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USE OF POLYMERIC WASTE IN THE MANUFACTURE OF STRUCTURAL CONCRETE: ADDITION OF TAILINGS (RIGGED POLYURETHANE FOAM), FROM REFRIGERATION EQUIPMENT DISPOSED OF AS A COMPONENT IN STRUCTURAL CONCRETE

Ronald Matheus Lobo Pereira
Instituto Militar de Engenharia -RJ, Brazil

Sergio Neves Monteiro
Instituto Militar de Engenharia -RJ, Brazil

Flavio Henrique de Jesus Pestana Sousa
Universidade CEUMA - São Luís, MA, Brazil

Jurandir Amorim Moraes Filho
Universidade Estadual do Maranhão- MA, Brazil

Yago Soares Chaves
Instituto Militar de Engenharia -RJ, Brazil

Abstract: Concrete is usually very requested in the field of civil construction, Its manufacturing process and application, in Brazil presents itself as the civil industry component that generates the most waste of environmental impact. Aiming at mitigating this environmental impact generated, studies have been developed relating the reuse of materials as a possible solution to solve this problem. In this fine line, the present work exposes an investigation on the mechanical characteristics in the increment of the concrete with different concentrations of rigid polyurethane volume, to replace a portion of the coarse aggregate establishing relationships with the days of curing of the predefined concrete, with the aim of to produce structural concrete that meets current standards. The methodology adopted was the characterization of materials, granulometric verification, the slump of the concrete, the percentage of moisture acquired after curing the concrete and compressive strength. The data obtained showed very satisfactory results and with the potential to support the correct designation project for fillings and sealing of walls, partitions and panels, but unfeasible for structural purposes and intended for civil construction.

Keywords: Waste, Polyurethane, Structural concrete, Civil construction, Aggregates.

INTRODUCTION

The construction industry has high levels of solid waste generation. Aiming at taking actions that reduce the impacts generated on the environment, it is important to carry out studies aimed at the reuse of materials (TINOCO; KRAEMER, 2011).

The arrangement of two or more diverse elements is a material designated as a composite, intended to achieve a better arrangement of properties. Several modern technologies demand materials with anomalous properties that are inherent to standard materials (CALLISTER, 2002). The use of polymeric waste, as a large aggregate of structural concrete, is a viable alternative, because by reusing this material we will be reducing the generation of waste in the civil and refrigeration industry.

Rigid polyurethane foams are widely used in the refrigeration industry segment, which can be found in the doors and cabinets of refrigerators and freezers. This type of polymer, after going through the final manufacturing process, cannot be melted and remodeled again, so it is not mechanically recyclable. Concrete, in turn, also has inputs that are non-renewable and from an exhaustible sources, such as sand, gravel and cement, which is highly requested in civil construction (VILAR, 2000).

The present work aims to analyze the behavior of this rigid polyureth´ano residue after its incorporation in the production of structural concrete, analyzing whether the data are within the parameter of the standard, in order to achieve interesting characteristics that add value to the new product.

The methodology applied was carried out by bibliographic research, after defining the type of material to be used, and a compression test was developed to analyze the resistance achieved after meeting the following steps: characterization of materials, granulometry analysis, trace determination, slump test, preparation of specimens, cure in 7, 14 and 28 days; check of the rupture tension by means of axial compression test ;and analysis of the obtained results.

EXPERIMENTAL PROCEDURE

The analysis of the reuse of PUR waste, as an insertion apart from the composite (PUR/cement/aggregates/water) for the development of new products in the field of civil construction. The characterization of the materials was carried out, followed by the definition of the traces to be used, slump test, preparation of the specimens and curing, according to predefined times.

The experimental procedure is applied according to Figure 1, which had an essential role in the development and analysis of the new mechanical properties acquired from concrete with the addition of rigid polyurethane. In Figure 1 is shown a flowchart of this summarized experimental procedure used, and shortly after the steps in detail.

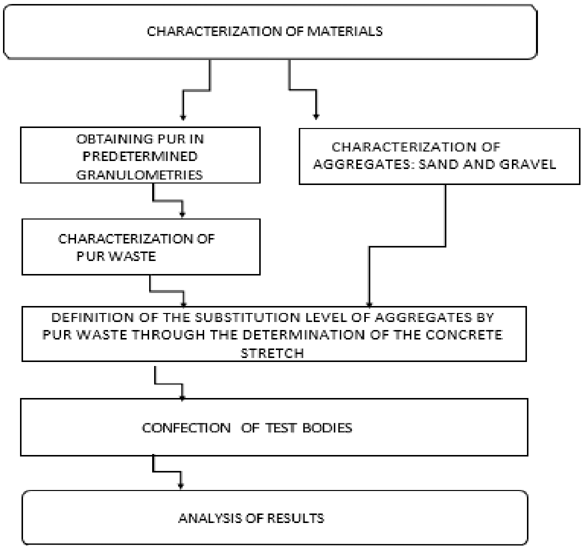

Figure 1: Shematic representation of the experimental process used.

CHARACTERIZATION OF AGGREGATES

The sieving method was carried out, using sieves for soil mechanics tests, brand BERTEL, meeting the requirements of the NBR NM-ISO 3310-1 standard. All the aggregates were sieved and granulometrically classified. The normal series of sieves used was: 50; 37.5; 25; 19; 9.5 and 4.8mm, for gravel and the series of 4.75;2;1.18;600;300;150 and 75mm for sand.

These materials applied as aggregates had their characteristics defined according to the standards: NBR NM46:2003, NBR NM 52:2009, NBR NM 52:2009 and NBR NM 248:2003. The amounts used, of each of the aggregates, are proportionally in the concrete mix.

PUR CHARACTERIZATION: GRANULOMETRIC ADEQUACY

To granulometrically adjust the PUR residues, which were initially in the form of plates of varying sizes, these residues were fragmented using a commercial juice extractor. Next, the sieving process was verified, using sieves for soil mechanics tests, brand BERTEL, meeting the requirements of the NBR NM-ISO 3310-1 standard. All material was sieved and granulometrically classified. The normal series of sieves used was: 50; 37.5; 25; 19; 9.5 and 4.8mm.

PUR GRANULOMETRIC CHARACTERIZATION

The characterization of the PUR was through the sieving that determined the diameter .Measurement was also carried out by ruler. The granulometric characteristics of the extracted and separated PUR are shown in Table 1.

IT PASSES THROUGH THE SIEVE (mm)	IT WAS RETAINED IN THE SIEVE (mm)
19	9,5

Tabela 1: Separation by cylindrical shape of the PUR by the orange juice extractor.

IMAGE CHARACTERIZATION

The particles referring to the granulometry, described in table 1, are presented in Figures 2 and 3.

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Figure 2: Rigid polyurethane separated in granulometry retained in the 9.5 mm sieve.

Figure 3: Granulometric separation from 19 to 9.5 mm.

Figures 2 and 3 refer to the sizes of the diameters that were verified apart from the sieving, which was retained in the 9.5mm opening and by measuring the ruler.

CHARACTERIZATION OF AGGREGATES

The characterization of the sand comes from weighing as a wet material plus the capsule recipient and soon after it goes through the drying process in the oven for 24 hours, with a temperature of 110ºC, thus obtaining the dry sand. The dry sand was weighed with the capsule, this way it was possible to determine the moisture content of the material. According to the results presented in the tables, it is observed that the sand presented a small percentage of particles of sizes 2.4 mm and a higher concentration of size 0.3 mm. The gravel showed a concentration of particles from 9.5 to 4.8 mm in size. The fineness modulus is the sum of the accumulated retained % the normal series sieves, which the samples are averaged to know the fineness modulus, so the sand fineness modulus was found as 2.6 and the maximum diameter is obtained by the percentage accumulated retention less than or equal to 5%.

PREPARATION OF MIXTURE

In the mixing stage, two variations were handled in relation to the percentages of material placed in the mix, with 25 and 50% of rigid polyurethane being inserted to replace the volume of gravel aggregate, as presented in table 2.

-	CEMENT (dm³)	SAND (dm³)	GRAVEL (dm³)	WATER (dm³)	PUR (dm³)
STANDARD	1	1,06	1,20	0,54	0
25%	1	1,06	0,90	0,54	0,30
50%	1	1,06	0,60	0,54	0,60

Tabela 2: Materials used to prepare each concrete mix, converted to volume in liters.

TRACE DETERMINATION

The defined and convenient trace for all samples was 1; 1.14 ;1.40 and 0.38, composed of cement, sand, gravel and water, respectively. This trait was refined by running the test by Slump using kneading with replacement of aggregates by the highest concentration of rigid polyurethane. The tests by Slump Test were carried out with the equipment of cone trunk, base and tamping rod that follows the specifications of NBR NM67: 1998.

PREPARATION OF SPECIMENS

The preparation of the concrete was carried out in accordance with the procedures described in NBR 12821. The equipment used is a 120 dm^3 concrete mixer. The equation below determines the method for converting the trace to volume:

$$T\,V = \frac{1}{\gamma c} + \frac{2{,}8}{\gamma a} + \frac{3{,}2}{\gamma b} + \frac{0{,}45}{\gamma h2o} \quad (1)$$

The holding duration was found to be 2 min, broken down according to NBR 16607:2018 –Determination of cement setting times, Portland brand.

The consistency of the concrete is one of the predominant factors that influence its workability, is defined from the concrete slump test, following the specifications of NBR NM67: 1998.

The preparation of the specimens was performed by placing 2 layers of mixture of the same volume, applying 12 strokes with a standard socket in each layer, according to the specifications of NBR 5738:2016.

All specimens made with the composites obtained were subjected to a compression test, carried out in accordance with the NBR 5739:2018 standard, in the city of São Luís – MA. The specimens were tested at ages of 7, 14 and 28 days.

Figure 4: Compression testing equipment.

RESULTS

SLUMP TEST

The Slump Test technique is used with the objective of achieving a coherent concrete mix for each mixture by properly replacing the crushed stone with rigid polyurethane.

Figure 5 shows the slump curve of the samples, prepared according to the concentration percentages with PUR and conventional concrete, without curing time, considering the percentage by volume of rigid polyurethane in the concrete mixture to replace part of the gravel. The reference concrete mixture for abatement was around 7 cm.

WATER ABSORPTION

The analysis by water absorption was verified by the percentage of water acquired due to the fact of leaving the samples immersed in water for a predefined time, correlated according to the curing time for rupture, thus making it possible to saturate the specimens . To determine the amount of water absorbed by the samples, it was weighed before and after saturation. The specific mass of the samples subjected to the compression test was calculated before performing the test.

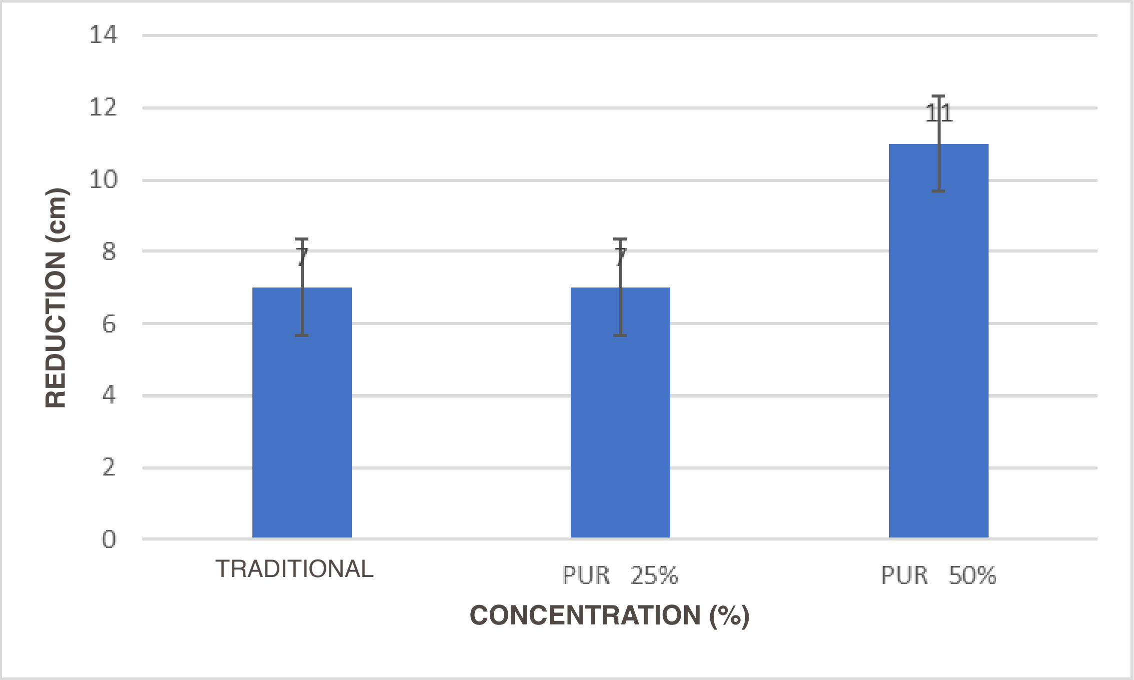

Figure 5: Slump teste.

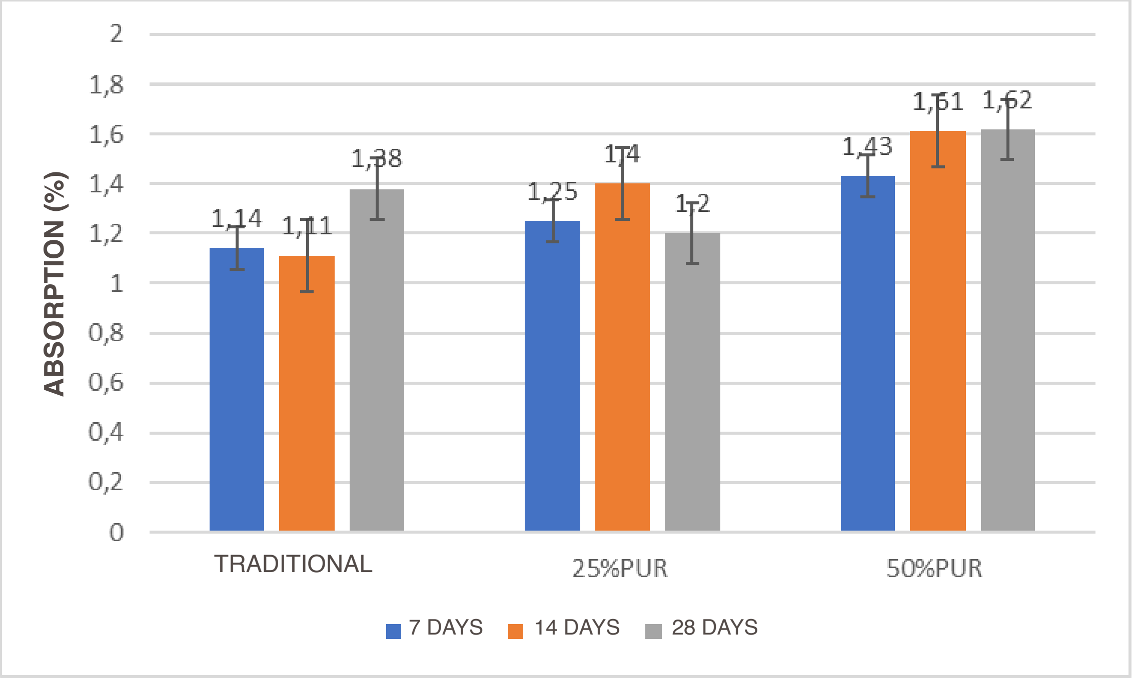

Figure 6: Water absorption.

The result of the analysis of all samples by water absorption is shown in Figure 6.

The samples of mixtures with increment of PUR with granulometry of 19 to 9,5 mm present different absorptions between the concentrations of 25 to 50 vol% and the conventional, and as the curing days went by, their water absorptions increased, it was verified that only the 25% PUR had a small decrease on the last day. The 50% PUR showed greater water absorption in relation to the others, at any curing time.

RUPTURE TENSION

The development of this characterization was carried out through the use of the press machine, which compressed the specimen, thus obtaining the data relative to the resistance. prepared, aged 7, 14 and 28 days, for a concrete dosage.

Figure 7 for, the strength for 7 days, it is observed that the conventional concrete reaches an average strength of 18MPa. As PUR is added, there is a decrease in strength in relation to the conventional, considering that with 25% of PUR in concrete the strength was 7.49 MPa and for 50% PUR 9 MPa. However, the more the PUR concentration increases, the compressive strength increases.

For 14 days, the compressive strength increases in relation to 7 days, for a concentration of 25%PUR we have 7.87 MPa and 50% of PUR 9.35 MPa. However, when compared to the conventional, it is far below the resistance, as it reached 24.5 MPa.

The results found in the compressive strength tests were performed on specimens, aged 28 days. It is analyzed that the compressive strength continues to rise in relation to days 7 and 14. With 25% PUR the strength reached 11.12 MPa and for 50% PUR we have 18.17 MPa, that is, as the days of curing we have an increasing result of compressive strength, and the more PUR is added with opening particles from 19 to 9.5mm, the strength increases. However, still below the conventional that is 30MPa.

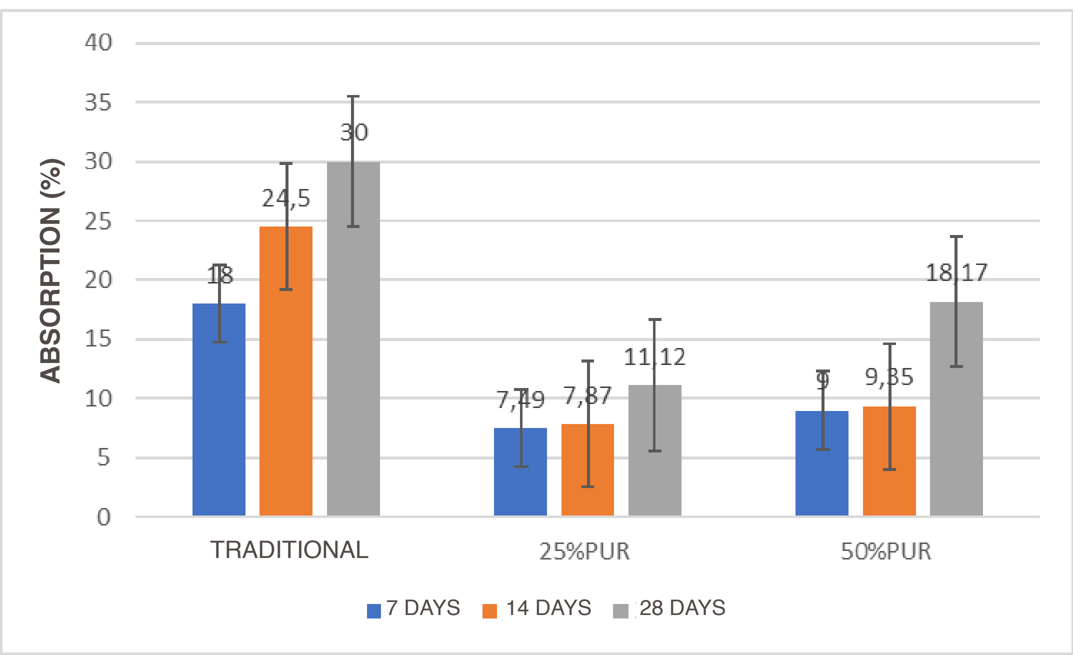

Figura 7: Of the curve of rupture stress versus concentration of PUR added in the composition of the concrete at ages of 7, 14 and 28 days.

CONCLUSION

The results obtained in the tests were quite satisfactory, the slump test with the increase of PÚR with a concentration of 25% and 50% did not differ much from the conventional one, respectively the slump was 7 cm and 11 cm in relation to the conventional one that obtained 7 cm. In the analysis of water absorption the data did not vary much, it remained almost similar to the conventional one. The tensile strength test showed a large difference in strength compared to standard concrete.

According to NBR 8953/2015, the concrete must reach at least 20MPa in axial compression. Considering this standard, the result obtained in the rupture stress tests was 18.17MPa below the allowed, making its designation for structural purposes unfeasible. Therefore, being designated for filling and sealing walls, partitions and panels, as established by ABNT NBR,6118:2014.

However, the study showed great potential to overcome this resistance determined by norm, because as the concentration of PUR increases, the resistance increases. The standard refers to the consistency of the concrete, which for slump from 10 to 50 mm and 50 to 100 mm, is indicated for strength below 20MPa, its functionality is designated for extruded concrete, pressed vibro and pavement.

REFERENCES

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR 12821: concrete preparation in laboratory. Rio de Janeiro: ABNT, 2009.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR 5738: criteria for molding and healing of the specimen. Rio de Janeiro: ABNT, 2016.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR 5739: concrete: compression test of cylindrical specimens. Rio de Janeiro: ABNT, 2018.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR 8953: designed for structural concrete according to the consistency of classes. New York: ABNT, 2015.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR 16607: determination ofpega. New York: ABNT, 2018.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR NM-46: indication of fine material. New York: ABNT, 2003.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR NM-52: requirements that determines the specific and apparent mass of the small aggregate. New York: ABNT, 2009.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR NM-67: Slump test. Rio de Janeiro: ABNT, 1998.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR NM-248: concrete: composition granulometric. Rio de Janeiro: ABNT, 2003.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. ABNT NBR NM-ISO3310-1 : technical requirements and test sieves. Rio de Janeiro: ABNT, 2016.

CALLISTER JR., W.D. Materials science and engineering: an introduction. 5. ed. Rio de Janeiro: LTC, 2002, 589p.

KRAEMER, Maria Elisabeth Pereira. The environment and sustainable development and waste class I. Available at: http://www.gestaoambiental.com.br/artieles.ph?id65 Access: Mar. 12, 2019.

VILAR, W. Polyurethane Chemistry and Technology. 2. ed. Rio de Janeiro: Editora Vilar Consultoria, 2000.