Ansys Granta EduPack™ Case Study

The Built Environment

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Ansys Software Used

This resource uses Ansys Granta EduPack™, a teaching software for materials education.

1. Materials in the built environment

The concept Built Environment is used when referring to surroundings created by humans, for humans, or to be used for human activity. This would include, for example, houses and other buildings, roads, parks, etc.

It is obvious that this is of huge direct importance to everybody's daily life, but it is also contributing some of our most urgent long-term challenges. With a world population of many billions, the impact from construction and maintenance is monumental. Resource extraction and material production as well as heating and other energy use, including transport systems, all have global-scale consequences. This can be seen in the annual production levels of materials in Figure 1 (oil and coal as reference):

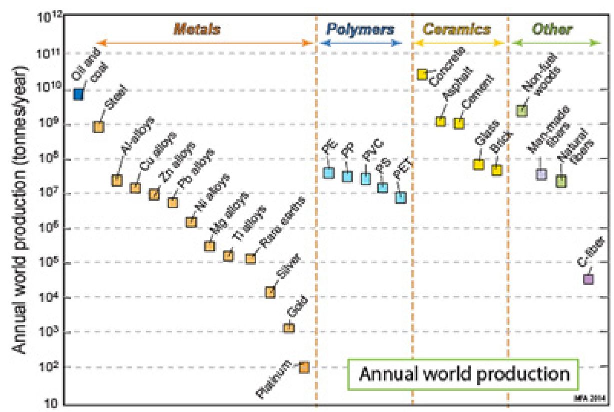


Figure 1: Annual production levels for different material families

The built environment is considered in one of the 17 UN Sustainability Goals (Figure 2), formulated in 2015. Goal 11 concerns many aspects of Urban planning, which shows that the built environment is also qualitatively important.

Figure 2: UN Sustainability Goals

In this case study, we will explore aspects of materials in buildings that can be investigated using the Granta EduPack Built Environment database. This contains some 127 materials, over a quarter more than the regular Level 2 database. These materials are linked to four building systems. The additional materials datasheets include:

- More classes of concrete
- More classes of brick and tile
- More fibers, particle and plywoods
- More materials for insulation

Building design can also benefit from the unique material properties supplementing the Level 2 datasheets:

- Mechanical properties in bending
- Hygro-thermal properties
- Acoustic properties
- Durability in various atmospheres

The study of the built environment is interdisciplinary in nature and includes disciplines such as architecture and many types of engineering. We will focus on buildings.

2. Material selection for buildings

The extended range of materials can be used for selection, for instance, minimizing cost and embodied energy for a resilient house cladding. The function, constraints, objectives, and free variables can be found in Table 1, with our selection chart with the top material candidate highlighted in red in Figure 3.

Table 1: Selection Criteria for Building Cladding

Selection Category	Property of Interest
Function	Protective cladding
Constraints	Form: sheet
	Tensile strength: > 50 MPa
	Elongation: >2%
	Durability in industrail environment: Excellent
	Durability in rural environment: Excellent
	Durability in marine environment: Acceptable & Excellent
Objectives	Minimize cost
	Minimize embodied energy
Free Variable	Choice of material

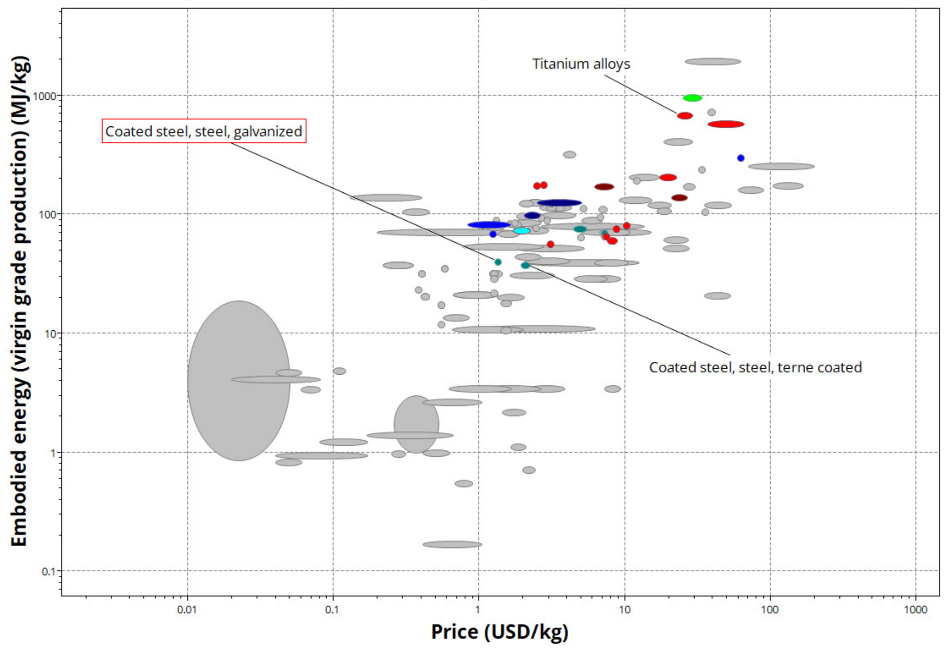


Figure 3: Chart of embodied energy and price, with coated galvanized steel sheet having both the lowest price and lowest embodied energy

3. Structural Sections

Although Goal number 11 refers to resilient and safe cities in a broader sense, the mechanical safety and integrity of buildings is certainly an important component. The Built Environment database is extended with a data-table of structural sections in standard dimensions (Figure 4). This makes it possible to discuss the importance of shape.

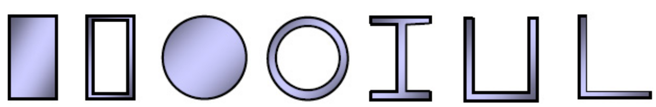


Figure 4: Different structural section cross sections

In order to visualize the structural element properties, we must remember that a conventional property chart consists of material performance for a given function (e.g. beam in bending) and usually a fixed cross section (e.g. square) so that shape can be eliminated from the performance index during selection within the chart. This is not the case if various structural elements are plotted.

An overview of steel structures (Angle, Channel, I Section, Rectangular, T-Section, Tube) is shown, below in Figure 5. Non-steels are grayed out by a Tree stage filter.

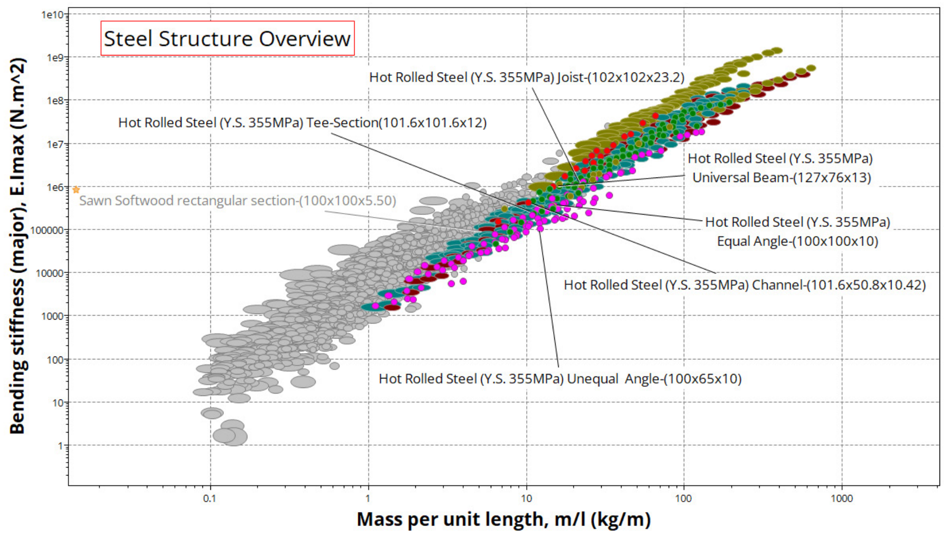


Figure 5: A selection chart for steel structures looking at bending stiffness and mass per unit length, focusing on steel materials

For these structures, low mass per unit length is more important than low density. Bending stiffness is maximized. We can see that steels occupy the middle range of the chart and that some woods, added for comparison, perform surprisingly well (basically planks of softwood or laminated beams, marked with stars).

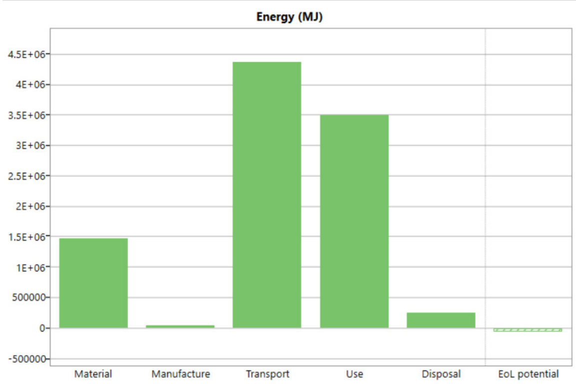
4. Eco Audit of a House

Safety and resilience are discussed above, but the environmental sustainability of a building can also be explored and discussed using the Granta EduPack Eco Audit tool. Using a Bill-of-materials (BOM) for a semidetached 1-2 story house built in Colombia with 140 m^2 floor area and three bedrooms, published by Oscar Ortiz-Rodriguez *et al.* (Figure 6), we can perform an Eco Audit for a typical brick, concrete and steel building. Generic transports were added; 100 km for a light goods vehicle and 100 km of a 14 tonne (2 axle) truck, for the concrete.

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	End of life
1	Mortar	Cement (ordinary Portl...	Virgin (0%)	3500		Landfill
1	Brick	Facing brick	Reused part	1.85e+04	Not applicable	Reuse
1	Steel	Low carbon steel	Typical %	4500	Metal rolling and f	Recycle
1	Ceramic Tiles	Ceramic tile	Virgin (0%)	3580		None
1	PVC	Polyvinylchloride (tpPVC)	Virgin (0%)	284	Polymer molding (	Landfill
1	Timber	Softwood (pine) parallel...	Virgin (0%)	1691		Combust
1	Asbestos	Asbestos fiber	Reused part	780	Not applicable	None
1	Roof Tile	Ceramic tile	Virgin (0%)	257		None
1	Glass	Low-e glass	Virgin (0%)	150	Glass molding	Downcycle
1	Aluminum	Aluminum, pure (120...	Typical %	15	Metal rolling and f	Recycle

Figure 6: BOM for the House Eco Audit. Note: all materials that do not have a primary process, it is considered in the value of the material itself

Eco Audit results Summary Chart of Energy use and Climate Change (CO_2-equivalent) can be seen in Figure 7. This chart can now be used to explore different design options (alternative materials, recycling etc).



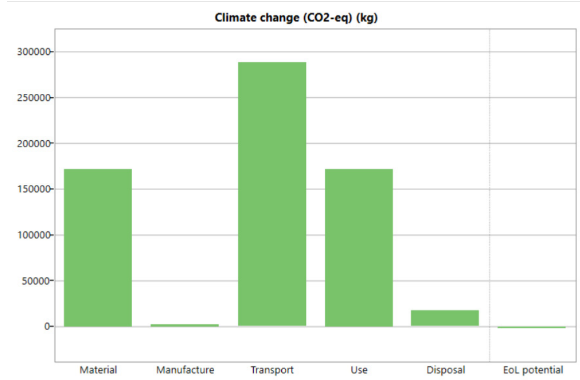


Figure 7: Summary Chart of Energy Use and Climate Change for the House Eco Audit

The scenario considers the operational energy over 50 years for a house in Latin America. It represents a typical energy consumption for a house with minimal mechanical heating or cooling, therefore, for both the energy and carbon footprint, the material phase is considerable (primarily due to concrete). This phase represents the embodied energy of the building. The average energy intensity per household in Columbia is 17 GJ/year according to the World Bank collection of development indicators, which is around 23% lower than our use phase, allowing for additional heating/cooling.

We can now explore the use-phase (operational) energy or recycling options. The Eco Audit tool includes data for the energy mixes of various countries/regions and the associated energy generation efficiencies. In the summary chart in Figure 8, the Climate Change for the house is shown for three countries of use: Latin America, North America and Spain, as examples of scenarios. We have used the same values for all other categories.

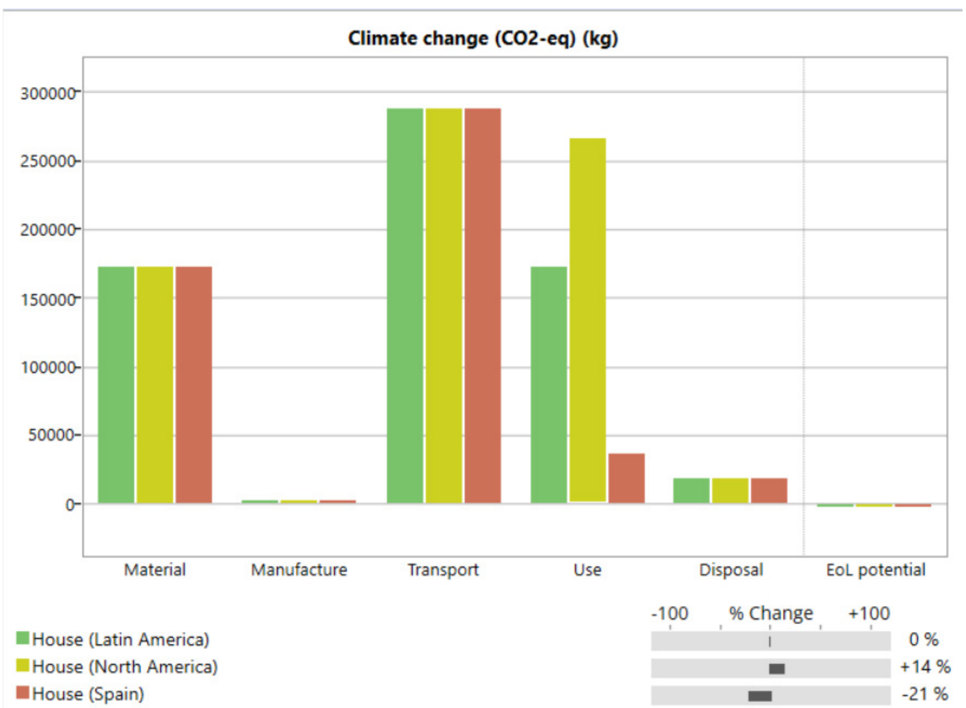


Figure 8: Climate Change for our house in Latin America, North America, and Spain.
Notice the dramatic differences in Energy Use

5. Conclusions

We have shown how the Granta EduPack Built Environment Database can be used to select materials from the whole MaterialUniverse, or some of the four building-specific subsets. The structural sections data-table links architecture with engineering. The Eco Audit tool can be used to explore various aspects of a building when it comes to eco-properties, such as energy use and climate change, as well as logistics, recycling and end of life options.

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