Constructions systems

Overview

The combinations of materials used to build the main elements of our homes: roof, walls and floor are referred to as construction systems. They are many and varied and each has advantages and disadvantages depending on climate, distance from source of supply, budget and desired style and appearance.

Choosing an appropriate system for climate and location will increase thermal comfort, lower construction and maintenance costs and reduce the overall environmental impact.

The majority of new housing stock is built to a common formula that varies only slightly between states and cities. The formula prevails regardless of the enormous range of climates, geographic locations and occupant lifestyles experienced by Australians.

The formula has developed for a variety of reasons including: availability of skills and materials; ease and speed of construction; market perception and familiarity with the final product and individual and community values.

Emphasis is often on "borrowed style" and greater size – at the expense of comfort, function and performance.

This approach rarely delivers the most appropriate or even the least expensive solutions for Australian housing needs. It contributes to the environmental and economic cost of our homes whilst adding little in the way of improved comfort and lifestyle.

This fact sheet analyses the merits of some common construction systems and explains the process of choosing or developing the best combination for your needs in your climate and geographic location.

IMPORTANT DIFFERENCES

A useful point of differentiation between construction systems is their mass content.

Heavyweight construction systems are usually masonry and include brick, concrete, concrete block, tiles, rammed earth, mud brick, etc.

Lightweight construction uses timber or light gauge steel framing as the structural support system for non-structural cladding and linings (eg. fibre cement, plywood and colourbond steel).

Heavyweight and lightweight materials have differing thermal performance and environmental impact depending on:

> Where they are used (internally or externally).

> How they interact with or moderate the climate.

> How far they need to be transported.

> Specific site requirements (eg. slope, thermal performance, noise control; fire resistance)

> Exposure to destructive forces of nature (fire, termites, rain, UV, humidity, etc.).

The source of the materials and the way they are processed will determine their environmental impact.

Similar materials can have vastly different environmental impacts depending on where and how they are sourced (eg. A timber frame can be sourced from a sustainably managed forest or an unsustainable managed forest).
[See: Biodiversity Off-site]

There is no single "best solution". Any combination of materials should be assessed in light of the above factors to arrive at the most appropriate compromise. See the following examples.

In most situations, a carefully designed combination of lightweight and heavyweight systems will produce the best overall outcome in economic and environmental terms.

Heavyweight construction:

> Generally has higher embodied energy.

> Improves thermal comfort and reduces operational (heating and cooling) energy use, when used in conjunction with passive design and good insulation.

> Is most appropriate in climates with high diurnal (day-night) temperature ranges and significant heating and cooling requirements.

> Requires more substantial footing systems and causes greater site impact and disturbance.

> Should be avoided on remote sites where there is a high transport component (eg. Darwin).

> Is often quarried or processed with high impact.

Lightweight construction:

> Generally has lower embodied energy.

> Can yield lower total life cycle energy use, particularly where the diurnal range is low.

> Responds rapidly to temperature changes and can provide significant benefits in warmer climates by cooling rapidly at night.

> Is preferred on remote sites with high materials transportation component.

> Usually requires more heating and cooling energy in cold to warm climates (where solar access is achievable) when compared to heavyweight construction with similar levels of insulation and passive design.

> Can have low production impact (eg sustainably sourced timber) or high impact (unsustainably sourced timber or metal frame).

High mass lower level (earth bermed pre-cast concrete) and low mass upper levels (insulated timber framed or AAC block) are combined to optimise use of embodied and operational energy.

SELECTING CONSTRUCTION SYSTEMS

Important factors influencing selection of residential construction system/s are:

> Durability compared to intended life span.

> Life cycle cost effectiveness.

> Lifecycle energy consumption.

> Source and environmental impact of all component materials and processes.

> Availability of skills and materials.

> Maintenance requirements.

> Adaptability and/or end use/recycling potential.

> Distances required for transportation of components.

General guidelines

The following "rules of thumb" are a guide only.

Every application is unique and should be individually evaluated. Exceptions are the norm-particularly in innovative design solutions.

Combine high and low mass construction within a building to maximise the benefits of each.

Use heavyweight systems internally and lightweight systems externally for lowest lifetime energy use.

Higher embodied energy content in heavyweight construction can outweigh operational energy savings (particularly in climates where heating and cooling energy requirements are low). [See: Embodied Energy]

Where solar access is unachievable or undesirable (eg. steep south facing or overshadowed sites, tropical locations) insulated lightweight construction is often more efficient as it responds quickly to mechanical heating or cooling.

Maintenance

Unpainted external brick cladding (brick veneer) has minimal maintenance requirements when compared to many alternative painted claddings.

Well maintained lightweight systems have durability equivalent to heavyweight systems.

Poor maintenance can reduce life span by up to 50 percent, negating embodied energy savings and doubling materials consumption.

Reliability of maintenance regimes for whole of life span is a critical consideration when selecting external cladding systems.

Source and use of materials

High renewable or recycled content systems are preferable where their durability and performance is appropriate for lifecycle (eg. fibre cement cladding and sustainably managed forest timber frames).

Design for de-construction, recycling and re-use to amortise the impact of materials high in embodied energy or non-renewable resources where these materials are the best option.

Structurally efficient systems minimise overall materials use, transport and processing.

Specify materials with similar and appropriate life spans (eg. use fixings, flashings or sealants with a similar life span to the material being fixed).

Use construction systems with known low wastage rates and environmentally sound production processes. [See: Waste Minimisation]

Transportation

Avoid systems with a high on-site labour component in remote projects to reduce travelling.

Use locally made products where possible to reduce transportation.

SOME COMMON SYSTEMS

Two commonly used systems, and one unusual solution, are detailed below to demonstrate some considerations when selecting construction systems. Cost, durability and embodied energy content are simple approximations for comparison with alternatives that could be considered for each specific example.

Lightweight walls with heavyweight floor

Insulated lightweight wall construction on an exposed concrete slab (not covered with insulating materials like carpets) is an efficient and economic combination on level sites in most climates. It is also the most commonly used in most states.

Concrete slabs provide thermal mass to even out diurnal temperature ranges, reducing heating and cooling energy and increasing comfort.

Embodied energy of normal reinforced concrete is high but can be reduced by using recycled steel and aggregate. Cement from an efficient kiln and use of cement extenders can further reduce embodied energy.

Insulated lightweight walls reduce heat loss and have minimal embodied energy content, depending on the cladding material used.

Cladding: Fibre cement sheet, plywood and other sheet cladding systems have low embodied energy and generally low environmental impact. They are very durable – although maintenance is required for any painted surface. [See: Embodied Energy]

Brick veneer is an inefficient, high embodied energy cladding system. The brick has no structural role. The above photograph shows a lightweight timber framed home structurally complete and ready for brick cladding. If this home was clad with lightweight, low embodied energy materials, its structural and thermal performance would be unaltered. Its embodied energy would be lowered along with its cost. [See: Thermal Mass]

Footing systems:

Slab integrated footings require excavation on all but level sites, increasing impact. They can reduce construction costs where slope is low.

Detached strip footings with load bearing brickwork to slab level can reduce excavation but increase embodied energy content.

Lightweight floor with heavyweight walls

A lightweight insulated floor can reduce site impact and construction costs on sloping sites. Reverse brick/concrete block veneer clad with insulated lightweight cladding (fibre cement or plywood) or internal masonry walls, provide thermal mass for effective passive design.

Embodied energy in the masonry will be offset by operational energy savings during the life span of the building in most climates, providing good insulation levels are included.

Timber framed flooring: has low embodied energy, low thermal mass but requires additional insulation in most climates. It is suitable for flat or sloping sites and durability is good when termite protection and sub-floor ventilation are correctly installed. Sustainably sourced timbers should be specified or biodiversity impact will be high. These floors can be a source of air infiltration if not well sealed. Low cost.

Steel framed flooring: as for timber framed but with slight increase in embodied energy. Durability is high. They can have greater durability advantages in termite prone areas and often have lower transport costs than equivalent timber structures. Usually more expensive than timber.

Lightweight suspended concrete floor systems are now available that are competitive in cost with timber and steel framed floors.

Footing systems:

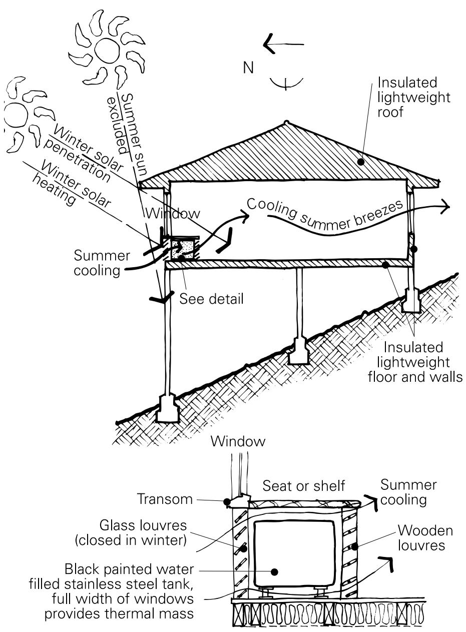
Strip footings and piers add embodied energy and create site disturbance. They are not easily relocated or re-used. Cost is low.

Engineered steel pile systems capable of supporting masonry walls are now available. They reduce excavation and site impact and speed construction. Cost varies with application but is generally more expensive than strip footings.

Lightweight walls and floor with water mass

Where slope and/or foundation materials prohibit the use of masonry construction for thermal mass, water filled containers behind passive shaded, north facing windows provide effective mass.

Water has twice the volumetric heat capacity of concrete. A stainless steel tank 600 x 600 x 3000mm has thermal mass equivalent to a 20m² concrete slab and can form a convenient window seat.



The above system is a cost effective solution for achieving high thermal mass passive design with the high insulation levels and low embodied energy of lightweight construction for difficult sites.

Footing systems:

Bore in or pile type systems have minimal site impact, can be relocated and re-used and have lowest embodied energy. Cost: medium to high.

Pole frame construction integrates footing and framing, giving benefits on steep sites with high wind exposure. Embodied energy is low for timber and medium for concrete or steel poles. Durability and efficient use of structure are important to maximise efficiency and reduce cost. Cost: medium to high.

OTHER SYSTEMS

Walls

Double brick: Highest embodied energy, a good source of thermal mass, requires added insulation. Low maintenance (if unpainted) and durable but poor re-cycling rates. High cost. [See: Construction Systems – Clay Brick)]

Reverse masonry veneer: High embodied energy with clay bricks, low to medium with concrete block. High thermal mass and high thermal performance with added insulation. Low internal maintenance, external maintenance dependent on finish. Very durable and re-use potential fair. Range of environmentally preferred external cladding includes fibre cement, plywood, sustainably sourced timber or colourbond steel. Cost varies with mass type, which can be any masonry.

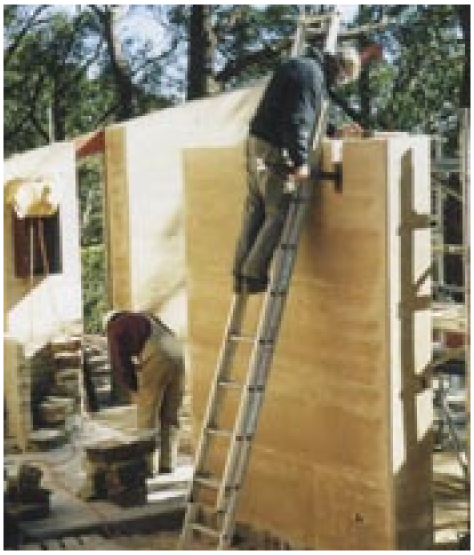
Autoclaved aerated block: Average embodied energy, fair thermal mass, fair insulation, average durability (depending on finishes). Maintenance required varies with finish; prone to impact damage; low processing impacts, good transport performance. Medium cost. [See: Construction Systems – Aerated Concrete Block (AAC)]

Concrete block: Low embodied energy; good thermal mass; low insulation (which is difficult to add unless lined externally); not easily recycled; low cost. Block walls have lower embodied energy than concrete walls because they are hollow and contain less concrete per square metre.

Insulated concrete (tilt-up or pre-cast): High embodied energy; high thermal mass; high insulation values; low maintenance internally and externally; extremely durable and can be re-used. Usually, painted finishes give rise to high maintenance component. High cost.

Rammed Earth: low -medium embodied energy, depending on cement content. High thermal mass; poor insulation (difficult to add unless lined externally as above); minimal transport energy when used on remote sites, minimal manufacturing process impact, very durable but requires some maintenance (re-application of waterproofing), average to high site impact, depending on footing system. High cost. [See: Construction Systems – Rammed Earth (Pisé)]

Mud brick: lowest embodied energy, high thermal mass, poor insulation (difficult to add unless lined externally), suited to remote sites; high labour content, no manufacturing impact and low site impact. [See: Construction Systems – Mud Brick (Adobe)]



Earth bermed: high embodied energy (assuming pre-cast concrete or reinforced block walls are used as the structural support). Highest thermal mass with additional thermal coupling benefits; high site impact during construction; insulation not required in locations where earth temperatures are favorable; extremely durable; significant operational energy savings. High cost.

Straw bale: low embodied energy (additional embodied energy and materials in extra width footings and slabs); medium-high thermal mass (depending on render thickness). Extremely high insulation; excellent thermal performance, and high level renewable material content. Long term durability is unproven in Australia and maintenance levels are variable. Bales should be compressed well to minimise settlement and movement. Cost varies from average to high. For more detailed information on straw bale construction. [See: Construction Systems – Straw Bale]

Sandwich panels have varying embodied energy depending on surface materials and insulation. Those in the photograph above are fibre cement outer linings with EPS studs and concrete core fill. The concrete fill adds thermal mass and an outer layer of insulation yields excellent all round thermal performance.

Other lightweight panel systems such as straw board and recycled paper products have low thermal mass, high insulation levels and very low embodied energy. They respond rapidly to heating and cooling and are ideally used with a concrete slab floor. The recycled content of many commonly available products is high. Re-use potential is good and transport costs are low. Construction cost varies from high to average.

Roofing

Tiles: Embodied energy is low for concrete and medium to high for terracotta. They require more structural support than lightweight material and can have an adverse heating effect (external thermal mass). High transport costs. They are inappropriate for remote sites. Medium cost.

Metal sheeting: High embodied energy; very durable; good to ideal for transport to remote sites; available in light colours to reduce heat gain in summer. Low cost.

Earth covered: High embodied energy; high thermal mass with excellent thermal performance from earth-coupling, no insulation required in many regions (dependent on soil temperature at various depths). Capable of zero heating and cooling energy; maintenance free; very durable when waterproofed correctly; high site disturbance during construction, minimal on completion. High cost.

Concrete slab: high embodied energy (recycled reinforcing steel reduces embodied energy), low insulation (in external application). Poor thermal performance unless insulated externally, increasing cost and maintenance requirement. High cost.

ADDITIONAL KEY REFERENCES

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