MATERIAL SYSTEMS: TIMBER

WOOD AND TIMBER

Truewood (heartwood)	Sapwood
Inner part of the log	Outer part of the log
Composed of inactive cells	Composed of active cells
Good for timber	Moist so not suitable for conversation of timber

- They are separated during conversation or seasoning process

WOOD

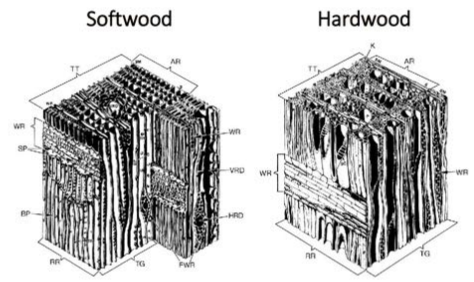
- Due to the hollow cellular microscopic structure of wood, timber is light weight

TIMBER RESOURCES IN AUSTRALIA

Timber in Australia comes from:

Managed native forests	Plantations
Hardwoods	Hardwoods and softwoods
60 - 100 years	30 - 50 years
90% not suitable for harvest 10% suitable for harvest 1% harvested annually and regrown	

SOFTWOOD AND HARDWOOD

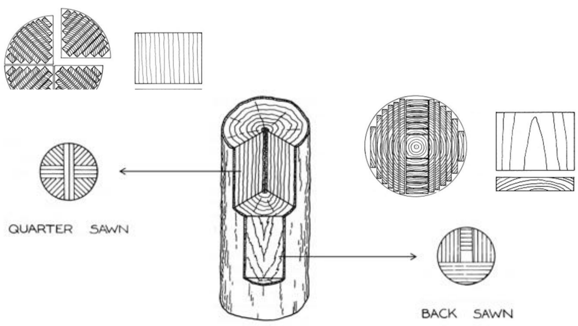


Timber products are divided into 2 broad families:

- **Softwoods (coniferous)**
- **Hardwoods (broad-leaved)**

A more appropriate distinction between softwoods and hardwoods is one that classifies them in relation to their cellular structure

PROCCESS - FROM HARVEST TO MILLING



1. Growth
2. Assessment
3. Harvest
4. Trimming
5. Transport
6. Milling

TIMBER CONVERSATION

The sawing of logs into boards at the mill. 2 main types are:

Back-sawn	Quarter-sawn
Higher recovery from the log	Many decorative timbers reveal their rich figure with interlocking grains only by quarter sawing
Faster and cheaper to produce	More expensive but more reliable for structural performance
Easy to separate knots, less shrinkage	Dries slower but less prone to defects e.g. cupping

MATERIAL SYSTEMS: CONCRETE

OPUS CAEMENTICIUM

- Concrete in a conglomerate, a mixture of elements that cannot be found in nature.
- The Romans developed a building technique called “opus caementicium” where stone rubbles were alternated with dense mortar and confined within courses of bricks acting as formwork
- The Romans perfected their knowledge on mortar and concrete also by developing Pozzolana, a cement obtained combining volcanic rocks with lime and sand which has the property to harden under water

HYDRAULIC LIME

- The term identifies different types of lime mortar, which set through hydration

CEMENT & CONCRETE

- Obtained through the admixture of sand aggregates (coarse and fine), water and cement (the bonding agent)


Cement


Aggregates


Water

CEMENT

- Cement used in the construction industry delivers from Aspdin’s Portland Cement and it is usually referred as Ordinary Portland Cement (OPC)
- OPC is a complex energy intensive industrial product obtained by burning limestone slurry and subsequently combining it with silica, iron and alumina
- OPC is an hydraulic type of cement. It reacts chemically with water by hardening and it provides a durable and chemically stable bond with the aggregates

CEMENT PRODUCTION PROCESS

- Cement is obtained form limestone and clay
- These materials are crushed and blended (‘kiln feed’), then heated in a kiln (‘klinker’)
- **Limestone/clay** —> blending —> kiln —> **klinker** —> cement mill —> **cement**

SUPPLEMENTARY CEMENTITIOUS MATERIALS

- Ordinary cement can be enriched by adding supplementary materials, creating cement ‘blends’
- Materials are added in quantities not exceeding 10%, to improve workability without affecting strength


FLY ASH
Material extracted from the flue gases of a boiler fired with pulverised coal


SLAG
Slag is a granulated material consisting of silicates and calcium aluminosilicate, a by product of steel making in a blast furnace


AMORPHOUS SILICA
A very fine pozzolanic material composed mostly of non christalline silica

MATERIAL SYSTEMS: STEEL

STEEL MANUFACTURING

Iron alloys:
- Wrought iron (purest form of iron - 0.02%)
- Cast iron (1.8 - 4%)
- Steel (0.4 - 1.7%)
- Stainless steel

Carbon content
- Critical to determine the properties of iron carbon alloys
- Too much carbon makes the alloy hard but very brittle
- Too little carbon makes the alloy soft and weak
- Steel is an alloy with an optimum carbon content between 0.04% and 1.8%
- The carbon content of steel is adjusted depending on the applications required

Wrought Iron (0.02% carbon content)
- The purest form of iron used for construction
- Contains a very low level of carbon (0.02%)
- Ductile and high strength
- Admirable working properties make it a viable option for ornamental ironwork
- Limitations: too costly and cannot be welded

Cast Iron (1.8 - 4% carbon content)
- Good fluidity making it ideal for casting of complex industry parts
- Reasonably strong but brittle
- Low melting point makes it almost impossible to weld

Metal properties
- Deform greatly before breaking and after their elastic phase they enter into a prolonged plastic flow before breaking. e.g. ruler bends and goes back to original form until it reaches a point where it fractures
- In other words they are a lot more ductile.

Mild steel (0.1 - 0.7% carbon content)
- For large scale structural applications iron alloys are preferred when they have these properties:
  - Weldability (less than 0.5 carbon content)
  - Ductility (at service temperature)
  - Low cost (to strength ratio)
  - Availability (in sections and plates)

Steel advantages and disadvantages:

Advantages	**Disadvantages**
High strength (in tention, compression and shear)	Doesn't provide the dual function of structure + envelope of other materials (masonry, concrete)
Excellent strength to weight ratio	
High stiffness (less prone to deflect)	Prone to corrosion (must be protected)
Relatively easy to connect	Fire threat

MATERIAL SYSTEMS: MASONRY

SMALL STONES (DRY CONSTRUCTION)

- Local small granite stones are simply stacked
- Larger stones form the base of the wall, stones progressively get smaller
- Stones are bound to one another only in virtue of their weight (no mortar)
- This system works well in compression but suffers to take tensional stress
- Very difficult to form a roof

STEREOTOMY (DRY CONSTRUCTION)

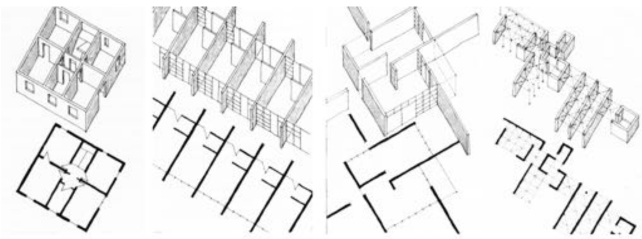
- Stones are cut to size (slightly tapered)
- Columns slightly tapered to reduce self weight
- Kept together by friction and self weight
- Allows for the build of the structural principles such as the arch, vault and dome (three-dimensional masonry)
- Allows for more complex construction methods to develop

CLAY MASONARY

- Bricks combine the advantages of small stone stacking systems with the precision and spanning capacity of large stone masonry
- Bricks are small enough to be held on one hand
- Bricks and stone work well together

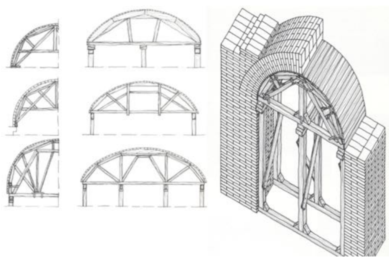
STRUCTURAL CONFIGURATIONS

- Masonry with small modular elements 'liberates' architects and builders from the 'cage'
- Meaning, structural walls can be separated from non-structural infills
- Structural configurations include:



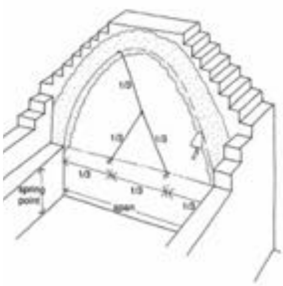
Cage Parallel Irregular Hybrid

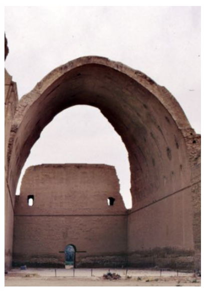
CENTERING



- The temporary structure which the stones of an arch / vault are laid during construction.
- Until the keystone is inserted, an arch has no strength and needs the centring to keep everything in place

NUBIAN VAULTS





- These vaults are built <u>without centring</u> due to:
  - Stickiness of mud mortar
  - Shape of the vault
  - Inclination of the courses that are placed one upon the other
  - Supporting wall which is thicker than the lateral walls

CONSTRUCTION MACHINES AND DESIGN AUTOMATION

MA = resistance / effort

* The mechanical advantage is given by the number of parts of the rope that act on the load

WHAT IS A MACHINE?

- Any device that helps you to do work
- We use machines to:
  - Transform energy
  - Transfer and/or increase the magnitude of a force (hammer)
  - Change the direction of a force (halyard, crane)
  - Increase the speed or distance of a force (bicycle)

SIMPLE MACHINE

- Use 'mechanical advantage' to multiply force
- The simplest form of using one thing to accomplish something faster or better
- There are six simple machines:
  - **Lever**
  - **Inclined plane**
  - **Block and tackle**
  - **Wheel and axle**
  - **Screw**
  - **Gear**
- In physics there are only 2 recognised principles (other 4 refer to these 2 principles):
  - Lever
  - Inclines plane

COMPLEX MACHINES (COMPOUND MACHINES)

- Combination of 2 or more simple machines
- High maintenance and expensive to repair

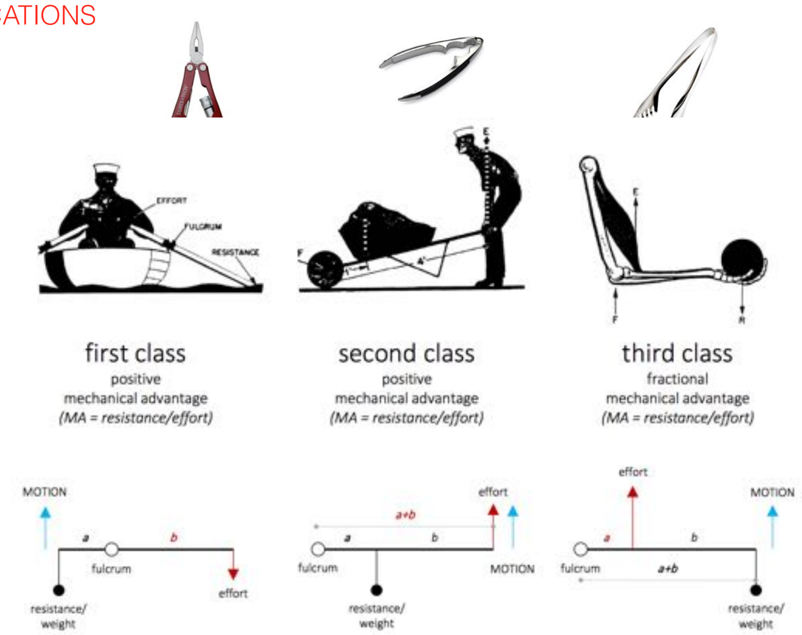
SIMPLE VS. COMPLEX MACHINES

- Simple machines often save:
  - Money
  - Time
  - Frustration

SIX SIMPLE MACHINES AND THEIR APPLICATIONS

The Lever

- A rigid bar resting on a pivot
- Used to move a heavy load at one end when pressure is applied to the other
- Three aspects:
  - Resistance
  - Fulcrum
  - Effort



SITE ANALYSIS (Guest Lecturer: Blair Gardiner)

WHAT IS A SITE ANALYSIS?

The detailed study or examination of an area proposed for or influenced by construction development in order to understand more about it and generate a response to the outcomes of such study and investigations

WHY UNDERTAKE A SITE ANALYSIS?

- Prepared in advance of design & in advance of construction (tendering)
- Purpose: to record & evaluate information on the site & surroundings & how this evaluation may impact on the design & construction of the building
- Site analysis procedure part of any design response. It is also critical in implementing the construction process & methodology

- Provides client with information on development feasibility factors
- Assists in locating building
- Opportunity factors from advantages of site (site features/environmental benefits)
- Identifies potential problems (short & long-term)
- Structure needs to be designed to account for site factors (e.g. footing system, building articulation)
- Servicing & infrastructure capacity for building needs to be determined
- Constructability factors need to be accounted for (manner of construction & management of construction)
- Safety factors arising from site need to be considered
- Influence of neighbouring facilities on site & new building need to be factored
- Amenity of adjacent structures & facility operation of adjacencies need to be considered

<u>Design response cannot commence without consideration on how to construct the building and how to respond to difficult and very particular site conditions</u>

- What materials do you use – If no room, can only work from one site so need to be easy to handle
- How do you minimise construction time – access issues, noise, amenity
- Systems need to provide fire rating for construction on boundary – should building be prefabricated but how to you get prefabricated elements up, no room for crane?

DESIGN SITE ANALYSIS (not a construction design site analysis)

- Planning policy – Land use considerations
- Heritage
- Density
- Urban context – neighbourhood character
- Streetscape
- Environmental overlays
- Amenity considerations – access to light, overshadowing....
- Site layout & landscaping
- Energy efficiency
- Building envelope
- Visual & acoustic privacy
- Car parking & vehicle access
- Private & communal open space (residential)
- Site facilities (mail, rubbish)
- Site entry points

ENVIRONMENTAL PERFORMANCES (Guest Lecturer: André Stephan)

ENVIRONMENTAL ASSESSMENT

A process of evaluating and establishing the significant short and long term effect of the building on the surrounding environment. It provides an opportunity to minimise and eliminate these effects.

CONCEPTS

- Stocks and flows
- Final (how much energy we need to heat/cool/light), delivered (amount of energy before loss), primary energy (initial amount of energy produced)
- Active energy (solar panels), passive energy (sun)
- Greenhouse gas emissions (CO2)

Primary energy

The amount of energy produced at the source to deliver the final energy stage
eg. at the coal fired plant in Gippsland to deliver to a house in Melbourne

Delivered energy

The amount of energy actually delivered
eg. energy delivered to the building, measured on the meter

Final energy

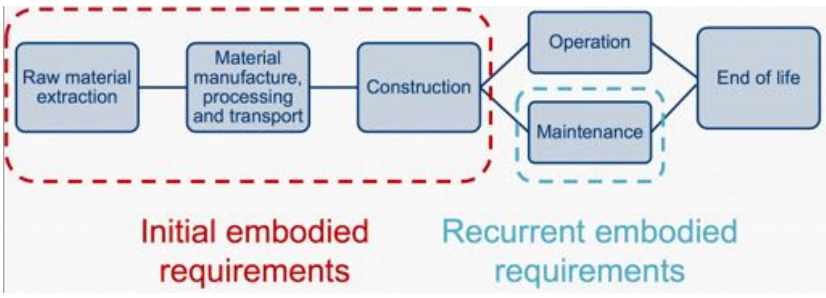
The amount of energy used at the operation / target
eg. how much energy is required in lights to actually provide for the site at working level

LIFE CYCLE ANALYSIS

Examines the total environmental impact of a material or product through every step of its life. From raw materials, to manufacture/transport, to construction, to using it / maintaining it to the disposal and recycling.

EMBODIED ENERGY

Embodied energy is the sum of all energy inputs, across the entire supply chain, supporting the production and delivery of a product or service.



OPERATIONAL ENERGY

Amount of energy required to run the building over its entire lifetime (depends on occupants)

FINDING STRUCTURAL FORMS

WHAT IS A SHELL

- A structure defined by a curved surface
- It is thin in the direction perpendicular to the surface
- Might be curved in 2 directions (dome, cooling tower) or it may be cylindrical and curve in 1 direction
- Work in tension and compression or only compression

MEMBRANE ACTION

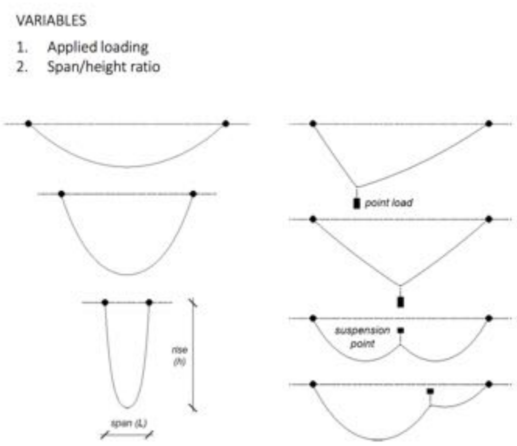
- All the forces are mainly transferred along the surface (there is no bending moment)
- In the case of gridshells, the mechanical behaviour is preserved through a clear grid of beams that highly reduce the amount of material implied for construction
- Nothing is lacking and nothing is superfluous

FORM FINDING

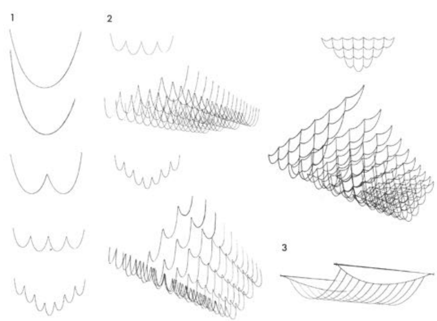
- Identifies the process of designing optimal structural shapes by using experimental tools and strategies (physical models) to simulate a specific (expected) mechanical behaviour
- Reverse hanging method is the oldest and probably most diffused form-finding technique for arches and shells
- A physical model, made with elastic cables or membranes with no rotational stiffness, is first subject to gravitational forces to obtain a structural state of pure tension. Such a form is then inverted to identify the mechanical compression-only situation

St Louis Arch, Missouri
- Eero Saarinen

Strings (reverse hanging method)



Sagrada Familia, Barcelona



WATERPROOFING (Guest Lecturer: Giorgio Marfella)

WATERPROOFING PRINCIPLES

Water penetration: 3 necessary conditions

1. Water must be present on the external surface
2. Must be an opening to permit to passage of water
3. Must be a force to drive the water through the opening

ALL 3 MUST BE PRESENT

Waterproofing: 3 basic strategies

1. Water is diverted and discharged form the surface of the building
2. The gaps/openings where water can enter are closed
3. Forces that can push the water inside the building envelope are neutralised

2 statistics to remember

- 90% of water leaks occur within 1% of the total building envelope area
- Only 1% of water leaks are caused by a system or material failures

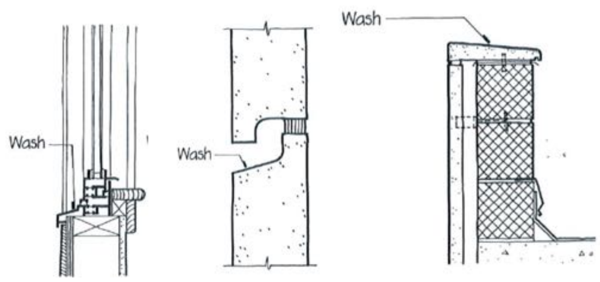
WATERPROOFING METHODS: DIVERSION

5 diversion strategies:

- Wash
- Slope to Drain
- Overhang / drip
- Overlap
- Weep

Wash

- Takes water out
- Parapet flashings (angled for water)



Wash: compatibility of metals

- Make sure metal materials are compatible when transferring water
- Copper will make other materials rust if contact is made (with water)
- Aluminium is a good material (compatible with most materials)
  but not concrete or mind steel (separation barrier)