INFLUENCE OF PARGE COAT SURFACE FINISH ON THE PERFORMANCE OF FACADE TILINGS

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ABSTRACT

This paper presents an experimental study that analyzes ceramic tile adhesion, considering different parge coat surface finish techniques, together with the variation of exposure conditions in the drying stage of this layer.

Laboratory tests were conducted on standard concrete panels used as a background for the subsequent layers. Two types of mortar were considered for the parge coat with a thickness of 3 cm, and two types of finish techniques: one with an aluminium rule and the other floated with a wooden trowel. The bonding material used was also kept constant. This was all in accordance with the specifications of the Brazilian standard for wall tiling. With regard to the environmental conditions, two temperatures were considered: 23°C and 30°C.

1. INTRODUCTION

The study of the characteristics that affect the mechanical performance of facade tilings is a topical issue in Brazilian Civil Construction, mainly because of the continuous efforts to avoid the appearance of pathologies.

The conditions in which facade tilings are executed vary highly, and are subject to many variables, such as: variation in climate conditions, labour, components, materials, layer thickness, etc.

The use of ceramic tiles as external tiling is still a tradition found in high-rise buildings in many Brazilian cities. However, the increasingly frequent appearance of pathologies in these claddings has generated great concern in technical circles and has led several researchers to study the causes of these problems.

The different subjects addressed in these researches include the characteristics of the backgrounds, the techniques for preparing these, characteristics of the different types of mortar for the regulatory layer and the parge coat, as well as the characteristics of the bonding materials and the tiles themselves.

There is a regulatory specification laid down by the ABNT(*) for the execution of facade tilings, which is NBR 13755, which will be cited in this text.

The characteristics of the backgrounds have been studied by IOPPI et al. (1995), who verified the influence of the initial absorption of concrete substrates in tile adhesion. COLLANTES (1998) analyzed base preparation techniques in the execution of cladding with cement and sand mortar, evaluating several types of bases and their preparation for the following layers, with different types of techniques and bonding material to receive the parging and render. Among the several forms of background preparation for the cladding, one of those that yielded the best results was the application of a bond layer with sprinkled mortar and another using dry bagged mortar applied with a notched trowel, the latter being the technique adopted in this study.

PÓVOAS et al. (1999); SILVA et al. (1999) studied the influence of the addition of different quantities of polymers on the properties of cementitious adhesive, concluding among other things that the effects of this addition varied as a function of the type of polymer. In turn, BUCHER; NAKAKURA (1999); FALCÃO BAUER; RAGO (1999); BREA, F. (2003); MARANHÃO et al. (2003) studied the influence of cementitious adhesive on the performance of ceramic tiling, among other variables analyzing open time. It should be noted that the Brazilian standard specifies three types of cementitious adhesive for tile installation on facades, and that these specifications were followed for the effects of this study.

The objective of this study was to verify the way in which parge coat surface finish techniques influence the mechanical performance of facade tilings, as an absence of studies on this subject was detected in Brazil.

For this, the technique recommended in Brazilian standard NBR 13755 was considered (1998): levelling of the rough finish with a rule, which we shall term "rodding". In addition to this condition, the variation of temperature and the use of two types of mortar were considered.

(*)ABNT stands for Asociación Brasileña de Normas Técnicas

This paper is based on an experimental study in which the mechanical performance of the ceramic tiling was evaluated, measuring its adhesive strength by pull tests, following Brazilian standard specifications. To verify the influence of parging surface finish techniques, surface adhesive strength tests were also used. As two types of mortar were employed for the parge coat, these were duly characterized in their fresh state, as well as in their hardened state, in accordance with the pertinent standard specifications.

1.1. MORTAR CHARACTERISTICS FOR THE PARGE COAT

MEDEIROS (1999) explains that the parging mortar in tiled facades plays a key role in the performance of the set of layers, while on the other hand, through its constituent materials, considerable study has been devoted to its properties in the fresh and hardened states, mixture proportions, etc. This author furthermore stresses that in Brazil, parging mortar may be mixed, prepared on site, or industrialized.

NBR 13755 (1996) recommends mortar prepared on site, consisting of a mixture of cement, hydrated lime, sand and water, while industrialized mortars may be used as long as they display the same behaviour as mixed mortars.

Analyzing the influence of the parging on the adhesion of the external tile cladding, MIBIELLI; ROMAN (1995) performed tests with different proportions of a mixture for conventional mortar and also with mortar containing additives, concluding that the mixture proportions of the mortar determined the layer in which tiling failure occurred. This study did not consider significant variations of temperature for the trial bodies subjected to testing.

Referring to the mixture proportions, LARA et al. (1995) consider the correct proportions of the mortar components to be of fundamental importance, and propose a proportioning methodology.

SELMO et al. (2002) explain that since the decade of the 90s, there has been a dissemination in the use of industrialized mortars in Brazil for the execution of masonry walls and tile fixing. They even indicate that the evaluation of the properties of these mortars is fundamental to enable characterizing them.

CARVALHO et al. (1995) studied the use of two types of parging mortar, comparing different proportions of cement and sand and cement, and lime and sand for these mortars, concluding that the performance of mixed mortars was extremely satisfactory, besides displaying better workability and water retention.

ALMEIDA et al. (1995) evaluated the characteristics of tilings produced with industrialized mortars, without establishing substantial differences in the potential performance of these claddings when they were compared with tiles fixed with mortars proportioned on site.

1.2. SURFACE FINISH TECHNIQUES FOR PARGE COATS

Few studies have been devoted to the techniques for executing each layer of the ceramic cladding, because many of these come from traditional procedures. The importance of studying these resides in establishing how they influence the mechanical performance of the ceramic tilings.

In this study, two surface finish techniques have been considered for the parge coat. The first is carried out to level the parging through an operation that only can be executed after reaching the "rodding point(*)". This operation consists of cutting the surface of the parging with an aluminium rule, supported on screeds or other references, with a to and fro movement.

On the other hand, the floating operation is conducted after a time known as "drawing time" has elapsed. The worker identifies the "floating point" by pressing his thumb on the mortar surface and verifying its consistency. While the mortar remains plastic, it may not be worked, in order to avoid fissures arising and to enable achieving a uniformly flat finish.

Floating is done by vigorously pressing a wooden trowel in circular movements across the rodded surface, to obtain maxima mortar compaction, and by doing so, seeking to minimize the intergranular voids. Compression by smoothing in circles in a given region should promote a flow of paste to the surface, which on surrounding the surface grains will allow obtaining appropriate mechanical strength in the floated surface.

In the case of the parge coat that is prepared for tiling, incompatible recommendations were found, because while NBR 13755 (ABNT, 1998) recommends the parging surface should be rodded with a rough finish, SABBATINI; BARROS (1990) recommend adopting a floated surface due to its better compatibility for adhesion and smaller adhesive consumption.

On the other hand, British standard BS 5385 (BSI, 1991) recommends a coarse floated finish made with a wooden trowel, when ceramic tiles are adhered with cementitious adhesive or adhesives.

1.3. EFFECT OF THERMAL VARIATION ON FACADE TILINGS

The variation of temperature due to solar radiation affects all the layers that make up the tiling, but to different degrees, depending on the type of material involved in each layer, causing dimensional variation owing to the different coefficients of thermal expansion and consequently differential movements between the components of the tiling subsystem. These displacements are restricted by the bonds between their layers, causing inter-layer stresses that can lead to bond failure.

COOL; SABBATINI (1999) explain that in São Paulo, temperature variations can swing in winter and summer between an average minimum temperature of 8°C and an average peak temperature of 30°C. These variations can last for short or long periods and, in elements made up of different types of material, they can generate internal stresses, which by thus increasing the already existing stresses in the building may exceed the foreseen limits, making it possible for pathologies to appear.

Another effect caused by the abrupt variation of temperature in external tilings, known as thermal shock, is also being studied as a potential degradation agent.

However, despite being considered a degrading agent in the tiled facade, the effect of thermal variation has not yet been thoroughly studied in Brazil, while reference parameters that might be used in the project phase are unavailable.

(*)The rodding point is determined by the time that needs to elapse before the cut can be made without any detachment of parging mortar. Reaching this point may take from a few minutes to about two hours.

1.4. EXPERIMENTAL PROGRAMME

The experimental programme consisted of executing 12 trial bodies of concrete slab measuring 50 cm x 50 cm, on which the following layers were applied: a first bonding parge undercoat, the actual parge coat, cementitious adhesive and ceramic tiles.

The conditions that were kept steady in the experimental programme were:

Type of base: Standard substrate(***)

Base preparation: Cleaning with abrasive and application of industrialized mortar with notched trowel as bonding material for the parge coat.

Labour: one single worker.

Cementitious adhesive: type AC III

Type of ceramic tile: Group BIIa(****)

Test age: 28 days (surface strength) 28 days (adhesive strength of the ceramic tile).

The variables for tiling evaluation were:

- Tiling mortar: industrialized mortar and mortar mixed with cement, lime and sand in a 1:1:6 proportion. The mortars are characterized in the following section.
- Surface finish technique: rodded finish (Figure 1) and floated finish (Figure 2).

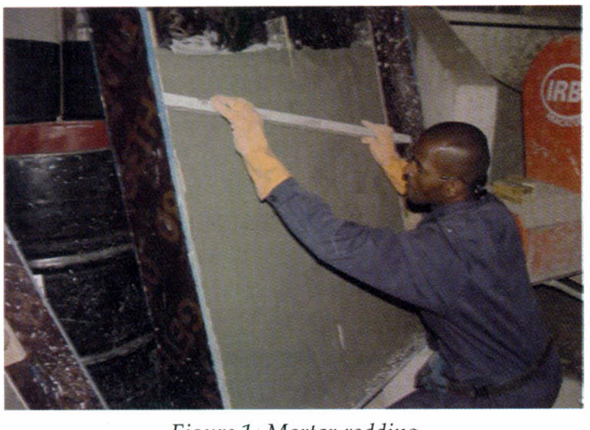


Figure 1. Mortar rodding

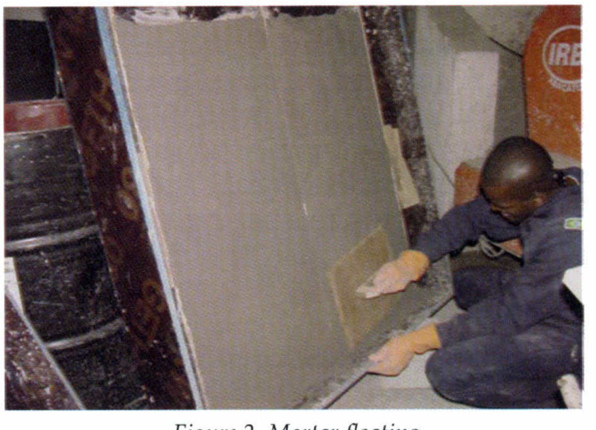


Figure 2. Mortar floating

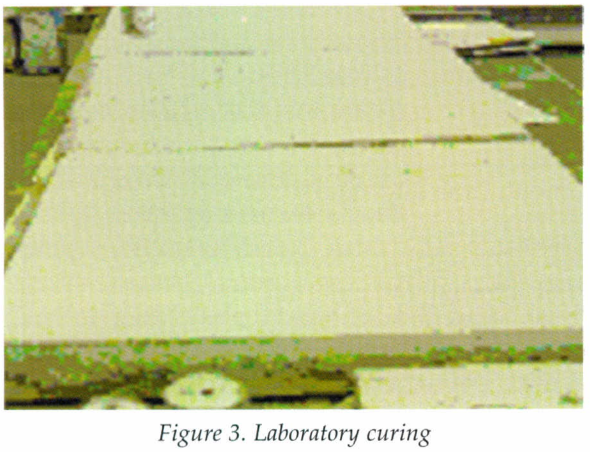


Figure 3. Laboratory curing

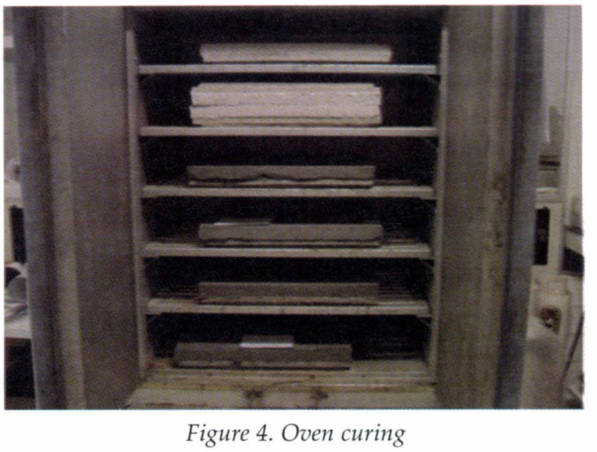


Figure 4. Oven curing

(***)Standard substrate made according to the recommendations of NBR 14082 (ABNT, 1998).

(****)Classification of ceramic tiles as a function of water absorption capacity according to NBR 13818 (ABNT, 1997) and ISO 10545 (ISO, 1994).

- Curing conditions: Two curing (drying) conditions were used: laboratory curing (Figure 3), in which temperature and moisture were controlled at 23°C and 50% R.H., and oven curing where the trial bodies were held for 14 days at a temperature of 30°C (Figure 4).

The experimental programme is the result of the combination of the execution alternatives with the variables introduced, as set out in the table (Table 1).

Industrialized mortar	Laboratory drying	Rodded
		Floated
	Oven drying	Rodded
		Floated
Mixed mortar 1:1:6 (cement:lime:sand)	Laboratory drying	Rodded
		Floated
	Oven drying	Rodded
		Floated

Table 1. Scheme of the experimental programme

1.5 CHARACTERIZATION OF THE PARGING MORTARS

1.5.1. Mortars

Mortar 1	Industrialized mortar – Manufacturer A
Manufacturer	A
Indication	Manual application of internal and external tiling.
Composition	Artificial sand of calcareous rock with controlled particle size, cement, lime and additives.
Water addition	15% of the dry mass
NBR 13281 classification	II – High C

Industrialized mortar

Mortar 2	Mixed mortar of cement, lime and sand
Proportioning	1:1:6 (cement:lime:sand)
Indication	Manual application of internal and external tiling.
Composition	Type CPII Portland cement , CHI lime, average particle size
Water addition	Visual control by the worker
NBR 13281 classification	II – High C

Mixed Mortar

1.5.2. Results of Mortar Characterization in the Fresh State

Characteristics determined	Test Method	Results	
		Industrialized Mortar	Mixed Mortar
Consistency	BS 4551 part 1 (BSI, 1980) "dropping ball"	6.7	11.0
Water retention	NBR 13277 (ABNT, 1995)	91%	98%
Entrained quantity of air	NBR 13278 (ABNT, 1995)	21.3%	24.2%

1.5.3. Results of Mortar Characterization in the Hardened State

Characteristics determined	Test Method	Results	
		Industrialized Mortar	Mixed Mortar
Flexural strength	European Norm EN 1015 part 11 (1993)	2.40 MPa	1.90 MPa
Compression	European Norm EN 1015 part 11 (1993)	7.99 MPa	6.98 MPa
Modulus of Deformation	NBR 7190 (ABNT, 1982)	10230 MPa	10160 MPa
Modulus of Deformation	Method GEPE TGP EPUSP adapted from standards BS 4551/80 and NBR 8522/84.	2050.4 MPa	-

1.6. TILING TESTS – SURFACE ADHESIVE STRENGTH

The adhesive resistance to normal stress, or resistance to pulling, is the maximum stress withstood by a test tiling body on being subjected to normal tensile stress.

Considering adhesive strength as the maxima surface stress withstood by the parging surface, this was taken as the evaluation parameter, considering that the detachments come from deficiencies in the interaction of the parging surface with the cementitious adhesive.

Adapting the test method for evaluating the adhesive strength of the cementitious adhesive for ceramic tile NBR 14084 (ABNT, 1998), tile adhesive strength was evaluated against the variables to which the trial bodies were subjected to obtain a correlation between both, since the evaluated parameter had no established limit in the standards or specifications in the literature surveyed. The results obtained with their respective variation coefficient are listed in Table 2.

		Industrialized Mortar			Mixed Mortar		
		Mean stress (MPa)	STD deviation	Variation coefficient %	Mean stress (MPa)	STD deviation	Variation coefficient %
Normal drying	Rodded finish	0.85	0.13	15.07	0.63	0.13	20.01
	Floated Finish	1.15	0.11	9.84	0.55	0.15	27.26
Oven Drying	Rodded finish	0.50	0.05	9.16	0.75	0.09	11.65
	Floated Finish	0.53	0.06	12.09	0.71	0.11	15.65

Table 2. Mean adhesive strength results

1.7. TENSILE ADHESIVE STRENGTH

The adapted tensile adhesive strength test of NBR 13.528 of 1995 was conducted.

The results obtained with their respective variation coefficients are expressed in Table 3.

		Industrialized Mortar			Mixed Mortar		
		Mean stress (MPa)	STD deviation	V. C. %	Mean stress (MPa)	STD deviation	V. C. %
Normal drying	Rodded Finish	0.74	0.08	10.64	1.21	0.28	22.74
	Floated Finish	0.86	0.14	16.69	1.30	0.18	13.86
Oven Drying	Rodded Finish	0.54	0.12	23.12	0.99	0.10	10.12
	Floated Finish	0.55*	0.12	20.91	1.02	0.29	28.78

Table 3. Mean tensile adhesive strength results

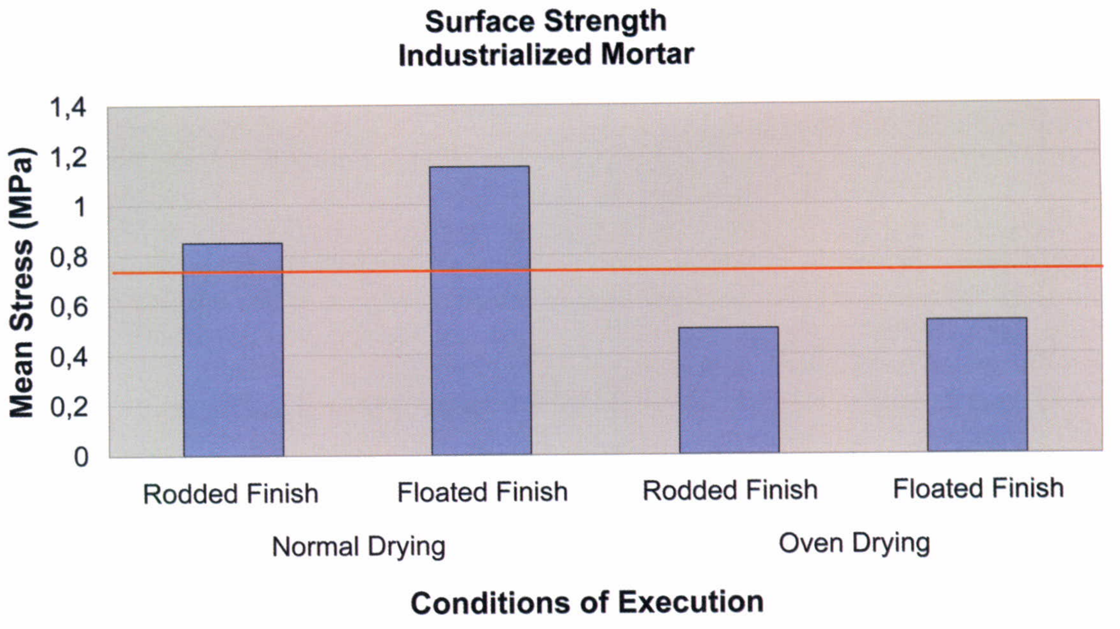
2. ANALYSIS OF RESULTS

2.1. TILING SURFACE STRENGTH

Analysis of parging surface strength shows that for industrialized mortar, strength decreases significantly with oven curing (Graph 1), yielding values below the recommended value(*****) in facade projects (≥ 0.70 MPa). The type of surface finish was not shown to be a relevant factor in this case.

The best surface strength results were obtained for this type of mortar slabs with a floated parge coat finish in normal curing.

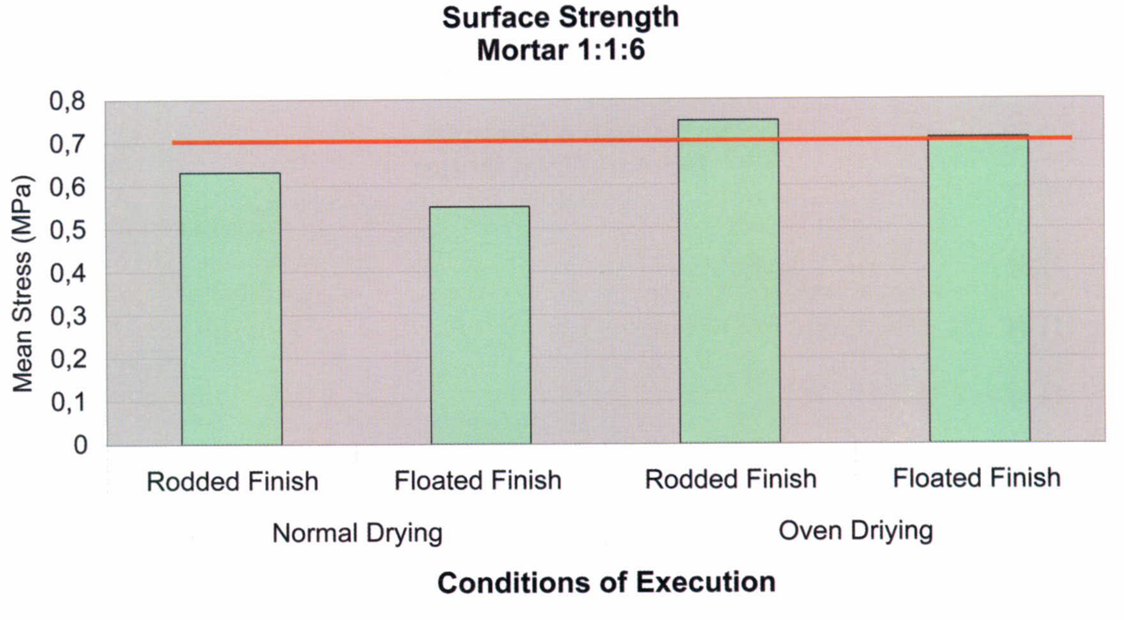
(*****)Recommended surface strength values for parge coats in facade tilings. Discipline Notes PCC 5816.



Graph 1. Surface adhesive strength of the tile with industrialized mortar

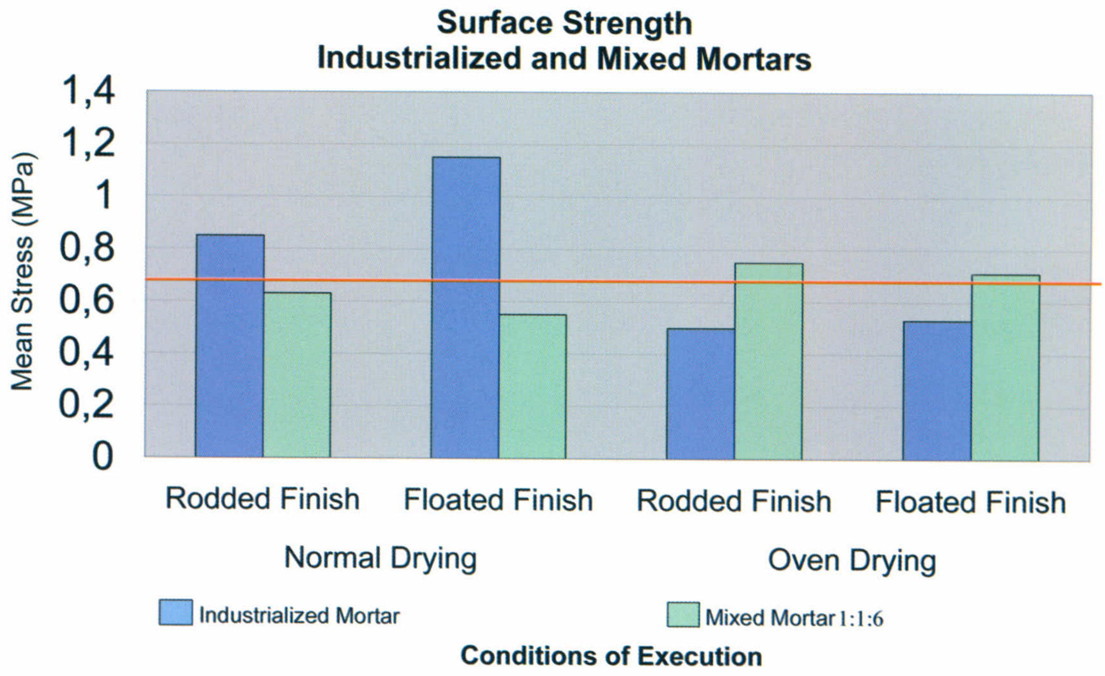
Graphic 2 shows that parging surface strength with mixed mortar displayed more homogeneous results, which increased curiously with oven curing, only thus reaching the recommended values. This fact determines the need for new tests, because the conditions of exposure with oven curing should theoretically produce lower rupture stress values, since mortar hydration is compromised by the evaporation of the water it contains.

The surface strength of this type of mortar exhibited a small decrease when the finish was floated, in both types of curing.



Graphic 2. Surface adhesive strength of the tile with industrialized mortar

Summing up, comparison of the parging surface strength of both types of mortar shows that the behaviour was the opposite, both when the type of curing was varied and when the type of finish was varied. (Graph 3)

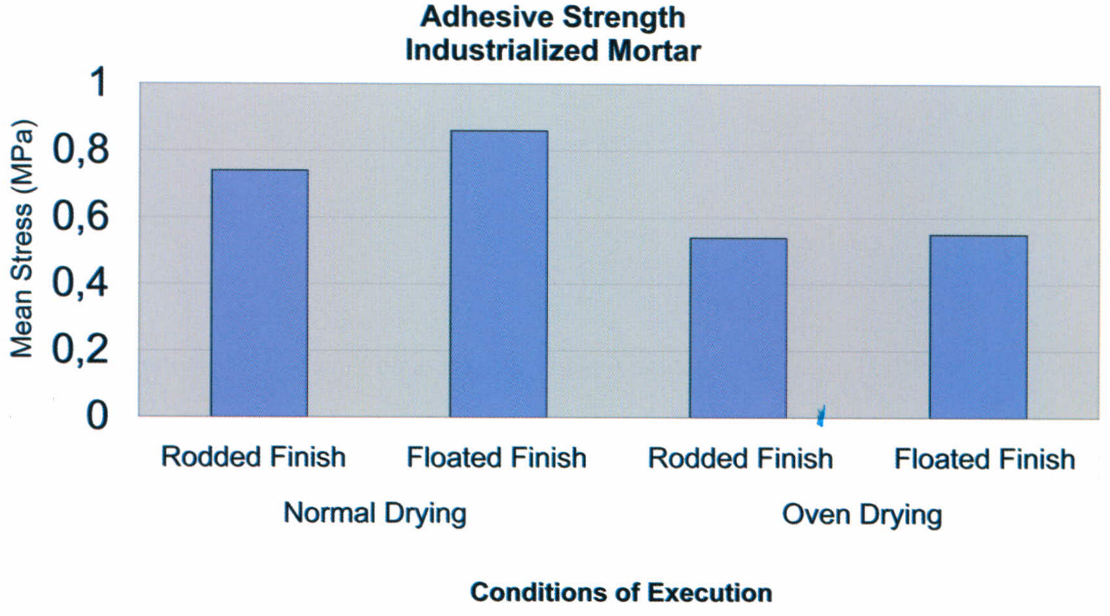


Graph 3. Tiling surface adhesive strength with industrialized and mixed mortar

2.2. TILING ADHESIVE STRENGTH

Analyzing the adhesive strength of the tiling executed with industrialized mortar, it can be observed that this also decreases significantly when oven cured, just as surface strength (Graph 4).

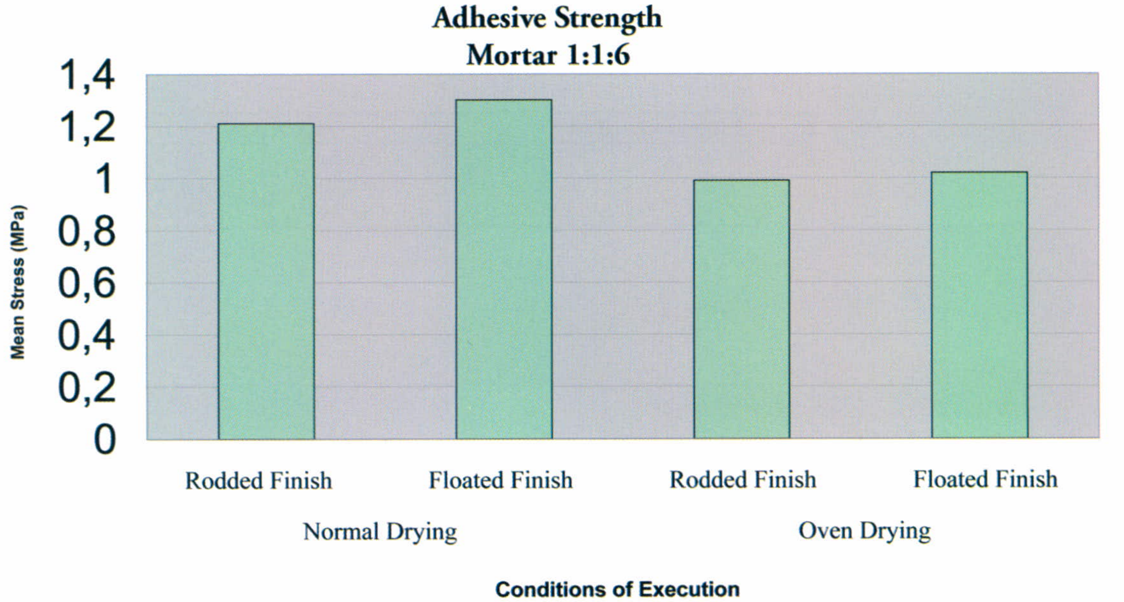
The best tiling strength results were also obtained for this type of mortar on slabs with parging finished by floating and normal curing.



Graph 4. Tiling adhesive strength with industrialized mortar

It can be observed (Graph 5) that tiling adhesive strength with mixed mortar, unlike surface strength, displayed a reduction in values when oven cured, which was a more logical result.

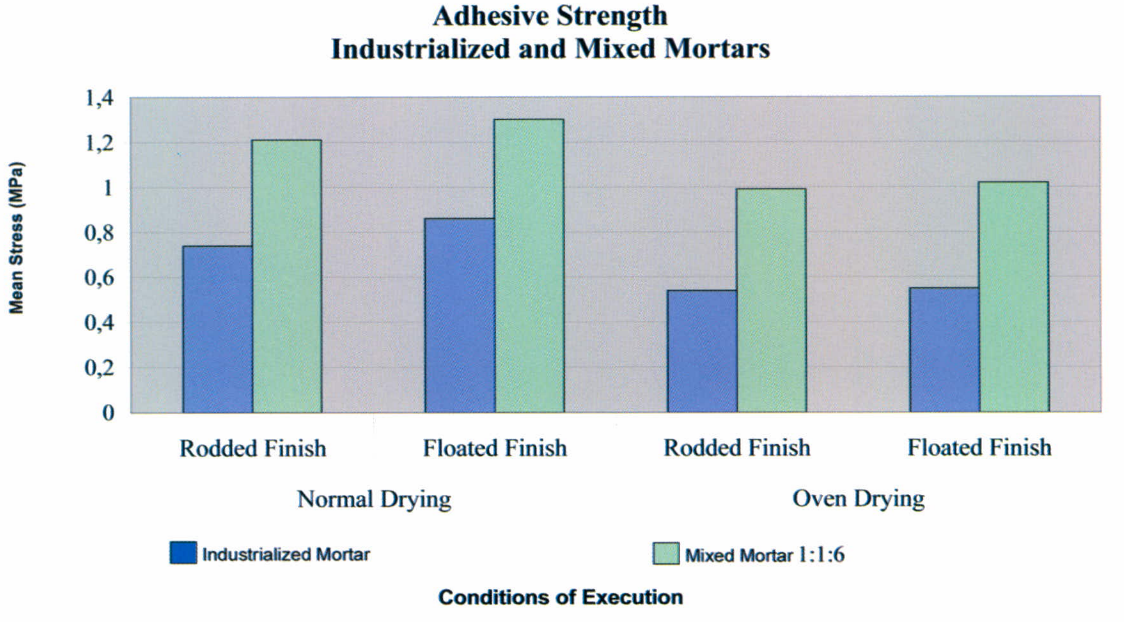
For this type of mortar, contrary to surface strength, a small increase in strength was also found for the floated finish, with both types of cures.



Graph 5. Tiling adhesive strength with industrialized mortar

The visualization of the adhesive strength results of the 12 analyzed slabs shows similar behaviour between the industrialized and mixed mortars, except that the results obtained with the mixed mortars were considerably superior.

The generic behaviour of mortars observed in Graphic 6 shows that the adhesive strength values decreased when trial slabs were subjected to higher temperature during drying and these values were higher in the trial slabs floated with a wooden trowel.



Graph 6. Surface adhesive strength of the tiling with industrialized mortar

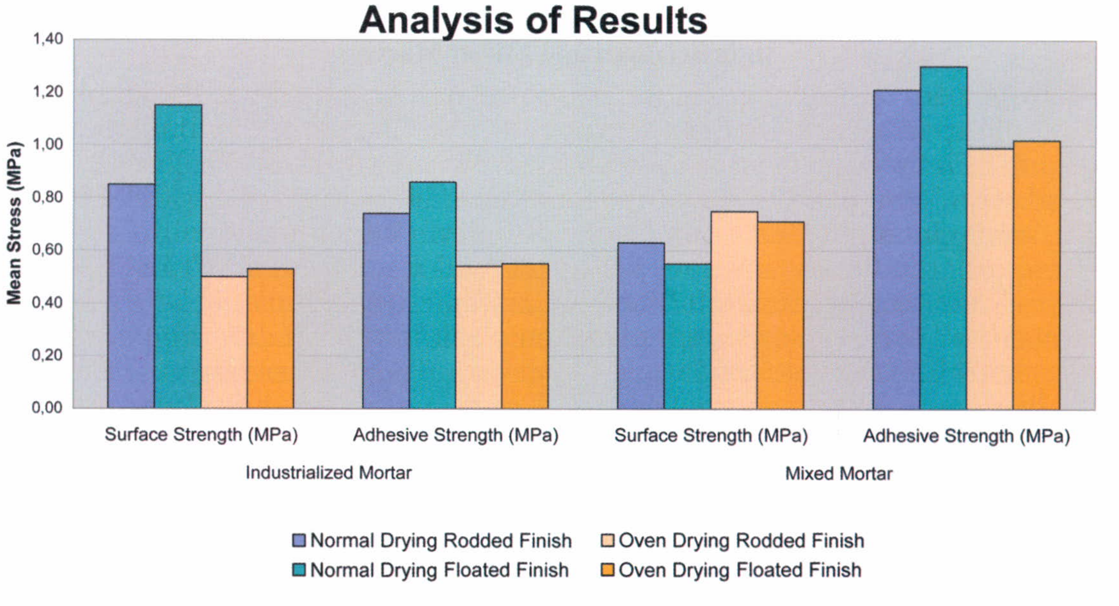
2.3. SURFACE STRENGTH X TILING ADHESIVE STRENGTH

The study thus provided a contribution with regard to the evaluation that the influence of the different surface finish techniques of the mortar bed for ceramic tiling, and the variation of the drying exposure conditions of this layer, have on external ceramic tiling adhesive strength.

The results of the parge coat surface adhesive strength and tiling adhesive strength tests are grouped in Table 4 and Graph 7, shown below.

		Industrialized Mortar		Mixed Mortar	
		Surface Strength (MPa)	Tiling Strength (MPa)	Surface Strength (MPa)	Tiling Strength (MPa)
Normal Drying	Rodded Finish	0,85	0,74	0,63	1,21
	Floated Finish	1,15	0,86	0,55	1,30
Oven Drying	Rodded Finish	0,50	0,54	0,75	0,99
	Floated Finish	0,53	0,55	0,71	1,02

Table 4. Synopsis of the adhesive strength results



Graph 7. Parge coat surface strength and tiling adhesive strength

3. CONCLUSIONS

The study conducted shows that the type of mortar bed surface finish of the ceramic tiling influences tiling adhesive strength, and that the mortar floated with a wooden trowel performed better in relation to adhesive strength than the rodded finish.

With regard to the curing conditions, raising temperature adversely affected the performance of the base and the ceramic tiling; this behaviour was expected, in view of the consulted references.

Regarding the type of mortar used, the mixed mortar showed better performance than the industrialized mortar, even with the two forms of curing, in relation to tiling adhesive strength. The techniques for executing tilings with industrialized mortars therefore need to be studied and evaluated individually with regard to traditional mortars, adapting the techniques for mortars with different properties.

The study is shown to be technically relevant, and for a more extensive analysis, a greater number of tests and trial bodies is required, with the introduction of other variables such as climatic conditions as close as possible to the building site reality.

It deserves to be noted that this subject needs further study, in view of the discrepancies observed between the international normative recommendations and those in the Brazilian standard with regard to the recommended surface finish technique for the mortar.

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