# From Equestrian Center to Recypark - Circularity Through Reused Glulam Structure

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## Abstract

The roof of the new Recypark in Anderlecht, spanning an area of 1100 m², uses glulam timber frames, allowing for large free spans. The unique ambition of both the client and the project designers was to embrace a circular approach by reusing a glulam timber structure.

Ensuring the structural integrity of reused materials within a circular economy framework raises numerous challenges, both administrative and technical. The project began with the creation of a specific agreement, clearly outlining the responsibilities and scope for all involved parties.

A detailed examination of the repurposed elements, both in terms of sanitary conditions and mechanical properties, was then carried out to qualify and document the materials as precisely as possible.

Finally, the elements were checked. Extending the lifespan of timber elements beyond the implicit limits set by Eurocode regulations, falls outside normative frameworks and requires the extrapolation of usual rules and safety factors.

**Keywords:** Timber construction, glulam, circularity, lifespan, lifecycle, modification factor.

## 1 Introduction

### 1.1 Context

The question of the technical performance of reused construction elements is a relatively innovative subject. It arises from the renewed interest in reuse practices. For several years, these have in fact been promoted, particularly in the context of public policies, because they open up great prospects for significantly reducing the environmental impacts of construction (particularly in terms of reducing greenhouse gas emissions). Adopting reuse in a way that goes beyond the anecdotal, however, implies rethinking a certain number of measures that today frame the practices of the construction sector and which, in their majority, were designed around the production of new materials and not around the specificities of reused materials.

## 1.2 The project

The Recypark workspace is covered by a laminated wood hall, an ecological and elegant product that allows for large open spans, partially made with existing arches recycled from an existing equestrian center in Liège (see Figure 1).

*Figure 1. The existing structure in Bierset (BE)*

The choice of wood for the hall is therefore partly due to the desire to reuse a laminated hall that was located in Liège.

The rest of the wooden structure was also made of laminated wood. The concept of reuse takes on a particular meaning in the Recypark program. Firstly, through the project program, but also through its architecture. The structure of the hall, which covers both the offloading quay and the public space, is a structure created through the act of reusing.

It appears both as a symbol of the exemplary nature of the project and as a significant element in the reuse of construction materials.

This ambition has now been achieved, and we hope to be able to make the most of this experience so that the project can serve as a precedent for new wood reuse projects at a structural level (see Figure 2).

Many other materials used in the project are bio-based: wooden cladding on the two gables of the hall, partitions and ceilings made of multiplex panels, wood wool and cellulose wadding insulation.

## 1.3 Administrative Framework

Prior to the reuse operation, an agreement was drawn up between the various stakeholders involved in the project. This fundamental document clearly and exhaustively established the responsibilities of each party at the various stages of the project. This document set a framework in an unusual context, which makes it all the more indispensable. Its drafting can also highlight gaps or weaknesses in the functioning of the project and in its supervision.

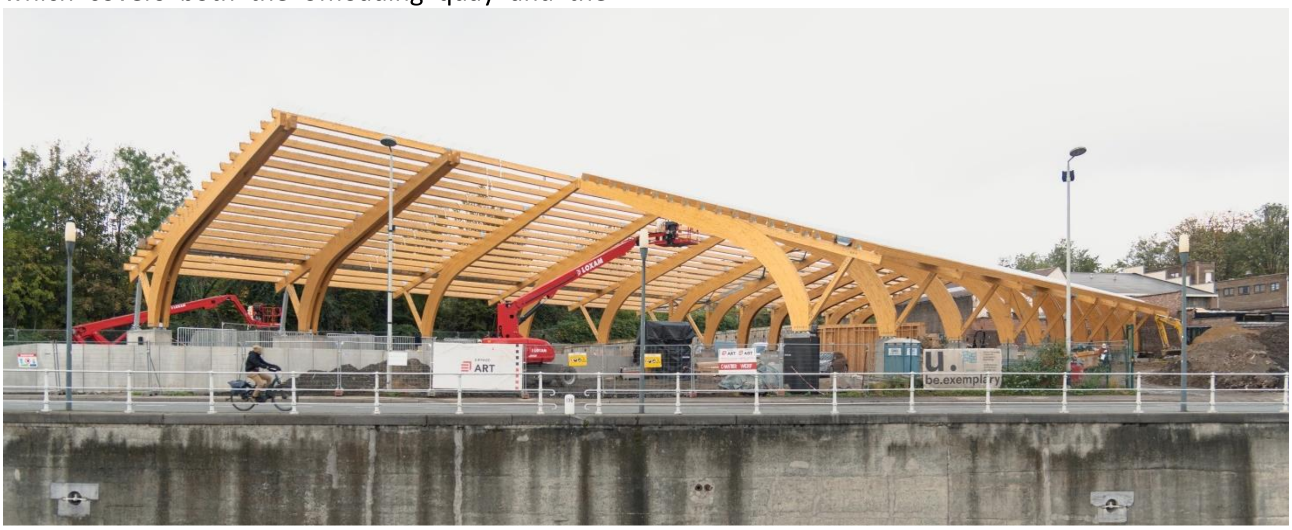



*Figure 2. Glulam structure erection in progress*

## 2 Characterizing the Resources

Ideally, any project involving reuse should begin with the characterization and documentation of the characteristics of the resource. While the quality or reliability of the information collected is of great importance, the long-term storage of this information is a challenge that could be met through its integration in BIM modeling. We once implemented this solution in the context of the reuse of steel profiles, with a BIM model of the existing and new structure, and a digital link between the elements in their old and new configuration. The digital model is therefore a solution to keep track of the history of every element in the old and new structure.

### 2.1 Direct Evaluation

#### 2.1.1 Geometry

One piece of information that is very easy to acquire is the geometric description of the elements. This is the basis for the design and integration of reusable elements in the new structure. The element's geometry was defined using 3D laser scanning.

#### 2.1.2 Visual Inspection

After careful dismantling, the glued laminated timber arches were stored in a dry, ventilated place protected from weather conditions. Though temperature and humidity were not monitored, this is comparable to service class 2 as defined by Eurocode 5. Finally, they returned to the carpenter's production hall, with conditions according to EN386, similar to service class 1 (see Figure 3).

*Figure 3. Glulam beams storage*

A visual inspection was then carried out – an initial inspection before dismantling had validated the choice of resource. Each arch was subjected to a detailed examination. Hygrometry measurements were taken at 5 points on each piece, on both sides. Visible defects were identified and damaged areas were catalogued and documented. The damage was also categorised: in particular, the extent of the areas of rot was estimated by sampling with a screwdriver (see Figure 4) : hitting the surface of the beam with the tool to check whether the outer layer was not concealing decay and rot hidden inside the cross-section. Each piece was then the subject of a summary sheet, gathering all the information collected. These sheets make it possible to identify the position of the pieces in the initial structure, but also in the reused structure. An additional visual inspection was carried out after the arches had been planned for the first time, to ensure that the old wood paint had not prevented certain defects from being identified.

No cracks or delamination that could be considered as the start of a detachment were detected. The area with a pronounced curvature was closely observed: we did not detect any incipient cracks related to excessive transverse tensile stress.

Some pieces that were too badly damaged were usefully repurposed for the next stage.

*Figure 4. Degradation caused by water exposure*

### 2.1.3 Laboratory Test

The elements that could not be integrated into the new structure because they were too badly damaged were stripped of their defects and cut into samples for destructive testing. Attention should be paid to the following elements:

• As this is a statistical analysis, many samples are required to obtain relevant and representative results. An excessively small sample size will produce too pessimistic values, as they will necessarily be too cautious.

• Some harmonized standards governing test protocols are not suitable for reuse products, for example due to the shape and dimensions of the samples to be used. As such, some normative protocols have had to be adapted.

• Current testing standards are designed around and for products that meet specific and strictly controlled manufacturing norms and standards. The application of these testing protocols to products that have - at least in part – deviated from these production standards may raise questions. Are the tests relevant in the case of older components? In this case, as the general principles of manufacturing the components have not significantly changed, we concluded that this concern can be dismissed.

The testing campaign ultimately included the following tests:

- 4-point bending tests (5 m span, section approx. 135 x 270) : 6 tests
- Shear strength test : 7 tests
- Tests to determine the density of the wood: 5 measurements
- Analysis to determine the species of wood
- Analysis of glue by infrared spectroscopy
- Ageing tests according to appendix C of EN 14080: 3 tests

*Table 1. Results of the main tests*

| Type of test | Mean value | Coefficient of variation |
|---|---|---|
| Bending strength [N/mm²] | 31,9 | 22,2 % |
| Young modulus [N/mm²] | 11524 | 16,4% |

It should be noted that, based on the results of the bending tests, the mechanical properties are similar to those of GL16h or GL18h laminated wood.

## 2.2 Indirect Evaluation

This involves studying how the initial technical characteristics may or may not have changed during the first life cycle, based on the available information (for example, in the original technical documentation, or during the preliminary analysis of the deposit). This approach may involve calculations (deduction of a property based on another known property) and hypotheses (for example, regarding the stresses to which the elements have been subjected). The initial structure has thus been verified: we will come back to this topic.

# 3 Designing the structure

## 3.1 Fitting the Structure to Its New Conditions

The project designers had taken care, in the design of the new facilities, to consider the severe deterioration of the bases of the reused arches. As such, the lower part of the arches has been replaced, in the new project, by concrete columns. In addition, the choice of a lighter covering than that of the initial roof, and an adaptation of the layout of the portal frames, made it possible to guarantee the feasibility of the operation. A conservative design had to be used as the mechanical properties were analyzed later in the process.

## 3.2 Design Referring to the Initial Configuration

A study of the structure in which the arches were initially placed was carried out. It was based on the information gathered during the analysis of the deposit: geometry of the initial structure, loads applied. The cross-section checks were conducted both based on current standards, as if it were a new structure, and based on old calculation codes such as [2]. This initial study made it possible to highlight the risk of damage to the structure due to excessive stress: this risk was considered non-existent here.

Subsequently, a study of the stresses in the new structure was carried out. Its results are compared with those of the previous study. This comparative analysis makes it possible to feel comfortable about the compatibility of the new stresses with any defects in the initial structure: if the stress diagrams are similar, the stress distributions should also be similar. The fact that the structure has already endured these stresses without apparent damage gives us confidence in its future capacity to withstand similar strains and stresses.

However, this verification is not sufficient: it ignores the delayed effects and the damage to the wood structure under long-term loading.

## 3.3 (Extra)-Long Term Design According to EC5

An extensive study of the new structure was then carried out, including verification in accordance with current standards.

Based on the mechanical characteristics determined from the tests, it is possible to carry out a verification of the elements based on [1]. Its applicability to an old structure is questionable since the standards of production, sorting, manufacturing, etc. that underlie the use of the Eurocodes were not applicable at the time of production of the elements. However, the tests carried out make it possible to validate a set of properties (quality of gluing, absence of finger-jointing defects) that go beyond simple bending strength, so we are confident that the use of the current calculation code is relevant.

However, the question of long-term verification of the elements needs to be addressed. The standard introduces a method of verifying delayed effects, enabling them to be dealt with in a relatively simple way: the mechanical strength is adapted according to the duration of the shortest-term applied load used in each ULS combination to achieve the expected reliability level. The longer a load is applied, the smaller the modification factor that will multiply the characteristic value of the strength property. We will focus on the value that this coefficient should take in the case of permanent loads: in this case, this modification coefficient usually takes the following value:

$$k_{mod} = 0{,}6 \tag{1}$$

The associated loading duration is, again according to Eurocode 5, greater than 10 years, without a maximum value being specified. In the absence of this information, it can be considered that the maximum duration would be consistent with the safe design life of the structure defined in Eurocode 1, i.e. 50 years.

The reused components of the project have almost reached this age of 50 years. Our aim is to determine the value of the new modification coefficient to be used in this reuse context. It should correspond to a period of application of the permanent loads associated with a second complete life cycle, i.e. 100 years in total. To do this, we propose to start from the formalism of the Eurocode, by returning to the founding articles of this model, including in particular [3] and [4]. These tests highlighted and proposed a linear relationship between the logarithmic root of the duration of application of a load, and the modification factor. We compare the proposed law with the Eurocode prescription.

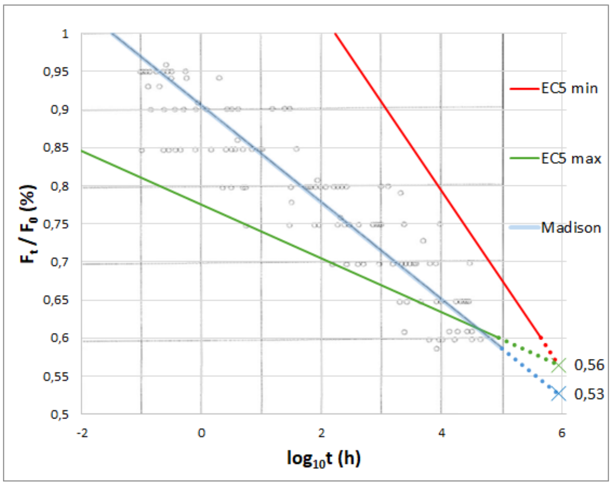
To do this, we start from the time range associated with long-term and short-term loading, and the associated modification factors, summarized in Table 2.

*Table 2. Modification factors*

| Load duration according to EC5 | Minimal duration | Maximal duration | Modification factor |
|---|---|---|---|
| Short-term | 1 s | 1 week | 0,9 |
| Permanent | 10 years | 50 years? | 0,6 |

These lines are plotted (see Table 3) on the results of the [3] tests, where we also indicate the proposed linear law from [4] (also known as the Madison curve).

*Table 3. Estimation of $k_{mod,\ 100\ years}$*




Extrapolation of the straight lines resulting from the use of Eurocode 5 data for a loading duration of 100 years leads us to a proposed value for the modification factor.

$$k_{mod,100\ years,EC5} = 0{,}56 \qquad (1)$$

One should notice that both Eurocode lines are pointing to the same value.

The linear law provided by [3] and [4] leads to

$$k_{mod,100\ years,Madison} = 0{,}53 \qquad (1)$$

It is this last value, more conservative, that was used in the context of the project.

It allows an evaluation of the strength of a wooden structure in a context of application of permanent loads over a lifespan of 100 years, rather than the 50 years corresponding to the basic context of Eurocode 5.

As this adapted stress check is similar to considering damage to the microscopic structure of the wood, it is necessary to check that the damage was not too significant during the first use of the elements. A new verification of the original structure was therefore carried out, based on this reduced modification factor, to ensure that no excessive damage was caused to the structure, that might reduce its lifespan.

### 3.4 Specific Topics

A change in manufacturing methods and habits can be seen when comparing the reused arches with the contemporary ones. It is no longer so common to make elements using such thin laminates. As a result, the bending radius of the new arches is less pronounced than on the old ones.

The small radius of curvature of the reusable arches also led us to recommend the implementation of transverse tensile reinforcement. Achieved by screws, it makes the beams more reliable regarding the risk of splitting in the curved zone.

## 4 Conclusions

Reused glued laminated timber elements were implemented in the construction of a Recycling Centre. The elements have been exhaustively documented, which will allow for easy monitoring and understanding of the possible evolution of the structure in the future.

Particular attention was paid to the verification of the elements under long-term loads. Through extension of the Eurocode 5 methods, a methodology was proposed to carry out this design within the framework of a service lifespan of the elements increased to 100 years instead of 50 years for traditional buildings. This 100 years lifespan covers both the previous and the future use of the elements.

In the future, it would be interesting to assess the relevance of models based on the concept of damage, which could potentially enable a more precise calculation of the residual lifespan of reusable items.

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General contractor: Eiffage Art Valens

Wood structure: Structure Wood - Sabem

Control office: SECO

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