Interlocking glued Solid timber from Reclaimed Stocks

عنصر انشائي مصفح متشابك من مخزون
الأخشاب المستعملة

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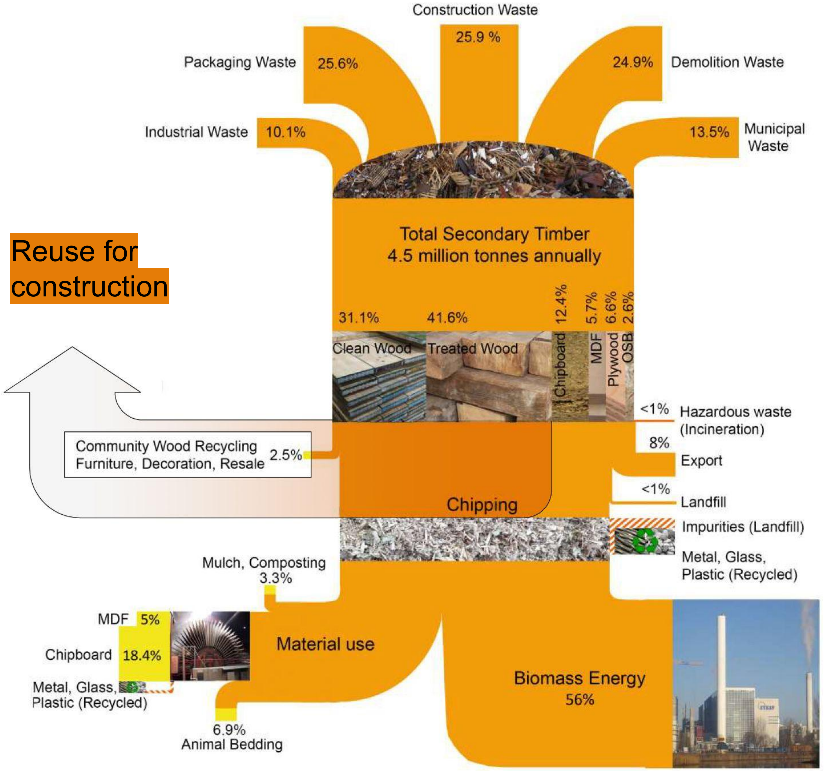
Why Reclaimed timber?

Future

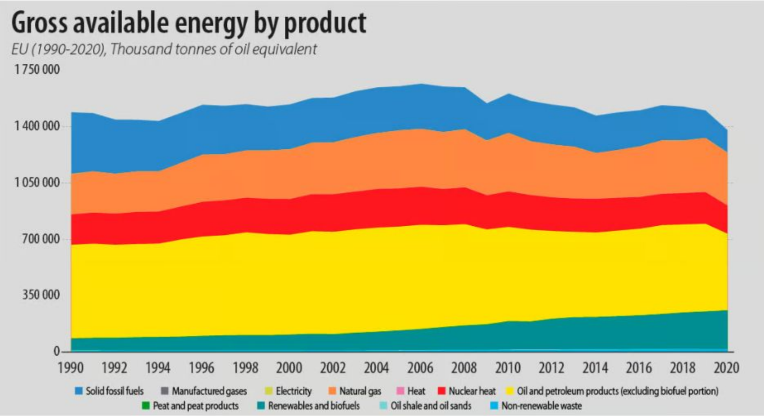
- Heading Towards Carbon Neutrality by 2050(FAO)
- France's 2022: 50% Natural Materials in New Buildings
- the push for sustainable construction materials raises the crucial issue of sourcing additional wood
- a 37% increase in the consumption of primary processed wood products by 2050 in a business-as-usual (FAO)
- additional 8% growth in a bioeconomic scenario as mass timber and man-made cellulose fibers, as substitutes for non-renewable materials like concrete and steel.
- Forestry Value Chain: Essential for Sustainable Wood Production



source:https://blogs.napier.ac.uk/cwst/timber-recycling-and-demolition/

Present

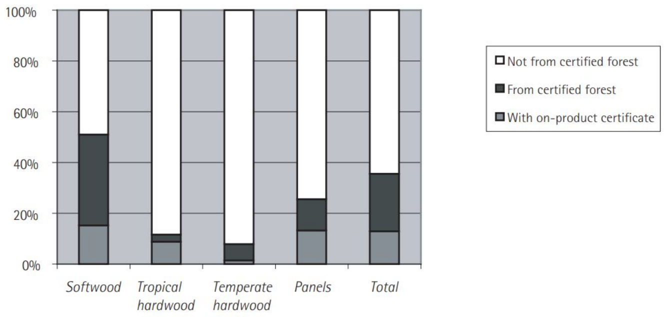
- EU Renewable Energy Directive retains woody biomass as renewable despite opposition.
- Concerns include carbon emissions and forest impact, leading to significant public and scientific opposition.
- Legal loopholes exist in forest protection regulations due to weak monitoring and enforcement.
- Dutch Parliament ceased subsidies for biomass heat plants in February 2021 to prevent unsustainable construction.

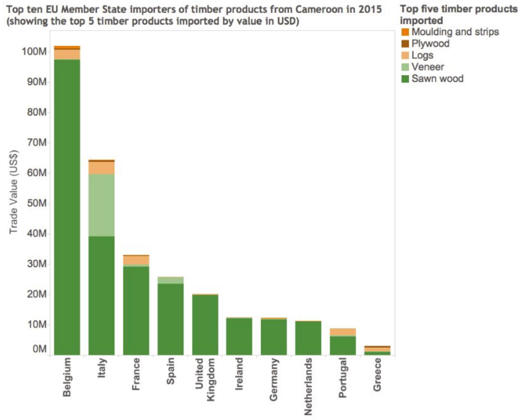


Past

- Indonesia and Malaysia collectively supplied around 40% of Netherlands' timber imports in 2006.
- Approximately 80% of tropical timber imported by the Netherlands is illegally sourced.
- Environmental risks of uncertified timber include illegal logging and deforestation.
- Social risks include poor labor conditions, human rights violations, and land rights disputes.

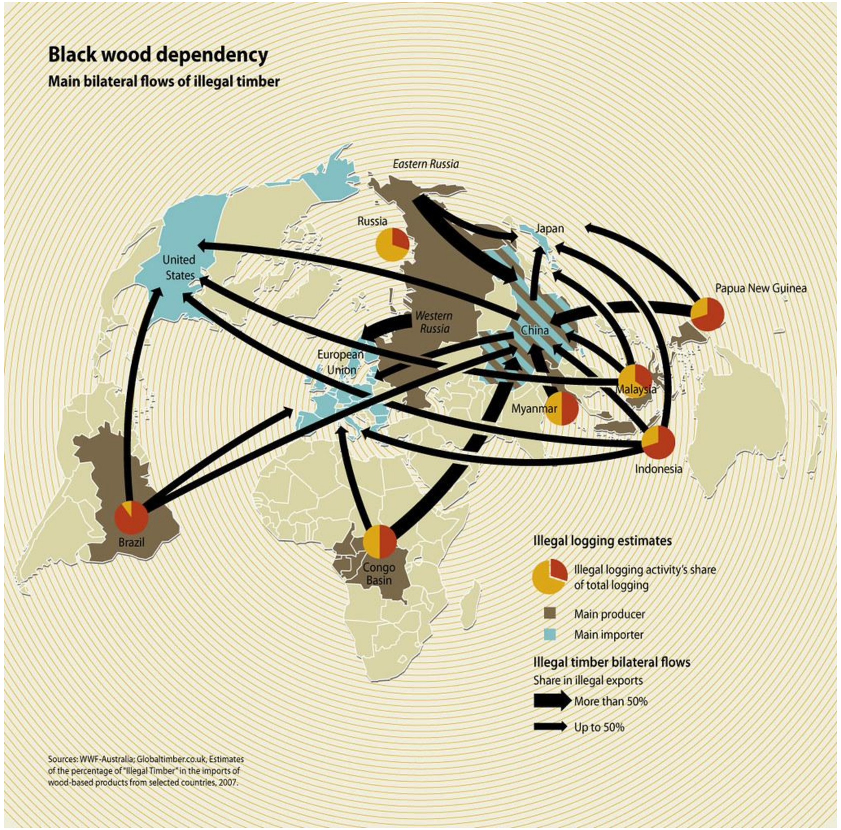
Figure 1. Timber with certificate and timber sourced from certified forest, per product group, as a percentage of total Dutch timber consumption in 2005





Data from UN Comtrade 2017 and compiled by Forest Trends 2017.

Sourcing timber Illegally



https://www.grida.no/resources/8016

Why Reclaimed timber ?

- A high Demand is expected in the future,
- the laws for using wood for biomass energy is matter of change due to the carbon emission research.
- The value of the timber exist in the new and reclaimed stocks has a value for EU region and beyond

Cascading flow for recycling timber

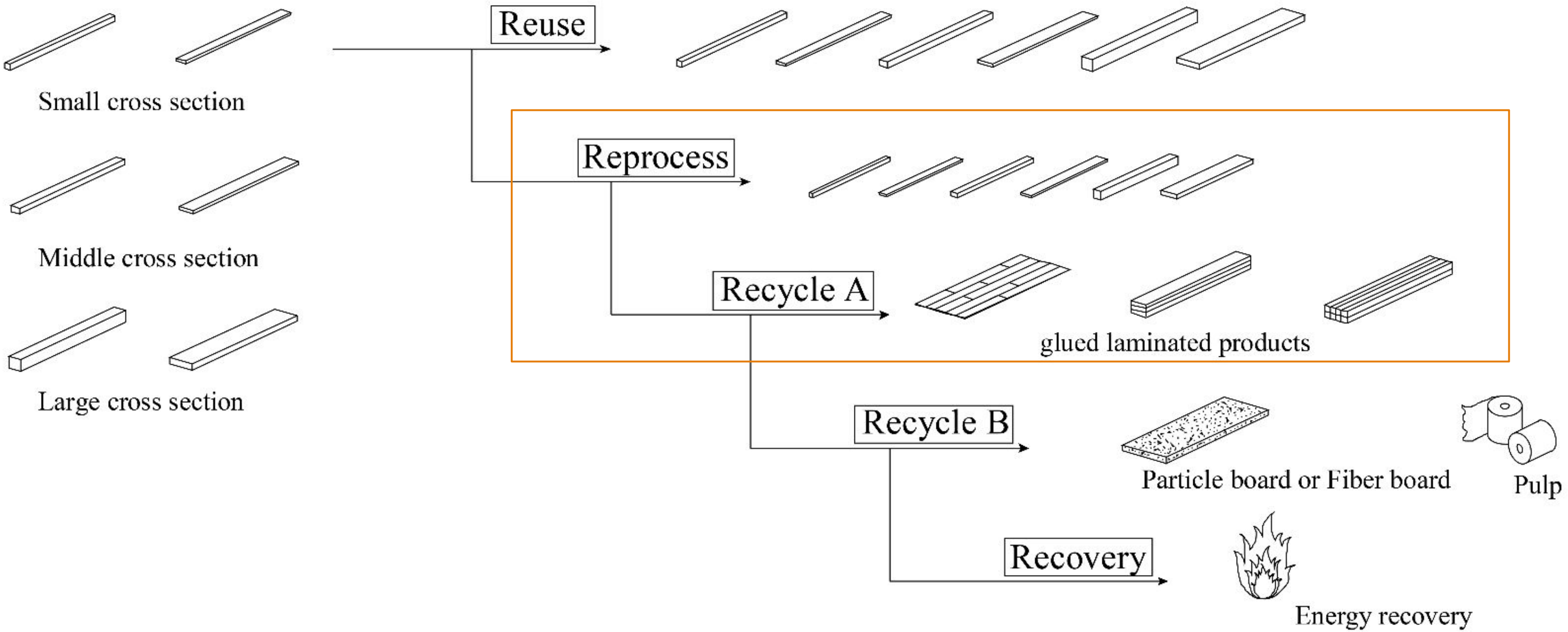


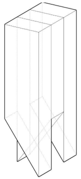
Figure 2. An example of a cascading flow for timber members from a deconstructed building (Sakaguchi 2014). Image courtesy of Daishi Sakaguchi.

الطرح

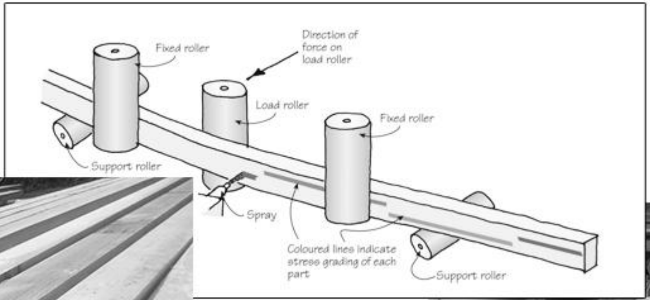
Discourse

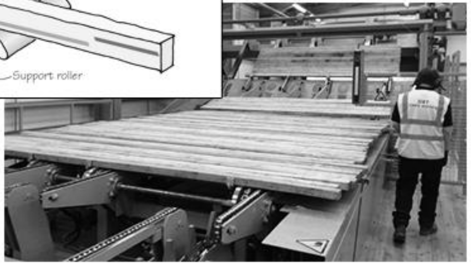
1

Rethinking Timber Reuse vs. Recycling



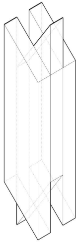
Using machine-graded timber since the 1950s, which has lower safety margins, raises concerns about reusing demolished timbers for structures due to possible strength loss, suggesting recycling as a more sustainable choice.



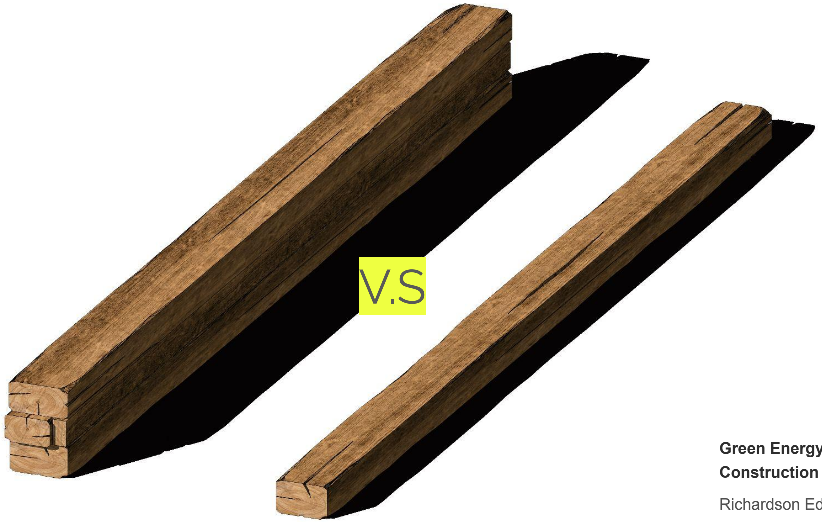


2

Element V.S Bundle of Elements!



Therefore, the use of reclaimed timber is governed by the concept of its structural capacity. Since each element undergoes a certain amount of degradation, using an aggregation of these elements will provide structural elements with better performance

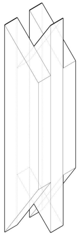


Green Energy and Technology Reuse of Materials and Byproducts in Construction Waste Minimization and Recycling

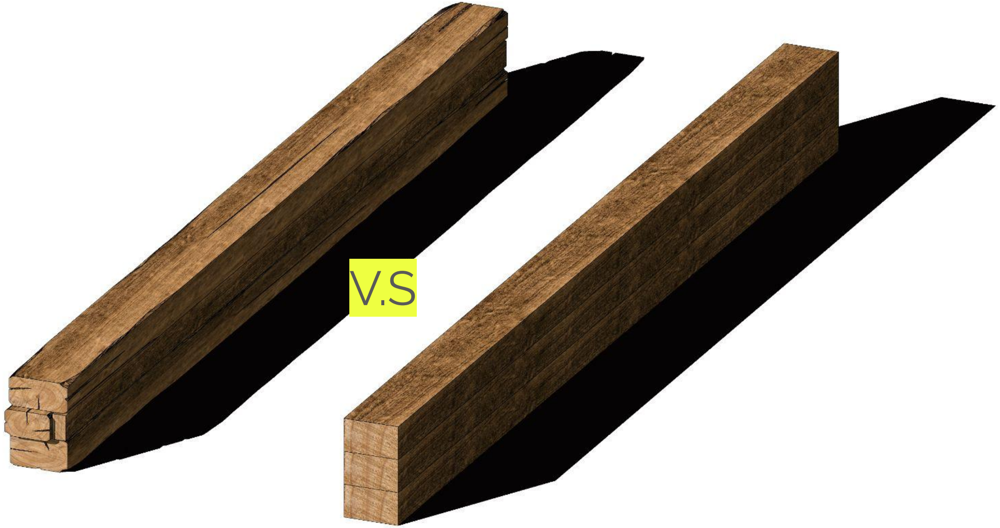
Richardson Editor A

3

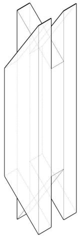
Newly sawn timber> reclaimed timber (Glulam)



still the making structural elements, from newly cut timber has better performance than using using reclaimed timber, but research has proven that glulam from reclaimed timber still satisfy the structural need in the construction market **Patlakas et al. 2019**



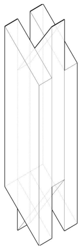
4 Unlocking Market Growth



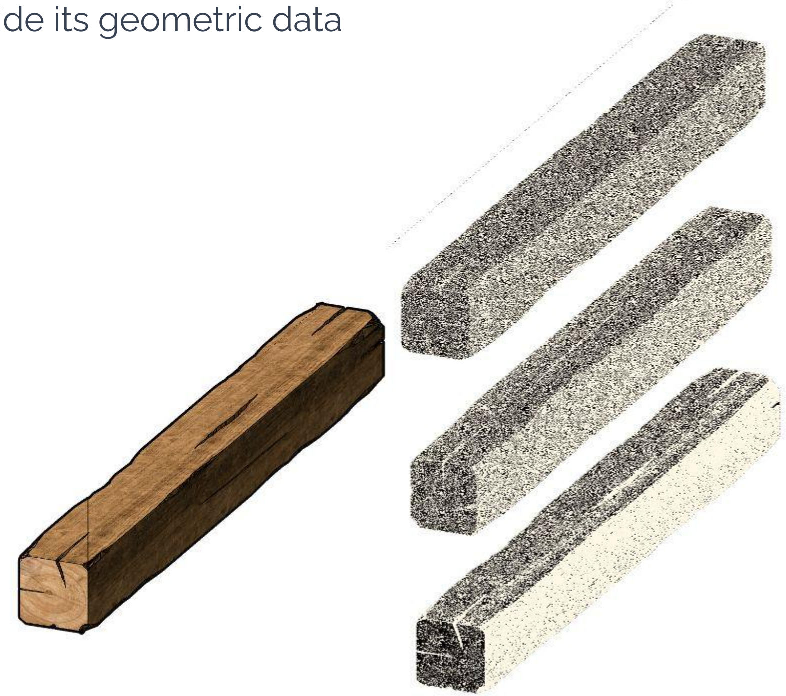
Sustainably sourced wood products are more expensive, causing mass timber buildings to cost 5–15% more than conventional ones. This significant cost increase limits widespread adoption. However, considering engineered timber from reclaimed timber can offer a solution with lower costs than newly sourced timber, helping support market growth (Mayencourt & Mueller, 2020).

5

Density + Geometrical properties

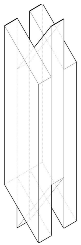


To design strong glulam from reclaimed wood, we need to check the wood's density, age, and structure alongside its geometric data

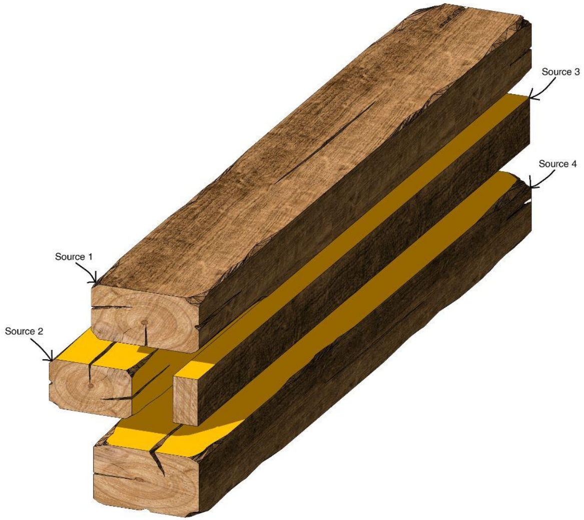


6

Multi source => Bonding Problem !

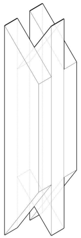


The evaluation results in a matrix of data, which the literature shows can be used directly to assess designing for optimum strength. The first question is linked to the essence of the salvaged material, the sourcing of the material, and the possibility of creating glulam from different wood species(Palma & Fink, 2013).

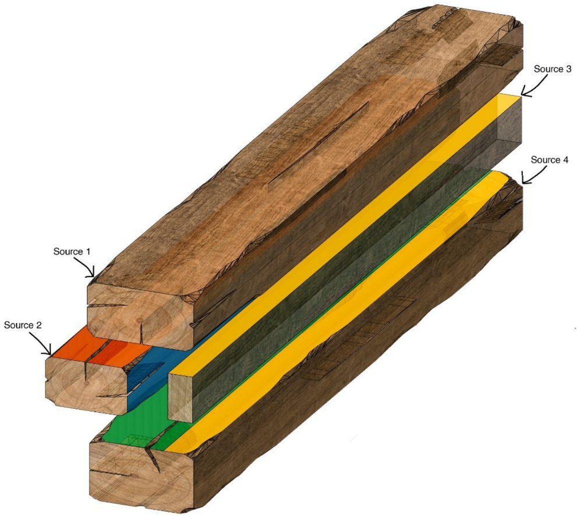


7

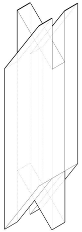
Better glued joint = Similar face treatment Chemical + physical (sanded or planared)



Various factors can impact how structural elements fit together. Reclaimed timber diverse wood types and surface treatments can affect bonding strength, requiring attention to glue compatibility, wood chemicals, pH, and surface smoothness to prevent weak bonds and damage(Palma & Fink, 2013).



State of art of EPW



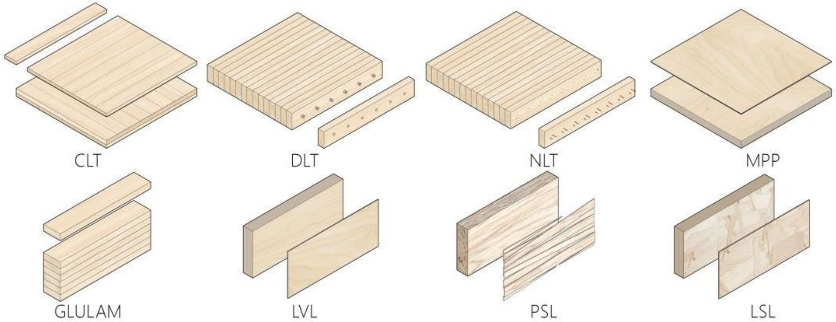
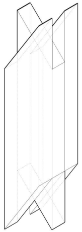


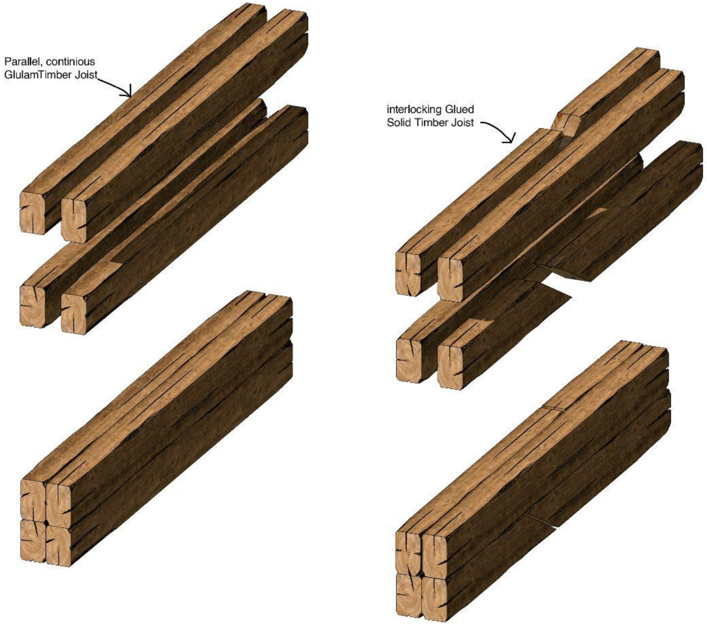
Figure 1. Main species of mass timber.

Glulam	Wooden planks	Glue	Parallel
CLT	Wooden planks	Glue	Orthogonal
IGST	Wooden planks	GLUE	Parallel Orthogonal
Non-glued types:			
DLT	Wooden planks	Dowels	Parallel Orthogonal
NLT	Wooden planks	Nails	Parallel Orthogonal
Structural Composite Lumber types:			
LVL	Veneers	Glue	Parallel Orthogonal
PSL	Wooden strands	Glue	Parallel
LSL	Wooden strands	Glue	Parallel Orthogonal Random

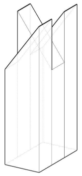
1:4 Slope edge , simple joint = increase the strength



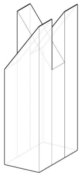
Most research on reclaimed materials focuses on straight structural parts, overlooking factors like joint shape, cost, and environmental impact(Patlakas et al., 2019).



Problem statement

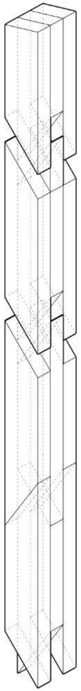


Moving to carbon-neutral construction will likely raise demand for engineered timber, putting pressure on the wooden materials industry and increasing costs for Mass Timber structures, which are already 15% more expensive than concrete buildings. However, creating mass timber structures from reclaimed timber could be an important alternative, despite lacking comprehensive design and production methods.



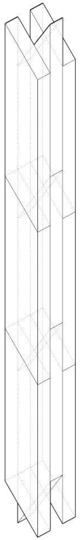
The goal of project is to find methods To help structural designer and craftsmen to make IGST structural elements from reclaimed timber stocks.

Research Question:



Main research question

How can we create interlocking glued Solid timber structural components from reclaimed element stocks?



Sub-Questions:

Preparing the Inventory

How to evaluate the timber in the stocks, with simple techniques

Matching algorithm

How to optimize the quality and quantity of the produced elements by controlling the matching process between design and stock?

Environmental Impact

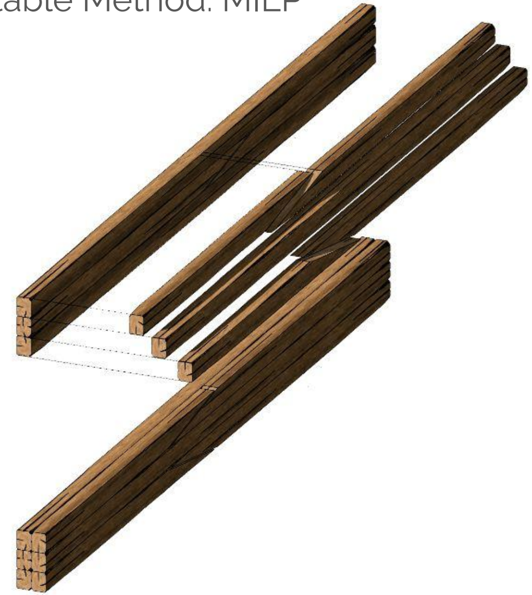
How to calculate the environmental impact of the resulting component and compare it with glulam from newly sawn timber, or combination from both?

Manufacturing

What to workflow needed to manufacture the designed structural component?

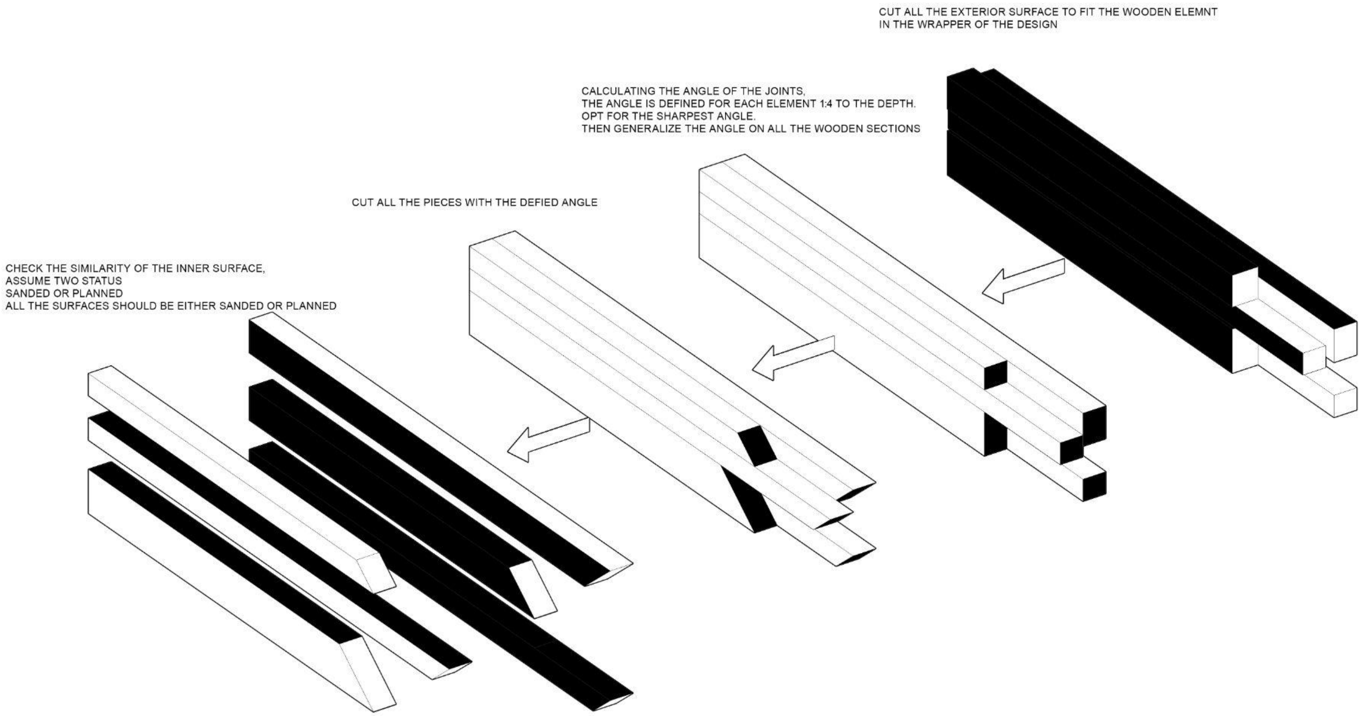
Design assignment

Case study A:
A single Beam
Suitable Method: MILP

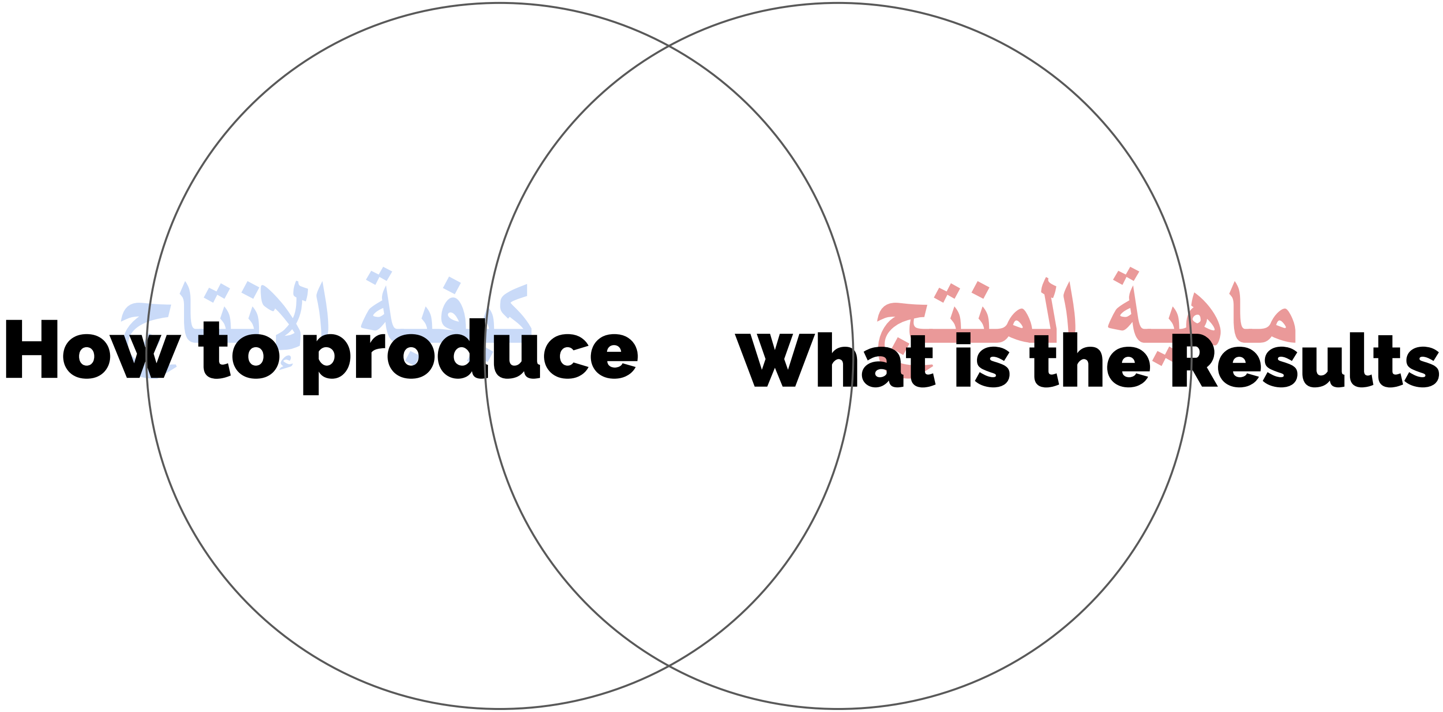


Case study B:
A collection of Beam
Suitable methods: Hungarian Algorithm

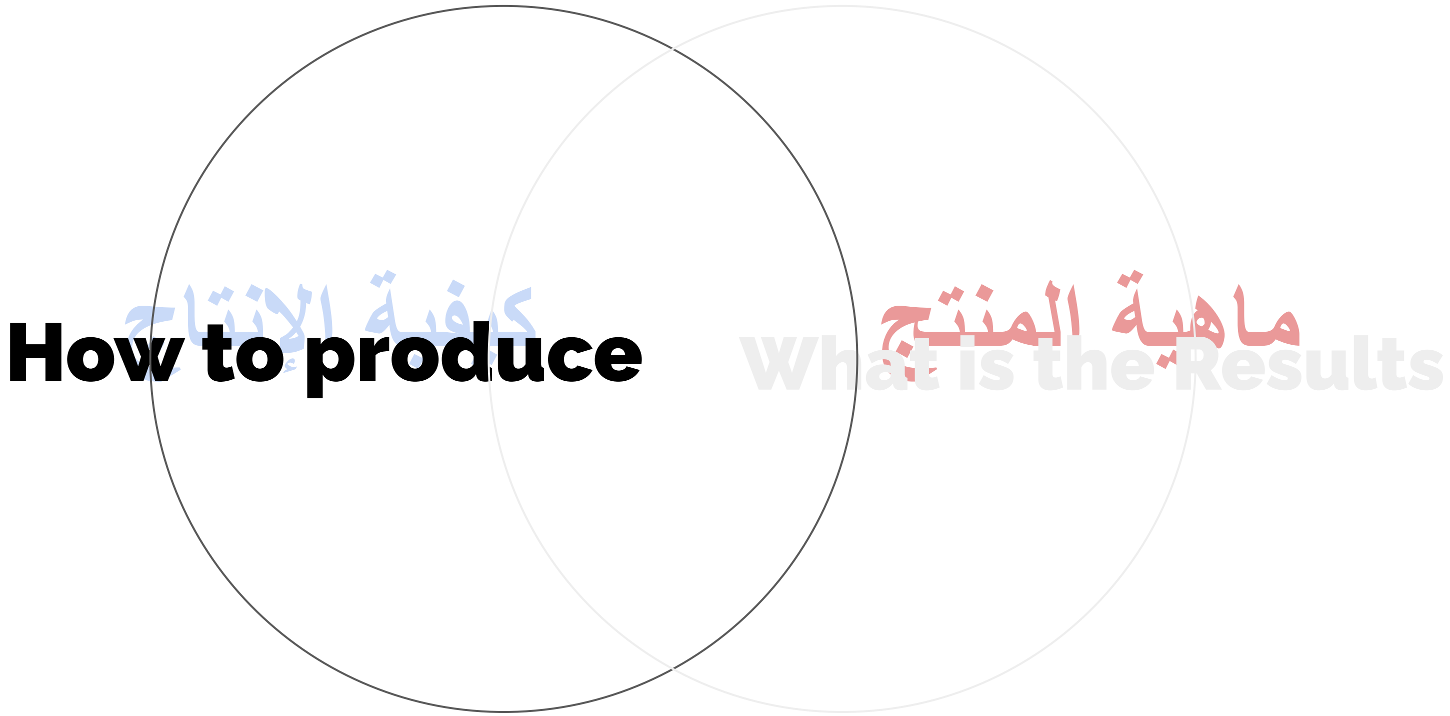
From Design to workshop workflow



How to proceeds with the concepts



How to proceeds with the concepts



How to produce IGST from Reclaimed timber

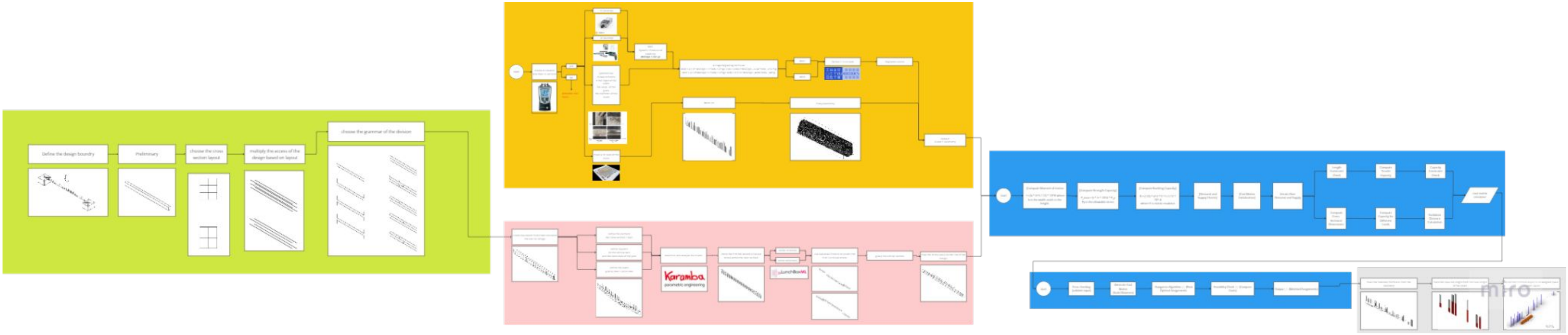
تصميم
Design

تصنيف
Regrading

انشائي
structure

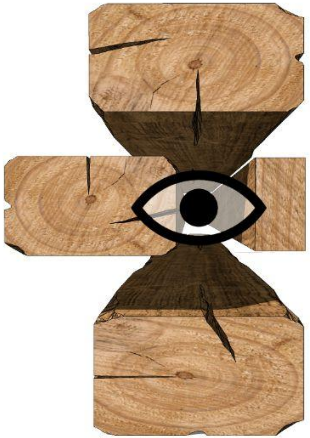
مطابقة
Matching

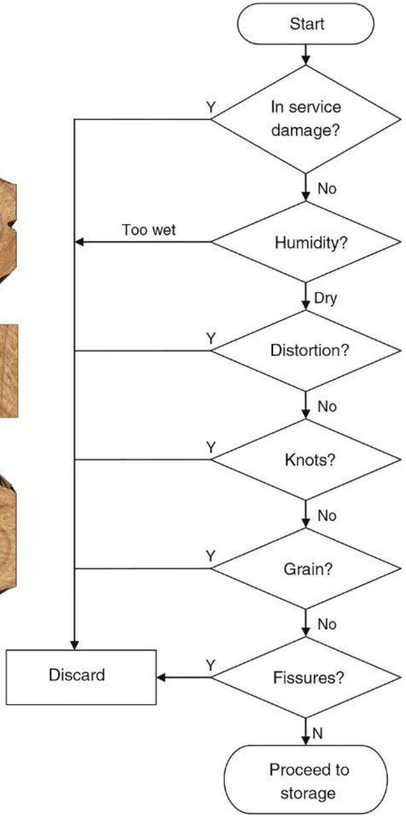
workflows(Layout -structural - matching -visualization)



تصنيف
Regrading

Visual Grading methodology





Discard if more than ***35 nail*** holes per meter. Holes and notches up to 15 mm wide are fine, except on narrow edge. ***Notches up to 25 mm near end are okay***; can be machined out if needed

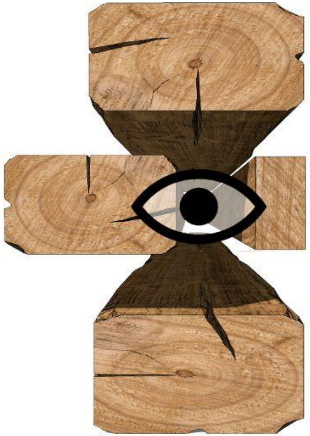
If a joist has recently been removed from its 'in-service' position, it should feel dry to the touch. Any timber feeling wet or damp could indicate rot and should be rejected.

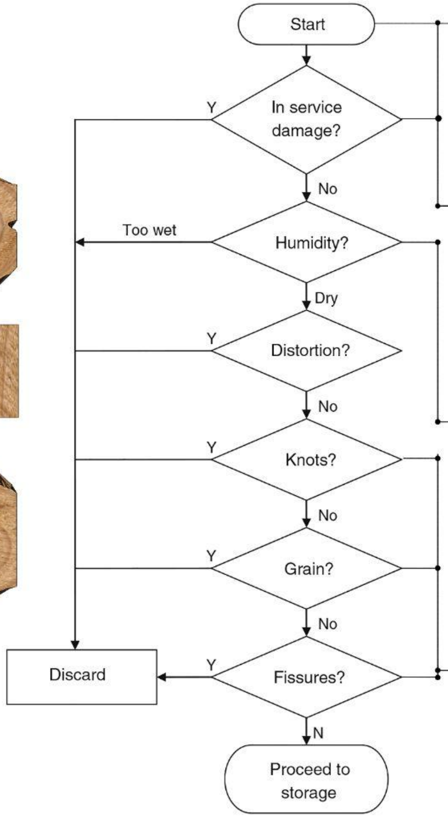
Bow—Not more than 20 mm over a length of 2 m
Spring—Not more than 12 mm over a length of 2 m
Twist—Not more than 2 mm per 25 mm width over a length of 2 m
If all of these conditions are met, the joist is a ‘Yes’; if not then it is a ‘No’ and must be rejected.

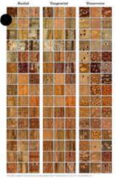
Any knots wider than ***30 mm on the surface of the timber and within a quarter of the joist's width*** from the edge are ***not allowed***. If knots violate this rule, the joist is considered failed and rejected.

The slope of the clear grain must ***not exceed 1 in 6***. There can be unlimited fissures, but ***none should be longer than 600 mm per meter***. Timbers failing this rule are rejected. No wane is permitted on the reclaimed joist according to the visual grade.

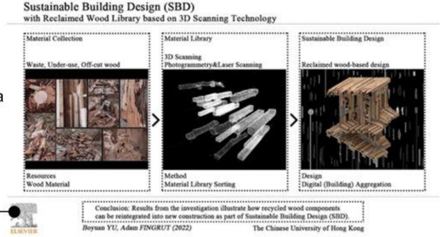
Visual Grading methodology



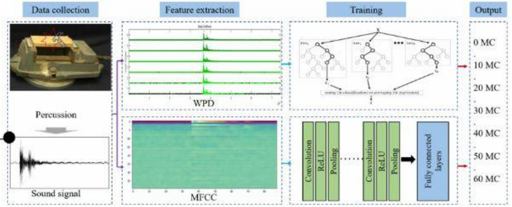




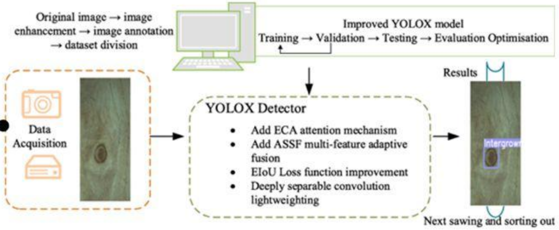
An analysis of timber sections and deep learning for wood species classification
de Geus A, Silva S, Souza J
Multimedia Tools and Applications (2020) 79(45-46) 34513-34529



Sustainable building design (SBD) with reclaimed wood library constructed in collaboration with 3D scanning technology in the UK
Yu B, Fingrut A
Resources, Conservation and Recycling (2022) 186



Timber moisture detection using wavelet packet decomposition and convolutional neural network
Yuan C, Zhang J, Kong Q
Smart Materials and Structures (2021) 30(3) 035022

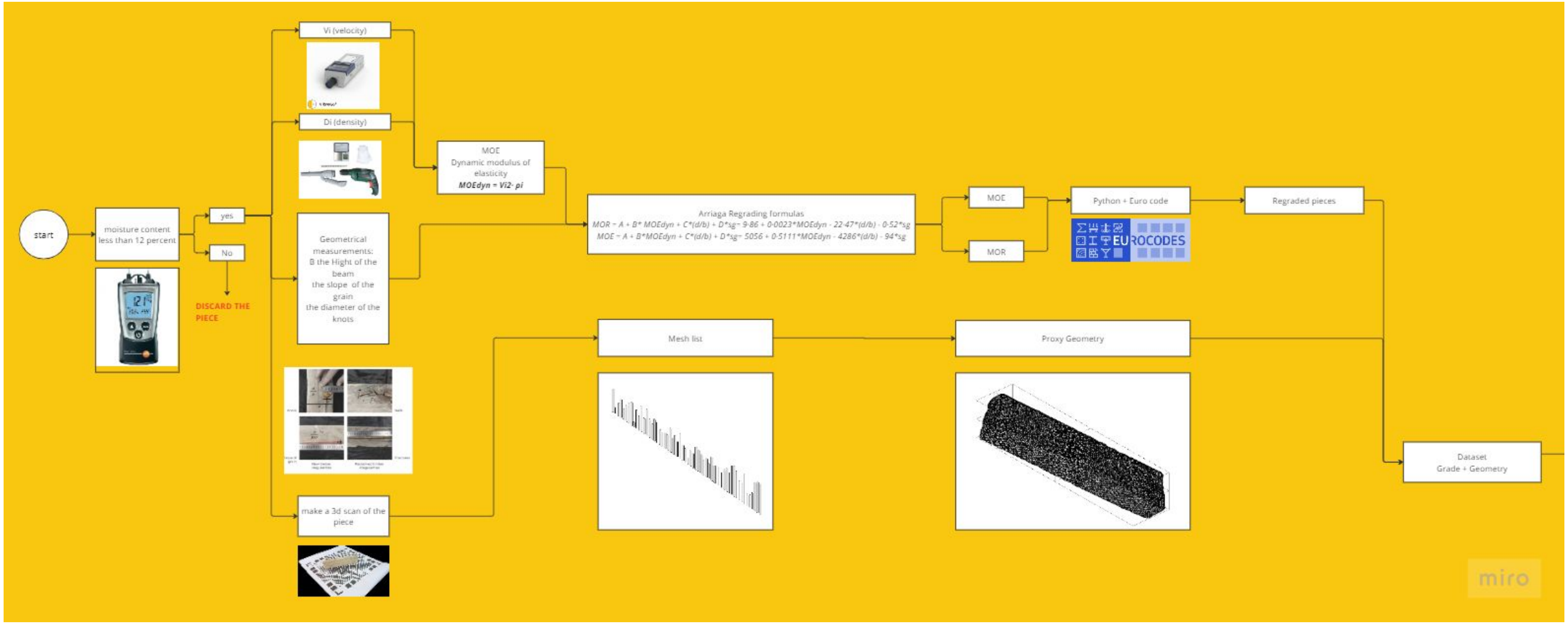


Detection method of timber defects based on target detection algorithm
Li D, Zhang Z, Deng L
Measurement (2022) 203 111937

Literature focus

How can we utilize visual grading, along with mechanical material characteristics, to re-grade reclaimed timber according to the Eurocode?

From stock to a grade workflow



Visual characterstics

Measure width (b)

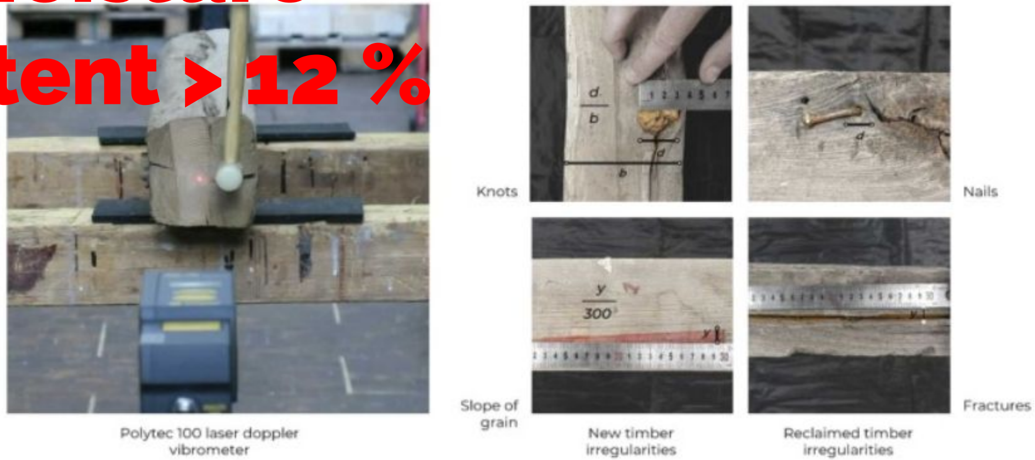
Measure hight (h)

Length (L)

knots diameters ratio(D)

Slope of grain

Moisture content > 12 %

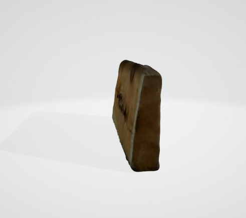


A 3d scan of the reclaimed pieces

-Using Qlone app on the phone

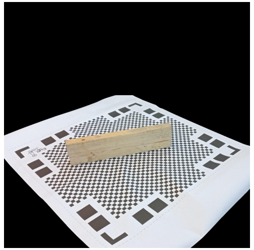
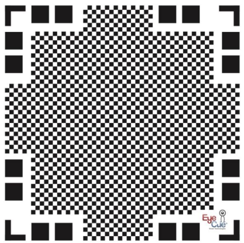
-create an obj file with the materials

-create a data set of meshes







Measuring Vi and Di

To get Vi

or

Micro second timer

To get ρi

or

$$\rho = \frac{m}{V}$$

MOEdyn = Vi2· ρi

MOR = A + B* *MOEdyn* + C*(*d*/*b*) + D**sg*= 9·86 + 0·0023**MOEdyn* - 22·47*(*d*/*b*) - 0·52**sg*

MOE = A + B**MOEdyn* + C*(*d*/*b*) + D**sg*= 5056 + 0·5111**MOEdyn* - 4286*(*d*/*b*) - 94**sg*

Classes from the eurocode

Table 1 — Strength classes - Characteristic values

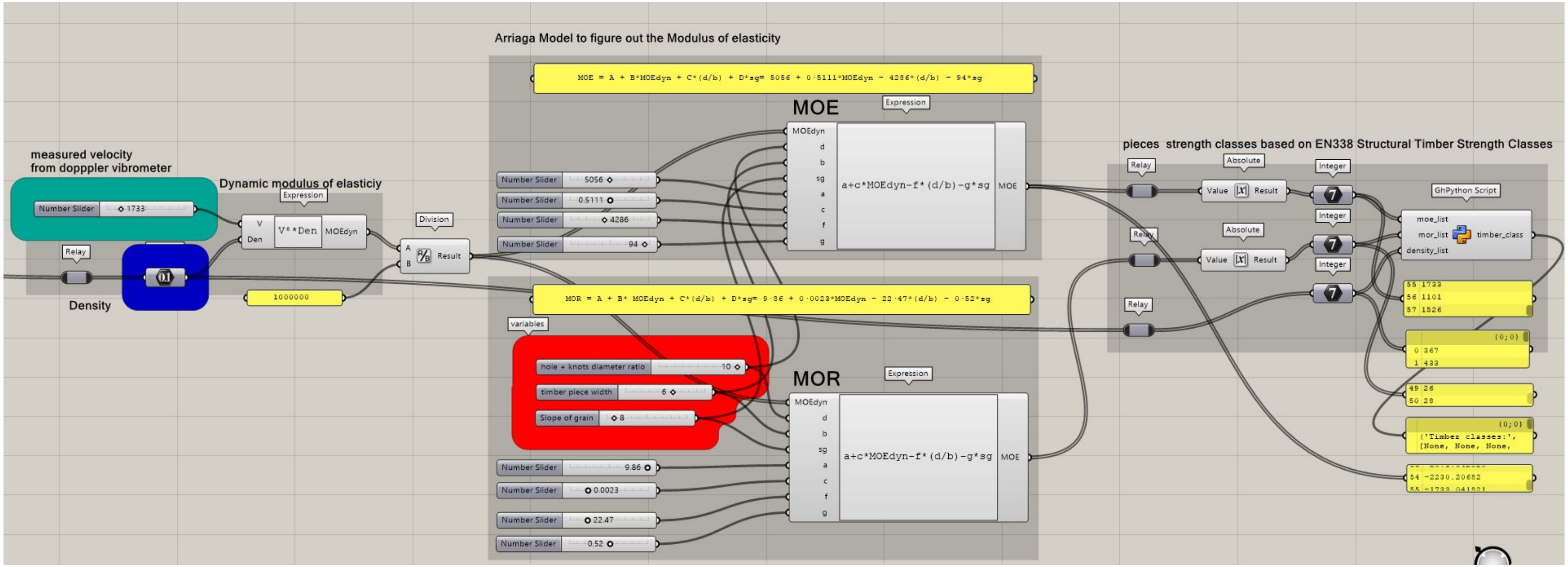
		Poplar and softwood species												Hardwood species					
		C14	C16	C18	C20	C22	C24	C27	C30	C35	C40	C45	C50	D30	D35	D40	D50	D60	D70
Stiffness properties (in kN/mm^2)																			
Mean modulus of elasticity parallel	$E_{0,mean}$	7	8	9	9,5	10	11	11,5	12	13	14	15	16	10	10	11	14	17	20
5% modulus of elasticity parallel	$E_{0,05}$	4,7	5,4	6,0	6,4	6,7	7,4	7,7	8,0	8,7	9,4	10,0	10,7	8,0	8,7	9,4	11,8	14,3	16,8
Mean modulus of elasticity perpendicular	$E_{90,mean}$	0,23	0,27	0,30	0,32	0,33	0,37	0,38	0,40	0,43	0,47	0,50	0,53	0,64	0,69	0,75	0,93	1,13	1,33
Mean shear modulus	G_{mean}	0,44	0,5	0,56	0,59	0,63	0,69	0,72	0,75	0,81	0,88	0,94	1,00	0,60	0,65	0,70	0,88	1,06	1,25
Density (in kg/m^3)																			
Density	ρ_k	290	310	320	330	340	350	370	380	400	420	440	460	530	560	590	650	700	900
Mean density	ρ_{mean}	350	370	380	390	410	420	450	460	480	500	520	550	640	670	700	780	840	1080

NOTE a Values given above for tension strength, compression strength, shear strength, 5% modulus of elasticity, mean modulus of elasticity perpendicular to grain and mean shear modulus, have been calculated using the equations given in annex A

b The tabulated properties are compatible with timber at a moisture content consistent with a temperature of 20^{0}C and a relative humidity of 65%

c Timber conforming to classes C45 and C50 may not be readily available.

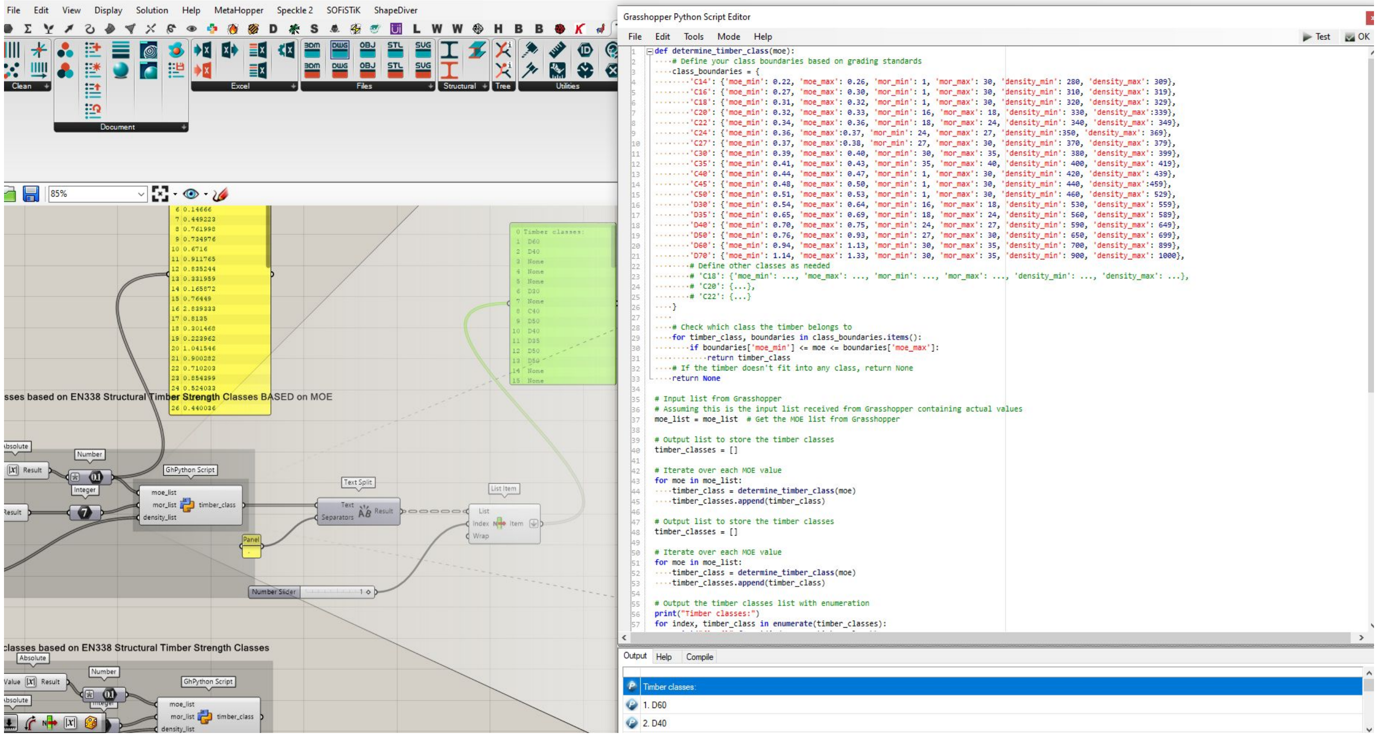
Using grasshopper to input the data



A snippet of the data set used

Timber piece	Section		Length	Moisture content	Knots diameter ratio d/b	Slope of grain	Density	MOE ^{dyn}	species
	B cm	H cm							
A	8	12	100	20	0.3	12	530	0.64	oak
B	20	7	60	12	0.4	5	350	0.73	spurce
C	8	10	35	8	0.1	8	480	0.35	oak
D	4.5	4.5	95	5	0.34	12	317	0.24	fir
…	…	..	…	…	…	…	…	…	…

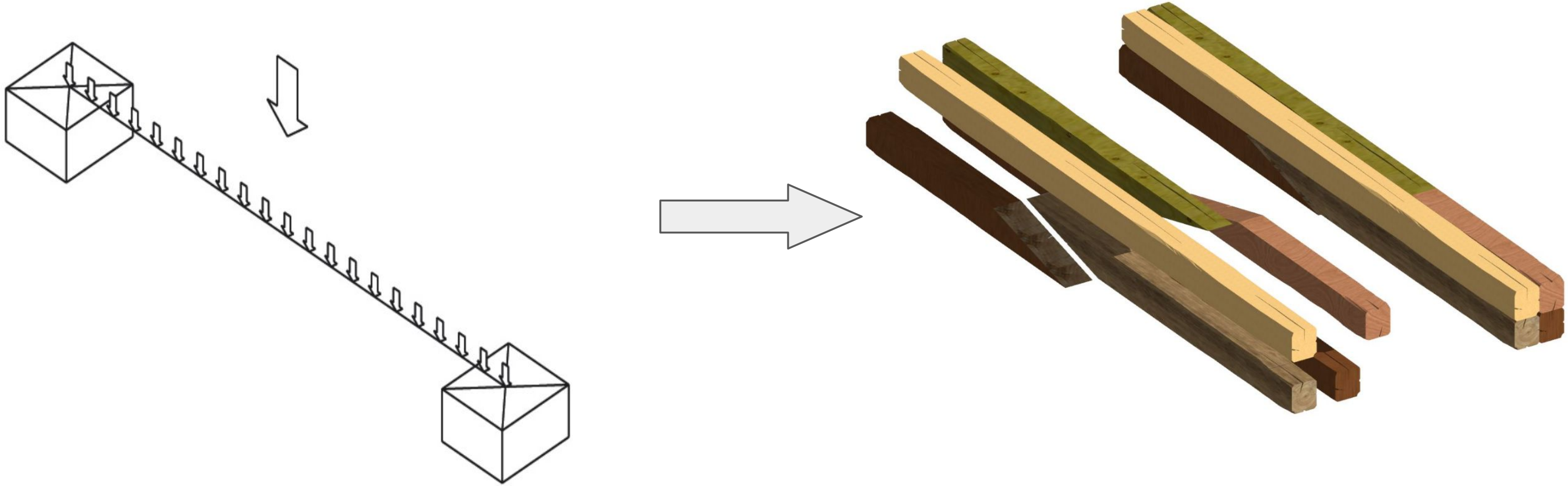
Insert the eurocode classes values as ranges in python



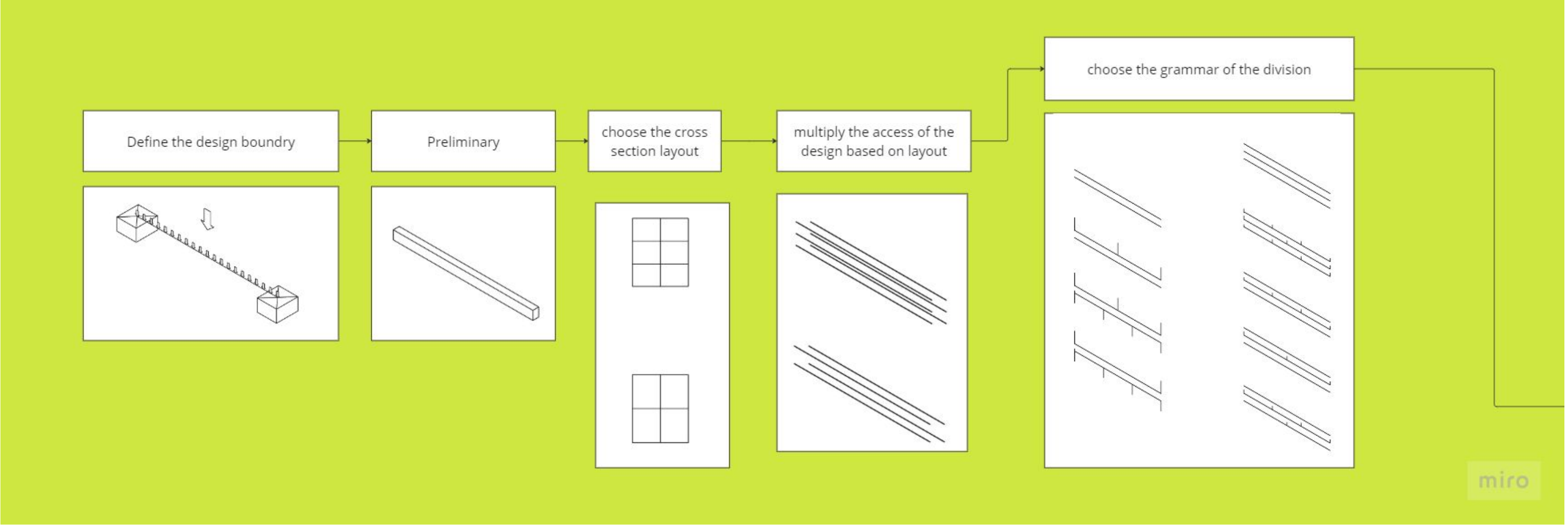
تصميم

Design

From design boundaries to ISGT

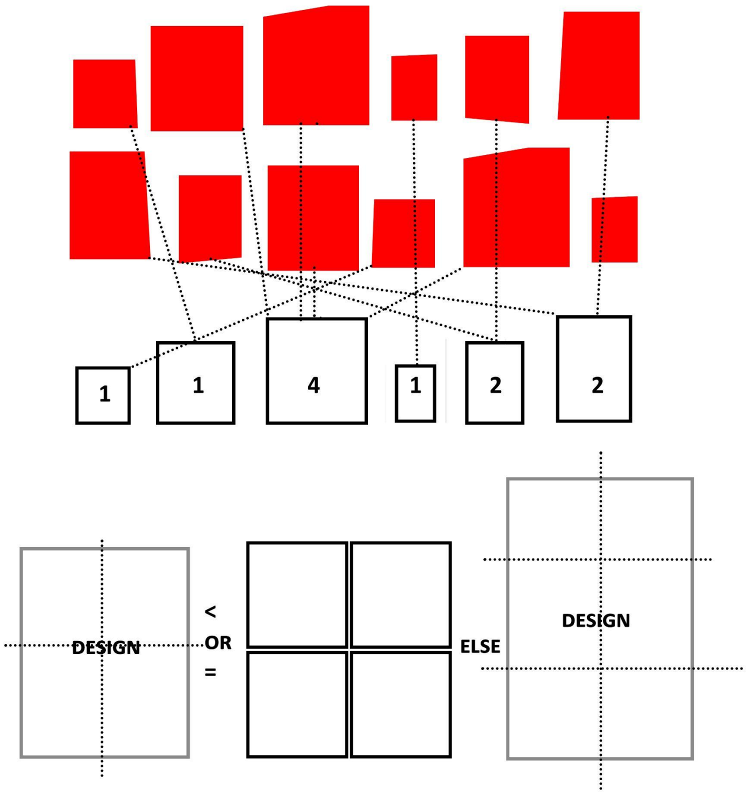


From a design constraint to a layout

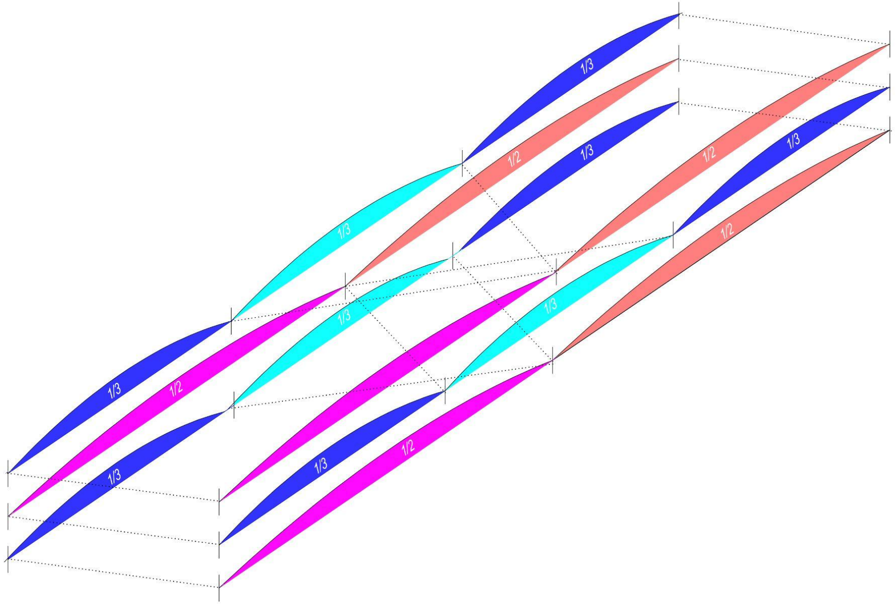


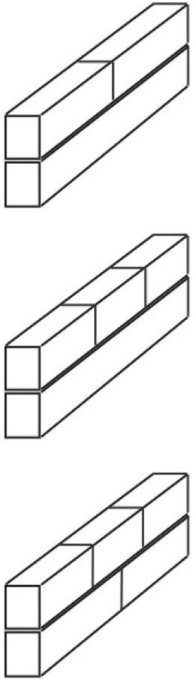
From a design constraint to a layout

-We conservatively discretize the areas of the sections.
-We calculate the mode (Mod) and the mean of the discretized areas dataset.
- If the area of the preliminary section is less than or equal to four times the area of the mode, we choose the four-lamella layout.
- Otherwise, we choose the six-lamella layout

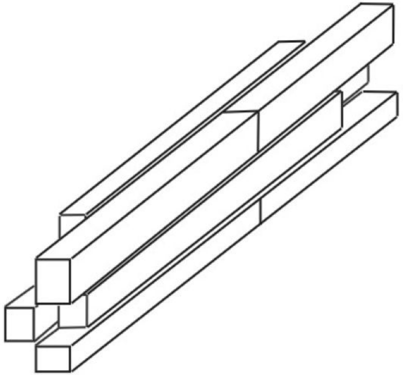


From a design constraint to a layout

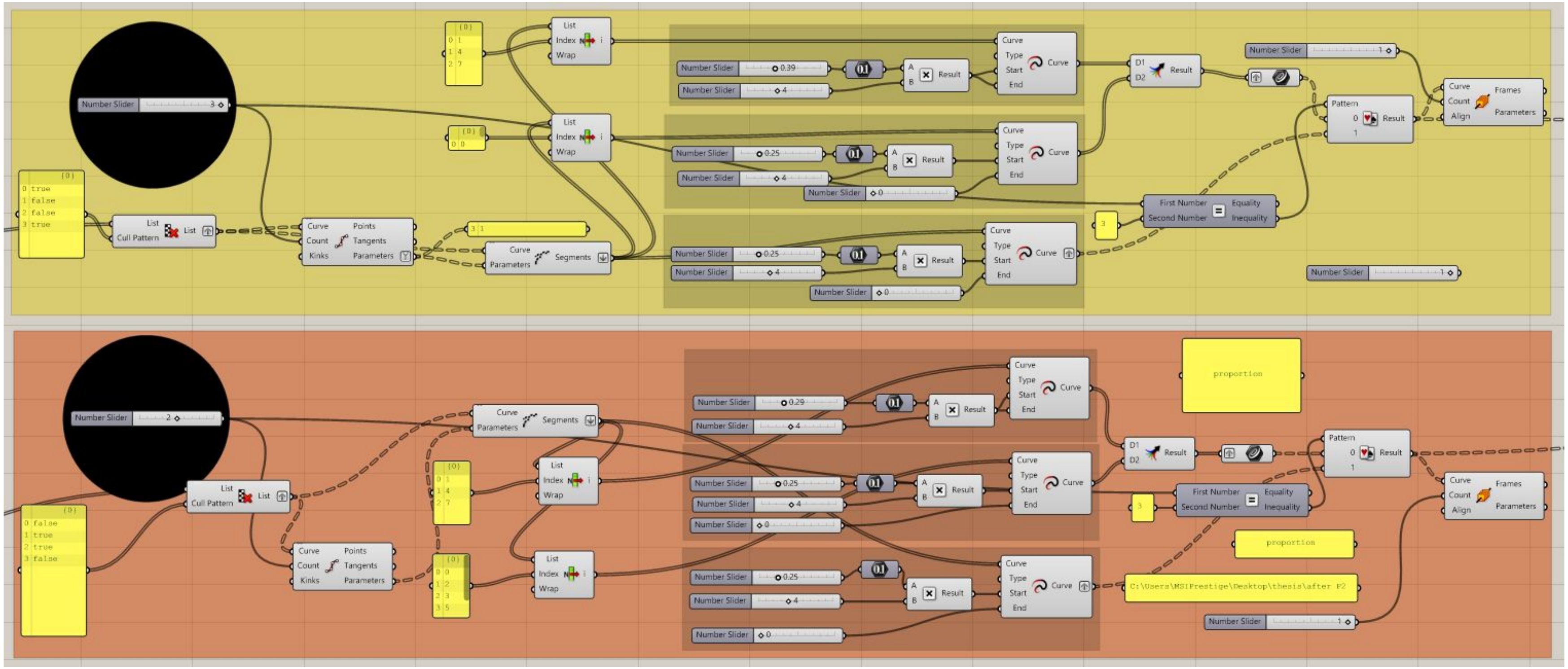




1: 1/2	1/2: 1
1: 1/3	1/3: 1
1/2: 1/3	1/3: 1/3



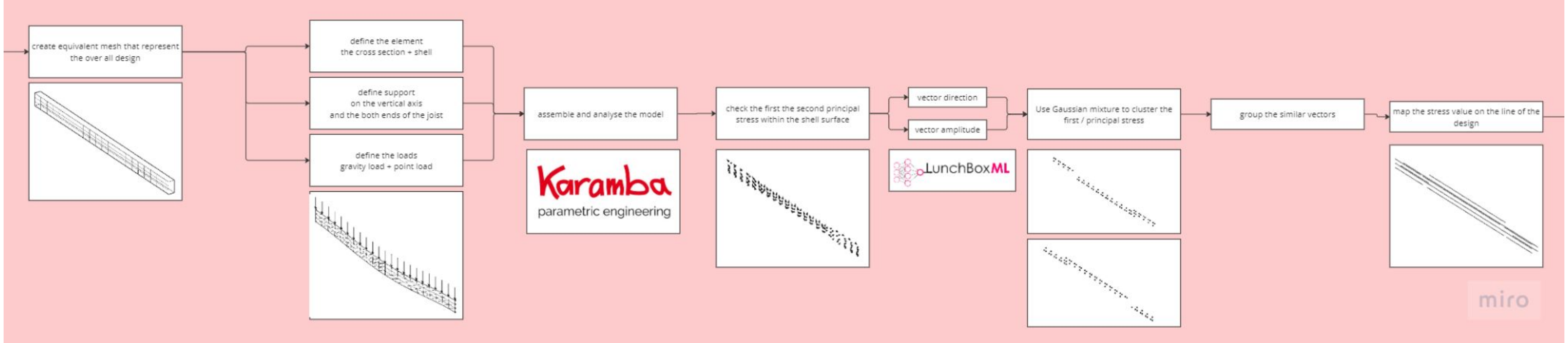
Using a simple grasshopper code to do the division



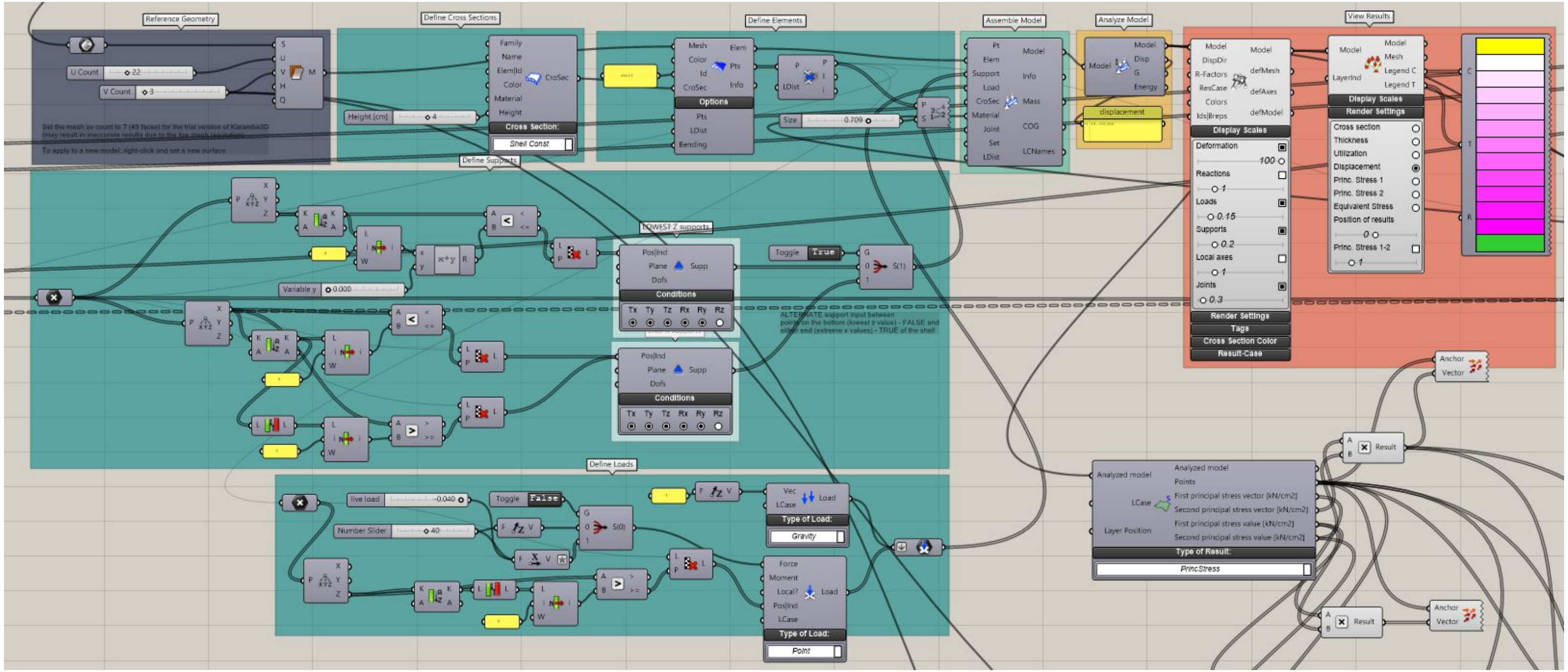
انشائی

structure

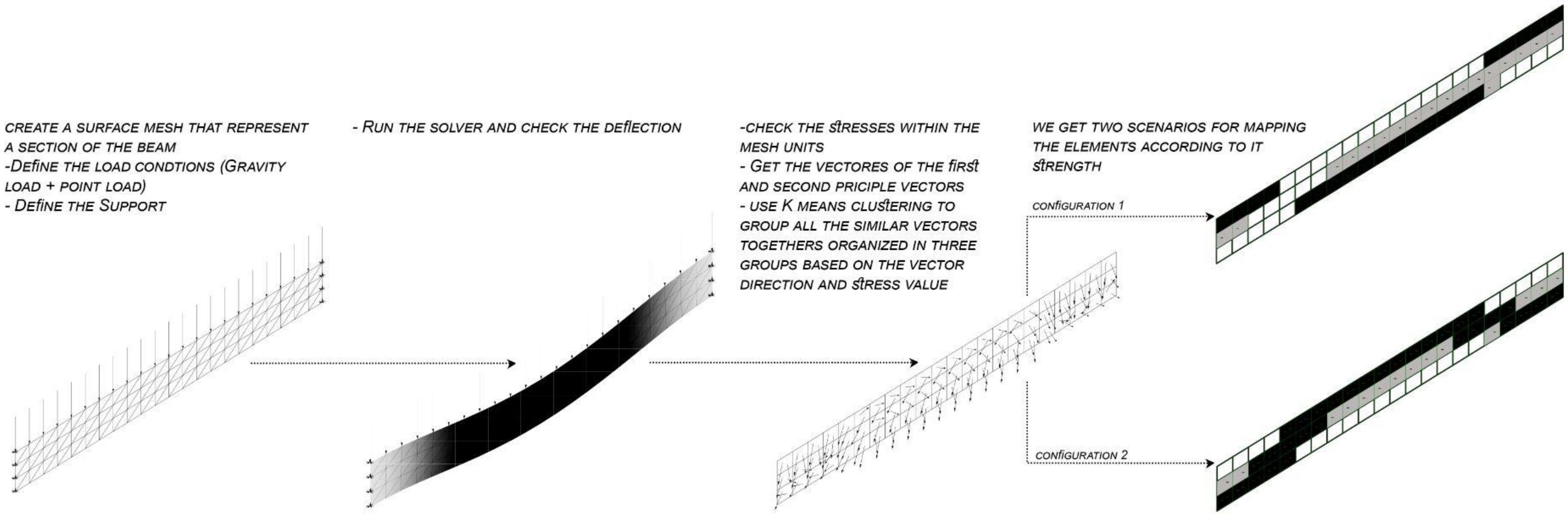
From Line to a structural demand



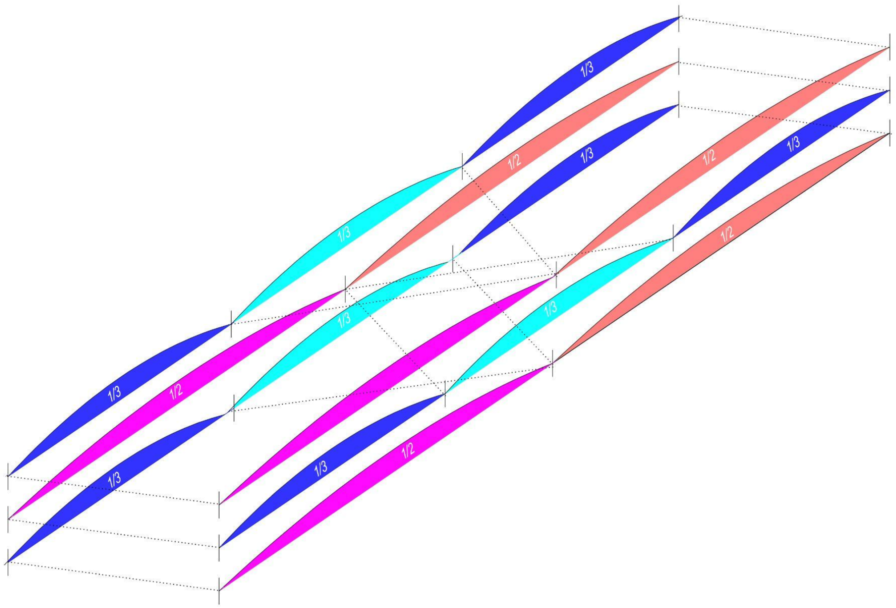
5 workflows(Layout -structural - matching -visualization)

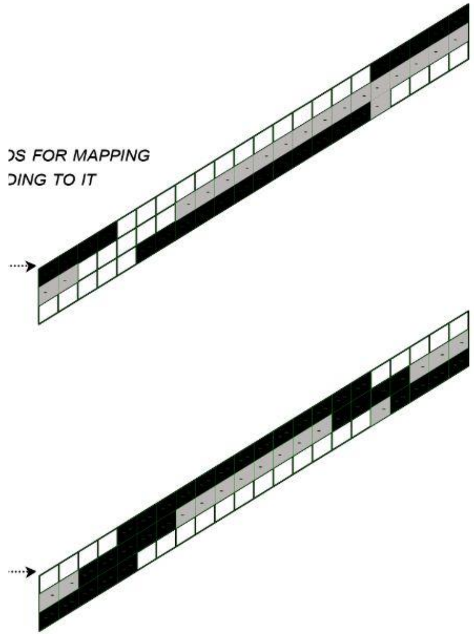


From principal stress to a structural layout



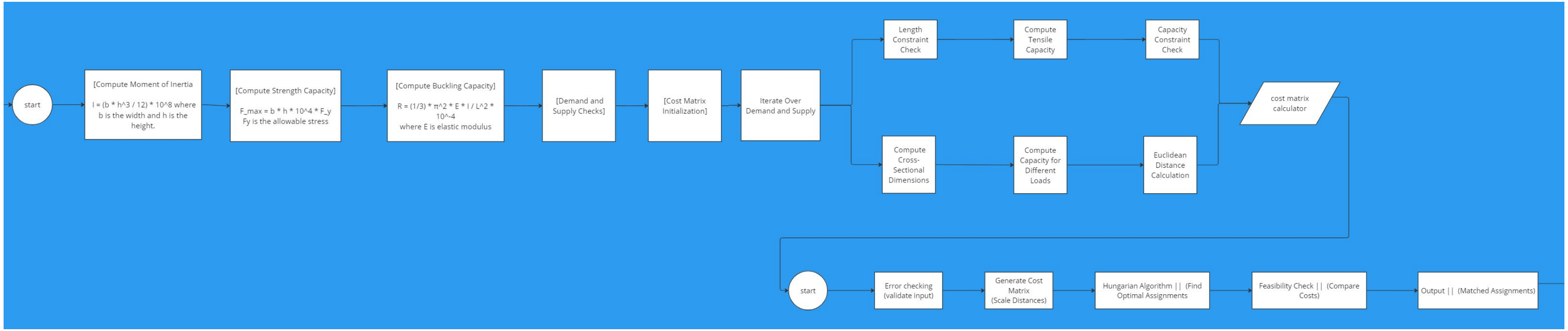
Map the stresses from the mesh to the linear layout





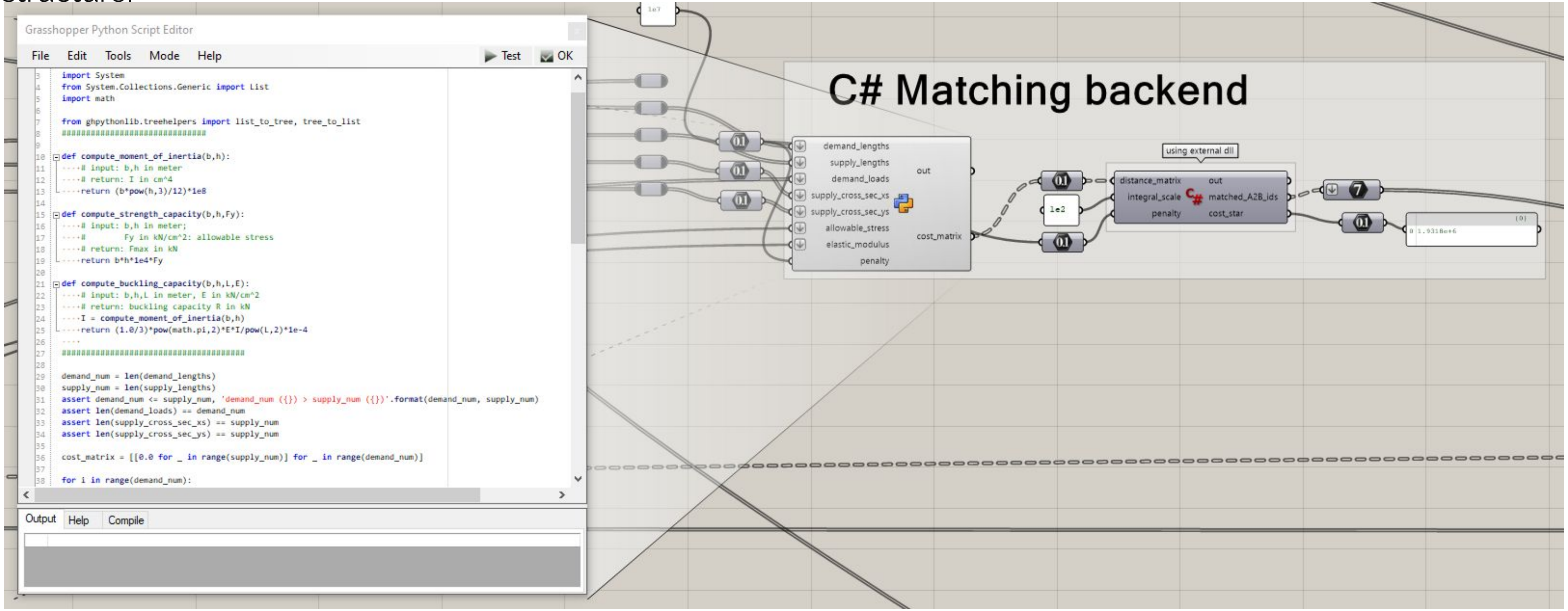
مطابقة
Matching

5 workflows(Layout -structural - matching -visualization)



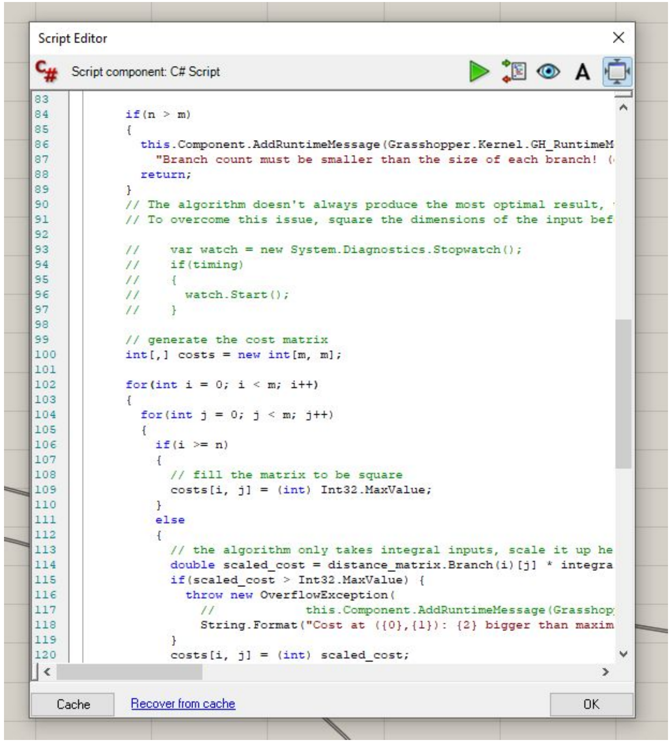
Creating the matching cost

The code calculates the cost matrix for assigning structural beams to different loads and lengths, considering constraints like length and capacity. It uses functions to compute beam properties and iterates through demand-supply combinations to determine costs, eventually converting the result into a Grasshopper data tree structure.



Using Hungarian Algorithm to solve the matching

The provided C# script implements the Hungarian Algorithm within Grasshopper for Rhino to solve assignment problems efficiently. It takes input parameters such as a distance matrix representing task-resource costs, scales the costs, and finds the optimal assignment. After validating the total cost against a penalty threshold, it outputs the matched assignments and total cost.



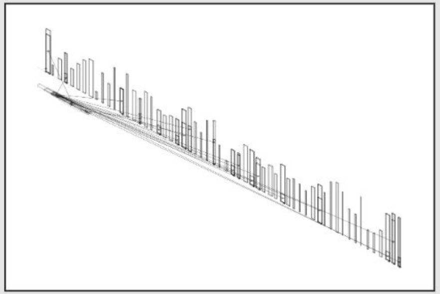
Code source for the hungarian algorithm:
https://github.com/yijiangh/algorithmic_circular_design

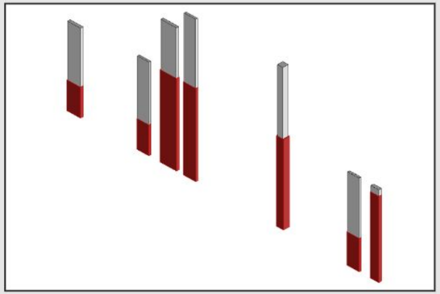
5 workflows(Layout -structural - matching -visualization)

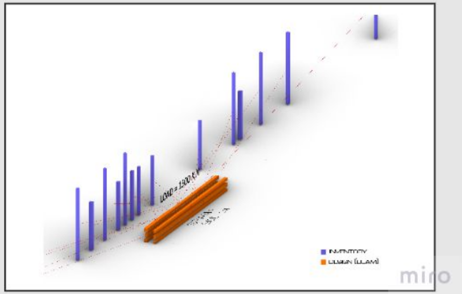
mark the matched members, from the Inventory

mark the required length from the total length of the beam

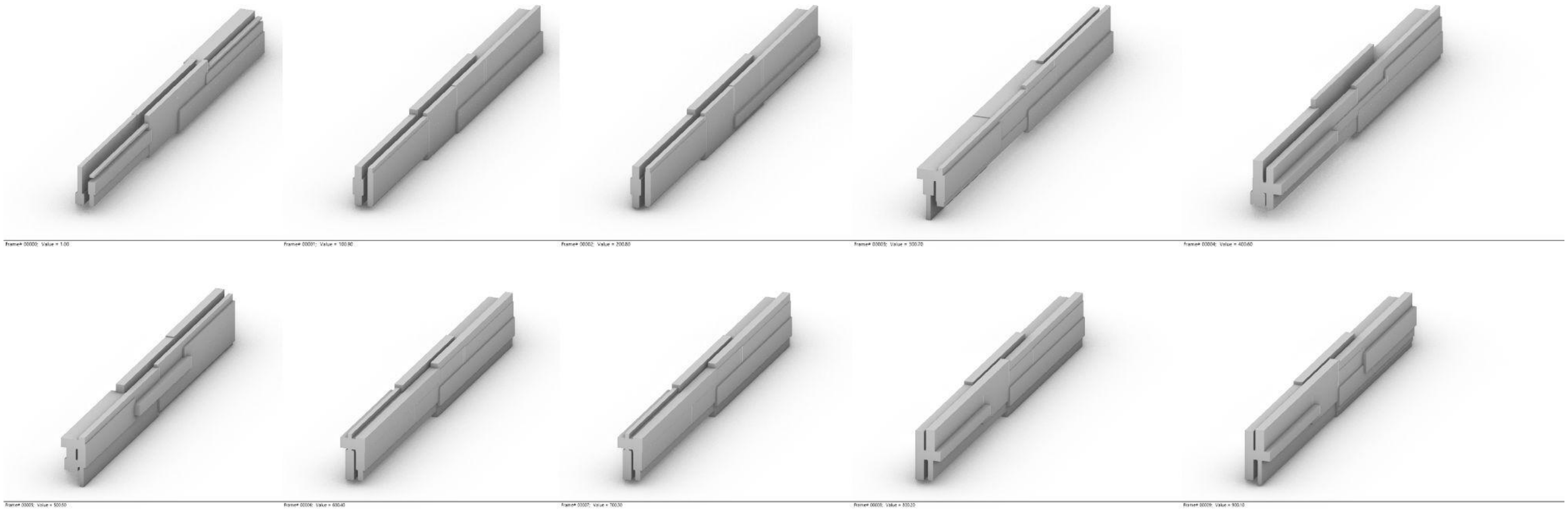
orient the trimmed object in its assigned place in beam layout



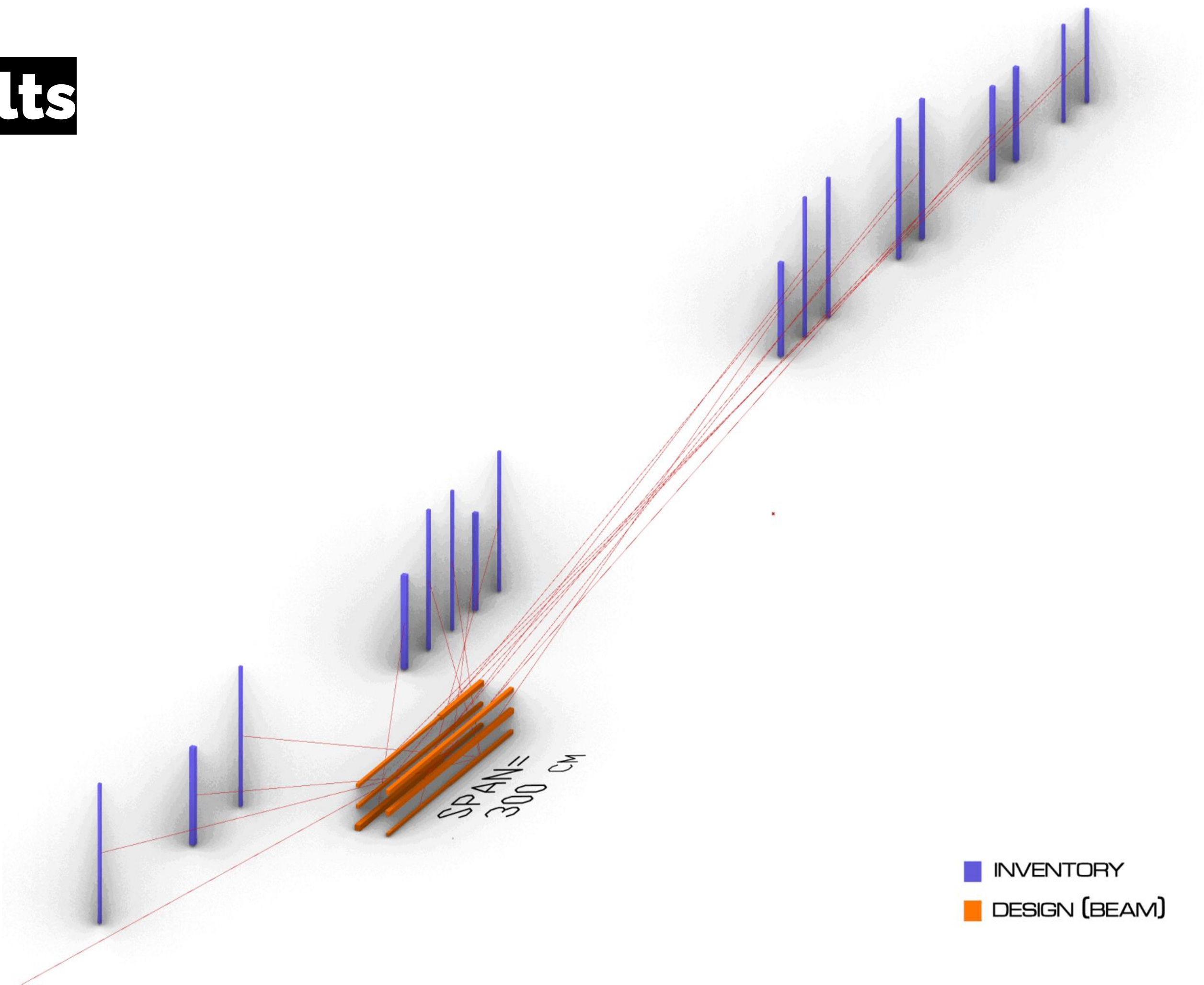




Creating the matching cost



Results



First phase of tests

المرحلة الأولى من التجارب

How to proceeds with the concepts

كيفية الإنتاج

How to produce

ماهية المنتج

What is the Results

How to proceeds with the concepts

What is the Product

IGST with different configuration

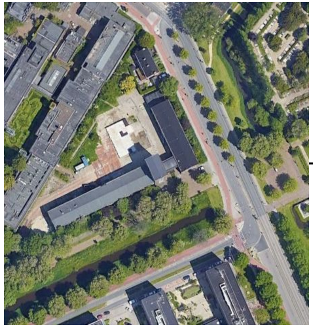
IGST from different Timber species

How to proceeds with the concepts

IGST from different Timber species

- **Hardwood/ Hardwood**
- **Softwood/ Hardwood**
- **Softwood/ Softwood**

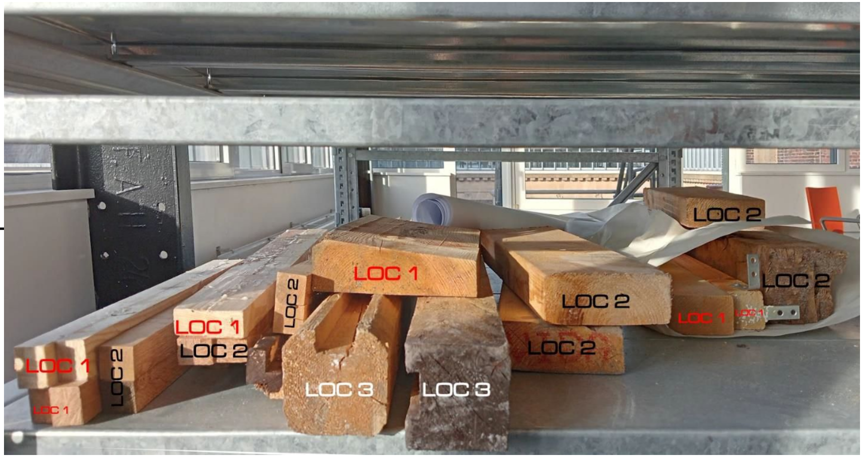
Collecting the timber



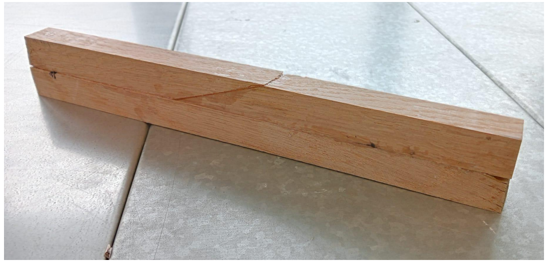
Prins
Bernhardlaan 6,
2628 BX Delft

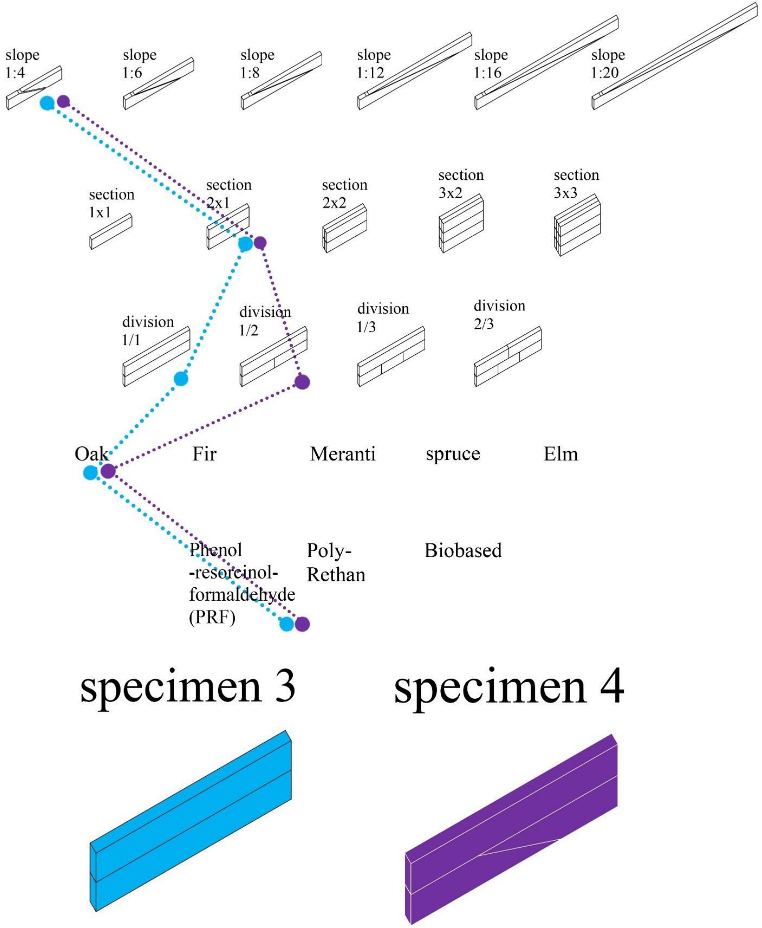
Julianala
an 134,
2628 BL
Delft

Van Hasseltlaan
2625 HS

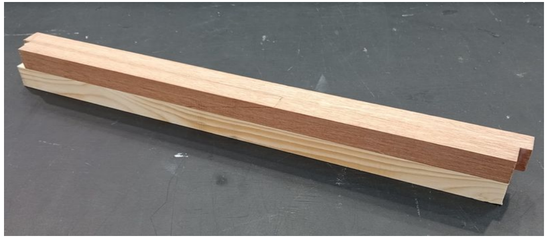


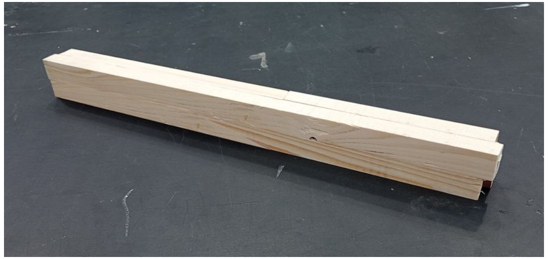
Sample 3, 4

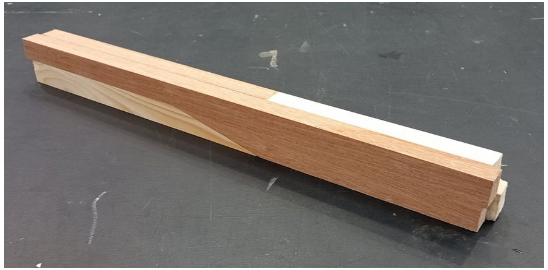


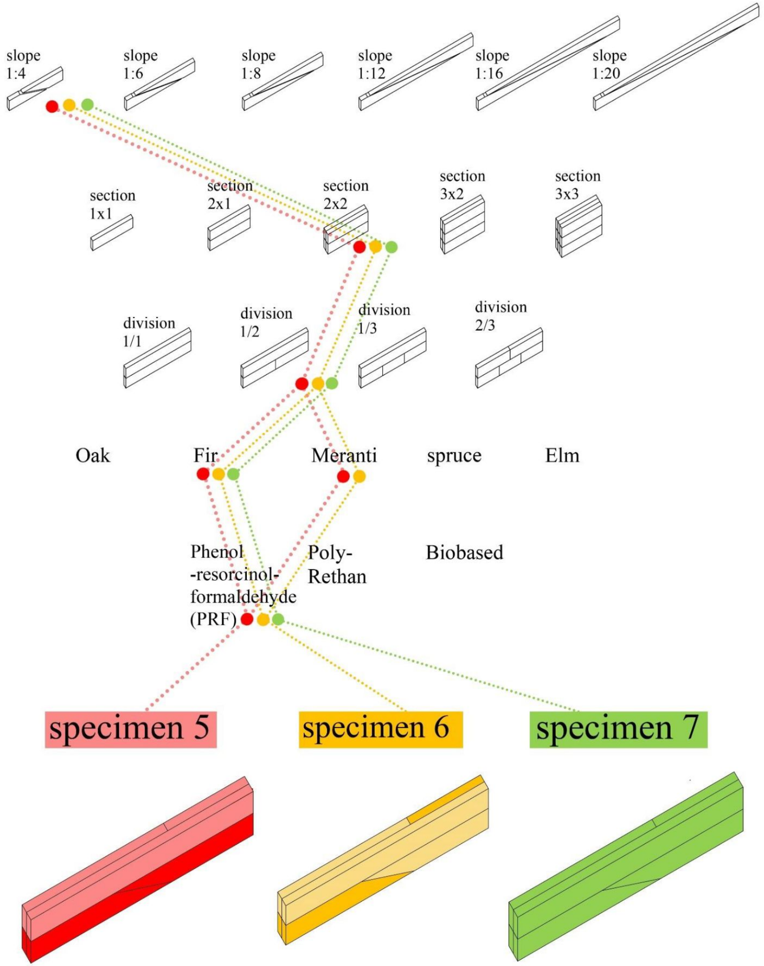

slope 1:4
slope 1:6
slope 1:8
slope 1:12
slope 1:16
slope 1:20
section 1x1
section 2x1
section 2x2
section 3x2
section 3x3
division 1/1
division 1/2
division 1/3
division 2/3
Oak
Fir
Meranti
spruce
Elm
Phenol -resorcinol-formaldehyde (PRF)
Poly-Rethan
Biobased
specimen 3
specimen 4

Sample 5,6,7







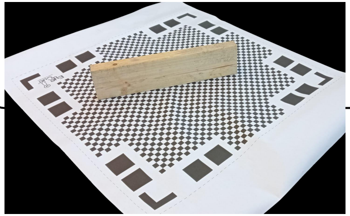

slope 1:4
slope 1:6
slope 1:8
slope 1:12
slope 1:16
slope 1:20
section 1x1
section 2x1
section 2x2
section 3x2
section 3x3
division 1/1
division 1/2
division 1/3
division 2/3
Oak
Fir
Meranti
spruce
Elm
Phenol -resorcinol- formaldehyde (PRF)
Poly- Rethan
Biobased
specimen 5
specimen 6
specimen 7

Manufacturing the specimens

Collecting the timber

assembly

Glueing the first two sample

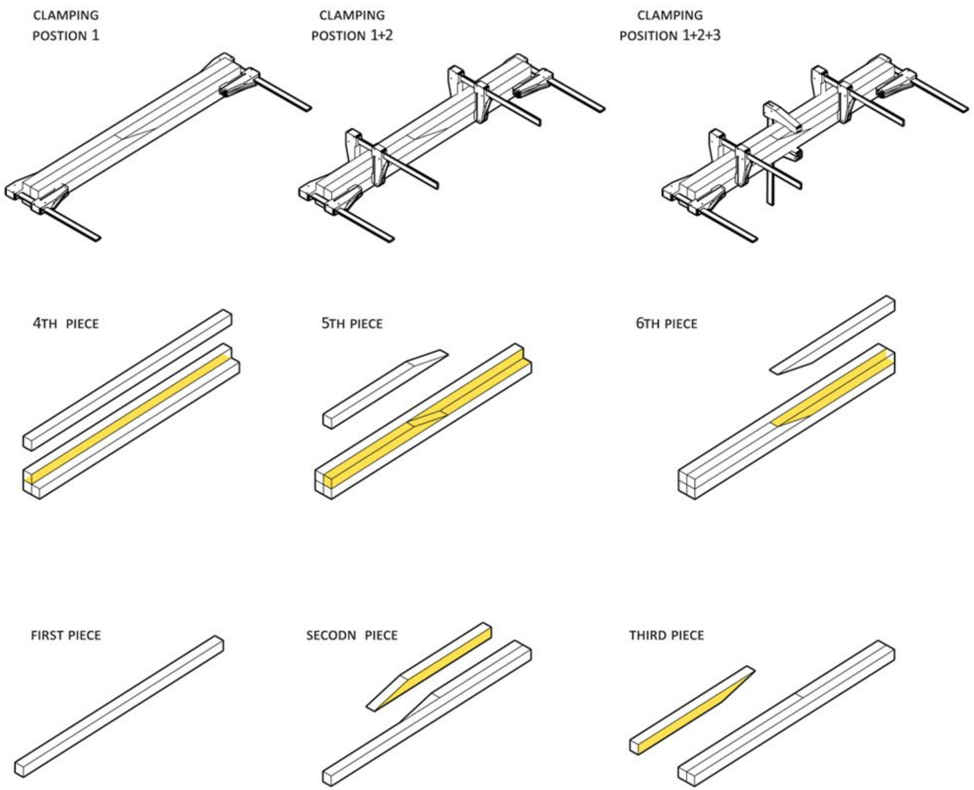


Scanning
and grading

Cutting and cleaning

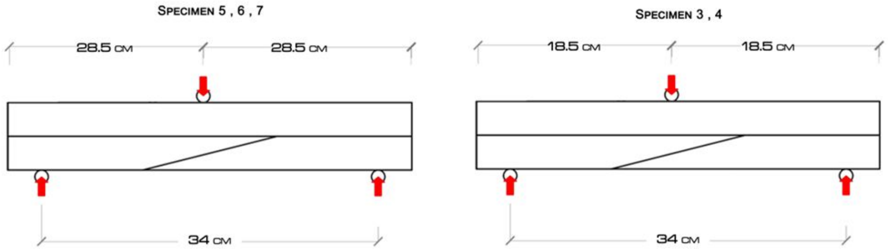
Glueing the first two sample

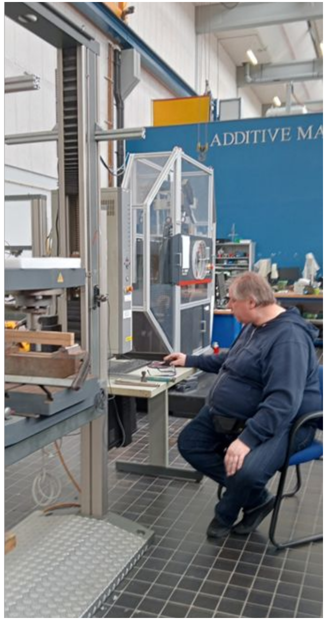
Assembly sequence:



Mechanical test

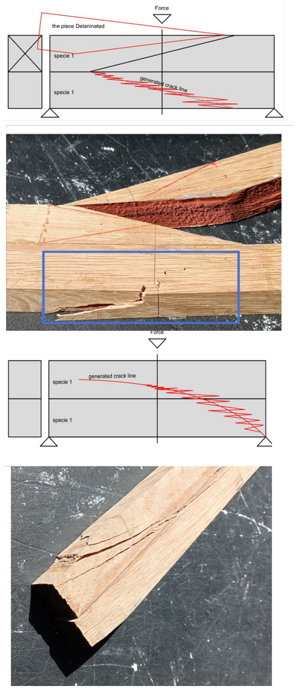
The 3-point bending mechanical test occurred in the 3ME faculty, in the lab of material mechanical behaviour, with the assistance of Dr. ir. F.A. Veer. The test utilized a low- and high-temperature tensile and fatigue testing machine with a span of 34 cm between the supports, a cylindrical pressure head with a diameter of 6 cm, and a pressure speed of 5 mm per second.

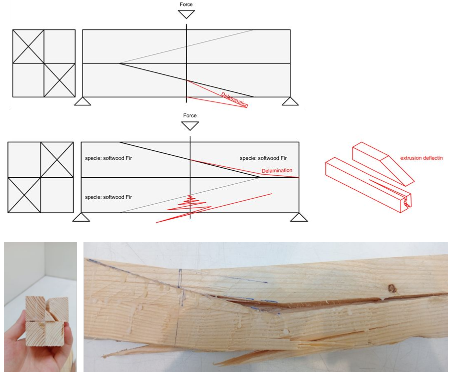


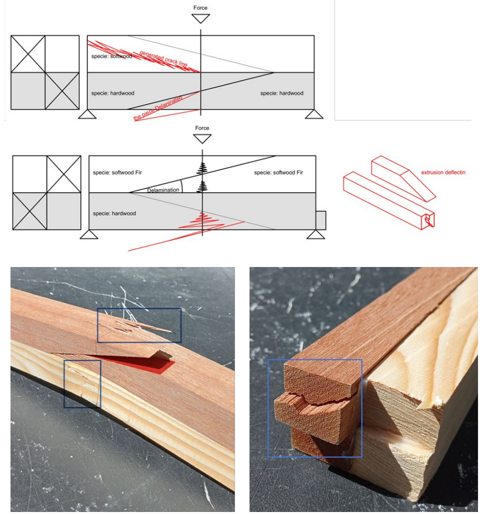


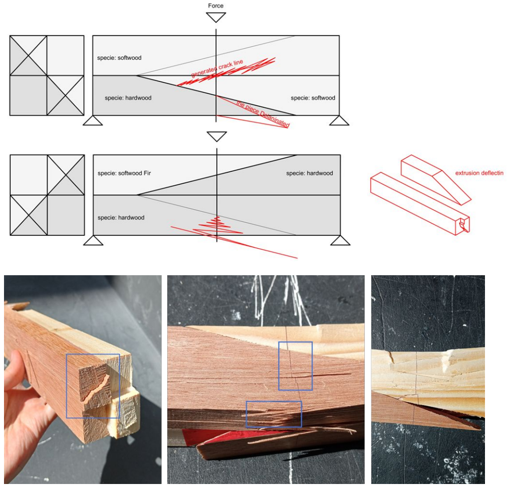
Mechanical test

Failures observations



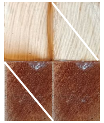


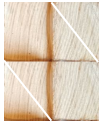


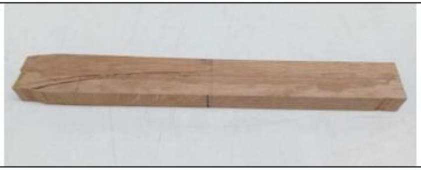


Failures observations

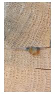
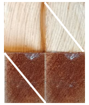
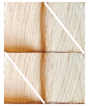




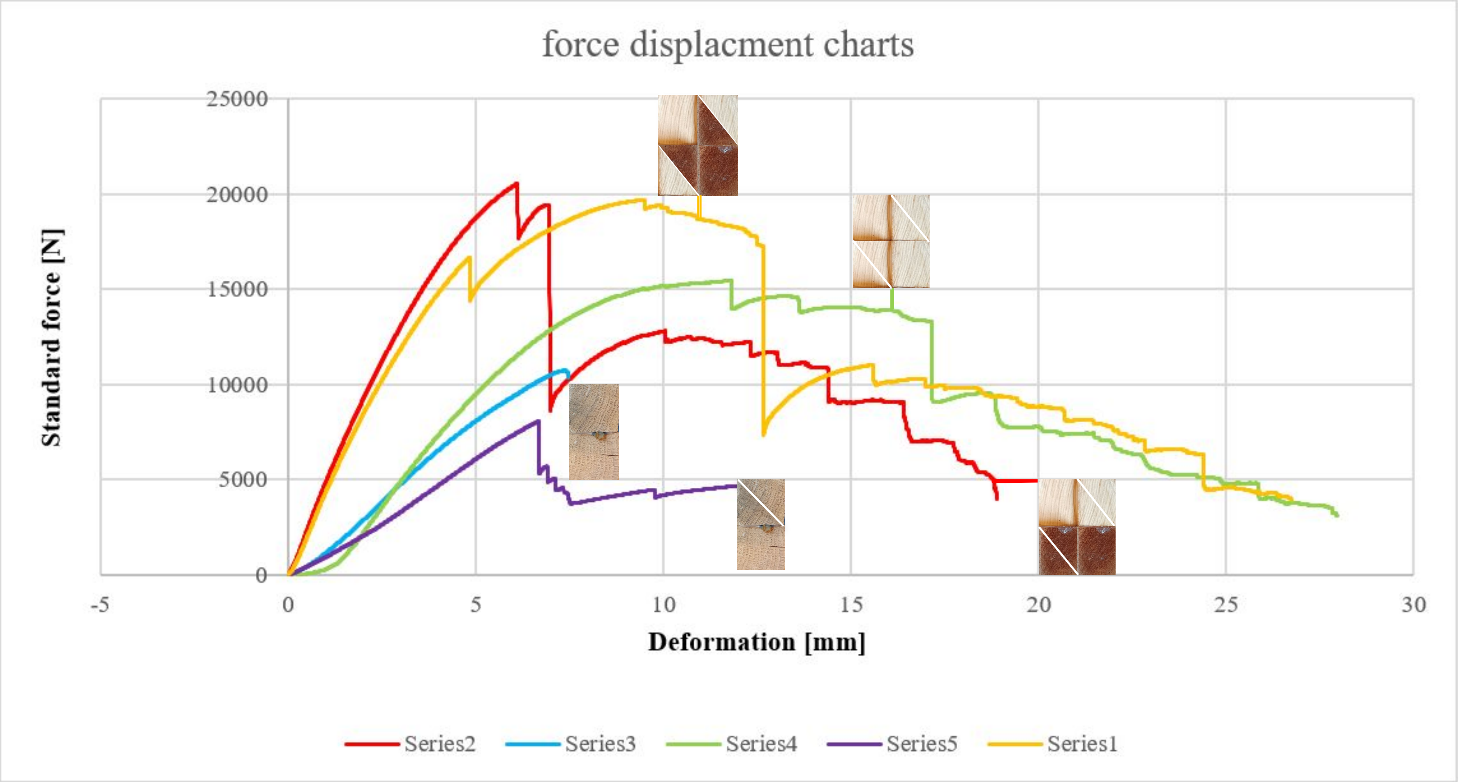


	CRACK IN THE MIDDLE	CRACK AT THE SUPPORT	LAMELLAS DELAMINATIONS	SCARF JOINT DELAMINATION	FIBER EXTRUSION	FIBER SPLIT	PHOTO
Specimen 3		×					
Specimen 4	×		×				
Specimen 5	×			×	×		
Specimen 6	×			×	×		
Specimen 7	×		×	×		×	

Breaking test results

		F_{max}	dL at F_{max}	F_{Break}	dL at break	a_0	b_0	S_0
		N	mm	N	mm	mm	mm	mm^2
	Specimen 3	10739.19	7.363589	10363.42	7.445922	100	100	10000
	Specimen 4	8088.012	6.674073	4688.503	11.99171	100	100	10000
	Specimen 5	20574.39	6.110257	3984.609	18.87277	100	100	10000
	Specimen 6	19697.14	9.479986	3933.534	26.73088	100	100	10000
	Specimen 7	15463.81	11.81508	3092.065	27.96162	100	100	10000

Results


force displacment charts
Standard force [N]
25000
20000
15000
10000
5000
0
-5
0
5
10
15
20
25
30
Deformation [mm]
Series2
Series3
Series4
Series5
Series1

Results:

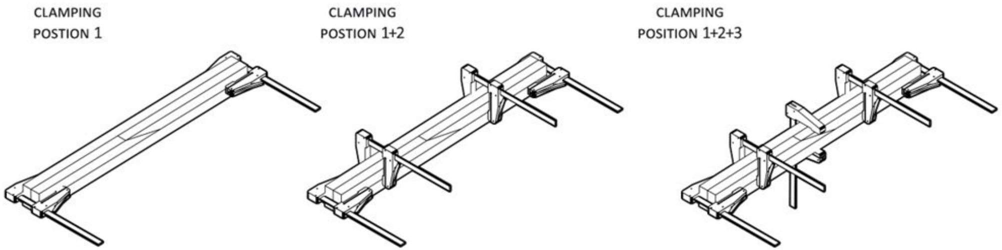
- Except for Specimen 3, all specimens show a sudden drop in applied force after lower lamella breakage due to lamination issues and specimen anatomy.
- Following the drop, pieces exhibit non-linear elastic behavior as strain transitions from lower to upper lamella. This behavior is most evident in Specimens 5 and 6, where lower lamella is mostly hardwood. Specimen 4 shows less clear non-linear elastic behavior, while Specimen 7, made of a single piece with uniform stiffness, does not exhibit prominent non-linear elastic behavior.
- Specimen 5 displays the highest stiffness, enduring over two tons before breaking, while Specimen 6 remains in the elastic range for a longer period despite reaching higher deformation values before failure.
- Specimen 7 experiences the longest period of plastic deformation before failure.

Key consideration(Glue)

- Careful consideration of glue selection and application is crucial, focusing on the type and quantity of adhesive used in the lamination process.
- Positioning of clamps and surface treatment techniques are equally important factors impacting specimen performance.

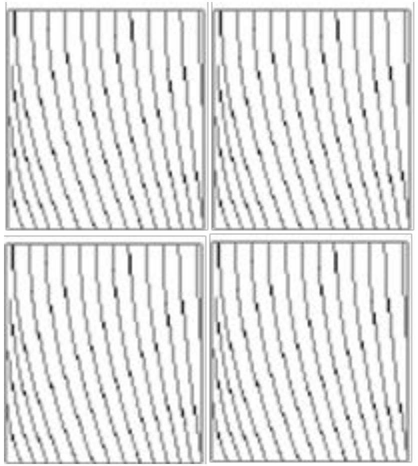
The type of glue used for the previous experiment

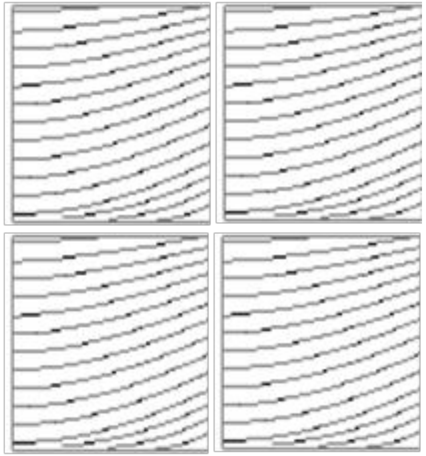
The proposed glue for future experiments



Key consideration(grain)

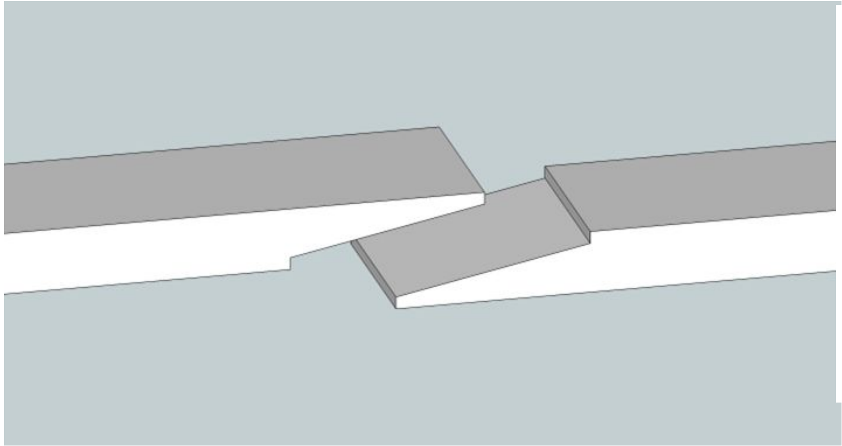
- Grain orientation is critical, especially in four-lamella specimens.
- Tearing of fibers in the lower lamella due to compression forces can occur.
- To prevent this, avoid diagonal grain orientation in the lower lamella.
- Promoting uniform grain direction across all lamellas enhances structural integrity.

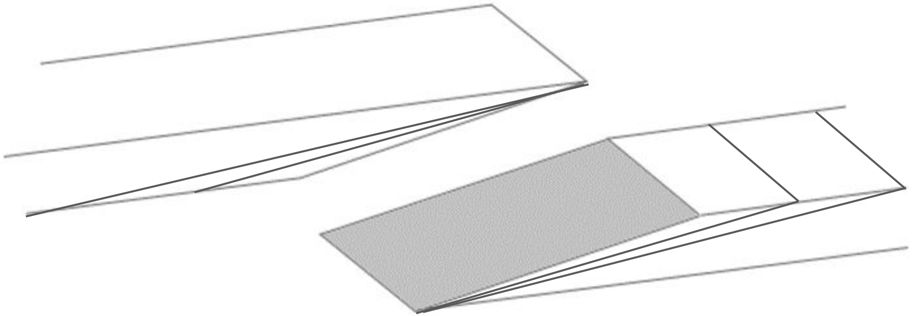




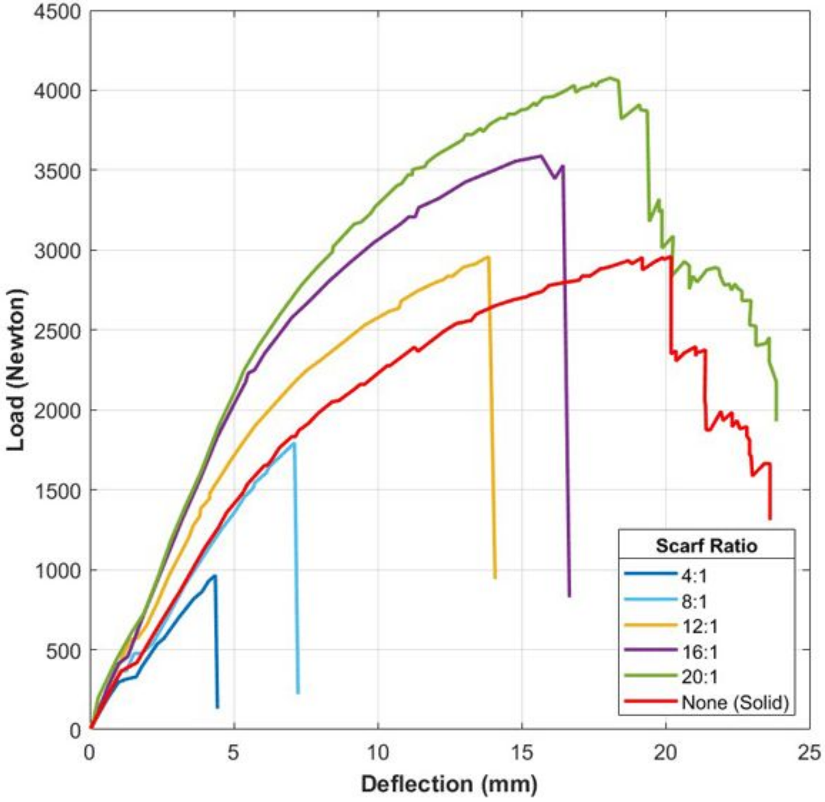
Key consideration(slope)

- Enhancing scarf joints is crucial to minimize delamination.
- Using a nipped scarf joint instead of a plane scarf joint can improve connection integrity.
- This modification reduces the risk of delamination, enhancing overall structural robustness.





Key consideration(slope)

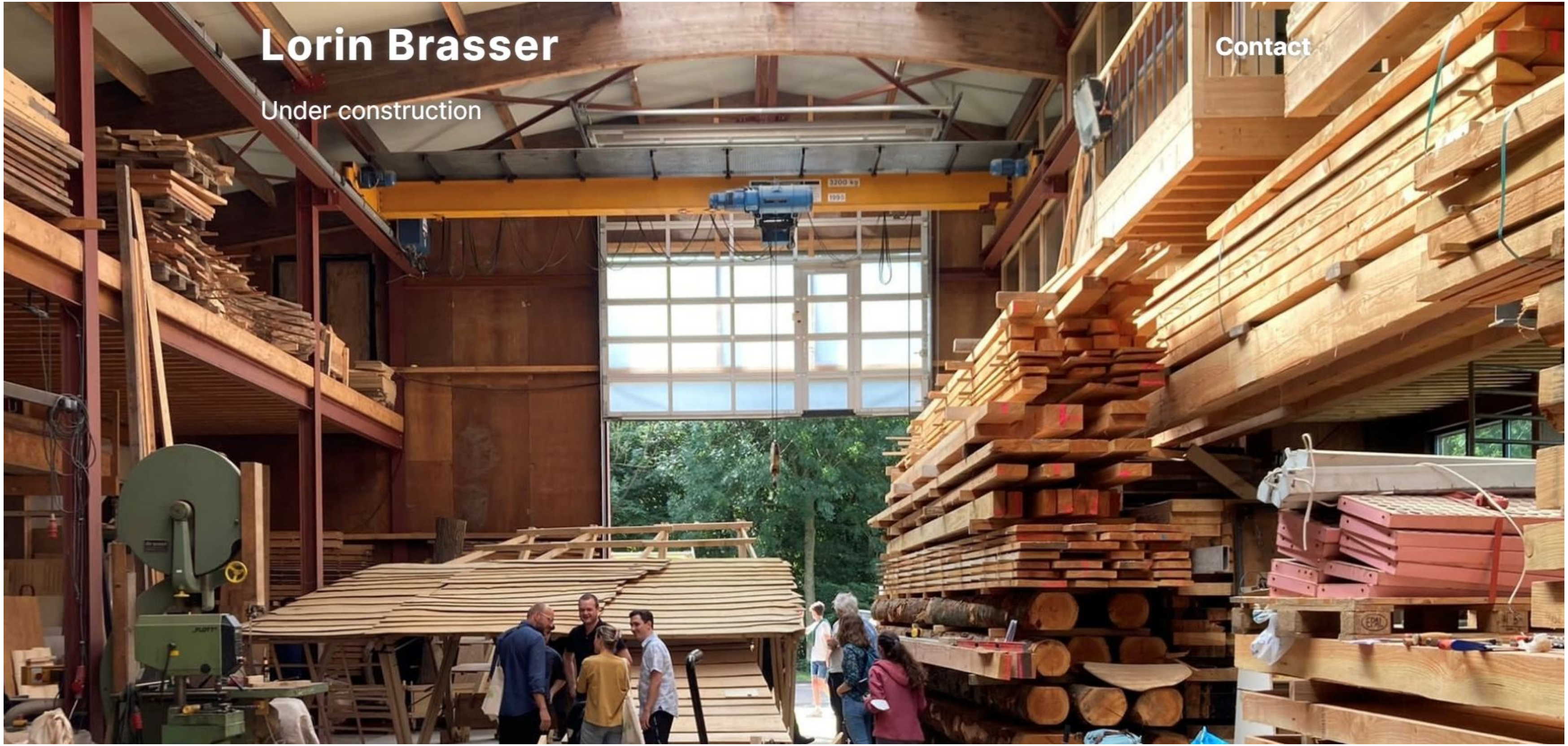


Mechanical Properties		Ultimate Flexural Strength (MPa)	Young's Modulus (MPa)
ABS Yachts (2017)		66.00	10,000
ISO 12215-5 (2019)		77.00	12,060
Experimental	Solid Timber	73.51	11,980
	4:1 Scarf	18.28	8,045
	8:1 Scarf	38.86	10,270
	12:1 Scarf	48.72	12,379
	16:1 Scarf	93.43	14,486
	20:1 Scarf	96.11	15,250

المرحلة الثانية من التجارب

second phase of tests

Second phase of experiments



Second phase of experiments

What is the Product

IGST with different configuration

IGST from different Timber species

Second phase of experiments

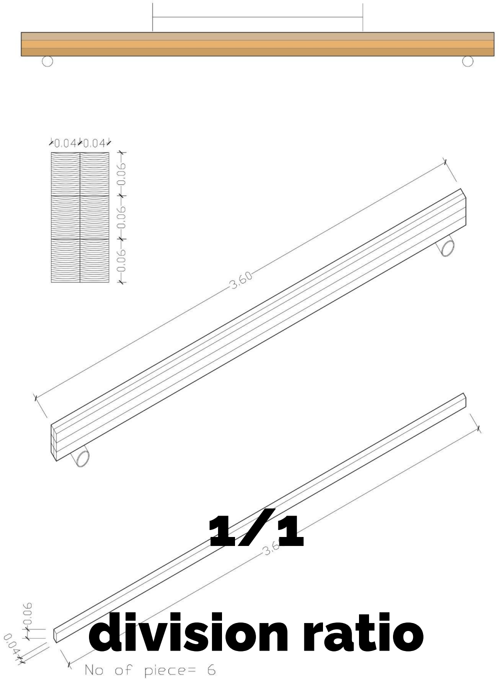
From design constraints to layout Workflow

The results of first phase experimen Scarf joint and Glue

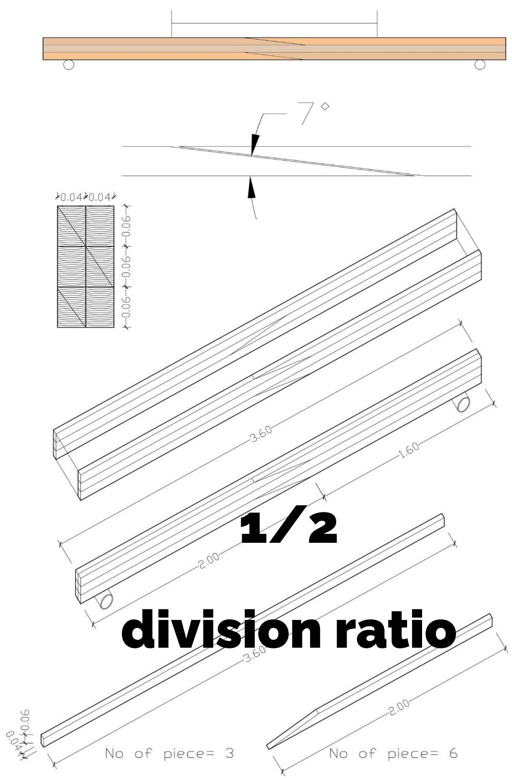
IGST with different configuration

1/1	1/2	2/3
division ratio	division ratio	division ratio

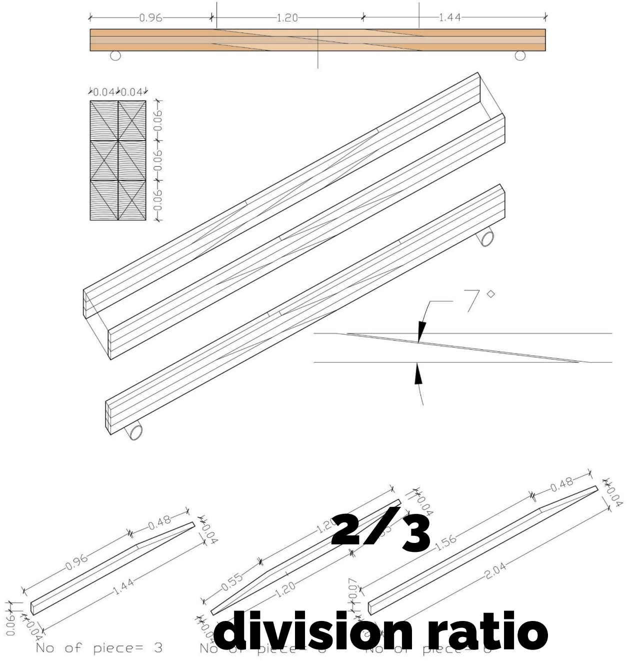
Developing specimens:



1/1 division ratio

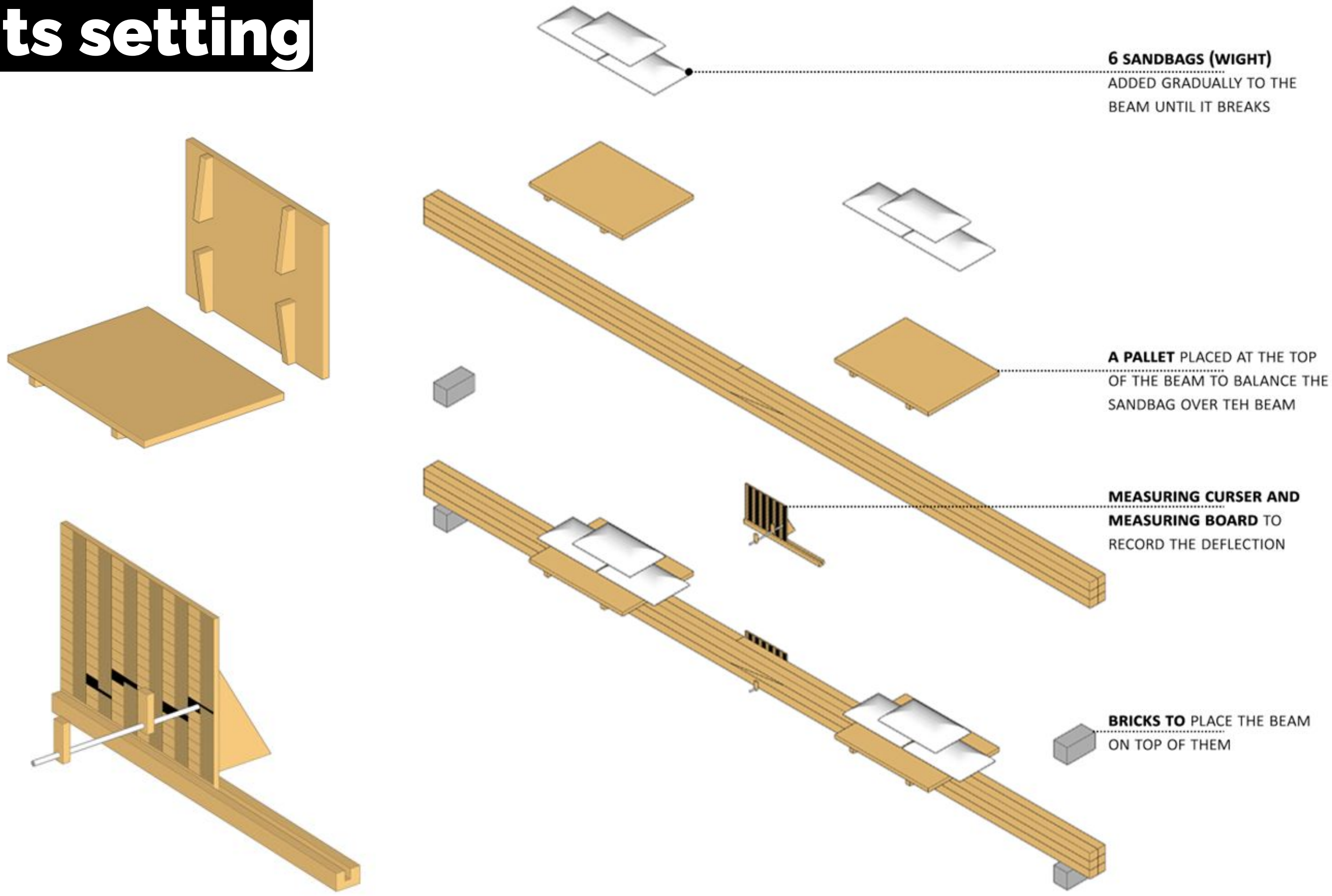


1/2 division ratio



2/3 division ratio

Experiments setting



Hypothesis

We hypothesize that in interlocking solid glued timber beams made from reclaimed stocks, increasing the number of lamellas and joints will increase strength. Additionally, the placement and slope ratio of the joints will significantly impact beam performance and strength

- How does the number of lamellas affect the strength of interlocking solid glued timber beams produced from reclaimed stocks?

- How do the quantity and placement of joints influence the overall strength of these beams?

On site Visual grading

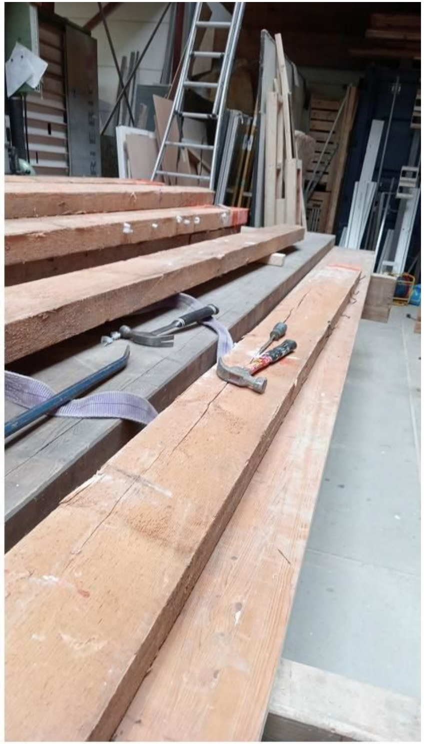
CONTINIOUS GRAIN
(PREFERED)

RAIN INTEREPTED BY BIG
KNOTS (AVOIDED)

AVOIDED ROT

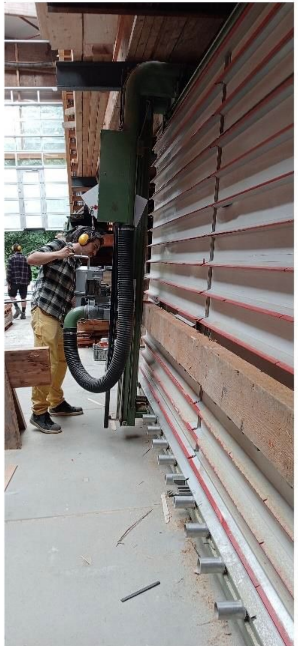
SEPERATING THE CHOSEN PIECES FROM THE VISUAL FIELD-GRADING

RUSTY SCREWS STUCK INSIDE THE FIBERS



DURING THE PROCESS OF CLEANING

Cutting and Planning



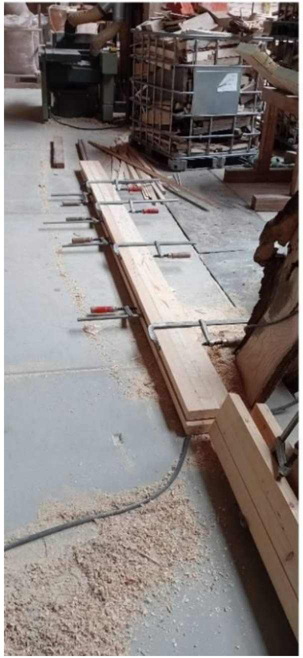
USING THE VERTICAL WALL SAWY TO CUT THE PIECES

USING THE PLANNER TO PLAIN THE PIECES IN SHAPE

USING TH TABLE SAW TO CUT THE BIGGER PIECES

BUNNDLE OF LAMELLA READY FOR LAMINATING

Dry fitting



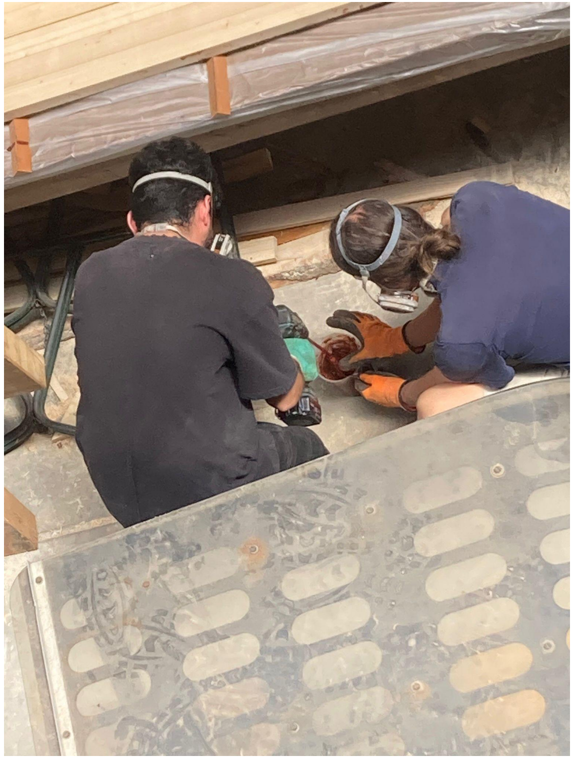
AGGREGATE THE DRY FITTED PIECES CLAMPS TO MOVE IT TO THE WORKING BENCH

PLACING THE PIECES ON THE WORKING BENCHES AND PLANNING THE THE CUT

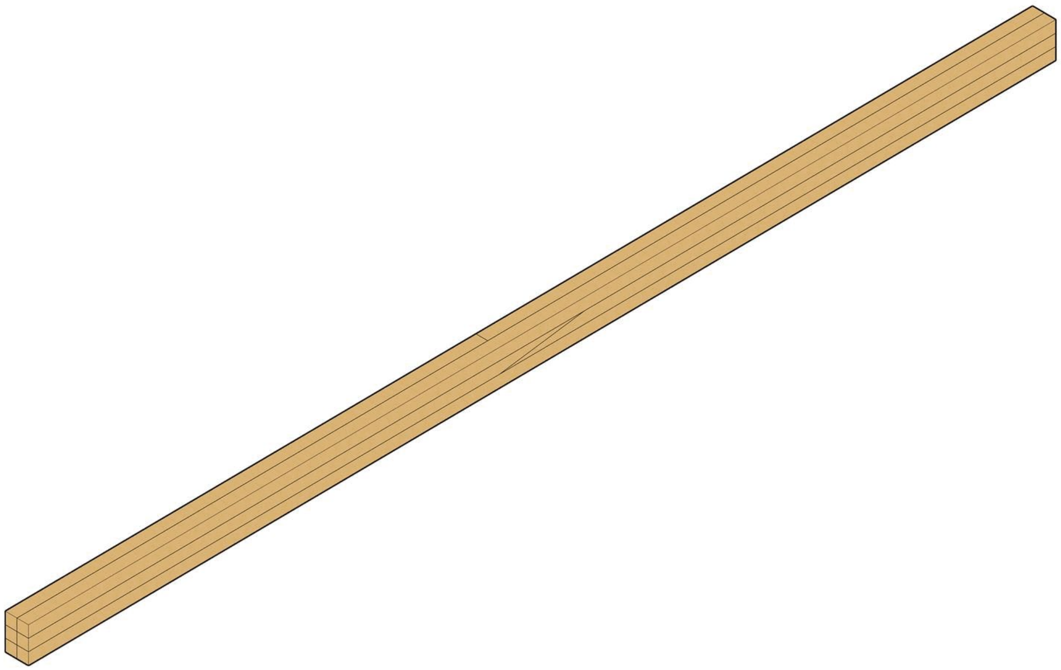
CHECKING THE MOISTURE CONTENT BEFORE LAMINATING

DRY FITTING , AND DOUBLE CHECL THE SIZE OF THE PIECES

Preparing for Lamination



Preparing for Lamination

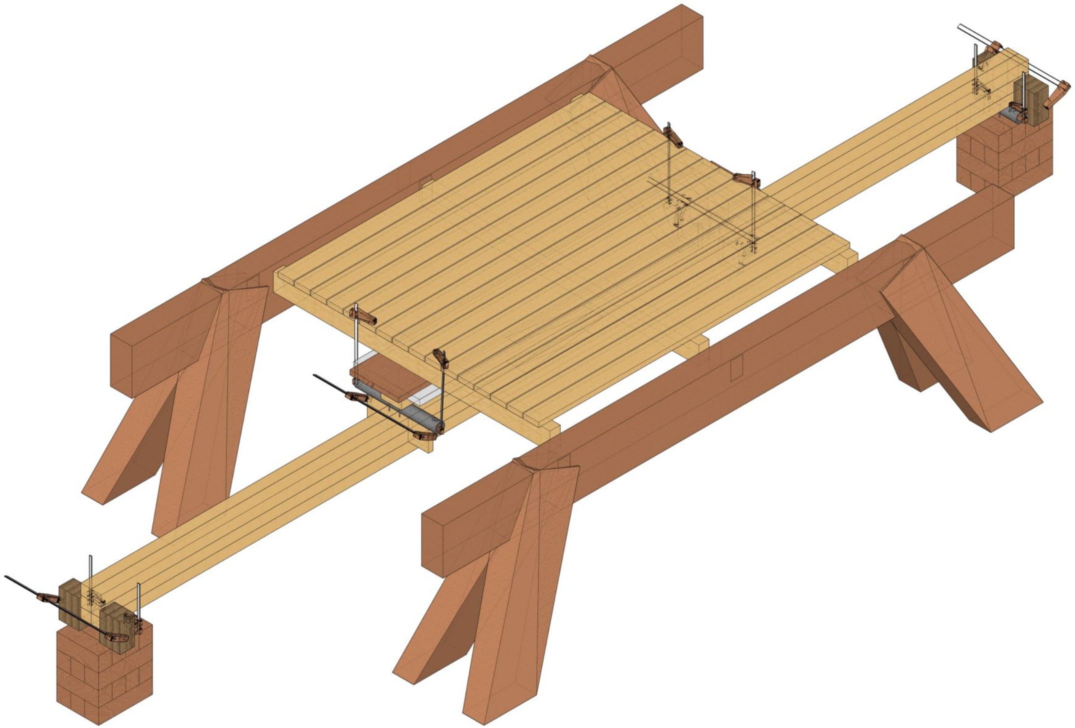


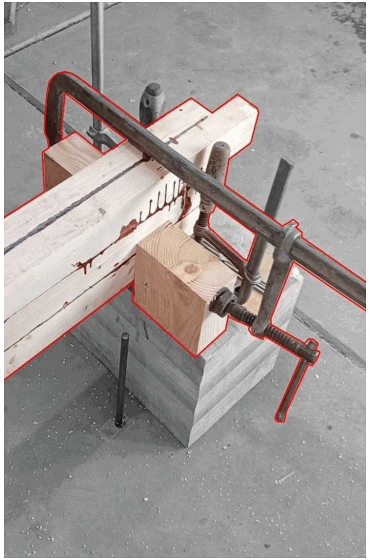
READY TO TEST

10 minutes + 10 Minutes

Drying 5 hours to one day

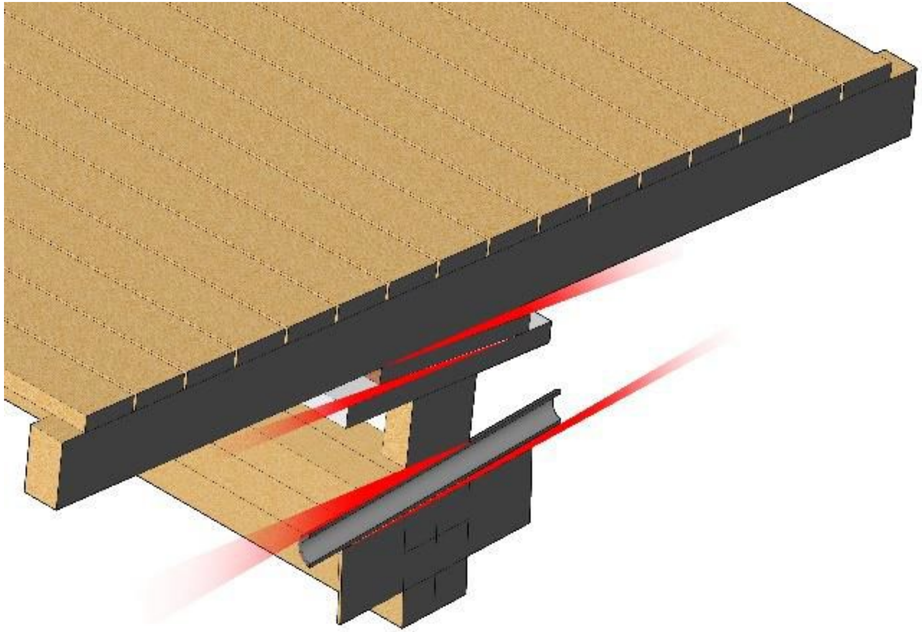
PREPARING AND BALANCING THE TEST SETTING



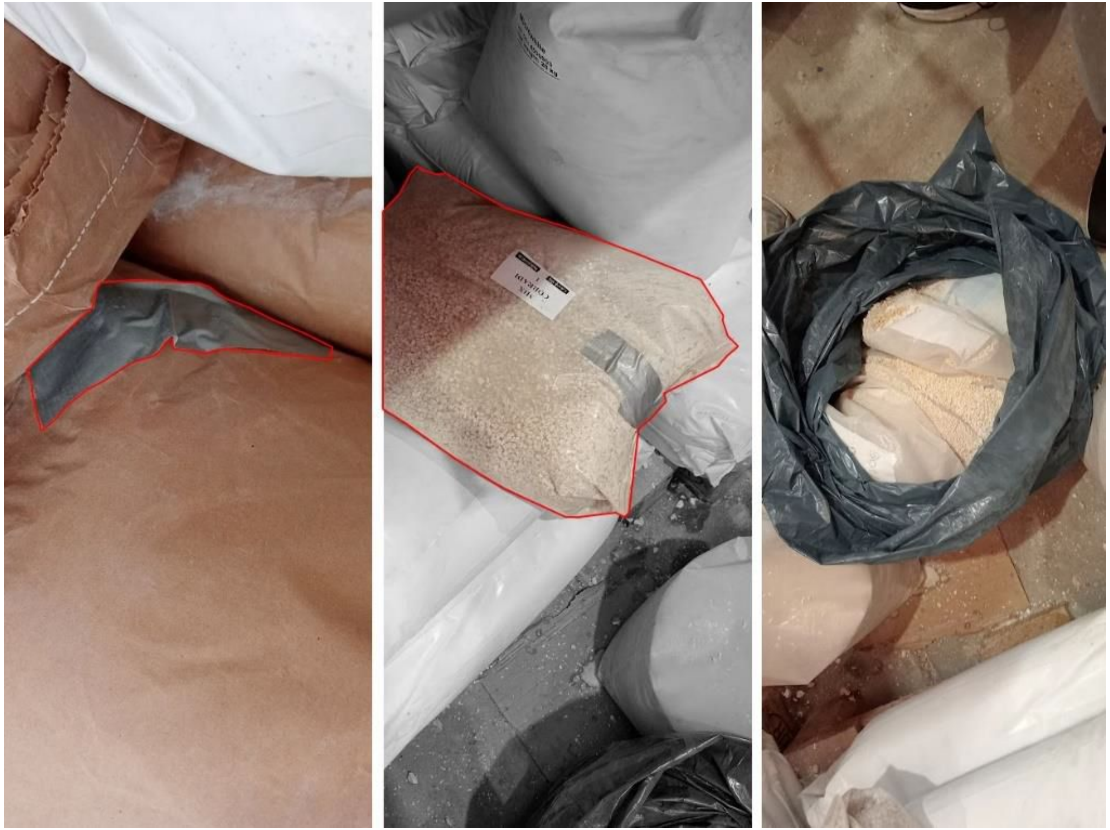


Using sand bags the loads

Tolerance and movement, an accurate



Sand bags gets torn through the process



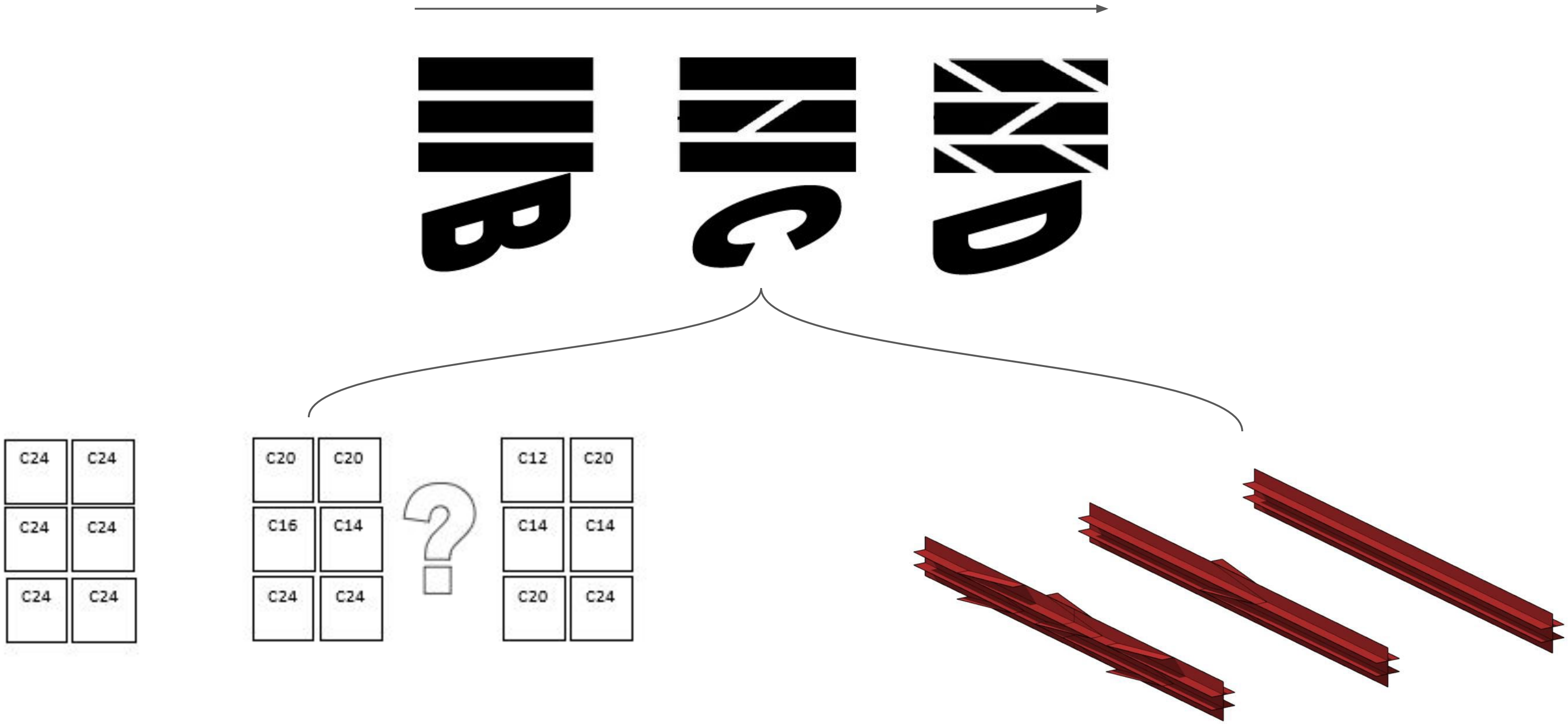
Using water tank for the load

Using water tank for the load

PREPARING AND BALANCING THE TEST SETTING

Speci-men	P	a	E	I	L	#DIV/0!	Inst SLS	Stat SLS	Max meas-ured def
D	10000	1.2	11000000000	0.000038	3.6	0.039617225	0.0072	0.012	**0.015**
	4000	1.2	11000000000	0.000038	3.6	0.01584689	0.0072	0.012	**none**
C	10000	1.2	11000000000	0.000038	3.6	0.039617225	0.0072	0.012	**0.016**
	4200	1.2	11000000000	0.000038	3.6	0.016639234	0.0072	0.012	
A	10000	1.2	11000000000	0.000038	3.6	0.039617225	0.0072	0.012	**0.021**
	5200	1.2	11000000000	0.000038	3.6	0.020600957	0.0072	0.012	**0.015**

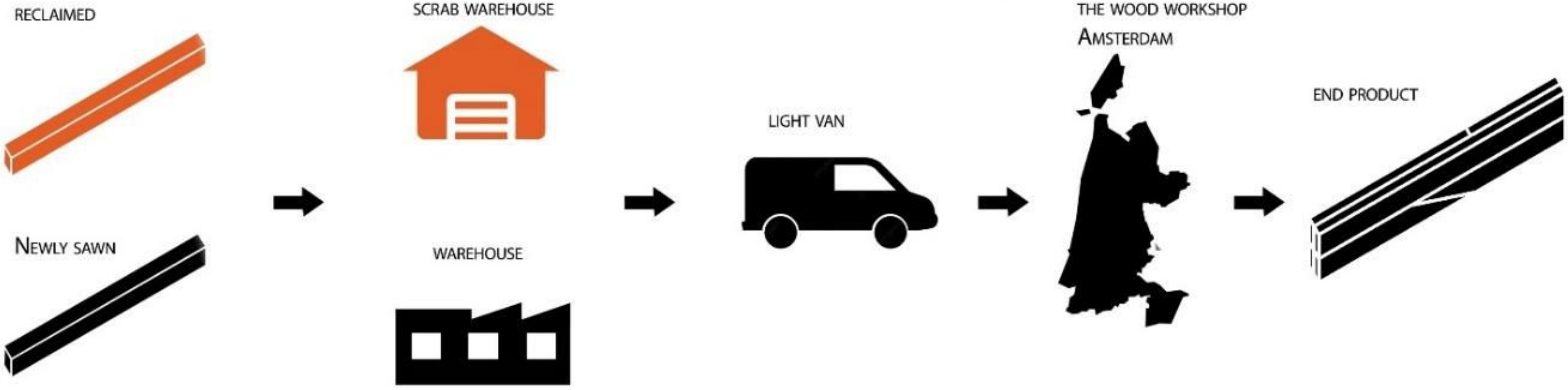
REASONING



B
C
D
C24 C24
C24 C24
C24 C24
C20 C20
C16 C14
C24 C24
?
C12 C20
C14 C14
C20 C24

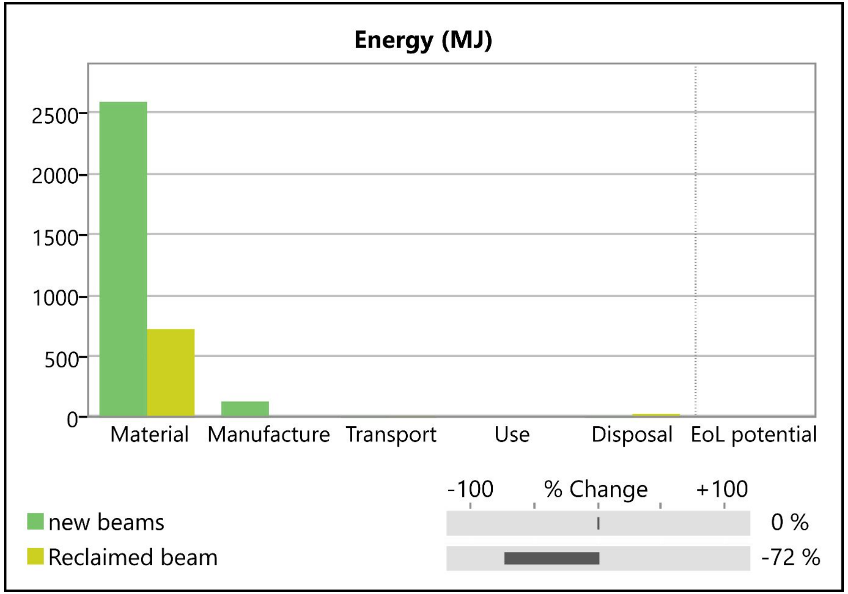
Environmental impact reclaimed vs New

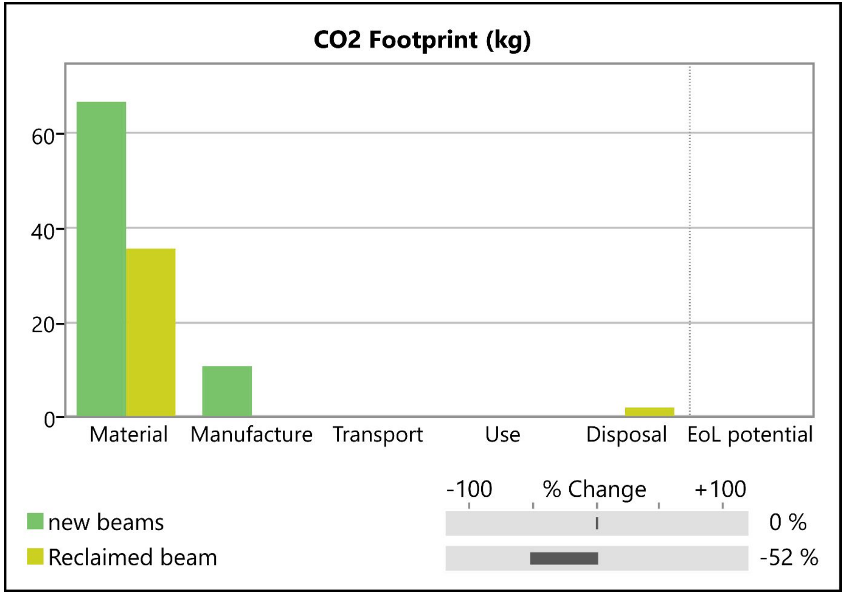
Defining a simple scenario that represent both source



Environmental impact reclaimed vs New

Using Granta Edupack Eco_Audit tool





conclusion:

IGST from different
Timber species

HardwooD/
Hardwood

Softwood/
Hardwood

Softwood/
Softwood

The results of first
phase experimen
Scarf joint and Glue

From design
constraints to
layout Workflow

IGST with
different
configuration

1/1

1/2

2/3

Structure Demand
workflow

conclusion:

From Literature

- Reclaimed timber has significant potential to fill the gap in structural materials due to current environmental challenges.
- The key aspect of using reclaimed timber is the regrading process; more tools and methods adopted by salvagers enable its structural use.
- IGST timber shows great potential as an engineered wood product (EWP), especially with larger sections allowing for wider spans than current EWPs.
- Despite the simple manufacturing techniques of IGST, optimizing production is complex, involving factors like the number of lamellas, slope of the scarf joint, timber species, and glue type.
- Literature indicates that for low-density timber like spruce, a higher slope for the scarf joint is preferable, ideally avoiding an 8:1 slope ratio.
- The number of lamellas is also crucial; more lamellas in the section typically provide better strength, though further investigation is needed.

conclusion:

From workflows:

- The developed workflow successfully selected the right piece from a dataset of regraded elements based on load and length demand.
- However, it does not optimize the overall IGST performance, as it needs to consider the slope of the scarf joint and the effect of the glue used.
- Integrating these factors and environmental impact calculations into the computational process would provide a more comprehensive analysis.
- Including all these parameters requires a more complex parametric model and a matching algorithm that can consider multiple aspects for accurate results.

conclusion:

From first phase experiment:

- Laminating different timber species can improve structural performance.
- However, delamination at the scarf joint with two timber species is a major issue. The connection should be modified by adjusting the slope or using a nibbed scarf joint, which requires more precise cutting.
- Future research should include FEA to analyze force distribution within the joist, helping to understand why failures like extrusion occur in specific locations.

conclusion:

From second phase experiment:

- Initial results of the 4-point bending test show that having more elements in a joist positively impacts beam performance.
- A homogeneous grade along the section improves performance, but splitting into smaller sections can cause waste.
- Using larger sections to manufacture IGST minimizes waste from regrading.
- Improved structural performance with more pieces may be due to the increased glue, which strengthens the fibers.
- The first three elements used epoxy resin-based glue, which is strong but hinders circularity. We are now testing a new piece with bio-based glue.
- Controlled destructive tests are essential to check the ULS of SLS beams. DIY testing systems have many flaws, affecting reliability and worker safety.

- The experiments will be extended to understand the potential of IGST with different glues and compare it with other EWP.

شكرا

Thank you