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ANALYSIS OF THE PET RESIDUE INCORPORATION EFFECT IN CONCRETE

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Abstract: This study aimed at using fiber of polyethylene terephthalate (PET) embedded in the concrete. The methodology used to obtain the results was based on the experimental IPT assay method. The concrete dosage is 1:0.8:4.2:0.5; 1:0.5:3.5:0.5; 1:3.1:2.9:0.5; with 0%, 2%, 3% and 4% polymer respectively with the nominal strength of 25 MPa and SLUMP 60 ± 20 mm, mixed in a concrete mixer with a capacity of 120 liters in the time 15 minutes each trait. Thus, were made following the test body 192 of cylindrical form 10 cm diameter by 20 cm, according to NBR 5738/2008, the concretes in ages of 7, 14, 21 and 28 days after twenty-four hours were immersed in tanks with water, remaining until the break according to the above requirement. In the analysis of the results revealed that all traces reached the desired strength, with the specimens 2%, 3% and 4% higher mechanical strength 25.84; 26.8; 30 MPa, among the samples analyzed, attributed to this increase possibly the geometric feature of the fiber 0.03mm x 0.01mm, allowing certain PET fiber grip with the concrete matrix.

***Keywords*- Polyethylene terephthalate, IPT method, Mechanical resistance.**

I. INTRODUCTION

Concrete is a material widely used by civil construction. Formed by mixing cement, water, sand, gravel or rolled pebble. In the mixing of the cement with the water the chemical reaction occurs forming the adherent paste and surrounding the aggregates thus, producing the material that can be molded, after its solidification becomes the material with good mechanical resistance and optimum performance to be used in the constructive processes [1].

The largest volume of concrete is formed by aggregate large and small, only in the year 2001 to 2007 were produced 279 million tons of sand and 217 million tons of gravel. The high consumption of these materials generates environmental imbalance in the future certainly the scarcity of raw material [2].

Thus, one of the peculiarities of civil engineering is the search for new materials that present good performance in the sense of improving the inherent properties of the concrete and that favors the preservation of nature. It is in these circumstances that studies have been carried out using fibers generated from different materials such as steel fibers, glass fibers, synthetic fibers and natural fibers as reinforcing element in the concrete matrix [3].

These alternatives proposed by engineers and researchers are intended to reduce the exploitation of natural resources, improve the property of concrete and promote the disposal channel is solid waste from human activities. Thus, for Alves *et al.* due to the high consumption of synthetic materials, the bottles PET (polyethylene terephthalate) post-consumption corresponds on average 20% of urban solid waste [4]. PET is a difficult material degradation, occupy a large volume in landfills and is found in abundance in nature. For this reason, the choice of the use of fiber from PET bottles as a reinforcement of the matrix of concrete.

The English Winfield and Dickson developed the PET polymer in 1941. Its great potential for initial application was as fiber for the textile industry, and subsequently went on to have great acceptance in food storage. In 1973, Dupont introduced the PET in the application such as bottles and revolutionized the market of packaging. However, with the gradual increase of population and exaggerated consumption of industrialized products caused serious impacts post-consumption, such as lack of infrastructure in landfills, waste collection deficient and Descartes inadequate.

For this reason, that the civil engineering through research, seeking new materials that present good performance and relatively low cost in order to contribute to the preservation of nature. The choice of fiber from post-consumer PET as an element of strengthening of the matrix of the concrete bases to be a material resistant to degradation and to be found in abundance in the environment.

The main objective of this research is to verify the mechanical resistance of concrete and concrete specimens with PET fiber for making concrete structures with local materials.

II. MATERIALS AND EXPERIMENTAL PROGRAM

The concretes produced in the laboratory of the Federal institute of Amapá (IFAP), initially for experimental study, was assayed for a characteristic resistance of 25 MPa. This resistance was chosen because it fits in the age of conventional concrete. The materials used for the production of concrete of departure were: Portland Cement CPII-E-32, according to the brazilian association of portland cement (ABCP) [5], the cement with the addition of granulated slag of blast furnace, have slow hydration reactions by modifying the microstructure of concrete, decreasing the ionic permeability, the diffusibility and the capillary porosity, increasing the mechanical resistance (Table 1).

TABLE I COMPOSITION OF PORTLAND CEMENT

Portland Cement	**Acronym**	**Composition of earth (%)**			**Brazilian standard**
		Clinker + gypsum	Blast furnace slag	Carbonate Material (symbol F)	
Compost	CPII – E-32	94 – 56	6 – 34	0 – 10	NBR – 13 578

The Sand used for confection of concretes was derived from natural deposits located in the municipality of Porto Grande – AP, Brazil. The same was stored at bay with covered area. The test of characterization of the sand was performed in accordance with the NBR 7211 (2009), see Fig. 1.

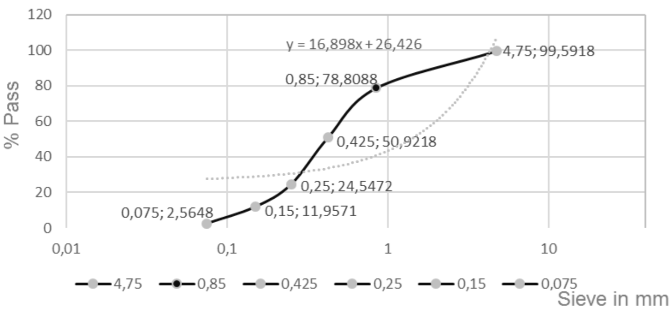

Fig. 1 Grading curve of sand in study

The nature aggregate, pebble rolled, used in the production of concretes was the type boulder curled from natural deposits located in the municipality of Porto Grande, Amapá, Brazil. It was stored in bowl, in dry covered area to the environment. The test particle size [6], see Fig. 2.

PET fibers used in the study were obtained in an artisanal manufactures located in the neighborhood of the Congos in the city of Macapá, Amapá, Brazil, which from soda bottles of post-consumption, clean and shredded in the form of wire of rectangular section, wrapped in a stand with dimensions of 40x40cm led to the oven at 150ºC for 40 minutes so that they can gain rigidity for manufacture of brooms.

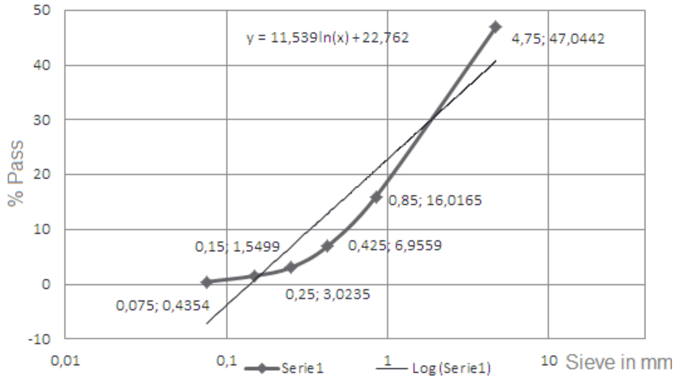

Fig. 2 Grading curve of the pebble rolled into the study

The fibers used in the manufacture of the Polymer concretes are cut from the bottom of the sweeper where, showed the average length of 0.03mm x 0.01mm of width (Fig. 3).

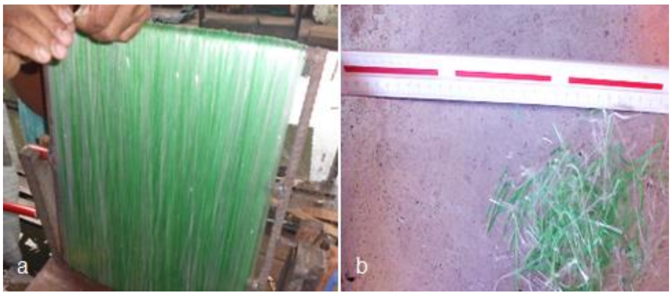

Fig. 3 PET fibers: (a) Manufacture of fiber from PET; (b) cuts of PET fiber for use in concrete specimens of evidence

For the amount of volume of fibers was calculated using the following equation.

$$Vf = \frac{Vf\%xVm}{1\text{-}Vf\ \%} \qquad (1)$$

Where:
Vf - volume of fibers, in cm³;
Vf% - percentage of fiber, in %;
Vm - volume of concrete, in cm³;
MF - masses of fibers, in grams.

The quantity of PET in the mixture shall be amended in accordance with the dosage described in reference [7].

The methodology used to obtain the results was based on the method of determination of the experimental research institute for technological research (IPT), technical standards ABNT and review of the literature. It was dosed in three traces 1:0.8:4.2:0.5; 1:0.5:3.5:0.5; 1:3.1:2.9:0.5; with 0%, 2%, 3% and 4% of polymer, respectively (Fig. 4), with a nominal resistance of 25 MPa and slump 60±20mm, mixed into concrete mixer with capacity for 120 litres in time 15 min. each trait. Thus, in the sequence were made 192 specimens of evidence of cylindrical shape 10 cm diameter by 20 cm height according to ABNT [8] at the ages of 7, 14, 21 and 28 days [9].

The specimens of evidence after 24 hours were immersed in containers with water until the day of the breaking according to the ABNT [8] in the ages of 7, 14, 21 and 28 days (Fig. 5).

Fig. 4 Modelling of the specimens of evidence

Fig. 5 Specimens immersed in water.

The specimens of evidence were tested on a machine EMIC brand DL3000 with a maximum capacity of 300 KN with the aim of compressing until their breakup, thus obtaining the strength characteristics of the material. The testes was performed in the laboratory of state university of Amapá (UEAP) (Fig. 6), following the guidelines of the ABNT [10].

Fig. 6 Equipment for testing compression

III.RESULTS AND DISCUSSIONS

Follows the results obtained for resistance to compression of concretes with and without the addition of PET the dosage of 1:4, being the concretes with 3% and 4% fiber from PET with higher mechanical resistance in relation to the concrete with 0% of PET (Table 2).

TABLE II
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 7 DAYS OF DOSING (1:4)

CP	Days	Dosage 1:4	PET fiber (%)	Loading (MPa)
1	7	1:0,5:3,5:0,5	0	18,74
2	7	1:0,5:3,5:0,5	0	14,67
3	7	1:0,5:3,5:0,5	0	19,71
4	7	1:0,5:3,5:0,5	0	18,16
5	7	1:0,5:3,5:0,5	2	17,58
6	7	1:0,5:3,5:0,5	2	16,93
7	7	1:0,5:3,5:0,5	2	15,81
8	7	1:0,5:3,5:0,5	2	18,28
9	7	1:0,5:3,5:0,5	3	21,39
10	7	1:0,5:3,5:0,5	3	23,22
11	7	1:0,5:3,5:0,5	3	26,46
12	7	1:0,5:3,5:0,5	3	27,16
13	7	1:0,5:3,5:0,5	4	26,82
14	7	1:0,5:3,5:0,5	4	21,28
15	7	1:0,5:3,5:0,5	4	25,39

The following are the results obtained from the resistance to compression of concretes and concrete with the incorporation of PET. Thus, the specimens of evidence of 3% and 4%, tends to larger resistors in relation to concrete with 0% of PET, performed at the age of 14 days (Table 3).

TABLE IIII
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 14 DAYS OF DOSING (1:4)

CP	Days	Dosage 1:4	PET fiber (%)	Loading (MPa)
17	14	1:0,5:3,5:0,5	0	21,76
18	14	1:0,5:3,5:0,5	0	22,95
19	14	1:0,5:3,5:0,5	0	23,34
20	14	1:0,5:3,5:0,5	0	25,02
21	14	1:0,5:3,5:0,5	2	20,25
22	14	1:0,5:3,5:0,5	2	20,01
23	14	1:0,5:3,5:0,5	2	21,17
24	14	1:0,5:3,5:0,5	2	21,47
25	14	1:0,5:3,5:0,5	3	27,79
26	14	1:0,5:3,5:0,5	3	27,8
27	14	1:0,5:3,5:0,5	3	27,42
28	14	1:0,5:3,5:0,5	3	27,35
29	14	1:0,5:3,5:0,5	4	30,73
30	14	1:0,5:3,5:0,5	4	30,57
31	14	1:0,5:3,5:0,5	4	29,73

Follows the results obtained in the resistance to compression of concretes and concrete with incorporation of

PET, however, the concretes of 3% and 4% with higher mechanical resistance to compression in relation to concrete with 0% performed at the age of 21 days (Table 4).

TABLE IV
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 21 DAYS OF DOSING (1:4)

CP	Days	Dosage 1:4	PET fiber (%)	Loading (MPa)
33	21	1:0,5:3,5:0,5	0	27,75
34	21	1:0,5:3,5:0,5	0	27,67
35	21	1:0,5:3,5:0,5	0	27,14
36	21	1:0,5:3,5:0,5	0	28,91
37	21	1:0,5:3,5:0,5	2	22,99
38	21	1:0,5:3,5:0,5	2	21,41
39	21	1:0,5:3,5:0,5	2	22,38
40	21	1:0,5:3,5:0,5	2	22,04
41	21	1:0,5:3,5:0,5	3	25,35
42	21	1:0,5:3,5:0,5	3	27,48
43	21	1:0,5:3,5:0,5	3	28,89
44	21	1:0,5:3,5:0,5	3	28,2
45	21	1:0,5:3,5:0,5	4	29,32
46	21	1:0,5:3,5:0,5	4	29,88
47	21	1:0,5:3,5:0,5	4	29,09

Follows the concretes with and without the addition of PET, however, the concretes with 3% and 4% for 28 days present higher resistances in comparison to concrete with 0% of PET. Since the specimens of evidence with 2% only met, the resistance initially to 25 MPa (Table 5).

TABLE V
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 28 DAYS OF DOSING (1:4)

CP	Days	Dosage 1:4	PET fiber (%)	Loading (MPa)
49	28	1:0,5:3,5:0,5	0	27,18
50	28	1:0,5:3,5:0,5	0	27,7
51	28	1:0,5:3,5:0,5	0	27,71
52	28	1:0,5:3,5:0,5	0	27,72
53	28	1:0,5:3,5:0,5	2	25,31
54	28	1:0,5:3,5:0,5	2	25,89
55	28	1:0,5:3,5:0,5	2	25,45
56	28	1:0,5:3,5:0,5	2	25,89
57	28	1:0,5:3,5:0,5	3	28,9
58	28	1:0,5:3,5:0,5	3	28,68
59	28	1:0,5:3,5:0,5	3	28,07
60	28	1:0,5:3,5:0,5	3	28,28
61	28	1:0,5:3,5:0,5	4	30,1
62	28	1:0,5:3,5:0,5	4	30,4
63	28	1:0,5:3,5:0,5	4	30,3

Follows the data obtained from the mechanical resistance of concretes with and without adding to the PET 1:5 the dosage, the concretes with 3% and 4% maintains with the higher mechanical resistance, compared with 0% of PET fiber (Table 6).

TABLE VI
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 7 DAYS OF DOSING (1:5)

CP	Days	Dosage 1:5	PET fiber (%)	Loading (MPa)
65	7	1:0,8:4,2:0,5	0	18,74
66	7	1:0,8:4,2:0,5	0	14,67
67	7	1:0,8:4,2:0,5	0	19,71
68	7	1:0,8:4,2:0,5	0	18,16
69	7	1:0,8:4,2:0,5	2	17,58
70	7	1:0,8:4,2:0,5	2	16,93
71	7	1:0,8:4,2:0,5	2	15,81
72	7	1:0,8:4,2:0,5	2	18,28
73	7	1:0,8:4,2:0,5	3	21,85
74	7	1:0,8:4,2:0,5	3	21,9
75	7	1:0,8:4,2:0,5	3	20,36
76	7	1:0,8:4,2:0,5	3	21,69
77	7	1:0,8:4,2:0,5	4	26,82
78	7	1:0,8:4,2:0,5	4	21,28
79	7	1:0,8:4,2:0,5	4	25,39
80	7	1:0,8:4,2:0,5	4	16,03

Follows the results of resistance of concrete and concrete with the addition of PET, dosage 1:5, being that the concretes with 3% and 4%, remain with the greatest resistance in comparison to concrete with 0% of PET performed at the age of 14 days (Table 7).

TABLE VII
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 14 DAYS OF DOSING (1:5)

CP	Days	Dosage 1:5	PET fiber (%)	Loading (MPa)
81	14	1:0,8:4,2:0,5	0	20,37
82	14	1:0,8:4,2:0,5	0	19,63
83	14	1:0,8:4,2:0,5	0	18,61
84	14	1:0,8:4,2:0,5	0	17,7
85	14	1:0,8:4,2:0,5	2	20,25
86	14	1:0,8:4,2:0,5	2	18,01
87	14	1:0,8:4,2:0,5	2	21,17
88	14	1:0,8:4,2:0,5	2	21,47
89	14	1:0,8:4,2:0,5	3	28,94
90	14	1:0,8:4,2:0,5	3	29,13
91	14	1:0,8:4,2:0,5	3	29,27
92	14	1:0,8:4,2:0,5	3	25,86
93	14	1:0,8:4,2:0,5	4	28,73
94	14	1:0,8:4,2:0,5	4	28,57
95	14	1:0,8:4,2:0,5	4	29,73
96	14	1:0,8:4,2:0,5	4	28,28

Following the results of mechanical resistance of concretes with and without adding PET, dosage 1:5, where the concrete with the addition of 3% and 4% with the higher mechanical resistance in relation to the concrete with 0% of PET (Table 8).

TABLE VIII
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 21 DAYS OF DOSING (1:5)

CP	Days	Dosage 1:5	PET fiber (%)	Loading (MPa)
97	21	1:0,8:4,2:0,5	0	23,99
98	21	1:0,8:4,2:0,5	0	26,37
99	21	1:0,8:4,2:0,5	0	23,92
100	21	1:0,8:4,2:0,5	0	24,11
101	21	1:0,8:4,2:0,5	2	22,99
102	21	1:0,8:4,2:0,5	2	21,41
103	21	1:0,8:4,2:0,5	2	22,38
104	21	1:0,8:4,2:0,5	2	22,09
105	21	1:0,8:4,2:0,5	3	27,6
106	21	1:0,8:4,2:0,5	3	27,2
107	21	1:0,8:4,2:0,5	3	27,91
108	21	1:0,8:4,2:0,5	3	27,09
109	21	1:0,8:4,2:0,5	4	28,32
110	21	1:0,8:4,2:0,5	4	28,88
111	21	1:0,8:4,2:0,5	4	28,09
112	21	1:0,8:4,2:0,5	4	28,3

Following are the results of resistance to compression of concretes and concrete with the addition of PET, dosage 1:5. However, the concretes with 3% and 4% have higher resistances in comparison to concrete with 0% of PET. Being that the specimens of evidence with 2% met the resistance initially dosed to 25 MPa at the age of 28 days (Table 9).

TABLE IX
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 28 DAYS OF DOSING (1:5)

CP	Days	Dosage 1:5	PET fiber (%)	Loading (MPa)
113	28	1:0,8:4,2:0,5	0	25,2
114	28	1:0,8:4,2:0,5	0	25,3
115	28	1:0,8:4,2:0,5	0	25,2
116	28	1:0,8:4,2:0,5	0	25,9
117	28	1:0,8:4,2:0,5	2	25,8
118	28	1:0,8:4,2:0,5	2	25,60
119	28	1:0,8:4,2:0,5	2	25,75
120	28	1:0,8:4,2:0,5	2	25,98
121	28	1:0,8:4,2:0,5	3	27,78
122	28	1:0,8:4,2:0,5	3	27,9
123	28	1:0,8:4,2:0,5	3	27,46
124	28	1:0,8:4,2:0,5	3	27,07
125	28	1:0,8:4,2:0,5	4	28,6
126	28	1:0,8:4,2:0,5	4	28,8
127	28	1:0,8:4,2:0,5	4	28,6
128	28	1:0,8:4,2:0,5	4	28,7

Follows the results obtained for resistance to compression of the dosage 1:2.9:3.1:0.5 with and without the addition of PET, dosage 1:6 to 7 days of healing. The concretes with the addition of 3% and 4% of PET, remaining with the higher mechanical resistance, compared with 0% of PET fiber at the age of 7 days (Table 10).

TABLE X
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 7 DAYS OF DOSING (1:6)

CP	Days	Dosage 1:6	PET fiber (%)	Loading (MPa)
129	7	1:3,1:2,9:0,5	0	16,35
130	7	1:3,1:2,9:0,5	0	19,69
131	7	1:3,1:2,9:0,5	0	14,38
132	7	1:3,1:2,9:0,5	0	17,65
133	7	1:3,1:2,9:0,5	2	17,58
134	7	1:3,1:2,9:0,5	2	16,93
135	7	1:3,1:2,9:0,5	2	15,81
136	7	1:3,1:2,9:0,5	2	18,28
137	7	1:3,1:2,9:0,5	3	21,85
138	7	1:3,1:2,9:0,5	3	21,9
139	7	1:3,1:2,9:0,5	3	21,36
140	7	1:3,1:2,9:0,5	3	21,69
141	7	1:3,1:2,9:0,5	4	18,5
142	7	1:3,1:2,9:0,5	4	22,04
143	7	1:3,1:2,9:0,5	4	24,37
144	7	1:3,1:2,9:0,5	4	24,28

The mechanical resistances obtained the dosage 1:2.9:3.1:0.5 of concrete and concrete with the addition of fibers of PET, dosage 1:6 to 14 days of curing, indicate the greatest resistance to compression to the concretes with the addition of 3% and 4% of PET (Table 11).

TABLE XI
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 14 DAYS OF DOSING (1:6)

CP	Days	Dosage 1:6	PET fiber (%)	Loading (MPa)
145	14	1:3,1:2,9:0,5	0	20,61
146	14	1:3,1:2,9:0,5	0	22,08
147	14	1:3,1:2,9:0,5	0	23,68
148	14	1:3,1:2,9:0,5	0	24,42
149	14	1:3,1:2,9:0,5	2	19,58
150	14	1:3,1:2,9:0,5	2	18,93
151	14	1:3,1:2,9:0,5	2	17,81
152	14	1:3,1:2,9:0,5	2	19,28
153	14	1:3,1:2,9:0,5	3	28,94
154	14	1:3,1:2,9:0,5	3	29,13
155	14	1:3,1:2,9:0,5	3	29,27
156	14	1:3,1:2,9:0,5	3	25,86
157	14	1:3,1:2,9:0,5	4	29,18
158	14	1:3,1:2,9:0,5	4	28,68
159	14	1:3,1:2,9:0,5	4	22,53
160	14	1:3,1:2,9:0,5	4	26,75

The following are the data obtained from the mechanical resistance of concrete at the age of 21 days, being that the concretes with the addition of 2%, 3% and 4% PET, dosage 1:6, presented a certain approximation of mechanical resistance with respect to the concrete with 0% of PET (Table 12).

TABLE XII
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 21 DAYS OF DOSING (1:6)

CP	Days	Dosage 1:6	PET fiber (%)	Loading (MPa)
161	21	1:3,1:2,9:0,5	0	23,05
162	21	1:3,1:2,9:0,5	0	23,73
163	21	1:3,1:2,9:0,5	0	24,33
164	21	1:3,1:2,9:0,5	0	23,76
165	21	1:3,1:2,9:0,5	2	22,99
166	21	1:3,1:2,9:0,5	2	21,41
167	21	1:3,1:2,9:0,5	2	22,38
168	21	1:3,1:2,9:0,5	2	22,04
169	21	1:3,1:2,9:0,5	3	23,6
170	21	1:3,1:2,9:0,5	3	23,2
171	21	1:3,1:2,9:0,5	3	23,91
172	21	1:3,1:2,9:0,5	3	23,09
173	21	1:3,1:2,9:0,5	4	24,32
174	21	1:3,1:2,9:0,5	4	24,38
175	21	1:3,1:2,9:0,5	4	25,09
176	21	1:3,1:2,9:0,5	4	25,3

The results of mechanical resistance of concretes with and without the addition of PET, dosage 1:6 to 28 days. Thus, there is a tendency for greater resistance to compression to the concretes with the addition of 3% and 4% fiber PET (Table 13).

TABLE XIII
DOSAGE OF CONCRETES WITH AND WITHOUT PET WITH 28 DAYS OF DOSING (1:6)

CP	Days	Dosage 1:6	PET fiber (%)	Loading (MPa)
177	28	1:3,1:2,9:0,5	0	25,66
178	28	1:3,1:2,9:0,5	0	25,41
179	28	1:3,1:2,9:0,5	0	25,59
180	28	1:3,1:2,9:0,5	0	25,58
181	28	1:3,1:2,9:0,5	2	25,84
182	28	1:3,1:2,9:0,5	2	25,17
183	28	1:3,1:2,9:0,5	2	25,65
184	28	1:3,1:2,9:0,5	2	25,01
185	28	1:3,1:2,9:0,5	3	26,78
186	28	1:3,1:2,9:0,5	3	26,9
187	28	1:3,1:2,9:0,5	3	26,06
188	28	1:3,1:2,9:0,5	3	26,7
189	28	1:3,1:2,9:0,5	4	27,77
190	28	1:3,1:2,9:0,5	4	35,89
191	28	1:3,1:2,9:0,5	4	36,19
192	28	1:3,1:2,9:0,5	4	35,3

An observation to be made is that specimens 16, 32, 48, 64, did not attest to their reliability in terms of confection and mechanical strength, so they were discarded from the related specimens.

The age of 28 days pointed out that there was no significant loss of resistance to compression of the concrete with addition of PET in relation to concrete without fiber of PET [11].

IV. CONCLUSIONS

In the analysis of the results showed that all traces reached the desired strength of 25 MPa in accordance with the ABNT [12]. The bodies of evidence of 2%, 3% and 4% were with higher mechanical resistance of 25.98; 28.9 and 30 MPa respectively for dosage 1:6 in 28 days. Among the specimens of evidence analyzed, attributes this increase possibly due to the geometrical characteristic of the fiber, allowing certain adhesion of PET fiber with the matrix of concrete.

The polymeric concrete can be used by civil engineering in the first moment for structural purposes, manufacture of blocks for sidewalks in the dosage of 1:6 and cure in 28 days as shown in Table 13.

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