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Comparative analysis between tensile adhesion and compressive strength in mortars produced with expanded vermiculite

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Análise comparativa entre aderência à tração e resistência à compressão em argamassas produzidas com vermiculita expandida

RESUMO

Na indústria da Construção Civil, o desempenho dos elementos construtivos constitui uma temática pertinente para a pesquisa científica. A sustentabilidade e a preocupação com os recursos naturais não renováveis têm estimulado a busca por materiais alternativos que apresentem potencial para beneficiar as propriedades das argamassas cimentícias. Apesar de ser um material ainda pouco empregado como agregado em argamassas, a vermiculita expandida possui propriedades interessantes, com possibilidades de substituir a areia natural, diminuindo o impacto ambiental causado pela sua extração. O objetivo do presente trabalho consistiu em analisar, com base nas características físicas e mecânicas, a redução do impacto ambiental ocasionado com a substituição de areia natural pela vermiculita expandida como agregado em argamassas de revestimento. Neste estudo, analisamos a resistência à compressão e resistência de aderência à tração, de argamassas de revestimento produzidas a partir do traço 1:1:6 em volume e com 10, 20, 30, 40 e 50% de substituição do agregado natural por vermiculita expandida, comparando-as com uma mistura de referência. A etapa experimental consistiu na caracterização dos agregados, confecção das argamassas, ensaios no estado fresco e endurecido. Conforme a NBR 13281-1 (ABNT, 2023), as misturas podem ser classificadas quanto à resistência à compressão como P3 (AN100, VE10, VE40 e VE50, com resistência entre 2,5 e 4,5 MPa) e P4 (VE20 e VE30, com resistência entre 4,0 e 6,5 MPa). Com base na mesma norma as misturas podem ser classificadas quanto à resistência de aderência à tração como RA1 (AN100, VE40 e VE50, pela resistência maior ou igual a 0,2 MPa) e RA2 (VE10, VE20 e VE30, pela resistência maior ou igual a 0,3 MPa). Destaca-se que os resultados para os traços intermediários VE20 e VE30, com resistência à compressão entre 4,0 e 6,5 MPa e resistência de aderência à tração maior ou igual a 0,3 MPa, podem ser classificados como P4 e RA2 respectivamente. Todos os traços atenderam à NBR 13749 (ABNT, 2013), que estipula os valores mínimos de 0,20 MPa para paredes internas e 0,30 MPa para paredes externas. Os traços VE10, VE20 e VE30 mostraram-se adequados para revestimentos externos, enquanto VE40 e VE50, para revestimentos internos. Nestes dois últimos casos, a mistura se distingue por satisfazer a norma e causar menor impacto ambiental.

PALAVRAS-CHAVE: Propriedades mecânicas. Vermiculita expandida. Sustentabilidade.

Comparative analysis between tensile adhesion and compressive strength in mortars produced with expanded vermiculite

ABSTRACT

In the construction industry, the performance of building elements is a pertinent topic for scientific research. Sustainability and concern for non-renewable natural resources have stimulated the search for alternative materials that have the potential to improve the properties of cement mortars. Although it is a material that is still rarely used as an aggregate in mortars, expanded vermiculite has interesting properties, with the potential to replace natural sand, reducing the environmental impact caused by its extraction. The aim of this study was to analyze, based on physical and mechanical characteristics, the reduction in environmental impact caused by replacing natural sand with expanded vermiculite as an aggregate in coating mortars. In this study, we analyzed the compressive strength and tensile bond strength of coating mortars produced from a 1:1:6 mix by volume and with 10, 20, 30, 40 and 50% replacement of natural aggregate with expanded vermiculite, comparing them with a reference mix. The experimental stage consisted of characterizing the aggregates, making the mortars and testing them in the fresh and hardened state. According to NBR 13281-1 (ABNT, 2023), the mixtures can be classified in terms of compressive strength as P3 (AN100, VE10, VE40 and VE50, with strengths between 2.5 and 4.5 MPa) and P4 (VE20 and VE30, with strengths between 4.0 and 6.5 MPa). Based on the same standard, the mixtures can be classified in terms of tensile bond strength as RA1 (AN100, VE40 and VE50, for strength greater than or equal to 0.2 MPa) and RA2 (VE10, VE20 and VE30, for strength greater than or equal to 0.3 MPa). It should be noted that the results for the intermediate traits VE20 and VE30, with compressive strengths between 4.0 and 6.5 MPa and tensile bond strengths greater than or equal to 0.3 MPa, can be classified as P4 and RA2 respectively. All the mixes complied with NBR 13749 (ABNT, 2013), which stipulates minimum values of 0.20 MPa for internal walls and 0.30 MPa for external walls. VE10, VE20 and VE30 were suitable for external cladding, while VE40 and VE50 were suitable for internal cladding. In these last two cases, the mixture stands out for meeting the standard and causing less environmental impact.

KEYWORDS: Mechanical properties. Expanded vermiculite. Sustainability.

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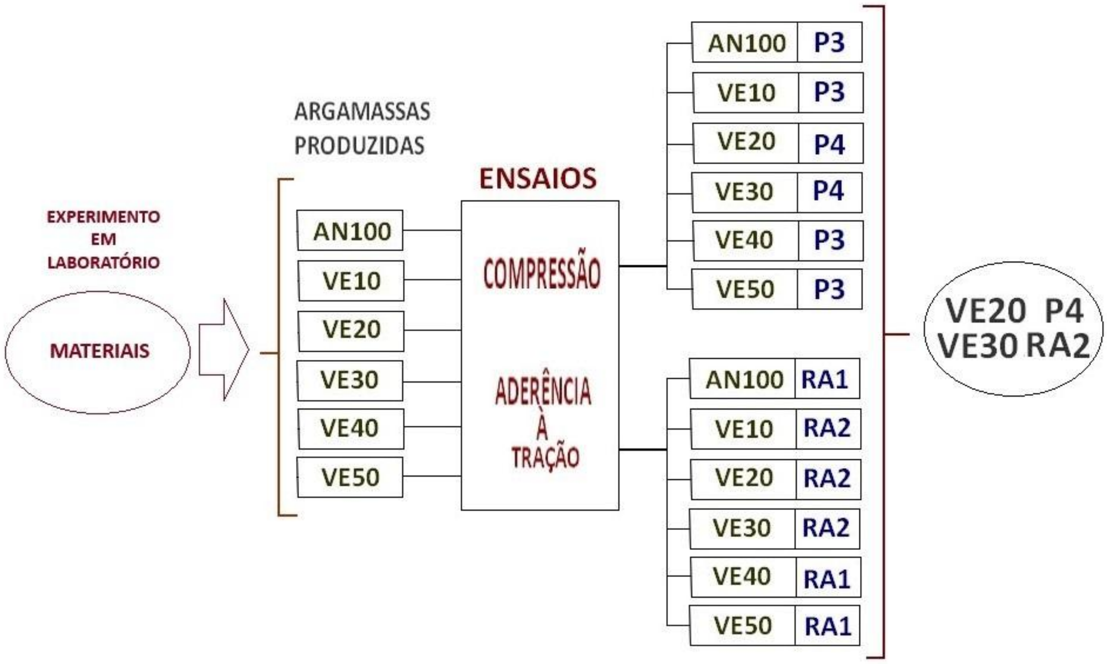
Análisis comparativo entre adherencia a tracción y resistencia a compresión en morteros elaborados con vermiculita expandida.

RESUMEN

En la industria de la Construcción Civil, el desempeño de los elementos constructivos constituye un tema relevante para la investigación científica. La sostenibilidad y la preocupación por los recursos naturales no renovables han estimulado la búsqueda de materiales alternativos que tengan el potencial de beneficiar las propiedades de los morteros de cemento. A pesar de ser un material todavía poco utilizado como árido en morteros, la vermiculita expandida presenta interesantes propiedades, teniendo la posibilidad de sustituir a la arena natural, reduciendo el impacto ambiental provocado por su extracción. El objetivo del presente trabajo fue analizar, en base a características físicas y mecánicas, la reducción del impacto ambiental que provoca la sustitución de arena natural por vermiculita expandida como árido en morteros de revestimiento. En este estudio se analizó la resistencia a la compresión y la adherencia a la tracción de morteros de revestimiento producidos a partir de una mezcla 1:1:6 en volumen y con 10, 20, 30, 40 y 50% de sustitución de árido natural por vermiculita expandida, comparándolos con una mezcla de referencia. La etapa experimental consistió en la caracterización de los áridos, preparación de los morteros, ensayos en estado fresco y endurecido. Según la NBR 13281-1 (ABNT, 2023), las mezclas pueden clasificarse según su resistencia a la compresión en P3 (AN100, VE10, VE40 y VE50, con resistencia entre 2,5 y 4,5 MPa) y P4 (VE20 y VE30, con resistencia entre 4,0 y 6,5 MPa). Basándose en la misma norma, las mezclas se pueden clasificar según su fuerza de adhesión a la tracción en RA1 (AN100, VE40 y VE50, para resistencias mayores o iguales a 0,2 MPa) y RA2 (VE10, VE20 y VE30, para resistencias mayores o iguales a igual a 0,3 MPa). Es de destacar que los resultados para las mezclas intermedias VE20 y VE30, con resistencia a la compresión entre 4,0 y 6,5 MPa y resistencia a la adhesión a la tracción mayor o igual a 0,3 MPa, se pueden clasificar como P4 y RA2 respectivamente. Todas las características cumplieron con la NBR 13749 (ABNT, 2013), que estipula valores mínimos de 0,20 MPa para paredes internas y 0,30 MPa para paredes externas. Los Trace VE10, VE20 y VE30 demostraron ser adecuados para revestimientos externos, mientras que VE40 y VE50 para revestimientos internos. En estos dos últimos casos, la mezcla destaca por cumplir la norma y provocar un menor impacto ambiental.

PALABRAS CLAVE: Propiedades mecánicas. Vermiculita expandida. Sostenibilidad.

GRAPHIC SUMMARY



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1 INTRODUCTION

Light aggregates, with a lower specific gravity compared to sand, reduce the self-weight of the construction elements, thus relieving the loads borne by the foundations (Silva, 2023). Porous aggregates, such as expanded vermiculite, despite significant effects on thermal insulation, can, on the other hand, reduce the mechanical strength of mixtures (Araújo, 2024).

In Brazil, internal and external vertical sealing systems (SVVIE) are generally composed of cement mortar elements and ceramic and/or concrete blocks. In addition to sealing and aesthetic function, they also influence the thermal performance of the construction. In addition to adhesion, factors such as mechanical strength and ability to absorb deformations are among the most relevant properties for coating mortars (Carasek, 2010).

For mortars intended for Wall and ceiling cladding, NBR 13281-1 (ABNT, 2023) specifies the requirements and test methods. Primarily employed to enhance thermal insulation (Passos and Carasek, 2018), expanded vermiculite has shown good results when incorporated into mortars.

Despite relevant gains shown by research, such as improved workability, weight reduction and thermal conductivity, studies point out the lack of comparative analysis between conventional mixtures and mortars with replacement of sand by expanded vermiculite. As compressive strength, flexion and adhesion are indispensable in the analysis of the behavior of coating mortars, this research is justified by investigating the mechanical performance of mixtures with varying levels of replacement of sand by vermiculite, aiming develop traces that meet regulatory recommendations and, employing an aggregate traditionally known for thermal insulation, collaborate with other studies focused on mechanical performance.

1.1 Compressive strength in mortars with aggregate replacement

Regarding the mechanical performance in wall and ceiling cladding mortars, NBR 13279 (ABNT, 2005) specifies the tests for the determination of tensile strength in bending and compressive strength.

Kaya and Koksal (2022) they obtained a compressive strength ranging between 0.59 MPa and 3.81 Mpa in samples of light geopolymer mortars based on fly ash (FA) Class C, produced with expanded vermiculite (EV) aggregate.

The study conducted by Cintra; Paiva and Baldo (2014) compared mortars produced with expanded vermiculite and mortars with vermiculite and addition of tire rubber residue. The authors were able to conclude that mortars containing expanded vermiculite and recycled tire rubber presented similar properties in the fresh state, while in the hardened state they presented better results of compressive strength and adhesion, than those presented by mortars that were not added with rubber (only with vermiculite). Thus showing that the combination of waste is a viable alternative.

Mo *et al*. (2018) found a reduction in compressive strength of 50% and 63% when expanded vermiculite was incorporated in volume substitutions of 30% and 60%, respectively. The authors attribute this decrease to the fact that expanded vermiculite has a soft and porous structure, in addition to stating that the small amount of fines can make it difficult to package the particles and negatively affect the strength. The research developed by Cintra (2013), Xu *et al*. (2015) and Barros (2018) also reported a reduction in compressive strength. Mo *et al*. (2018) also analyzed the consistency, water absorption, density and mechanical strength at room and elevated temperatures. The results showed efficiency in resistance to high temperatures.

Guilherme (2019) conducted studies with the replacement of 25, 30, 35, 40, 45 and 50% of the natural aggregate by vermiculite. The value of compressive strength at 28 days decreases

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according to the increased content of replacing the natural aggregate with vermiculite, which was already expected, since the microstructure of vermiculite is porous and its density is lower in relation to sand. There is a 21% reduction of the compressive strength in the trace with 25% aggregate replacement when compared to the reference mortar. The other mortar compositions present practically constant results, all within the standard deviation, indicating that vermiculite does not have a significant influence on the compressive strength in traces with up to 50% substitution.

Brandão, Lima & Alexandre (2024) studied the use of recycled post-consumer polyethylene terephthalate (PET-PCR) as an alternative aggregate in mortars for civil construction. In addition to the environmental benefits and contribution to reducing the demand for natural resources and minimizing waste generation, the study showed that it is possible to maintain the essential properties of mortars by incorporating PET-PCR, maintaining the compressive and tensile strengths in bending within the established regulatory standards.

1.2 Adhesion tensile strength in mortars with aggregate substitution

The standards for conducting tests for the determination of tensile strength are specified in NBR 13528 (ABNT, 2019).

According to the studies carried out by Guilherme (2019), the results of the adhesion resistance tests of the mortars, indicate that all values in the traces with substitution are higher than the reference, which is contrary to other research and the results of the mechanical tests of compression and traction. The mortar with 25% replacement content showed an increase of 46% in adhesion strength, when compared to the reference mortar, but the trace with 30% reduced 33% of this value. The 35% content increases by 37%, and the following mortars (40%, 45%, and 50%) show a reduction of 6.0%, 5.0%, and 25%, respectively.

Záleská *et al*. (2021) used expanded perlite, expanded glass and zeolite in the mixtures and noticed, in all investigated mixtures, a significant increase in mechanical strength as the curing age progressed.

Erba and Azambuja (2022) evaluated the influence of replacing natural sand with crushing sand in mortars. The results obtained in the tensile strength showed that the replacement is feasible, improving the performance of the coatings up to the proportion of 20% crushing sand and 80% natural sand for external coatings. And, for internal coatings, the replacement can reach up to 30% of crushing sand without compromising the quality of the coating performed.

Given the importance of coating mortars for the general operation of buildings and the high consumption of this material in buildings traditionally found in Brazil, it is important to technologically evaluate the performance of mixtures made from the replacement of aggregates. Thus, in this study, derived from a master's thesis, the compressive strength and tensile strength were adopted as the main tests for the discussion of the mechanical behavior of the mixtures.

2 OBJECTIVE

The objective of this study is to reduce the environmental impact caused by the extraction of natural sand, a non-renewable resource widely used in the construction industry. To this end, a comparative analysis will be made between the compressive strength and the

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tensile adhesion in coating mortars prepared with the 1:1:6 trace in volume, replacing the natural aggregate with expanded vermiculite in different proportions (10, 20, 30, 40 and 50%).

3 METHODOLOGY

The first part of the study comprised the formation of the theoretical framework, while the second part consisted of experimental analysis. The experimental stage involved the characterization of the aggregates (sand and vermiculite), the manufacture of mortars and the evaluation of the mixtures through tests in the fresh and hardened state.

The characterization of the aggregates, the preparation of the mixtures and the tests of the mortars were carried out in the Civil Construction Laboratory of the Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP).

The binders used were Portland cement type CP II E-32 and hydrated lime type CH-III. The aggregates used - natural washed quartzous river sand and expanded vermiculite-were previously dried in an oven for 24 hours and the NBR 7211 standard (ABNT, 2022), aimed at Concrete Aggregates, was adopted to evaluate the fine aggregates.

Before being used in the mixtures, all the aggregates were evaluated using the following tests: granulometric composition, according to NBR NM 248 (ABNT, 2001); specific mass, according to the Chapman Jar method; unit mass of aggregate in a loose state and in a dry state, both from NBR NM 45 (ABNT, 2006); content of powdery material, according to NBR NM 46 (ABNT, 2003) and determination of organic impurities, according to NBR NM 49 (ABNT, 2001).

Depending on the desired finish and in search of a standardization of the mixtures, the aggregates passed through sieves with an opening of 2.8 mm for the standardization of the maximum diameter and removal of impurities. Physically different, Figure 1 shows natural sand compared to vermiculite after sieving.

Figure 1 – Natural sand on the left and vermiculite on the right

Source: authors (2024).

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The mortars were produced from the 1:1:6 trace (cement:lime:aggregate) in volume based on the theoretical framework (Carasek, 1996 and Barros, 2018). The sand was replaced by expanded vermiculite in the percentages of 10% (VE10), 20% (VE20), 30% (VE30), 40% (VE40) and 50% (VE50) for comparison with a reference mortar, without replacement (AN100).

In the fresh state, the mixtures passed the mass density test according to a NBR 13278 (ABNT, 2005).

In order to evaluate the mortars in the hardened state, larger quantities of specimens were molded for each trait than established by the standard in order to expand the database. The 40 x 40 x 160mm prismatic models were demoulded after 24 hours and then stored under ambient temperature and humidity conditions in the laboratory (Figure 2).

As recommended by NBR 13279 (ABNT, 2005), the test was performed on specimens 28 days old. For the test, the specimens were positioned on the support devices of the test equipment so that the flush face did not come into contact with the support devices or with the load. Figure 2 illustrates part of the specimens produced in the research.

Figure 2– 40 x 40 x 160 mm test specimens

Source: authors (2024).

4 RESULTS

The physical properties of aggregates (natural sand and expanded vermiculite) are presented in Table 1.

Table 1 –Physical properties of aggregates

Property	Natural sand	Expanded vermiculite
Maximum dimension (mm)	1,20	2,40
Fineness modulus (mm)	1,78	2,87
Specific mass (g/cm³)	1,68	0,63
Unit mass (g/cm³)	1,59	0,18

Source: authors (2024).

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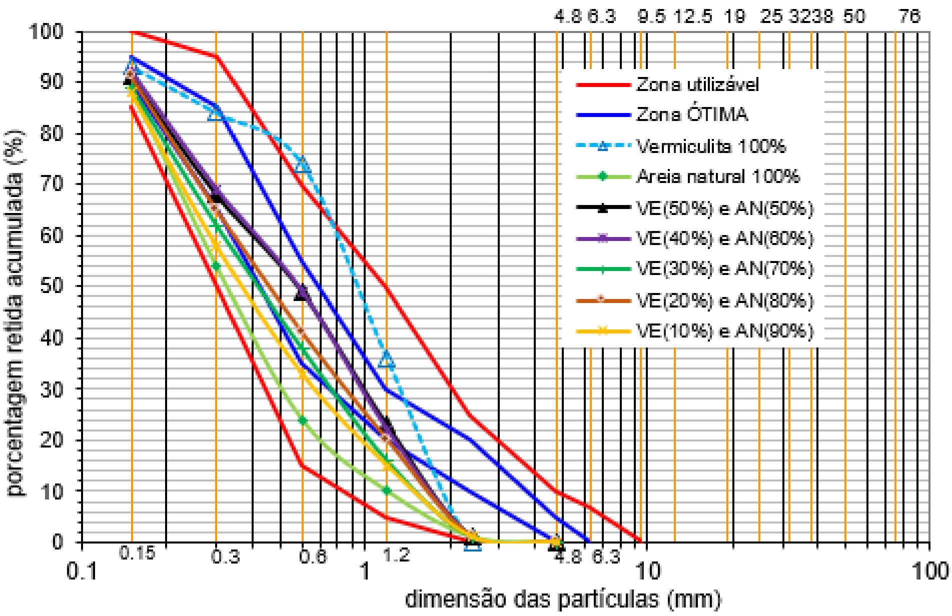
For the manufacture of mortars, the amount of components in each trace was determined by analyzing the grain size curves. In the granulometric characterization of sand and expanded vermiculite, performed according to NBR 7211 (ABNT, 2022), most of the aggregates were concentrated in the usable area. Figure 3 shows the granulometric curves of the aggregates.

Figure 3 - Granulometric curves of aggregates



Source: authors (2024).

According to NBR 13276 (ABNT, 2016), in case of lack of data, the amount of water in the mixture must ensure a Consistency Index of 260 ± 10 mm. Thus, the water content of each trace was defined according to the consistency index test.

For the reference mortar (AN100), a water/cement ratio of 1.44 was found. The amount of water was adjusted in the traces with vermiculite to hit the consistency index of 260 ± 10 mm recommended by the standard. A plasticizer additive was also used to improve the workability of the mortars, according to the manufacturer's recommendation of 2ml of additive for every 1.0 kg of cement. Table 2 shows the final consumption of each component in the mixtures.

Table 2 – Final consumption of mixture components

Trace	Cement (kg)	Lime (kg)	Sand (kg)	Vermiculite (kg)	Water (kg)	Plasticizing aditive (ml)
AN100	5,00	3,08	39,92	0	7,24	10
VE10	5,00	3,08	35,93	0,45	7,24	11
VE20	6,25	3,08	31,94	0,90	9,05	12
VE30	7,75	3,08	27,94	1,36	11,22	13
VE40	5,87	3,08	23,95	1,81	8,50	14
VE50	6,75	3,08	19,96	2,26	9,77	15

Source: authors (2024).

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Regarding the binders, the values provided by the manufacturers for the specific masses (real and unit) of cement and lime were used for the transformation of the traces in mass proportion (Guilherme, 2019 and Guilherme, Cabral and Souza, 2020). The traces in volume and mass are presented in Table 3.

Table 3 – Traces in volume and mass

Trace	Substitution content	Trace in volume	Trace in mass	Water/cement ratio
AN100	0%	1:1:6:0	5:3,08:39,92:0	1,44
VE10	10%	1:1:5,4:0,6	5:3,08:35,93:0,45	1,44
VE20	20%	1:1:4,8:1,2	6,25:3,08:31,94:0,90	1,44
VE30	30%	1:1:4,2:1,8	7,75:3,08:27,94:1,36	1,44
VE40	40%	1:1:3,6:2,4	5,87:3,08:23,95:1,81	1,44
VE50	50%	1:1:3:3	6,75:3,08:19,96:2,26	1,44

Source: authors (2024).

After the preparation of the traces, the characterization of the mortars in the fresh state occurred through the mass density and consistency index tests carried out according to NBR 13276 (ABNT, 2016), which recommends a Consistency Index of 260 ± 10 mm.

Table 4 shows the results obtained in the tests of the mortars in the fresh state.

Table 4 – Properties of mortars in the fresh state

Trace	Water/cement ratio	Mass density (kg/m³)	Consistency index (mm)
AN100	1,44	1840	257,85
VE10	1,44	1990	250,64
VE20	1,44	1980	252,02
VE30	1,44	1940	250,50
VE40	1,44	1860	256,00
VE50	1,44	1810	251,00

Source: authors (2024).

The observation of the results obtained in the tests in the fresh state shows that, compared to the reference trace, the traces with vermiculite presented higher mass density values for the intermediate traces and a decrease for the traces with a higher replacement rate. The VE10 mix had the highest mass density index (1990 kg/m³), followed by a slight reduction in VE20 (1980 kg/m³); the VE50 mix was the only one below the value found for AN100 (1840 kg/m³). Similar results were observed by Affonso and Azambuja (2024) for the traces AN100, VE10 and VE20.

In the case of the consistency index, all values were lower in the traces with vermiculite. Considering the trait without replacement, the Consistency Index decreased in LV 10 (250.64 mm) and, even increasing a little in LV 20 (252.02 mm), both did not reach the value of AN100 (257.85 mm). The analysis of these results allows us to infer that, in this study, the higher the substitution content, the lower the value of mass density and Consistency Index.

All the mortars in this study can be used in cladding and are classified as normal, as they have a fresh mass density in the range between 1400 kg/m³ and 2300 kg/m³, according to Carasek (2010).

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4.1 Compressive strength

According to NBR 13279 (ABNT, 2005), the compressive strength test must be performed at the age of 28 days and use the halves of the three specimens of the bending test, totaling 6 specimens. Figure 4 illustrates the specimen positioned in the test equipment (left) and after the compressive strength test (right).

Figure 4 - Compressive strength test

(a) (b)

Source: authors (2024).

In particular, in this research, the majority of the tests was performed with at least twelve specimens for each trace, or which allowed, above all, the observation of the coefficient of variation. The results obtained in the compressive strength test for the six traces investigated in this study are presented in Table 5.

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Table 5 – Compressive strength (MPa) at 28 days

Test specimen	AN100	VE10	VE20	VE30	VE40	VE50
1	3,69	2,49	5,60	6,17	3,88	4,12
2	3,41	3,47	5,62	6,59	3,49	3,39
3	3,04	3,46	5,90	6,06	4,93	3,07
4	2,78	3,23	5,49	5,54	4,06	3,26
5	3,42	3,83	3,65	6,21	3,29	3,12
6	3,47	4,12	5,78	5,60	2,23	3,88
7	4,46	3,28	5,93	6,03	2,86	3,83
8	4,96	3,25	4,74	4,90	4,74	4,04
9	4,10	3,07	6,00	6,50	3,33	3,38
10	3,96	5,03	7,01	5,26	3,18	4,40
11	3,20	3,80	4,24	4,60	4,22	3,44
12	3,51	4,63	5,97	3,63	4,01	3,41
Mean (MPa)	3,56	3,63	5,47	5,26	3,74	3,66
Standard deviation	0,56	0,69	0,80	1,01	0,67	0,55
Coefficient of variation	15,95	19,19	14,69	19,27	17,99	15,18

Source: authors (2024).

The results of the compressive strength test showed that, in general, the addition of vermiculite increased the compressive strength. All the traces with the light aggregate showed compressive strength value above that found for AN100.

According to NBR 13281-1 (ABNT, 2023), the mixtures can be classified in terms of compressive strength as P3 (AN100, VE10, VE40, and VE50, with strength ranging from 2.5 to 4.5 MPa) and P4 (VE20 and VE30, with strength ranging from 4.0 to 6.5 MPa).

The insertion of vermiculite increased the compressive strength in the mortars evaluated in Dias (2018). For the author, the increase can be attributed to the very characteristics of vermiculite that, similar to clay and belonging to the group of micaceae, increase the cohesion between water molecules and particles of residue and cement, which contributes to increased strength.

The VE20 trace, with 5.47 MPa at 28 days, obtained the highest compressive strength, indicating an increase in mechanical strength in the traces with replacement of sand by expanded vermiculite.

4.2 Tensile adhesion strength

According to NBR 13528 (ABNT, 2019), the tensile adhesion strength was evaluated at 28 days through the pull-off Test (pull-off test) using 12 specimens.

Figure 5 shows the tensile tensile strength test.

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Figure 5 - Tensile adhesion strength test

Source: authors (2024).

The results observed after testing all specimens are presented in Table 6.

Table 6 – Tensile bond strength (MPa) at 28 days

Test specimen	AN100	VE10	VE20	VE30	VE40	VE50
1	0,32	0,34	0,28	0,32	0,18	0,42
2	0,30	0,34	0,33	0,28	0,19	0,28
3	0,30	0,41	0,21	0,38	0,19	0,28
4	0,32	0,42	0,28	0,41	0,22	0,22
5	0,24	0,30	0,34	0,48	0,19	0,20
6	0,25	0,30	0,37	0,29	0,17	0,21
7	0,23	0,25	0,41	0,40	0,14	0,27
8	0,39	0,37	0,40	0,41	0,11	0,19
9	0,20	0,37	0,43	0,52	0,27	0,30
10	0,15	0,36	0,46	0,51	0,24	0,34
11	0,19	0,28	0,28	0,39	0,37	0,27
12	0,12	0,32	0,44	0,38	0,31	0,24
Média (MPa)	0,25	0,33	0,36	0,38	0,21	0,26
Standard deviation	0,07	0,05	0,07	0,07	0,07	0,06
Coefficient of variation	31,32	15,46	19,54	20,41	34,11	24,29

Source: authors (2024).

Analysis of the data shows that with the addition of vermiculite, there was an increase in tensile adhesion strength. With the exception of VE40, all other results were higher than those found for AN100, the ruptures occurred in the mortar itself and VE30 presented the highest value.

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Tensile adhesion strength is one of the most important properties for coating mortars, as it refers to the performance of the mortar when subjected to one of its main requests (Sinhorelli, 2019).

All traces complied with NBR 13749 (ABNT, 2013), which stipulates minimum values of 0.20 MPa for internal walls and 0.30 MPa for external walls The traces VE10, VE20 and VE30, with tensile strength greater than 0.30 MPa, were suitable for external coatings, while VE40 and VE50, with values between 0.20 and 0.30 MPa, for internal coatings.

Based on the same standard, the mixtures can be classified in terms of tensile strength as RA1 (AN100, VE40 and VE50, by resistance greater than or equal to 0.2 MPa) and RA2 (VE10, VE20 and VE30, by resistance greater than or equal to 0.3 MPa).

5 CONCLUSION

Based on the experimental results carried out in this study, the following conclusions can be presented:

- There was an increase in fresh mass density in VE10 followed by a slight reduction in ve20 trace, both being greater than the density of AN100. The mixture with 50% vermiculite presented the lowest mass density in the fresh state, with a result very similar to that of the reference mortar.
- The results of the compressive strength test showed that, in general, the addition of vermiculite increased the compressive strength. All the traces with the light aggregate showed compressive strength value above that found for AN100. At all ages, the trait with the highest value of compressive strength corresponds to VE20.
- A análise dos dados mostra que, com a adição da vermiculita, houve um aumento na resistência de aderência à tração. With the exception of VE40, all other results were higher than those found for AN100, the ruptures occurred in the mortar itself and VE30 presented the highest value.
- It is important to note that the results for the intermediate traces VE20 and VE30, with compressive strength ranging from 4.0 to 6.5 MPa and tensile strength ≥ 0.3 MPa, can be classified as P4 and RA2, respectively.
- The traces VE10, VE20 and VE30 proved to be suitable for external coatings, while VE40 and VE50, for internal coatings. In these last two cases, the mixture stands out by meeting the standard and causing less environmental impact.
- The vermiculite production process in the granulometry of coarse aggregate generates residue that can be used as fine aggregate (sand) in Civil Construction. The study showed that facing mortars with the use of up to 50% vermiculite in the mixture are within the norms.

Therefore, the study shows the feasibility of using expanded vermiculite in coating mortars, under the conditions of granulometry and contents investigated in relation to the mechanical properties analyzed, in addition to reducing the environmental impact related to construction activities.

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DECLARAÇÕES

CONTRIBUIÇÃO DE CADA AUTOR

Ao descrever a participação de cada autor no manuscrito, utilize os seguintes critérios:

- **Concepção e Design do Estudo**: Informe quem teve a ideia central do estudo e ajudou a definir os objetivos e a metodologia: **Stella Bruna Ananias Affonso e Maximiliano dos Anjos Azambuja.**
- **Curadoria de Dados**: Especifique quem organizou e verificou os dados para garantir sua qualidade: **Stella Bruna Ananias Affonso e Maximiliano dos Anjos Azambuja.**
- **Análise Formal**: Indique quem realizou as análises dos dados, aplicando métodos específicos: **Stella Bruna Ananias Affonso, Edson Alves e Maximiliano dos Anjos Azambuja.**
- **Aquisição de Financiamento**: Identifique quem conseguiu os recursos financeiros necessários para o estudo: **Stella Bruna Ananias Affonso e Maximiliano dos Anjos Azambuja.**
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- **Redação - Rascunho Inicial**: Indique quem escreveu a primeira versão do manuscrito: **Stella Bruna Ananias Affonso, Edson Alves e Maximiliano dos Anjos Azambuja.**
- **Redação - Revisão Crítica**: Informe quem revisou o texto, melhorando a clareza e a coerência: **Stella Bruna Ananias Affonso, Edson Alves e Maximiliano dos Anjos Azambuja.**
- **Revisão e Edição Final**: Especifique quem revisou e ajustou o manuscrito para garantir que atende às normas da revista: **Stella Bruna Ananias Affonso, Edson Alves e Maximiliano dos Anjos Azambuja.**
- **Supervisão**: Indique quem coordenou o trabalho e garantiu a qualidade geral do estudo: **Maximiliano dos Anjos Azambuja.**

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DECLARAÇÃO DE CONFLITOS DE INTERESSE

Nós, **Stella Bruna Ananias Affonso, Edson Alves e Maximiliano dos Anjos Azambuja**, declaramos que o manuscrito intitulado "**Análise comparativa entre aderência à tração e resistência à compressão em argamassas produzidas com vermiculita expandida"**

1. **Vínculos Financeiros**: Não possui vínculos financeiros.
2. **Relações Profissionais**: Não possui relações profissionais que possam impactar na análise, interpretação ou apresentação dos resultados.
3. **Conflitos Pessoais**: Não possui conflitos de interesse pessoais relacionados ao conteúdo do manuscrito.
