The Built Environment:

Materials for construction

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Learning objectives for this lecture unit

Ansys software mentioned	• Ansys Granta EduPack™, a teaching software for materials education

Intended Learning Outcomes	
Knowledge and Understanding	Understanding of the materials used in the built environment
Skills and Abilities	Ability to select materials to meet design criteria in built environment structures and interiors
Values and Attitudes	Insight into the diverse use and importance of materials in architecture and the built environment

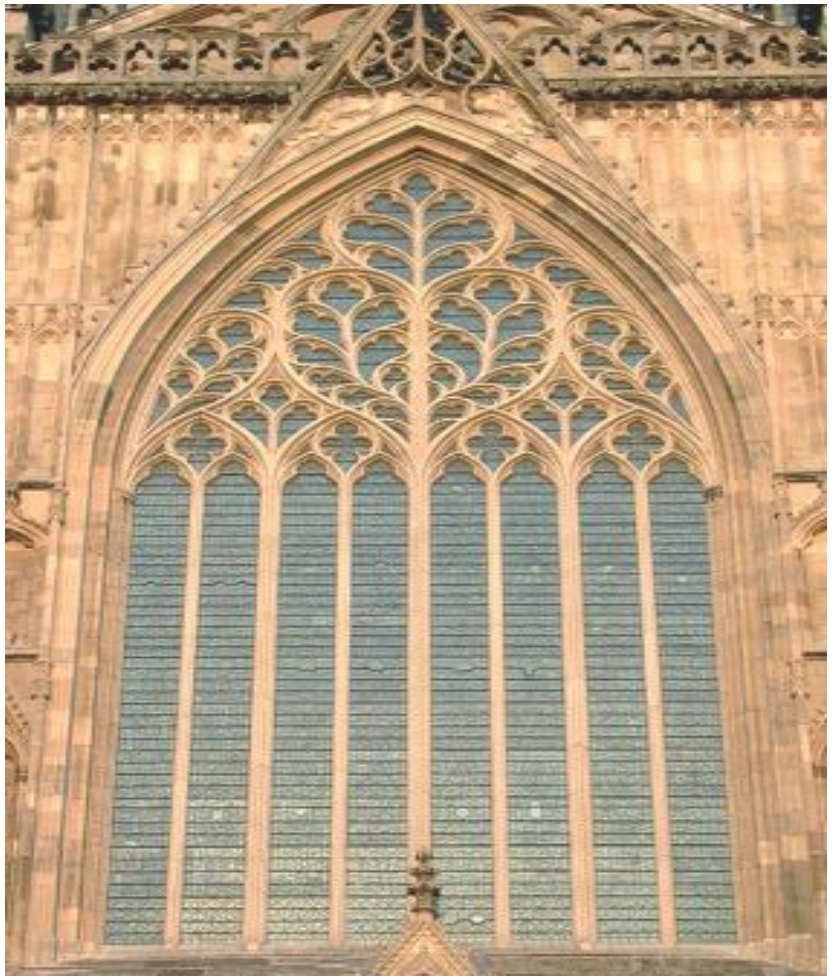
Resources

- **Text:** "Material Architecture – emergent materials for innovative buildings and ecological construction" by John Fernandez, Architecture Press, Elsevier, Oxford, UK, 2006 ISBN 0-7506-6497-5.
- **Software:** Ansys Granta EduPack software Built Environment Database (www.ansys.com/products/materials/granta-edupack)

Outline of the lecture unit

- Why are architects and engineers interested in materials?
- ***Architecture and the Built Environment***
- The expanded Level 2 ***Built Environment*** database

Why do engineers and architects need to know about materials?



Pre-industrial revolution
Stone, wood, glass

York Minster,
York, UK.

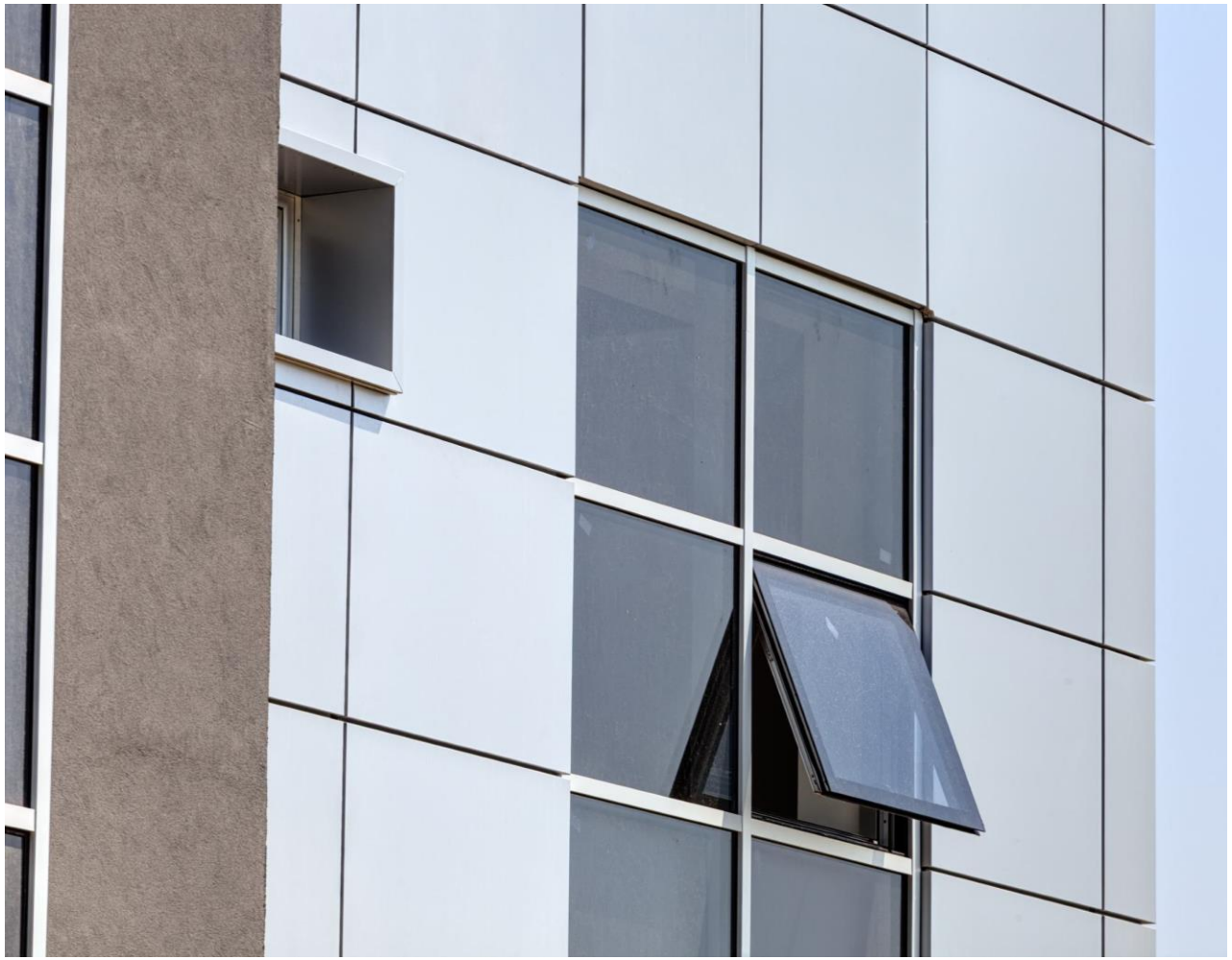
Post-industrial revolution
ETFE *(and thousands more)*

Eden Project,
Cornwall, UK

Products, not just materials

Today, architects and structural engineers specify products, not just materials

Low-e laminated glass



Aluminum composite panels used as building ‘skins’

Unfamiliar materials used in new products

Angle selective glass

Institute of Contemporary Art, Boston, MA. Diller + Scofidio, Architect.

Unfamiliar materials used in new products

Many materials used in these products may be unfamiliar to designers.

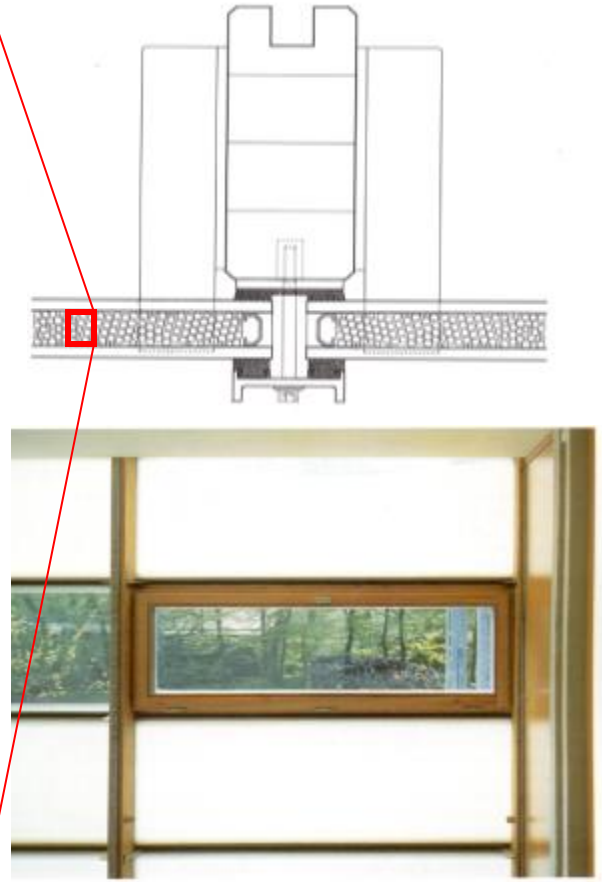
Aluminum skin, covering…..

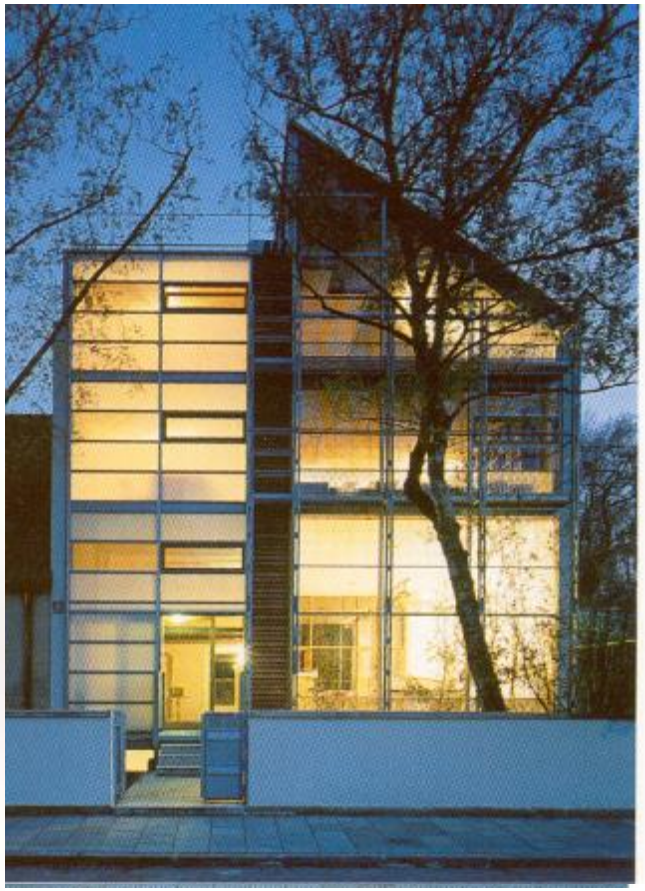
Simmons Hall Student Dormitory, MIT, USA. Steven Holl, Architect.

Waterproof, adhesive-backed EPDM

Unfamiliar materials used in new products

Apartment Building, Munich, Germany. Thomas Herzog, Architect.





Silica aerogels allowing…..

translucent walls with high thermal resistance

Unfamiliar materials used in new products

Cathedral of Los Angeles, USA. Rafael Moneo Architect

High density concrete with stainless steel reinforcement

Stata Center, MIT, USA. F.O. Gehry Architect

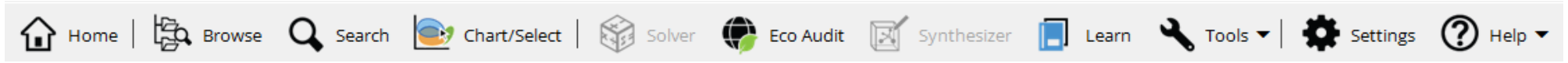
Stainless steel, zinc coated titanium, polymer sealants

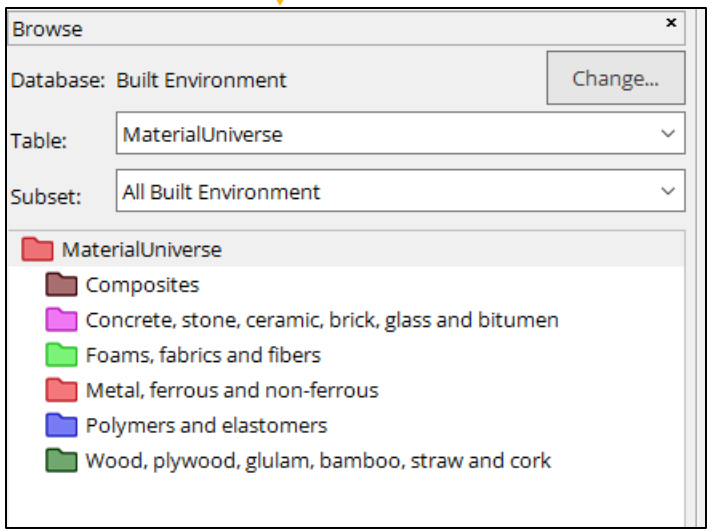
Different building systems require different materials

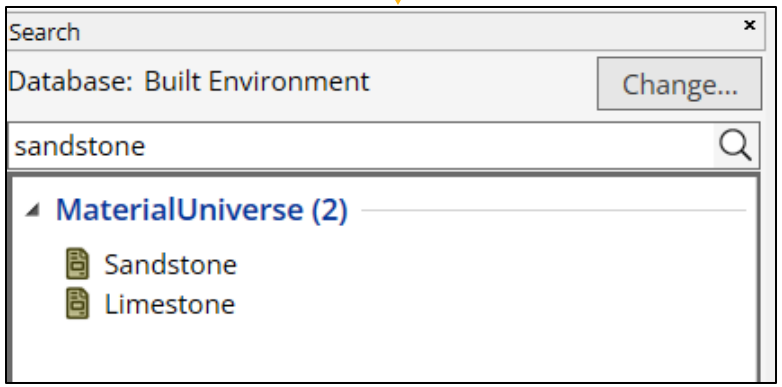
System	Functions	Materials
Superstructure	• Transmit vertical loads to foundation • Resist dynamic loading from wind & seismic loads • Provide long term service	▪ Steel reinforced concrete, stone ▪ Cast iron and steel alloys ▪ Timber ▪ Brick, clay-based ceramics
Enclosure	• Control the transfer of air, heat, water, vapor • Regulate radiation • Provide acoustic separation	▪ Glass ▪ Aluminum ▪ Silicone, neoprene, epoxies, bitumen ▪ Insulating fibers and foams
Interiors	• Delineate interior space and distinct climate zones • acoustically separate zones • Provide space for finished surfaces	▪ Wood particle boards ▪ Polymer reinforced plaster ▪ Resins and other polymers ▪ Tiles, terracotta, brick
Building services	• Manage heating, cooling and ventilation • Regulate artificial and natural light • Provide water and waste removal	▪ Galvanized sheet metals ▪ Polymer electrical insulators ▪ Heat exchange materials ▪ Copper and PVC piping

Ansys Granta EduPack software database for the built environment

Toolbar







The Built Environment data records

A typical record: Sandstone

Some unique properties

Sandstone

Datasheet view: All Built Environment | Show/Hide | Find Similar

Concrete, stone, ceramic, brick, glass and bitumen > Concrete, stone and brick > Stone >

Description

Illustration

Figure caption

1. Sandstone bricks. 2. Traditional Maltese building made of sandstone. 3. Weathered sandstone on a façade. Images used under license from Shutterstock.com

The material

Sandstone is consolidated sand particles (quartz), bonded by a cementing agent: feldspars, limes, silica or clays. The size of the sand particles, the porosity and the strength vary greatly in different sandstones. The colors derive from iron or manganese impurities and give sandstones their character.

Building system

Superstructure	✓
Enclosure	✓
Interiors	✓
Services	✓

Mechanical properties

Young's modulus	14	-	25	GPa
Shear modulus	5.6	-	10	GPa
Bulk modulus	11	-	20	GPa
Bending modulus	* 14	-	40	GPa
Poisson's ratio	0.22	-	0.29	
Yield strength (elastic limit)	4	-	22	MPa
Tensile strength	4	-	22	MPa
Compressive strength	* 50	-	155	MPa
Bending strength	5	-	16	MPa
Elongation	* 0.02	-	0.16	% strain
Hardness - Vickers	7	-	38	HV
Fatigue strength at 10^7 cycles	* 3.1	-	12	MPa
Fracture toughness	* 0.7	-	1.1	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.0019	-	0.0057	

Thermal and combustion properties

Thermal conductor or insulator?	Poor insulator			
Thermal resistivity	* 0.2	-	1.11	m.°C/W
Thermal expansion coefficient	* 8	-	20	µstrain/°C
Specific heat capacity	* 840	-	920	J/kg.°C
Melting point	* 1.2e3	-	1.4e3	°C
Maximum service temperature	* 400	-	600	°C
Minimum service temperature	-273			°C
Flammability	Non-flammable			
Emissivity	0.6	-	0.83	

Hygro-thermal properties

Water absorption	2	-	8.5	%
Frost resistance	Average			

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	* 1e10	-	1e14	µohm.cm
Dielectric constant (relative permittivity)	* 6	-	9	
Dissipation factor (dielectric loss tangent)	* 0.001	-	0.01	
Dielectric strength (dielectric breakdown)	5	-	12	MV/m

Optical properties

Natural color

Pure siliceous sandstone is white or cream. But red, gray, blueish or black sandstones are common.

Transparency	Opaque			
Transmissivity	0			%

Acoustic properties

Sound absorption	Poor			
Sound isolation	Good			

Processability (scale 1 = impractical to 5 = excellent)

Machinability	3	-	4	

Durability

Water (fresh)	Excellent			
Water (salt)	Excellent			
Weak acids	Acceptable			
Strong acids	Acceptable			
Weak alkalis	Excellent			
Strong alkalis	Acceptable			
Organic solvents	Excellent			
UV radiation (sunlight)	Excellent			
Wear resistance	Limited use			
Industrial atmosphere	Acceptable			
Rural atmosphere	Excellent			
Marine atmosphere	Acceptable			

Primary material production: energy and climate change

Climate change (CO_2-eq), primary production (virgin grade)	* 0.0571	-	0.0629	kg/kg
Embodied energy, primary production (virgin grade)	* 0.951	-	1.05	MJ/kg
Water Usage	* 3.23	-	3.57	l/kg

Material processing: energy

Grinding energy (per unit wt removed)	* 7.34	-	8.11	MJ/kg

Material processing: climate change

Grinding CO_2 (per unit wt removed)	* 0.551	-	0.608	kg/kg

The expanded Level 2 database

- **Images** relating to the built environment where possible

Millau Viaduct, France

- **133 records** emphasising materials for the built environment

More classes of concrete

More classes of brick and tile

More fibers, particle and plywoods

More materials for insulation

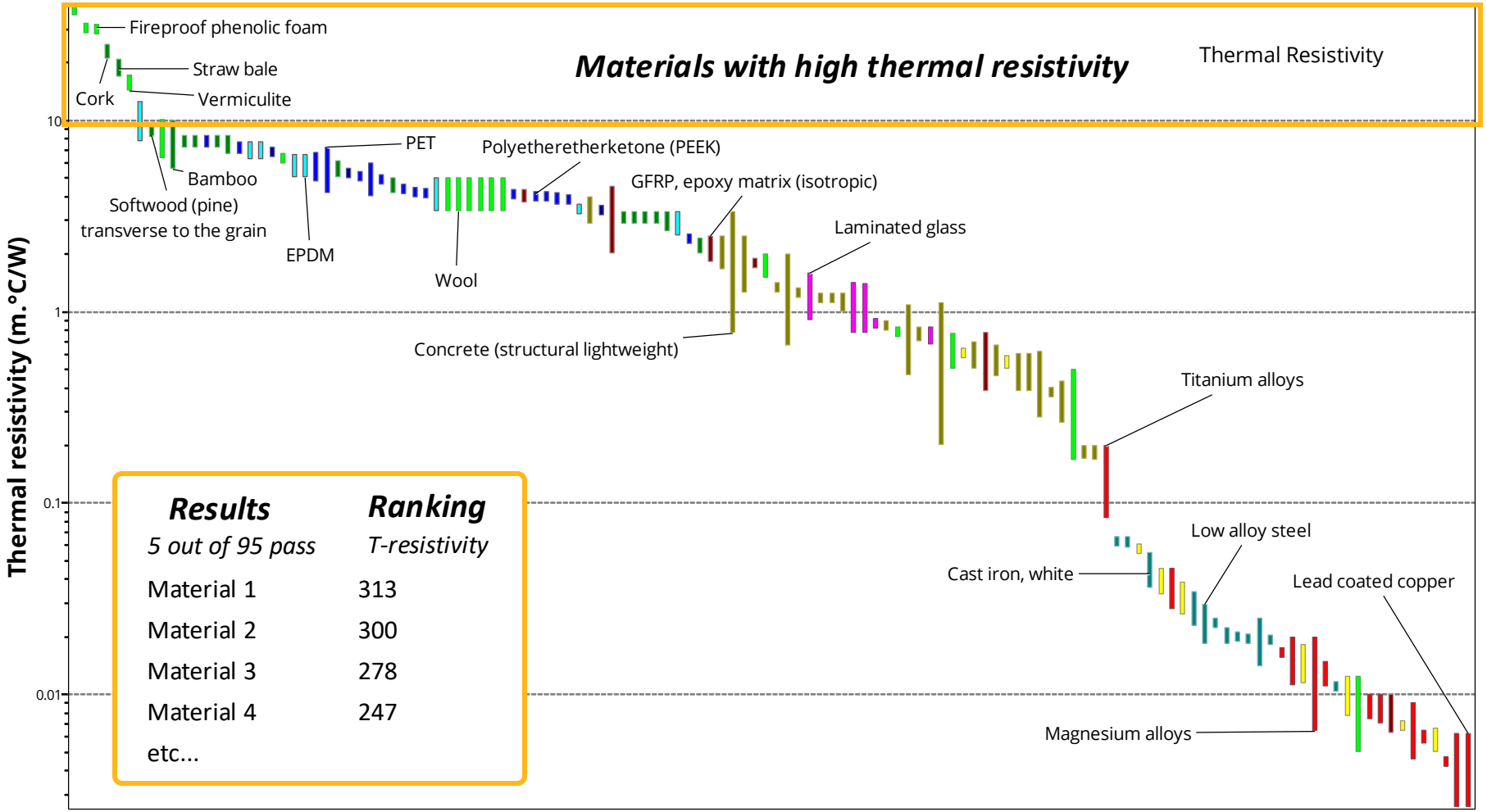
- **Additional property fields**

Mechanical properties in bending

Hygro-thermal properties

Acoustic properties

Ability to create property charts



- **Enables students to explore relationships**
- **Carry out elementary selections (“*Find materials with large thermal resistivity*”)**

Material selection project: cladding for buildings

- **Translate design requirements**

Design requirements

- Durable, strong, ductile cladding
- Available in sheet form
- Environmentally friendly
- As cheap as possible

Translation

Function — Protective cladding

Constraints

- Form: sheet
- Tensile strength > 50 MPa
- Elongation > 2%
- Durability in industrial environment: Excellent
- Durability in rural environment: Excellent
- Durability in marine environment: Acceptable

Objectives

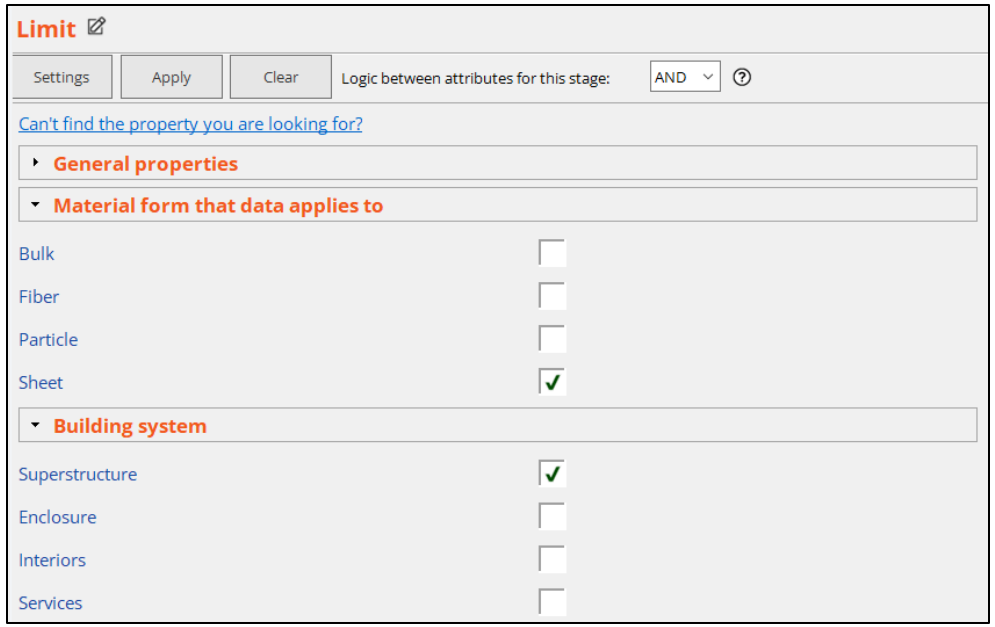
- Minimize cost (and / or)
- Minimize embodied energy

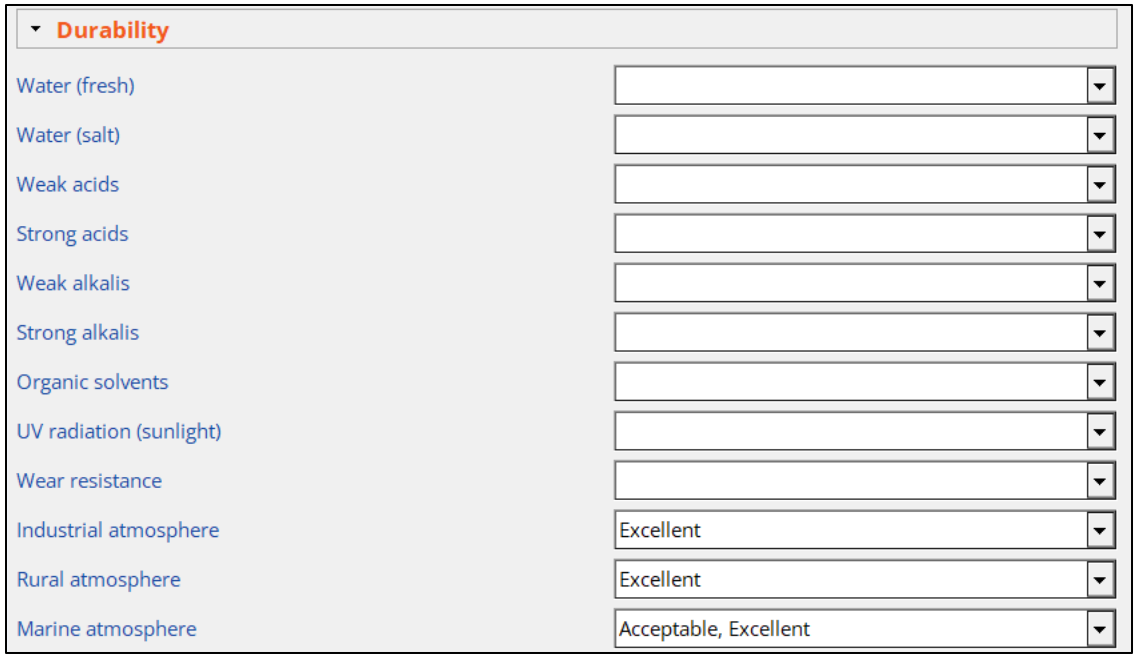
Free variable — Choice of material

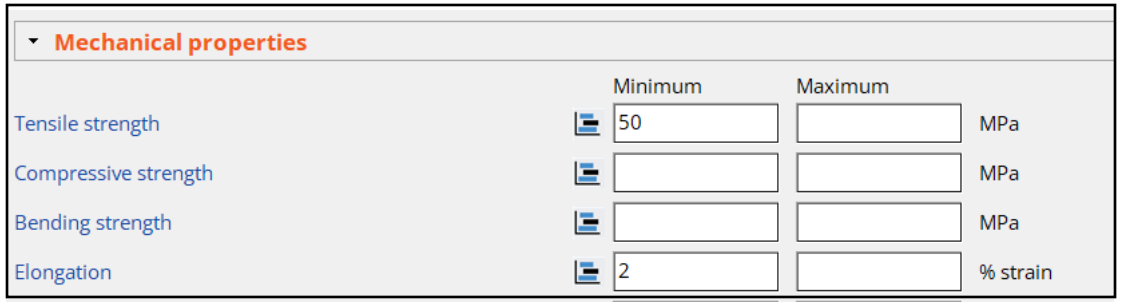
Material selection project: cladding for buildings

- **Apply constraints using a Limit stage**

In addition to numerical constraints, additional qualitative properties may be screened

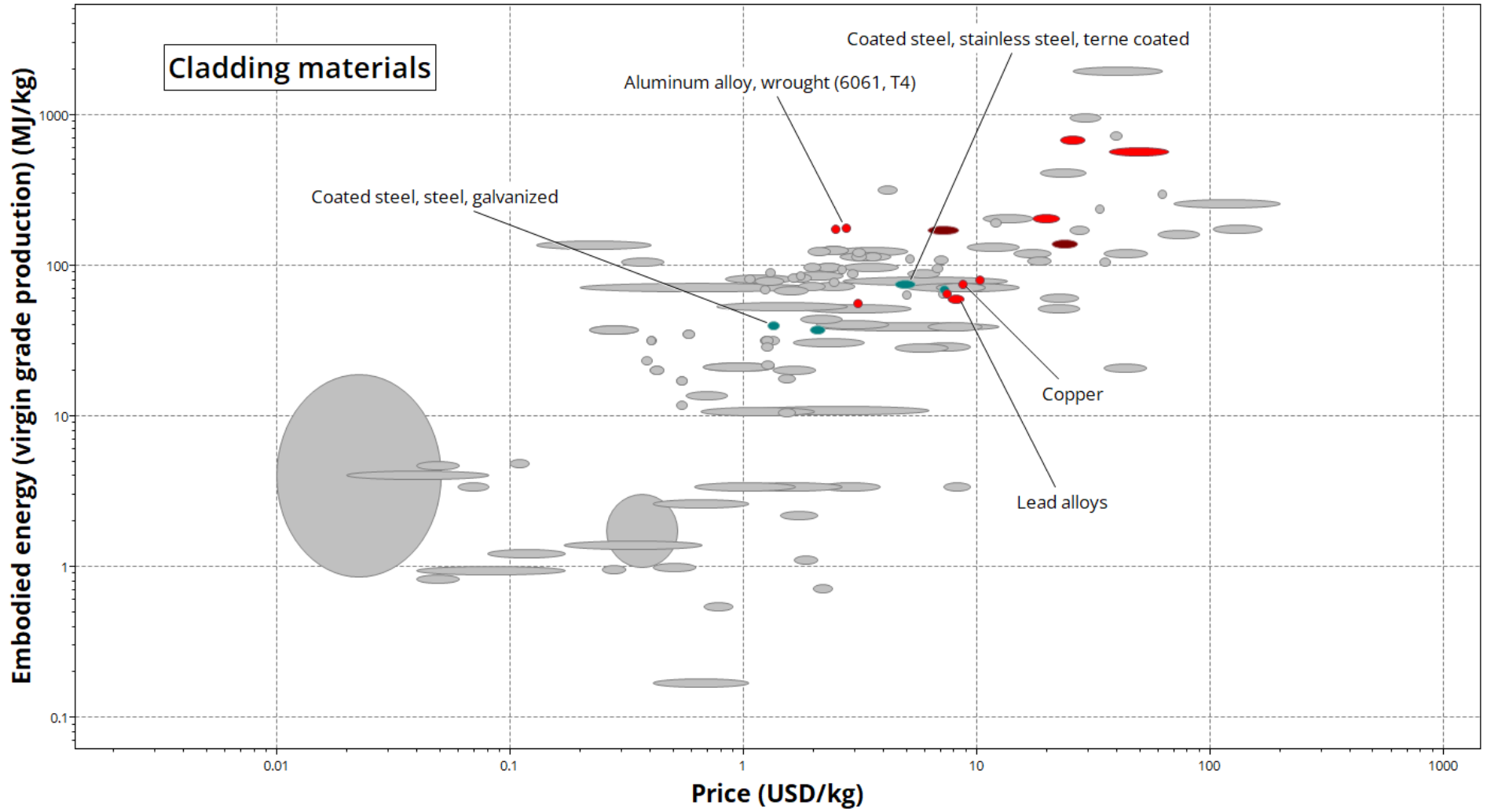






Material selection project: cladding for buildings

- **A graph stage to minimize cost and embodied energy after suitable constraints**



Material selection project: cladding for buildings

- **Result**

Coated steel, steel, galvanized

Datasheet view: All Built Environment | Show/Hide | Find Similar

Metal, ferrous and non-ferrous > Ferrous alloys > Coated steel >

Description

Illustration

Figure caption

1. Components being galvanized in a zinc bath. 2. Typical galvanized corrugated steel sheet for roofing. Images used under license from Shutterstock.com

The material

The galvanization of steel enhances its corrosion properties by forming a protective coating of zinc. In the event of water coming into contact with the galvanized steel, an electrochemical cell is set up and this zinc layer corrodes sacrificially instead of the steel beneath it.
Hot dip galvanized coatings are readily available on all standard and most proprietary grades of steels. This datasheet describes the properties of galvanized steel in which the substrate is the low carbon steel AISI 1015.

Summary

- Engineers and architects get acquainted with new materials in a visual and engaging way
- Environmental data is available for all materials in the database, sustainability concepts can easily be incorporated
- Materials selection and substitution is facilitated

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