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Original Research Article

EXPERIMENTAL STUDIES OF OSB LAMINATED BEAMS AND I-BEAMS MADE OF WOOD AND WOOD-BASED MATERIALS

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Abstract

The article presents the results of comparative studies of I-beams and laminated beams made of OSB boards, aimed at demonstrating the impact of flange joint defects in I-beams on their load-bearing capacity and at presenting an alternative structural solution. As part of the experimental research, destructive bending tests were carried out on beams with a span of 540 cm and a cross-sectional height of 30 cm, in accordance with EOTA guidelines. The results revealed a significant sensitivity of I-beams to the presence of material defects in the flanges. In contrast, the double-glued laminated beams, despite their slightly lower stiffness, achieved substantially higher load-bearing capacities as well as more repeatable and predictable behavior. The analysis showed that OSB laminated beams can be a viable alternative to I-beams in applications where greater reliability is required.

Keywords: laminated beams, wood, wood-based materials, I-beams, experimental studies

1. INTRODUCTION

Modern timber construction is developing dynamically, making use of advanced wood-processing technologies and innovative wood-based composites, which enable the design and implementation of more efficient and durable structures [1, 2]. Wood and wood-based materials are playing an increasingly important role in contemporary construction, aligning with the global trend of sustainable development. Their appeal stems not only from their low carbon footprint and renewable sourcing, but also from the wide range of mechanical properties that can be tailored through appropriate engineering processes. Timber structures, ranging from traditional solutions to modern mass timber systems, are regarded as future-oriented approaches that can significantly reduce CO_2 emissions in the construction sector [3, 4].

In recent decades, engineered wood products (EWPs) such as OSB, LVL, LSL, PSL, and CLT [5–7] have undergone intensive development, enabling the rational utilization of wood resources, including low-grade timber and sawmill by-products [8]. A distinct subgroup consists of strand-based EWPs, which, due to their high material yield and favorable mechanical properties, are widely used in

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structural components, including the flanges and webs of I-beams [8]. I-beams themselves enjoy particular popularity in floor and roof construction [9, 10], as they combine high stiffness with low self-weight. Their widespread application is also attributed to material efficiency, low production costs, and ease of prefabrication, making them an attractive solution in single- and multi-family housing, and increasingly in public utility buildings.

In addition to wood and traditional wood-based materials, alternative lignocellulosic resources such as bamboo are increasingly being used. Studies have shown that I-beams made of laminated bamboo can achieve high load-bearing capacity and stiffness while maintaining a low environmental footprint. However, their structural efficiency depends on the design of connectors and the reinforcement of critical zones [11]. Similar development trends include attempts to utilize waste materials, such as recycled particleboards, combined with wooden elements through mechanical fasteners, which supports the concept of a circular economy [12].

Despite their numerous advantages, I-beams may exhibit significant limitations resulting from their material structure—primarily the presence of finger joints in flanges made of solid wood joined with micro-dowels [13], as well as natural wood defects such as knots, cracks, or variability of mechanical properties along the flanges. These defects can considerably weaken local sections of the element and reduce its load-bearing capacity, particularly in the bottom flanges subjected to tension [13]. As a result, in the presence of discontinuities or damage, I-beams may fail suddenly, reducing their reliability in applications that require a high level of safety. In such cases, the catalog load-bearing capacity declared by the manufacturer is not maintained. This poses a major issue for producers, not only in terms of meeting the required strength parameters of these products but also in terms of reputation. Notably, as a result of the research and analyses presented in this article, one of the world's leading manufacturers of such products decided to withdraw them from production.

This article attempts to address the question of whether laminated beams made of OSB boards can serve as a functional alternative to I-beams in terms of strength and reliability, while also identifying the potential limitations of such a solution. The comparison of these two types of structural elements was intended to evaluate their behavior under conditions close to real ones, taking into account the influence of material defects and the method of joint execution. The analysis also examined the impact of wood defects and joint locations on the failure mechanisms of I-beams, with particular emphasis on the bottom flanges, which are most susceptible to tensile stresses.

2. LABORATORY TESTS OF I-BEAMS AND LAMINATED BEAMS

For the purposes of the study, two groups of structural elements were used: the first group consisted of three double-glued OSB laminated beams with a total length of 540 cm and a rectangular cross-section measuring 7.4 cm by 30.0 cm, while the second group comprised three I-beams of the BS-D 300 type, also with a total length of 540 cm.

The research process consisted of two main stages: determining stiffness and establishing the load-bearing capacity of the elements in a four-point bending test. Each specimen was tested under identical laboratory conditions, and all experiments were conducted using an INSTRON 8804 testing machine (Figure 1), equipped with a system enabling precise measurement of displacements and applied loads.

Fig. 1. OSB laminated beam a) and I-beam b) on the test stand

In the first stage of the study, aimed at determining the stiffness of the tested beams, the specimens were placed on supports with a span of 528 cm and subjected to loading according to the four-point bending scheme. In this setup, the pure bending zone covered a central section of 176 cm, extending 88 cm on each side from the midpoint of the beam (Figure 2).

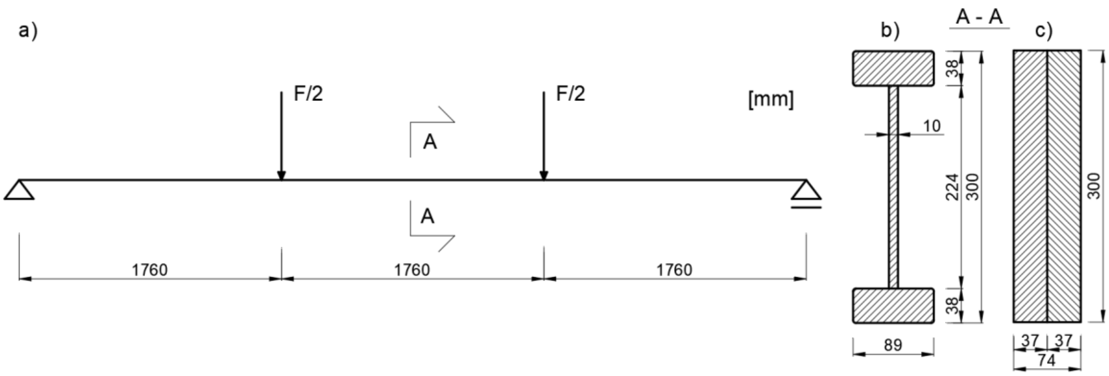

Fig. 2. Static scheme of the tested system a) and cross-section I-beam b), OSB laminated beam c)

Stiffness measurements were carried out using a two-stage loading procedure. Initially, each specimen was loaded until the actuator displacement of the testing machine reached 10.0 mm, and then unloaded to a displacement of 2.0 mm. After this preliminary stage, the main measurement phase followed, consisting of reloading the beam with displacement increasing from 2.0 mm to 10.0 mm. During this phase, the mid-span deflection of the beam within the measurement setup was recorded with an accuracy of 0.001 mm, while the applied force was measured with an accuracy of 1.0 N. Based on the collected data, load–deflection curves were generated, which subsequently enabled the calculation of element stiffness. The bending stiffness was determined using the following formula:

$$(EI)_{beam} = \frac{\Delta F \cdot l \cdot l_k^2}{48 \cdot \Delta w_4} \tag{2.1}$$

where:

ΔF – the increment of force during the change in actuator displacement of the testing machine from 2.0 mm to 10.0 mm,
l – the span of the beam measured between the support axes,
l_k – the span of the deflection measurement system within the pure bending zone,

Δw_4 – the mid-span deflection of the deflection measurement system.

In the second stage of the study, aimed at determining the load-bearing capacity of the elements, the specimens were first unloaded to an actuator displacement of 0.0 mm. The beams were then reloaded until complete failure occurred. The load was applied at an actuator displacement rate of 0.1 mm/s, and the total duration of the test until failure was approximately 10 minutes. During this stage, detailed observations were made regarding the mode and location of beam failure, and the relationship between the applied force and the corresponding specimen deflection was recorded. Based on the measurement results, the maximum destructive force was determined, which allowed for the calculation of the load-bearing capacity of the tested elements. The bending capacity was calculated using the following formula:

$$M_u = \frac{F_u \cdot l}{6} \tag{2.2}$$

where:
F_u – the maximum force recorded during the test,
l – the span of the beam measured between the support axes.

All tests were thoroughly documented with photographs, which enabled a detailed analysis of the mechanism and characteristics of the failure process for each element. The obtained results were subjected to a detailed statistical analysis to assess the repeatability and reliability of the measurements. The described research methodology made it possible to objectively compare the strength and stiffness parameters of I-beams and OSB laminated beams, thereby allowing for the formulation of practical recommendations regarding their further application and potential structural and technological improvements.

Assuming that the bending capacity of the I-beams is limited by the tensile or compressive strength of the wooden flanges, and in the case of laminated beams made of OSB by the bending strength of the material, the theoretical load-bearing capacity of the tested beams can be estimated based on the following formulas:

$$M_{I-beam} = \min(f_t \cdot A \cdot z\ ;\ f_c \cdot A \cdot z) \tag{2.3}$$

where:
$M_{I\text{-}beam}$ – bending capacity of the I-beam,
f_t , f_c – tensile and compressive strength of the wood used for the flanges of the I-beam,
A – cross-sectional area of the I-beam flange,
z – internal force arm (distance between the centroids of the flanges) of the I-beam.

$$M_{OSB} = f_m \cdot W = f_m \cdot \frac{b \cdot h^2}{6} \tag{2.4}$$

where:
M_{OSB} – bending capacity of the OSB laminated beam,
f_m – bending strength of the OSB board,
b, h – width and height of the cross-section of the OSB laminated beam,
W – section modulus for bending strength of the OSB laminated beam.

3. LABORATORY TEST RESULTS

The experimental tests were carried out to determine the differences in the behavior of laminated beams made of OSB boards and I-beams of the BS-D 300 type under bending conditions. The analysis included elements with a cross-sectional height of 30 cm and a support span of 5.28 m. The tests were conducted in accordance with the recommendations of the European Organisation for Technical Approvals (EOTA), using a four-point loading scheme that allowed the determination of the relationship between deflection and applied force up to the point of failure.

The choice of two different cross-section types was motivated by the need for a detailed comparison between traditionally used I-beams and the new concept of laminated beams. I-beams, owing to their configuration with a thin-walled web and solid flanges, are characterized by high stiffness combined with relatively low self-weight, which makes them a popular solution in lightweight floor and roof systems. However, their drawback may lie in their sensitivity to the quality of flange joints and the presence of weakened zones, which can govern the load-bearing capacity of the entire element. In contrast, laminated beams, manufactured by bonding layers of OSB boards, are free from weak points in the form of flange joints and exhibit a more uniform material structure. As a result, they may demonstrate greater repeatability of test outcomes, more predictable behavior, and higher load-bearing capacity under ultimate conditions. The comparison of these two solutions makes it possible to identify potential directions for optimizing timber structures, where stiffness and load capacity play a key role in ensuring both safety and cost-effectiveness in design.

3.1 Stiffness test results

In the graphs illustrating stiffness within the elastic range (Figure 3), the noticeably steeper slopes of the curves corresponding to the I-beams clearly confirm their higher bending stiffness and smaller deflections under comparable loads.

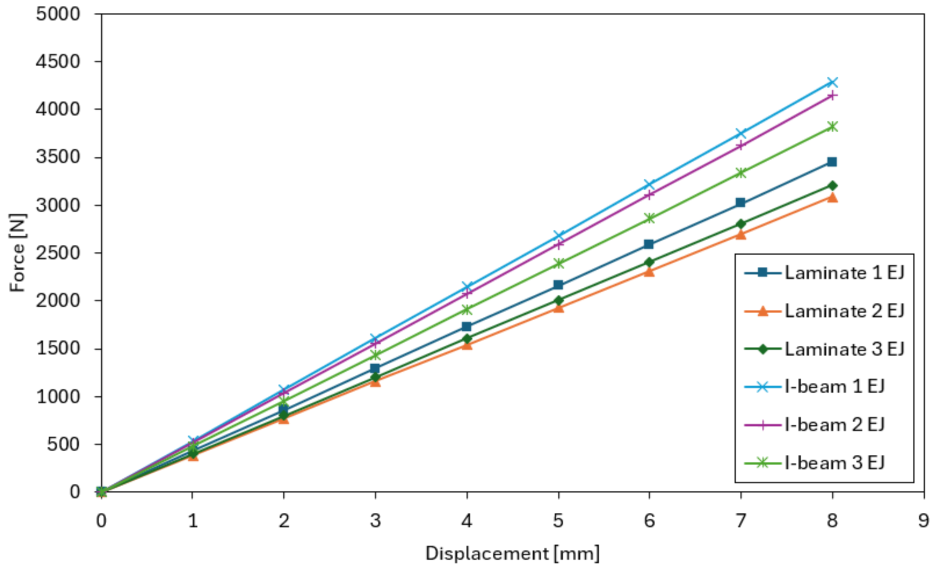

Fig. 3. Force – displacement relationship during the stiffness test

In contrast, the laminated beams exhibited lower line slopes, and thus lower EJ values. However, their performance in this range was more uniform and predictable, with only minor differences between individual specimens. This indicates that despite their lower stiffness, the laminated beams demonstrated greater repeatability of behavior (an observation also confirmed in destructive tests), which may represent an important advantage in the design context, where ensuring stable mechanical parameters across an entire production series is crucial.

In the tests of I-beams, the average flexural stiffness EJ was obtained as 1.17×10^{12} Nmm², confirming the high resistance of these elements to deflection within the elastic range. The individual values for the specimens (Figure 4) ranged from EJ = 1.10×10^{12} Nmm² to EJ = 1.30×10^{12} Nmm², indicating limited variability. Specimen I-beam 1 exhibited slightly higher stiffness than the others. For OSB laminated beams, the average EJ value was 9.40×10^{11} Nmm², with results ranging from 8.12×10^{11} Nmm² to 1.02×10^{12} Nmm². In this case, one specimen, Laminate 2, showed a lower stiffness value compared to the others, which affected the scatter of results. Overall, however, the fluctuations in stiffness values were similar to those observed for the I-beams.

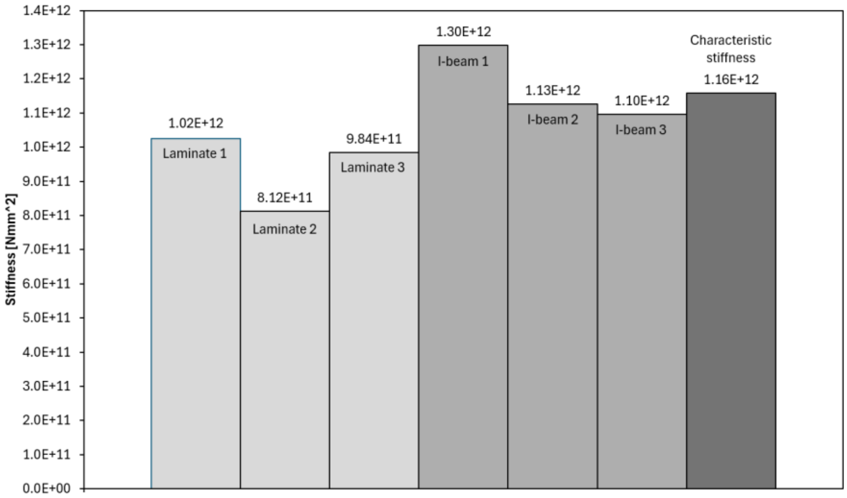

Fig. 4. Stiffness of the tested beams

Figure 5 presents a comparison of the average flexural stiffness values EJ for the tested laminated and I-beams, along with a reference to the characteristic value. The analysis shows that the I-beams achieved an average stiffness of 1.17×10^{12} Nmm², which is very close to the adopted characteristic stiffness of 1.16×10^{12} Nmm².

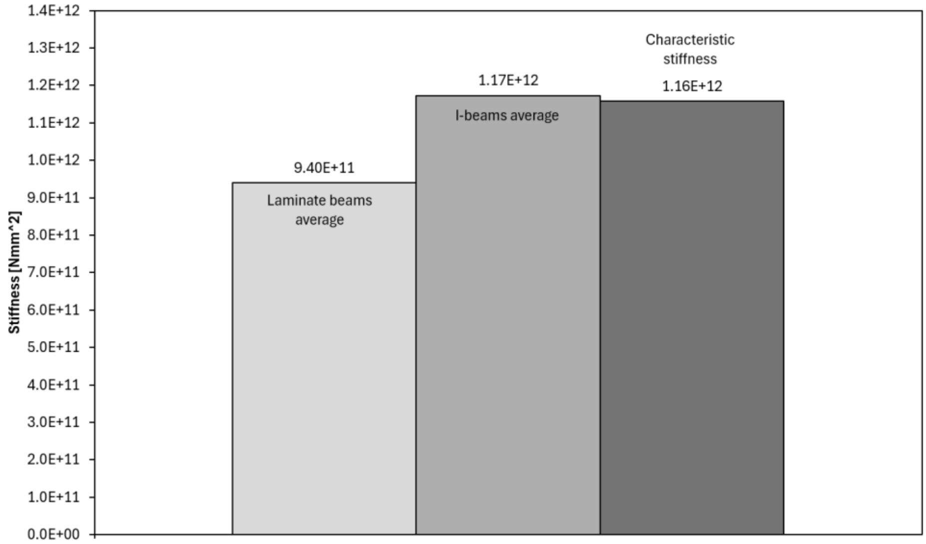

Fig. 5. Average stiffness values of the tested beams

This indicates that the test results are in good agreement with catalog data and confirm that I-beams perform according to design assumptions in terms of stiffness. The laminated beams reached an average stiffness of 9.40×10^{11} Nmm², i.e., about 20% lower compared to the I-beams. Despite this difference, these values remain sufficient to ensure proper structural performance and do not significantly deviate from expectations. However, it should be noted that, relative to the characteristic stiffness value, the laminated beams exhibited a clearly lower level, confirming that their main advantages lie in load-bearing capacity and behavioral consistency rather than stiffness.

3.2 Load-bearing capacity test results

The interpretation of the load–deflection curves provides deeper insights into the test results and allows for a broader understanding of the behavior of the two analyzed beam types. In the graphs illustrating load-bearing capacity (Figures 6–8), a clear increase in force is observed up to the maximum values, followed by a sudden failure of the element.

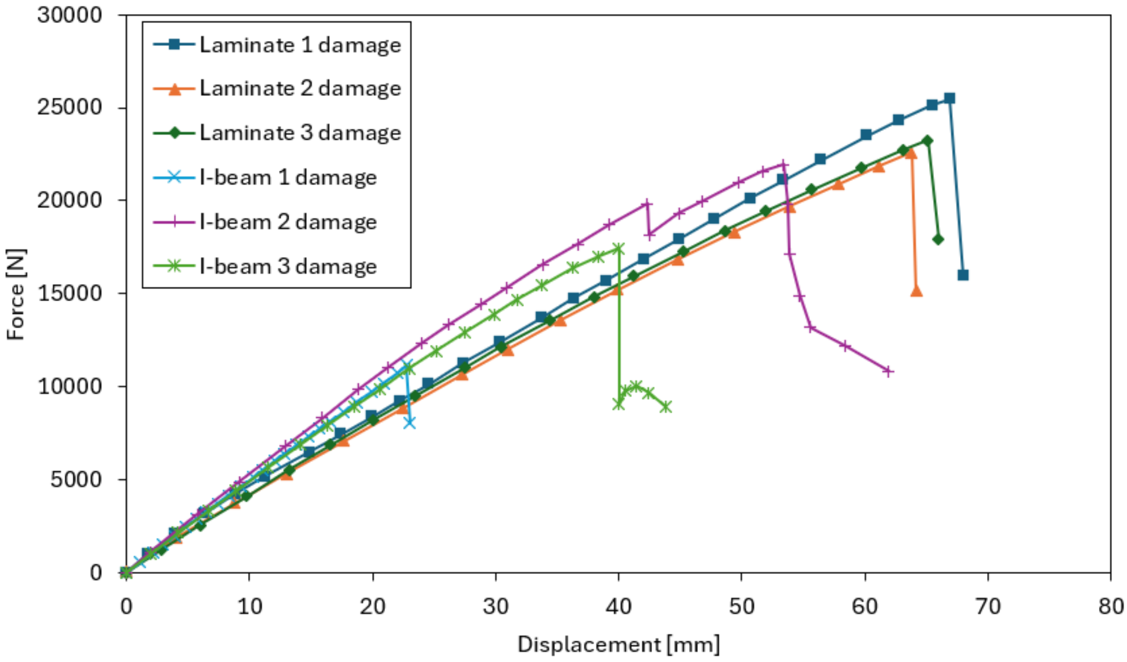

Fig. 6. Force–displacement relationship during the load-bearing capacity test

The laminated beams exhibited significantly higher ultimate capacity, reaching values in the range of 20–22 kNm, with failure occurring at larger displacements compared to the I-beams. This indicates a higher ability to sustain ultimate loads as well as a more ductile mode of behavior. In the case of I-beams, failure was more gradual and progressive, with early weakening observed in the region of the bottom flange joints or supports, highlighting the susceptibility of this type of cross-section to local material defects and structural weak points.

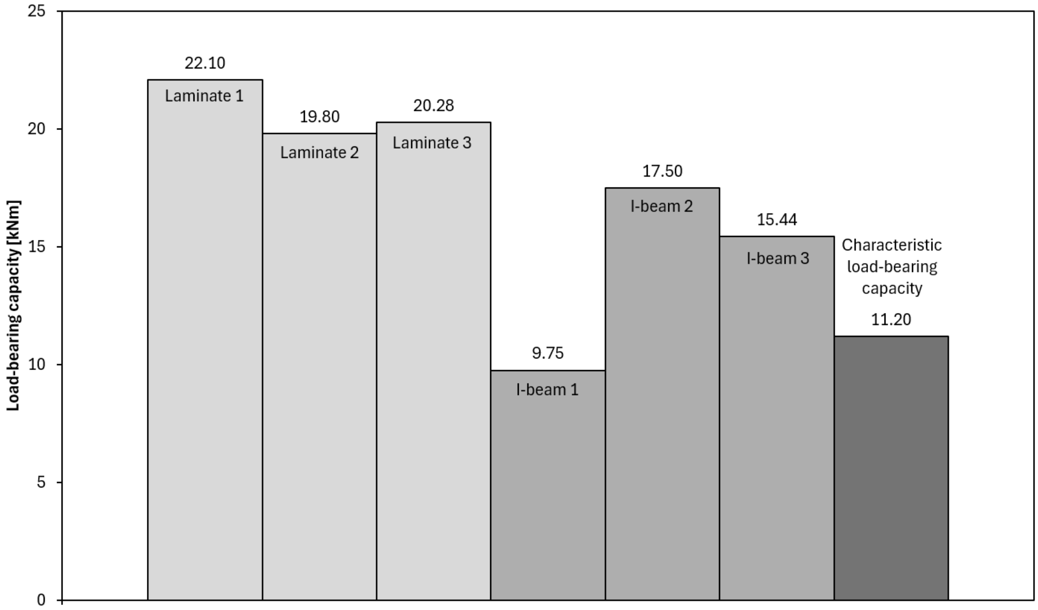

Fig. 7. Load-bearing capacities of the tested beams

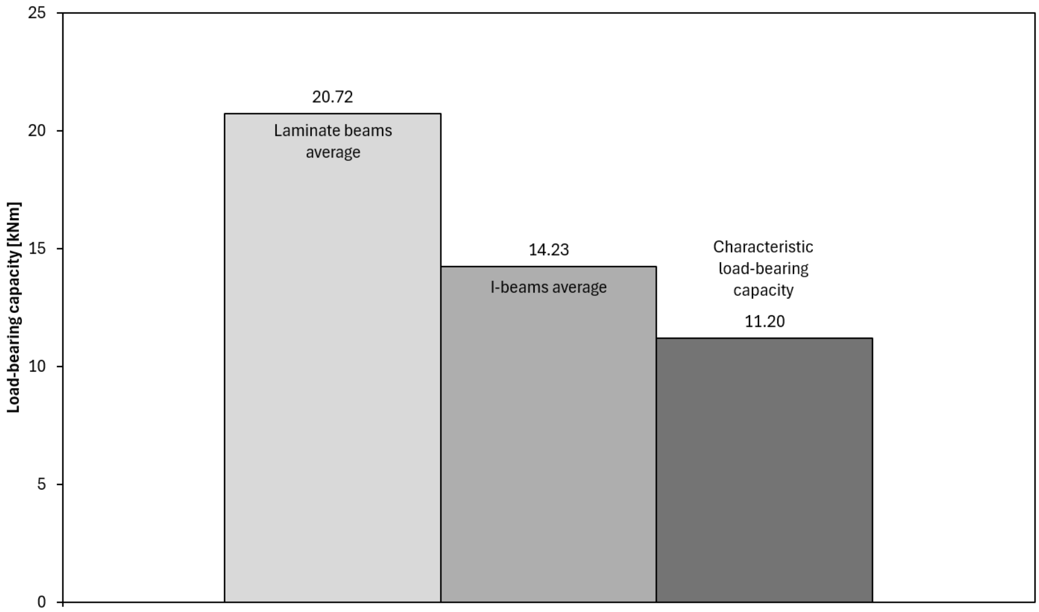

Fig. 8. Average load-bearing capacities of the tested beams

Among the tested I-beams, one specimen (I-beam 1 – Figure 7) showed a clearly divergent result, reaching a load-bearing capacity of only 9.75 kNm. This value was significantly lower than that of the other beams in this group and below the characteristic capacity (catalog value provided by the manufacturer), defined at 11.2 kNm. The theoretical value calculated based on formulas 2.3 and 2.4 for the tested beams is $M_{I\text{-}beam}$ = 11.52 kNm and M_{OSB} = 19,98 kNm for f_t = 13 MPa, f_c = 20 MPa, f_m = 18 MPa. A detailed analysis revealed that the cause of premature failure was a defective joint in the bottom flange, which acted as the initiator of the damage process and consequently limited the beam's ability to carry loads (Figure 9).

Fig. 9. I-beam on the test stand a), left and right side of the beam after failure b), c), and the damaged finger joint in the bottom flange d)

When comparing the load-bearing capacities obtained in the tests with the characteristic capacity, it can be observed that most of the I-beams fell within a range close to or slightly above the reference value. Only the previously mentioned specimen I-beam 1, with a capacity of 9.75 kNm, significantly lowered the average, confirming the sensitivity of this type of cross-section to local material and manufacturing defects. This result highlights the importance of quality and precision in executing flange joints, which, in the case of I-beams, represent the weakest link of the entire structure (Figure 9).

In contrast, the laminated beams demonstrated not only higher load-bearing capacity compared to the characteristic values but also greater repeatability of results. All tested specimens achieved capacities exceeding the reference level, indicating stable and uniform material performance. Differences between individual beams were minimal, and the force–deflection curves exhibited consistency and a predictable failure progression. This makes laminated beams a more reliable solution in both design and practical applications, particularly in situations where ensuring a high level of safety and minimizing the risk of local, uncontrolled damage is essential.

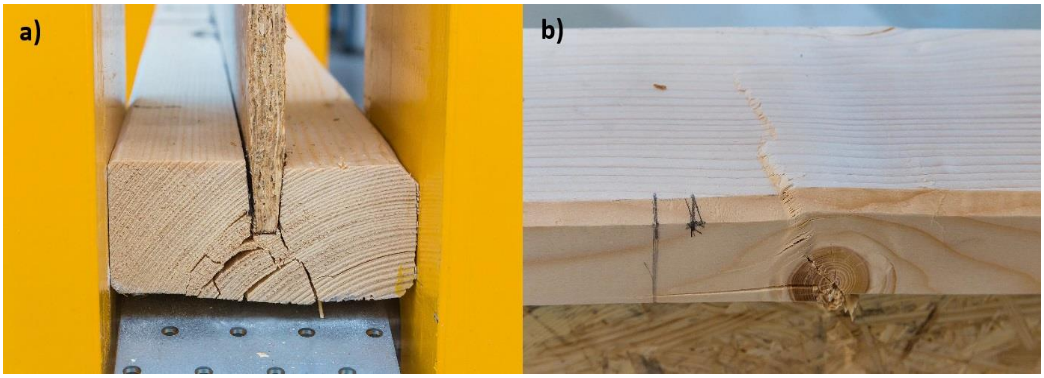

Fig. 10. Damage to the flanges of I-beams in the support zone a) and in the span b)

Figure 10 presents typical damage mechanisms observed in I-beams during laboratory tests. In Figure 10a, the initiation of failure in the region of the bottom flange of the I-beam is visible. Characteristic cracks propagate radially from the flange–web interface, indicating stress concentration at the joint. Such damage is typical for I-beams, where the bottom flange works in the tension zone and any material defect or adhesive imperfection can lead to failure initiation. In Figure 10b, damage to the top flange is shown in the area of a natural wood defect in the form of a knot. The crack passes through the knot axis and spreads diagonally upward. This is an example of a situation where local material defects significantly reduce the load-bearing capacity of the element and may lead to premature beam failure.

The interpretation of both cases indicates that the main cause of the reduced load-bearing capacity of I-beams lies in the weak points located in the flanges. These may result from the quality of structural joints as well as from natural material defects in the wood. These findings confirm that the flanges of such beams represent the critical area determining their strength and reliability in structural performance.

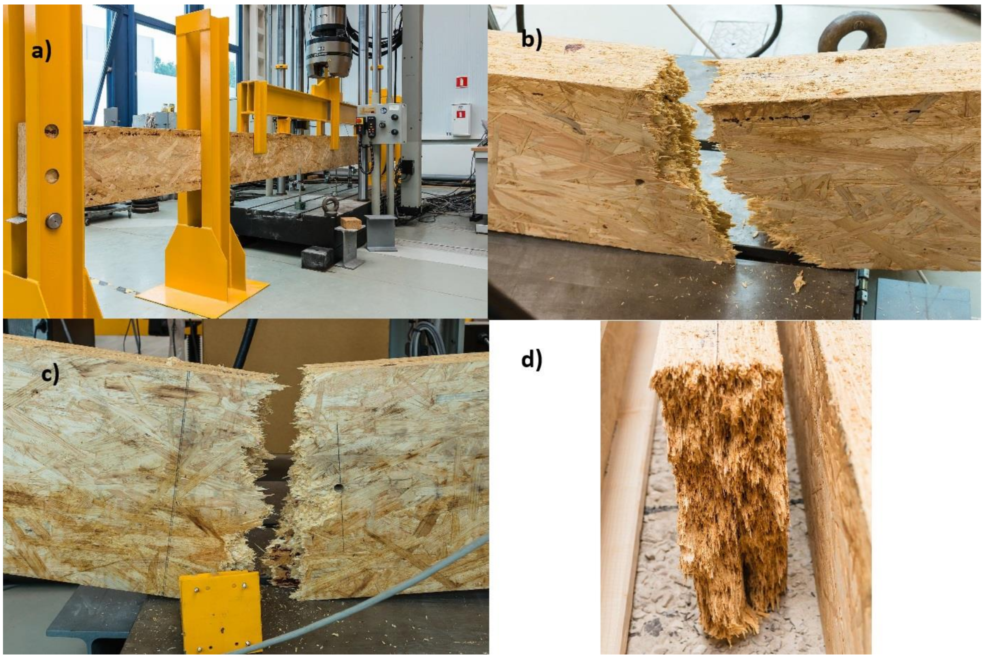

Fig. 11. Laminated beam on the test stand a), left and right side of the beam after failure b), c), and cross-sectional view after failure d)

Figures 11b and 11c show a laminated beam after failure, with a characteristic fracture in the central part extending across the entire depth of the cross-section. This damage is extensive and continuous, involving both the tensile and compressive zones, which indicates a uniform stress distribution across the section and the engagement of the entire element up to the point of failure. Figure 11d presents a detailed cross-sectional view after failure, where delamination and tearing of OSB strands can be observed. This mechanism indicates that failure was governed by the exhaustion of adhesion and the internal strength of the material structure, without clear initiation at a single, localized point.

The interpretation of this failure pattern leads to the conclusion that laminated beams do not contain critical weakening zones such as joints or flange defects present in I-beams. Their failure occurs in a more global and predictable manner, and the load-bearing capacities achieved in the tests were significantly higher than the characteristic values. As a result, laminated beams demonstrate greater reliability and behavioral consistency, which constitutes a considerable advantage in both design and practical applications.

4. CONCLUSIONS

Based on the experimental tests and the comparative analysis of I-beams and OSB laminated beams, the following conclusions were drawn. The obtained results allow for a clear assessment of the impact of flange defects in I-beams on their load-bearing capacity and highlight the structural potential of alternative solutions in the form of laminated beams.

I-beams exhibit significant sensitivity to material defects in the flanges, particularly the bottom flange, which is subjected to tension. The presence of finger joints, knots, or cracks leads to local weaknesses and may result in a sudden reduction of load-bearing capacity, often falling below the values declared in catalogs.

Laminated beams made of OSB boards, despite their slightly lower flexural stiffness, achieved significantly higher load-bearing capacities (by 46%) in the experimental tests. The uniform structure of laminated beams, without flange joints, provides greater predictability and homogeneity of mechanical performance. This makes them a promising alternative in applications where structural safety, production repeatability, and durability are of key importance.

Despite their material efficiency and high stiffness-to-weight ratio, traditional I-beams made of wood and OSB exhibit several limitations:

- their load-bearing capacity is strongly dependent on the quality of finger joints and the absence of defects in the flanges;
- the possibility of sudden brittle failure in the tension zone reduces their suitability for use in safety-critical elements (e.g., main floor or roof girders);
- their long-term performance can be affected by humidity-induced creep and potential degradation of adhesive joints.

Therefore, their use should be limited to elements with moderate load levels and well-controlled production quality.

OSB laminated beams can provide a competitive alternative to traditional I-beams, particularly in situations where high reliability and safety in service are required.

The obtained results provide a basis for further research on the optimization of OSB layer configurations and on the possibilities of practical implementation of this type of solution in timber-frame construction and in structures with increased strength requirements.

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