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Comparison of Polyethylene Terephthalate and Fly Ash as an additive in Concrete

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Abstract— **The problem of searching for ecological and economic additives exists in various parts of the world. Visualizing the need for this problem, it is necessary to opt for various alternatives in buildings that help us promote the comparison of two additives, which are polyethylene terephthalate and fly ash. , as a replacement option without altering its composition in a negative way, defining the points that could serve as a reduction in costs, improvement of the properties of the concrete and in this way, showing its favorable results by comparing them for the use of these same adding to the concrete giving a viable option in both works and construction, also taking care of the environment. In section I, a summary of the various scientific articles is made demonstrating the viability of these additives in concrete from the point of view of the authors cited later. Section II details the filters used to select the articles. Section III details the different results obtained from the information collected, showing several tests carried out by the authors and the times they took for each test.**

Keywords—Polyethylene Terephthalate, Buildings, Fly ash, Concrete.

I. INTRODUCTION

In the world the use of PET (polyethylene terephthalate) material is abundant and diverse, it is used in beverages, packaging of aesthetic products and among others that use this PET material. In the construction sector, this PET material is just becoming known for its economic savings, reduction of environmental impact and to be able to make the most of it. The use of waste in construction has become a necessary solution to the environmental and economic problems of countries, particularly in the third world [1]. Show how the partial replacement of conventional aggregate in concrete by granulated polyethylene terephthalate (PET) impacts in terms of its compressive strength.[2]

Polyethylene terephthalate is one of the most used materials in the world, which is why they considered the use of solid waste of high-density polyethylene as an additive in the dosage of concrete, with the purpose of combining both materials, improving the mechanical properties. , complying with the regulations for different types of concrete and seeking to minimize the environmental impact produced by the variants of this type of waste[3].

The use of polyethylene terephthalate (PET) as a partial substitute for fine aggregate in the composition of concrete mixtures. The research explores how this substitution affects the properties and characteristics of the resulting concrete, taking into account the durability and resistance of the material.[4]. The impact of the addition of recycled polyethylene terephthalate (PET) on the flexural strength of concrete construction elements is examined. This study focuses on the search for sustainable alternatives for construction, using recycled materials to improve the mechanical properties of concrete[5].

Compare and evaluate the mechanical behavior of two types of modified concrete: one with recycled polyethylene terephthalate (PET) fiber and another with fly ash, focusing on critical properties such as strength and durability.[6]. Show the feasibility of using PET plastic, recycled from soda bottles, as an aggregate in construction mixtures [7]. Describe in detail the procedures used for the preparation of concrete with the addition of PET and its physical and mechanical properties will be analyzed in detail.[8]. On the other hand, fly ash is produced from the combustion of coal and is a material commonly used in concrete as a supplement to cement, with the aim of improving the properties of concrete.

The study will analyze the effect of the properties of mechanical resistance to compression, capillary absorption and chloride permeability of concrete when implementing fly ash in concrete.[9]. Present the results obtained after evaluating the properties of commercial cement pastes, by adding fly ash as part of the proportions of the concrete mix.[11]. Describe the characteristics that concrete presents after using fly ash and how its dosage varies and the benefits that certain properties of concrete present when additives are used.[10]. Show the different results after studying various types of tests implementing fly ash in the concrete mixing proportions that, in turn, contribute to the environment. The use of this additive as a replacement in the concrete mix is beneficial because it reduces the percentage of material that will be used in the mix, saving the budget in addition to providing better properties to the concrete.[12].

Fly ash is an environmental polluting waste so, when stored, it is harmful to the environment. A good use of this additive provides better properties, reaching maximum resistance. This study will evaluate the dosage of concrete mixtures by adding fly ash, in such a way that its resistance is not reduced and that it helps mitigate the environment [13]. Present and discuss the results obtained by adding fly ash to concrete, analyzing how its properties improve when using this material in its mixture[14].

In this study, fly ash will also be used, analyzing how it will improve concrete properties when using the material and the data obtained after evaluating several tests will be compiled. The question posed in the research was to determine the influence of polyethylene terephthalate compared to fly ash as an additive for concrete, posing the objective as evaluating the viability in the compressive strength of polyethylene terephthalate and fly ash as an additive to the concrete. concrete.

II. Methodology

The present research is a systematic review, in which repositories and scientific articles were taken, with the help of search engines, Scielo, Redalyc, among others,Since these search engines allow you to find documents of an academic nature such as articles, books, magazines, to make use of this fundamental tool of our systematic review of scientific literature, specific criteria are needed.

There were certain problems when searching for the items since some items were paid. At first, a range of 5 to 10 years old was taken, but in the end it was decided to extend it to expand the search and obtaining of scientific articles.

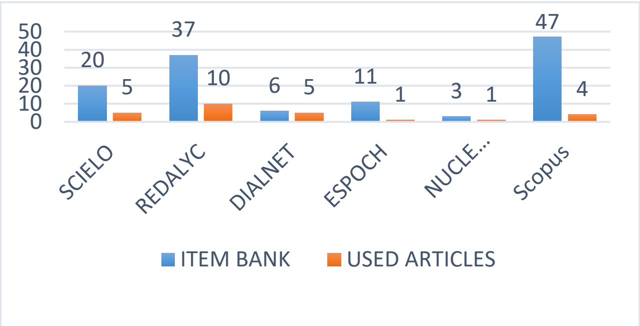

Figure 01. Search Engine

Graph 01 shows the blue color defined as the articles, magazines, from different search engines that were found on the topics to be discussed and the orange color are the articles that passed the filters to be taken into consideration in the present systematic review research. .

Inclusion Criteria: Keywords such as polyethylene terephthalate or concrete or fly ash were used. In the selection of articles, an age range of 10 years 2013 - 2023 was considered. In the search, articles from the English and Spanish languages were taken into consideration.

Exclusion Criteria: Paid scientific articles were not taken into consideration. Only scientific journals that contributed relevance to the systematic review were searched. No articles were taken that altered or modified our results as a result of not having agreement with the systematic review.

Table 01: Research Matrix

No.	SEARCH ENGINE	ITEM BANK	USED ARTICLES
1	SCIELO	20	5
2	REDALYC	37	5
3	DIALNET	6	5
4	ESPOCH	11	1
5	NUCLEODOCONHECIMENT	3	1
6	Scopus	47	4
TOTAL		124	21

As can be seen in Table 1, these 9 search engines were searched with the parameters of years, there was no exclusion of language, they were searched with the same keywords as the scientific article. Among the scientific articles and repositories, a total of 109 articles were obtained, of which 86 articles were excluded, taking the parameters mentioned above.

III. Results

The research is based on 21 main scientific articles, which followed a pattern using the inclusion and exclusion criteria mentioned in the methodology.

It will be made known the properties that polyethylene terephthalate and fly ash give as an additive in concrete, its resistance to compression, also other properties that it will give to the concrete in detail, according to the experimental models that are adhered to it by percentages or quantity, making it known if it is a viable option as an additive in concrete.

Table 02: Weight - Resistance Ratio [15].

Reference	**Container**	**Volume**	**Maximum load**	**Weight**	**Load/Weight**
		cm3	***N***	***N***	
E9	Soda	3,000	508.65	0.63	814.4
E17	Mineral water	1,750	438,610	0.550	803,700
E23	Soda	2,500	661,390	1,290	513,000
E12	Soda	2,000	244,070	0.480	504,700
E15	Mineral water	2,000	218,370	0.500	436,700
E22	Soda	2,000	235,440	0.550	429,600
E16	Mineral water	2,000	219,250	0.550	402,100
E24	Soda	3,000	198,950	0.580	352,200

In Mexico, according to Table 02, they took the references that will be used in bold, they show higher values in volume with load-weight, and that they have a high potential to be used as a material that helps to achieve high resistance.

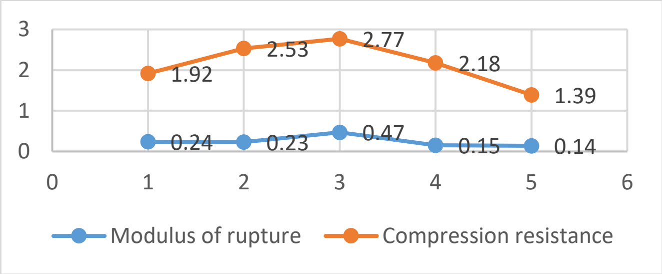

Figure 2. Comparison of Flexural and Compressive Strength. [18]

According to the source[twenty-one], they made hollow blocks by replacing part of the sand with PET material, analyzing its compression and bending behavior, obtaining as a result, from highest to lowest, hollow block with 40% PET, hollow block 20% PET, hollow block 60% PET, traditional hollow block and traditional hollow block.

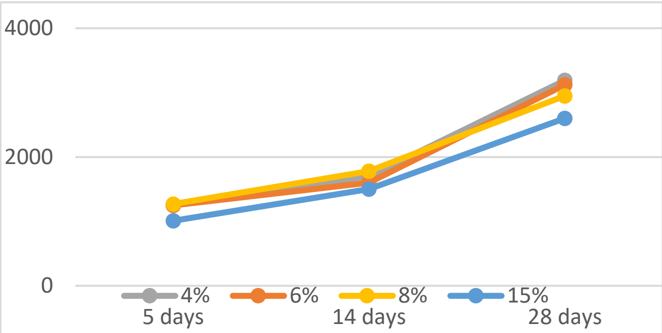

Figure 3. Compressive strength up to 28 days. [5]

In the values obtained in Figure 03 it can be seen that 4%, 6% and 8% are the highest values, on the other hand, 15% of PET has low values, through the results obtained, demonstrating that the first values give good compression resistance, therefore, they are a viable and sustainable option.

Table 03: Test results. [4]

Mix	Compressive Strength (MPa)						Settlement (mm)		Density (kg/m3)	
	3 days		*7 days*		*28 days*					
REF	13.5		20.9		29.9		75		2437	
PET 5 -1	10.3	9.7	19.1	19.3	28.1	28.8	80.0	75	2393.0	2403
PET 5 -2	9.10		19.4		29.5		70.0		2413.0	
PET 10 -1	6.7	8.7	16.2	16.4	25.9	26.2	75.0	70	2377.0	2374
PET 10 -2	10.6		16.6		26.5		65.0		2370.0	
PET 15 -1	10.5	10.2	19.3	19.0	25.5	25.7	95.0	90	2357.0	2355
PET 15 -2	9.9		18.6		25.9		85.0		2353.0	
PET 20 -1	11.7	10.2	17.6	16.8	24.7	24.7	40.0	65	2340.0	2342
PET 20 -2	8.6		16.0		24.7		90.0		2343.0	

In Table 03, we have the Pattern concrete, and different percentages of PET material, in the 3-day tests, it is seen that the highest percentages of PET obtain favorable results, at 7 days, the 5% PET is the one that It has better results in the tests and after 28 days the 5% PET obtains the most optimal results compared to the other percentages.

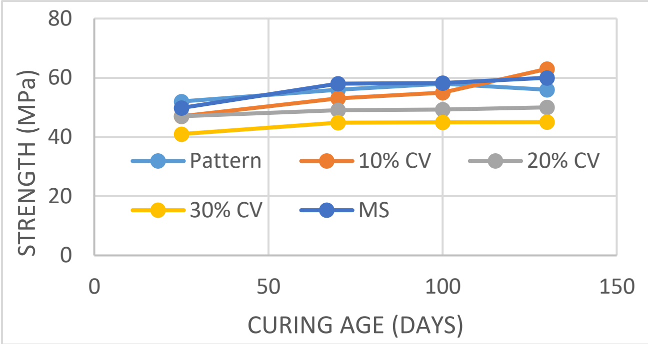

Figure 4. Results of compression resistance tests. [9]

The tests in Figure 04 showed that, at a higher curing age, greater resistance is obtained, while at early ages, its resistance decreases. The specimen with 10% fly ash (CV) achieved the highest resistance based on the standard sample. For the samples with 20% and 30%, their resistance shows a decrease, making the test piece with 10% CV a good option for marketing.

Studies show the benefits of using additives in the concrete mix, since they improve its properties by using a dosage of less than 5% of the cement mass. Among the benefits provided by the additives, the reduction in the W/C ratio, increase in resistance and modulus of elasticity, obtained from the replacement of sand and cement, by CV, stand out. Concrete will have greater resistance by replacing up to 20% of the cement mass [11].

Table 04: Results of compressive strength at 28 and 90 days.[12]

ID	28 days (Mpa)					90 days (Mpa)				
	Esp 1	*Esp 2*	*Esp3*	*x*	*CV%*	*Esp 1*	*Esp 2*	*Esp3*	*x*	*CV%*
PC8-FA2	14.45	15.08	13.92	14.50	3.3	23.19	24.80	21.46	23.13	1.8
PC8-BFS2	17.11	16.99	17.32	17,16	0.8	27.83	28.76	27.57	27.77	5.9
PC6-FA4	9.48	9.85	9.21	9.53	0.3	20.59	21.25	20.59	20.30	5.9
PC6-BFS4	13.61	13.82	13.29	13.73	0.2	26.81	26.05	26.89	26.77	1.4
FA8-BFS2	21.94	22.32	21.70	22.02	0.3	24.25	23.69	24.11	24.03	1.0
FA6-BFS4	25.11	24.97	26.45	24.89	1.1	27.99	27.91	27.26	27.19	1.2
FA4-BFS6	26.68	25.48	27.70	26.60	0.2	30.80	31.28	28.99	30.73	3.2
FA2-BFS8	28.97	31.07	29.98	30.03	1.7	35.01	34.89	35.12	35.09	0.3

According to Table 04, the increases in compressive strength of tests from 28 to 90 days for the 4 binary mixtures with concrete are described, having increases of: 64% in the PC8-FA2 mixture, 63% in the PC8-BFS2 mixture. , 110% in the PC6-FA4 mixture and 95% in the PC6-BFS4 mixture. With what was previously shown, the results at 90 days, the mixtures with CV, presented a greater increase in compressive strength, compared to the mixtures with slag.

Table 05: Average resistance to simple compression, 2016.[13]

% fly ash	7 days	14 days	28 days	90 days
0.0	146	178	218	226
2.5	147	180	223	231
5.0	150	185	231	235
10.0	139	170	200	211
15.0	125	159	192	204

For the dosage of a concrete of f'c = 210kg/cm2, an average compressive strength was obtained from tests of 7, 14, 28 and 90 days detailed in Table 05, with its CV percentage in each sample. From their results, it is observed that the maximum value of the simple compression resistance was reached by the sample with 5% CV. In the case of 10% and 15%, its resistance decreased, demonstrating that, using the smallest amount of CV, a good compressive strength can be achieved.

Table 06: Mix design results. [19]

No.	Fly ash (kg)	Water (L)	Cement (kg)	Strength (MPa)
1	0	288.09	182	10.54
2	0	264.81	196	11.43
3	0	241.53	210	12.81
4	28	253.17	175	9.51
5	14	288.09	168	9.06
6	7	253.17	196	10.76
7	7	288.09	175	10.91
8	0	311.37	168	10.33
9	14	264.81	182	10.97
10	28	264.81	168	9.21
11	42	241.53	168	8,045
12	14	264.81	182	11.25

In this study, 12 samples with different proportions of CV, water and cement were evaluated. The samples that do not have the addition of CV, present, on average, a greater resistance than the samples with CV. The addition of water provides more resistance to the concrete, but in excess, it can cause disfigurements in the specimen. For CV tests, they must have an increase in water to prevent the mixture from being dry and thus achieve better compression resistance.

Table 07: Physical-mechanical properties before being exposed to aggressive environments. [20]

Compression resistance		
Days	OPC control	Geo CV/ES
7	21.90	34.75
28	30.93	42.92
Physical properties		
Capillary Absorption Coefficient, k, (kg/m2 s1/2)	0.0292	0.0162
Resistance to water penetration, m, (s/m2)	1,899	3,242

The tests studied for the evaluation of the compressive strength of a conventional cement (OPC) and another with CV and blast furnace slag in a ratio of 80/20, showed the difference between both described in Table 07, with Geo CV/ predominating. ESC as the one that obtains the most resistance at 7 and 28 days, which shows that this test is suitable for use due to the durability it presents.

Table 8: Physical properties of mortars. [21]

Properties	A/C, mortar without CV				A/C, mortar with CV			
	0.35	0.45	0.55	0.65	0.35	0.45	0.55	0.65
fresh state								
mini slump	4.5	4.5	4.5	4.5	5.0	5.0	5.0	5.0
Trapped air %	3.0	5.6	5.6	4.6	2.5	3.7	4.7	4.3
hardened state								
Absorption %	8.2	8.3	8.6	9.6	5.2	6.2	6.5	6.7
Saturated surface dry volumetric weight, kN/m3	22.6	22.4	22.1	21.9	21.6	21.4	21.3	21.1
Compressive strength at 28 days, Mpa	62.9	45.4	39.4	29.7	58.4	40.6	34.7	27.9

For the mortars in Table 8, it is observed that the compressive strength at 28 days had an average reduction of 10% in the samples in the hardened state with the addition of CV.

Table 9: Results of compressive strength tests of concrete containing Class C and Class F fly ash. [22]

Fly Ash in Class C Concrete				Fly ash in concrete Class F			
Mixture No.	***Concrete Type***	***Compressive strength (N/mm 2)***	***Compressive strength (N/mm 2)***	***Mixture No.***	***Concrete Type***	***Compressive strength (N/mm 2)***	***Compressive strength (N/mm 2)***
		28 days	***90 days***			***28 days***	***90 days***
M1	C260	40.20	46.20	M1	C260	40.20	46.20
M2C	C234 C26	40.50	47.00	M2F	C234F 26	38.75	44.45
M3C	C234 C39	41.32	49.53	M3F	C234F 39	40.25	47.87

M4C	C234 C52	42.54	50.16	M4F	C234F 52	39.25	46.93
M5C	C216 C44	38.71	45.27	M5F	C216F 44	36.49	44.55
M6C	C216 C66	39.86	46.40	M6F	C216F 66	38.14	46.21
M7C	C216 C88	41.27	48.75	M7F	C216F 88	40.06	48.39
M8	C320	47.80	54.87	M8	C320	47.81	54.87
M9C	C288 C32	48.62	55.99	M9F	C288F 32	46.81	55.02
M10 C	C288 C48	50.85	57.56	M10 F	C288F 48	47.93	57.31
M11 C	C288 C64	50.55	56.95	M11 F	C288F 64	46.69	54.76
M12 C	C288 C54	48.26	55.57	M12 F	C288F 54	45.90	52.33
M13 C	C288 C81	50.54	57.43	M13 F	C288F 81	46.23	53.95
M14 C	C288 C108	51.22	59.84	M14 F	C288F 108	47.52	55.76
M15	C400	60.53	72.33	M15	C400	60.53	72.33
M16 C	C360 C40	57.90	68.96	M16 F	C360F 40	57.76	71.65
M17 C	C360 C60	60.88	72.88	M17 F	C360F 60	61.10	75.06
M18 C	C360 C80	63.26	73.84	M18 F	C360F 80	63.31	73.42
M19 C	C332 C68	58.87	68.65	M19 F	C332F 68	55.27	69.79
M20 C	C332 C102	60.19	72.06	M20 F	C332F 102	58.44	71.72
M21 C	C332 C136	62.91	73.15	M21 F	C332F 136	61.12	74.94

The studies carried out show that the compressive strength is greater as the concrete cures older. Likewise, concrete with CV type C reached its maximum compressive strength by reducing 10% of cement and replacing it with CV. When cement is replaced by 17%, concrete with CV type C and type F presented a reduction in its compressive strength.

IV. Discussions

The results of Tables [3] and [4] were compared, showing that the 28-day compression strength tests had a difference in the data collected, both for the concrete with 5% PET and the concrete with 10%. of PET, reaching the conclusion that the type of material could have differed in the result.

When comparing the results of table [4] with table [7], in the results of 28 days with 10% of each additive, it could be seen that fly ash gives better results than polyethylene terephthalate and Likewise for the addition of 20% of each additive.

Comparing figure [3] with figure [4], it was observed that the results of 8% PET and 10% CV are the highest, for the use of each additive the ease that could be obtained would have to be considered and the budget of the work. On the other hand, fly ash provided better compressive strength by replacing sand and cement with fly ash unlike common concrete. According to the researchers' data, several tests were carried out with different proportions of replacement of fly ash in the concrete mix, at different curing ages. In the tests by Janneth Torres Agredo, Ruby Mejía de Gutiérrez and Claudia Patricia Valderrama [F04], the sample with 10% CV reached its maximum resistance at a higher curing age compared to its standard sample. Several studies affirm that, to have maximum compressive strength, concrete must have a longer curing age. Different tests showed that they obtain greater compression resistance by replacing up to 20% of fly ash, otherwise its resistance decreases.

This research work reveals two types of additives for the concrete mix, so there were limitations for its preparation, among them the following stand out: the articles that cannot be viewed, the scarce information on the most recent articles, the capital to invest in one's own experimentation and the time to search for information on the topics presented. Finally, the research work concludes by arguing that in the ecological issue the two additives are a very good option, in the economic issue polyethylene terephthalte, because it can be obtained in an accessible way since it is used in all parts of the world, in another case in the matter of compression resistance and proportion used, fly ash is the best option because it replaces the common additive in greater quantities without the need to significantly alter its properties, therefore the two additives Alternatives are viable since they are economical, take care of the environment and maintain the properties that conventional concrete contains.

V. Conclusions

The present research work allowed us to learn about the properties generated by polyethylene terephthalate and fly ash, as well as their recommended percentages to achieve their maximum desired compression resistance. In the investigation carried out it was demonstrated:

Concrete with fly ash reaches its maximum strength by having a greater number of days of curing. It is important to know the proportions of the CV percentage, since this provides greater resistance up to a 20% CV substitution, however, a CV substitution greater than 20% causes a decrease in compression resistance, which already It would not be recommended for use or marketing. Given the investigations taken, it is concluded that it is viable to take 3% and 5%, taking into account the results, giving an economic option for the use of buildings, reducing material waste, and taking care of the environment.

The study focused on the concrete mix adding polyethylene terephthalate in structural buildings, there are also other topics and analyze the results that could give both positively and negatively. The databases were very useful for collecting information, although it is not found in the desired language, there are other languages available to search for information.

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