ARCHITECTURAL STRUCTURE

Week 3: Timber Structure

Photo by Miikka Luotio on Unsplash

Outline

1

INTRODUCTION

Aims

LOs

2

LECTURE:

- **TIMBER AS MATERIALS**
- **TIMBER AS STRUCTURAL COMPONENT**
- **TIMBER CONSTRUCTION**

3
SEMINAR:

CASE STUDIES
SHARING SESSION

4
SUMMARY
REFLECTION

- UPLOADING
STUDY MATERIALS TO
DISQUS

Aims and objectives

- To gain understanding on timber as **building materials** and its characteristics
- To learn about timber as main **structural materials**
- To expand on timber within **construction system**

Learning outcomes

Students will be able to..

01 Understand strength and weaknesses of timber as building materials

02 Potentially incorporate the use of timber in future projects

03 Become aware of structural behaviour of the material

Previously in Week 2..

Mia Tedjosaputro Mod · 4 days ago

Elijah F18511003

I don't know how to post my comment on the website yet, but this is what I learnt from yesterday's class 1. Learning the history of a building helps us a lot in our design as we can get to know what is and what isn't possible 2. I learnt the different use of materials to change the general Aesthetic of the building 3. I did some research on cantilevers and learnt a lot about them as well as exoskeleton structures 4. I learnt about structural patterns and grids, with references to old cathedrals 5. And finally I did some group work with my classmate and that was fun too

Reply · Share ›

Mia Tedjosaputro Mod · 4 days ago

CHITUNDU SHULA. F18511011
WEEK 2

WHAT I LEARNT FROM THIS WEEKS LESSON?
• The importance of appreciation previous historic architecture milestones cause its through these concepts of the past our modern day architecture is rooted in.
• The pre historic architecture systems help us or rather teach us the most effective support systems cause these different methods have been tried there fore we can tell which ones help the building more durable.
• In the prehistoric different types of materials where used some of which are still used today in improved and more efficient designs
• Different means are used to ensure a building reaches its centre of gravity the point to which it is most stable such as cantilevered structure
• Different support systems are used to ensure the building is able to stand such as columns and panel systems.

Reply · Share ›

Mia Tedjosaputro Mod · 4 days ago

Yassine Fath

Personal reflection:
Today's lecture was about the historical background of structural architecture . We went trough the old period of when man kind was ignorant about the science of structure engineering and was making buildings (shelters) constantly just for protection, until the very first civil engineering practice in history (1742) , up until now days .
Also the research we maid about the law of the lever and centre of gravity give me a basic idea about cantilever structure and the mechanism behind it.

Reply · Share ›

Part 1:
Timber as materials

1. Historical reference
2. Timber processing
3. Characteristics of timber as a material
4. Types of timber for building industry
5. Sustainability

Photo by Brian Simcoe on Unsplash

Historical reference

Ancient Egyptians produced furniture, sculptures, coffins and death masks from 2500BC.

Headrest, Ancient Egyptian | Mia (artsmia.org)

Dinwoodie, J. M. (2000). *Timber: its nature and behaviour*. CRC Press.

Historical reference

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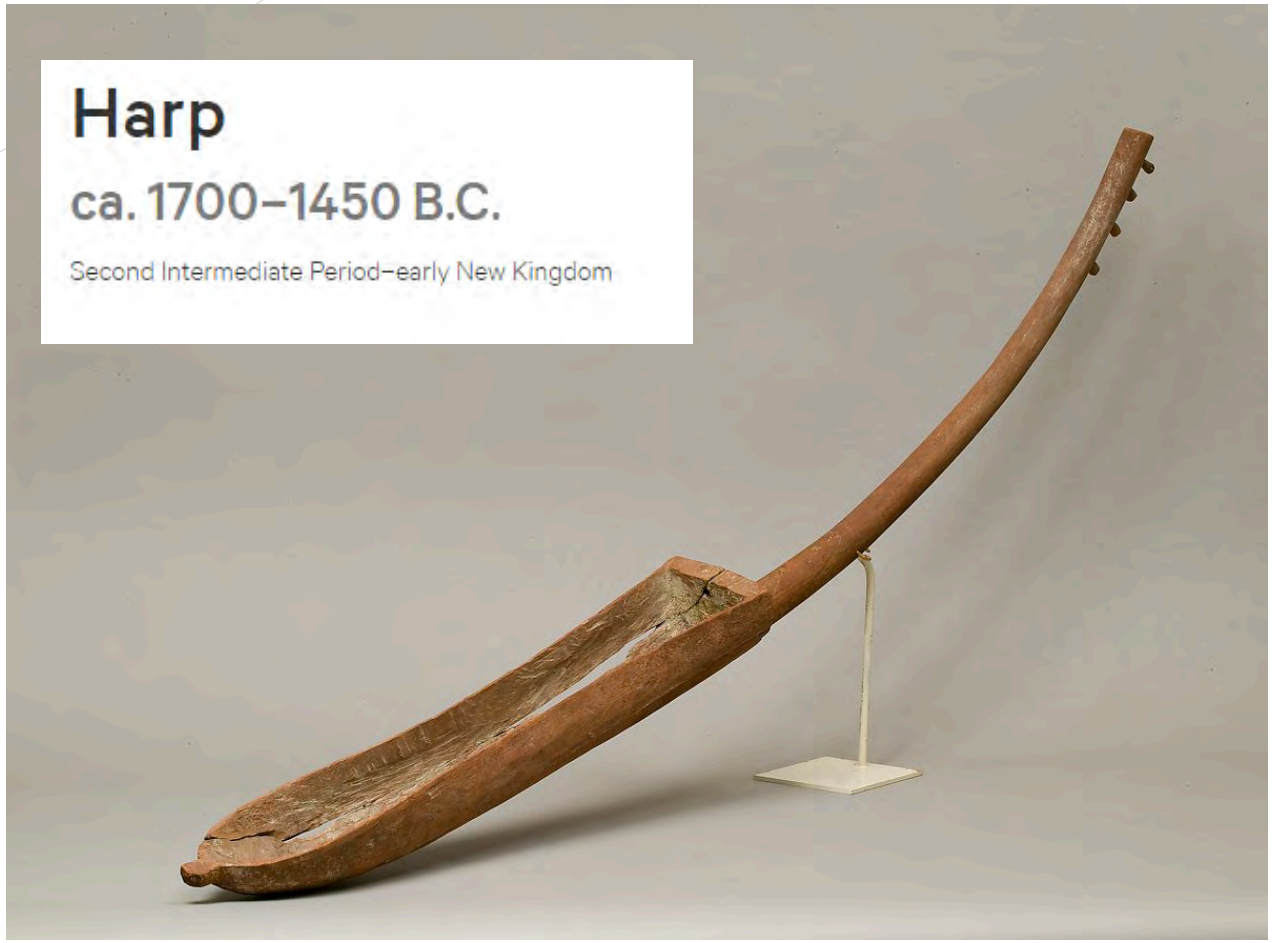


https://www.metmuseum.org/art/collection/search/561518

Dinwoodie, J. M. (2000). *Timber: its nature and behaviour*. CRC Press.

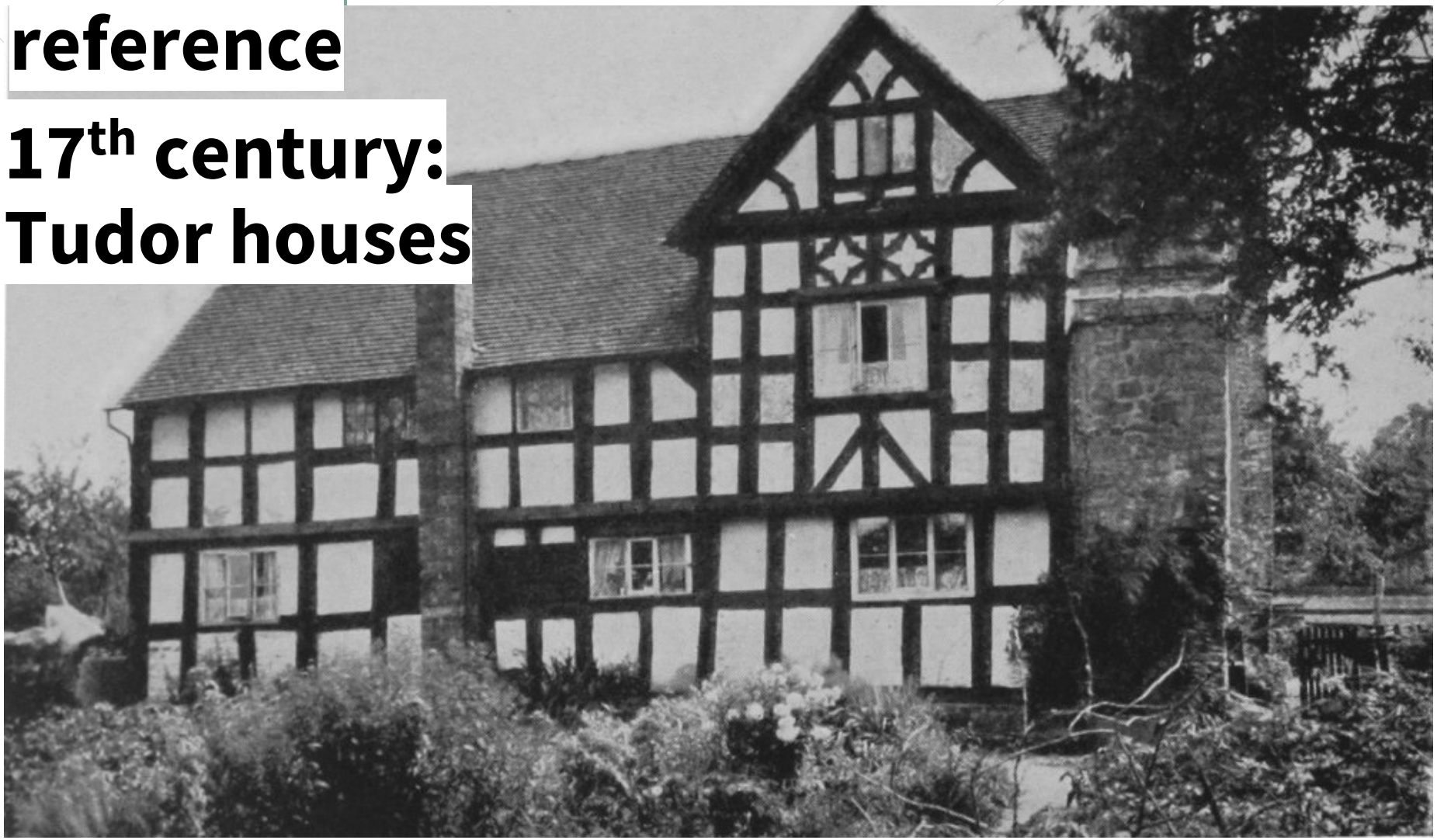
Historical reference

North America and Europe were covered in expansive forests, which then where early timber framed structure flourished.

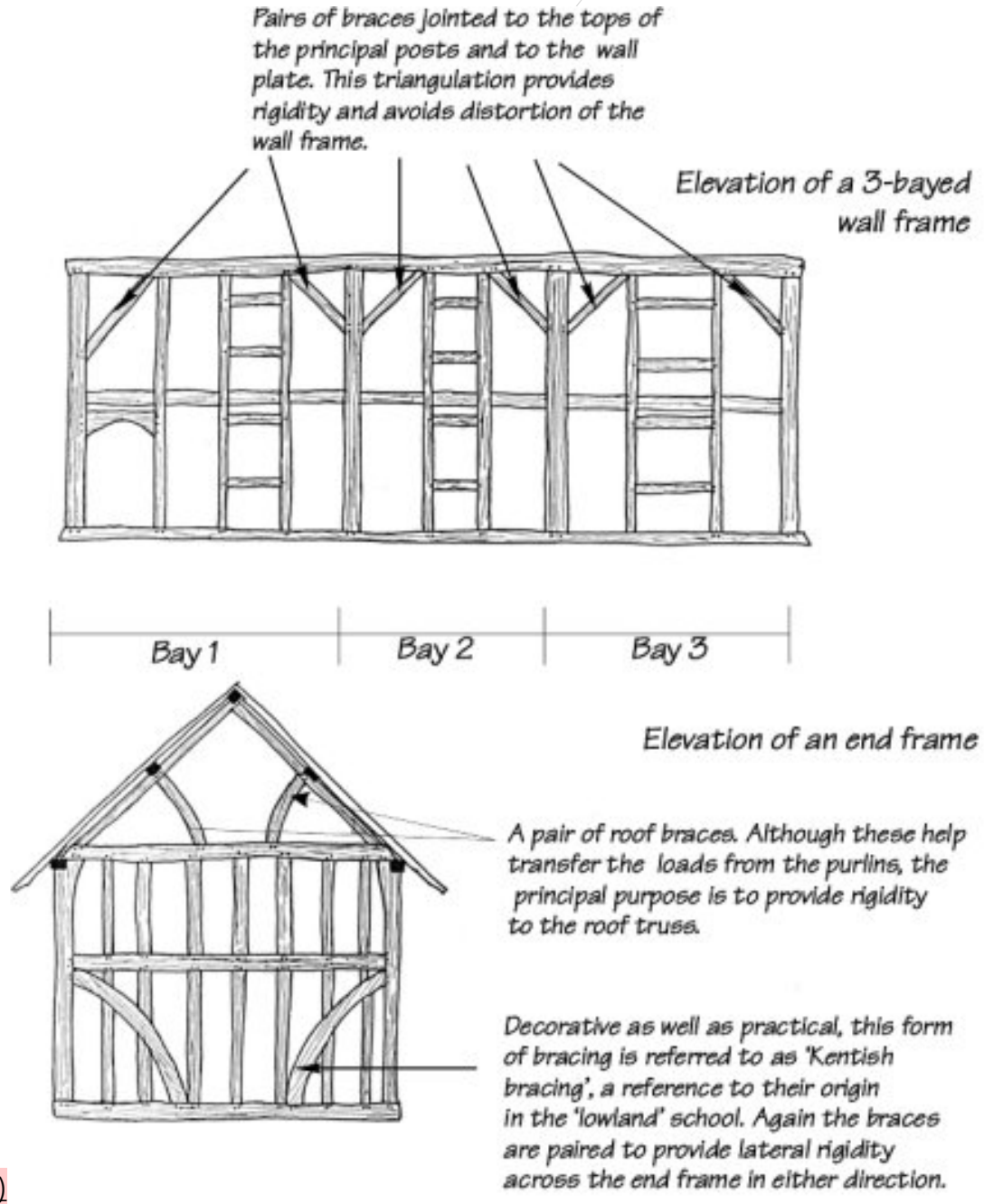
Main disadvantage: moisture infiltration

Historical reference

17th century: Tudor houses



Historical reference 17th century



Traditional Timber Framing - A Brief Introduction (uwe.ac.uk)

Historical reference

19th century

Repair Shanty At Lumber Camp (C.1898)

NBGS Miramichi / Repair Shanty At Lumber Camp

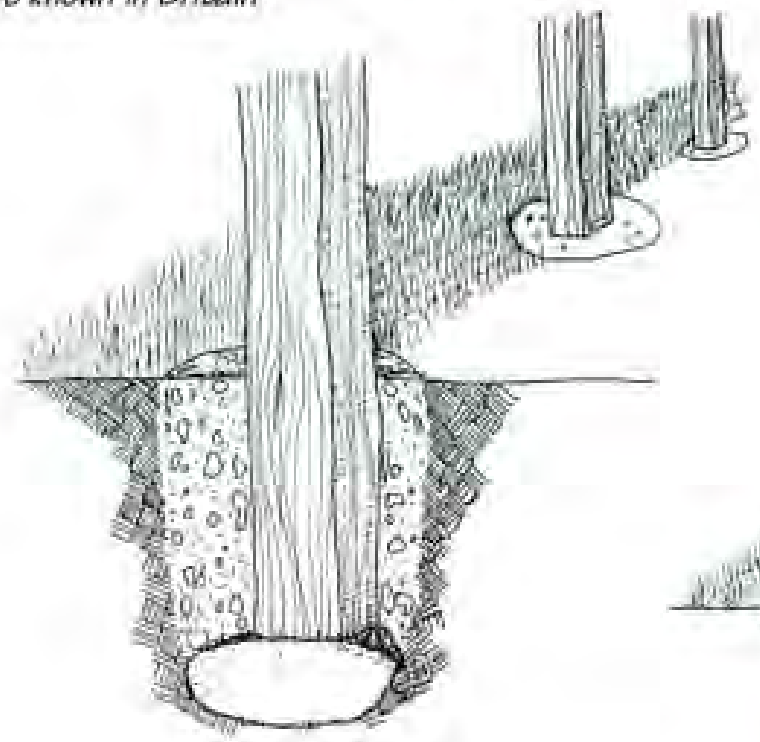
Historical reference 19th century

Montmorency County History (montmorencycountymichigan.us)

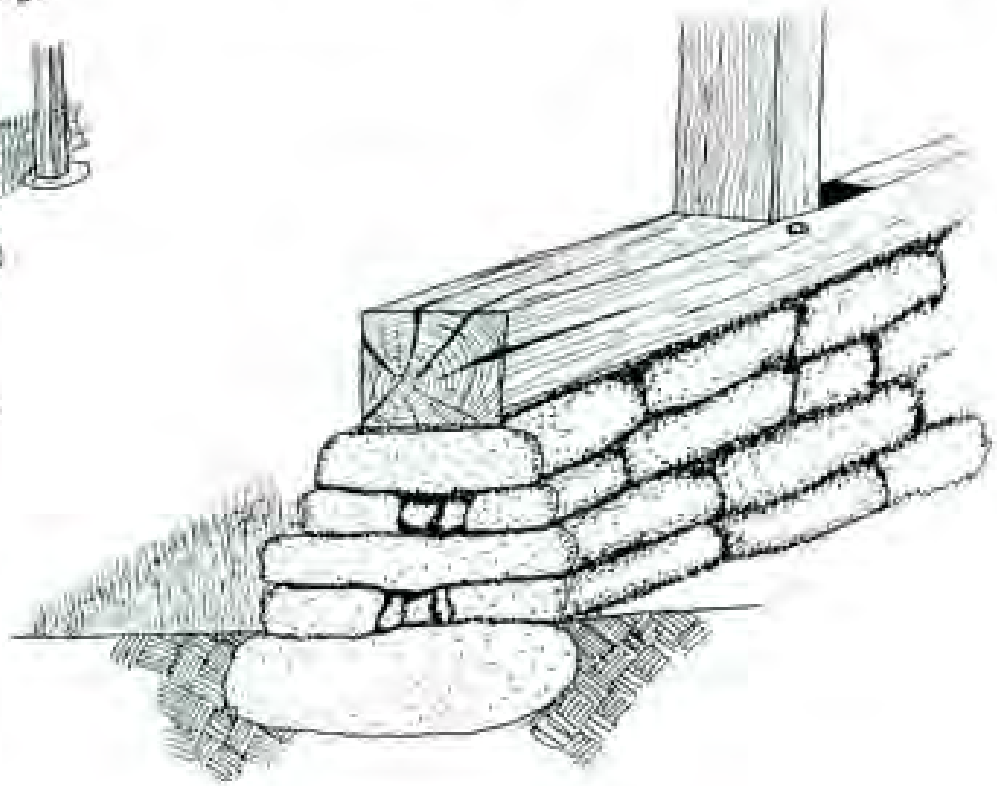
Historical reference

1920 in Cheddar, UK

Post holes in the ground provide widespread archaeological evidence that pre-1200 timber buildings were provided with rigidity by setting their posts into the ground. Post holes of dwellings from over 10,000 years ago are known in Britain



A typical dry-stone plinth wall for post-1200 timber frame. If the frame and wall were dismantled, little evidence would be left for the existence of the building.



Traditional Timber Framing - A Brief Introduction (uwe.ac.uk).

Historical reference

20th century

New materials such as lightweight steel and plastics. In UK construction, a big chunk of consumption is still used structurally (roof trusses and floor joists) and for non-structural elements (doors, window frames, skirting boards, etc).

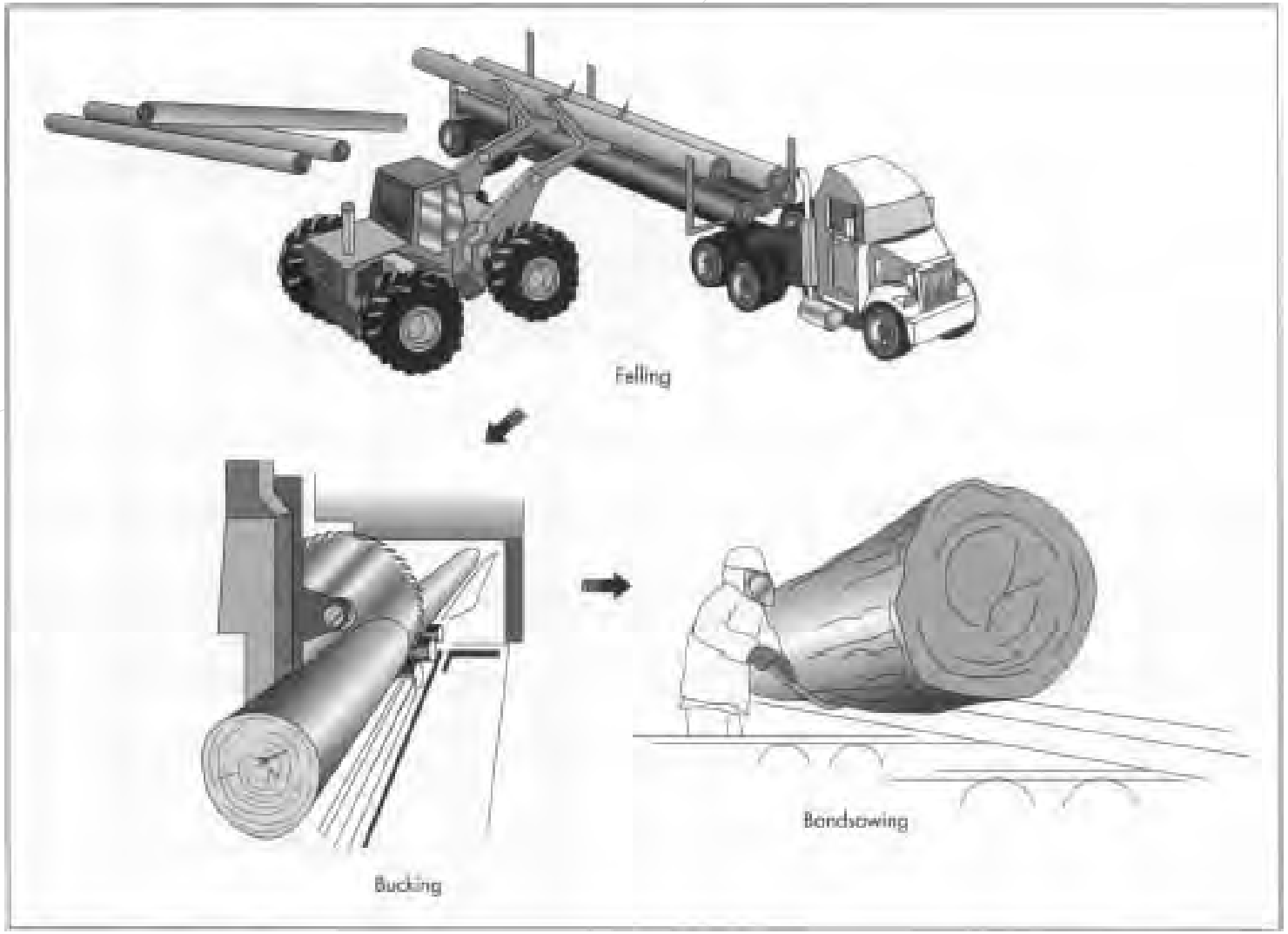
Dinwoodie, J. M. (2000). *Timber: its nature and behaviour*. CRC Press.

Timber processing

https://youtu.be/MVS89KUylKc

Timber processing

1. Felling
2. Debarking and bucking
3. Sawing
4. Drying or seasoning
5. Planing
6. Grade stamping and banding



How lumber is made - material, manufacture, history, used, processing, dimensions, industry, machine (madehow.com)

Timber processing

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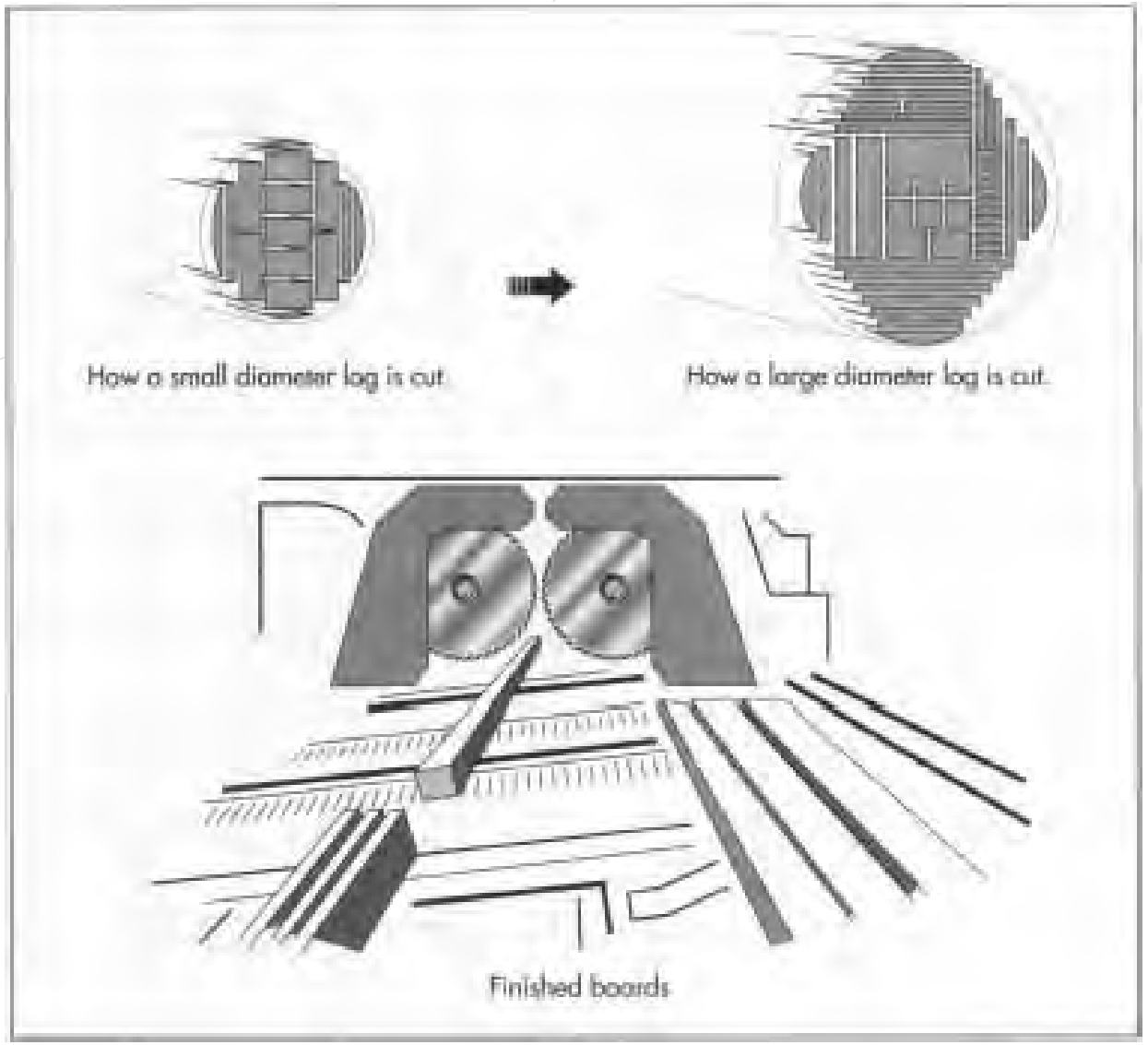


How lumber is made - material, manufacture, history, used, processing, dimensions, industry, machine (madehow.com)

Characteristics of timber as material

Wood is anistropic: has unequal strength when loaded in different directions.

GRAIN

Its strength lies along the grain. Wood is incredibly strong *along* the grain (along directions of its fibres) and is weak *across* the grain.

Grain versus particular application

Main ingredient: the organic substance called *cellulose*.
It is strongly-linked molecule, considered as natural type of carbon fibre.

Coulson, J. (2011). *Wood in construction: How to avoid costly mistakes*, John Wiley & Sons.

Characteristics of timber as material

MOISTURE

Wood reacts to changes in its moisture content. It might sweel or shrink (only *across* the grain), depends on whether it gains or loses moisture.

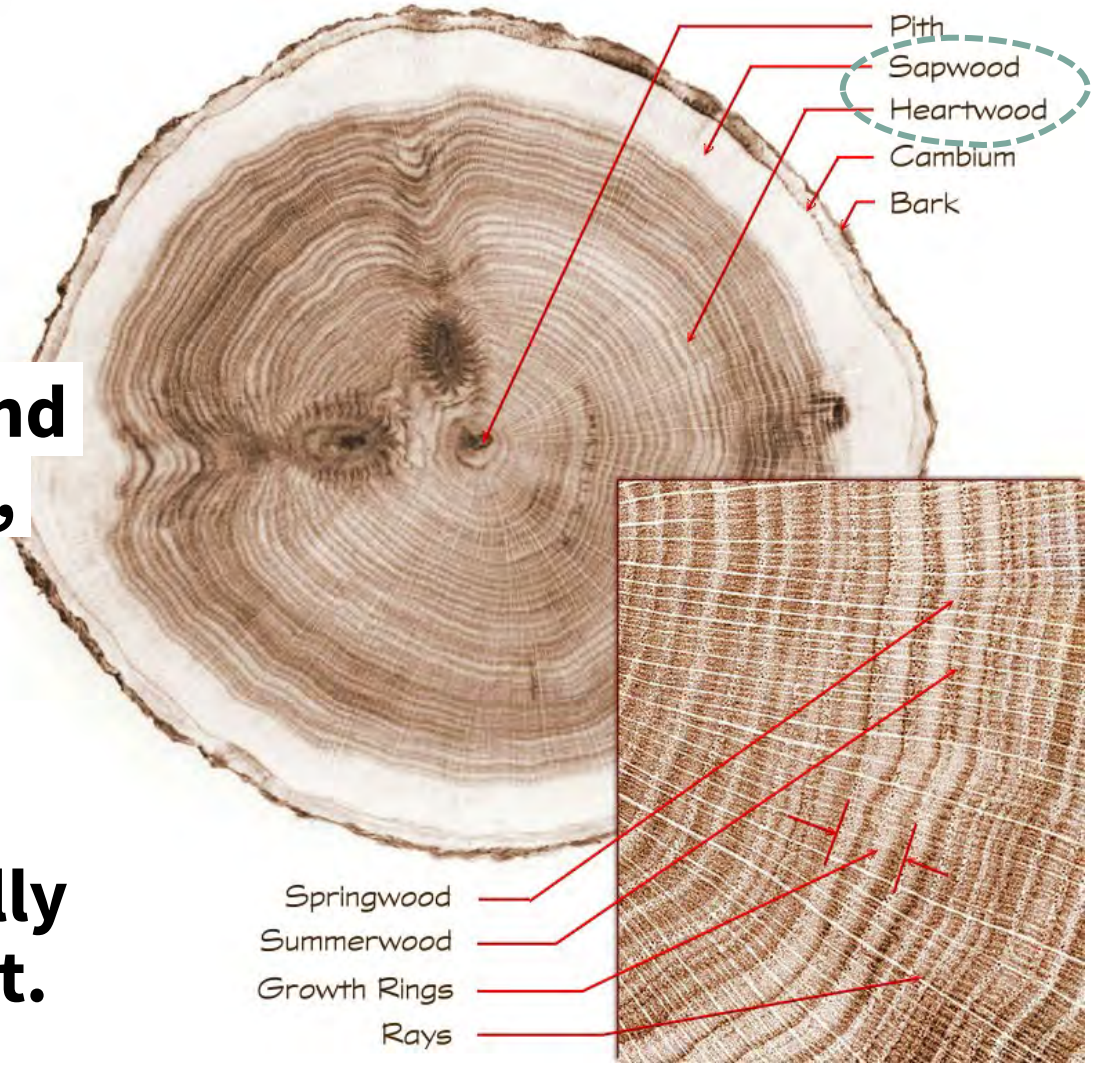
Coulson, J. (2011). *Wood in construction: How to avoid costly mistakes*, John Wiley & Sons.

Characteristics of timber as material

HEARTWOOD AND SAPWOOD

Heartwood is the central zone and forms the oldest part of the tree, that's why trees have 'growth rings'.

Sapwood is the outer part, still plays its day-to-day life. Generally pale in colour and visibly distinct.



Coulson, J. (2011). *Wood in construction: How to avoid costly mistakes*, John Wiley & Sons.
Image: https://workshopcompanion.com/KnowHow/Design/Nature_of_Wood/1_Wood_Grain/1_Wood_Grain.htm

Characteristics of timber as material

HEARTWOOD AND SAPWOOD

Heartwood may have degree of *natural durability*, due to lower content of moisture (resistant to fungi).

Sapwood, has no great amount in *natural durability*, <u>not in any species.</u>

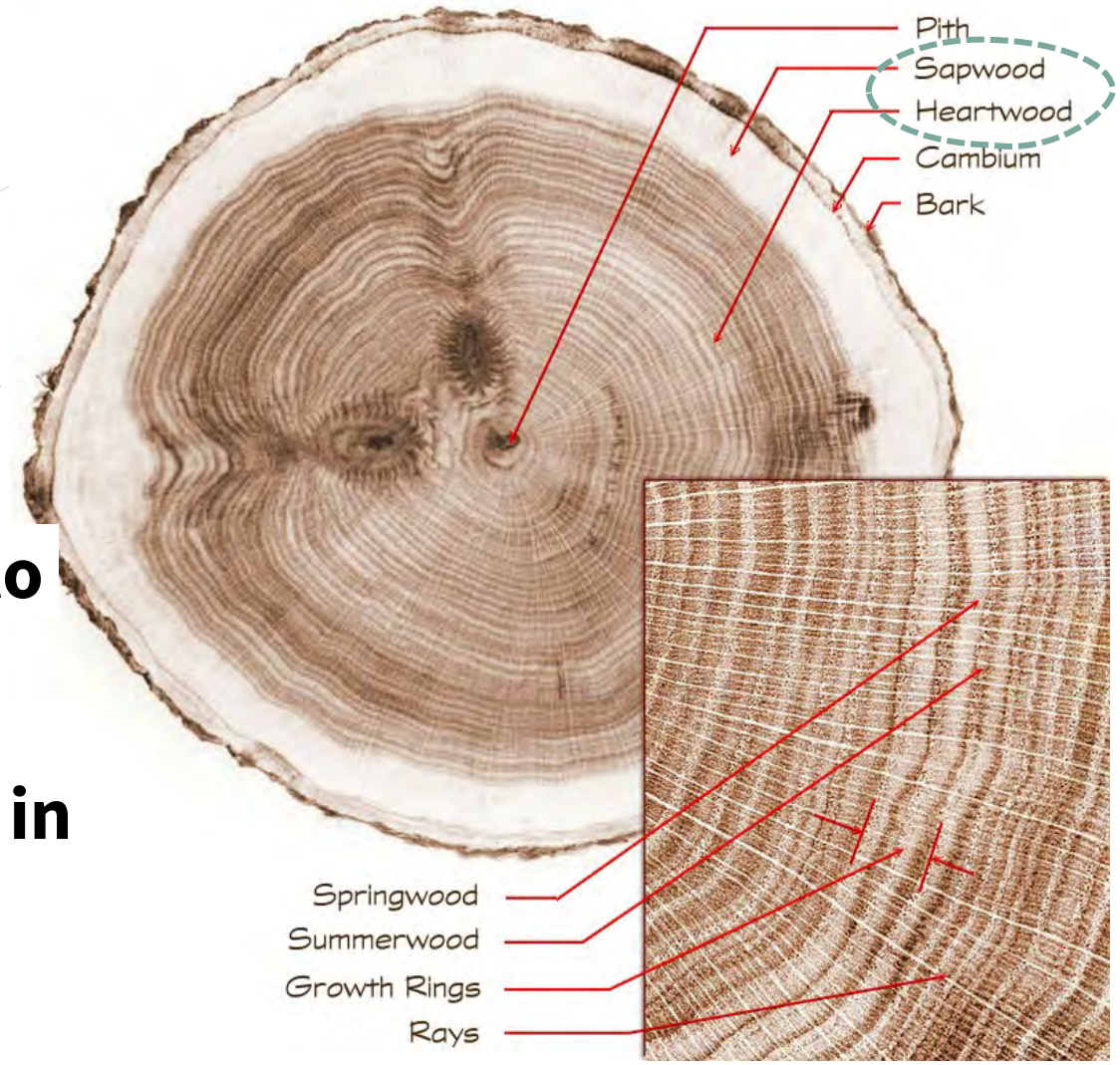


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Image: https://workshopcompanion.com/KnowHow/Design/Nature_of_Wood/1_Wood_Grain/1_Wood_Grain.htm

Characteristics of timber as material

RAY

Special type of wood cell, radiating from the centre towards outside of tree. Function is to move foodstuffs and waste products across tree trunk.

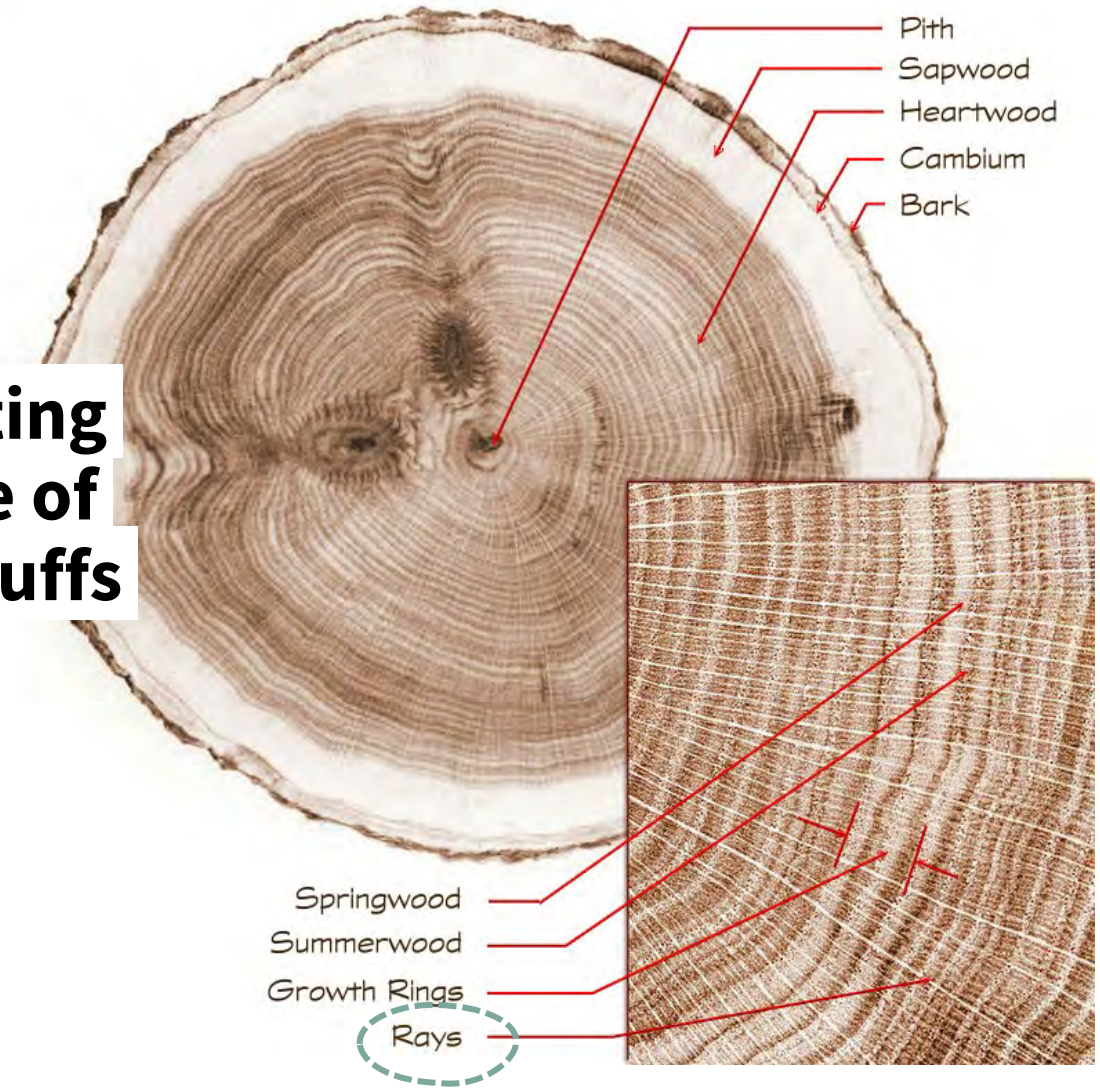

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Image: https://workshopcompanion.com/KnowHow/Design/Nature_of_Wood/1_Wood_Grain/1_Wood_Grain.htm

Characteristics of timber as material

WOOD OR TIMBER?

Wood: materials that grows within the tree
Timber: after tree fell

WOOD SPECIES

There are a few thousand commercially used timber, construction industry makes up the biggest user.

Coulson, J. (2011). *Wood in construction: How to avoid costly mistakes*, John Wiley & Sons.

Characteristics of timber as material

TWO BASIC SUBDIVISION

Hardwoods:
from broadleaf trees

Softwoods:
from conifer trees

Coulson, J. (2011). *Wood in construction: How to avoid costly mistakes*, John Wiley & Sons.

Characteristics of timber as material

	Hardwood	Softwood
Origionates from	Deciduous trees	Evergreen trees
Examples	Oak, Teak, Mahogony	Pine, Spruce, Fir
Price	More expensive	Less expensive
Density	Typically harder (not always)	Usually softer (not always)
Colour	Generally dark	Almost always light
Structure	Lower sap	Higher sap
Grain	Close	Loose
Fire resistance	Good	Poor
Weight	Heavy	Light

Loadbearing capacity, more suitable for: **Compressive loads** **bending loads**

https://www.laver.co.uk/blog/hardwood-vs-softwood-whats-the-difference/

Characteristics of timber as material

PROPERTIES

Thermal insulation properties
Flammable
Load is to be placed on its efficient longitudinal axis (where it can absorb compression and tensile forces)

Steiger, L. (2017). *Basics timber construction*, Birkhäuser.

Timber construction products

SOLID WOOD

Construction timber is available from sawmills as stock squared timber, in particular cross sections and lengths.

Classifications: laths, planks, boards and squared timber according to ratio of thickness to width.

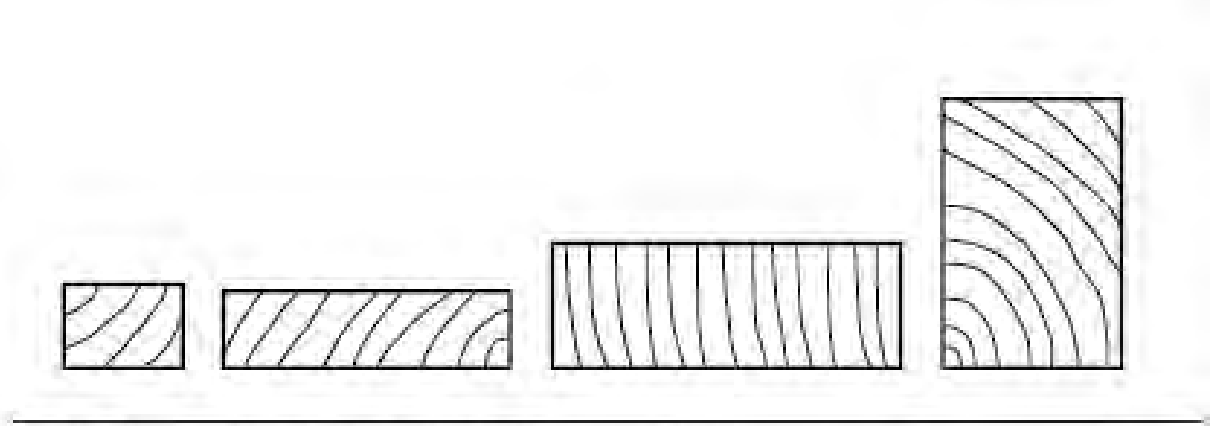


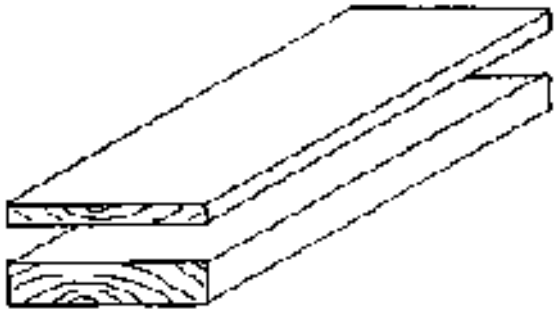
Fig. 6: Cross sections: lath, plank, board, squared timber

Tab. 2: Cross sections for lath, plank, board, squared timber

	Thickness t	Width w
	Height h [mm]	[mm]
Lath	$t \leq 40$	$w < 80$
Plank	$t \leq 40$	$w \geq 80$
Board	$t > 40$	$w > 3d$
Squared timber	$w \leq h \leq 3w$	$w > 40$

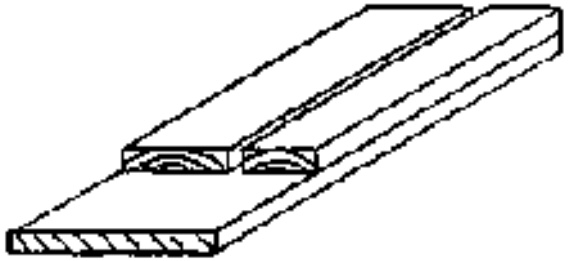
Steiger, L. (2017). *Basics timber construction*, Birkhäuser.

Commercial shapes of timber

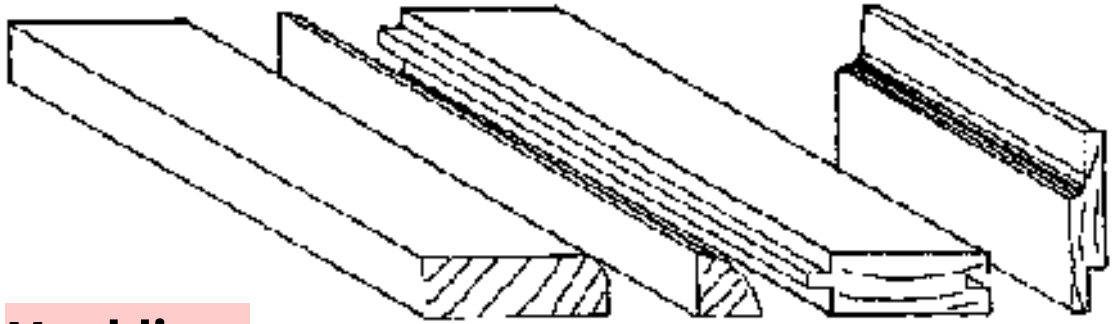


Planks

Battens and strips



Boards



Mouldings

Timber construction products

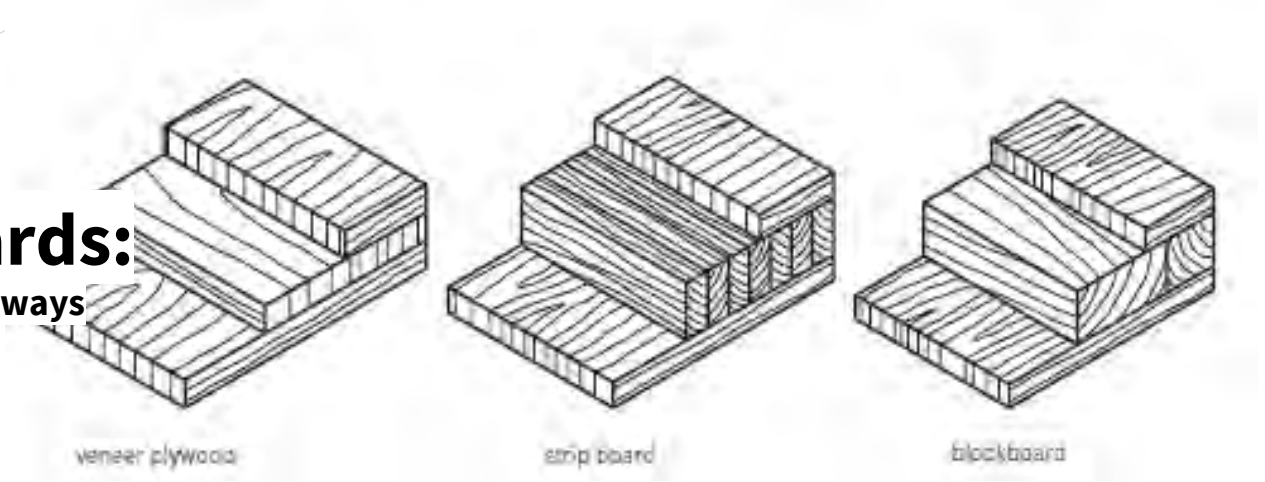
TIMBER BASED PRODUCTS

Plywood and laminated boards:

At least 3 layers of glued wood, grain direction ser crossways

Chip products

Fibre products



Steiger, L. (2017). *Basics timber construction*, Birkhäuser.

Sustainability issue

They should come from managed forestry, for instance FSC in the UK.

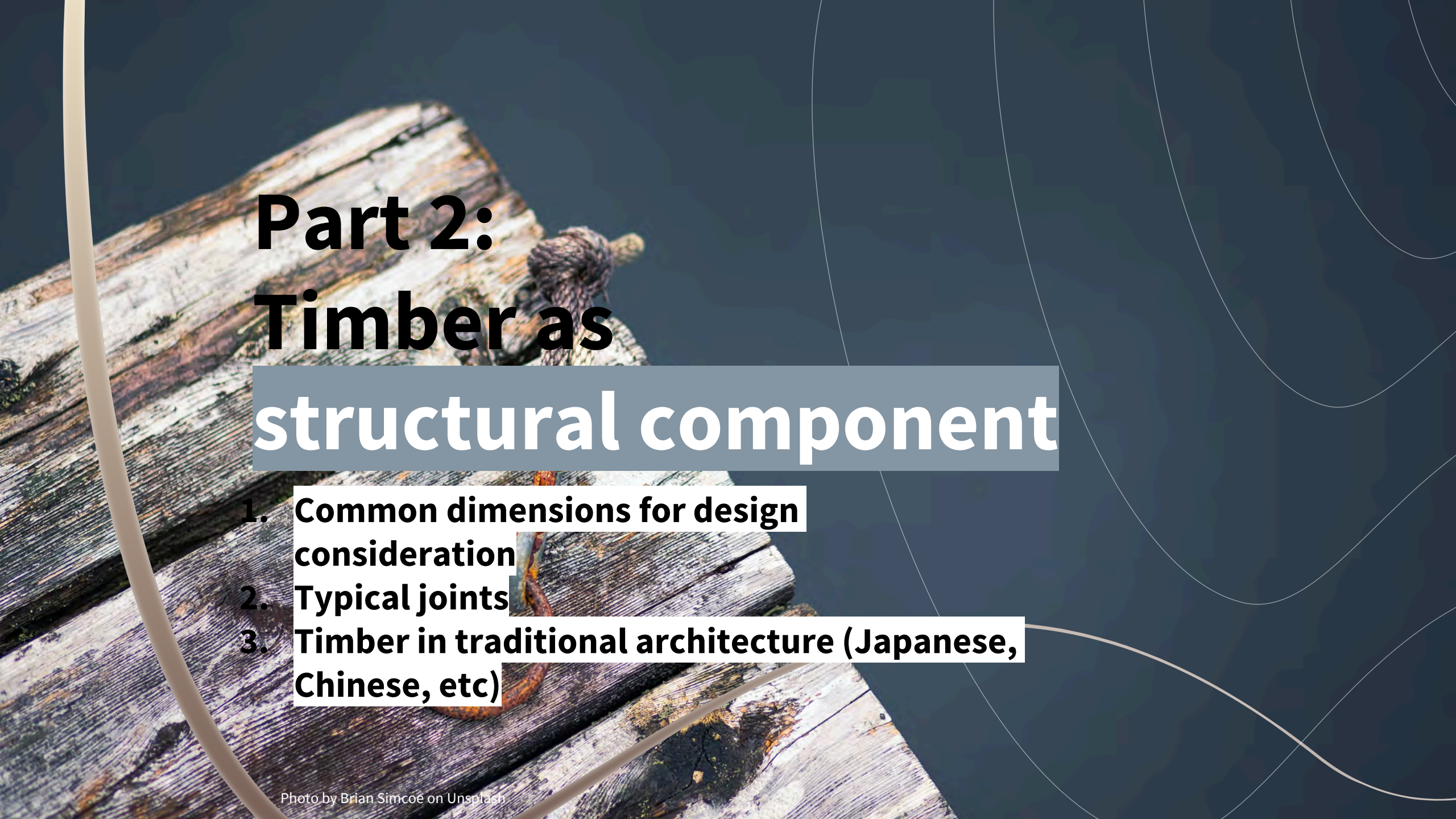
Impact of deforestation.

Problems with sustainable forests.

Life Cycle Assessment.

Typical timber joints (non-structural)

https://youtu.be/-f7tTNRH_04



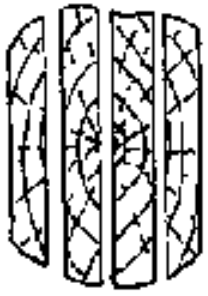
Part 2: Timber as structural component

1. Common dimensions for design consideration
2. Typical joints
3. Timber in traditional architecture (Japanese, Chinese, etc)

Photo by Brian Simcoe on Unsplash

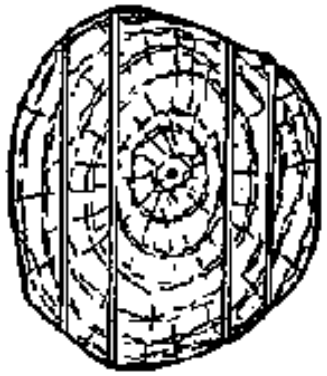
Common timber cuts

The log goes through the circular saw while still held in one position.



Showing a piece of board from a single pass live sawing.

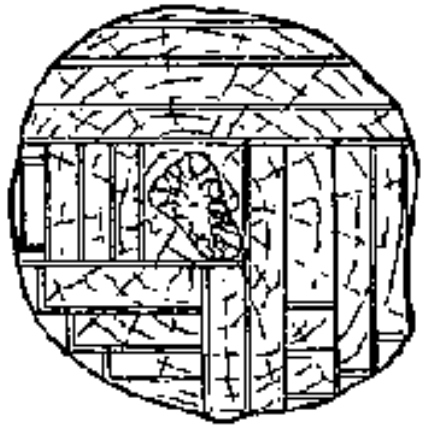
Single pass live sawing



The log passes trough the saw in two separate operations.
Firstly - Slicing the outside parts
Secondly - Slicing the middle section.

Showing a piece of board from double pass live sawing.

Double pass live sawing



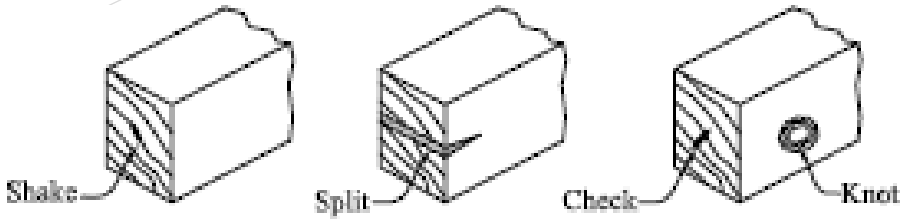
Back sawing (tangential cut)

Quarter sawing (radial cut)

http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0cdl--00-0----0-10-0---0---0direct-10---4-------0-0l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-00&cl=CL1.252&d=HASH01ba0f381a45a4ad83b37c47.3.7&gt=1

Common defects

Shake
Live knot
Dead knot
Gum pocket



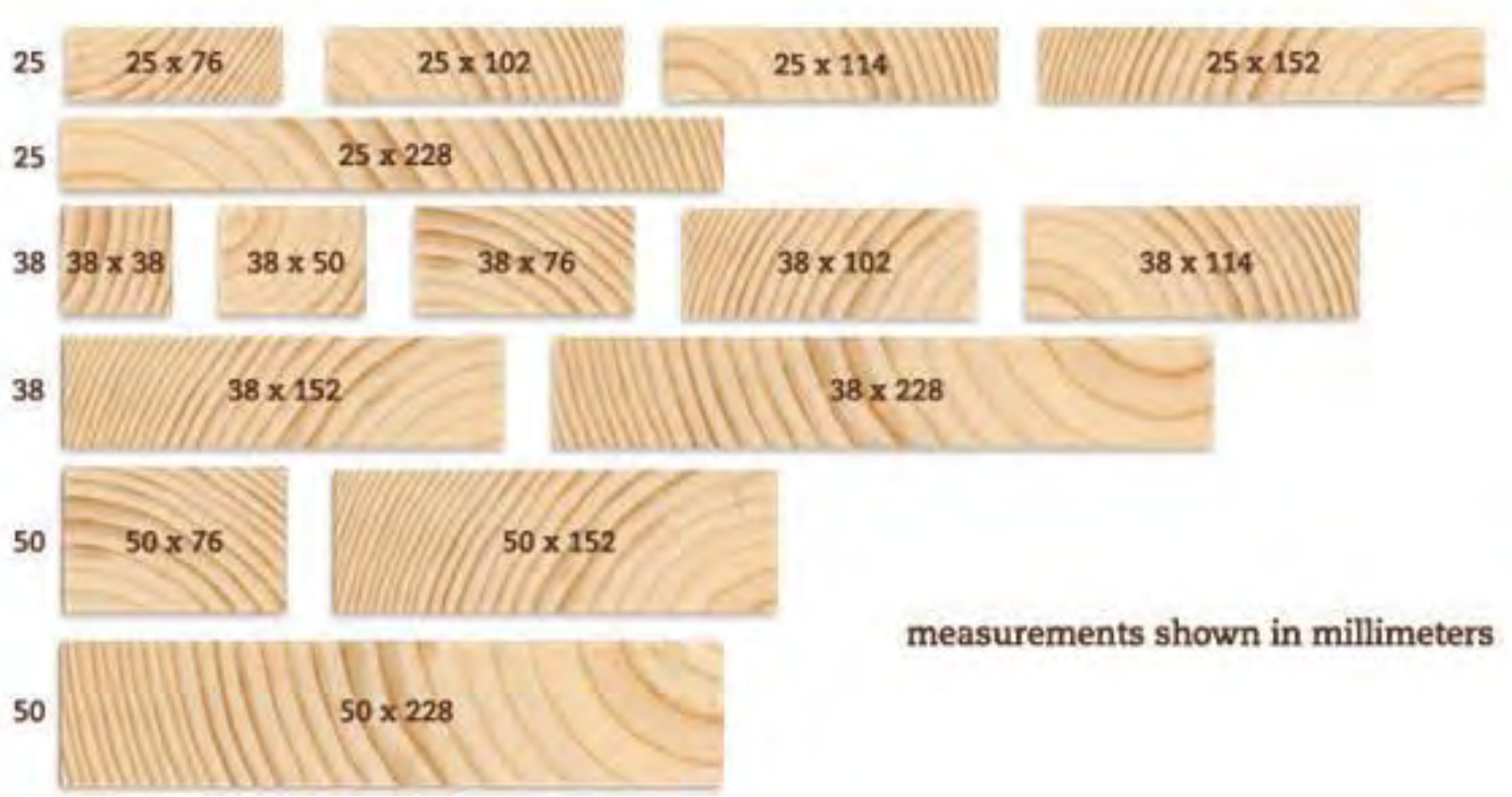
Bow
Twist
Cup

Termites

Commercial size of timber

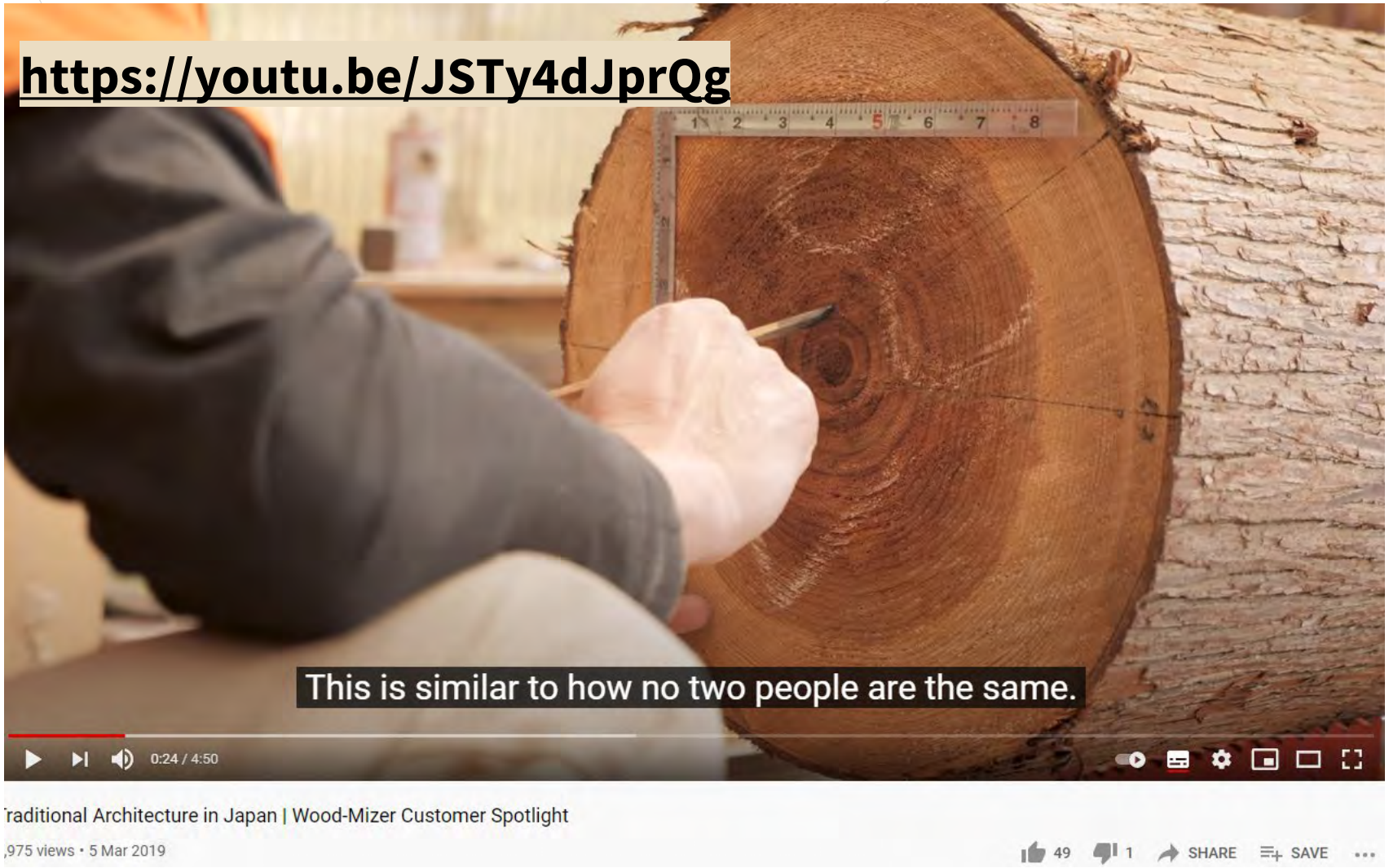
Standard lengths are: 1.80m 2.10m 2.40m 2.70m 3.0m 3.30m 3.60m 3.90m 4.20m 4.50m 4.80m 5.10m 5.40m 5.70m 6.0m and 6.30m.

Standard cross section size:

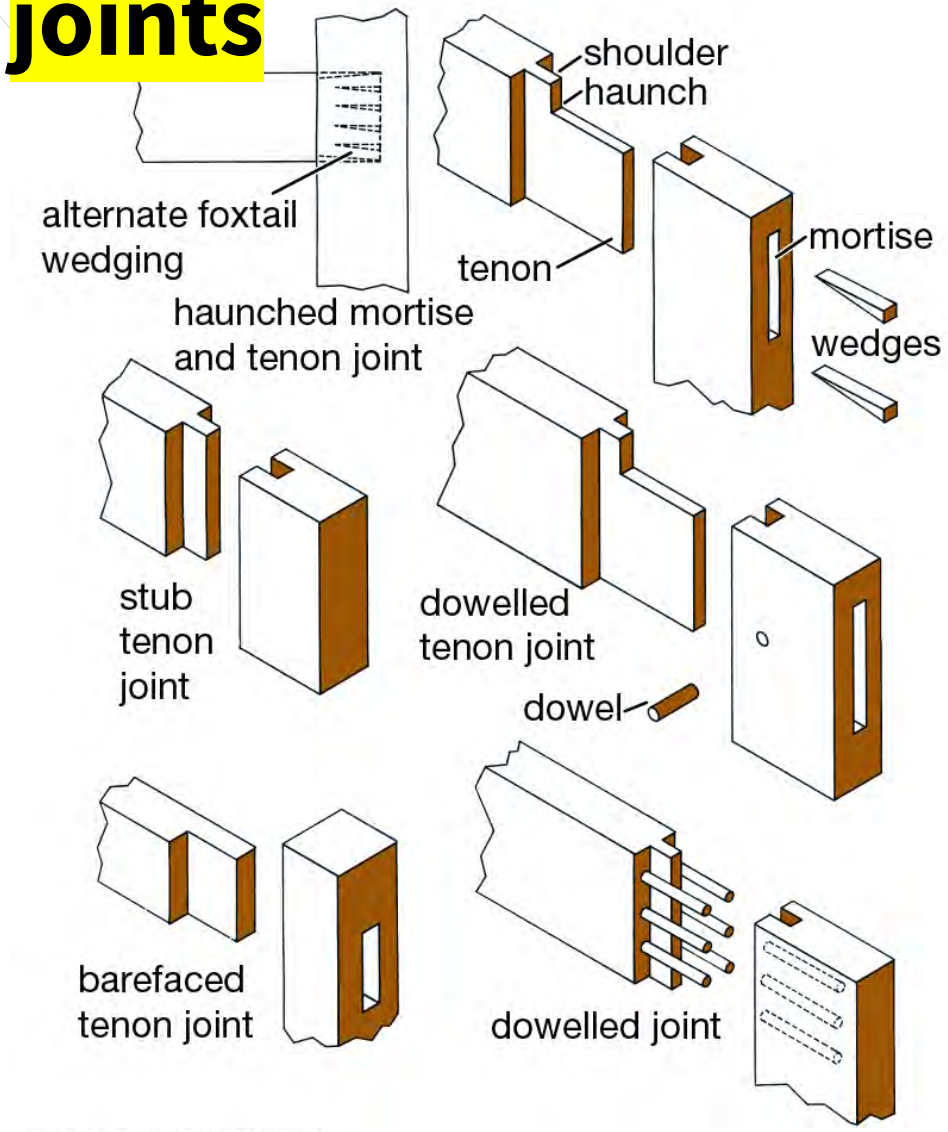


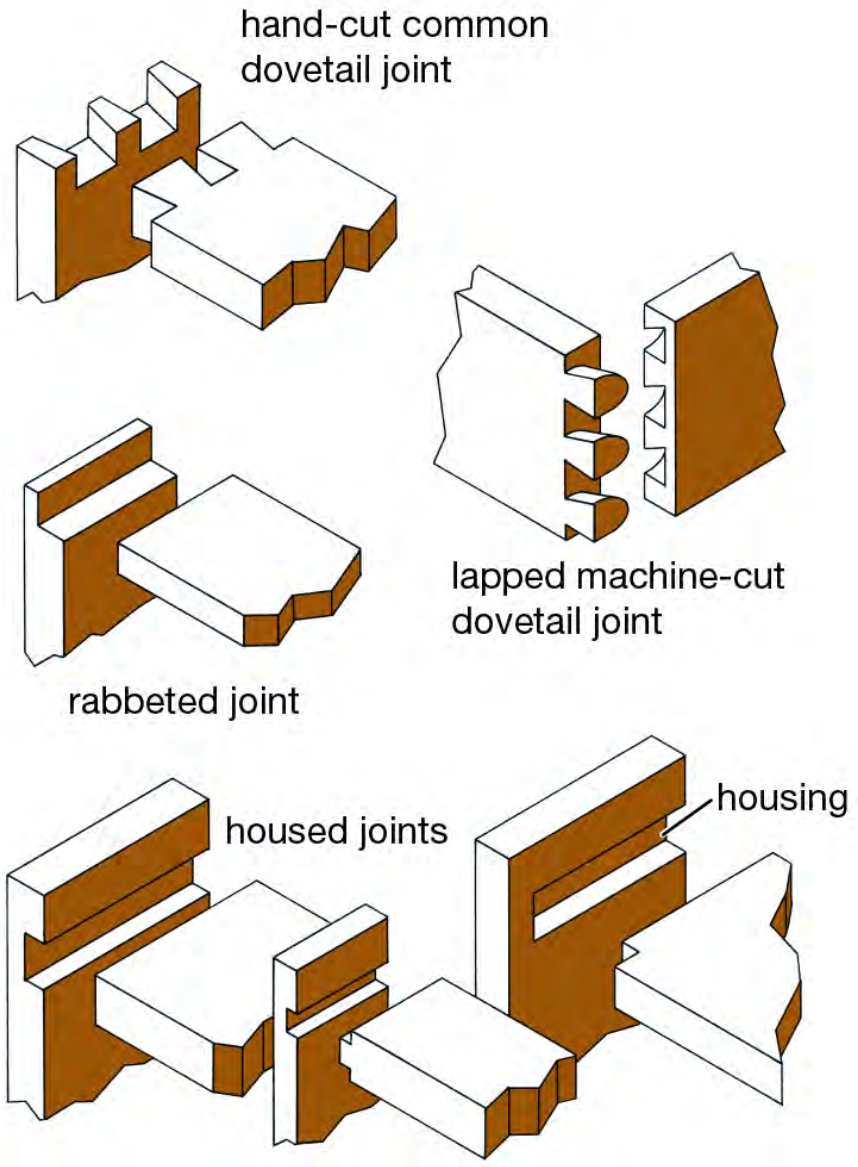
Japanese wood carpentry

https://youtu.be/JSTy4dJprQg



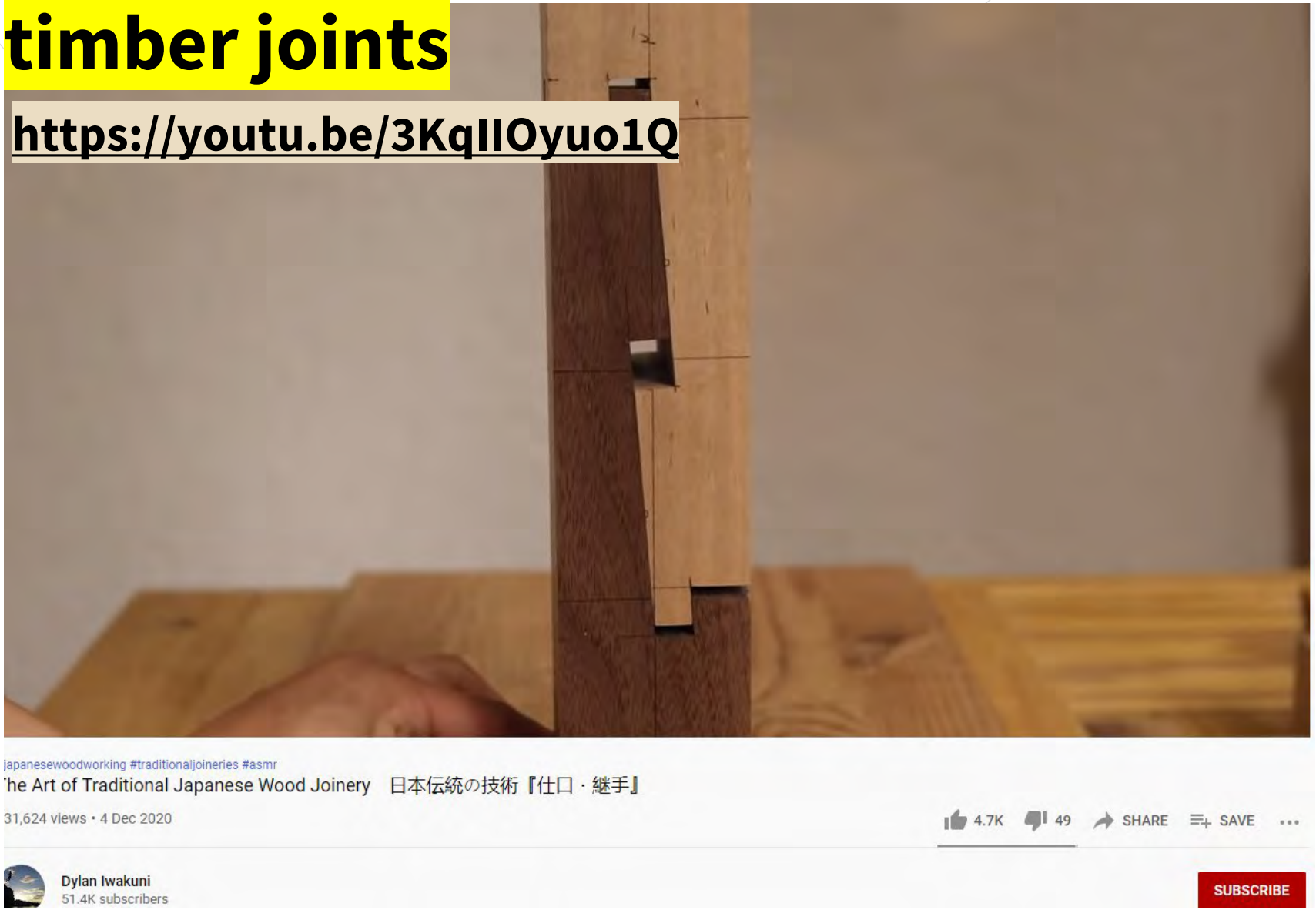
Basic timber joints





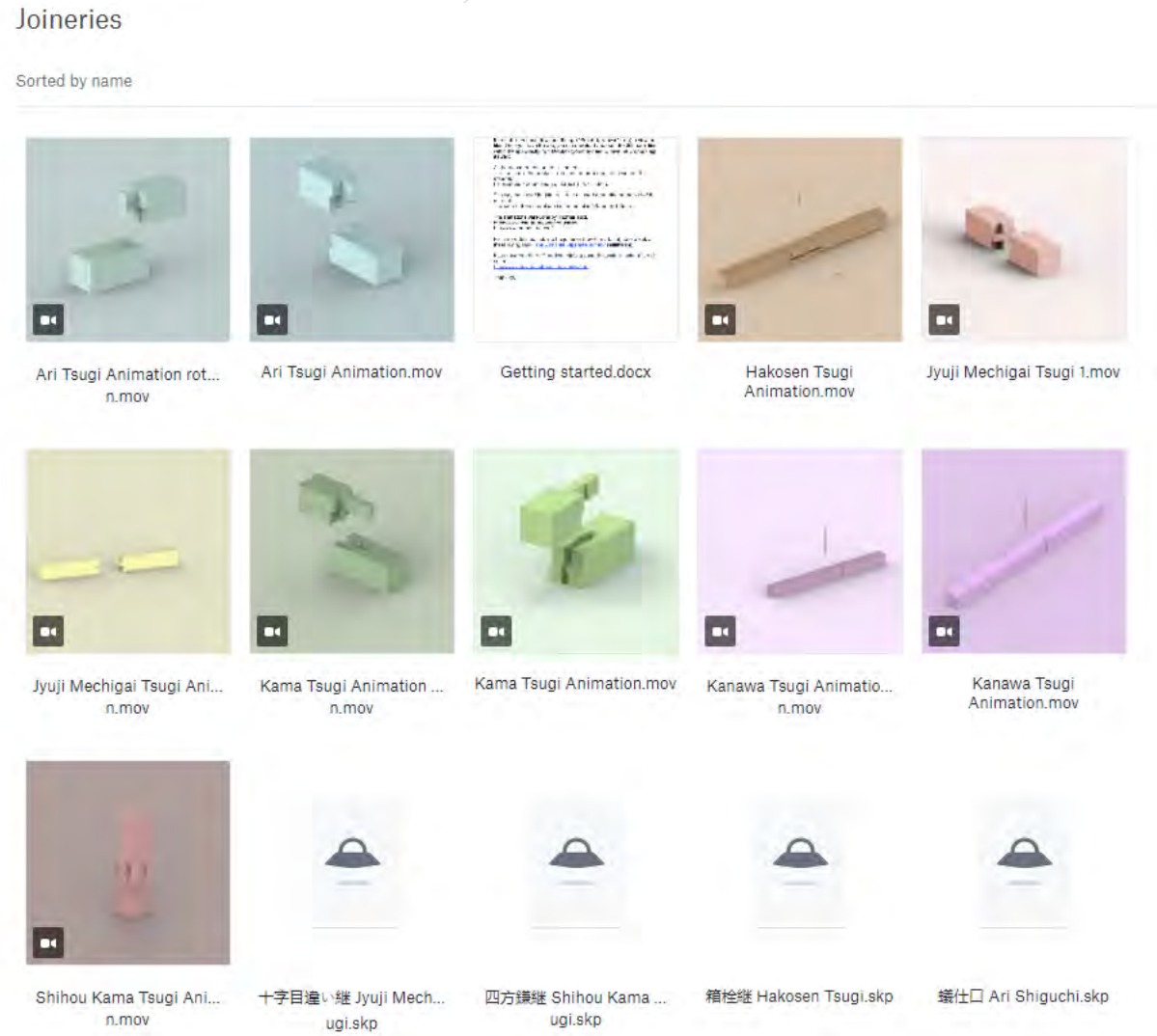
Japanese timber joints

https://youtu.be/3KqIIOyuo1Q



Japanese timber joints

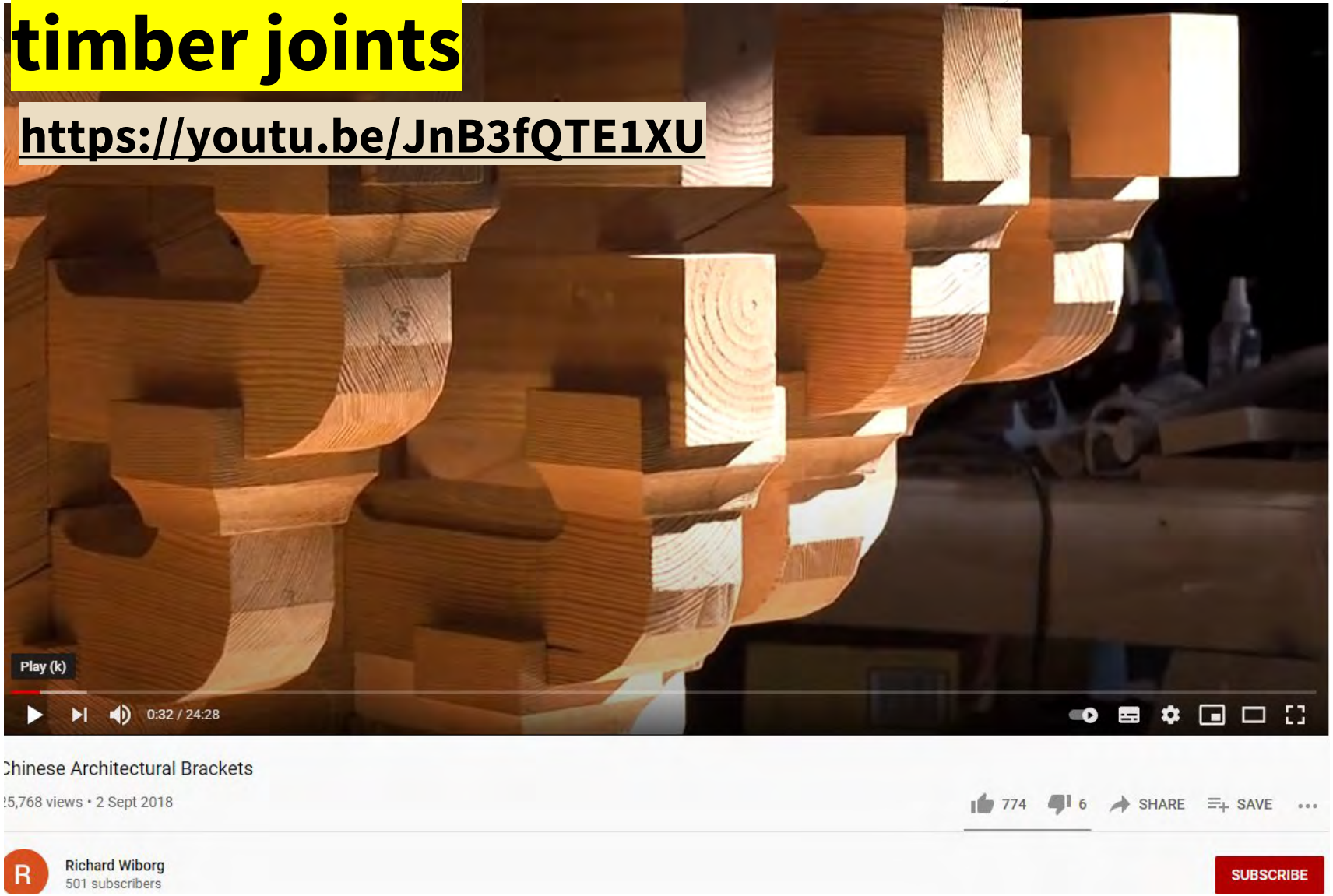
https://www.dropbox.com/sh/ethawktkhzylbxt/AAAgY1i5Vc-f8BEphNZJ6mWKa?dl=0



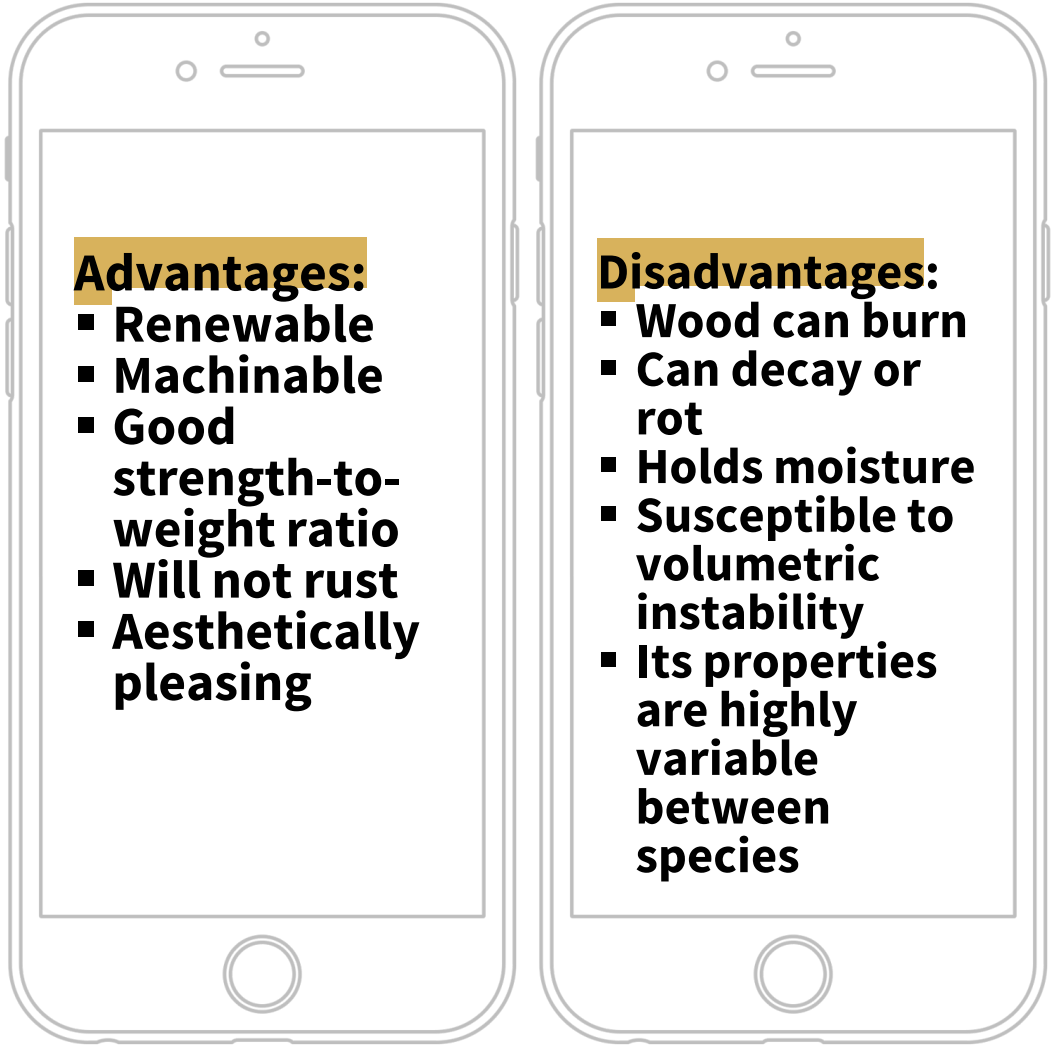
Buy him a coffee to say thank you if you download the files : https://www.buymeacoffee.com/dylaniwakuni

Japanese timber joints

https://youtu.be/JnB3fQTE1XU



Advantages and disadvantages: Wood as structural material



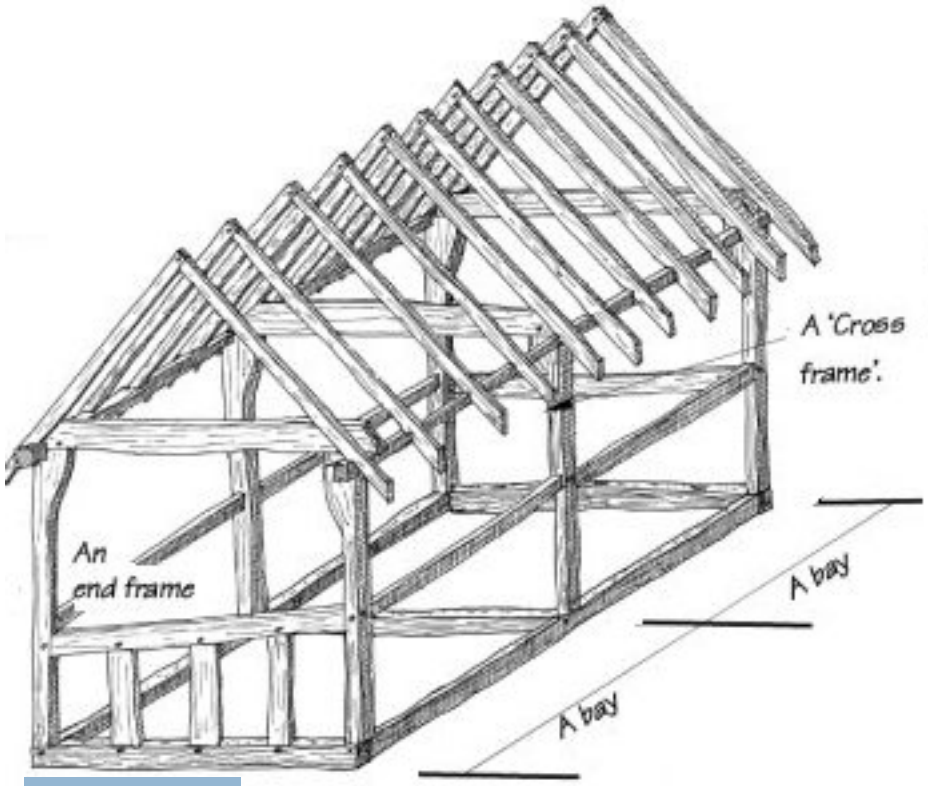
Agahayere, A. & Vigil, J. (2007). Structural Wood Design: A Practice-Oriented Approach. Wiley, ISBN.

Part 3:
Timber construction

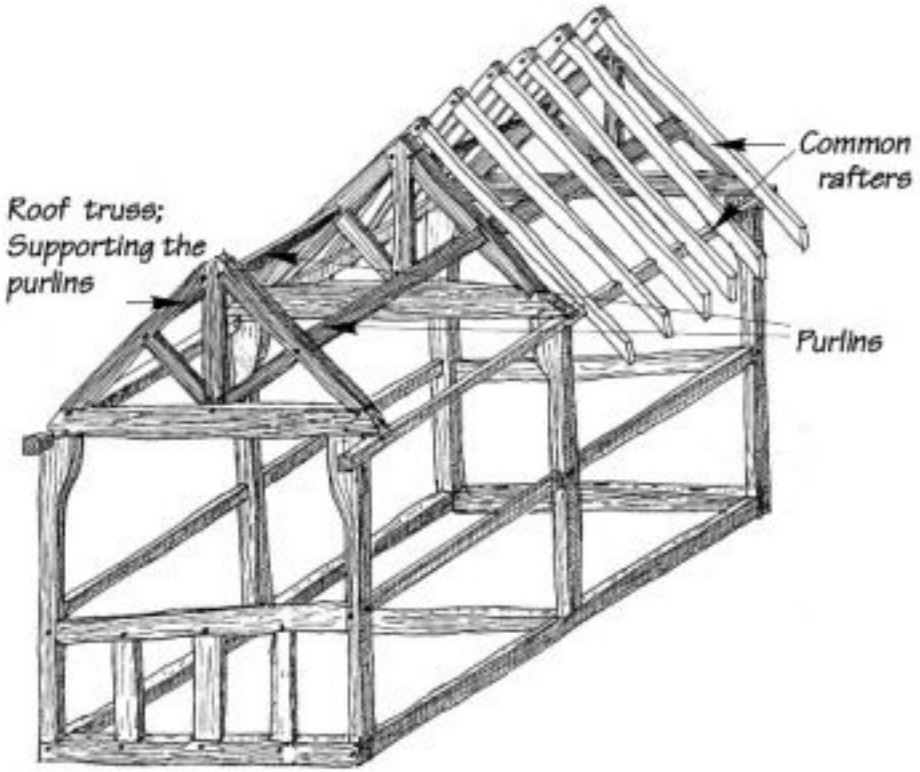
1. Timber construction system
2. Behaviour of structure
3. Local regulations
4. Computational timber design

Photo by Brian Simcoe on Unsplash

Traditional timber framing



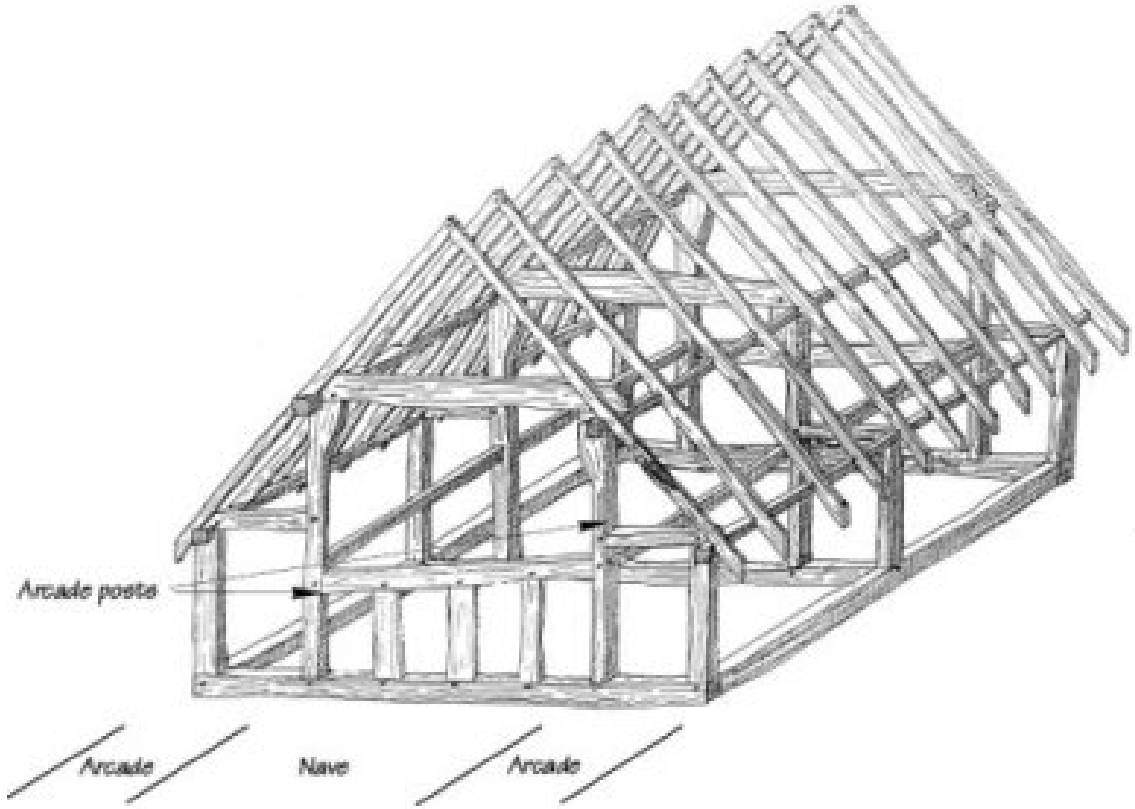
Box frame



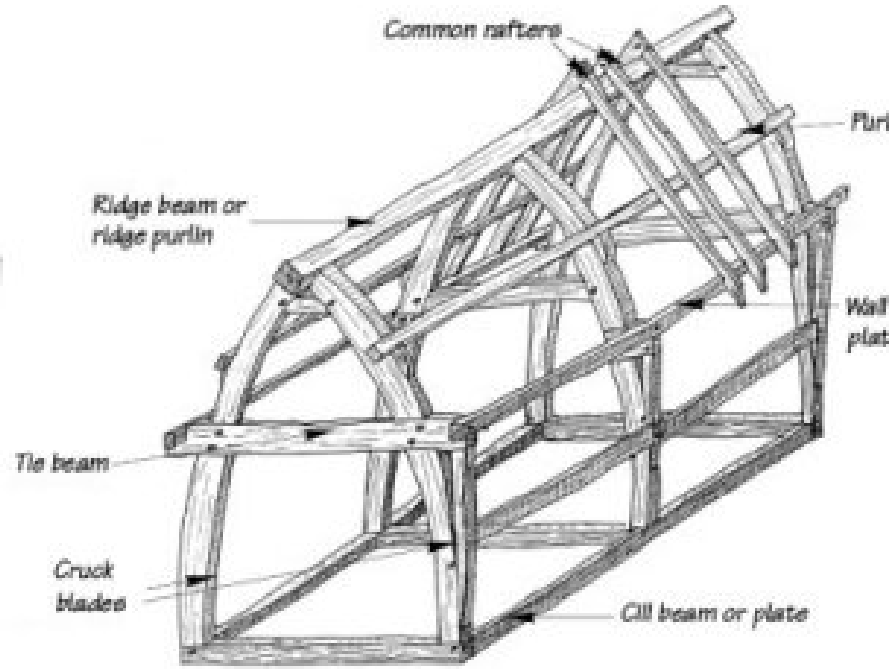
Post and Truss

Traditional Timber Framing - A Brief Introduction (uwe.ac.uk)

Traditional timber framing



Aisled construction



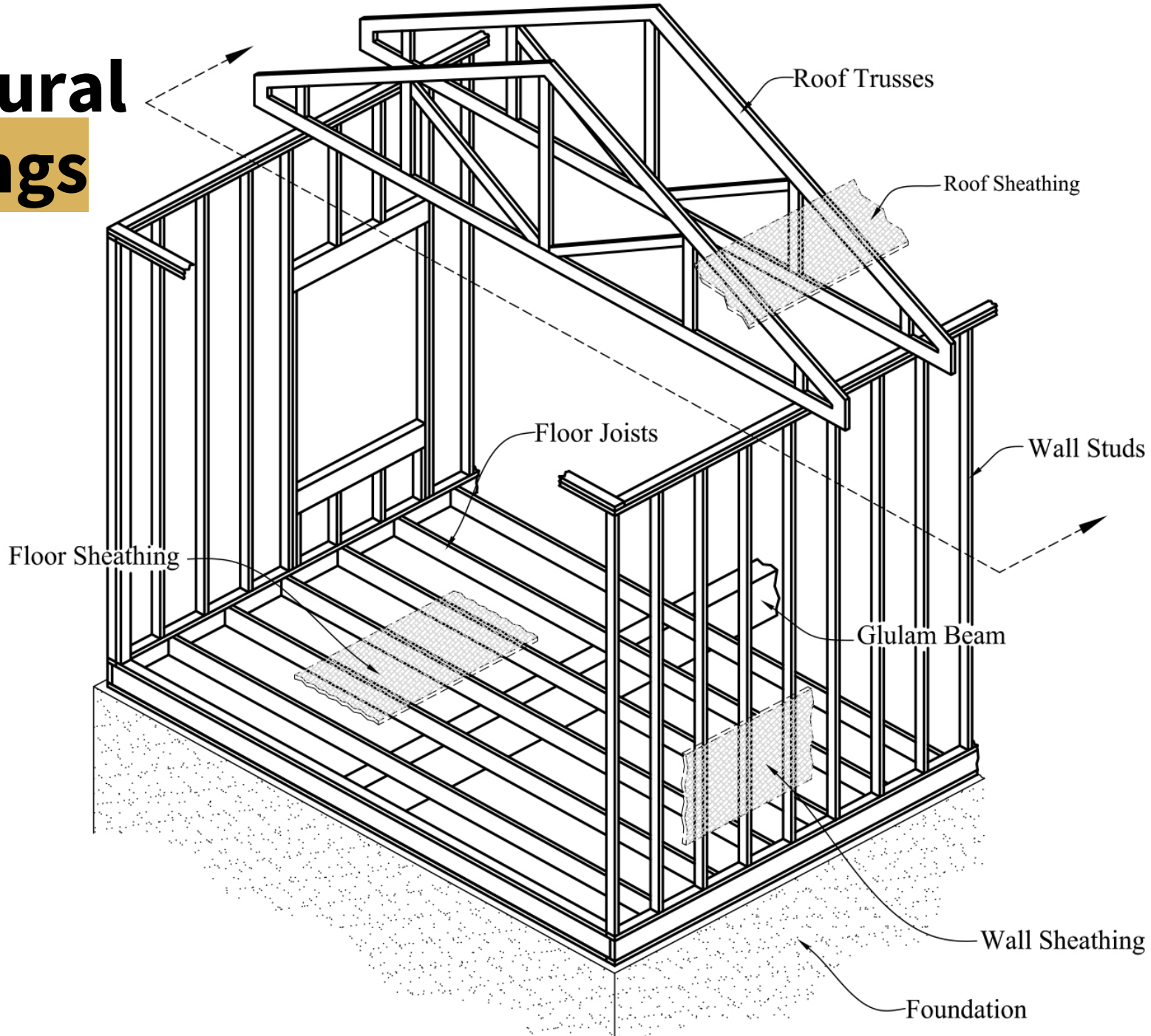
Cruck construction

Traditional Timber Framing - A Brief Introduction (uwe.ac.uk)

Typical structural timber buildings

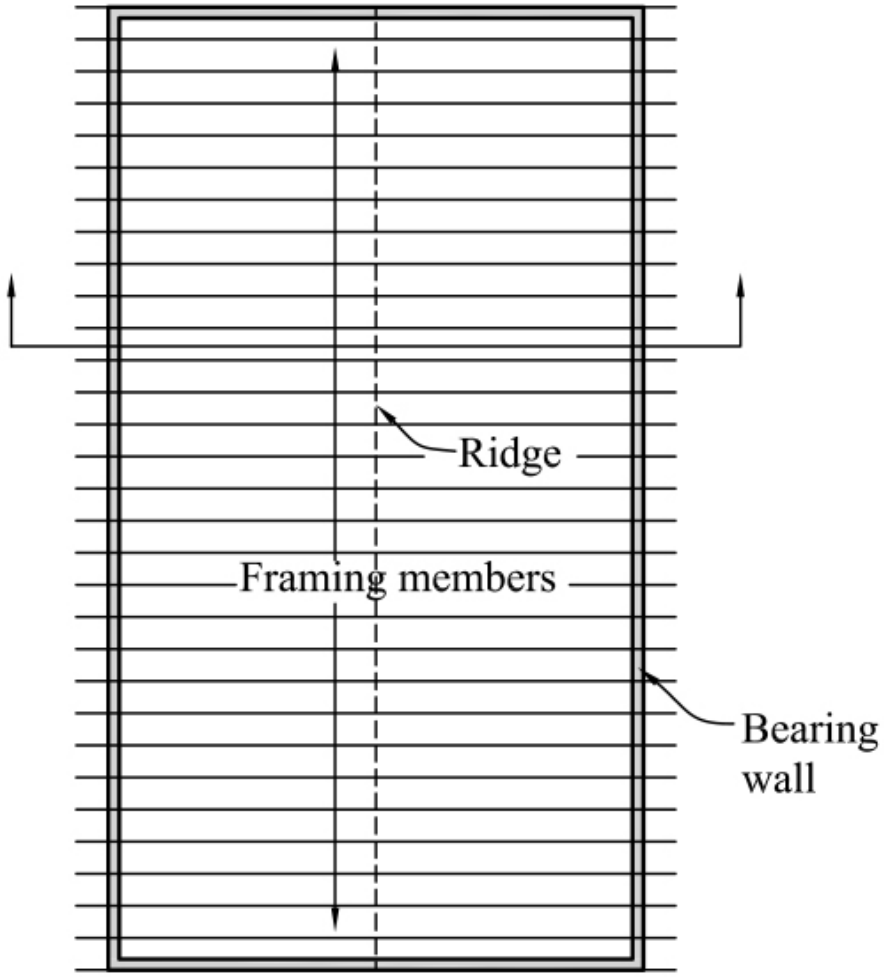
Structural systems:

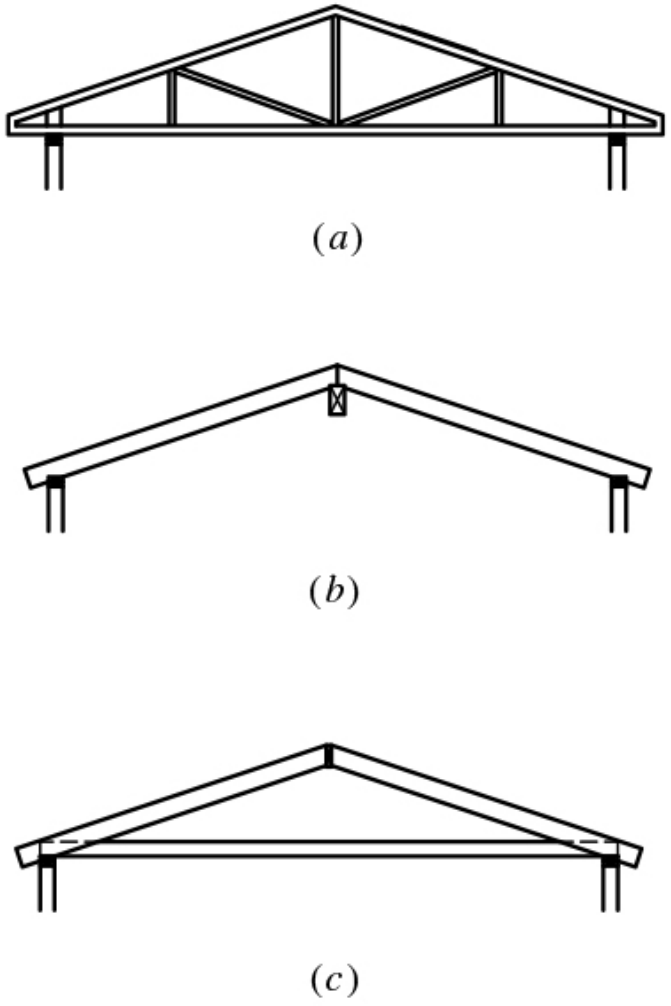
- **Roof framing**
- **Floor framing**
- **Wall framing**



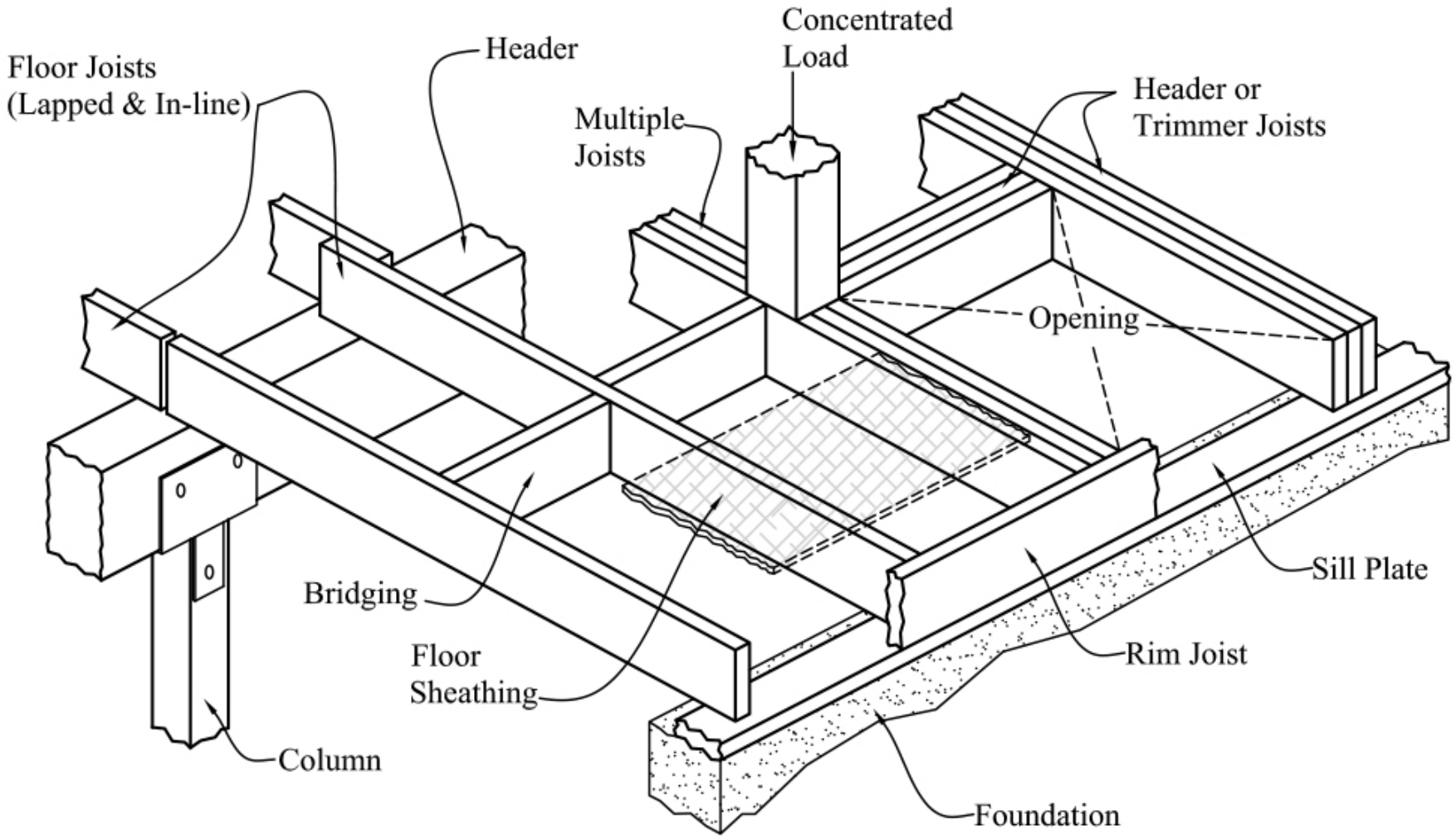
Platform framing

1- Roof framing

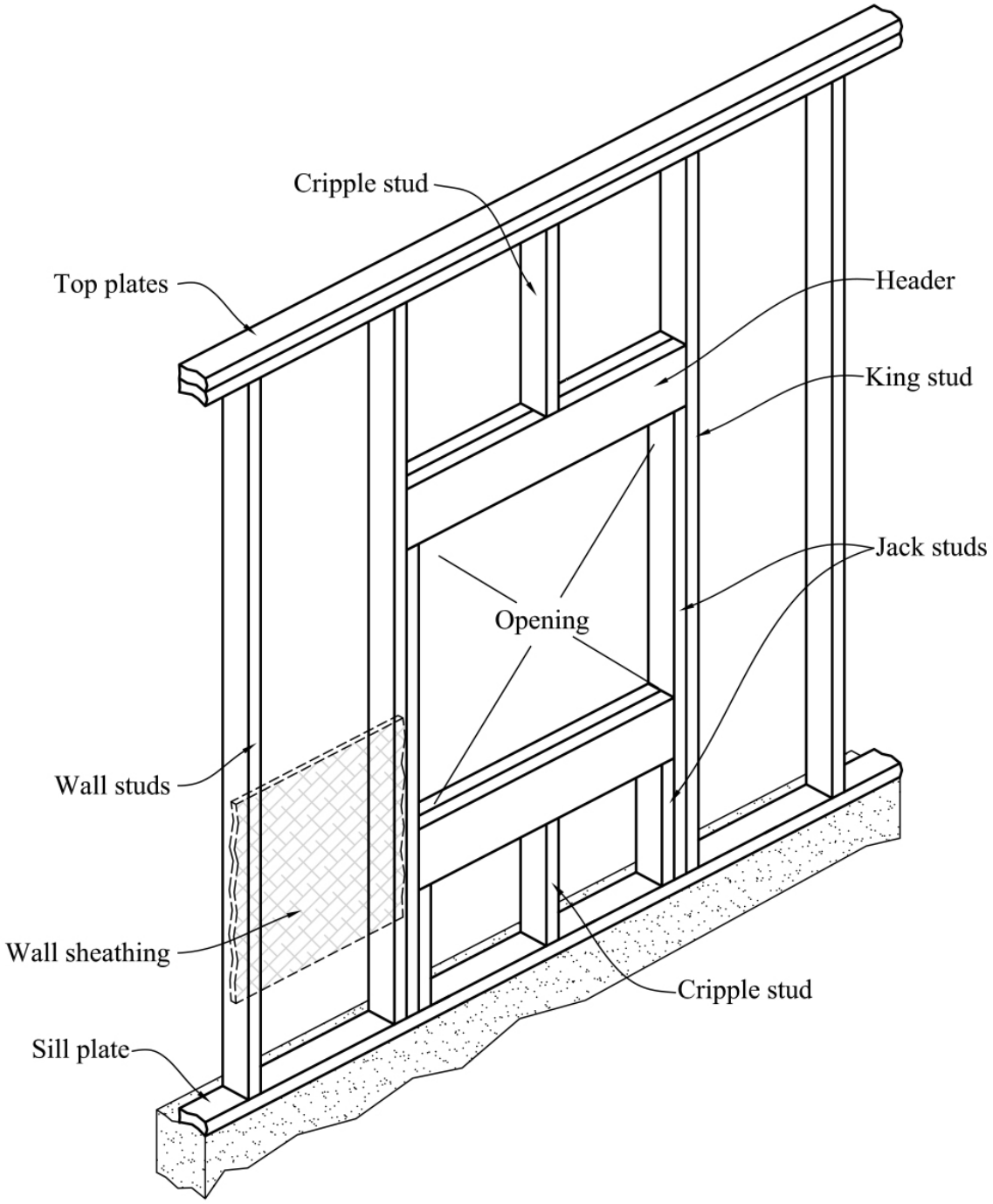




2- Floor framing



3- Wall framing



Typical structural timber buildings

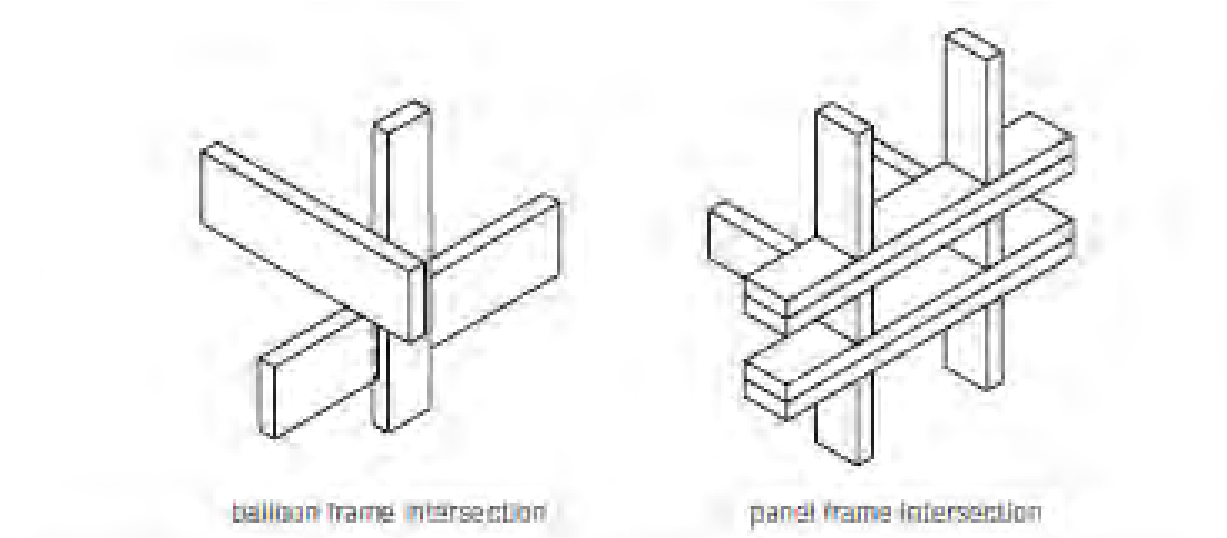


Fig.17: Isometric diagram of post-and-beam – timber-frame construction

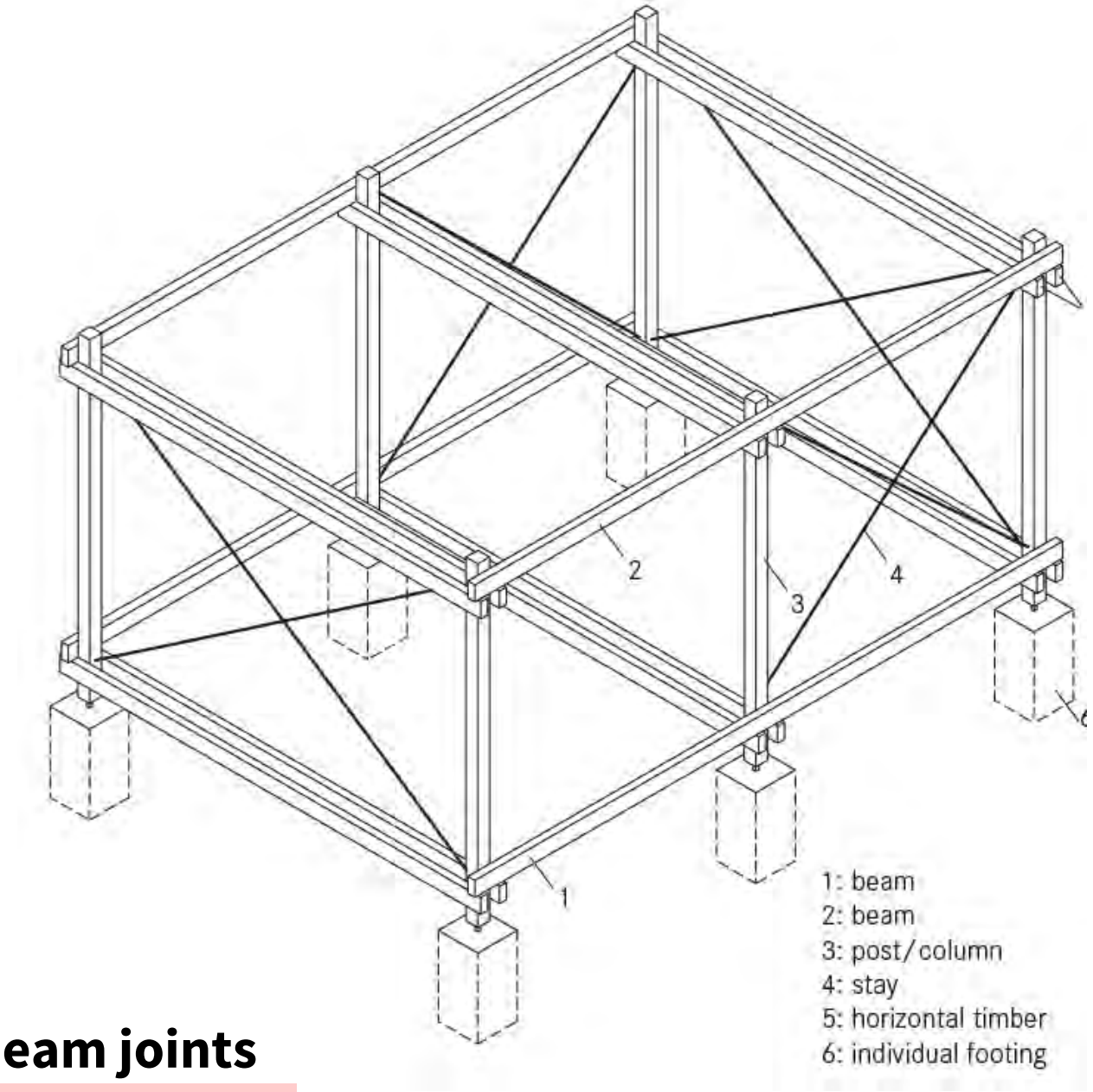
Balloon framing

Steiger, L. (2017). *Basics timber construction*, Birkhäuser.

Typical structural timber buildings

More freedom on dividing space.

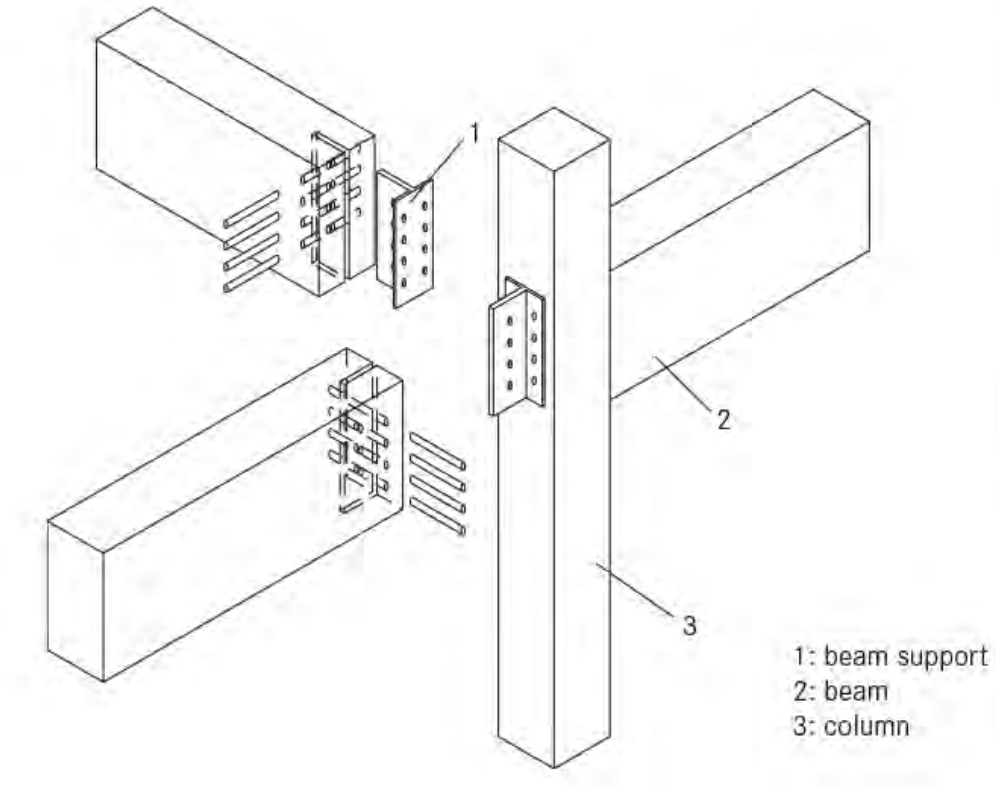
Made of primarily load bearing structure: columns and beams, supporting secondary loadbearing structure of beams and rafters.

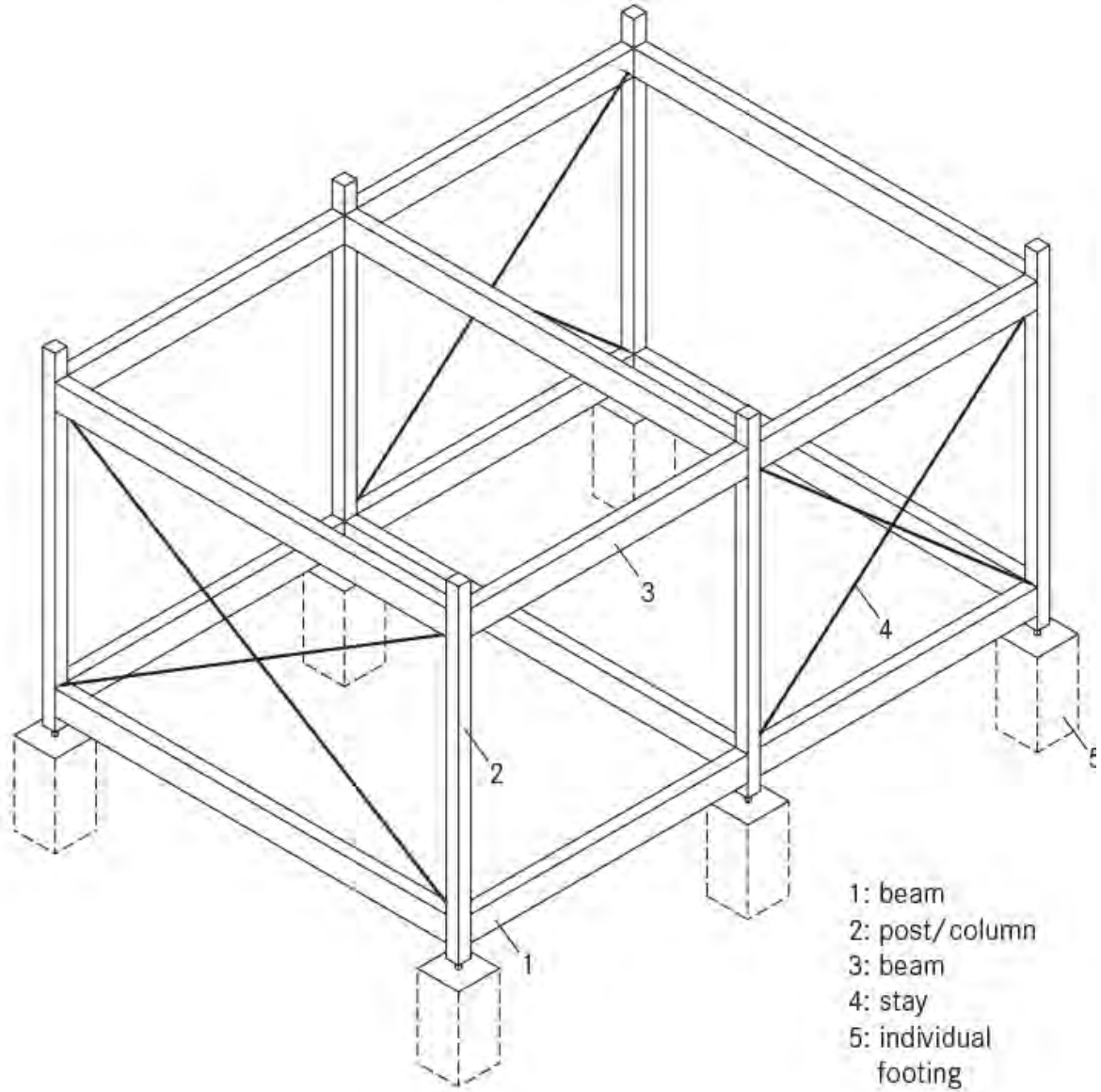


Skeleton construction- tie beam joints

Steiger, L. (2017). *Basics timber construction*, Birkhäuser.

Typical structural timber buildings





Skeleton construction- butted joints

Steiger, L. (2017). *Basics timber construction*, Birkhäuser.

Behaviour of structures under Loads and Forces

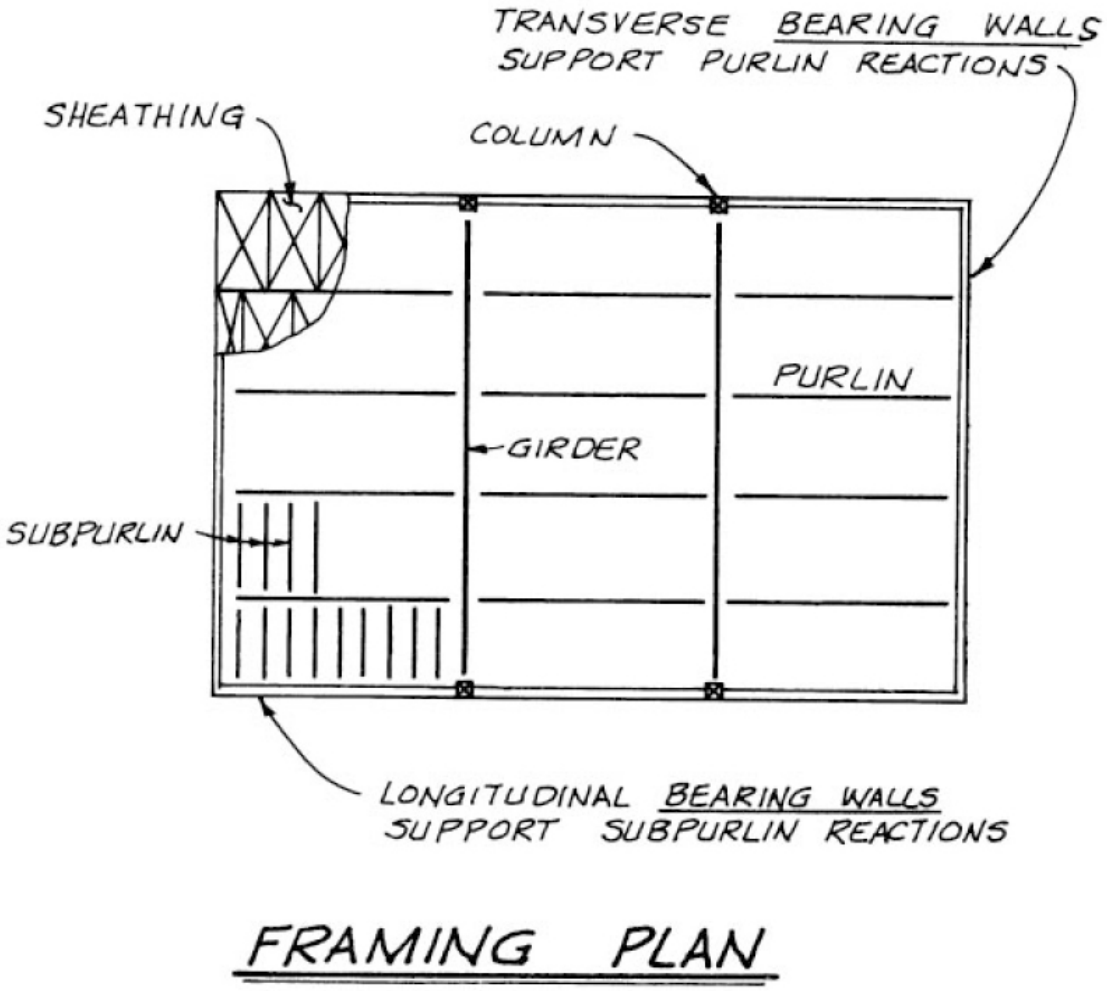
Two main loads and forces:

1. **Vertical loads (dead load, live load and snow load)**
2. **Lateral forces (horizontal wind and seismic effects)**

Breyer, D. E., Cobeen, K. E., Fridley, K. J. & Pollock, D. G. (2015). *Design of wood structures—ASD/LRFD*, McGraw-Hill Education.

Structures subject to Vertical Load

Sheathing to subpurlins, then to purlins, then to the largest beams in the system (girder), then to column



Structures subject to Lateral Forces

3 types of vertical LFRS (lateral-force-resisting-systems):

1. **Moment frame → *not common in timber construction***
2. **Vertical truss (braced frame)**
3. **Shearwall**

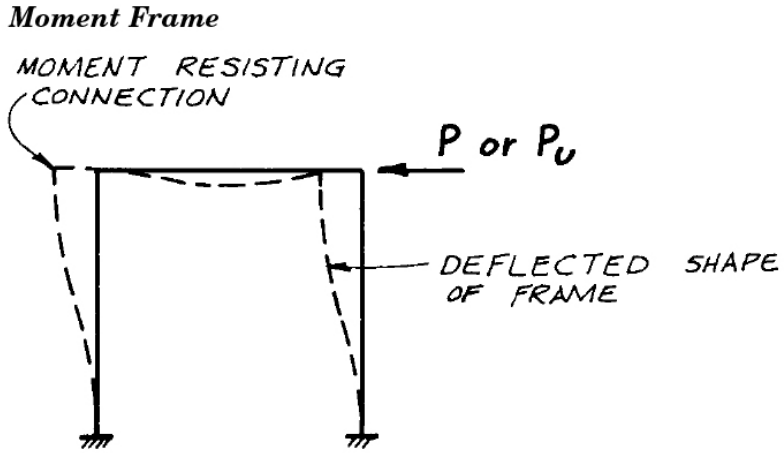


Figure 3.5*a*

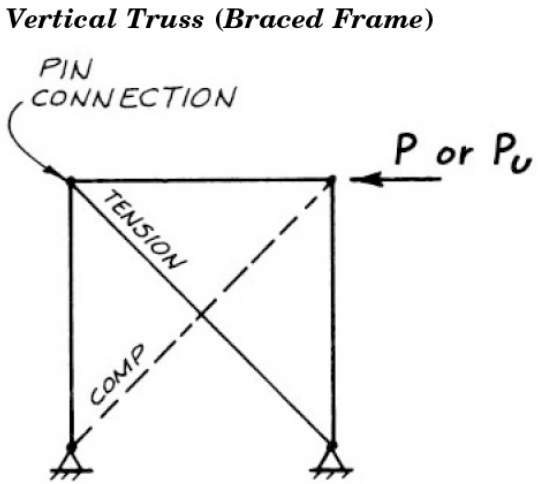


Figure 3.5*b*

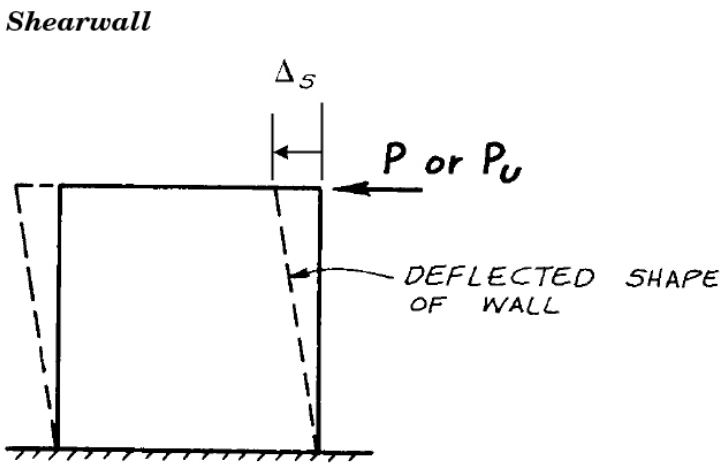


Figure 3.5c

Structures subject to Lateral Forces

Combined vertical and horisontal LFRS elements

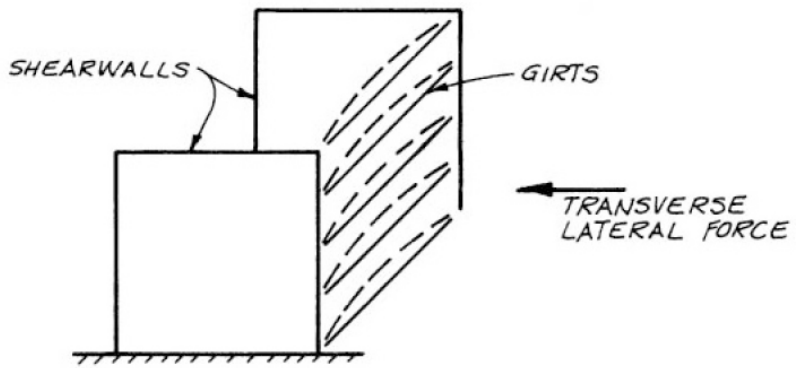
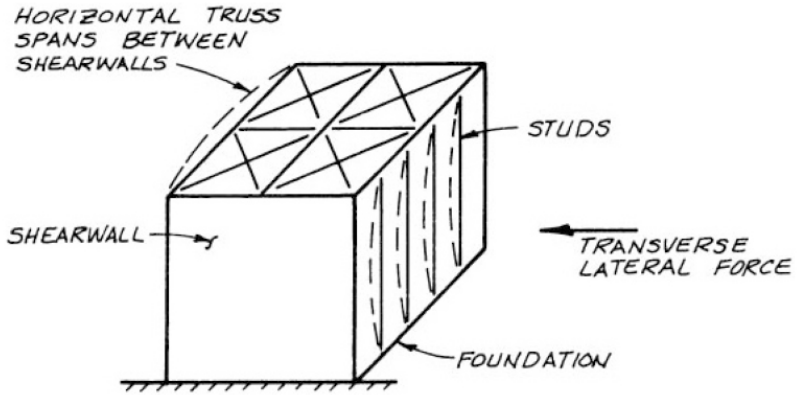
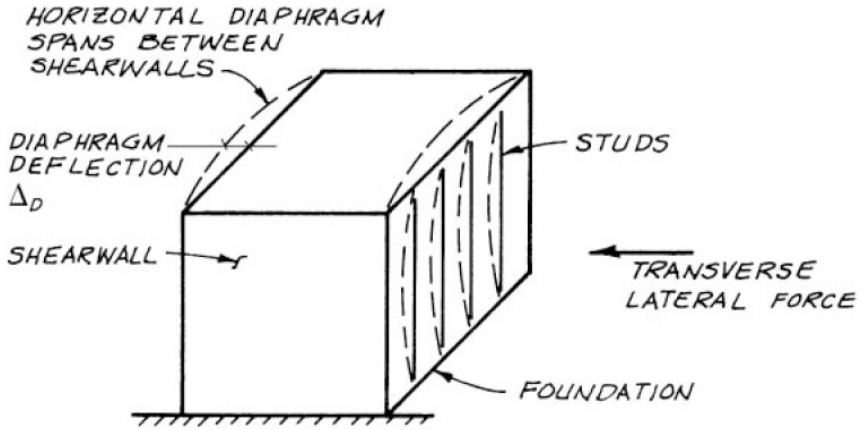


Figure 3.6*a*

Horisontal wall framing



Vertical wall framing w/ horizontal trusses

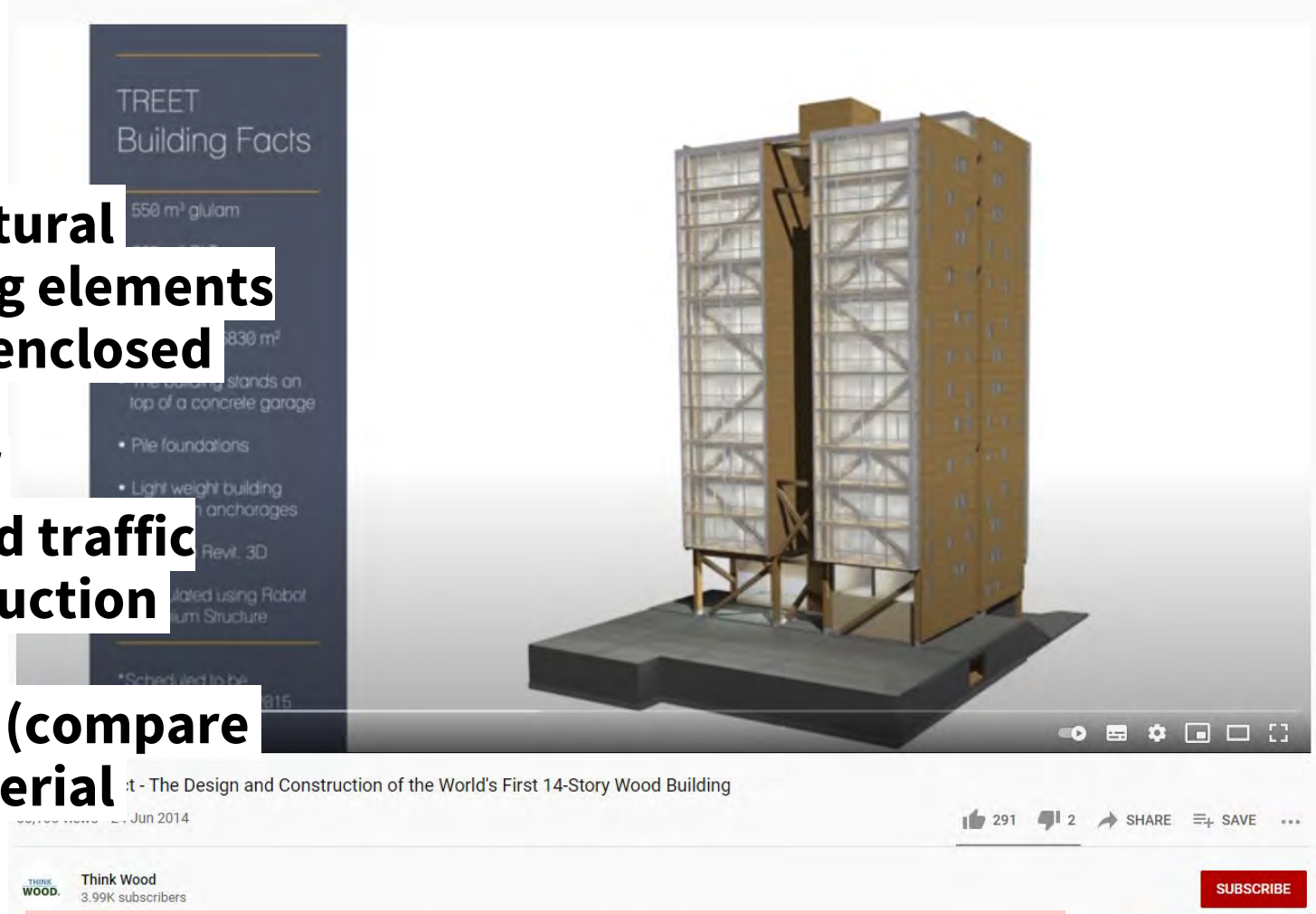


Vertical wall framing w/ horizontal diaphragms

On-site and off-site timber construction

OFF-SITE

- **Prefabricated structural members or building elements**
- **Prefabricated fully enclosed modular units**
- **Reducing volume of construction-related traffic**
- **Reduction of construction noise**
- **Weather protection (compare to the wrapped material during delivery)**



Treet Apartment, Norway. https://youtu.be/e5XsqauBCX4

Other timber products

Products

Timber

34 Solid wood
35 Structural solid wood
36 Glued laminated timber
37 Glued laminated beams
38 Boards/planks
39 Profile boards

Manufactured Wood Products

40 Blockboard and laminated board
41 Three- and five-ply panels
42 Laminated construction board
43 Parallel laminated veneer
44 Parallel strand lumber
45 Laminated strand lumber
46 Oriented strand board
47 Fibreboard
48 Flat-pressed boards
49 Extruded particle boards
50 Fibre-Reinforced cement boards

Hugues, T., Steiger, L. & Weber, J. (2004). *Timber construction: details, products, case studies*, Walter de Gruyter.

Other timber products:

Glulam

Modified solid wood, glued with industrial adhesives. Highly durable and moisture resistant.

Advantages:

- **High load capacity**
- **Long span**
- **Resists transformation**
- **Flexible**
- **High fire resistance**
- **Less need for connections**
- **Pound by pound is stronger than steel**

Other timber products:

Glulam

Other timber products:

Plywood

Three- and Five-Ply Panels

Consist of three or five layers of softwood. Common uses from structural system, exterior cladding, interior cladding, furniture, flooring, light doors etc.

Other timber products: Marine Plywood

Hardwood plywood made with waterproof glue, usually used for building boats for boat parts.

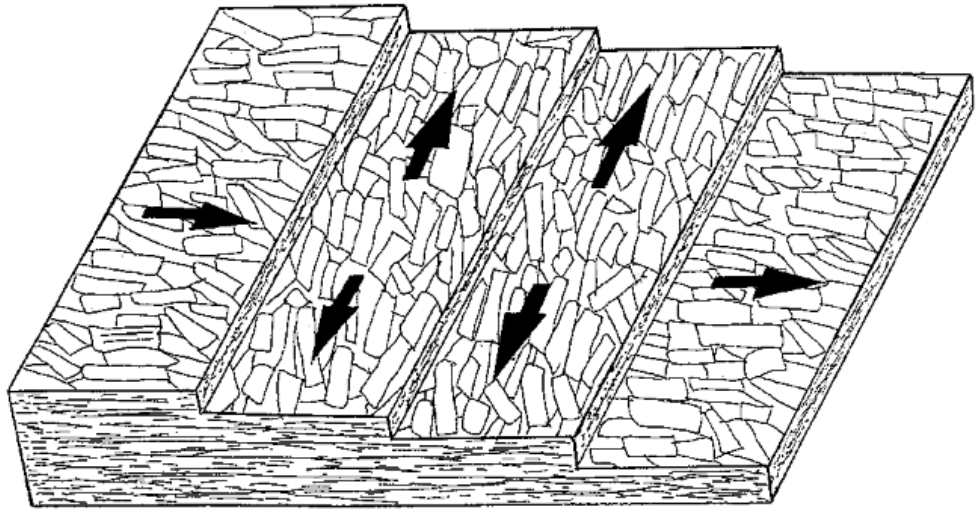
The use in construction: Structural integrity, rot resistance, resistance to impact and excellent finish.

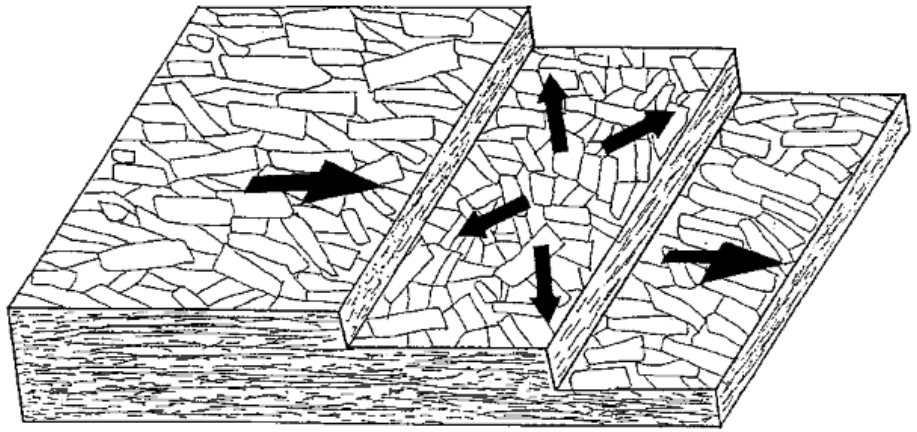
Other timber products:

Oriented Strand Board (OSB Board)

Most commonly used engineered wood-based panels.
For structural and non-structural elements. Was first produced in Canada in 1964.

OSB is manufactured from fast-growing, small trees.





Fire resistance

Timber is not fire retardant. Depending on function of structural elements, we need to consider:

1. **Mechanical resistance → *structure needs to stay strong and stiff to allow fire exit***
2. **Integrity → *forming effective barrier to smoke and flame***
3. **Insulation → *should limit the transfer of heat***

Adequate mechanical resistance can be achieved by:

- **Insulating structural assemblies and members in fire from heat**
- **The use of sacrificial timber**

How?

- **Cover structural members with insulating materials**
- **Applying chemicals**

Other building performances

Fire Safety
Acoustic Performance
Thermal Performance

Sound insulation consideration:
Design of floor/ceiling and wall assemblies

Thermal performance:
Wood is natural insulator
The biggest factor is building envelope.
Insulation, vapour retarders, air barriers and moisture control.

Local regulations:
Timber structures

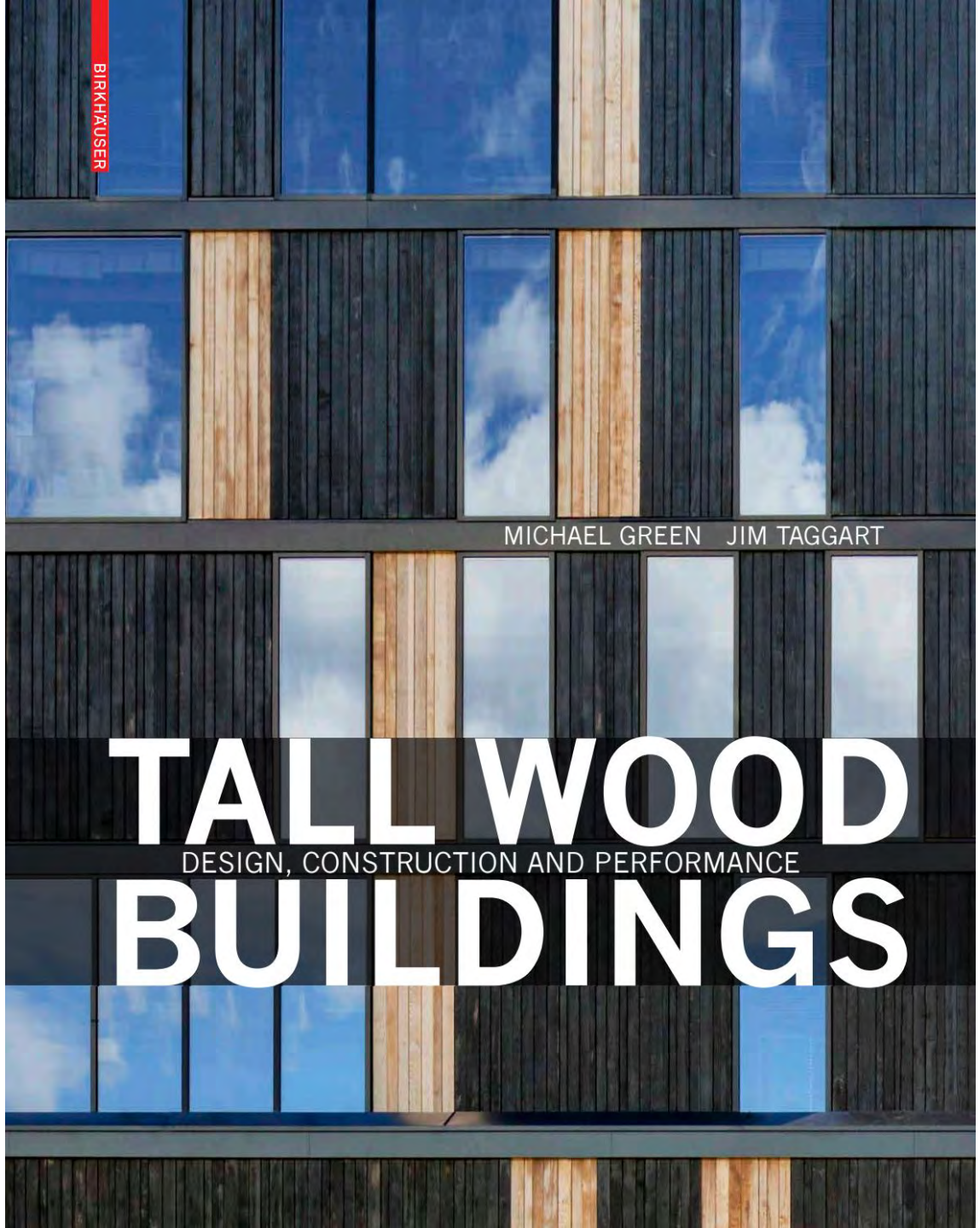
Eurocode 5

AS1684 for Australia

GB 50005-2017 for China

etc

Tall wood buildings



Green, M. & Taggart, J. (2020). *Tall wood buildings: Design, construction and performance*, Birkhäuser.

Hoho Wien, Vienna

24 storeys
75% timber

https://www.lainer.at/projekte/hoho/

Computational timber design

Photo credit: Roland Halbe

Freeform
timber design

Swatch headquarters, Beil, Switzerland
By: Shigeru Ban

https://www.dezeen.com/2019/10/18/swatch-headquaters-shigeru-ban-switzerland

DURATION: 2 HOURS

DigitalFUTURES Talks: Material agency in wood architecture & BIM to Fabrication?

1,289 views • Streamed live on 31 Oct 2020 33 0 SHARE SAVE ...

DigitalFUTURES world
4.21K subscribers
SUBSCRIBED

Martin Self /Xylotek & head of the Architectural Association's Design + Make masters program

https://youtu.be/S66RBJIFWAg

ACTIVITIES

1. PRESENTATION BY TIMBER GROUP 30MINS.
2. Q&A (OTHER GROUPS SHOULD AT LEAST POSIT ONE QUESTION).
3. NO ONLINE SUBMISSION

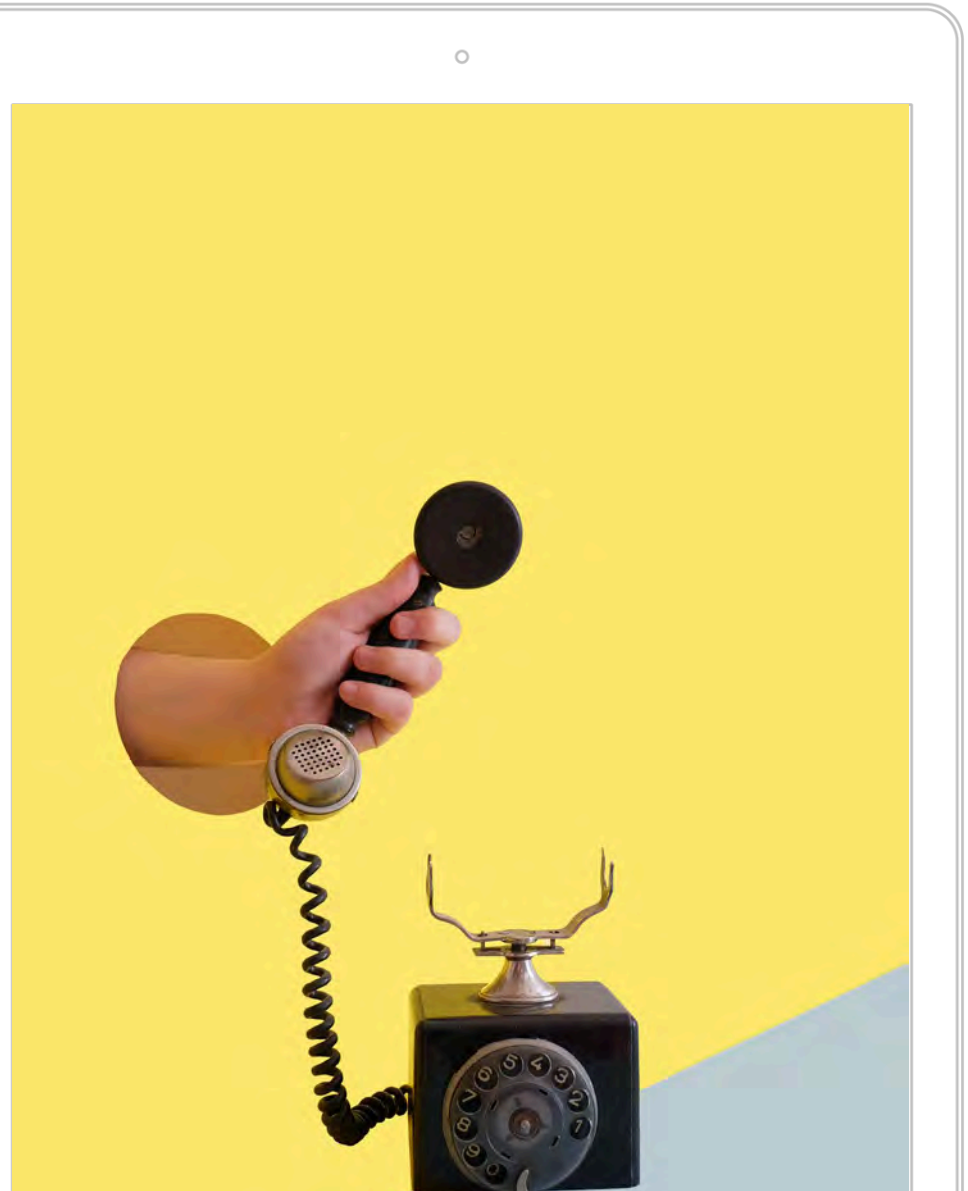
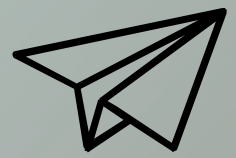


Photo by Elena Koycheva on Unsplash



What do we need to consider before designing timber structure?

Aims and objectives

- To gain understanding on timber as **building materials** and its characteristics
- To learn about timber as main **structural materials**
- To expand on timber within **construction system**