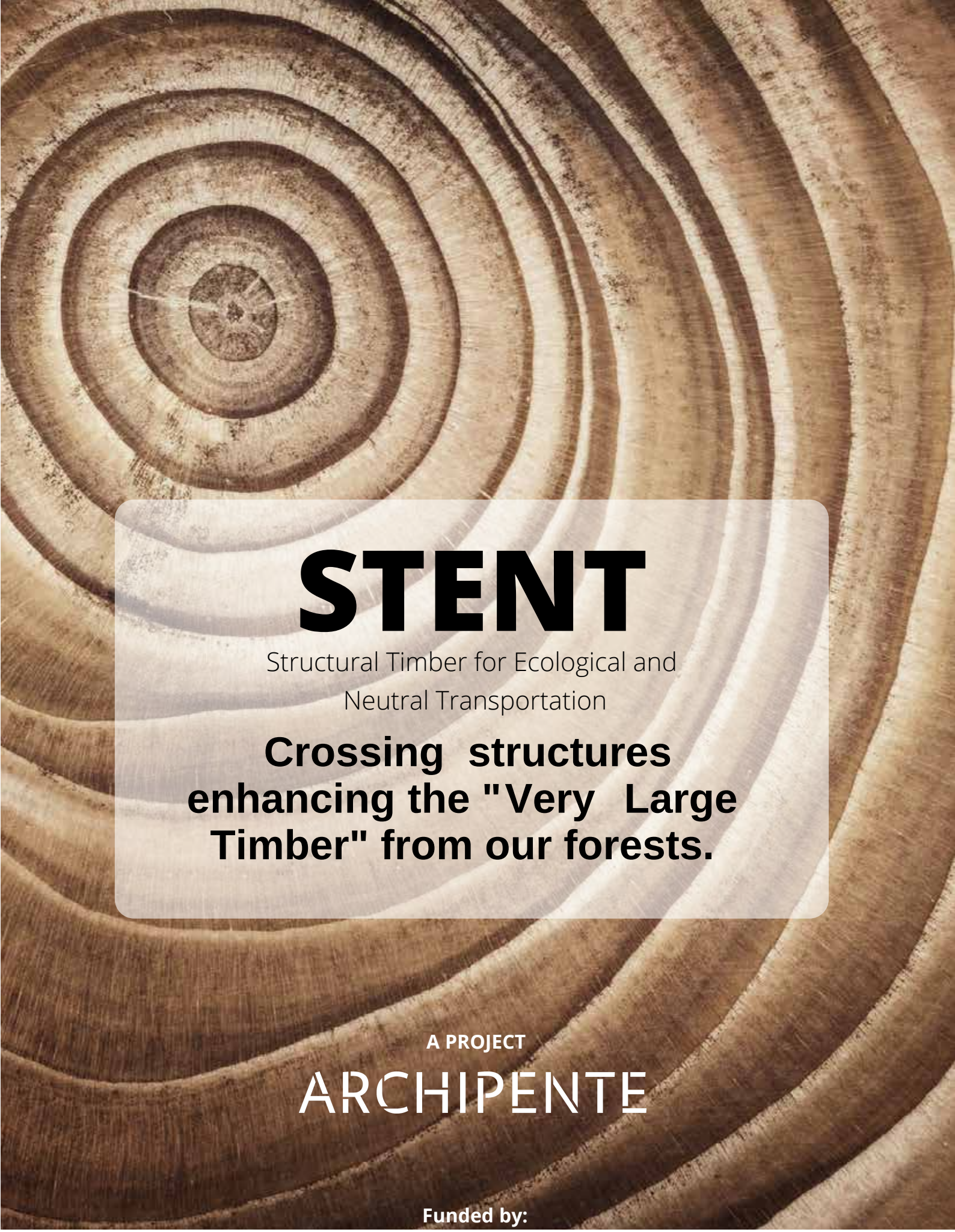


STENT

Structural Timber for Ecological and Neutral Transportation

Crossing structures enhancing the "Very Large Timber" from our forests.

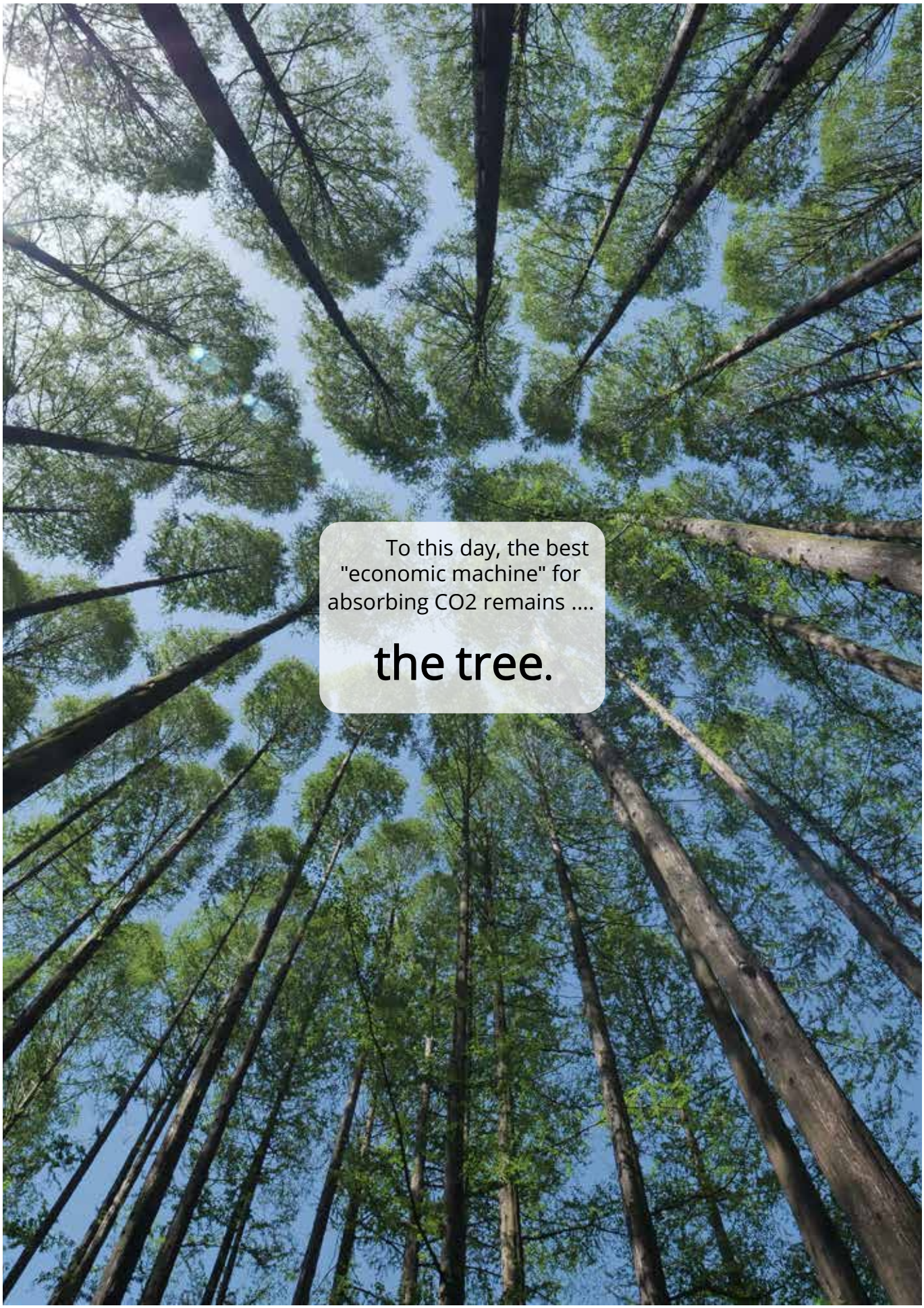
A PROJECT

ARCHIPENTE

Funded by:

STENT is co-financed by the European Union. Europe is committed to the Massif Central region through the European Regional Development Fund.

The issue of very large wood.



A tree in full growth captures more CO2 than a mature tree.

It is necessary to harvest the "large timber " from the forest to allow young shoots to develop in their place, avoiding clear-cutting.

Large and Very Large Resinous Timber are important issues for the Auvergne-Rhône-Alpes region, as well as throughout France.

The CRPF (Regional Forestry and Wood Promotion Center) highlights the issue of "outdated" wood, which affects their quality

.

"It is unrealistic to expect better days to come for removing these trees without a future from our stands, which pose obstacles to proper forest management and the future of our forests..."

Excerpt from the CRPF review

"Another specific concern with fir trees is their inherent heterogeneous quality , particularly concerning overaged trees that have experienced various traumas throughout their long history (wind breakage , ice damage , wounds , etc .). Heart cracks , log splits , pockets of water , and a significant variation in wood due to changing growth conditions over time contribute to this highly negative portrayal of internal defects in large and very large fir trees."

Anne-Marie Bareau, président of CNPF Auvergne-Rhône-Alpes.
«Mention bois» n°17

Developing new techniques

"Innovative" bridge with precast concrete deck versus deck made from squared logs

Wood-concrete composite bridge of Cognin (73160)

The very large Timber in the region faces difficulties in being brought to the market for the following two reasons:
The wood quality has hidden defects that are only discovered during the sawmill cutting process.The industrial tooling is ill-suited, with the majority of mills limited to sections of 60cm. However, **is it necessary to systematically employ costly laminated timber** in terms of infrastructure and energy when creating large-span beams, considering that "equivalent beams" exist in our forests?

Altusried Grandstands in Germany

An abundant resource

The Very Large Softwood Timber is a significant issue in France, especially for the Auvergne-Rhône-Alpes region.

source IFN

Small wood	Medium wood	Large timber	Very Large timber
Diameter ≥ 7.5cm et < 22.5cm	Diameter > 22.5cm et < 47.5cm	Diameter > 47.5cm et < 67.5cm	Diameter > 67.5cm
Circumference ≥23.5cm et <70.5cm	Circumference ≥70.5cm et <149.5cm	Circumference ≥149.5cm et <212.5cm	Circumference ≥212.5cm

Wood species	Very Large Timber	Volume (millions of m3)	Number of stems (millions of stems)	Number of stems (stems/ha)
Pin sylvestre	Vey Large Timber	2±1	**inf 0,5±0,5**	inf 0,5±0,5
Sapin pectiné	Vey Large Timber	25±4	**4±1**	inf 0,5±0,5
Épicéa commun	Vey Large Timber	9±2	**2±0,5**	inf 0,5±0,5
Mélèze d'Europe	Vey Large Timber	1±1	**0,5±0,5**	inf 0,5±0,5
Douglas	Vey Large Timber	7±3	**1±0,5**	inf 0,5±0,5
Total levé	Vey Large Timber	45±5	**8±1**	inf 0,5±0,5

Table of standing volumes by tree species in France according to IGN

Very Large Softwood Trees in France >67.5cm according to IGN

45 million cubic meters out of 726 million cubic meters, representing 6% in volume of large softwood trees with a diameter greater than 67.5cm, which is:

8 million individual softwood trees out of 1,481 million, accounting for 0.5%

... including Silver Firs:

25 million cubic meters out of 222 million cubic meters, making up 11% in volume of Silver Firs with a diameter greater than 67.5cm, which is:

4 million individual Silver Fir trees out of 391 million, constituting 1%.

Develop proven techniques.

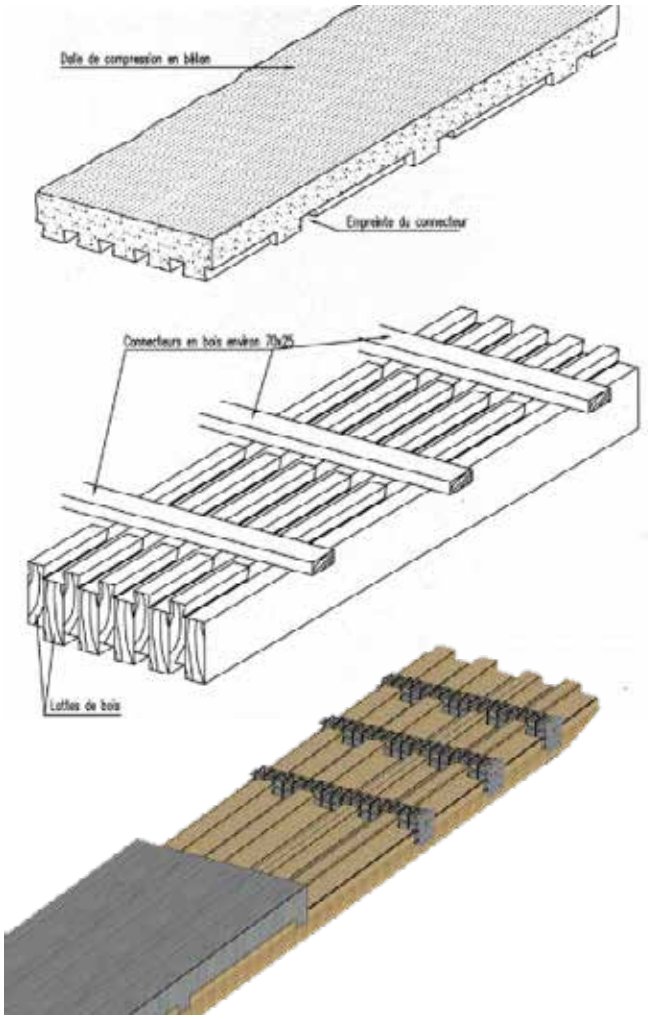
The "solid" deck system allows for the valorization of these woods, creating a "social effect" that compensates for the potential poor quality of a log. This technique was used by Professor NATTERER to build bridges....

from 8 meters to 13 meters in span

in agricultural building floors up to 15m.

and tests up to 17 m at EPFL.

STENT: Wood-concrete composite solid slab deck



The deck is constructed using a collaborative wood -concrete slab , based on the Lignadal ® floor system developed by Archipente in 1998 and approved by the CSTB since 2000.

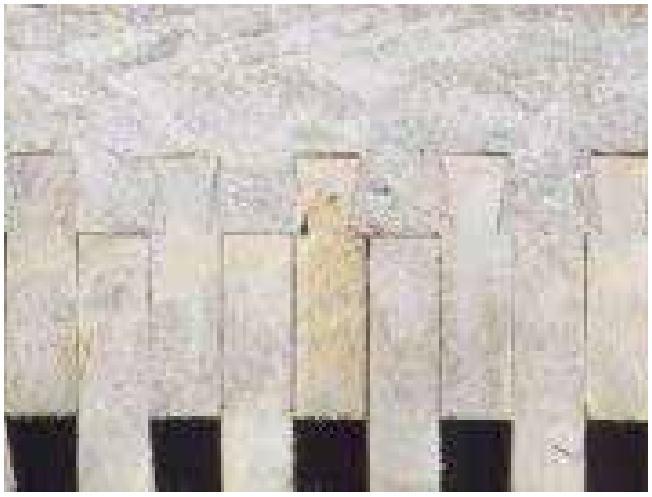
Trees with a diameter greater than 67.5 cm are selected in the forest. They are felled and transported to the roadside like traditional logs.

Log carriers transport them to the log yard at the STENT manufacturing site.

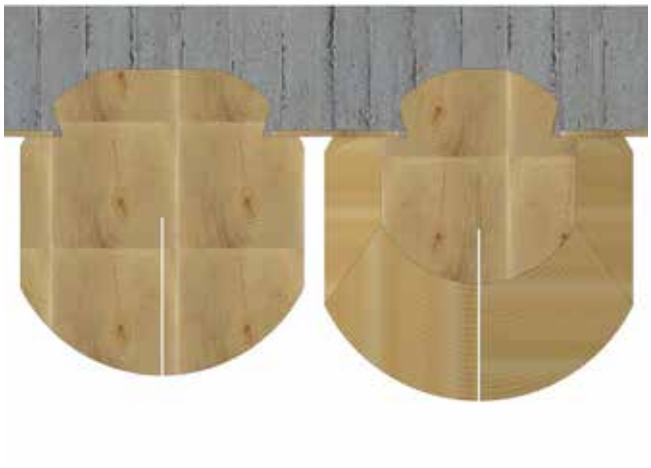
STENT : Constructive system

STENT is made from slightly squared logs , with a core withdrawal slot , a dovetail joint in the upper part to absorb lifting forces and ensure connection with the concrete compression slab poured above . Preliminary sizing is performed using the calculation method developed for LIGNADAL . For instance , for a span of 13m for vehicles with a laden weight of less than 3.5T, the results are as follows :

If the connection is 66%, as in the case of LIGNADAL, and the wood quality is C18, the minimum average diameter of the logs must be 57cm. Following tests conducted in June 2023 on a prototype under a load of 24T, which represents the service load of the deck , the deflection is only 8mm , whereas the standard NF EN 1995-2: 2005 allows 32 mm (1/400 th of the span). It can be concluded that the STENT connection is close to 100% and that the "social effect " of the system justifies an overall better quality of the logs.



Lignadal®



STENT

STENT : Constructive system

The logs are positioned "head -to -tail " to compensate for their taper.

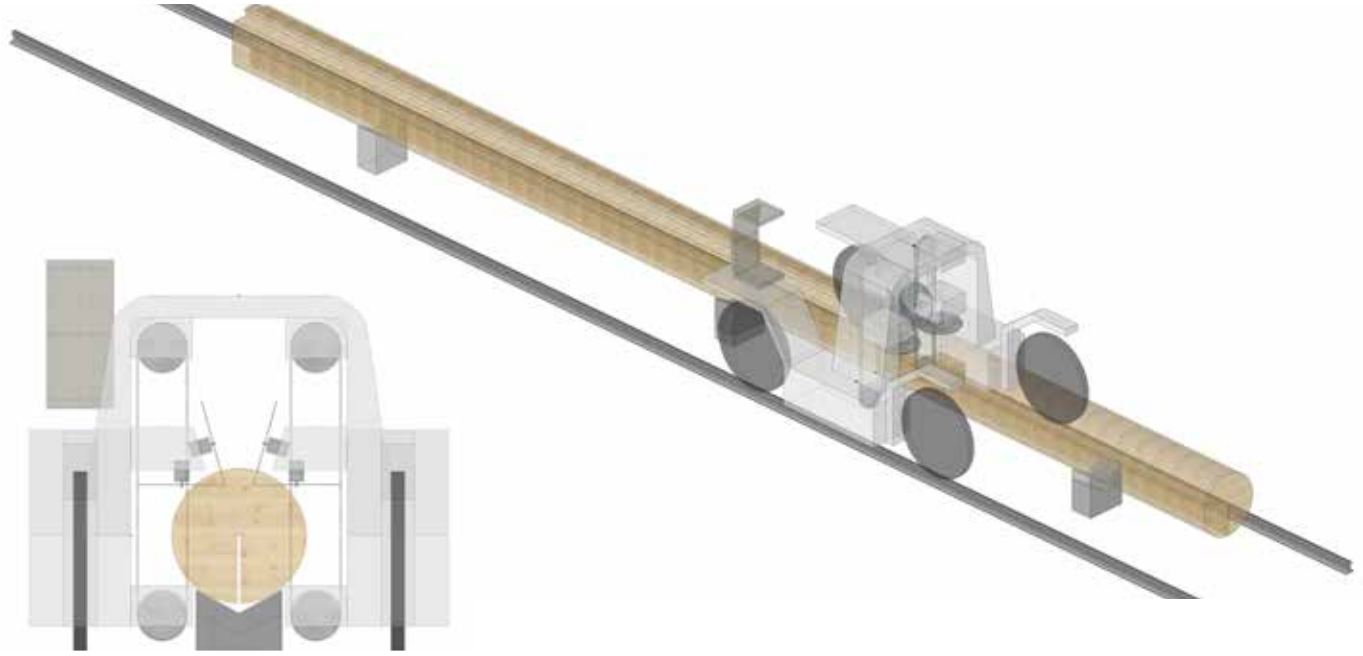
The wood must be air -dried to 30 % moisture content before being used.

Drying can continue down to 20% moisture content after the logs are put in place, aided by natural ventilation.

Notches are machined into each log to create a "button" that helps distribute shear forces. Continuous reinforced concrete stiffeners are integrated into these notches to provide rigidity for panel transport and prevent the "piano effect." Shrinkage due to drying occurs log by log due to the dovetail joint, which dictates its position in space. Support treatments at the ends take into account this altitude-related shrinkage if it's detrimental to the structure.

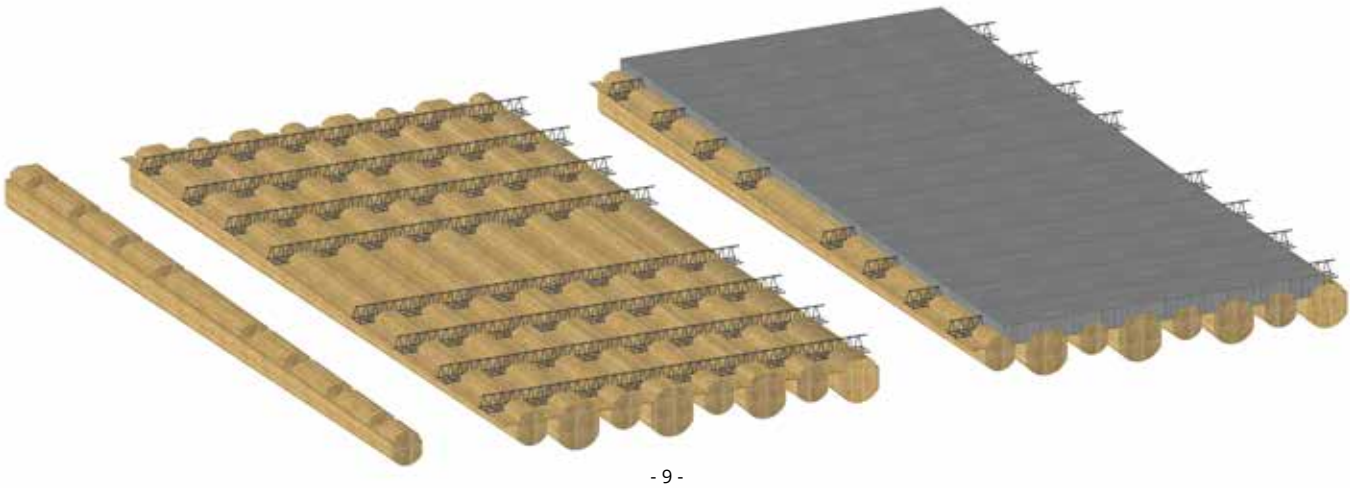
STENT's evolution from previous work involves eliminating metallic connectors to simplify implementation and reduce embodied energy.

STENT : Constructive system



The "frugal" shaping is conceived by using " straddle tractors ," mobile saws equipped with complementary specific tools , or robots like the one operational at Lignatech in St Haon le Vieux (42)..

Concrete is cast in a workshop , leaving a gap area on each side of the prefabricated element . This reserved space is then filled on-site once the elements are placed side by side. This arrangement allows the concrete to experience maximum shrinkage during the 28-day curing period and minimizes longitudinal expansion joints.



Development of STENT

Bridges with spans ranging from 8m to 15m.

Vihantasalmi Bridge en Finlande- Photos PUU Info

Secondary system bridge decks

Road elevations

Renaturing existing roads with the creation of a photovoltaic power plant, pedestrian-friendly pathways, community gardens, and wooded areas to mitigate heat islands

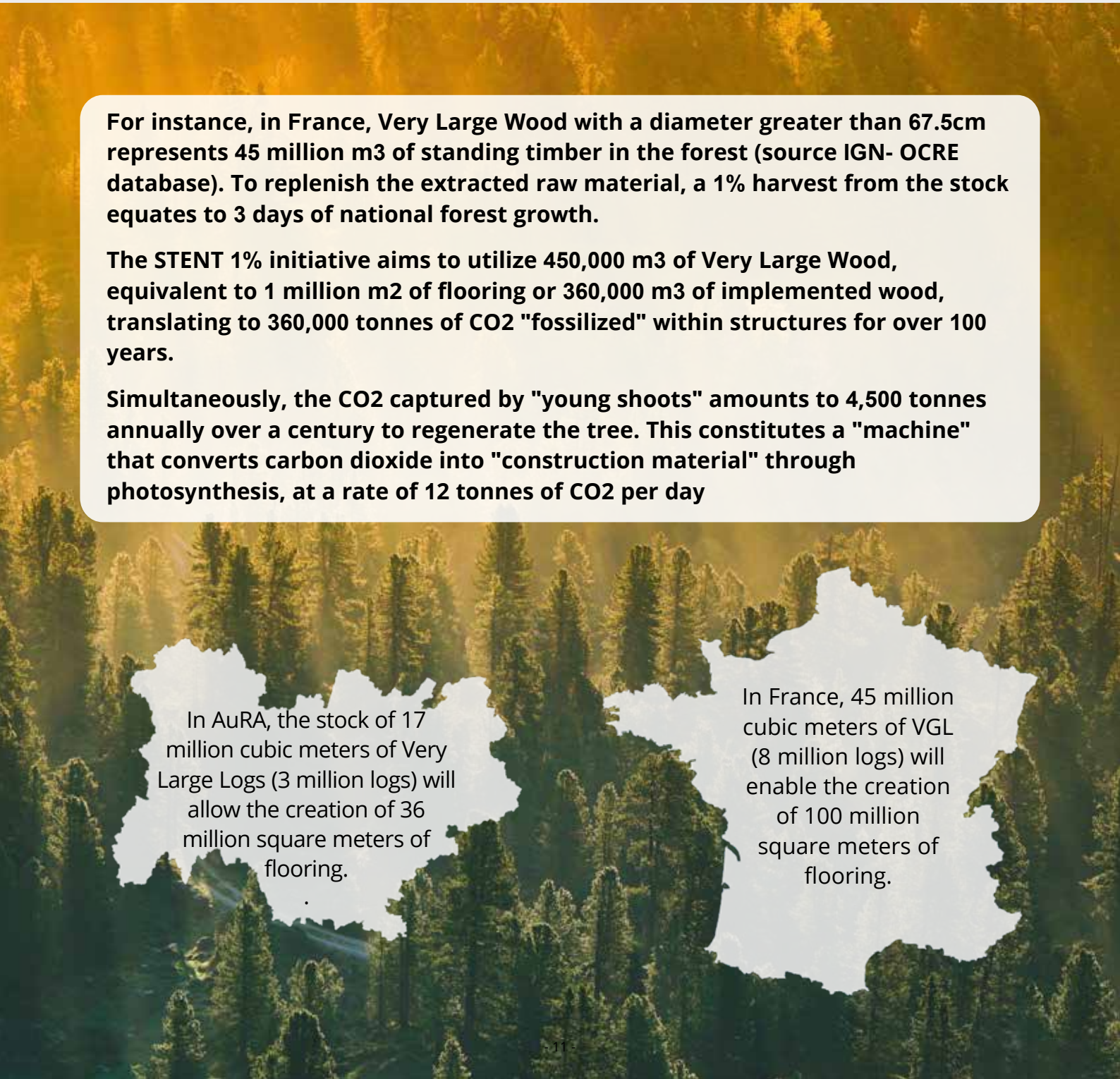
Construction of a silo parking structure with a span of 16 m, vegetated roof featuring tall trees, and a photovoltaic power station

Photovoltaic shading on parking areas with tree vegetation to re-nature impermeable parking surfaces within the framework of ZAN (Net Zero Artificialization).

STENT 1%

"The time scale" for forest management is very long. The mass exploitation of "Very Large Timber " cannot be accomplished in a short time frame . Therefore , we simulate the reduction of the current stock over 100 years and quantify its environmental properties for a single year, hence the term STENT 1%.

STENT 1% allows for the creation of 1 million square meters of green roofs per year in France for at least a century. This corresponds to 10% of artisanal, industrial, and commercial spaces (out of 11 million square meters per year, according to INSEE 2021), requiring vegetated coverings to mitigate the consequences of soil impermeability and comply with the "Climate and Resilience Law" of August 24, 2021. This ratio can increase to 22% in the Auvergne-Rhône-Alpes region (out of 1.6 million square meters per year, according to INSEE 2021).



Train of thought : STENT - A47

A flagship project for the Stéphanoise region : an alternative to the A45 with STENT-A47

The A47 highway that connects Lyon and Saint -Étienne is congested . Its duplication through the A45 project , planned for over 25 years , was abandoned in July 2020 while waiting to find an "acceptable alternative for all " that has minimal environmental impact and doesn't require new land.

Our response:
Elevating the existing A47 highway.

Train of thought : STENT - A47

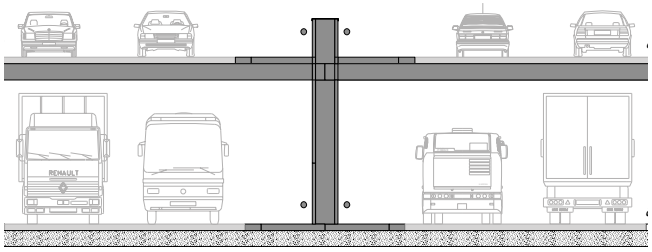
The idea is to keep heavy truck traffic on the current roadway and to allow cars and vehicles up to 3.5 tons to travel on the upper level.

The external support system maintains a view of the landscape, significant ventilation , and avoids being classified as a tunnel in terms of fire safety.

The supporting structure is protected from weather conditions by a widened section of the upper road , which can be used for transportation:

Either for soft modes of transportation on both sides,

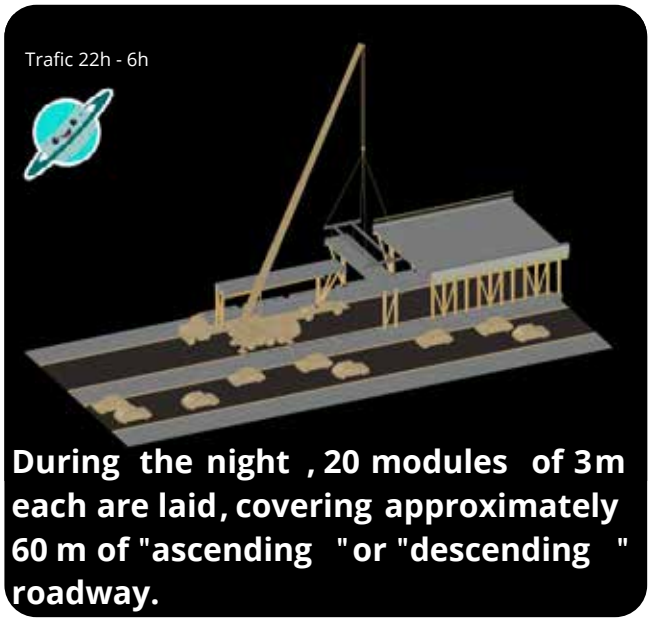
Or for a tramway or tram-train system in the central part , improving public transportation connections between Lyon and St Etienne.



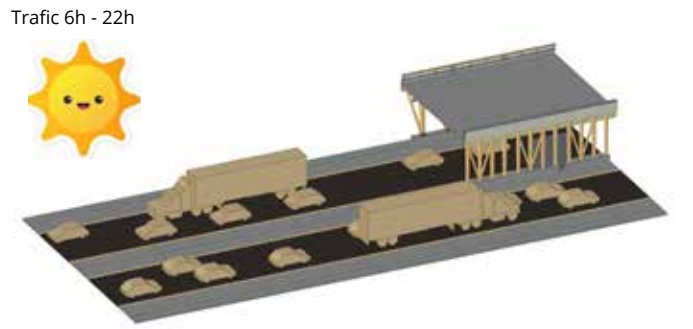
A view of the lower roadway from a truck, with the acoustic coverings also serving as fire protection for the supporting panels.

Train of thought : STENT - A47

The implementation is carried out through "Off-Site" prefabrication in 3D modules. The load-bearing structure is created using wooden posts or panels made of nailed or glued solid wood slabs. The STENT deck is constructed on the load-bearing structure, forming a self-supporting portal. The weight of an entire 3-meter module is around 45 tonnes. The module is then loaded onto a semi-trailer or a log truck to travel between the workshop and the construction site, using an existing accessible road: the current highway pavement.



During the night, 20 modules of 3m each are laid, covering approximately 60 m of "ascending" or "descending" roadway.

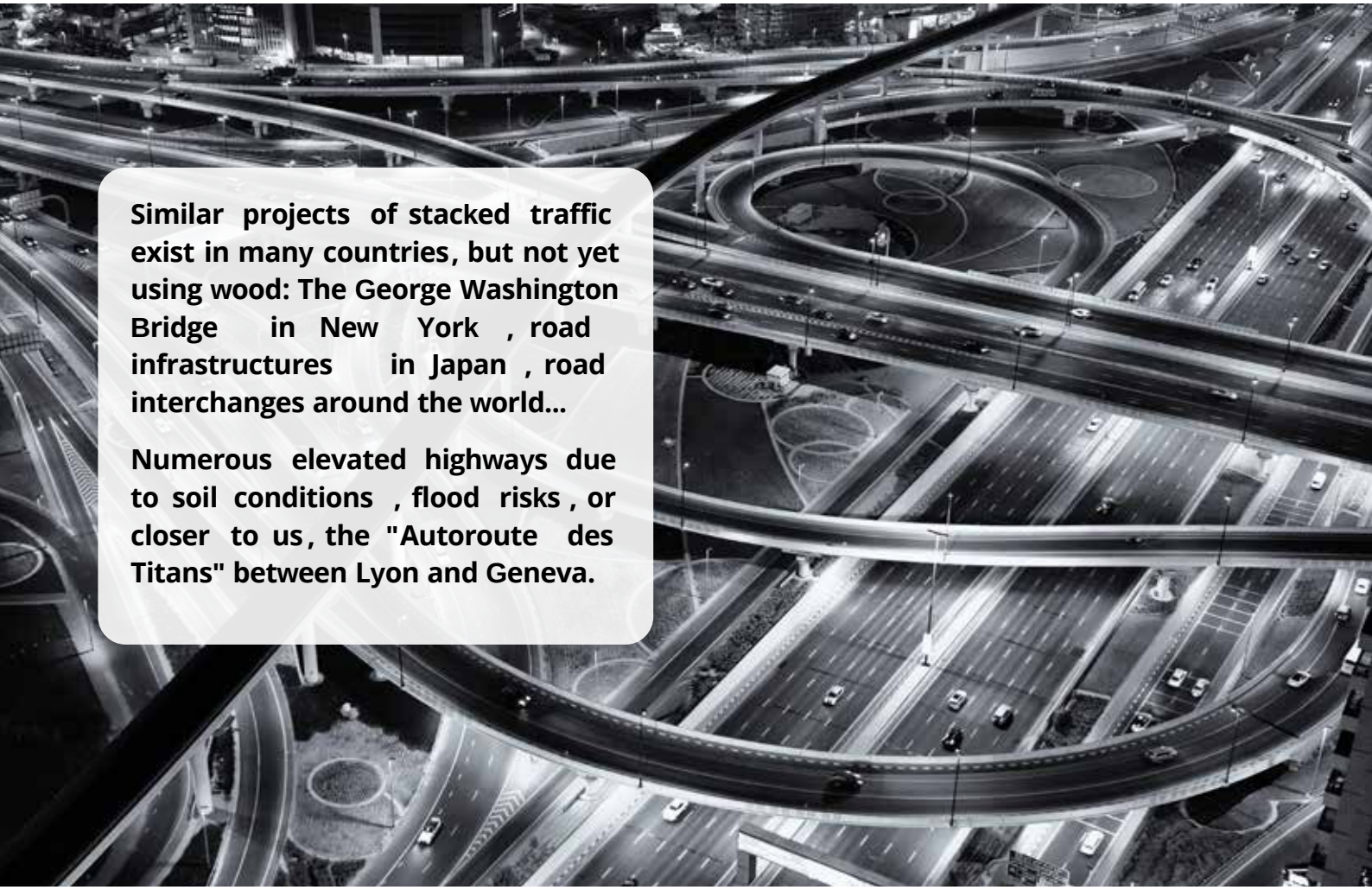


From 6 a.m. onwards, the installation work of the 3D modules is halted, and traffic can be restored on both lanes under safe conditions.

It takes 350 nights to complete one of the two lanes.

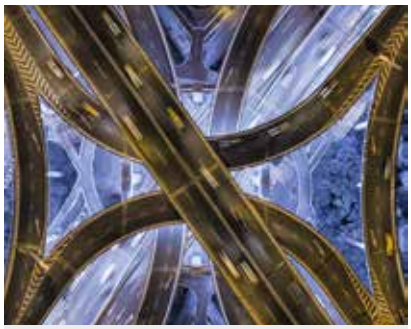
With 20 days of work per month, this amounts to 18 months for the completion of one of the two lanes, **which means 3 years for the entire 20km elevation.**

Train of thought : STENT - A47



Similar projects of stacked traffic exist in many countries, but not yet using wood: The George Washington Bridge in New York , road infrastructures in Japan , road interchanges around the world...

Numerous elevated highways due to soil conditions , flood risks , or closer to us, the "Autoroute des Titans" between Lyon and Geneva.



"Interchange node," Shanghai.

George Washington Bridge in New York with 14 lanes of traffic
.

Elevated roadways in Hong Kong

Infrastructure in Japon

Brenner Autobahn, Austria

The Titans Highway, Lyon - Geneva.

Train of thought : STENT - A47

The STENT A47 project has the support of elected officials to whom we presented the concept and its environmental cause:

Senators -Deputies -Departmental Councilors - local officials and naturally the associations of the wood sector including Fibois AuRA , Fibois 42, Bois des Territoires du Massif Central , and the project was labeled by the competitiveness cluster Xylofutur in December 2020.

LES PÔLES DE COMPÉTITIVITÉ
MOTEURS DE CROISSANCE ET D'EMPLOI

Projet labellisé du
Pôle de Compétitivité
Xylofutur
Produits et Matériaux des Forêts Cultivées

They support the project :


Julien Borowzyck
Former Deputy of Loire


Jean Michel Mis
Former Deputy of Loire


Bernard Fournier
Senator of the Loire


Jean Claude Tissot
Senator of the Loire


Bernard Bonne
Senator of the Loire


Alain Laurendon
Ex-Vice Président du
Département of the Loire


Chantal Brosse
Conseillère Départemental
of Loire


Jean Yves Bonnefoy
Conseiller Départemental
of Loire

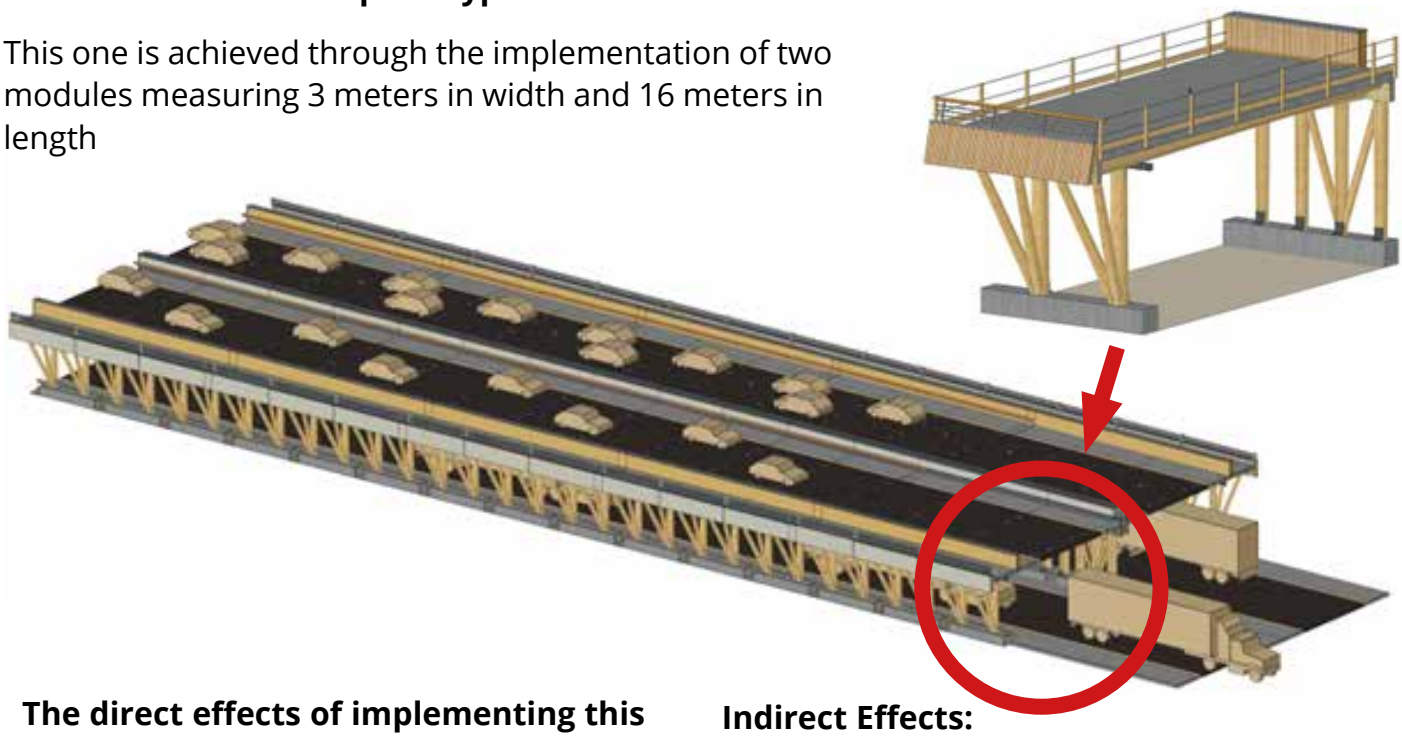

Christophe Bazile
Président of Loire Forez
Agglomeration


Jean Paul Forestier
Vice -Président of Loire
Forez Agglomeration

Train of thought : STENT - A47

The first step in implementing our project is the creation of a 1:1 scale prototype.

This one is achieved through the implementation of two modules measuring 3 meters in width and 16 meters in length



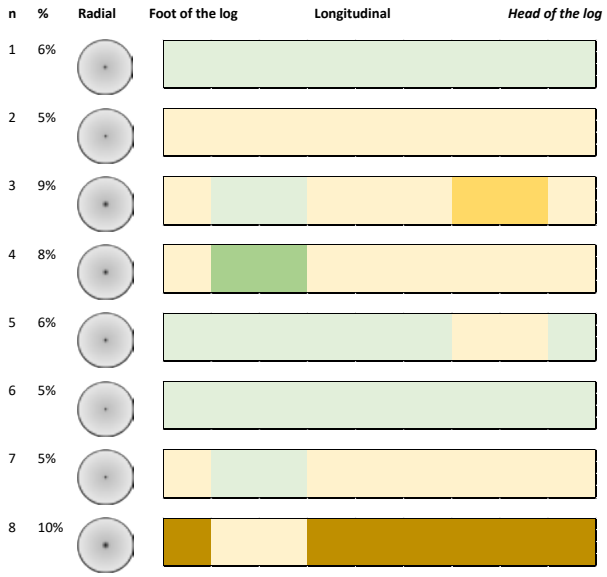
The direct effects of implementing this prototype.

- Finalize all aspects of the project's design.
- Test log shaping, tools, and implementation times.
- Assemble the deck and load-bearing walls to create off-site 3D modules.
- Assemble the 3D elements together and test lifting methods.
- Conduct load and vibration tests to validate the sizing.

Indirect Effects:

- A study on "green " wood , aiming to reduce the environmental impact of the wood industry in construction , where CO_2 emissions are primarily linked to artificial drying.
- The initiation of a project to characterize roundwood at Sylvatest with the expertise of CBS/CBT, as no European standards currently exist for this purpose

Report on Log Quality:



High-performance mechanical quality.
Superior mechanical quality:
Standard mechanical quality:
Average mechanical quality:
Inferior mechanical quality:e

After locating the TGB logs in the forests , a campaign for characterizing the mechanical qualities is carried out using the Sylvatest , a device utilizing ultrasonic technology developed by CBT.

The trees are then felled and skidded for transportation by a log truck to the processing site . Subsequently , they are debarked , and a core removal cut is made to facilitate drying and prevent any unwanted cracking..

For the shaping of logs, a robot is programmed to perform side squaring, dovetail cuts, and notching of buttress beams.

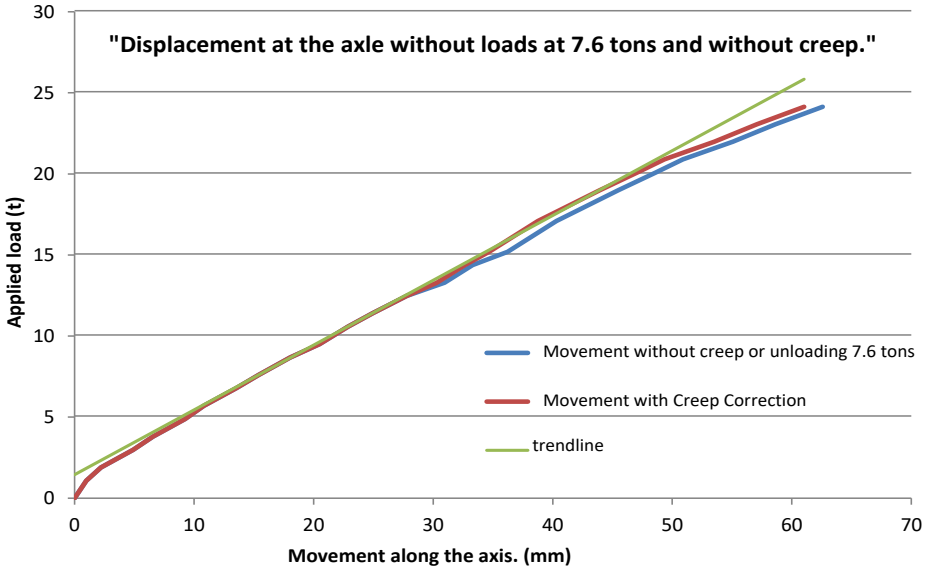
The logs continue to dry while awaiting implementation on the prototypes.

Small prototypes 1.5*15.5m for rupture and creep testing

Two small prototypes with a range of 15 meters and a width of 1.50 meters, limited to two logs placed "end to end," were created at a human height, allowing for easy instrumentation and testing. One of the two prototypes is equipped with instruments to study its long-term behavior (weather stations, hygro-thermal sensors, weight sensors, displacement sensors for settling on supports, central deflection, wood/concrete sliding sensors, etc.), while the other was designed for destructive testing. The tests took place on April 7, 2023, under favorable weather conditions.

The instrumentation was carried out by the GC2D laboratory at the University of Limoges.

The structure was loaded using concrete blocks of various calibrated masses to provide multiple progressively stepped loading solutions. Failure was not reached with 24 tons of concrete blocks, even though calculations based on the Lignadal method predicted failure at 23 tons.

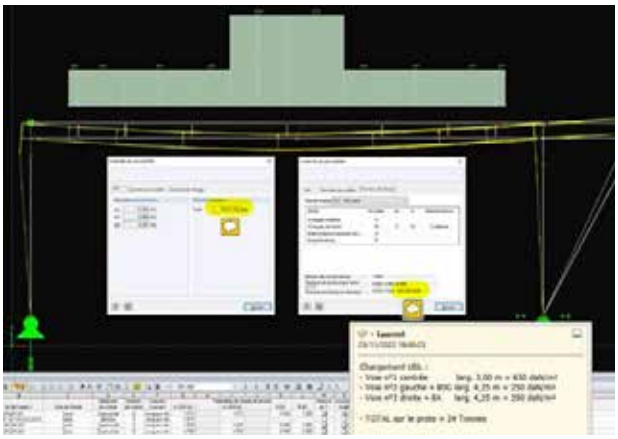


Large prototype 6x16m for bending and vibration testing.

The large prototype underwent deformation monitoring under loading , followed by a vibrational study under dynamic excitation. The instrumentation was carried out by the

GC2D laboratory at the University of Limoges.

Three loading zones were identified on the structure (refer to Figure 1, Spans G, C, and D), and its distribution was done in accordance with these zones.



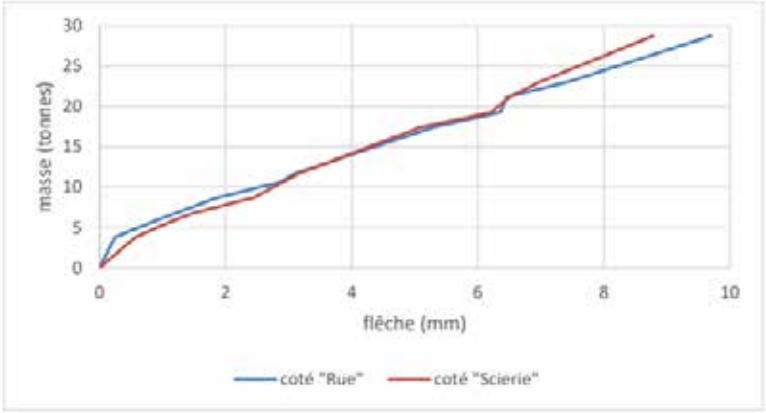
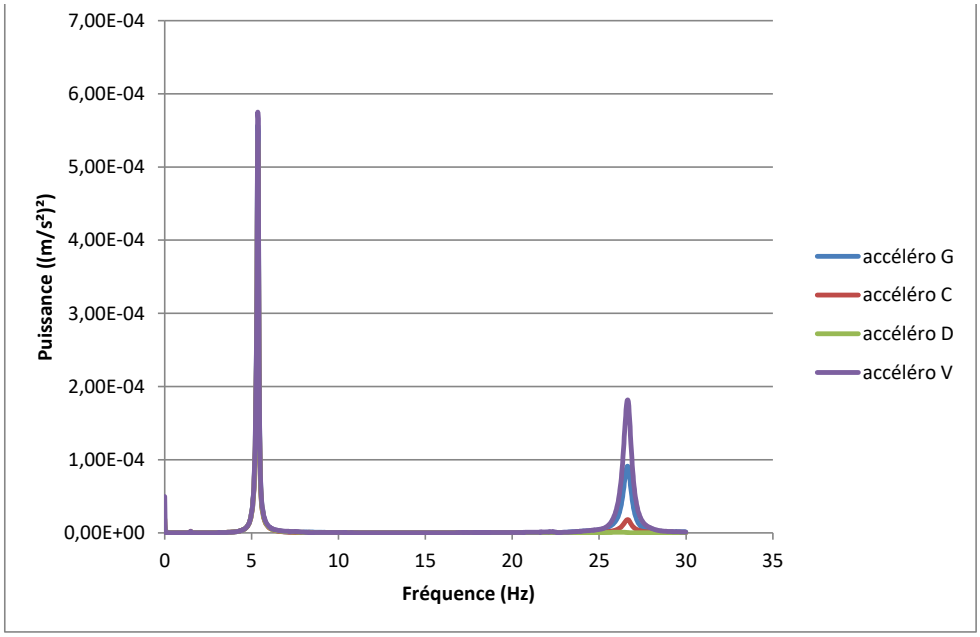


Figure 5 : Évolution de la flèche centrale par rapport à la charge

Under a load of 24 tons, equivalent to 16 vehicles of 1.5 tons each, the deflection is around 8mm, whereas the allowable theoretical deflection is 1/400th, which is 32mm.

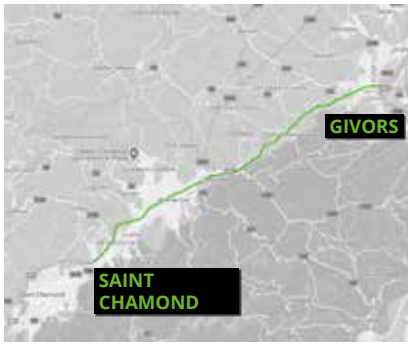
Instrumentation of the large prototype - dynamic testing

PFor conducting dynamic tests, four IEPE (Integrated Electronics Piezo Electric) accelerometers were used. A 6-meter HEB180 beam, placed longitudinally (thus covering the entire span), to which a strap was attached and connected to a suspended mass of 1.9 tons, a few centimeters above the ground, was used to load the structure. The rapid release of this mass, using a quick-release carabiner, allowed for dynamic excitation of the structure to visualize its resonance using the accelerometers. **The natural frequency of the structure is 5.38 Hz (with a minimum target of 2.6 Hz)**



Spectral response

STENT - A47 - Appendices



The elevated section of the A47 under consideration is being developed from the northern bypass of St Chamond to the Givors Bridge over the Rhône River.

The existing overpasses on the current highway are removed and replaced with underpasses in the same area, or elevated by 3 meters if the clearance allows.

The access roads are enhanced for the elevated part by creating entry and exit points for light vehicles traveling on the upper roadway or for service access.

Financial approach

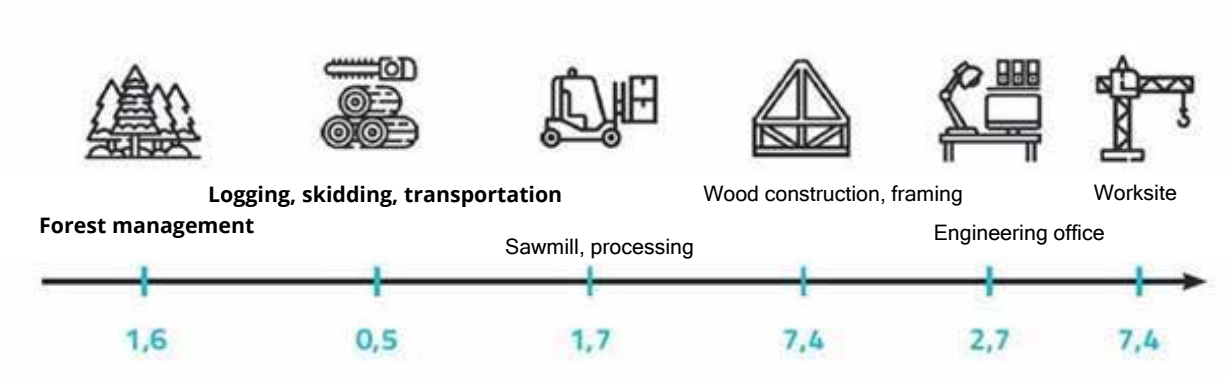
The cost of the 15m by 6m prototype , which represents half a roadway , is €90,000 excluding tax (VAT) in 2023 value . Based on this , the cost price of one kilometer of highway, excluding site adaptation engineering, special foundations, and road equipment, is €30 million excluding tax per kilometer . For the considered 20km stretch , the investment for the superstructure would be approximately €600 million excluding special foundations, additional civil engineering structures, and engineering costs. The budget for A45 was estimated at €1.2 billion (as of June 28, 2017, reported in Le Monde).

This budget was distributed among local authorities (SEM / Loire Department / AuRA Region), the government, and a concessionaire. The available budget was €800 million in 2017 value, without accounting for the concessionaire's funding share.

With this assumption , the cost of the superstructure represents 75% of the allocated budget. There remains 25% to finance foundations, additional civil engineering structures , and studies . For comparison , the civil engineering structures in the A45 project accounted for 25% of the overall construction costs.

STENT - A47 - Annexes

A positive impact on the job market.



Number of jobs generated per 1000m2 of local wood implemented according to FIBOIS AuRA.

To implement the 260,000 m3 of wood that the project represents, the number of generated jobs is 2000 jobs over a period of 3 years.

These 2000 jobs allow for nearly 100 million euros of employee and employer charges to be raised.

If these individuals are unemployed during the same period, their cost to society (benefits, job incentives, business startup assistance, vocational training, operational expenses of the Employment Center) amounts to a nearly equivalent sum of 100 million euros.

A positive impact on our forests

- STENT-A47 requires 300,000 cubic meters of wood in the form of logs, which corresponds to the utilization of 53,000 logs of "large timber" fir and spruce exclusively for the deck.
- The volume of wood used for the 20 kilometers of elevated road on STENT-A47: 260,000 cubic meters.
- The CO2 stored in the wood structure amounts to 260,000 metric tons of CO2.
- The Very Large Timber, amounting to 17 million cubic meters in the Auvergne-Rhône-Alpes region, is consumed by STENT-A47 at less than 2% of the "Very Large Timber" resource in the region.
- The amount of wood mobilized represents only 7 days of forest growth in the Auvergne-Rhône-Alpes region to renew the extracted raw material.

A positive environmental impact:

The current traffic between Saint Chamond and Givors is 35,000 vehicles per day. Based on the projected average emissions in Europe in 2021: 81 g/CO2.km, STENT stores carbon equivalent to the CO2 emissions corresponding to 25 years of current traffic. Considering the reduction in CO2 emissions from combustion engine vehicles and the development of "clean" cars aiming for "Carbon Neutrality by 2050," it can be estimated that the carbon stored in STENT will be equivalent to the carbon emitted by all "combustion engine" vehicles that will travel on the structure until 2050

The "carbon neutrality" of this highway sector would be effective in 3 years, just the time needed to build STENT A47!!

Who are we? A team of experts in the field of wood with references and a common philosophy: to participate in the fight against the greenhouse effect.

We are a team of designers: architects, engineers, and businesses working in the field of bio-sourced construction in partnership with wood industry associations, with a wealth of references in timber construction. We have been actively engaged in combating the greenhouse effect for the past 40 years.

ARCHIPENTE

Dominique MOLARD, architecte
& Edouard MOLARD, architecte

• ARCHIPENTE, the project leader, is a creator of eco-products and architects specializing in timber construction for over 40 years. Our projects utilize wood in structures and highlight the significance of trees in designing welcoming spaces. Initially, we focus on a "High Tech" approach, transitioning to a "Low Tech" approach in our recent projects. Our ultimate goal is to achieve carbon-neutral buildings, eliminating carbon emissions at the building level.

"High Tech" reconstructed trees...

Magasin Alinéa St Etienne (42)

Lycée of Villarbonnot (38)

...to natural "Low Tech" trees

Cinema REX Montbrison (42)

Collège Veauche (42)

Collège St Martin en Haut (69)

The project stakeholders

- Professors **NATTERER** and **WINTER**, who are affiliated with EPFL (École Polytechnique Fédérale de Lausanne), are pioneers in the development of wood products and valorization techniques , aiming to "restore the economic role to forests , ensuring their maintenance."

NDA - Julius NATTERER passed away on October 25, 2021, and his son Johannes has taken over.

- **ARBORESCENCE** & **CBS / CBT** : engineering and project management firms.
- **FORGE MAHUSSIER** sawmill and **LIGNATECH** carpentry.
- Stefan **STAMM** : Master Carpenter specializing in digital technologies.
- **University of Limoges** for instrumentation

Road bridge over the Drôme River in Crest (26) and Fayettes Bridge in Valbonnais (38) (Arborescence)

Professeur Julius NATTERER

Professeur Wolfgang WINTER

Arteplage: Temporary platforms designed by CBS/CBT to accommodate thematic buildings. These platforms are constructed prior to the design of the buildings and are intended to withstand the operational loads associated with the weight of the pavilions ' structures and their installation..

Palazzo Nice Méridia consists of a 9-story office building (CBS/CBT)

Stefan STAMM, master carpenter

The Lignatech Team

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