Principles of material choice with reference to the Green Star SA rating system.

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Introduction

According to the South African Constitution's Bill of Rights, every citizen, including future generations, has the right to a safe and healthy environment, and to have the environment protected. In response to this right, the South African government as well as each citizen have the responsibility to ensure the protection of the environment. This right, and the associated obligation to protect the environment, is translated into the built environment by the promotion of green, or sustainable, buildings.

The concept of green buildings is in response to the built environment's high negative environmental impact, including its contribution towards greenhouse gas emissions and the resultant climate change. At its core, the green building movement strives to create buildings that are designed, constructed and operate in such a way as to reduce the direct and indirect negative impact of development on the environment and its inhabitants.

The Green Building Council of South Africa (GBCSA) was established to promote and guide green building design and defines green building as follows: "Green building incorporates design, construction and operational practices that significantly reduce or eliminate the negative impact of development on the environment and people. Green buildings are energy efficient, resource efficient and environmentally responsible." [1]

The Green Star SA rating system was developed by the GBCSA as a means of assessing and scoring a building's level of transformation from the conventional (traditional) way of building construction and management to a more environmentally responsible solution. There are Green Star SA rating tools available for various building types as well for interiors (currently in Pilot). Issues pertaining to the environmental impact of a building are addressed in categories under which various credits are available for factors that potentially improve a building's environmental performance [1].

Significant value in terms of credits available is placed on the choice of materials, which has a dedicated category. However, it is almost impossible to address any component of a building without considering the material aspects associated with it and therefore some credits falling under other categories must be also be considered in the choice of materials for a green building.

When viewed with reference to the GBCSA definition of green buildings, the following principles regarding material choice can be identified: materials are to be assessed according to their impact in all stages of a buildings life – design, construction and operation (including end-of-life); materials are to be assessed with regard to their *energy efficiency*, *resource efficiency* and *environmental responsibility*.

Energy efficiency

The energy efficiency of a specific material can refer to the energy efficiency of its production (pre-installation) or the energy efficiency of its performance (post-installation). The Green Star SA rating system only recognises a material's energy efficiency in its pre-installation phase. This is relevant when looking at materials individually, though the designer should also consider the energy efficiency of the building as a whole during operation.

Embodied energy

Development and manufacturing processes pose a risk to the environment in the way that they damage or alter ecosystems at ground level and – arguably, more significantly – in the way that they lead to greenhouse gas emissions, which in turn lead to climate change. The construction process as well as the extraction, manufacture, transport and disposal of building materials require energy, usually in the form of carbon-based fuel. This amounts to the embodied energy of a product, which is directly proportional to the environmental impact as the burning of fuel releases greenhouse gasses.

Although the quantification of the embodied energy of materials is not required in the Green Star SA rating tool, there is recognition for reducing the use of identified materials that have high embodied energy (eg. cement). This is achieved through the reduction, reuse or recycling of such materials.

Local sourcing

Part of the embodied energy of a material product is contributed by transport emissions. This is specifically addressed under the *Materials: Local sourcing* credit.

The reduction of transport emissions by using materials and products that are sourced within close proximity to the site is recognized and encouraged in an effort to lower the embodied energy of a building. In the Green Star SA Interior Pilot tool, the use of products manufactured within the country is recognized, with additional merit where products are also extracted, harvested and processed in the country.

On a finer scale, the other Green Star SA rating tools award merit where 20% or 10% of the building materials are sourced, from extraction to dispatch, within 400km or 50km of the site respectively.

Resource efficiency

The concept of resource efficiency is aimed at limiting the amount of virgin material used in construction to mitigate the environmental impact and resource depletion.

Resource efficiency can be achieved through reduction of material use, reuse of materials or recycling of materials.

Material reduction

In mitigating the exploitation of virgin materials, the Green Star SA rating tool encourages the reduction of the amount of material, and the reduction of the damaging components of a material.

Dematerialisation

The *Materials: Dematerialisation* credit addresses resource efficiency by encouraging designing for less material. This credit addresses good design more than choice of materials and is crucial for the responsible designer to consider. This Green Star SA rating identifies specific areas that can be considered to achieve dematerialisation:

- Designing to achieve the building’s structural requirements and integrity with 20% less steel, concrete or timber.
- Designing ventilation with little or no ducting.
- Designing space efficiently to lower the ratio of gross floor area to usable area.
- Minimising the application of finishing materials, leaving the structure exposed.
- By making use of dual function cladding (eg. photovoltaic panels serving as cladding).

- By reducing piping through, for example, the use of water-free toilets.

Although not recognized by the rating tool, a responsible designer will also design efficiently to reduce the amount of unusable off-cuts of products on site.

Substitution

When an environmentally damaging material cannot be avoided, it is sometimes possible to reduce the harmful component by substituting it with an alternative. This is the case with concrete. The *Materials: Concrete* credit recognises the reduction and substitution of Portland cement in concrete, which has a very high embodied energy. The Portland cement content can be reduced by making use of a percentage of acceptable industrial waste substitutes (such as fly ash) or using oversized aggregate. This needs to be carefully engineered to ensure that strength is not compromised, requiring more structural elements as this would be counter the goal of material reduction.

Reuse

Perhaps the most effective way to reduce virgin material usage is to rather reuse existing materials. The reuse of materials and buildings is encouraged by the rating tool as a means of mitigating resource depletion. Reuse of materials should be used in preference to recycling of materials.

Building reuse

The Green Star SA *Materials: Building reuse* credit acknowledges two levels of building reuse– either by reusing the structure (or part thereof) and stripping the façade, or by reusing the structure and the façade (or part thereof). The benefit of reusing a building is not only and efficient use of materials but also of land and finances.

Material reuse

Materials: Designing for disassembly facilitates the reuse of materials. Elements such as framework, cladding or roofing can be reused in future projects if they are detailed in such a way that they can easily be removed without damage. This reduces demolition waste as well as emissions associated with demolition and removal.

For this to be practical, the end-of-life must be considered at the design and detailing stage. Instructions for disassembly must be included in the building's Operations and Maintenance Manual and elements must be marked with their date of manufacture and inherent properties to enable correct reuse.

The Green Star SA Interiors Pilot rating tool credits the reuse of furniture, assemblies, walling coverings and flooring, where there is also creative opportunity to reuse demolished structural elements in furniture and fittings.

The *Materials: Steel* credit encourages the reuse of structural steel that is extracted from the building and put to a new use. Steel elements that remain in the building being refurbished fall out of this credit and into the credit for *Materials: Building reuse*, while non-structural elements, such as roof sheeting, that are reused will fall under the *Materials: Reused and recycled materials* credit.

Timber structural elements may be best reused in cabinetry or other interior fittings, or re-milled and used in the structure or cladding, as recognised under *Materials: Timber*.

The *Materials: Concrete* credit does not recognise reuse, but rather recycling. However, it would still be good practice to reuse concrete elements wherever possible, such as precast lintels or pavers.

Recycling

When choosing building materials to specify, both the recycled content and the recyclability of the material waste should be considered in terms of its environmental impact.

Construction materials

Of the commonly used building materials - concrete, timber and steel - all can be recycled to some degree and points are awarded for the recycling of these materials specifically. Recycling is distinguished from reuse in that recycled materials are re-manufactured, having been deconstructed (crushed, chipped or melted) and processed to produce an entirely new product.

Under the *Materials: Concrete* credit, the use of recycled aggregate is recognised. Processed concrete waste can be used as fill, aggregate or concrete fines, depending on its structural capacity as determined by a suitably qualified engineer.

The *Materials: Steel* credit encourages the use of steel with a certain percentage of post-consumer recycled content. This needs to be verified by the supplier and includes structural steel as well as concrete reinforcing. Note that post-consumer content refers to content that has been returned from the end-user and not content that is waste from within the processing plant.

The recycling of timber (*Materials: Timber*) is recognised, although this must be used with caution as recycled timber is most often in the form of particle board, the use of which is discouraged under the *IEQ: Formaldehyde* credit.

Construction waste reduction

The recycling of material is also addressed in the *Management: Waste* management credit, encouraging the minimisation of construction waste going to disposal. Points are awarded where demolition and construction waste is reused or recycled. In this case, the specification of materials that can be recycling is merited, though the material may not contain recycled content.

Environmental responsibility

The environmentally responsible material is one that does not cause harm to the environment or to people. Three factors that are to be considered here are sustainability of materials and hazardous content.

Sustainability

Although in some cases the reduction of virgin material use is difficult to achieve, the impact can at least be reduced if the resource is sustainable. Sustainability essentially means that a natural material resource is able to be maintained at a certain level by renewal, preventing depletion. The means of extraction should also not cause unnecessary, avoidable damage to the environment. Timber is the only renewable resource acknowledged by the Green Star SA rating tool.

The *Materials: Timber* credit encourages the renewal of depleted resources, requiring all timber used to be certified by the Forest Stewardship Council (FSC), meaning that it is sourced from a sustainable forest. This applies to all timber used on a project including structure, cladding, joinery, furniture (for Interior tool) and formwork.

Hazardous content

Apart from the impact of materials exploitation and production on the greater environment, the green building movement is also concerned with the health of the indoor environment and its occupants. The removal and minimisation of materials with hazardous content is dealt with in various credits of Materials and Indoor Environment Quality (IEQ) due human health risks.

Hazardous materials

The *IEQ: Hazardous materials* credit is mostly applicable when old buildings are reused, since most hazardous materials are no longer used in modern products. A hazardous materials survey should be carried out in an existing building and all identified hazardous materials should be removed and disposed of according to the relevant standards for that material. The materials specifically identified in the Green Star SA rating tools are asbestos, lead and Polychlorinated Biphenyls (PCBs). Each of these materials has known adverse health effects for humans.

Asbestos is a strong, insulating, heat-resistant mineral that was commonly used in roofing, cladding, pipes, insulation and many other building products. The asbestos fibers can be breathed in causing potentially fatal lung diseases such as asbestosis, mesothelioma and lung cancer [2]. Although the fibers are only released when the product is worked (cut, sanded, drilled, etc.) the health risk is high enough to warrant a total ban on the use of asbestos in many countries.

Lead in buildings is most commonly found in paints. It can be absorbed into the body by breathing in paint chips or dust [3] and can cause health problems as it inhibits the transport of oxygen and calcium in the body. Lead-based paint has now been largely phased out of use.

Polychlorinated Biphenyl (PCB) is a man-made organic chemical used in many industrial and commercial applications. It has good electrical insulating and dielectric properties, making it useful in transformers, capacitors and heat transfer fluids. It was commonly used in fluorescent light fixture ballasts, which the Green Star SA rating tool identifies and condemns.

The United States Environmental Protection Agency views it as a probable human carcinogen and there are strong indications of effects on the immune system, reproductive system and nervous system [2]. PCBs accumulate in the body and health risks thus increase with exposure. If discovered to be present in a building it must be removed in accordance with the Department of Water Affairs and Forestry: Minimum requirements for handling, classification and disposal of hazardous waste.

Since reuse of buildings and materials is promoted by the Green Star SA rating system, it is important to ensure that no such hazards are inherited in a building.

VOCs

Volatile Organic Compounds (VOCs) are carbon-based products that off-gasses at room temperature [4] and include a wide range of chemicals used in the manufacture of various materials, such as paints, paint strippers, solvents, wood preservatives and detergents. The chemical emissions vary in toxicity and may cause membrane irritations, headaches, nausea or damage the liver, kidneys or central nervous system [5]. Because of their toxicity, the use of materials containing them is limited under the *IEQ: VOCs* credit of the building rating tools of Green Star SA and under the *IEQ: Pollutants* credit of the Interior Pilot tool.

The Green Star SA rating tools address engineered wood products (only in Interior Pilot tool), paints, adhesives and sealants, and carpets and flooring. VOC limits are specified and the use of materials that boast low VOC emissions or are VOC free is encouraged.

It is important to note that this requires acutely detailed specifications to ensure that a good choice of material is not compromised by a poor of specification of paint, adhesives or sealants to be used with the material.

Formaldehyde

The *IEQ: Formaldehyde* credit specifically deals with formaldehyde, although it is a VOC. Formaldehyde is a chemical produced from methane that is used widely in glues, resins, laminates, cleaning agents, dyes, ink, disinfectants and many other products [6]. It is a colourless chemical that is a gas at room temperature with a pungent odour.

In a poorly ventilated area, the effects of formaldehyde gas on humans range from respiratory effects (eg. Asthma) to eye, nose and throat irritations, skin irritation and fatigue and is classified as a probable human carcinogen [5].

In terms of building products, formaldehyde is most commonly found in the binding resins of composite wood products and in glues. While formaldehyde is present in numerous building products, the Green Star SA rating tool singles out composite wood products and discourages their use, regardless of whether the product is exposed or concealed. This includes applications in interior fittings and furniture, such as cupboards, flooring and paneling.

While the Green Star SA tool condemns the use of formaldehyde in the form of composite wood products, the effects can be minimised by ensuring good ventilation or specifying a lower formaldehyde content product. Different kinds of formaldehyde compounds contain varying levels of the toxin. Urea-formaldehyde releases formaldehyde more readily than melamine- or phenol-formaldehyde. It is therefore preferable to use pressed wood products that contain phenol-formaldehyde, for example softwood plywood and orientated strand board, that are intended for exterior construction, than those containing urea-formaldehyde, such as medium density fibreboard [7].

PVC

Materials: PVC minimization is in response to the known health risks associated with the manufacture and use of PVC products. Polyvinyl chloride (PVC) is a plastic used in pipes, conduits, carpets and backings, vinyl flooring and cladding, window frames, cable coatings and many other products. It contains chlorine, which results in the release of dioxins during manufacture, and often contains phthalates (to make it softer or more flexible) or Bisphenol. These three chemicals respectively are known to carry health risks and thus the use of PVC in buildings is discouraged.

PVC products should be replaced with alternatives, for example, PVC window frames could be replaced with timber or aluminium. However, great care must be taken to consider all factors together so as not to replace one hazardous material with another as many alternatives may contain VOCs.

Conclusion

It is evident from this discussion that the choice and use of materials for construction and operation has a high impact on the environment.

The principles extracted and discussed give guidance regarding material choice and are to be considered simultaneously when choosing a green material. While the Green Star SA rating tool credits certain material choices, there is no single material that can check all the boxes, so to speak. However, these principles will enable the designer to analytically motivate an environmentally responsible decision.

One should also bear in mind that the major portion of a building’s embodied energy as a whole is contributed by the operational phase of the building, implying that although a material may have a high environmental impact in its manufacturing phase, its performance during the operation of the building could outweigh the benefits of an alternative material.

The chart in *Figure 1: Material choice decision questions* is a collection of questions to answer when making a choice of materials.

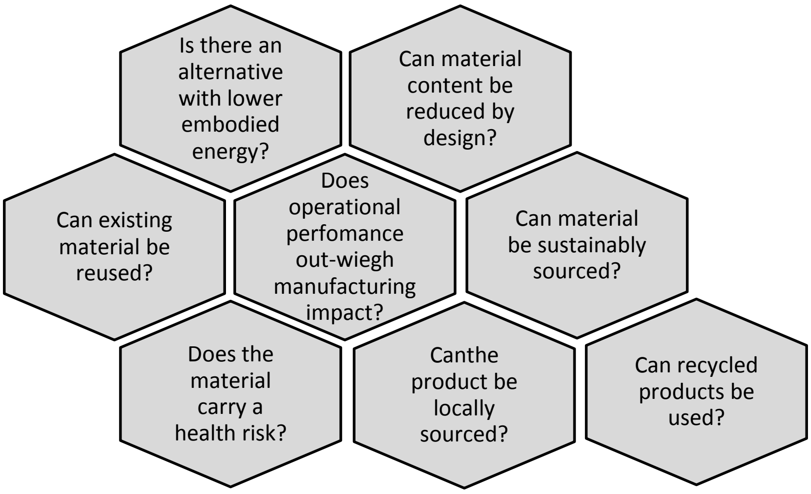

Figure 1: Material choice decision questions

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