Structure and Mechanical Properties of Cement-Based Polymer Membranes and Mortars for Waterproofing

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Abstract. Polymer-modified, cement-based waterproofing systems are widely used in civil construction; however, they still exhibit recurring failures related to poor adhesion between their layers. In this context, the aim of this study was to evaluate the strength of adhesion between the different layers of systems composed of rigid polymeric mortars, cementitious membranes. For this purpose, the materials are applied to cementitious substrates with different combinations of layers, on which bond strength tests are performed. The evaluation of the tensile behavior of the mortars allows a characterization of the cementitious membranes used. For this purpose, plates were cast with different combinations and numbers of layers of the waterproofing materials, on which bond strength tests were performed, as well as tensile strength and elongation tests on the cementitious membrane. The results indicated that increasing the number of layers of the cementitious membrane led to a small but progressive reduction in bond strength, with the failure mode tending to shift to the waterproofing system itself. It can be concluded that, although the minimum regulatory values were met, the low tensile strength and insufficient elongation of the cementitious membrane compromise the overall performance of the system, emphasizing the importance of mechanical compatibility between the layers.

Keywords: Polymeric mortars and membranes, waterproofing, bond strength.

1 Introduction

Cementitious waterproofing and rigid polymeric mortars are widely used in civil construction, primarily applied in reservoirs, swimming pools, and wet areas, where watertightness is essential [1, 2]. Different combinations of thickness, layers, and contents depend on the performance required for each application. Bond strength and tensile behavior are important factors in the structural aspect of the systems [3].

Rigid mortars are mainly used in structures without movement, such as basements and underground reservoirs, as they are low-deformation materials that do not accommodate structural shifts [4]. They are suitable for working under both negative and positive pressures. Cementitious polymeric membranes are recommended for substrates subject to greater deformations, offering higher flexibility and better bond due to polymer modification, and perform well under positive pressure conditions.

This polymer modification has a significant influence on the hydration mechanisms and the microstructure of the cement material. Thus, the incorporation of polymeric dispersions can enhance tensile strength, impermeability, and, most importantly, bond to the substrate [5]. Depending on the type of polymer, the amount incorporated, and the curing conditions, these changes directly affect the mechanical behavior and watertightness of the waterproofing system.

It is also worth noting that the use of composite systems is common, in which the rigid polymeric mortar is applied directly onto the substrate, serving as a leveling and protective layer, while the flexible cementitious membrane is applied on top of this layer, providing greater deformation capacity, improved bond between layers, and enhanced overall performance of the waterproofing system.

In civil construction, these materials are often used as a base layer for finishing coatings, such as ceramics, natural stones, or mortars [6]. Proper bond between the substrate, the waterproofing system, and the final coating is essential for the overall performance of the system and is influenced by surface preparation, roughness, polymer content, mechanical compatibility between layers, and curing conditions [1]. Thus, the performance of the waterproofing system depends not only on the individual properties of the materials but also on the interaction between their layers.

However, despite the widespread use of these systems, there are recurring reports of failures in construction projects related to the detachment of the waterproofing layers [7].Such detachments compromise the waterproofing function, promote water infiltration, and can result in high maintenance and repair costs for the affected elements (coatings, masonry, structure), highlighting the need for a deeper understanding of the behavior and bond between system layers.

In this context, this study aims to investigate the adhesion between the different layers of systems employing rigid polymer mortars and cementitious membranes. This analysis seeks to improve understanding of the mechanisms responsible for adhesion failures and to enhance the performance of waterproofing systems. Because the thickness of waterproofing is increased with a focus on improving performance, there appears to be an increase in delamination between layers due to lower bond strength values.

2 Materials and Methods

2.1 2.1 Materials

For this study, two types of polymeric waterproofing mortars widely marketed in Brazil were used: a rigid polymeric mortar and a cementitious membrane. The investigation aimed to evaluate the bond behavior of the system with these mortars, starting with the rigid mortar and subsequently overlaying layers of the flexible cementitious membrane. This combined arrangement is commonly used in construction, particularly when a higher-performance waterproofing system is required.

The products are commercially supplied in two components corresponding to the polymeric resin (material 1) and component 2 to the cement and mineral aggregates (material 2). Observing Table 1, it can be seen that flexible membranes have a higher polymer content (solids content), and a lower content of fine particles compared to rigid mortar. This fact explains the significant difference in the flexibility of the materials, which is associated with their application.

Table 1 Composition of mortars and membranes

Material 1 (polimeric resin)	**Rigid mortar**	**Flexible membrane**
Sólidos content - mass	8.1 %	56.8 %
Water content - mass	91.9 %	43.2 %
Material 2 (cement and mineral aggregates)	**Rigid mortar**	**Flexible membrane**
Cement and fines content - mass (<0.075mm)	57,10%	38,70%
Larger particle content -mass (<0.600mm)	38,20%	59,30%

2.2 Methods

Molding and curing

For the study, the mortars and membranes were applied to two cementitious plates [8], as specified by the Brazilian Standard NBR 12171:2021. The plates were subdivided into six zones, as illustrated in Figure 1. The zones received different combinations of the materials, described as follows:

- Zone A: 1 layer of rigid polymeric mortar;
- Zone B: 2 layers of rigid polymeric mortar;
- Zone C: 2 layers of rigid polymeric mortar and 1 layer of cementitious membrane;
- Zone D: 2 layers of rigid polymeric mortar and 2 layers of cementitious membrane;
- Zone E: 2 layers of rigid polymeric mortar and 3 layers of cementitious membrane;
- Zone F: 2 layers of rigid polymeric mortar and 4 layers of cementitious membrane;

In each layer, the application was carried out in a crosswise manner relative to the previous layer. The application interval between layers was 3 hours, and the application rate for each layer was 1 kg/m².

In Figure 1, the schematic of the plate layer division can be seen. The rigid polymeric mortar or cementitious membrane was applied in all layers in order to evaluate the evolution of bond between the layers. After 7 days of curing the last layer, the preparation and bond testing were carried out.

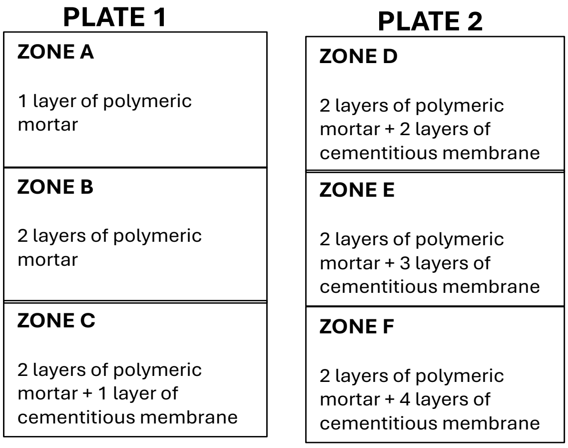


Fig. 1. Schematic of plate division.

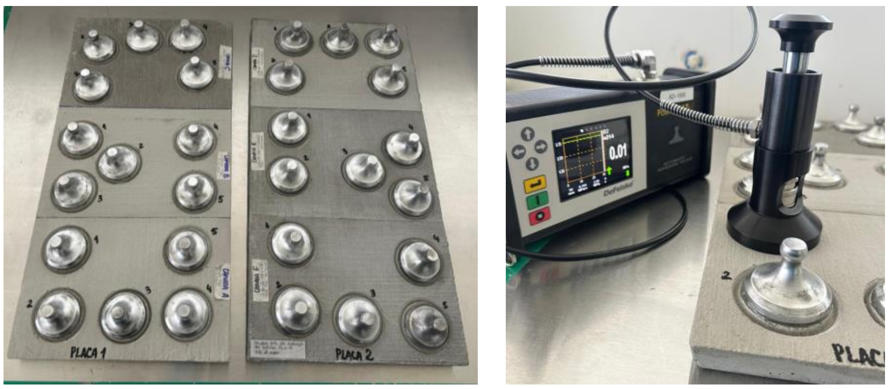
During the interval between layers, the panels are covered with a plastic container, in order to avoid any abrupt changes in environmental moisture. At the end of the application of all layers, the panels are sealed in plastic bags, remaining so for a period of 7 days.

Testing

Bond strength

After the curing period, five specimens were cut from each zone of the plates. Metal discs were then bonded to the surface of each specimen (Fig. 2(a)).

The test was carried out in accordance with the Brazilian Standard NBR 12171:2021 [9] using an bond tester (PosiTest AT-A, DeFelsko). In Figure 2, the arrangement of the discs bonded to the surfaces of the specimens can be seen (Fig. 2a), as well as the execution of the test (Fig. 2b).



(a) (b)

Fig. 2. Bond strength test: (a) arrangement of the test specimens (b) test execution.

Tensile strength and elongation

The tensile strength test was performed on the cementitious membrane. For this purpose, five specimens measuring 50 × 300 mm with an approximate thickness of 3.0 mm were prepared. The aim was to determine the magnitude of the tensile values and compare them with the bond values observed.

The test was carried out in accordance with the Brazilian Standard NBR 9952:2024 [10], using a dynamometer (AME-5 kN, Oswaldo Filizola). In Figure 3, the test execution can be seen (Fig. 3a), as well as the specimens after failure (Fig. 3b).

(a) (b)

Fig. 3. Tensile strength and elongation test: (a) test execution and (b) specimens after failure.

3 Results

3.1 Bond strength

The results are presented in Table 2. It can be observed that the highest bond values were found in the layers of rigid polymeric mortar, particularly in Zone B. The predominant type of failure occurred at the interface between the layer and the substrate (Fig. 4). In Zone C, which includes the first layer of cementitious membrane, there is a significant reduction in bond, with the failure mode occurring partially within the membrane layer itself, as well as in the underlying layer of polymeric mortar. With the addition of successive layers of cementitious membrane (Zones D, E, and F), bond values were lower than the maximum observed in Zone B, which consists of rigid mortar only. Failure occurs within the membrane layer and between the membrane layers. Despite this variation in bond strength, it should be noted that all layers meet the minimum standard value of 0.50 MPa [11].

Table 2 – Bond strength results

Specimens	Bond Strength [MPa]					
	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
1	1.66	1.30	1.28	1.61	1.23	1.27
2	1.22	1.62	1.32	1.37	1.22	1.37
3	1.37	1.57	1.00	1.43	1.33	1.11
4	1.32	2.14	1.15	1.42	1.21	1.25
5	1.53	1.90	1.01	1.32	1.34	1.15
Average	**1.42**	**1.71**	**1.15**	**1.43**	**1.28**	**1.23**
Failure type	**b**	**b**	**b/c**	**c**	**c**	**c**

a – rupture in the substrate; b – rupture at the interface substrate/polymeric mortar; c – rupture in the cementitious membrane; d – rupture in the adhesive.

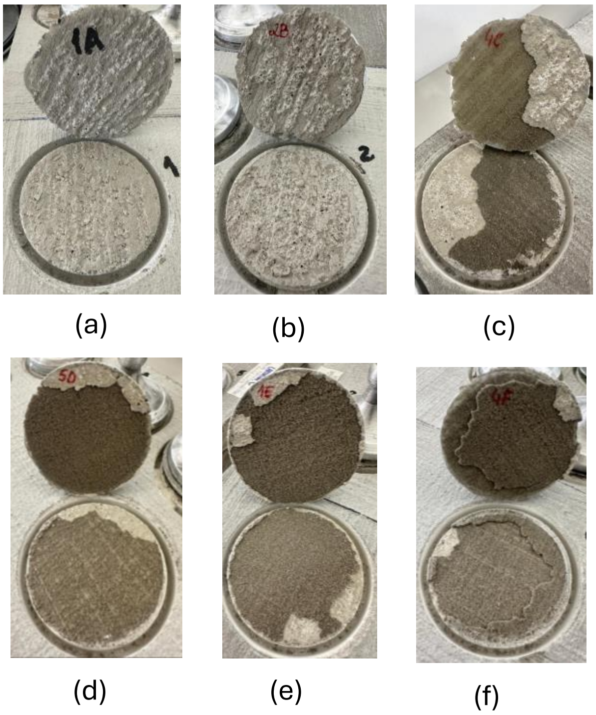


Fig. 4. Failure types in the specimens: (a) Zone A, (b) Zone B, (c) Zone C, (d) Zone D, and (e) Zone E.

3.2 Tensile strength and elongation

The results of the tensile stress strain on the cementitious membrane are presented in Figure 5.

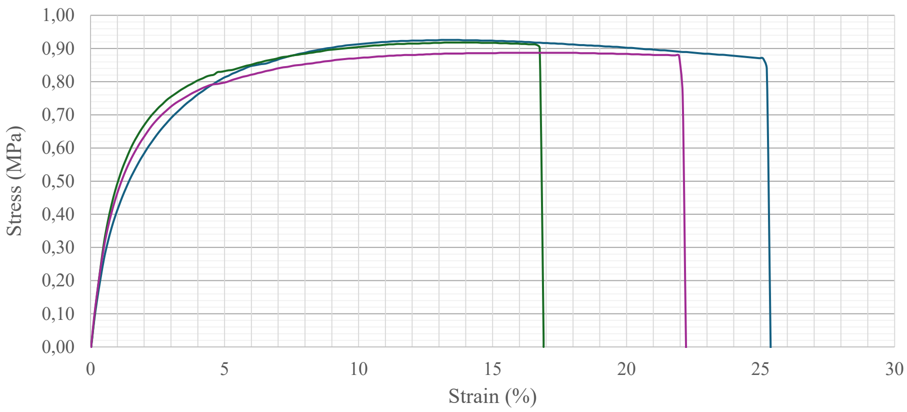


Fig. 5 – Tensile test results for cementitious membranes

These results show an average ultimate stress of 0.86 MPa and an average elongation at failure of 19.8%. In terms of elongation, a significant variation between samples is observed, and none of them reach the minimum required value of 30.0% [10]. Thus, this behavior directly affects the system's performance, as a higher elongation capacity of the material would allow better stress absorption, load redistribution at the interface, and consequently, a higher maximum load capacity before bond failure occurs.

Although the material meets the regulatory requirements, its tensile stress is lower than the bond strength value observed for layer A. This behavior directly affects the bond performance of the system, as failure tends to occur initially within the material itself, which limits the attainment of maximum strength at the interface between the waterproofing layers, as observed in layers C, D and E (Fig. 4).

4 Conclusions

The results demonstrate that the performance of polymer-modified, cement-based waterproofing systems depends strongly on the interaction between their layers. The rigid polymeric mortar exhibited high bond to the substrate, while increasing the number of cementitious membrane layers resulted in a progressive reduction of this bond. The fact that the tensile strength is lower than the bond value may explain the failure mode observed in the cementitious membrane. Failures within the layer and between layers may be associated with this behavior.

Systems with high waterproofing requirements, needing many layers of cementitious membranes, may exhibit some compromise in bond within the cementitious membrane and between the layers. It is necessary for designers to understand these behaviors in order to find solutions that minimize the problems of these reduced bond strengths.

Furthermore, although the minimum regulatory requirements were met, the insufficient elongation capacity of the cementitious membrane compromises stress redistribution. Thus, the need for mechanical compatibility between the materials is highlighted, along with the need for further studies focused primarily on improving the interface bond strength and tensile performance of the materials.

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