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ARTIFICIAL DEGRADATION OF TWO WOODEN SPECIES OF DIFFERENT DENSITY AND THEIR USE FOR OPTIMIZATION OF THERMAL COMFORT IN CLIMATIC AREAS OF MARINE AND MESOANDEAN DESERT

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ABSTRACT

Objective: The objective of this study was to evaluate the behavior of two species of wood of different density and the most commercialized in the southern regions of Peru: Schizolobium excelsum (pashaco) and Aniba gigantiflora (mohena), in order to choose the appropriate timber species for housing coating and contribute to thermal comfort. Wood is known to be a widely used material in construction due to its mechanical, aesthetic and sustainable properties. However, its durability is compromised by environmental factors. The degradation of wood can manifest itself in the form of cracking, erosion and discoloration, affecting its structural integrity and appearance. On the other hand, several studios have designed multilayered facades as an architectural strategy that seeks to optimize the thermal comfort of the interior spaces. Previous studies have shown that the configuration of multilayer facades with wood can result in a significant improvement of the thermal performance of buildings, for this purpose the best timber species must be chosen.

Context: In this context, samples of two timber species were selected and evaluated in their natural state and coated with commercial surface protector, and wood thermally treated at 180 °C; these samples were subjected to accelerated degradation in a QUV equipment under conditions of UV radiation (0.89 W/m2 nm at 340 nm), humidity (by condensation and spray) and high temperatures (up to 60 °C), according to EN 927-6:2018 (European Committee for Standardization, 2018) for a total of 2016 hours.

Results: The results showed statistically that the wood in its natural state, and with commercial coating presented cracking, fissures, erosion and discoloration. However, the heat treated wood presented better results of resistance against cracks. Finally, the species Schizolobium excelsum (density 0.33 g/cm3) is more resistant to exposed climatic conditions. Chosen the best timber species, it was configured as part of the multi-layer facade system composed of: heat treated wood, elastomer, air, OSB board and polyurethane insulators and its behavior was simulated to optimize thermal comfort in homes of marine desert climates and Andean meso with THERM software. The result showed an internal temperature concentration of 20 °C versus 0 °C of external temperature, this result considering only structures of walls of the house.

Implications of the research: The implications of the research is at the level of material development, since the results reflect the need to develop coatings and treatments for wood that offer greater protection against degradation that respond to demands for durability and sustainability. Another implication is at the level of design strategy, the configuration of multi-layer facade with heat treated wood, can be adopted in architectural design to improve thermal comfort in marine or Mesoandean desert climatic areas.

Originality: The originality of this inside research in which an accelerated degradation equipment was used, which allowed to have a realistic frame of reference to evaluate the behavior of materials in adverse climatic conditions. Likewise, it was possible to identify the timber species, more resistant to extreme climatic factors and by simulating the thermal behavior of this material, it is concluded that it is viable against other timber species.

Keywords: Temperism, Artificial Degradation, Wood, UV, Cracking, Thermal Comfort.

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DEGRADAÇÃO ARTIFICIAL DE DUAS ESPÉCIES DE MADEIRA DE DENSIDADES DIFERENTES E SUA UTILIZAÇÃO PARA OTIMIZAÇÃO DO CONFORTO TÉRMICO EM ZONAS CLIMÁTICAS MARINHAS E DO DESERTO MESOANDÊS

RESUMO

Objetivo: O objetivo deste estudo foi avaliar o comportamento de duas espécies de madeira de densidade diferente e a mais comercializada nas regiões do sul do Peru: Schizolobium excelsum (pashaco) e Aniba gigantiflora (mohena), a fim de escolher as espécies adequadas de madeira para revestimento de habitação e contribuir para o conforto térmico. Sabe-se que a madeira é um material amplamente utilizado na construção devido às suas propriedades mecânicas, estéticas e sustentáveis. Mas sua durabilidade é comprometida por fatores ambientais. A degradação da madeira pode se manifestar como rachaduras, erosão e descoloração, afetando sua integridade estrutural e aparência. Por outro lado, vários estudos projetaram fachadas multicamadas como uma estratégia arquitetônica que busca otimizar o conforto térmico dos espaços interiores. Estudos anteriores mostraram que a configuração de fachadas multicamadas com madeira pode resultar em uma melhora significativa no desempenho térmico dos edifícios, por isso é necessário escolher as melhores espécies de madeira.

Contexto: foram selecionadas e avaliadas amostras de duas espécies de madeira no seu estado natural e revestidas com um protetor de superfície comercial, e a madeira tratada termicamente a 180 °C; estas amostras foram submetidas a degradação acelerada num equipamento QUV em condições de radiação UV (0,89 W/m2 nm a 340 nm), humidade (por condensação e pulverização) e temperaturas elevadas (até 60 °C), de acordo com a norma EN 927-6:2018 (Comitê Europeu de Normalização, 2018), num total de 20 16 horas.

Resultados: Os resultados mostraram estatisticamente que a madeira em seu estado natural e com revestimento comercial apresentou rachaduras, fissuras, erosão e descoloração. No entanto, a madeira tratada termicamente apresentou melhores resultados contra rachaduras. Por fim, a espécie Schizolobium excelsum (densidade 0,33 g/cm3) é mais resistente às condições climáticas expostas. Escolhida a melhor espécie de madeira, foi configurada como parte do sistema de fachada multicamadas composto por: madeira tratada termicamente, elastômero, ar, placa de OSB e isoladores de poliuretano e seu comportamento foi simulado para otimizar o conforto térmico em casas com climas desérticos marinhos e meso andino com software THERM. O resultado mostrou uma concentração de temperatura interna de 20 °C versus 0 °C de temperatura externa, este resultado considerando apenas estruturas de parede da casa.

Implicações da pesquisa: As implicações da pesquisa estão no nível de desenvolvimento do material, pois os resultados refletem a necessidade de desenvolver revestimentos e tratamentos de medera que ofereçam maior proteção contra a degradação que atenda às demandas de durabilidade e sustentabilidade. Outra Implicação é no nível da estratégia de projeto, a configuração de fachada multicamadas com madeira tratada termicamente, pode ser adotada no projeto arquitetônico para melhorar o conforto térmico em zonas marinhas desérticas ou climáticas mesoandinas.

Originalidade: A originalidade desta pesquisa dentro da qual um equipamento de degradação acelerada foi usado, o que permitiu ter um quadro de referência realista para avaliar o comportamento dos materiais em condições climáticas adversas. Também foi possível identificar as espécies de madeira, mais resistentes a fatores climáticos extremos e simular o comportamento térmico desse material, conclui-se que ele é viável contra outras espécies de madeira.

Palavras-chave: Envelhecimento, Degradação Artificial, Madeira, UV, Rachadura, Conforto Térmico.

DEGRADACIÓN ARTIFICIAL DE DOS ESPECIES MADERABLES DE DIFERENTE DENSIDAD Y SU USO PARA OPTIMIZACIÓN DEL CONFORT TÉRMICO EN ZONAS CLIMÁTICAS DESÉRTICO MARINO Y MESOANDINO

RESUMEN

Objetivo: El objetivo de este estudio fue evaluar el comportamiento de dos especies de maderas de diferente densidad y las más comercializadas en las regiones del sur del Perú: *Schizolobium excelsum* (pashaco) y *Aniba gigantiflora* (mohena), con la finalidad de elegir la espécie maderable apropiado para revestimento de viviendas y contribuir al confort térmico. Se sabe que la madera es un material ampliamente utilizado en la construcción debido a sus propiedades mecánicas, estéticas y sostenibles. Sin embargo, su durabilidad se ve comprometida por factores ambientales. La degradación de la madera puede manifestarse en forma de agrietamiento, erosión y decoloración,

afectando su integridad estructural y apariencia. Por otro lado, diversos estudios han diseñado fachadas multicapas como una estrategia arquitectónica que busca optimizar el confort térmico de los espacios interiores. Estudios previos han evidenciado que la configuración de fachadas multicapas com madera puede resultar en una significativa mejora del rendimiento térmico de las edificaciones, para ello se debe elegir la mejor especie maderable.

Contexto: En este contexto, se eligieron muestras de dos especies maderables se evaluaron en su estado natural y recubierto con protector superficial comercial, y madera tratada térmicamente a 180 °C; dichas muestras se sometieron a degradación acelerada en un equipo QUV bajo condiciones de radiación UV (0,89 W/m^2 nm a 340 nm), humedad (por condensación y spray) y temperaturas altas (hasta 60 °C), según la Norma EN 927-6:2018 (European Committee for Standardization, 2018) por un total de 2016 horas.

Resultados: Los resultados evidenciaron estadísticamente que la mdera em su estado natutal, y con recubrimiento comercial presentaron agrietamiento, fisuras, erosiòn y decoloraciòn. Sin embargo, la madera tratada térmicamente presentò mejores resultados de resistencia frente a agrietamientos. Finalmente, la especie *Schizolobium excelsum* (densidad 0,33 g/cm^3) es más resistente a las condiciones climáticas expuestas. Elegida la mejor especie maderable, se configuro como parte del sistema de fachada multicapas compuesta por: madera tratada térmicamente, elastómero, aire, tablero OSB y aislantes de poliuretano y se simulo su comportamiento para optimizar el confort térmico en viviendas de climas desértico marino y meso andino con el software THERM. El resultado evidenciò una concentración de temperatura interna de 20 °C frente a 0 °C de temperatura externa, este resultado considerando solo estructuras de paredes de la vivienda.

Implicaciones de la investigacion: Las implicaciones de la investigacion es a nível de desarrolho de materiales, ya que los resultados reflejan la necesidad de desarrollar recubrimientos y tratamentos para medera que ofrezcan mayor proteccion contra la degradacion que respondan a demandas de durabilidad y sostenibilidad. Otra Implicancia a es a nível de estrategia de diseño, la configuraciòn de fachada de multicapas con madera tratada termicamente, puede ser adoptada en el diseño arquitectonico para mejorar el confort térmico en zonas climáticas desérticas marino o mesoandinos.

Originalidad: La originalidad de esta investigaciòn inside em que se utilizo un equipo de degradacion acelerada lo que permitio tener um marco de refrencia realista para evaluar el comportamiento de materials en condiciones climaticas adversas. Asimismo, se pudo identificar a la especie maderable, mas resistente a factores climáticos extremos y al simular el comportamento térmico de este material, se concluye que es viable frente a otras especies maderables.

Palabras clave*:* Intemperismo, Degradación Artificial, Madera, UV, Agrietamiento, Confort Térmico.

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1 INTRODUCTION

Wood is one of the most abundant and versatile natural materials. Wood also has a strong relationship with its weight, is an insulator of heat and electricity, has acoustic properties and is relatively easy to work with. Today, despite technological advancement and competition from metals, plastics, cement and other materials, wood maintains a place in most of its traditional functions and its service capacity is expanding through new uses. Tsoumis et al. (2022).

The use of wood in construction is an alternative that improves the quality of life of the population not only because of the well-being provided by the better habitability of homes built with this material but also because of its enormous contribution to the environment Gysling and Kahler (2021). Wood when exposed outdoors suffers weathering which refers to the slow degradation of this material (Rowell, 2012). The agents responsible for physical changes on the surface of wood, such as discoloration, chalking, blistering and cracking, are solar radiation, humidity and temperature.

Surface degradation in wood exposed to the elements is a process that takes years, depending on several factors such as its natural state, heat treatment, chemical treatment, with some type of protective coating or the position in which the material is exposed to the sun, wind and rain. When wood is exposed to the environment, the combined action of atmospheric agents causes physical and chemical alterations in its structure, Acevedo et al. (2013).

In order to avoid and/or delay the effects generated by weathering, there are products that are applied to the surface of the wood, called surface coatings Taraborelli et al. (2016). The one used for this work is varnish, which is a product composed of binders, plasticizers, solvents and diluents that after application and in a dry state, create a water-insoluble, adherent, hard, generally smooth and shiny film that allows the grain of the wood to be seen, Tamarit et al. (2016).

Although surface coatings and some treatments applied to wood give it an increase in its useful life, this also depends on the effect that weathering has on it and on the intrinsic properties of the material Rivera et al. (2016). The properties described above can influence the correct incorporation and absorption of the coating or treatment in the wood, as well as its effectiveness and permanence during the useful life Flores et al. (2001); Taraborelli et al. (2016).

The main applications of wood in the local market are construction, both in cylindrical material and in sawn material: boards, beams, moldings as well as laminated beams and wooden bricks Taraborelli et al. (2016).

According to the above, the objective of this work is to evaluate the behavior of two wood species with greater commercial demand in departments of southern Peru, which are: Schizolobium excelsum (pashaco) and aniba gigantiflora (mohena). The aspects to be evaluated using European standards are the formation of cracks, chalking and their behavior in improving thermal comfort in homes in marine desert and meso-Andean climates.

2 THEORETICAL FRAMEWORK

Wood materials exposed to outdoor conditions, particularly materials placed above ground level, fail due to the effects of weathering. Under the combined effects of several environmental factors, such as sunlight and rainwater, the chemical components of wood, particularly lignin, are depolymerized and modified, subsequently resulting in discoloration, roughness and cracking of surfaces.(Kanbayashi et al., 2024).

Surface coating is a widely used conventional technique for wood protection. It is a simple and effective strategy to provide wood with weather-resistant capabilities. However, long periods of outdoor exposure inevitably lead to defects on the wood surface. Therefore, periodic repainting of the wood is required. Currently, many researchers have conducted various studies to extend the life of wood coatings.(Peng et al., 2020).

The weather resistance of coated wood depends not only on the performance of the coating, but also on several factors such as wood species, grain orientation, and moisture content. In addition, a higher degree of coating absorption and light protection provides greater durability to wood surfaces. Furthermore, the distribution of coating agents in the wood is an important factor in determining the performance of coated wood.(Kanbayashi et al., 2024).

Regarding the relationship between thermal comfort and the material, in the theoretical framework it was found that in the world there is a tendency to revalue wood construction where its physical characteristics and interactions with the occupants are numerically analyzed, integrating these findings in the construction planning stage.(Kim et al., 2024).

One of the current trends in being able to measure the relationship between thermal comfort and wood is through psychological factors perceived by the occupants, which are translated into numerical data for interior environmental planning using qualitative research methodologies and preference surveys as a basis.(Ojala et al., 2023).

Studies examining the psychological impression of wood spaces primarily cover “warmth” and “cozy.” According to the HHH, wood can be perceived as warm due to its yellow spectrum. These visual and perceptual effects can influence changes in thermal sensation, potentially affecting the thermal comfort temperature range and aiding carbon reduction by minimizing cooling and heating loads. (Wang et al., 2018).

In the state of the art it was also found that the thermal perception of the inhabitants of a building can be measured by the PMV thermal comfort theory and the ASHRAE standard 55-2004(Yao et al., 2009).

Regarding the thermal sensation of wooden walls, it was found that, on average, inhabitants of houses with wooden walls in the coastal area feel more comfortable than those living in mountainous areas. The average AMV of residents living in houses with wooden walls in the coastal area is -0.28, while the AMV of those living in the mountains is -1.12. It can be determined that wooden walls are able to absorb heat more than cold. Although the material is not the only factor that determines comfort in buildings, it largely determines thermal comfort, especially in the fit of the clothes worn.(Hermawan et al., 2015).

3 MATERIALS AND METHODS

Wood species were used; they came from Tambo plantations in the department of Madre de Dios. The samples were obtained from the middle part of the trunk, said samples were obtained from a longitudinal-tangential cut.

Two species of wood were used: Schizolobium excelsum (pashaco) and Aniba gigantiflora (mohena). The samples were labelled. 48 samples were evaluated, each measuring 85 mm ± 2 mm x 74 mm ± 1 mm and 18 mm ± 1 mm thick, smooth and uniform. Three groups of each species were formed: i) eight samples heat-treated at 180 °C with a temperature increase of 2 °C/min, eight varnished samples each protected with Rubio Monocoat Oil varnish (water- and solvent-free varnish) and eight control samples (in their natural state).

The aesthetic properties were based on visual assessments of weathering or chalking, discolouration and cracking according to EN 927-6:2018 (European Committee for Standardisation, 2018). The samples were conditioned for one week under laboratory conditions: ambient temperature of 20 °C and relative humidity of 45 %. The accelerated weathering tester – QUV, model Spray with UVA-340 lamps was used. To achieve aging in less time, the light of the QUV equipment was calibrated at 0.89 W/m ^{2} /nm for each cycle, with periods of spray (dew, not rain) and condensation to moisten the tests, using deionised water with a pH value between 5.0 and 7.5 and an electrical conductivity of a maximum of mS/m, measured at (25±1).

The total weathering cycle applied was 2016 hours (12 weeks). A regular cycle lasted 168 hours (1 week). Each one-week exposure cycle consisted of the cycle detailed in Table

Table 1.

Table 1

Accelerated degradation test cycle description

Passed	Function	Temperature	Duration	Condition
1	Condensation	(45±3) °C	24 h	--
2	Subcycle step 3+4	--	144 h consisting of 48 cycles of 3h	--
3	UV	(60±3) °C	2.5 h (150 min)	Irradiance 0.89 W/m ^{2} nm
4	SPRAY	--	0.5 h (30 min)	7 L/min, UV off

The variables evaluated in the tests carried out were:

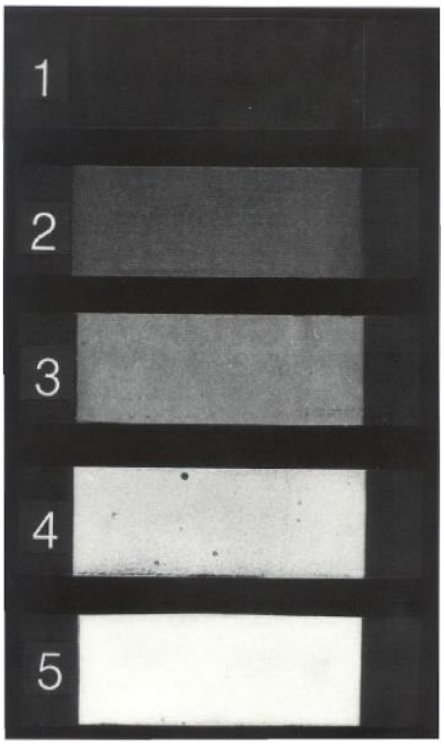
3.1 CHALKING

It was carried out according to the procedure described in EN ISO 4628-6 (International Organization for Standardization, 2011), using a 10x magnification microscope. By means of an adhesive tape, the chalk was removed from the coating under test. The chalk marking adhering to the tape was examined against a contrasting black background, the degree of chalkiness was assessed according to the following calibration scale, see

Figure 1.

Figure 1

Degree of chalking



3.2 DEGREE OF CRACKS OR FISSURES

The degree of surface cracking was evaluated by comparison with graphic patterns, using the designation system defined in EN ISO 4628-1 (International Organization for Standardization, 2016).

The degree of cracking is the assessment that describes the cracks on a surface in terms of quantity, size and depth. According to the standard, several types of cracking are specified, among the most important: i) Cracking with or without preferred direction (area of the test pieces from 100 cm ^{2} to 200 cm ^{2}), ii) Irregular, iii) Long lines, iv) Short parallel, v) Criss-cross, vi) Crow's feet, vii) Short and random and viii) Mosaic.

The number of cracks is assessed with reference to

Table 2and using the images of the EN ISO 4628-1 standard (International Organization for Standardization, 2016) as a reference.

Table 2

Classification scheme for designating the amount and size of cracking

Classification	Defect quantity	Classification	Defect size
0	None	0	Not visible with 10x magnification
1	Very few	1	Only visible under 10x magnification
2	Few	2	Only visible with normal corrected vision up to 0.2 mm
3	Moderate number	3	Clearly visible (0.2 – 0.5 mm)

4	Considerable	4	visible from 0.5 mm to 1 mm
5	Dense pattern	5	Greater than 1 mm wide

Source: International Standard ISO 4628-4:2016

3.3 CLIMATIC SEVERITY OF THE STUDY AREAS

In order to estimate the mesoclimate, or local climate, it was necessary to analyse the exposure factors, urban configuration or the existence of key geographic elements (elevations, valleys, etc.) that cause or not the climate of the locality to differ from the identified macroclimate. In many cases, macroclimate and mesoclimate may coincide, which is why it is necessary to proceed to a separate estimation of both, especially in the elements made of wood that form part of the building envelope, as well as its carpentry and exterior structures Fernández - Golfín *et al.* (2016).

To determine the climatic severity of locations with marine and meso-Andean desert climates (Chivay, Islay and Arequipa considered in this study), the Scheffer index was estimated, which is a method of evaluating microbiological risk that compares the risk of rotting of a wooden element exposed to the outside based on its geographical exposure.

Based on what was published in the book "Guide for the assignment of use and service classes to wood products" Fernández - Golfín *et al.* (2018), we determined the Basic Exposure Index, which would have the wood products that are applied in marine desert and meso-Andean climates, is detailed in

Table 3.

Table 3

Criterion for converting the Scheffer index value into the basic exposure index value

Scheffer index calculated value	Station rating	Basic exposure index Is0
IS≤35	Dry	3.0
35<IS≤70	Wet	3.3
70<IS≤100	Very humid	3.5
IS>100	Extremely humid	3.7

Source: Fernandez - Golfin *et al.* (2018)

According to Peláz et al. (2017), thermal comfort is the "rational consumption of energy while maintaining the comfort of the occupants". To this end, comfort criteria have been defined in relation to existing international regulations in order to establish different levels or categories based on the evaluation of thermal comfort. Therefore, we can mention terms such as the estimated mean vote index (PMV) and the estimated percentage of dissatisfied people (PPD), considering variables such as temperatures, currents and vertical differences in air temperature.

Facade systems made up of multiple layers are effective in significantly improving the thermal transmittance of the building, providing an adequate thermal environment for users, hence the importance of using porous materials as an exterior protective cladding element in buildings. Belloli et al. (2014)

On the other hand, there are also computer programs that make it possible to analyze heat transmission at a two-dimensional level. This software has been developed by Lawrence Berkeley National Laboratory (LBNL), where it is possible to model complex geometries corresponding to the different construction elements. After the modeling is finished, it is possible to perform the calculation (meshing and heat transmission) which is done automatically. The results can be visualized in THERM in various ways, including calculations of the U-factor, isotherms, flow vectors and temperatures at each point.

3.4 PHYSICAL TESTS

Determining the density of wood is essential to assess the natural degradation and thermal comfort of wood species. Density is not only a direct indicator of the resistance and durability of wood against biological factors, such as fungi and insects, but also influences its thermal insulation capacity. Woods with a higher density tend to offer better performance in terms of heat retention, which is crucial for thermal comfort in buildings. On the other hand, knowing the density allows the selection of appropriate materials that optimize energy use and minimize environmental impact, guaranteeing the sustainability and energy efficiency of living spaces.

4 RESULTS AND DISCUSSION

4.1 DENSITY

The results of this variable were carried out with wood of the two species with a moisture content below 9.2%, with variability of less than 0.6% (uniform moisture between test tubes). The results of basic density obtained for the “Pashaco” and “Mohena” wood in their natural state were 0.33 g/cm ^{3} and 0.45 g/cm ^{3} respectively. With the results obtained, the wood is classified as very soft and light wood.

A complementary test carried out on both species was dimensional stability (linear swelling or shrinkage). It was observed that in all cases the tangential direction was the one that

presented the greatest changes. The differences between the contractions occur because, in the radial direction, the woody radii restrict its dimensional change, and for the longitudinal direction its value is much lower because the main tissues that form the wood are found in this orientation. In this sense, the anisotropy values obtained, the pashaco presented an average value of 0.81 and the mohena of 0.96, both woods are classified according to their coefficient of anisotropy "Very Low" that is, they are "very stable" which would translate into both woods in their natural state not presenting much variation dimensionally when losing or gaining humidity.

4.2 CHALKING

The degree of chalkiness for the species of *Aniba Gigantiflora.* (Mohena) and *Schizolobium Excelsum.* (Pashaco), evaluated with the EN ISO 4628-6 Standard (International Organization for Standardization, 2011) are shown in the calibration scale of

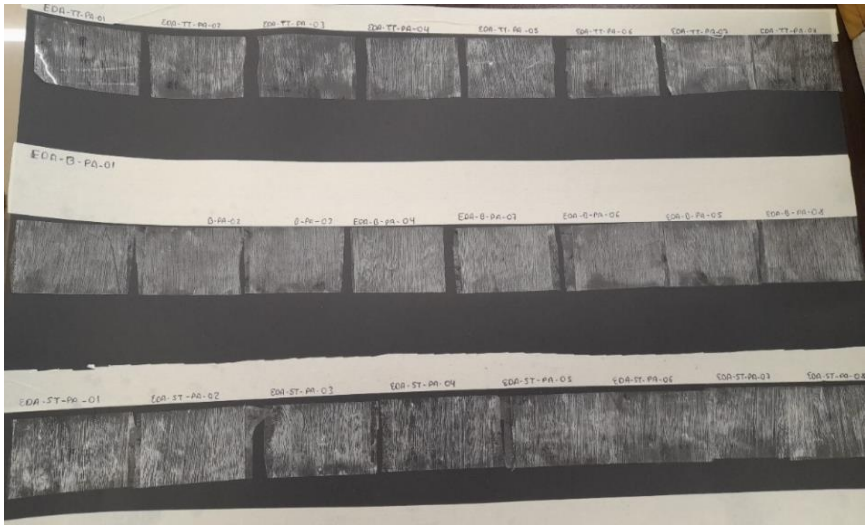
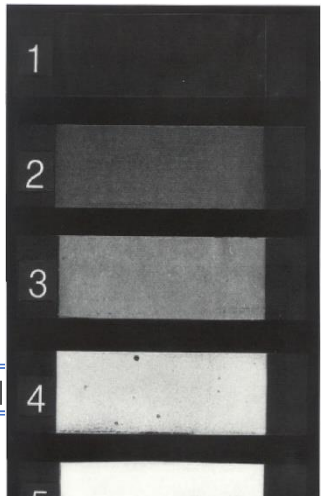


Figure 2and

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Figure 2

Chalking standards for the species Aniba Gigantiflora. (mohena)



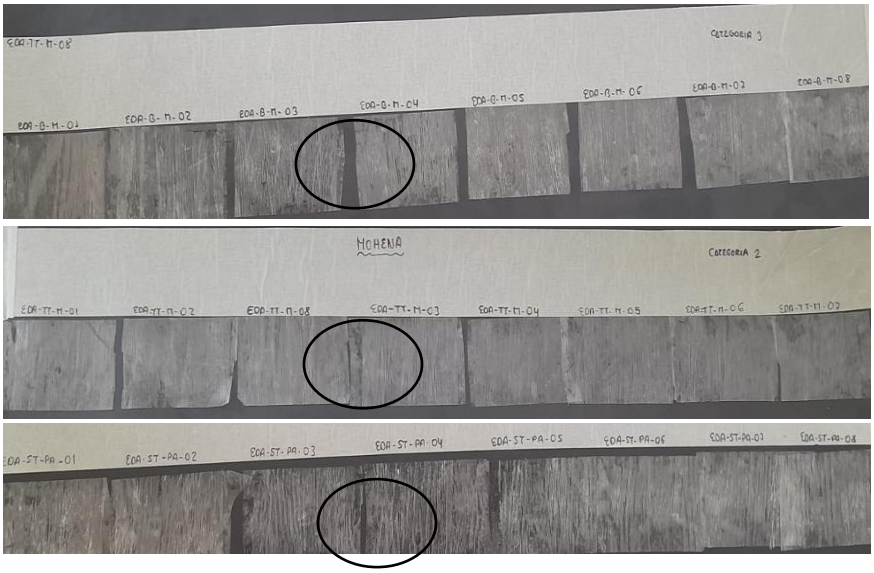


Figure 3

Chalking standards for the species Schizolobium Excelsum. (pashaco)



From the photographic reference standards obtained for both samples of wood degraded under exposure to UV radiation, condensation and spray, it is evident that:

From the species *Aniba Gigantiflora* . (mohena):

The heat-treated samples are those with the highest concentration of chalking, that is, peeling of the surface bark, their peeling level is grade 3; while the varnished woods have a peeling degree of grade 2, probably due to the protective effect of the varnish used and finally the control samples (without any treatment) present a peeling degree of grade 2.

While in the species Schizolobium Excelsum (pashaco): The heat-treated and untreated samples show a lower degree of chalking, while the varnished ones on average are in the order 3.

4.3 COLOR CHANGE AND WEAR

In general terms, both wood species suffered discoloration after being exposed to the QUV equipment for a cycle of 2060 hours. According to the photographs shown in

Figure **4**and

Figure 5it was observed that the degree of shade lost is general for each group of samples (varnished, heat-treated and control). In particular, it is observed that the varnished wood of both species has lost the most color; possibly related to the absorption and reflection of energy given by the UV rays of said pigment, followed by the control wood and finally the wood treated at 180 °C, which apparently the heat treatment favored the anchoring of the cellulose to the anatomical structure of the wood.

According to Rowell (2012), the coating or protector loses its useful life when it suffers a loss of gloss or wear; given the meteorological conditions of the test. The greatest colour wear and loss of gloss of the pashaco species occurred at the eighth cycle (approximately 1344 hours) while the mohena at the sixth cycle (approximately 1006 hours). The main factors that influenced this were the humidity (condensation and spray) that could enhance the leaching of the components degraded by UV radiation, and the increase in the moisture content in the wood could cause subsequent swelling and contractions that favoured the appearance of cracks and/or splits, wearing down and greying the surface finish. In agreement with the results of this work, Taraborelli et al. (2016) demonstrated that white finishes behave better, in terms of cracking of the substrate and the coating, than those containing pigments of another colour. Chromatic degradation of coatings can be mainly caused by UV rays Avila Delucis et al. (2016).

Figure 4

Photographic record before and after degradation of the Schizolobium Excelsum species. (pashaco)

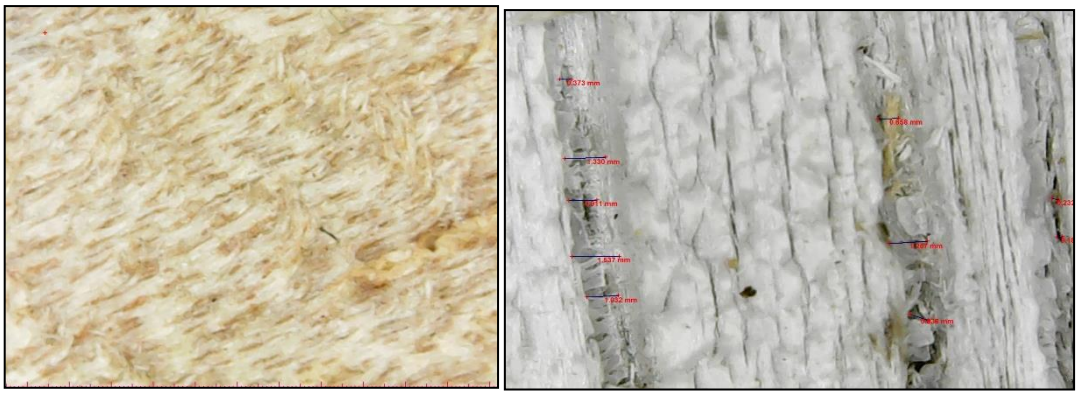
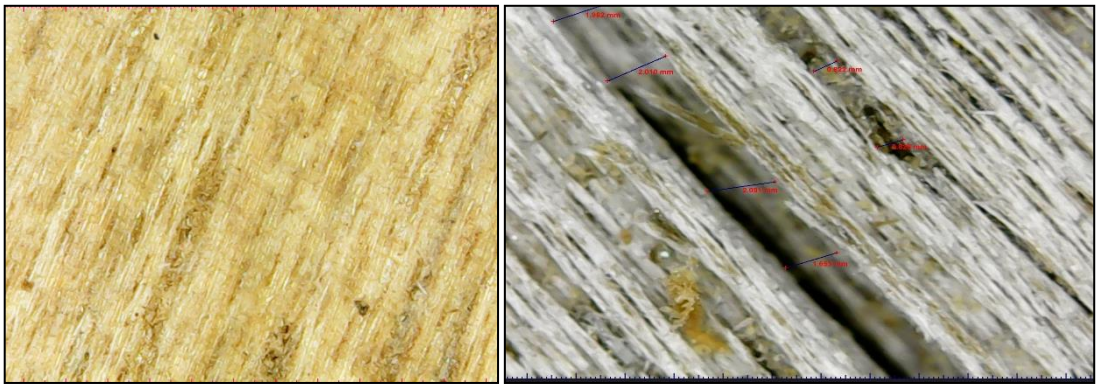


Figure 5

Photographic record before and after degradation of the species Aniba Gigantiflora. (mohena)



4.4 PRESENCE OF CRACKS

The results of the evaluation of the degree of cracking of the surfaces by comparison with graphic patterns using the designation system defined in EN ISO 4628-1 (International Organization for Standardization, 2016) are shown in

Figure **6**and

Figure 6

Degree of fissures of the species Schizolobium Excelsum. (pashaco)

Figure 7.

Figure 6

Degree of fissures of the species Schizolobium Excelsum. (pashaco)

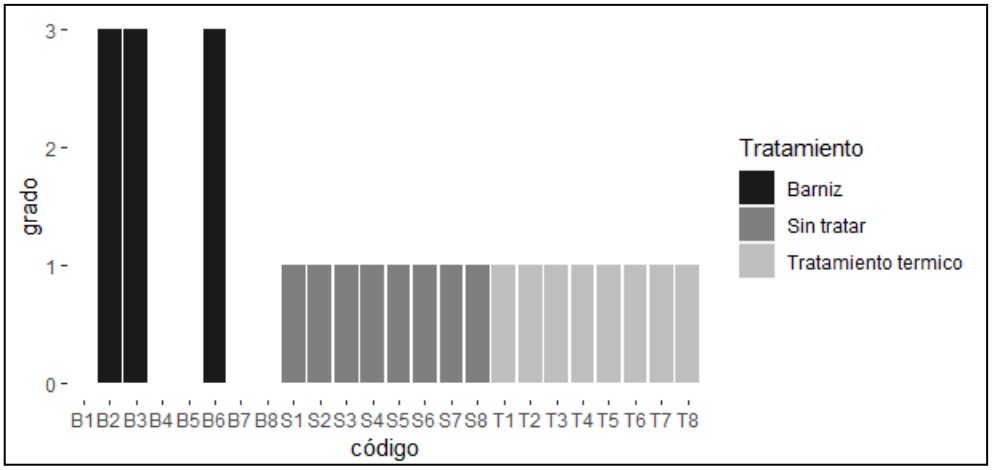
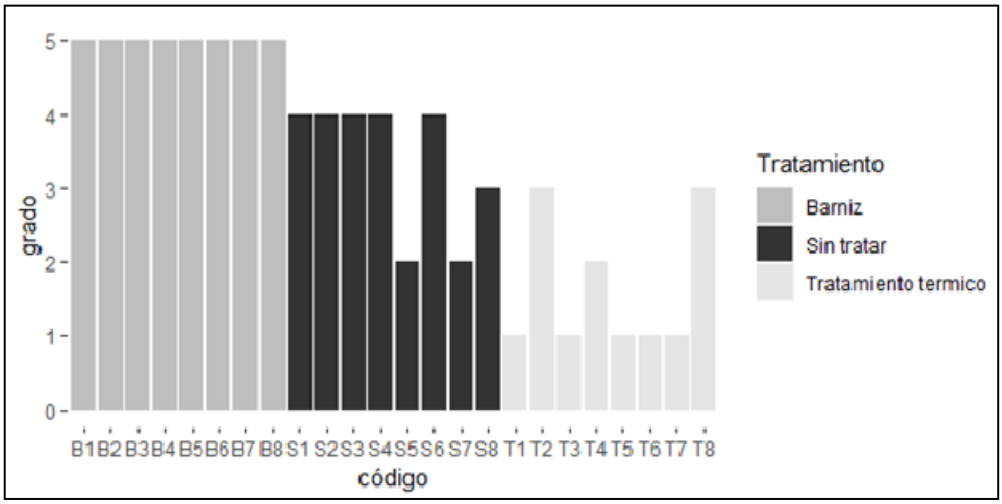


Figure 7

Degree of cracking of the species Aniba Gigantiflora. (mohena)



Regarding the formation of cracks, it is observed that the pashaco species is the one that showed this anomaly to the least degree, being on average in grade 1 in quantity and size, only visible under magnification x 10.

While for the mohena species the three groups (heat treated, varnished and controls) presented a degree of cracks between 2 and 5 according to the EN ISO 4628-1 Standard (International Organization for Standardization, 2016). While in crack size this was observed in grade 3 to 5. In both species the coating used did not fulfill its function of isolating the wood from dimensional changes and therefore making it less prone to the formation of cracks. According to the statistical test (

Figure **6**and

Figure 7) the species most resistant to humidity changes is pashaco wood.

When analyzing the quantity and size of defects in the wood samples evaluated under a microscope, it was possible to observe superficial cracks that do not fully penetrate the finishing layer (i.e., only superficial crazing); cracks that penetrate the finishing layer, without substantially affecting the underlying layer(s) and cracks that affect the entire surface system.

Dimensional changes caused by differences in the moisture content of the wood gave rise to cracks and/or splits possibly due, among other things, to the degradation of the middle lamella as expressed in the bibliography by Acevedo *et al* . (2013); Rowell (2012).

In general terms, it was observed that between weeks eight and nine (1100 to 1300 hours) of naked eye exposure, the appearance of cracks was observed, which became more prominent in some groups. As for the coating used, in some cases the failure was evident early, possibly due to the rigidity of the coating that did not accompany the movements of the wood (Flores *et al* ., 2001).

4.5 CLIMATIC SEVERITY

It is necessary to determine the Scheffer index (1971), of the cities considered with marine desert and meso-Andean climates, the average temperature of the localities was considered. The data of this variable were obtained from the meteorological stations near the cities of Chivay, Punta de Bombón and Arequipa described in the Regional Hydroclimatic Bulletins, provided by SENAMHI, see Table 4.

Table 4

Average monthly air temperature

City	Jan.	Feb	Sea.	Apr.	May.	Jun.	Jul.	Aug	Set.	Oct.	Nov	Dec.	Annual
Bombon Tip	25.0	25.8	24.2	23.0	20.0	17.7	17.2	17.9	19.2	21.0	21.0	22.0	21.2
Arequipa	17.9	18.0	18.4	17.4	16.9	16.6	15.9	16.3	17.0	16.7	17.8	17.9	17.2
Chivay	11.2	10.4	10.9	10.5	9.2	8.7	7.9	9.4	10.4	10.5	11.4	11.7	21.2

Source: SENAMHI (2021)

In this way we can say that the Scheffer Index for Bombón Tip is (Eq. 1) :

$$Índice_{Scheffer-P.de\ Bombón} = \sum_{Ene.}^{Dic.} \frac{(18{,}8)(0)}{16{,}7} = \frac{0}{16{,}7} = 0 \qquad (1)$$

The Scheffer Index for Arequipa is (Eq. 2) :

$$Índice_{Scheffer-Arequipa} = \sum_{Ene.}^{Dic.} \frac{(15{,}2)(6)}{16{,}7} = \frac{91{,}2}{16{,}7} = 5{,}5 \qquad (2)$$

The Scheffer Index for Chivay is (Eq. 3) :

$$Índice_{Scheffer-Chivay} = \sum_{Ene.}^{Dic.} \frac{(8{,}2)(5)}{16{,}7} = \frac{41}{16{,}7} = 2{,}5 \qquad (3)$$

As can be seen in

Table 3, according to the calculated value of the Scheffer Index, both Punta de Bombón, Arequipa and Chivay correspond to a “Dry” type Station Rating, and also have a Basic Exposure Index (I_{s0}) of 3.0.

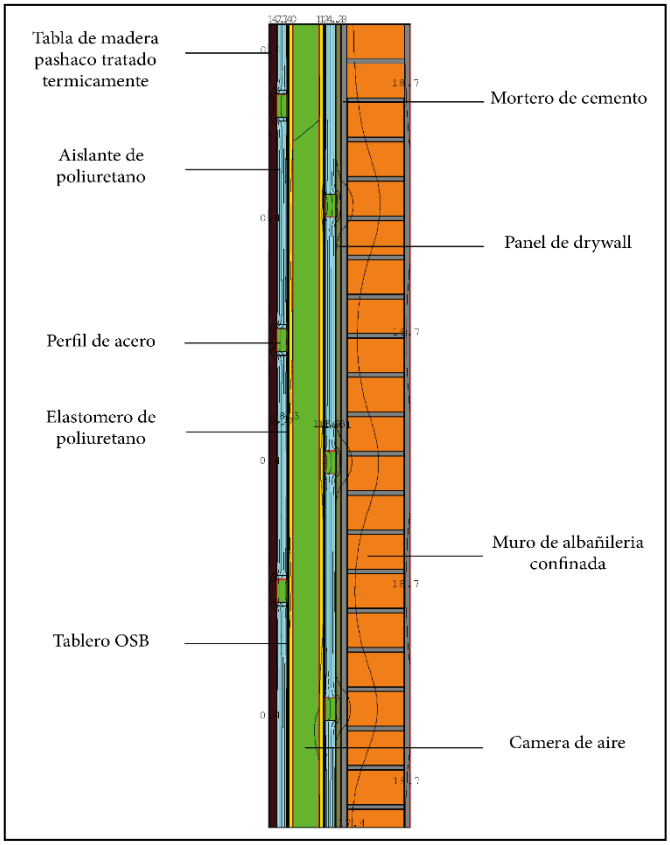
Based on the climatic factors mentioned above, it is proposed to create a façade system with two insulating components: an air chamber and two layers of insulating material made of polyurethane foam. The other elements are made up of the structures that support the system, which include steel studs, steel profiles, fixing screws and a drywall panel.

On the other hand, there are also elements of protection of the system, among them we can mention the polyurethane elastomer, a plasticizer that can resist the inclemency of the weather (relative humidity, attack of organisms, friction, shearing among others) and finally there is the final coating of thermally treated wood. As is known, this material has a good resistance to climatic exposure, (the wood acquires greater dimensional stability against humidity, absorbs less water, presents greater resistance to attack by xylophagous fungi, and a lower level of aging by having greater resistance to UV rays). Figure

Figure 8an isotherm diagram. In the isotherm diagrams the heat transfer through the wall is treated only as one-dimensional. MENDELEY CITATION PLACEHOLDER 0.

Figure 8

Isothermal diagram of the proposed facade system



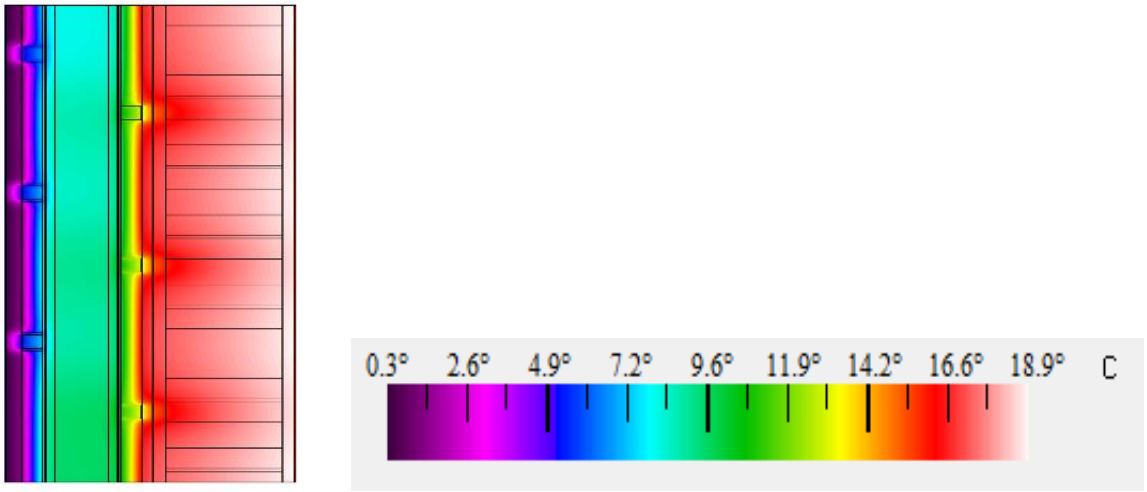
In the isotherm diagram produced (section view) it can be observed that the heat transfer lines remain constant in the insulating material that is the polyurethane layer (the lines remain together and perpendicular to each other), however in materials that tend to transfer heat, such as steel profiles or the confined masonry system, it can be observed that the lines have an oscillating behavior, which means that heat or cold can easily escape, this means that for an application in a building it is necessary to counteract the heat loss produced by these materials, for this reason a double insulating layer is applied, which guarantees the thermal gain of the building.

The minimum temperature (outside the building) was 0 °C (minimum value possible in the software). The graph shows that the coldest temperatures (outside the building) are located in the outer layer of the system (heat-treated wood). As the thermal transmittance from the outside to the inside of the building shifts, the level of cold decreases thanks to the composition and materials used in this proposal. This is evident in the air chamber (light blue), which significantly cushions the cold. The last layer of polyurethane insulating material (yellow) acts as the last thermal buffer.

Finally, the interior of the building (pink – white color) can be considered a thermal environment (18.9 °C), thanks to the implementation of the façade system as seen in *Figure 9*

Erro! Fonte de referência não encontrada.

Temperature diagram of the proposed facade system



5 IMPLICATIONS OF THE RESEARCH

Peru ranks ninth in the world in terms of the extent of its forest resources and second in Latin America. However, despite having a vast forest heritage, the sector contributes only 1% to the country's gross domestic product, equivalent to 541.6 million dollars. An additional problem is deforestation, which is estimated at around 260,000 hectares each year, resulting in the loss of approximately 7.3 million hectares of forests so far.(SERFOR, 2019)

A sustainable solution to address these challenges is to use wood responsibly, through practices such as forest plantations, silviculture and forest conservation, as well as promoting the use of bamboo, a non-timber forest resource. These actions not only represent an adaptation and mitigation strategy against the impacts of climate change, but also constitute a viable alternative to reduce the vulnerability of rural communities.(SERFOR, 2022)

This research becomes relevant in the field explained above, since by determining a degradation factor in the material it is possible to provide technical information to builders interested in working with wood . The use of wood as a renewable resource in construction has a positive impact on local communities, especially in rural areas, where the timber industry can be an important economic driver. In addition, it creates jobs in activities such as responsible logging, processing and manufacturing of wood-derived products.

6 CONCLUSIONS

The objective of the study was to test the resistance to accelerated degradation by simulating environmental conditions such as UV radiation, humidity and high temperatures in two woods of different densities and the most in demand in the southern region of Peru, in order to choose the most suitable one and apply it as a multi-layer façade system in homes in marine desert and meso-Andean climate zones and optimize thermal comfort.

The surface chalking, degree of cracking and the appropriate combination of materials for the façade system to optimize thermal comfort in the homes were evaluated. The results obtained allow the following conclusions to be drawn:

The accelerated ageing mode caused significant changes in roughness, chalking and degree of fissuring or cracking especially in the wood species *Aniba Gigantiflora.* - mohena (density 0.45 g/cm ^{3}), while the wood species *Schizolobium Excelsum.* - pashaco (density 0.33 g/cm ^{3}) showed better resistance to humidity conditions, UV radiation (0.89 W/m ^{2} nm at 340 nm) and concentrated temperatures up to 60 °C.

In the wood species *Schizolobium Excelsum* (pashaco) that showed the best resistance to accelerated degradation, it was evident that the heat-treated wood showed a lower degree and quantity of cracks, as well as a lower degree of chalking. This provides evidence that the surface treatment that had been applied did not result in a total softening of the wood's anisotropy. The water resistance of the tested coating system has been rejected by experimental tests, since these degraded and began to flake off the surface after the seventh cycle, generating internal cracks in the wood up to 4.5 mm thick.

The dimensional stability of the wood was observed to be modified, since in both species, buckling and deformation were observed in more than 50% of the samples without thermal treatment exposed to artificial accelerated degradation. On the other hand, color variability was observed in all the samples subjected, especially from the fifth cycle of being subjected to artificial accelerated degradation.

Schizolobium Excelsum (pashaco) wood as part of the multi-layer façade system in THERM software, it was observed that it concentrates the temperature indoors by up to 20 °C compared to the outside temperature of 0 °C. This result considering as a structure only masonry walls covered with the façade system composed of: thermally treated wood, elastomer, air, OSB board and polyurethane insulation.

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