cement	6,667

As compensation was made because of the presence of water in the sand, the values of the water volumes were decreased by 4.3% which corresponds to a total of approximately 0.565 kg of water and added in the weight of the sand. Then, the separate calculations were performed for each trait in order to find the correct values which would have to decrease in the water and add in the weight of the sand, since there was a change in the amount of glass replaced by sand, and glass material was dry and the sand was wet and both were small aggregates. Table 3 presents the reference line already discarded the moisture of the sand, the mass of sand replaced by water and the amount of glass per trace.

Table 3 - Discounted reference trait

Trace	% Glass	Sand mass (Kg)	Sand mass replaced with water (kg)	Glass paste (Kg)
T1	0	13,699	0,000	0,0
T2	5	13,014	0,144	0,685
T3	15	11,644	0,431	2,055
T4	25	10,274	0,719	3,425
T5	35	8,904	1,006	4,795

Table 4 presents the volume of materials calculated for the preparation of the concrete, with no additions of ground glass, ie 0% glass, indicated as trace 1.

Table 4 - Volume of concrete without addition of glass

T1 – 0% of Glass	
Material	Mass (Kg)
Brita	15,201
Water	2,875
Sand	13,699
Glass	0,0
Cement	6,667

Table 5 shows trace 2, where the kid's aggregate was replaced by 5%.

Table 5 - Volume of concrete with addition of 5% of glass to replace the small aggregate

T2 – 5% of Glass	
Material	Mass (Kg)
Brita	15,201
Water	2,731
Sand	13,158
Glass	0,685
Cement	6,667

In trace 3 there was a replacement of the glass in 15% of the kid's aggregate, as shown in Table 6.

Table 6- Volume of concrete with addition of 15% of glass in replacement of the small aggregate

T3 – 15% of Glass	
Material	Mass (Kg)
Brita	15,207
Water	2,444
Sand	12,075
Glass	2,0592
Cement	6,667

The volume of substitution of the small aggregate per glass in 25% is described in Table 7 as trace 4.

Table 7 - Concrete volume with addition of 25% of glass to replace the small aggregate

T4 – 25% of Glass	
Material	Mass (Kg)
Brita	15,207
Water	2,156
Sand	10,993
Glass	3,425
Cement	6,667

Table 8 shows trace 5, where the kid's aggregate was replaced by 35%.

Table 8 - Volume of concrete with addition of 35% of glass to replace the small aggregate.

T5 – 35% of Glass	
Material	Mass (Kg)
Brita	15,207
Water	1,869
Sand	9,910
Glass	4,795
Cement	6,667

For each trait 6 test bodies were molded for the test of compressive strength and curing time of 7 days by immersion in water. After curing, the test bodies (CP) were submitted to compression pressures in hydraulic press. The resistances were obtained in Tf (ton force) and transformed into Mpa (megapascal), by the formula described below.

$$Fc = \frac{4*Q}{\Pi*D^2} * \frac{9810}{10^6} Fc = \frac{4*Q}{\Pi*D^2} * \frac{9810}{10^6}$$

At where:

Fc: compressive strength in MPa;

Q: maximum load reached in tf;

D: is the diameter of the test piece in meters

The data were submitted to analysis of variance (ANOVA) and the averages were compared by the Tukey test at 5% probability between them (SILVA, 2010). The Tukey test allows to verify if the means of the k treatments are different or not, through the equation:

$$HSD = q_{\propto;gl_1;gl_2} \cdot \sqrt{\frac{s^2_{Inside}}{n}}$$

At where:

HSD means fairly honest differences. The lowest value or distance between two means to be considered statistically equal according to the level of significance α chosen.

s^2_{Inside} Sample variance within k treatments, with a mean of the sample variances of k treatments

$s^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})}{n-1}$ Sample variance for each treatment with n replicates is given by:

n= amount of replications in the treatment

$q_{\propto;gl_1;gl_2}$ Study range, which depends on the level of significance α, degree of freedom 1 (gl 1 = k) and degree of freedom 2 gl 2 = n. (k-k).

3 Results and discussion

Table 9 shows the percentage retained, accumulated and passed through the sieves, after granulometric analysis.

Figure 1 shows that the percentage retained in the mesh was 4.8 mm (0.1%), 2.4 mm (21.7%), 1.2 mm (32.3%), 0.6 (22.7%), 0.3 (10.5%), 0.15 (11.2%) and the bottom was 1.5%. The fineness modulus was 3.38.

Figure 2 shows the granulometric curve of the ground glass, considering the percentage passing through.

The result of the Slump Test test was a reduction of 6.5 cm +/- 2.5, which is within the pre-established maximum limit. Table 10 presents the individual compressive strength results of the specimens of each concrete trace. The individual strengths of the test specimens were submitted to the Tukey test for statistical analysis. Then the following steps were followed: calculating the sum of the resistances of each trace, the arithmetic mean and finally the variance.

Table 10 - Results of compressive strength at 10 days cure in MPa. (No glass additions and glass additions - 5, 15, 25 and 35%)

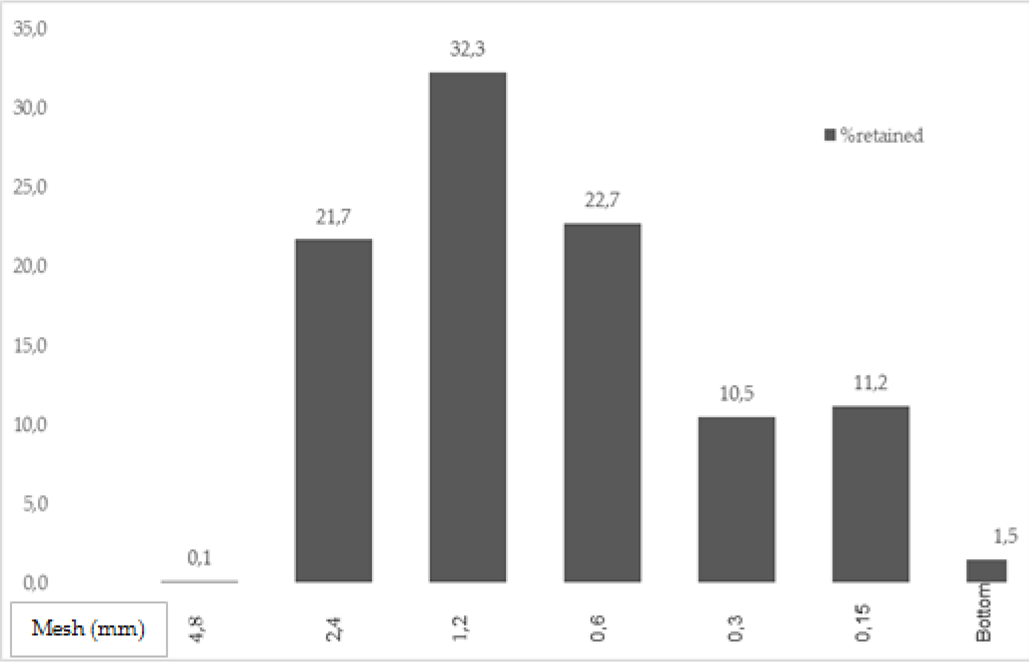
Repetitions	k- Treatments				
	T1 (MPa)	T2 (MPa)	T3 (MPa)	T4 (MPa)	T5 (MPa)
n	0%	5%	15%	25%	35%
1	25,27	22,00	20,75	26,24	29,82
2	25,47	24,76	23,92	26,51	32,23
3	25,54	24,82	23,93	26,78	32,66
4	25,71	24,89	24,02	26,86	32,95
5	25,98	24,91	24,06	27,43	33,21
6	26,17	25,16	24,19	27,45	33,38
$\bar{X}$	25,69	24,42	23,48	26,88	32,37
s^2	0,11	1,43	1,80	0,24	1,74
s^2	0,34	1,20	1,34	0,49	1,32
cv (%)	1,30	4,90	5,71	1,81	4,07

Where: x is the mean, s^2 is the sample variance, s is the sample standard deviation and cv is the sample coefficient of variation

Table 9 - Granulometry test of ground glass

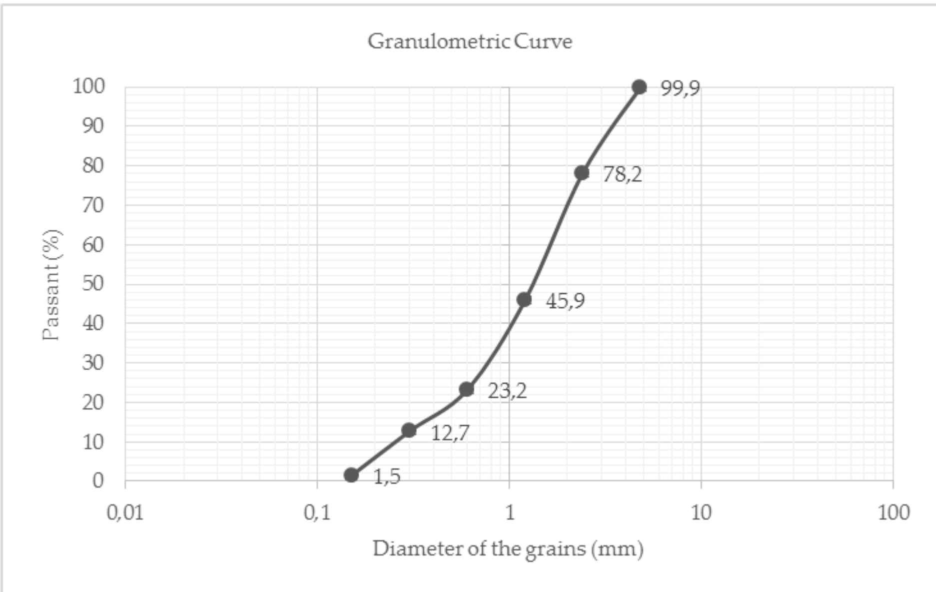
Opening of sieve mesh (mm)	Samples (g) 1°	2°	Average (g)	% Retained	% Accumulated	% Passant
6,3						
4,8	0,3	0,4	0,4	0,1	0,1	99,9
2,4	255,4	277,2	266,3	21,7	21,8	78,2
1,2	394,2	397,0	395,6	32,3	54,1	45,9
0,6	272,7	283,8	278.3	22,7	76,8	23,2
0,3	130	128,4	129,2	10,5	87,3	12,7
0,15	130,6	143,0	136,8	11,2	98,5	1,5
Bottom	16,8	20,4	18,6	1,5	100,0	0,0
Mt= Total	1200	1250	Fineness Module = 3,38			

Figure 1 - Granulometry of ground glass



Source: Authors (2018)

Figure 2 - Granulometry of ground glass



Source: Authors (2018)

Then, the correlation between the means of the test specimens of the concrete traces in decreasing order, we reached the results described in Table 11.

We then analyze the data exposed with the result of interaction between the test bodies, where our HSD = 1.74, interpreted so that any value above this, statistically would be different from the common one.

It was concluded that the trait with the percentage of 35% of substitution is statistically different from the other traits whose percentage of substitution was 0%, 5%, 15% and 25%, since their values gave 6,68,7, 95, 8.89 and 5.49 respectively. The percentage of replacement of 25% and 0%, are statistically equal with values of 5.49 and 6.68. Also the percentages of 0 and 5% with values of 6.68 and 7.95 are equal; and the percentages of 5 and 15% with values of 7.95 and 8.89.

From the results, it was observed that the highest strength (fck) occurred with the addition of ground glass, in a total of 35%, replacing the sand present in the trace.

Since glass is a material not much appreciated by recycling, due to the low price paid per kilo, and for this reason with great availability, there is the possibility of using it as an aggregate in the production of concrete, saving the environment of the use of sources

Table 11 - Result of application of the Tukey test between the test specimens.

Trace	Mean	k					Tukey
		5	4	1	2	3	
5	32,37						a
4	26,88	5,49					b
1	25,69	6,68	1,19				bc
2	24,42	7,95	2,46	1,27			cd
3	23,48	8,89	3,39	2,21	0,94		d

of aggregates contamination by excessive glass disposal (BENATTI, 2016).

The concretes produced with residues have different characteristics from the conventional concretes. The degree of difference will vary according to the type and quality of the waste used. Some concrete characteristics that can be modified by the use of waste include: mechanical resistance; water absorption; porosity and permeability; drying retraction; modulus of elasticity; fluency; specific mass (OLIVEIRA, 2007).

The scrap glass has much to contribute, because it is a recyclable material, at very low cost, and has in its composition, a great amount of silica and calcium oxide, being able to present pozolanic characteristics, improving the mechanical properties of the concrete (MALIK et al., 2013; TAMANNA; SUTAN; YAKUB, 2013). In this sense, the use of ground glass scrap, added to concrete as a fine aggregate, would be minimizing environmental impacts, encouraging the reuse of materials used in construction, fostering sustainability in the various construction sectors, and expanding economic alternatives for construction companies, recycling companies and also for glassworks (GOMES, 2011).

The present study revealed that the partial replacement of the sand with 35% of ground glass achieved a compressive strength of 32,37 MPa at 7 days of wet curing, higher than the minimum allowed of 25 MPa for structural concrete.

The feasibility of using ground glass in concrete was also evidenced in another study, with the proportion of 50% ground glass and 50% sand, the concrete reached a characteristic resistance (Fck) at 28 days of 30.4 MPa. In addition, it is possible to use a high mechanical strength of the concrete, which can be used for structural purposes (NASCIMENTO et al., 2014).

Another study also revealed that, using a partial replacement of the sand with 40% of ground glass to the concrete, it achieved a satisfactory result, proving that it presents technical feasibility in the execution part, but also contributes to the sustainability of the environment (CIRILO, 2016).

International studies have also shown that the production of concrete with ground glass, regardless of the proportions of substitution of the small aggregates, did not have a significant influence on the physical or mechanical properties of the concrete (GERGES et al., 2018). Another study showed that the substitution of 20% of fine aggregates with glass residues increased the compressive strength by 15% at 7 days and 25% at 28 days (MALIK et al., 2013).

Since glass is a material made from a melting silica mass, it can be seen that, at the end of its production process, the glass is a composite of amorphous silica. Since the glass residue classified by NBR 10004 (ABNT, 2004) as a class II B residue, considered as non-hazardous and inert, this type of residue can be used in cementitious matrix, as long as it is finely ground, since as an aggregate may trigger alkali-aggregate reactions (PAIVA, 2009; TAMANNA; SUTAN; YAKUB, 2013).

The presence of amorphous silica in its composition makes glass a material with potential for promoting pozzolanicity, when it presents a high degree of fineness. Care should be taken in the analysis of the alkali-aggregate reaction, especially the alkali-silica reaction, since the large amount of silica can react with the alkalis in the cement generating a gel that is expanding in the presence of water, with damage to concrete (SOUSA NETO, 2014).

4 Conclusions

The glass scrap has become a recyclable material for its low cost, besides presenting pozzolanic characteristics, contributing with the mechanical properties of the concrete and with the increase of its resistance.

The ground glass used in the preparation of the concrete presented good granulometric characteristics, since it facilitated the confection of the trait, due to its granulometry similar to that of the small aggregate, such as sand. The pre-established tracing for the preparation of the concrete was maintained during the whole process, since it presented good workability.

After the curing process over a period of 7 days, the axial compression test result was satisfactory for the concrete in which 35% ground glass was used as the replacement of the small aggregate. The result obtained shows that during this curing period the concrete presented a resistance greater than the established minimum that was of 25 MPa.

In view of the results obtained, it can be concluded that the concrete with the use of ground glass presents technical feasibility for execution, and also helps in the preservation of the environment by giving a correct destination to the “51” and “Long Neck” bottles. A Long Neck bottle weighs on average 200 grams and 250 bottles equals 50,000 grams of glass (50 kg), which were not deposited directly into the soil, waiting 1,000,000 (one million) years to decompose.

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