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Mechanical properties and self-cleaning mortar capacity C/A 1: 5 of Portland cement modified with titanium dioxide (TiO2)

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Abstract. The deterioration of the surfaces of the constructions made with mortar C/A 1: 5 of Portland cement, are produced by being exposed to the emission of toxic gases emanating from the growing automobile fleet, this problem causes alternatives to be sought in order to counteract its effect on buildings and the environment. A new method to deal this problem is the incorporation of the titanium dioxide photocatalyst (TiO2) into the Portland cement mortar, which can develop self-cleaning and air purification properties to be in contact with sunlight. This work seeks to introduce this organic component to the Portland cement mortar, used for the facade charging and structural elements, for this purpose, different percentages (5%, 7.5% and 10%) of titanium dioxide (TiO2) are added and the properties of the modified mortars making use of [1] compression tests, [2] fluidity tests, [3] absorption tests and [4] photocatalytic activity tests with which the self-cleaning capacity was verified. This study concludes that the best percentage of titanium dioxide addition is 5%, with which the Portland cement mortar is granted self-cleaning property without substantially damaging its mechanical properties.

1. Introduction

In South American countries, air pollution is largely due to the disproportionate increase in its car fleet. The gases emitted by public and private transport vehicles (some with more than 15 years old) contain polluting particles, according to the investigations carried out there is a good mortality rate, due to cardiovascular, respiratory and lung cancer problems. Likewise, they produce aesthetic and physical damages to the materials of the buildings, monuments and works of art, which are mostly constructed of concrete, which are located around places with moderate vehicular influx, and which are damaged by the dry or wet deposition of particulate material [5]. That is why the investigations of Titanium Dioxide (TiO2) in the world have concentrated on finding techniques to solve pollution problems, this through the process called photocatalysis that by making sunlight contact with a catalyst such as dioxide Titanium (TiO2) generates self-cleaning properties that not only help keep the material clean, but also give it the property to purify the air. [6] This research, after reviewing an extensive bibliography [7] [8] [9], hopes to introduce a new material that helps not only improve the conservation of cement-based materials but also the quality of life of people. For this purpose, tests are carried out to determine if after adding titanium dioxide to the mortar mixture with Portland cement, the mechanical properties are not altered and if the self-cleaning property is added.

2. Materials and methods

2.1. Materials

Figures 1, 2 and 3 show the components used to make the portland cement mortar mix, Figure 4 shows the organic component (rhodamine) that will be used to verify if is granted or not the mortar self-cleaning capacity of this investigation.

Figure 1. *Portland cement type I.*

Figure 2. *Fine sand*

Figure 3. *Titanium Dioxide (TiO2)*

Figure 4. *Rhodamine*

2.2. Method

The mortar was mixed according to [10] table 1, which shows the dosage used and the percentage of titanium dioxide addition (TiO2), table 2 summarizes the number of specimens, tests and standards used. All samples had a curing time of 28 days except those used for the compression test which were tested at 3, 14 and 28 days respectively.

Table 1. Mortar dosage C:A 1:5 for a volume of 0.000375m3

Specimen	TiO2		Cement	Fine Aggregate	Water
	%	kg	Kg	Kg	lts
Mortar C/A 1:5	0	0.000	0.177	0.892	0.128
Mortar C/A 1:5 + 5% TiO2	5	0.009	0.164	0.892	0.128
Mortar C/A 1:5 + 7.5% TiO2	7.5	0.013	0.160	0.892	0.128
Mortar C/A 1:5 + 10% TiO2	10	0.017	0.155	0.892	0.128

Table 2. Test chart and specifications

Status	Type of test	Number of specimens	Curing time (days)	Methods used
Plastic	Fluency	12		[10], [2]
Tough	Compression resistance	54	3,14,28	[10], [1]
Tough	Absorption	12	28	[10], [3]
Tough	Self-cleaning capacity	16		[10], [4]

3. Results and analysis

3.1. Mortar fluidity

Table 3 and Figure 5 show the percentages of fluidity that are achieved after incorporating the different replacements (in percentage) of titanium dioxide in the mortar mixture, the results are compared with the corresponding tables to observe their consistency [11]. Thus, the percentages of decrease of this property of the mortar were 8.26%, 14.51%, 21.65% according to the addition of titanium dioxide in percentages of 5%, 7.5% and 10% respectively.

Table 3 Average fluency

Modified mortar	Average fluency (%)	Consistency
Mortar C/A 1:5	109.87	Medium
Mortar C/A 1:5 + 5% TiO2	100.80	Medium
Mortar C/A 1:5 + 7.5% TiO2	93.61	Tough
Mortar C/A 1:5 + 10% TiO2	84.87	Tough

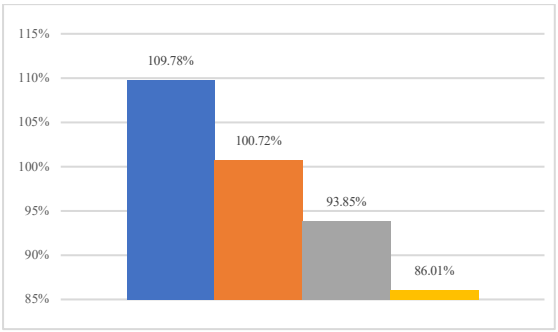

Figure 5. Average fluency

3.2. Compression resistance

Table 4 and Figure 6 show the compression resistance according to the curing days requested by [1] which shows that the higher the percentage of replacement of titanium dioxide, the lower the compression resistance, however the only one set of samples that at 28 days do not exceed the minimum resistance limit for a mortar of C: A 1: 5 as it refers [12] are those that have a 10% replacement. This decrease in resistance is due to the replacement of the weight percentage of the cement with titanium dioxide. It can be noted that the percentages of decrease in mortar compression were 4.76%, 15.24%, 24.76% according to the addition of titanium dioxide in percentages of 5%, 7.5% and 10% respectively.

Table 4 Compression resistance

Modified mortar	Curing days		
	3*	14*	28*
Mortar C/A 1:5	47.83	78.63	124.30
Mortar C/A 1:5 + 5% TiO2	44.05	77.72	118.38
Mortar C/A 1:5 + 7.5% TiO2	40.07	70.02	105.35
Mortar C/A 1:5 + 10% TiO2	36.80	62.07	93.52

*The records of this table in kg/cm2

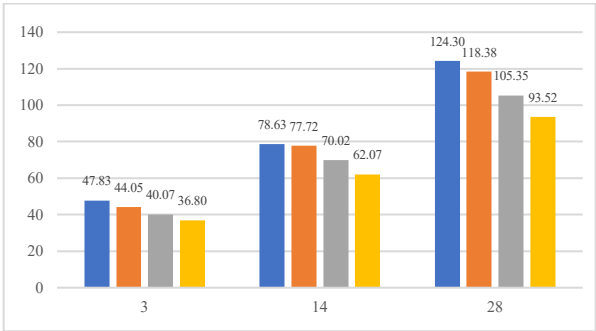

Figure 6. Compression resistance

3.3. Absorption percentage

Table 5 and Figure 7 show the results of the absorption test according to [3] a decrease is observed in comparison with the standard mortar in the range of 13.49%, 16.46% and 17.09% according to the additions of 5%, 7.5% and 10% of titanium dioxide, here the mortar added with 5% presents a slight advantage against the rest of percentages it can be said that the modified mortar has the ability to retain a certain amount of water that can help in the plastering of the facades of ceramic bricks.

Table 5 Absorption percentage

Modified mortar	Test Hours		
	0.25	1.4	24
Mortar C/A 1:5	15.95	29.79	131.35
Mortar C/A 1:5 + 5% TiO2	12.74	25.69	113.63
Mortar C/A 1:5 + 7.5% TiO2	9.11	23.19	109.72
Mortar C/A 1:5 + 10% TiO2	6.50	20.88	108.91

*The records in this table are in percentage (%)

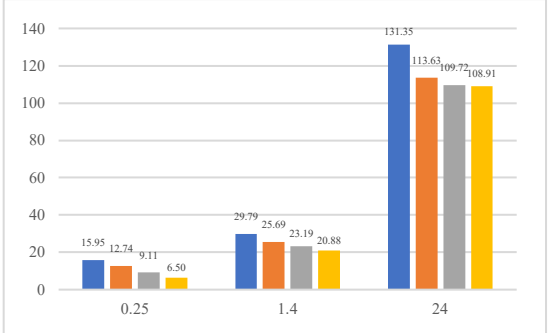

Figure 7. Absorption percentage

3.4. Self-cleaning capacity

Figures 8 and 9 show the specimens prepared following [4] as well as the exposure to UV rays contained in the standard, figure 10 shows the specimens exposed to the sun. The results presented in table 6 and figure 11 show the final condition of the tests, where it is verified that the mortars added with titanium dioxide acquire the photocatalytic capacity since the indexes obtained after the exposure comply with the following condition:

$$R_4 > 20\% \; y \; R_{24} > 50\%$$

Where:
R4 index obtained at 4 hours of exposure to UV rays and material evaluation using a digital colorimeter.
R24 index obtained at 24 hours of exposure to UV rays and material evaluation using a digital colorimeter.

Figure 8. Specimens with rhodamine

Figure 9. Artificial UV exposure

Figure 10. Sun exposure

Table 6 Photocatalytic capacity indexes

Modified mortar	Indexes		
	R4	R24	Condition
Mortar C/A 1:5	6.94	19.60	It is not photocatalytic
Mortar C/A 1:5 + 5% TiO2	43.95	67.50	It is photocatalytic
Mortar C/A 1:5 + 7.5% TiO2	36.48	82.21	It is photocatalytic
Mortar C/A 1:5 + 10% TiO2	47.04	84.19	It is photocatalytic

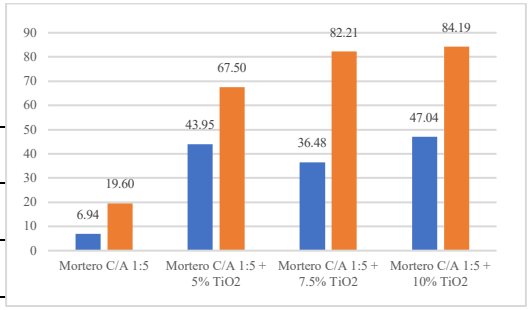

Figure 11. Photocatalytic capacity indexes

4. Conclusions

- The addition of titanium dioxide (TiO2) to the mortar mixture used for charging (C:A 1:5) alters its mechanical properties as fluidity, compression resistance, absorption percentage are reduced according have varied the percentages of addition of the organic component (5%, 7.5% and 10%) in the mixture. Likewise, the modified mortar acquires the photocatalytic capacity since the results of the tests obtained after exposing the samples to UV rays are in the range established by [4].
- By granting photocatalytic capacity to the portland cement mortar, the number of times a building is give maintenance when is exposed to sunlight is reduced.
- This new mortar could and should be applied in the short term on facades of buildings, murals, parking lots, central berms and others.
- Also, this research suggests that improving the appearance of construction works creates a more friendly environment for ordinary citizens.

5. References

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