Mix Sustentável

Panorama do uso da madeira engenheirada em escolas brasileiras e seu potencial sustentável

Panorama of the use of engineered wood in brazilian schools and its sustainability potential

Panorama del uso de la madera de ingeniería en escuelas brasileñas y su potencial de sostenibilidad

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Resumo: A adoção da madeira em edificações tem sido associada a condições de bem-estar, saúde dos usuários e desempenho ambiental. Em um cenário marcado pelos impactos significativos da construção civil na crise climática, cresce o in-

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teresse por soluções materiais e projetuais capazes de reduzir danos ambientais e qualificar os ambientes construídos. Entre essas alternativas, destacam-se as tecnologias de madeira engenheirada, como sistema estrutural, integrando eficiência técnica, menor impacto ambiental e benefícios psicofisiológicos. Paralelamente, reconhece-se o papel essencial dos edifícios educacionais no desenvolvimento humano, reforçando a importância de ambientes escolares projetados com qualidade. Assim, este estudo tem como objetivo identificar e caracterizar edifícios escolares brasileiros que adotaram sistema de madeira engenheirada, de modo a compreender como tal tecnologia se insere no panorama nacional. Quanto à metodologia, é de caráter qualitativo e exploratório, com estratégias de coleta de dados e analíticas pautadas na revisão bibliográfica, no levantamento de obras escolares em madeira engenheirada e na análise das soluções adotadas. Ao articular as aplicações identificadas com a base teórica, o estudo busca contribuir para a arquitetura escolar, evidenciando o potencial da madeira na promoção de saúde, bem-estar e sustentabilidade. Como resultado, foram identificados doze casos, distribuídos entre uma fase precursora, concentrada no Rio Grande do Sul, e uma fase recente de consolidação, marcada pela ampliação tecnológica e presença predominante na região Sudeste.

Palavras-chave: Madeira engenheirada; Arquitetura escolar; Qualidade ambiental.

Abstract: The use of engineered wood in buildings has been linked to improvements in user health and well-being and environmental quality. This is relevant since civil construction has a significant impact in the current climate crisis. As a result, there is a growing focus on the use of materials and projects that are able to decrease environmental impact while also improving the quality of living spaces. One such alternative is the use of engineered wood in structural systems in order to integrate technical efficiency, lower environmental impact and bring psychological and physiological benefits to users. Tangentially, educational building design has an essential role in human development and, as such, should be planned in order to offer a qualified learning environment. Thus, this study aims to identify and characterize Brazilian school buildings that have adopted engineered wood systems, in order to understand how this technology is positioned within the national panorama. Regarding methodology, the study is qualitative and exploratory, with data collection and analytical strategies based on a literature review, a survey of school buildings constructed with engineered wood, and an analysis of the solutions adopted. Analysis coupled with theoretical concepts

permite o compartilhamento do trabalho com reconhecimento da autoria e publicação inicial nesta revista.

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offered contributions to the field of school architecture with respect to the potential of wood to promote health, well-being and sustainability. From the survey, the application of engineered wood was identified in 12 schools split between a preliminary phase concentrated in the state of Rio Grande do Sul and a recent resumption and consolidation phase in the Southeast region characterized with a diversification of the technology in use.

Keywords: Engineered wood; School architecture; Environmental quality.

Resumen: La adopción de la madera en edificaciones se ha asociado a condiciones de bienestar, salud de los usuarios y desempeño ambiental. En un escenario marcado por los impactos significativos de la construcción civil en la crisis climática, crece el interés por soluciones materiales y proyectuales capaces de reducir daños ambientales y cualificar los ambientes construidos. Entre estas alternativas, se destacan las tecnologías de madera de ingeniería como sistema estructural, que integran eficiencia técnica, menor impacto ambiental y beneficios psicofisiológicos. Paralelamente, se reconoce el papel esencial de los edificios educativos en el desarrollo humano, lo que refuerza la importancia de ambientes escolares proyectados con calidad. Así, este estudio tiene como objetivo identificar y caracterizar edificios escolares brasileños que adoptaron sistemas de madera de ingeniería, con el fin de comprender cómo dicha tecnología se inserta en el panorama nacional. En cuanto a la metodología, esta es de carácter cualitativo y exploratorio, con estrategias de recolección de datos y analíticas basadas en la revisión bibliográfica, el relevamiento de obras escolares en madera de ingeniería y el análisis de las soluciones adoptadas. Al articular las aplicaciones identificadas con la base teórica, el estudio busca contribuir a la arquitectura escolar, evidenciando el potencial de la madera en la promoción de la salud, el bienestar y la sostenibilidad. Como resultado, se identificaron doce casos, distribuidos entre una fase precursora, concentrada en Rio Grande do Sul, y una fase reciente de consolidación, marcada por la ampliación tecnológica y la presencia predominante en la región Sudeste.

Palabras clave: Madera de ingeniería; Arquitectura escolar; Calidad ambiental.

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1 INTRODUCTION

National and international studies have linked the use of wood in structures to improvements in user health and well-being and environmental performance. In addition, since civil construction is considered one of the main causes of the current climate crisis, it is essential to consider the use of sustainable materials. Consequently, engineered woods and related technologies are seen as potential building materials to be used in conjunction with design choices that promote comfort, health and safety.

Concurrently, advances in industrialized wood techniques have produced materials such as glued laminated timber (GLULAM), cross-laminated timber (CLT) and laminated veneer lumber (LVL). These materials expand the possibilities of structural design while providing technical performance, lower environmental impact and physical and psychological comfort. Tangentially, there is a growing understanding that educational buildings impact significantly human development through effects on experience and cognitive and social processes. Consequently, these environments should be designed with appropriate architectural quality.

In Brazil, a growing use of engineered wood technology can be observed, although still limited relative to its potential for application. Within the scope of school building production, systematic analyses of such applications also remain scarce. Given this, the objective of this study is to identify and characterize Brazilian school buildings that have adopted engineered wood systems, in order to understand how this technology is positioned within the national panorama. To this end, this exploratory study was conducted in 3 methodical steps: a bibliographical review of studies on environmental psychology, healthy environments, engineered wood technologies and school architecture; a survey of school buildings in Brazil that made use of engineered woods and analysis of these known structures.

The analysis of this study linked surveyed practical applications to related theories in order to add to the body of knowledge of school architecture. Findings denoted the potential of wood as a material able to promote health and well-being while also achieving technical markers in structural design and sustainability.

2 THEORETICAL FUNDAMENTALS

The work of designers, architects and engineers must fulfill functional demands while also ensuring environmental quality. In other words, they must account for user health and well-being while also minimizing negative environmental impacts of the building. These become even more important when considering educational environments. Thus, this section contains theoretical fundamentals on healthy environments, school architecture, sustainability principles and engineered wood concepts that guided the analysis of this study.

Regarding healthy environments, Shigue (2024) discussed the effect of wood on the quality of an internal living space through a broad systematic bibliographical review. It was concluded that the impact of wood on user health and well-being occurred through physiological and psychological effects. For example, significant evidence was found that decreases in stress and induced relaxation could occur from contact with

the material. In addition, frequent reports related health and mood improvements and a positive perception of the material. While lacking depth in some areas, results also mentioned improvements in other factors such as body temperature, perceived temperature, sleep quality, sociability and performance of activities.

Regarding the internal living space itself, Shigue (2024) denoted that wood could affect physical aspects such as relative humidity, thermal, visual and acoustic comfort and internal air quality. In particular, wood's visual comfort potential was based on color, texture and visual patterns which affected receptiveness and impacted user experience.

Studies of the relationship between user and environment come from the environmental psychology area. According to Cavalcante and Elali (2011) these studies sought to understand how impacts were achieved and behaviors manifested in living spaces. These effects and transformations were also examined from the subjective perspective of the user. In this sense, it is understood that environmental influence on human beings is a constant in daily life, triggering psychological manifestations in response to environmental stimuli (Cavalcante, Elali, 2011; Port, 2026).

It should be noted that currently humans spend most of their lives in constructed environments. Consequently, it is necessary to understand the relationships that develop from habitation in order to evaluate environmental quality. Along these lines, school environments are spaces with a great potential for environmental psychology both due to the time spent inhabiting them and also due to their role in education and human development.

Project design solutions and alternatives that add environmental quality and well-being in educational spaces are currently being examined. Adequate educational spaces can decrease stress, stimulate coexistence, promote cognitive processes and enable student engagement. These qualifying effects encompass UN Sustainable Development Goals on health and well-being (SDG 3) and quality education (SDG 4) (UN, 2015).

These factors denote the potential of wood as constructive systems in school buildings. Pioneering reference work on educational architecture was conducted by Kowaltowski (2011) which stressed the notion that educational spaces must be functional, welcoming and meet the expectations of the community.

Recent studies reinforce this challenge: in an action research project conducted over five years with architecture students, Kowaltowski et al. (2020) found that, although students develop greater confidence in their design processes, the effective incorporation of sustainability and bioclimatic architecture concepts into the core of architectural design remains a challenge, requiring structured approaches, a consolidated technical repertoire, and time for assimilation.

By this point it has become clear that environmental quality directly affects educational processes. Observations on the architecture of residential buildings point out positive and negative elements that could affect teaching and learning processes. For example, building materials with different colors and textures and scale relationships between width and height are selected by designers based on their own lifetime and user experience which are, in essence, an extension of their own formative process (Alberton et al. 2019).

Kowaltowski (2011) contributed to the school environment issue by defining 32 design parameters for school projects. One parameter was "sustainability elements" which recommended a design that minimized environmental impacts during construction and made use of materials with no health risks. This specific pa-

rameter of low-impact materials was also linked to health and well-being factors and could be fulfilled with structural and build components made of wood. Beside its sustainability characteristics, wood also provided sensory aspects which affected school community perception and experience.

Engineered or industrialized wood structures are understood to have been manufactured with technology that allows higher precision and large scale production. In Brazil, the most common elements are manufactured from glued laminates and are glued laminated timber (GLULAM) and cross-laminated timber (CLT). Elements manufactured from there materials have higher structural performance than traditional ones made from cut wood (Oliveira and Oliveira, 2023).

The use of industrialized materials allows the issuing of proof of origin certificates. This is a crucial factor in a system expected to promote sustainable construction. A certificate would demand that correct planting and extraction techniques of timber are to be followed, reforestation cycles are observed and manufacturing processes make use of non-toxic products and adhesives (Aflalo, 2023).

The use of sustainable wood has other benefits in addition to previously mentioned contributions to human and internal living spaces. It impacts global carbon cycles with its CO2 capture nature and consumes less energy during manufacture (Aflalo, 2023; Oliveira and Oliveira, 2023).

However, it should be noted that, as a material of natural origin, the magnitude of its effects and benefits may vary. These variations may be a result of different wood species, finished appearance, location of use and human factors themselves (Shigue, 2024).

Although the dissemination of information on the advantages of wood in school environments is growing, particularly on the part of the business sector, academic research systematically investigating this adoption in Brazil remains scarce, and this solution represents a small percentage of the national typology (Lino, 2021). Based on these findings, the research proceeded to define procedures that would allow for a systematic examination of the presence and characteristics of this constructive system within the Brazilian context.

3 PROCEDURES

This research, of an applied nature and with a qualitative and exploratory approach, was developed based on two main methodological strategies: 1) Data collection: through the procedures of a Literature Review and a Survey of School Buildings in Engineered Wood in Brazil; and 2) Data analysis: through the procedure of an analytical summary table of the buildings found and their main characteristics.

It should be noted that the term "survey"is used here in the sense of documentary research, based on secondary data collected from supplier catalogs and architecture databases, rather than in the sense of a "survey"in quantitative research based on structured interviews or questionnaires.

In Step 1 of this study, a bibliographical review was conducted examining national and international references focused on engineered wood, sustainability, benefits of wood on health and well-being, environmental psychology and educational architecture. Results were used to define the theoretical fundamentals of Sec. 2.

In Step 2 of this study, a survey was conducted of school constructions in Brazil that made use of

engineered woods. This was accomplished in 3 substeps:

1) Identification of suppliers: a survey was conducted of national businesses that manufacture structures with engineered wood;

2) Systematic search of buildings: based on client lists of businesses surveyed in substep 1, school buildings built from these materials were found and organized in spreadsheets;

3) Contact with reference business: the chief engineer of Esmara was contacted. This pioneering business was the first and oldest in the segment and was helpful in providing details on construction of school buildings;

4) Cross-referencing with digital architecture databases: periodicals, news and publications were surveyed with respect to the use of wood in schools in order to find schools that may have been missed by the survey of substep 2.

Finally, in Step 3 of this study, an analysis of known school buildings was conducted based on a summary table that listed institution, location, type of institution, year built, useable area, wood type, structural element and technical responsibility.

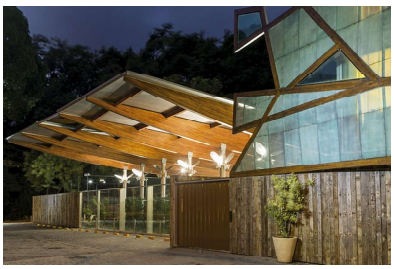
4 RESULTS AND DISCUSSION

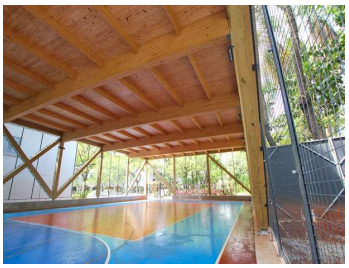
It is understood that wood brings benefits to human health and well-being. These manifest to users as reductions in stress and positive perception, and to the living space with improved air quality and comfort. Thus, wood has a potential use in school environments, based on the theoretical framework established herein, since they should be designed as a welcoming learning environment in order to offer the best experience to the school community (Shigue, 2024; Kowaltowski, 2011).

It should be noted that currently there is a demand for sustainable alternatives in civil construction due to the impact of this sector on the climate crisis. The use of industrialized wood as structural components complies with this demand with advantages in sustainability, low water consumption during construction, shorter build times and resource optimization (UN, 2025; Oliveira et. al., 2023).

The final survey of school buildings in Brazil constructed with engineered wood are presented in Table 1. Data was organized systematically in order to understand how this technology is positioned within the national panorama.

Tabela 1 – Summary of Brazilian schools built with engineered wood

 Source: Acervo Esmara, 2025.	Institution	Standard School
	Location	Pelotas, Viamão, Caxias do Sul, Bento Gonçalves, Torres and Santa Rosa, RS
	Type	Public
	Year built	Late 1970's
	Area	Not informed
	Engineered wood	GLULAM
	Structural element	Beams
	Technical responsibility	ESMARA
 Source: Acervo Esmara, 2025.	Institution	Temporary school
	Location	São Leopoldo, Guaíba, Porto Alegre, Ronda Alta and Sarandi, RS
	Type	Public
	Year built	1980's
	Area	Nor informed
	Engineered wood	GLULAM
	Structural element	Panels
	Technical responsibility	ESMARA
 Source: itaengenharia.com.	Institution	Escola Vera Cruz (Art Pavilion)
	Location	São Paulo, SP
	Type	Private
	Year built	2013
	Area	550 m^2
	Engineered wood	GLULAM
	Structural element	Beams and pillars
	Technical responsibility	Base Urbana / Pessoa Arquitetos / Kipnis Arquitetos / ITA Engenharia
 Source: archdaily.com.	Institution	Escola MOPI
	Location	Rio de Janeiro, RJ
	Type	Private
	Year built	2015
	Area	5,610 m^2
	Engineered wood	GLULAM
	Structural element	Beams
	Technical responsibility	Mareines+Patalano Arquitetura / Carlos Alberto Szücs

 Source: itaengenharia.com.	Institution	Beacon School II
	Location	São Paulo, SP
	Type	Private
	Year built	2015
	Area	796 m^2
	Engineered wood	GLULAM
	Structural element	Beams and pillars
	Technical responsibility	Base Urbana / Pessoa Arquitetos / ITA Engenharia
 Source: itaengenharia.com.	Institution	Escola de Canuanã (Housing)
	Location	Formoso do Araguaia, TO
	Type	Private foundation
	Year built	2015
	Area	25,700 m^2
	Engineered wood	GLULAM
	Structural element	Beams and pillars
	Technical responsibility	Rosenbaum / Aleph Zero / ITA CONSTRUTORA
 Source: crosslam.com	Institution	Concept School
	Location	São Paulo, SP
	Type	Private
	Year built	2019
	Area	3,000 m^2
	Engineered wood	GLULAM and CLT
	Structural element	Beams and pillars (GLULAM) and slabs (CLT)
	Technical responsibility	Triptyque / Timbau Estruturas / CROSSLAM
 Source: crosslam.com.	Institution	Escola PMS
	Location	Suzano, SP
	Type	Public
	Year built	2019
	Area	Not informed
	Engineered wood	GLULAM and CLT
	Structural element	Beams and pillars (GLULAM), slabs and structural walls (CLT)
	Technical responsibility	CROSSLAM

 Source: crosslam.com.	Institution	Escola Parque (EMEI Cleide Rosa Auricchio)
	Location	São Caetano do Sul, SP
	Type	Public
	Year built	2020
	Area	Not informed
	Engineered wood	GLULAM
	Structural element	Beams
	Technical responsibility	Carolina Penna Arquitetos / CROSSLAM
 Source: itaengenharia.com.	Institution	Beacon School
	Location	São Paulo, SP
	Type	Private
	Year built	2021
	Area	Not informed
	Engineered wood	GLULAM
	Structural element	Beams and pillars
	Technical responsibility	Andrade Morettin Arquitetos / ITA Engenharia
 Source: g1.com	Institution	Escola Plínio Gonçalves de Oliveira
	Location	São Sebastião, SP
	Type	Public
	Year built	2024
	Area	4.000 m^2
	Engineered wood	GLULAM and CLT
	Structural element	Beams (GLULAM) and structural walls (CLT)
	Technical responsibility	Fernando Brandão Arquitetura e Design / Pisossul
 Source: crosslam.com.	Institution	Colégio Santa Cruz Infantil
	Location	São Paulo, SP
	Type	Private
	Year built	2025
	Area	3866 m^2
	Engineered wood	GLULAM and LVL
	Structural element	Beams and pillars (GLULAM) and slabs (LVL)
	Technical responsibility	Andrade Morettin / CROSSLAM

Source: Elaborated by the authors.

4.1 Results Analysis

Brazilian schools that made use of engineered wood were surveyed from supplier client lists, architecture databases and direct contact with Esmara. In total, 12 schools in Brazil were identified as having used this material in structural systems as listed in Table 1.

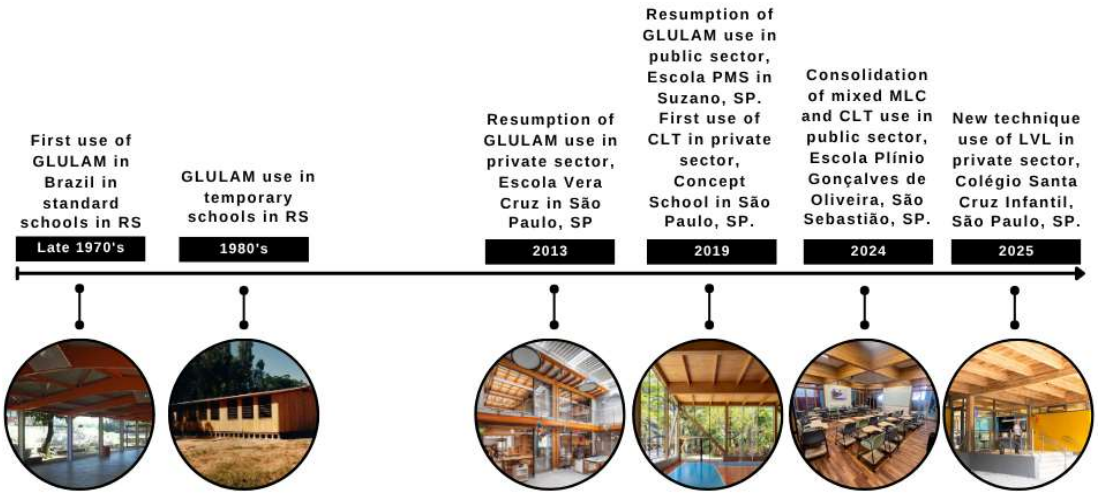
Table 1 shows that glued laminated timber (GLULAM) was the most common material used in all surveyed schools in beams and/or pillars. This material was used in the first school projects of this type in the state of Rio Grande do Sul and up to the current period.

More recent projects show gradual integration of other materials such as cross-laminated timber (CLT) as wall panels or slabs in conjunction with glued laminated timber (GLULAM). In addition, the last school listed in Table 1 included a new technique with slabs made from laminated veneer lumber (LVL).

4.2 Location of Schools

The historical use of engineered wood in schools can be traced from geographical location and date of execution of each project. In terms of dates of execution, there are 2 distinct phases starting from the first pioneering projects up to the current period as seen in the timeline of Figure 1.

Figura 1 – Timeline of use of engineered wood in school buildings



Source: Elaborated by the authors.

Preliminary phase: the initial adoption of engineered wood in schools started at the end of the 1970's and lasted for 10 years. During this period, projects concentrated in the state of Rio Grande do Sul in public schools financed with governmental funds. These schools were classified as standard or temporary, and made use of GLULAM in beams with double support and glued panels. This structural configuration was seldom used with these materials.

Resumption and consolidation phase: after a gap of several decades, the use of engineered wood resumed in 2013 in a private school in the state of São Paulo. This started a new consolidation phase in which this material was used in the Southeast region of Brazil with most projects in the state of São Paulo. New materials were also added in addition to GLULAM such as CLT and LVL in wall panels and slabs.

The timeline of Figure 1 shows a time gap between the preliminary and resumption and consolidation phases. Several factors could be attributed to this gap such as a decrease in the manufacture of engineered wood during this period as noted by Laverde and Salvador (2025). Also noted were three additional main factors for the gap: economic slowdown of national industries, lack of awareness of applications of engineered wood among civil construction professionals and availability of few initial academic studies on the topic.

Projects in the preliminary phase were conducted by Esmara which was directly consulted for this study. This enterprise continuously developed and manufactured GLULAM elements from 1963 to 2019. The more recent concentration of projects in the Southeast region could be a reflection of regional growth in the industrial production of these materials as noted by Laverde and Salvador (2025).

4.3 Type of Institution

Regarding the type of institutions in the survey, 5 were public and 7 private. However, in the resumption and consolidation phases since 2013, only 3 of the 10 institutions found were public schools, which underscored the recognition of the private sector of the potential of this structural material.

The quality of education, in particular in public schools, is frequently questioned in Brazil. This signals a need for a closer inspection of this issue in other to propose improvements. Kowaltowski, (2011) noted that there was a direct relationship between student health and school activity evasion. This signaled a possible link between school evasion and architectural quality of a school building. For example, improvements could be obtained with the use of wood and its benefits in environmental comfort and air quality.

As a special case, Escola Plínio Gonçalves de Oliveira, a public school in São Sebastião, SP was rebuilt after historical severe storms destroyed previous facilities. Classrooms and laboratories were rebuilt with a combination of GLULAM and CLT modules which concluded rapidly over 8 months. The rebuilt school resumed activities and was also able to take up activities from another school affected by severe rain (G1, 2024).

The shorter build time is one of the advantages of engineered wood. As a pre-fabricated structure, elements are delivered to the construction yard ready for assembly and installation. In the case of Escola Plínio Gonçalves de Oliveira, engineered wood provided a solution to an emergent problem caused by climate crisis with architectural quality. This demonstrated the potential of this material in promoting health and well-being of students while also having a lower environmental impact.

4.4 Potential of engineered wood

Engineered woods such as GLULAM, CLT and LVL have several aspects of a quality structural material such as rational use of resources, shorter build times and freedom of form.

Glued laminated timber (GLULAM) is produced from stack-gluing wood laminates in a parallel orientation. The resulting linear structure has high compressive strength, resistance to vertical loads and can be used in beams, pillars, arches and porticos. It was the first engineered wood available in the market and was used in all surveyed schools by itself or in conjunction with CLT and LVL elements (Aflalo, 2023; Oliveira and Oliveira, 2023).

Cross-laminated timber (CLT) is produced from large-size panels stack-glued with laminates in perpendicular orientations with respect to each other and always in odd numbers. This material is usually used as walls or slabs and has good structural stiffness in both directions (Aflalo, 2023).

Laminated veneer lumber (VLV) is a high strength composite wood produced from gluing thin layers or veneers of wood under pressure. Raw material is sourced from peeling wood or processed with rotary saws. Currently, VLV has not been used significantly in Brazil with only a single school completed in 2025 found in the survey (Aflalo, 2023).

As mentioned, engineered wood affords a significantly shorter build time due to its industrialized nature. Aflalo (2020) considered the fast production and short build times as new paradigms in construction. In additional to economic savings, further sustainability benefits could be pointed out such as less wastage, lower energy consumption and possible end-of-life repurposing or recycling since it was a natural material.

Another aspect of engineered wood is freedom of form. Digital modeling prior to manufacture allows experimentation in the concept phase of a project. Several compositions, curves and organic shapes can be explored which add to the aesthetic quality of the material.

The potential interactions of engineered wood with the living space can provide a positive perception of the material and produce an effect in the learning environment. As mentioned in Sec. 2, choice of material can lead to different user experiences in a school environment and directly affect formative processes (Alberton, et. al, 2019). Thus, engineered wood can be pointed out as an effective structural and aesthetic material for school environments.

5 FINAL CONCLUSIONS

The school survey, summary table and analysis conducted in this study yielded a panorama on the use of engineered wood in school architecture. Engineered wood is a technological structural material with great potential to improve school environments in Brazil. Benefits of its use are linked to user health and well-being and physically to technical, environmental and constructive advantages. This potential is supported by the theoretical framework examined in this study.

Studies in the bibliographical review provided evidence of wood being able to decrease stress, promote a sense of receptiveness, increase thermal and acoustic comfort and improve indoor air quality. These characteristics are part of what is considered necessary to create more adequate learning environments as noted by studies on environmental psychology and school architecture.

In addition, factors such as reduced construction time, lower water consumption and the material's carbon capture capacity are associated with the use of engineered wood. These characteristics directly connect the technology to efforts to mitigate the environmental impacts of civil construction on the climate crisis.

The survey of this study identified 12 school buildings which made use of GLULAM and/or CLT and LVL. However, the adoption of these materials in construction is still limited in Brazil. A timeline analysis found two distinct phases of the use of this technology. Nonetheless, sectors other than education have demonstrated growing interest in sustainable solutions that can be quickly implemented in construction.

A caveat of this study is the possible existence of additional schools that made use of engineered wood but were not listed in surveyed references. This denoted a need of wider databases and information sharing about sustainable technologies in Brazil.

Consequently, it is recommended that future studies focus on the following: conducting deeper evaluations on the performance of schools incorporating GLULAM, CLT and VLV elements after a period of operation; conduct surveys on user perceptions of comfort and environmental quality; compare cost and environmental impact between conventional and engineered wood build systems and evaluate how these technologies can be incorporated in public policy regarding educational infrastructure.

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