RGSA – Revista de Gestão Social e Ambiental
ISSN: 1981-982X
Data de submissão: 23/10/2023
Data de aceite: 22/01/2024
DOI: https://doi.org/10.24857/rgsa.v18n5-039
Organização: Comitê Científico Interinstitucional
Editor Chefe: Christian Luiz da Silva
Avaliação: Double Blind Review pelo SEER/OJS

STUDY OF THE DETERMINATION OF THREE-POINT FLEXURAL STRENGTH LOADING IN RESIN AND REINFORCING ORNAMENTAL STONES

Evanizis Dias Frizzera Castilho [1]
Mario Sergio de Brito Lacerda [2]
Ana Paula Meyer [3]
Maria Angelica Kramer Sant'Ana [4]
Mariane Costalonga de Aguiar [5]
Carlos Paulino Agrizzi[6]

ABSTRACT

Theoretical framework: Brazil is one of the world's largest producers of ornamental stones, and is therefore the richest country in granite diversity in the world. Improvements in processing and production techniques have been developed over the years to add value to the final product. The resistance of stones is a preponderant factor for their application in certain environments. Some stone industries try to improve the resistance of the material by resining or reinforcing (resin plus fiberglass mesh) on their material.

Method/project/approach: the work studied the behavior of resined and reinforced stones (resin plus fiberglass mesh). three-point flexural strength tests were carried out on pegmatite stones and quartzites. They were divided into groups with just resin and others with resin plus fiberglass mesh.

Results and conclusion: The results showed that in the group of Pegmatite stones it was possible to obtain a gain of up to 44% in material resistance when resined and reinforced. However, the Quartzites did not have a significant gain, in some cases they obtained a lower value when reinforced. Only one of the quartzites achieved a 14% gain in resistance. Therefore, it is necessary to carry out a preliminary study with laboratory tests before resining and reinforcing the ornamental stones for sold.

Research implications: Compare the three-point flexural strength between samples of pegmatic and quartzite stones and evaluate the resistance of reinforced (resin plus fiberglass mesh) and resin (resin) stones.

Originality/value: analyze the influence of resin and fiberglass mesh on the three-point flexural strength of ornamental stones.

Keywords: Ornamental Stones, Fiberglass Mesh, Resin, Three-Point Flexural Strength.

[1]Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo, Cachoeiro de Itapemirim, Espírito Santo, Brazil. E-mail: evanizis1@gmail.com Orcid: https://orcid.org/0000-0002-4435-6987
[2]Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo, Cachoeiro de Itapemirim, Espírito Santo, Brazil. E-mail: msbritolacerda@gmail.com Orcid: https://orcid.org/0000-0001-9187-7075
[3]Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo, Cachoeiro de Itapemirim, Espírito Santo, Brazil. E-mail: paulam@ifes.edu.br Orcid: https://orcid.org/0000-0001-5040-5629
[4] Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo, Cachoeiro de Itapemirim, Espírito Santo, Brazil. E-mail: mariaangelicaks@gmail.com Orcid: https://orcid.org/0000-0002-3804-4661
[5] Centro de Tecnologia Mineral, Núcleo Regional do Espírito Santo, Cachoeiro de Itapemirim, Espírito Santo, Brazil. E-mail: maguiar@cetem.gov.br Orcid: https://orcid.org/0009-0001-1309-6481
[6] Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo, Cachoeiro de Itapemirim, Espírito Santo, Brazil. E-mail: carlosagrizzi@gmail.com Orcid: https://orcid.org/0000-0002-0879-3661

ESTUDO DA DETERMINAÇÃO DA FLEXÃO POR CARREGAMENTO TRÊS PONTOS EM ROCHAS ORNAMENTAIS RESINADAS E TELADAS

RESUMO

Referencial teórico: O Brasil é um dos maiores produtores mundiais de rochas ornamentais, sendo, portanto, o País mais rico em diversidades de granitos no mundo. A melhora do beneficiamento e das técnicas de produção são desenvolvidas ao longo dos anos para agregar valor ao produto final. A resistência das rochas é um fator preponderante para a sua aplicação em determinados ambientes. Algumas indústrias de rochas tentam melhorar a resistência do material resinando ou telando (resina mais tela de fibra de vidro) no seu material.

Método/projeto/abordagem: o trabalho estudou o comportamento das rochas resinadas e teladas (resina mais tela de fibra de vidro). Foram realizados ensaios de resistência a ruptura de flexão 3 pontos em rochas pegmatíticas e quartzitos. Elas foram divididas em grupos com apenas resina e outras com a resina mais a tela.

Resultados e conclusão: Os resultados apontaram que no grupo de rochas Pegmatíticas foi possível obter um ganho até de 44% de resistência do material quando resinado e telado. Porém, os Quartzitos não tiveram um ganho significativo, em alguns casos obteve valor inferior quando telados. Apenas um dos quartzitos conseguiu um ganho de 14% de resistência. Por isso, é necessário fazer um estudo preliminar com ensaios laboratoriais antes de resinar e telar as rochas ornamentais para comercialização.

Implicações da pesquisa: Comparar a resistência mecânica (flexão 3 pontos) entre as amostras de rochas pegmáticas e quartzíticas e avaliar a resistência das rochas teladas (resina + tela de fibra de vidro) e resinadas (resina).

Originalidade/valor: analisar a influência da resina e tela de fibra de vidro na resistência mecânica à flexão 3 pontos das rochas ornamentais.

Palavras-chave: Rochas Ornamentais, Tela Fibra Vidro, Resina, Flexão 3 Pontos.

ESTUDIO DE LA DETERMINACIÓN DE LA FLEXIÓN MEDIANTE LA CARGA DE TRES PUNTOS SOBRE ROCAS ORNAMENTALES RESINADAS Y TAMIZADAS

RESUMEN

Referente teórico: Brasil es uno de los mayores productores mundiales de rocas ornamentales y, por lo tanto, el país más rico del mundo en diversidad de granito. Con el paso de los años se desarrollan técnicas de procesamiento y producción mejoradas para añadir valor al producto final. La resistencia de las rocas es un factor preponderante para su aplicación en determinados ambientes. Algunas industrias de roca tratan de mejorar la resistencia de la resina o el material telando (resina más pantalla de fibra de vidrio) en su material.

Método/proyecto/enfoque: el trabajo estudió el comportamiento de la resina y las rocas cubiertas (resina más pantalla de fibra de vidrio). Se realizaron pruebas de resistencia a la rotura en flexión de 3 puntos en rocas pegmáticas y cuarcitas. Se dividieron en grupos con solo resina y otros con resina más la pantalla.

Resultados y conclusión: Los resultados indicaron que en el grupo de rocas Pegmatitas fue posible obtener una ganancia de hasta 44% en la resistencia del material al ser resinas y techos. Sin embargo, las cuarcitas no ganaron significativamente, obteniendo en algunos casos un valor menor al ser examinadas. Solo una de las cuarcitas logró un aumento del 14% en la resistencia. Por esta razón, es necesario realizar un estudio preliminar con pruebas de laboratorio antes de resinar y techar las rocas ornamentales para su venta.

Implicaciones de la investigación: Comparar la resistencia mecánica (flexión de 3 puntos) entre las muestras de rocas pegmáticas y cuarcitas y evaluar la resistencia de las rocas cubiertas (resina + pantalla de fibra de vidrio) y resinatos (resina).

Originalidad/valor: analizar la influencia del tejido de resina y fibra de vidrio en la resistencia mecánica de 3 puntos a la flexión de rocas ornamentales.

Palabras clave: Rocas Ornamentales, Pantalla de Fibra de Vidrio, Resina, Flexión de 3 Puntos.

1 INTRODUCTION

Ornamental stones are produced and sold by several countries around the world, with Brazil being one of the main producers and exporters. The use of ornamental stones in the construction industry is constantly expanding, and Brazil grows stronger year after year, recording high averages in production and exports (SOUZA et al., 2023).

In 2023, exports reached US$ 1.11 billion, totaling 1.8 Mt of material sold. The sector has around 12 thousand companies operating in the production chain, generating around 150 thousand direct jobs. This shows the importance of the sector for the Brazilian economy, generating jobs and revenue for the country (ABIROCHAS, 2024).

The production of ornamental stones involves some stages of processing the material, until reaching the finished or semi-finished product. New production technologies have been studied and used in the sector with the aim of increasingly improving the characteristics of the material, adding value to the product sold (SANT'ANA and CASTILHO, 2023, MATURANA and SILVEIRA, 2018, FRASCÁ, 2014).

The stones sold often have high added value, and can vary greatly depending on the quality of the material. The technological characterization of stones has been a support both for determining stone treatment methods and for specifying their application and use.

A common production stage for stones with high added value is the reinforcing of the slabs. Reinforcing is one of the processing stages that has the function of creating a reinforcement system, improving the flexural strength efforts of the slabs. This prepares the stone to go through other stages of processing, transportation and finally application.

Therefore, this study aims to evaluate the three-point flexural strength loading of three types of ornamental stones, reinforced and resined and resined only.

2 THEORETICAL REFERENCES

According to the ABNT NBR 15012 (2013) standard, ornamental stone is characterized as a natural stone material subject to various processing processes with the aim of giving it aesthetic attributes. These materials are widely used in surface finishing, particularly on floors, walls and facades, aiming to improve their aesthetic appearance (CASTILHO et al., 2023).

After extracting the blocks from the deposits, they are transported to processing facilities, where they are subjected to unfolding operations using sawing machines, resulting in the production of slabs. These slabs are then subjected to a variety of surface finishing processes, including honing, polishing, flaming, bush hammered, sandblasting and brushing, in accordance with the aesthetic specifications and technical requirements of the clients and the project in question (VIDAL et al., 2014).

In addition to the stage common to all stone, some slabs also undergo other surface treatments, fiberglass mesh, resining, among other processes. The sequence of these stages may vary depending on the desired product and the technologies available in the industry (SANT'ANA and CASTILHO, 2023).

Stone resining is a process used to improve the mechanical and aesthetic properties of ornamental stones. During this procedure, a resin is applied to the surface of the rock, penetrating the pores and fissures, filling empty spaces and thus strengthening its structure. This process is commonly used in ornamental stones and facade covering, where the aim is to improve both the aesthetics and durability of the material (VIDAL et al., 2014).

The process of reinforcement the stones with fiberglass mesh is carried out on the back of the ornamental stone slabs, after processing the block into slabs fixed with resin. This procedure aims to reinforce the stone structure and increase its mechanical resistance.

The fiberglass mesh used in this process can be of different meshes and weights, depending on the need and specification for each type of material. The resin commonly used in the sector is epoxy resin, which requires drying time (curing) after its application. To apply the fiberglass mesh with resin to the stone, this drying step can be carried out in manual dryers or automatic ovens (SILVEIRA et al., 2014).

Technological characterization and flexural tests play a fundamental role in the evaluation and development of materials used in various structural applications, such as building facades. Through these procedures, it is possible to obtain information about the mechanical properties and structural behavior of materials, allowing an appropriate selection for the specific needs of each project.

The three-point flexural strength loading test method simulates in the laboratory the bending forces relevant to structural applications, such as facades, where metallic anchorage plays a crucial role in fixation (CASTILHO, 2018). To ensure the consistency and precision of the technological parameters obtained in this type of test, the technical standard NBR 15845-6:2015 is used.

3 METHODOLOGY

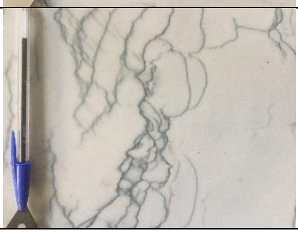
For this study, three groups of stones with different characteristics were chosen: Yellow Pegmatite commercially known as Persian, White Pegmatite known as Romanix and White Quartzite known as Maldive. The specimens were prepared under two conditions: stones with resin only and stones with resin plus fiberglass mesh. The specimens were prepared to be subjected to the modulus of rupture test using three-point flexural strength in accordance with the Technical Standard (ABNT) NBR 15845-6:2015.

The fiberglass mesh used was 80 g/m² and resin from the manufacturer Tenax AbelionA-5008 plus hardener Abelion BBM37/PH in a proportion of 37%. The samples were selected to determine the modulus of rupture through by three-point flexural strength and subsequent comparison of the results obtained. Some characteristics of the stone samples were taken into consideration for the test. The mineralogical composition, texture, structure and commercial name of the material were considered.

Table 1 shows the specifications of each stone material analyzed.

Table 1

Stone materials tested

MATERIAL	CLASSIFICATION	COMMERCIAL NAME	DESCRIPTION MINERALOGIC	TEXTURE
	Fine-grained yellow pegmatite	Persa	Feldspar 42%, plagioclase 28%, quartz 20% and biotite 10% (CEPED, 2015)	Cohesive, coarse to medium grained, dense and equigranular.
	Fine-grained white pegmatite	Romanix	Plagioclase 35%, alkali feldspar 25%, quartz 25%, biotite 10% and muscovite 5% (CEPED, 2016)	Massive, dense, heterogeneous, equigranular, fine to medium grained.
	Coarse-grained white pegmatite	Romanix	Plagioclase 35%, alkali feldspar 25%, quartz 25%, biotite 10% and muscovite 5% (CEPED, 2016)	Massive, dense, heterogeneous, equigranular, fine to medium grained.
	Fine-grained white quartzite parallel to the structure	Maldive	100% Quartz (CEPED, 2018)	Massive with fine grain.
	Fine-grained white quartzite perpendicular to the structure	Maldive	100% Quartz (CEPED, 2018)	Massive with fine grain.
	Coarse-grained white quartzite parallel to the structure	Maldive	100% Quartz (CEPED, 2018))	Massive with coarse grain.
	Coarse-grained white quartzite perpendicular to the structure	Maldive	100% Quartz (CEPED, 2018)	Massive with coarse grain.

Source: Prepared by the authors (2024)

Ten specimens were submitted to the test for each of the 7 stone samples, 5 with resin only and 5 with resin plus fiberglass mesh. The samples were cut on a diamond disc cutter and prepared in accordance with the procedure standard for performing a three-point flexural strength test, ABNT NBR 15845-6:2015. The dimensions of the specimens were (30 x 70 x 220) mm. Once prepared, they were placed in an oven for 48 hours at 70°C. The specimens were completely dried for 48 hours to carry out the flexion test. The three-point flexural strength test was carried out on the EMIC hydraulic press. The result obtained was in determining the rupture stress in (MPa). Figure 1 below shows the execution of the test on the hydraulic press.

Figure 1

Hydraulic press

Source: Prepared by the authors (2024)

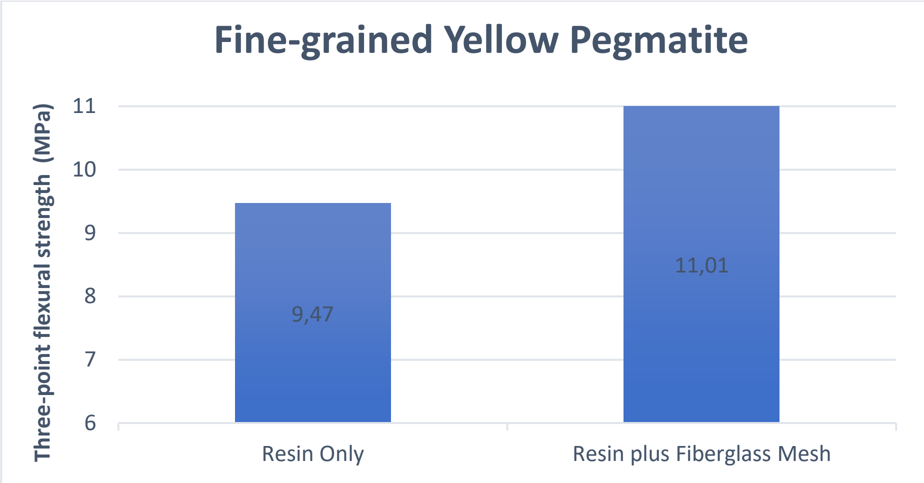
4 RESULTS AND DISCUSSION

The results expressed in the graphs refer to the average of the 5 specimens with resin only and 5 with resin plus fiberglass mesh, these referring to the 7 stone materials chosen.

The thin-mass Yellow pegmatite, commercially known as Persian, presented 9.47 MPa (resin only) and 11.01 MPa (resin plus fiberglass mesh). In this test it can be observed that the stone with the resin plus the fiberglass mesh, subjected to flexural strength, presents a resistance gain of 16%, graph in Figure 2.

Figure 2

Three-point flexural strength - Fine-Grained Yellow Pegmatite

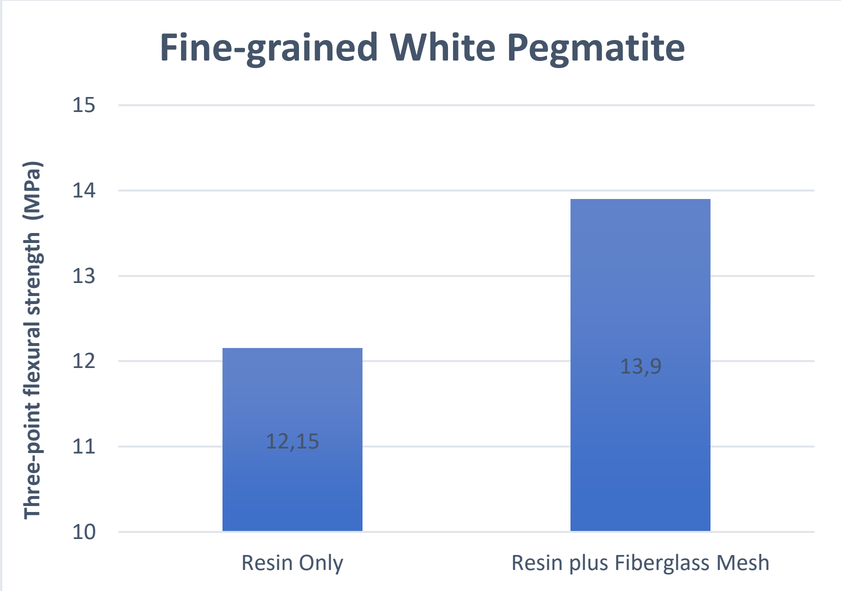


Source: Prepared by the authors (2024)

White Pegmatite, commercially known as Romanix, presented a variation in results depending on its texture characteristics, fine grained and coarse grained. The one classified as fine-grained White Pegmatite presented 12.15 MPa (resin only) and 13.90 MPa (resin plus fiberglass mesh). Therefore, he had a gain of 14% using the resin plus the fiberglass mesh, graph in Figure 3.

Figure 3

Three-point flexural strength - Fine-Grained White Pegmatite

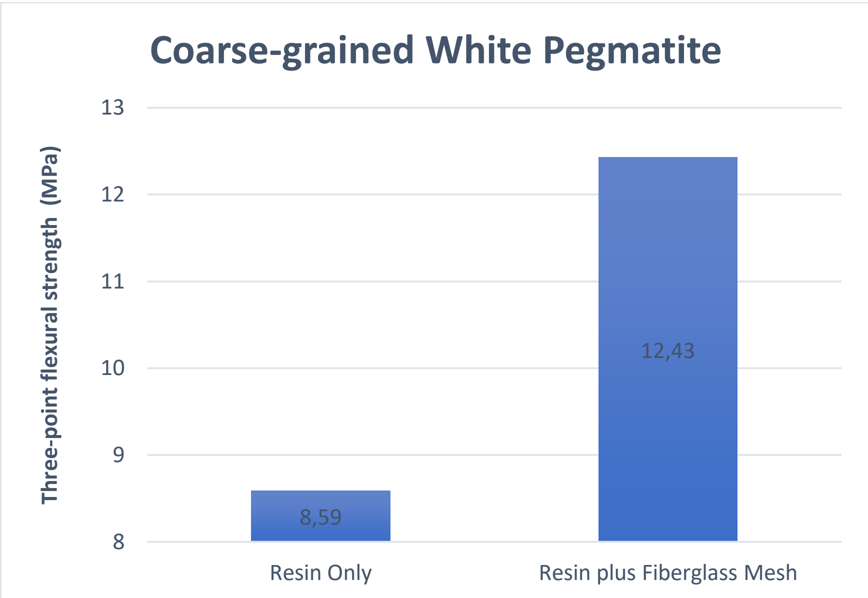


Source: Prepared by the authors (2024)

The coarse-grained White Pegmatite obtained 8.59 MPa (resin only) and 12.43 MPa (resin plus fiberglass mesh). This tested material had a gain of 44% with the application of resin plus fiberglass mesh, graph in Figure 4.

Figure 4

Three-point flexural strength - Coarse-Grained White Pegmatite



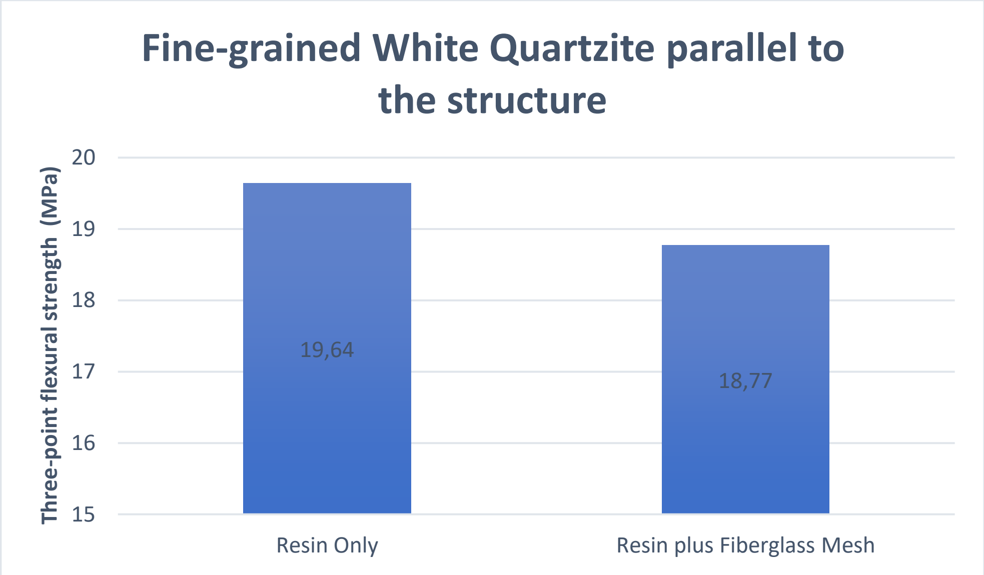
Source: Prepared by the authors (2024)

The results obtained in the graphs above showed that the texture of the stones also influences the resistance to rupture of the specimens, due to the mineralogy and distribution of minerals within the stone, combined with its geological formation. The material with more cohesive, compact and fine grain showed greater resistance in bending tests.

White Quartzite, commercially known as Maldive, also showed different results depending on its grain size and compositional structure. The fine-grained white quartzite parallel to the structure obtained 19.64 MPa (with resin only) and 18.77 MPa (resin plus fiberglass mesh). This case was different from the others, showing that resin plus fiberglass mesh will not always increase the strength of the stone. This shows us that other factors and structural characteristics of the stone also influence its resistance, and not just the resining and reinforcing of the stone material, graphic in Figure 5.

Figure 5

Three-point flexural strength - Fine-grained White Quartzite Parallel to structure

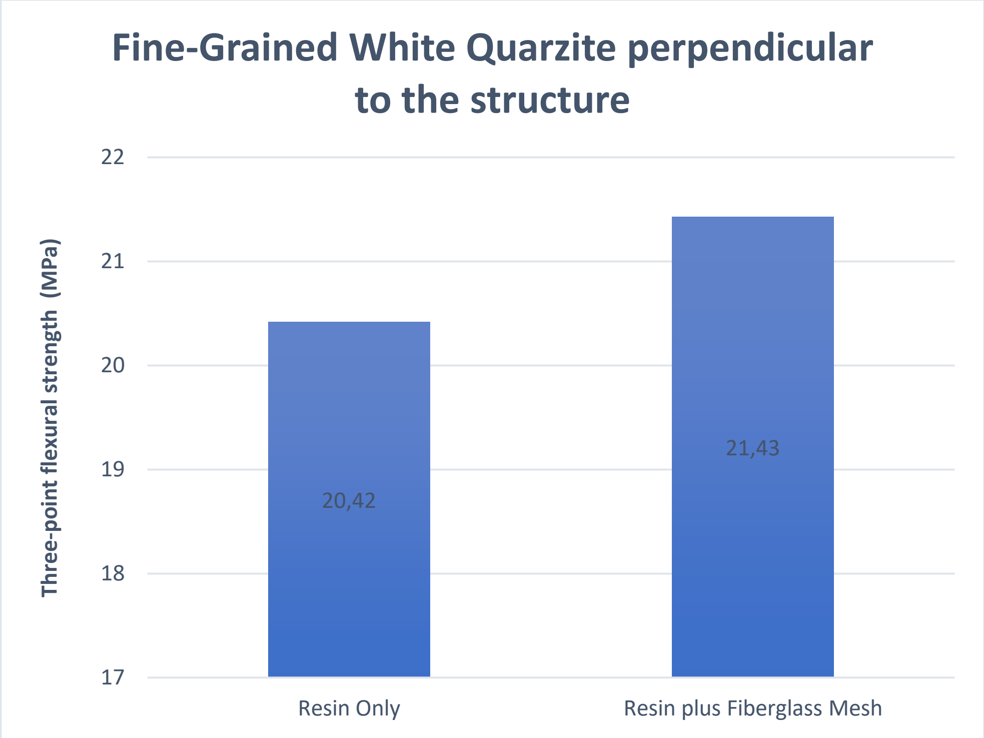


Source: Prepared by the authors (2024)

The fine-grained white Quartzite perpendicular to the structure obtained 20.42 MPa (with resin only) and 21.43 MPa (resin plus fiberglass mesh), graph in Figure 6.

Figure 6

Three-point flexural strength - Fine-Grained White Quartzite Perpendicular to the structure



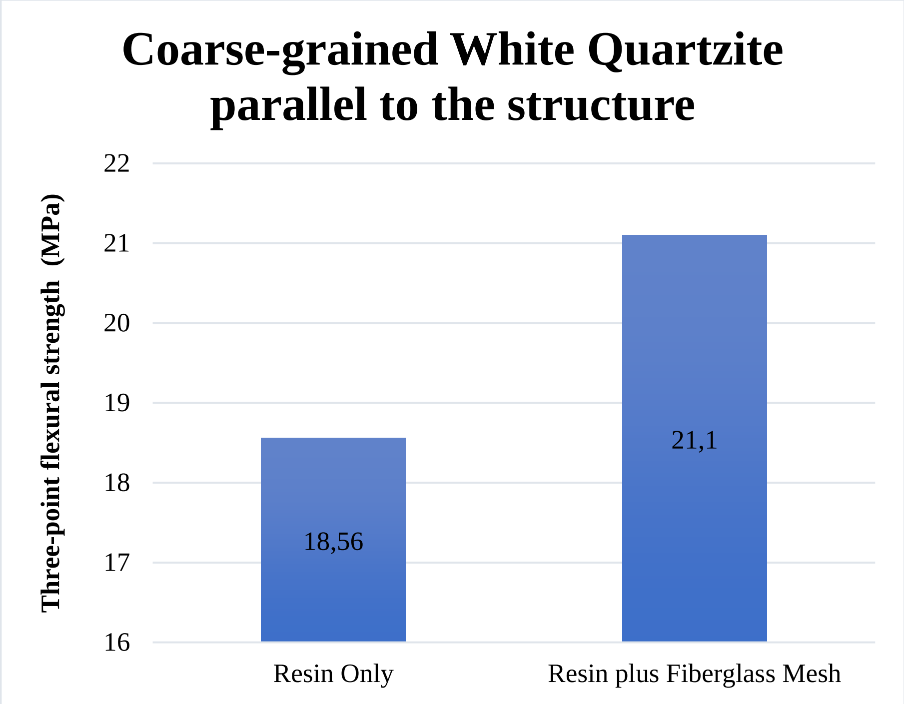
Source: Prepared by the authors (2024)

The 5% gain in resistance is very small, which indicates that the resined and reinforced material did not greatly influence the resistance of this Quartzite. This shows us, according to the previous result, that the two Quartzites already have a high resistance, therefore, the application of resin plus reinforcing does not significantly change their rupture voltage.

The coarse-grained white Quartzite, parallel to the structure, showed a resistance of 18.56 MPa (with resin only) and 21.10 MPa (resin plus fiberglass mesh). The stone material achieved a gain of 14%. In this case, the resin plus the fiberglass mesh contributed to increasing the resistance of the stone material, as shown in Figure 7.

Figure 7

Three-point flexural strength - Coarse-Grained White Quartzite Parallel to structure

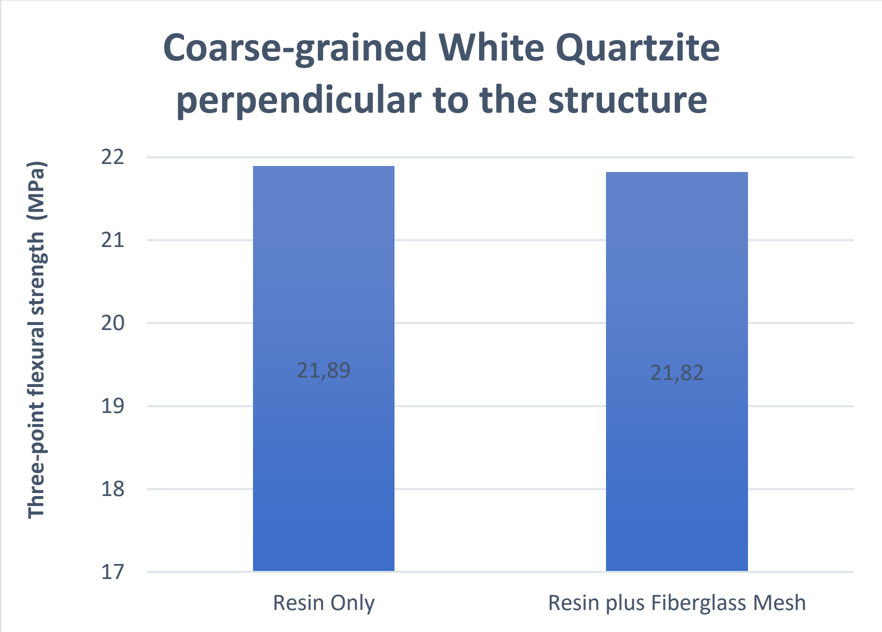


Source: Prepared by the authors (2024)

The coarse-grained white Quartzite perpendicular to the structure, obtained rupture resistance of 21.89 MPa (with resin only) and 21.82 MPa (resin plus fiberglass mesh), graph in Figure 8.

Figure 8

Three-point flexural strength - Coarse-grained White Quartzite perpendicular to the structure



Source: Prepared by the authors (2024)

In these chosen Quartzites, with these specific characteristics, it can be seen that the resin plus the fiberglass mesh did not greatly influence the resistance of the material. On the contrary, the material dropped its breaking strength in two cases. This indicates that the resining and reinforcing process must be evaluated individually for each type of stone material. Quartzites have high resistance to rupture naturally, perhaps that is why the process with just resin and resin plus fiberglass mesh does not influence all stone materials. One fact that could be observed was that the increase in resistance is also directly linked to the structure of the stone tested.

According to the classification of ABNT NBR 15844 (2015), the three-point flexural strength must be at least 10 MPa. The only stones that did not meet the standard requirement with the application of resin alone were the fine-grained yellow pegmatite (9.47 MPa) and the coarse-grained white pegmatite (8.50 MPa), being classified according to the Application Guide for Stones as a low-resistance material (CHIODI FILHO and RODRIGUEZ, 2020).

All stone materials with the application of reinforcing plus resin meet the requirement of the ABNT NBR 15844 (2015) standard, and can be safely applied in places that require a structural function of bending efforts.

5 CONCLUSION

The results obtained made it possible to evaluate the three-point flexural strength of the specimens in the resined and reinforced conditions.

Analysis of the results indicated that in the pegmatite specimens tested, the process of applying resin plus fiberglass mesh contributed to increasing the resistance of the stone material. One of the materials tested, coarse-grained White Pegmatite, achieved a 44% increase in three-point flexural strength, when the stone was resined and reinforced with fiberglass mesh. All pegmatites tested obtained a percentage gain in rupture resistance in stones that were resined and reinforced.

The Quartzite results were different, they had a distinct variation. In two cases, fine-grained white quartzite parallel to the structure and coarse-grained white quartzite perpendicular to the structure, the stone material lost resistance when resin plus fiberglass mesh was applied. In the cases of fine-grained white quartzite perpendicular to the structure and coarse-grained white quartzite parallel to the structure, the resistance was a little higher, but nothing considered much higher. The latter achieved a 14% gain in breaking strength. Quartzites already have greater resistance than other stones, so in this material the results showed that the application of resin plus fiberglass mesh does not greatly influence the gain in resistance. The variation in Quartzites may be due to the natural resistance of this type of stone material, as it has high-resistance minerals such as quartz.

Therefore, it is always necessary to evaluate each type of stone with a laboratory test before applying the resin and fiberglass mesh. If this is not done, the industry may generate unnecessary labor costs and the application of products to stone materials that do not require resining or reinforcing.

ACKNOWLEDGMENTS

This work was carried out with financial support from the Federal Institute of Education, Science and Technology of Espírito Santo (IFES) through resources from Public Notice PRPPG 08/2024 - Institutional Scientific Diffusion Program (PRODIF).

REFERENCES

ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA DE ROCHAS ORNAMENTAIS - ABIROCHAS. Balanço do Setor Brasileiro de Rochas Ornamentais e de Revestimento em 2023. Informe: 01/2024. Brasília, 2024.

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 15012:2013. Rochas para revestimentos de edificações — Terminologia. 23p. Rio de Janeiro, 2013.

ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 15844:2015. Rochas para revestimento — Requisitos para granitos. Rio de Janeiro, 2015.

ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 15.845-6:2015 Rochas para revestimento – Parte 6: Determinação da resistência à flexão por carregamento em três pontos. Rio de Janeiro, 2015.

CASTILHO, E.D.F., Caracterização tecnológica de rochas ornamentais: práticas laboratoriais, 1 ed., Vitória, IFES, 2018.

CASTILHO, E. D. F., SANT'ANA, M. A. K., TEIXEIRA, D. N. L., SILVA, M. E. D., GADIOLI, M. C. B. (2023). Evaluation of the Technological Properties of Artificial Agglomerated Stones in Epoxy Resin and Castor Oil-Based Vegetable Polyurethane Matrix. *Revista De Gestão Social E Ambiental*, *18*(1), e04249. https://doi.org/10.24857/rgsa.v18n1-034

CHIODI FILHO, C.; RODRIGUEZ, E.P. Guia de aplicação de rochas em revestimentos. São Paulo: Abirochas, 2020, 119p.

CENTRO DE PESQUISA E DESENVOLVIMENTO (CEPED). Análise Petrográfica. Bahia. 2015.

CENTRO DE PESQUISA E DESENVOLVIMENTO (CEPED). Análise Petrográfica. Bahia. 2016.

CENTRO DE PESQUISA E DESENVOLVIMENTO (CEPED). Análise Petrográfica. Bahia. 2018.

FRASCÁ, M.H.B., "Tipos de rochas ornamentais e características tecnológicas", In: Vidal, F.W.H., Azevedo, H.C.A., Castro, N.F. (eds), Tecnologia de Rochas Ornamentais: Pesquisa, Lavra e Beneficiamento, 1 ed., capítulo 2, Rio de Janeiro, BR, Centro de Tecnologia Mineral CETEM-MCTIC, 2014

MATURANA, M. R., SILVEIRA, L. L. L. Estudo comparativo da resistência à flexão 4 pontos de rochas ornamentais silicáticas teladas com resina epóxidica e poliuretana à base de óleo de mamona colorida. In: ANAIS DA JORNADA DE INICIAÇÃO CIENTÍFICA, 26. Rio de Janeiro: CETEM/MCTIC, 2018. 5p.

SANTANA, M. A. K., CASTILHO, E.D.F. Estudo comparativo de caracterização tecnológica de rocha ornamental silicática telada com diferentes gramaturas. EDIFES, Vitória – ES, 2023

SILVEIRA, L.L.L., VIDAL, F.W.H., SOUZA, J.C., “Beneficiamento de rochas ornamentais”, In: Vidal, F.W.H., Azevedo, H.C.A., Castro, N.F. (eds), Tecnologia de Rochas Ornamentais: Pesquisa, Lavra e Beneficiamento, 1 ed., capítulo 7, Rio de Janeiro, BR, Centro de Tecnologia Mineral CETEM-MCTIC, 2014.

SOUZA, T. C. B., CASTILHO, E. D. F., SANT’ANA, M. A. K., DE AGUIAR, M. C., GADIOLI, M. C. B. (2023). Gloss Analysis of Agglomerated Stones Subjected to Natural Cycling. Revista De Gestão Social E Ambiental, 18(3), e04472. https://doi.org/10.24857/rgsa.v18n3-028

VIDAL, F.W.H.; AZEVEDO, H.C.A.; CASTRO, N.F. Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento. Centro de Tecnologia Mineral. Rio de Janeiro: CETEM/MCTI, 2014, 700p.