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Specifying and Sourcing Materials for Best Practice Sustainable Education Facility

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ABSTRACT

The new building that houses the Mirvac School of Sustainable Development at Bond University (Australia), opened in June 2008, is the first education building in Australia to receive a rating of six Green Stars under the Green Building Council of Australia's environmental rating scheme. It was awarded the RICS Sustainability prize for 2009. The building features a wide range of techniques and initiatives that combine to make the building a landmark for sustainable design and building in Australia and beyond. Central to the design is a range of technologies including extensive use of recycled materials, particularly Australian hardwood, onsite power generation through photovoltaics, wind and bio-diesel, rainwater harvesting and greywater recycling, and the recycling or re-use of 90% of the waste generated during construction. The selection and supply of materials contributed significantly to the building achieving the maximum possible Green Star rating.

INTRODUCTION

The Mirvac School is the first educational building in Australia to receive a six Green Star (Design) rating. It also won the RICS Sustainability award for 2009 [RICS, 2009]. Green Star is a suite of environmental rating tools produced by the Green Building Council of Australia and the School was the pilot project around which the Green Star rating tool for education buildings was devised. Green Star is a voluntary standard that was introduced several years ago. New rating tools, for different building types, are being added to the suite and the existing tools are under regular review and development. With 11% of CBD office buildings in Australia now "Green Star certified" [GBCA, 2009a] there is growing incentive for building owners to look for certification. The governing council of Bond University located on Queensland's Gold Coast, was resolute in its determination to achieve the maximum rating and during the design phase every aspect of the building was considered with that aim in mind. In this paper the focus is on the materials used, how they were specified and how they contributed to the overall rating of the building.

THE GREEN STAR RATING SYSTEM

The Green Star system covers eight key areas of which Materials is only one; others include Emissions, Indoor Environment Quality and Water [GBCA, 2009b]. Points are scored for addressing a number of criteria in each area. Some additional points are available for Innovation. The focus here is on the materials used and how they contributed to the final Green Star rating for the building's design.

It should be noted that Green Star ratings are awarded for a building's design and may be subsequently awarded for the building when it is completed; this is the "As Built" rating. Currently the School building has been assessed only under the "Design" rating.

BUILDING OVERVIEW

The building (Fig. 1) is a purpose-designed home for the Mirvac School of Sustainable Development (MSSD) [Bond University, 2009].

Fig. 1 The Mirvac School of Sustainable Development at Bond University, Queensland, Australia.

Mirvac is a large Australian property development company that directly sponsors the school. The building comprises teaching space, academic offices and various ancillary spaces including a computer laboratory, meeting rooms and resources rooms. A separate smaller building, the Living Laboratory, is a multi-purpose function space used for meetings and small public gatherings.

Modelling suggests that the building produces 82% less CO_2 than a benchmark building and sends 52% less effluent to the sewer system [Lysnar, 2008]. It could be entirely self-sufficient in water supply through a combination of rainwater capture and greywater recycling, however, government regulation in Queensland currently prevents this [Arup, 2008].

Other features of the project include the following [Arup, 2008]:

- 90% of construction waste by weight was recycled or reused
- 95% of all paint, adhesives, sealants, carpets and other floor finishes are low VOC emitting (VOC: volatile organic compounds)
- Peak demand on electricity infrastructure is reduced by 40% through demand reduction and onsite power generation
- 95% of joinery (by area) and more than 50% (by area) of structural framing, roofing and façade cladding is designed for easy disassembly.

MATERIALS STRATEGIES

Green Star credits under the Materials heading are aimed at reducing resource consumption, minimising impacts on the indoor environment and the natural environment. Methods include selection of the most appropriate materials, reuse initiatives (in both sourcing materials and planning for reuse or recycling later) and efficient management practices.

Concrete

Much of the structural frame (including the suspended floor slabs) was constructed using *in situ* concrete in which 30% of the cement content was replaced by fly ash. The Green Star tool makes provision for extra credits if cement content in *in situ* concrete is reduced by 60% and/or no natural aggregate is used in non-structural elements and at least 20% of aggregate in structural concrete is recycled or slag aggregate [GBCA, 2009b].

Options for replacement of cement include fly ash, slag and a fly ash/slag blend. The blend option is the most useful from a building perspective as it achieves maximum strength in about the same time as concrete made with cement [Bedford, 2009]. The location of the Bond building precluded the use of a blend as slag was not available locally and although fly ash/slag blend concrete could be sourced in Brisbane the transport time to the building from the Brisbane batching plant exceeds practical transport times for wet concrete. Using 60% fly ash produces concrete that takes significantly longer to reach full strength and this adversely affects construction schedules as, *inter alia*, formwork must be left in place longer to allow the concrete to cure [Bedford, 2009].

Fly ash is readily available in the region, however, during construction the supply was limited for a time due to the drought that was affecting the area. Restrictions on water use that were in force at the time constrained some operations at the power stations that are the source of the material and this caused some temporary reductions in availability [Stiles, 2009].

The contractors paid only a 2% premium on the supply cost of the concrete as a result of using the fly ash [Bedford, 2009]. This cost could have been lower than expected as several suppliers were keen to be involved in what was to be a landmark project and they may have seen the publicity potential in being part of the process.

Timber

The timbers specified for the building gained a number of Green Star points. Timber was used both for both structural and decorative purposes as well as for joinery to doors and door frames.

Recycled Australian hardwood was used for most structural timber and some external trim. Australian hardwood is available from many sources these days, with larger sections sourced from the demolition of large structures such as wool stores, bridges and army barracks [NSW Business Chamber, 2009] and smaller sections including cladding and trim coming from the demolition of houses [Woolloongabba Demolitions, 2009]. In many cases the timber was first used more than 100 years ago and the long natural seasoning of the timber has produced timber that is not only hard and strong but is more stable than kiln-dried timber [AAH, 2009]. The best timber is de-nailed and put through a metal detector to ensure that all nails and other fixings have been removed.

At present recycled hardwood can be bought for similar or even lower cost than new timber. Common sections and sizes are milled from larger recovered members and supply is generally not a problem. The recycled hardwood is, however, labour intensive in use due to its hardness. Connections generally require drilling and bolting rather than nailing and specialist tools are needed to work with the timber [Pholeros, 2009]. Tools also wear more quickly. Wastage is also a factor; supplied timber has to be sorted carefully to ensure quality standards are met and up to 20% of the timber supplied may be rejected onsite [Bedford, 2009].

In Australia recycled hardwood is used extensively by boutique furniture makers as many species can be polished to a high lustre and are extremely hard-wearing. In the Mirvac building such timber was used for flooring (including structural beams supporting timber floors) in several locations, some of it polished (in the Living Laboratory) and some with an oiled finish (to external walkways). Similar oil-finished hardwood was used for external seating, roof beams over the outdoor eating area, vertical sunscreens, fencing and gates, and as decorative external wall cladding.

In nearly all locations the timber was secured with bolts or screws thus ensuring that the timber can be salvaged when the building reaches the end of its useful life or if major renovations are ever required. Figure 2 shows the underside of one of the timber walkways and part of the decorative wall treatment. Note the fixing of the floor timbers with bolts and the wall timber with screws, both fixings allowing simple dismantling in the future.

Fig. 2 Structural and decorative recycled Australian hardwood.

Internal door and window frames were fabricated from plantation-grown softwood. This timber had to be certified by the Forest Stewardship Council and the specification required that Chain of Custody Certification [FSC, 2009] for all FSC certified timber had to be provided to the client or the design team.

The Green Star tool gives credit for minimisation of use of products containing formaldehyde. The specification stipulated that no composite wood products (e.g. particleboard) were to be used in the construction of the building, however, under the rules if no "engineered wood products" are used then the potential credit is deemed to be "Not Applicable". This does not, however, mean that in the overall Green Star calculation that avoiding these products completely that no credit is gained; a final Green Star score (which determines a building's star rating) is based on a weighted basket of items and if an item is "Not Applicable" then that item is actually taken out of the basket thus increasing the weighting on the remaining items. This situation arises with a number of items in the rating tool, e.g. if the value of the concrete in a building is less than 1% of the total building cost then the potential credits available for reductions in cement content are deemed "Not Applicable" and thus the other items under the Materials heading carry greater weight.

Steel

The rating tool gives credit for reducing the use of what it calls "virgin steel" as follows:

- One point is awarded where 60% of all steel, by mass, in the project either has a post consumer recycled content greater than 50%, or is re-used.

- Two points are awarded where 90% of all steel, by mass, in the project either has a post consumer recycled content greater than 50%, or is re-used.
- If the material cost of steel represents less than 1% of the project's total contract value, this credit is 'Not Applicable' and is excluded from the points available used to calculate the Materials Category Score.

The Mirvac building contains both structural steel and reinforcing steel. While reinforcing steel could be sourced with the required post consumer recycled content structural sections of similar type were not available at the time of construction. As the Green Star credits are based on the percentage of "all steel" that is recycled or re-used the unavailability of structural steel of the required specification meant that no credits were achieved for this category. Structural steel with 50% or more recycled content is now available but it has to be imported and therefore has some cost penalty [Bedford, 2009].

The Materials item in the rating tool covering steel is currently under review as it has been suggested that it militates against the very aims of the tool. The imported steel mentioned above is produced using electric arc furnaces in countries where pollution controls are much less rigorous than they are in Australia and when the effects of transport are added to the mix the carbon footprint of this steel is considered to be greater than that of virgin steel produced in Australia [Ryan, 2009]. The Australian Steel Institute in collaboration with the Green Building Council is developing a new steel component for the Green Star tools that will encourage, first of all, reductions in material use, then increased use of locally made recycled material produced with minimised environmental impacts [Ryan, 2009].

Although no Green Star credits were to be gained reinforcing steel with at least 50% recycled content was used in the Mirvac building [Bedford, 2009].

Thermal insulation

The specification required that all thermal insulation have an ozone depleting potential (ODP) of zero. In Green Star ODP is based on both the manufacture of the material and its constituents. Fibreglass batts were used in walls and ceilings/roofs where required.

PVC minimisation

Green Star points are awarded under this item for reductions in the use of PVC (polyvinyl chloride) products. A 30% reduction earns a point, 60% earns two points. Assessment of reductions is based on the estimated cost for all PVC compared to the cost of PVC if substitute materials are used where appropriate and practical. To claim these points involves a rigorous procedure in which all consultants specifying components or products that might typically be made from PVC are asked to provide estimates of cost for those parts of the works that might be PVC and similar estimates based on the use of suitable alternative materials.

The following extract from the section headed "PVC Minimisation" in the Electrical Services specification for the Mirvac building illustrates this:

> PVC minimisation is an integral component of the Green Star [*sic*] requirement and a 60% reduction (by cost) of PVC is required on this project. As such it is a requirement that non-PVC cabling be utilized for all electrical and communications cable used as a part of the electrical works. All cable ties are to be non-PVC (e.g. nylon). Additionally the Electrical Services Contractor is required to provide the pricing differential as a part of the tender schedules for non-PVC cable use as compared to the cost if PVC cable had been utilise din the project [Bassett, 2007].

In other specification sections (e.g. Hydraulic Services) alternatives are clearly specified for items that might have been PVC. A variety of materials are specified for pipework depending on purpose and location; they include polyethylene, HDPE (high density polyethylene), fibre reinforced cement, copper, stainless steel and cast iron.

The following evidence must be submitted when claiming Green Star credits for PVC reduction [GBCA, 2008]:

- A short report prepared by a "suitable professional" that identifies all major standard PVC uses in the project
- the reference case for the anticipated/estimated cost of PVC in the project
- the expected cost of those items where alternatives to PVC are to be used
- calculations and a summary showing how the PVC cost will be reduced by the use of alternatives.

A report prepared by a quantity surveyor to support the validity of the reference case and relevant extracts from the specification(s) are also required.

Establishing the reference case involves assessing the cost contribution of the PVC only in various applications of the material in a typical building. Such uses include not only sheathing to cabling and pipework but also pipe insulation, conduits and flooring. Calculations of PVC reduction are based on the cost of PVC only and not on the cost of the whole item (where PVC comprises only part of the product, e.g. PVC sheathed cable). The cost of alternatives is not relevant, only the reduction in PVC cost is important. The following table is taken from the Technical Manual; it provides indicative cost shares for the PVC content of typical items.

Table 1 Major standard PVC uses and the expected contribution of PVC towards their cost [GBCA, 2008: 269]

PVC use	Expected cost of PVC within the project
Insulation	Actual cost
Pipes	95%-100%
Conduits	95%-100%
Sheathing for copper wires and cables	10%
Backing of commercial grade carpet tiles	10%

The following sample calculation is also from the Technical Manual; it illustrates the method used to establish the percentage reduction in PVC cost for a project.

Table 2 Example of a PVC reduction calculation [GBCA, 2008: 270]

Standard material plus other PVC uses	Total final budgeted cost for those items (Standard PVC cost)	Actual material used in the project (Actual PVC cost)	Cost for PVC items used in the project	Reduction in use by cost
Stormwater Pipes	$10,000	Cast iron above ground, clay pipes below ground	$0	100%
Sewerage Pipes	$10,000	PVC above ground, clay pipes below ground	$6,000	40%
Electrical conduit	$6,000	Steel used for 30% of conduits, PVC for remainder	$3,300	45%
Electrical cabling	$15,000	PVC	$15,000	0%
Total	**$41,000**		**$24,300**	**41%**

This sort of costing analysis and the requirement that it be verified by a quantity surveyor adds to the design costs for any project seeking Green Star credits.

The Mirvac building achieved a 96.7% reduction in PVC cost with the only PVC used being for the cabling and conduits in the Fire Services installation. The maximum of two Green Star credits was thus easily achieved. Substituting other materials for PVC does not necessarily lead to cost increases; for example, the cost (including labour to lay) for 225mm diameter PVC stormwater pipe is much the same as that for the same size fibre cement or HPDE pipe, while polyethylene and concrete are respectively 27% and 36% more expensive [Rawlinsons, 2007].

Volatile organic compounds

This part of the rating tool covers paints, adhesives and sealants, and carpets and flooring. In the Mirvac building specification various limits on VOC content and emissions were set for a variety of products. Paints were specified according to maximum permissible VOC content expressed as grams per litre with values ranging from 14g/l to 75 g/l depending on the type of paint (gloss, low sheen, latex and so on).

Adhesives and sealants were treated in the same way as paints while carpets were specified in terms of VOCs emitted per hour with a maximum allowable of 0.5mg/m^2 per hour.

Flooring

Flooring materials are assessed against a number of criteria under three environmental impact categories in the Green Star rating scheme. The criteria are grouped as follows:

- Resource Utilisation
  - Eco-preferred content (EC) and
  - Durability (DU)
- Management
  - The flooring manufacturer's environmental management system (EMS) and
  - Product stewardship (PS)
- Reusability
  - Modular (MO) and/or
  - Designed for disassembly (DD)

All criteria are equally weighted. The number of points achieved is determined according to the area of each material used.

In the Mirvac building four flooring materials achieved maximum scores: recycled hardwood decking, exposed concrete (i.e. no applied finish), modular carpet tiles and marmoleum. Both the carpet and marmoleum are certified by Good Environmental Choice Australia [GECA, 2009]. Marmoleum [HubPages, 2009] is manufactured from linseed oil, pine flour and rosin (both from managed forests) and natural pigments. It does not outgas and is fixed with solvent free adhesives, making it a sound material choice.

Dematerialisation

Green Star awards points for reducing the overall usage of materials. Points may be achieved for meeting any of a number of possible targets. Examples include 95% reductions in the amount of ductwork for ventilation by designing buildings that are fully naturally ventilated, and reductions in structural framing achieved through careful design of structural steel frames. Other possibilities include the use of water-free toilets and urinals – not only do these reduce water use but points may be gained through reductions in the amount of pipework required. At the time of the design of the Mirvac building this item had not been included in the tool; it was subsequently introduced but has been found to be problematic in use and is likely to be significantly revised in the near future.

Design for disassembly

The contract for the design and construction of the Mirvac building included requirements that a deconstruction plan was prepared and that all relevant materials were fixed in such a way that disassembly would take place easily and with minimal damage. All roof sheeting, for example, was screw fixed to allow ease of removal and minimisation of damage to both sheeting and the supporting purlins. As mentioned above recycled timber was bolted or screwed for similar reasons.

Loose furniture

Loose furniture is assessed under similar criteria to flooring (e.g. eco-preferred content, durability), however, points can also be gained for re-using furniture from other buildings. In the case study building loose furniture from other parts of the university was moved to the new building and Green Star credits were awarded. Ironically, however, about a year after the Mirvac building was opened an adjacent faculty building underwent a major refurbishment and several skips of quite serviceable furniture were taken away and replaced with new. This part of Green Star may benefit from some revision.

CONCLUSION

Choice and use of materials was a key factor in the Mirvac achieving its maximum Green Star rating. Not all potential points were achieved due to various circumstances such as the local unavailability of slag for use in concrete and the general unavailability of recycled structural steel sections. Overall, however, the building demonstrates that there is ample scope for achieving Green Star points under various sections of the Green Star Education building tool. The building serves as an exemplar of what can be done and how the environmental impact of building materials can be reduced substantially without undue additional cost.

REFERENCES

AAH (2009) Australian Architectural Hardwoods. www.aahardwoods.com.au/about.html

Anning, H. (2009) Arup Sustainability. Personal communication.

Arup (2008) *Bond Uni Building Training*. Fact sheet. Arup Sustainability.

Bassett (2007) *Bond University/Mirvac School of Sustainable Development – Electrical Services.* Bassett Consulting Engineers.

Bedford, M. (2009) Design Manager, ADCO Constructions. Personal communication.

Bond University (2009) *The Building.* Mirvac School of Sustainable Development. www.bond.edu.au/faculties-colleges/faculty-of-business-technology-and-sustainable-development/schools-and-centres/school-of-sustainable-development/the-building/index.htm

FSC (2009) "Three types of FSC certificates". Forestry Stewardship Council. www.fsc.org/types-of-certification.html

GBCA (2008) *Technical Manual; Green Star Office Design & Office As Built Version 3 2008.* Green Building Council of Australia.

GBCA (2009a) "What is Green Star?" Green Building Council of Australia www.gbca.org.au/green-star/green-star-overview/

GBCA (2009b) "Green Star – Education v1" Green Building Council of Australia. www.gbca.org.au/green-star/rating-tools/green-star-education-v1/1762.htm

GECA (2009) Good Environmental Choice Australia. www.geca.org.au/

HubPages (2009) *Marmoleum Flooring: The New Linoleum*. http://hubpages.com/hub/Marmoleum-FlooringThe-New-Linoleum

Lysnar, R. (2008) *Bond University's Mirvac School of Sustainable Development*. Fact sheet – Mirvac School of Sustainable Development.

NSW Business Chamber (2009) "Australian Architectural Hardwoods: Recycled design". NSW Business Chamber. www.nswbusinesschamber.com.au/default.aspx?content=/channels/About_membership/About_Membership/Regional_offices/MNC_AustralianArchitechturalHardwoods.xml

Pholeros, P. (2009) Architect. Personal communication.

Rawlinsons (2007) *Australian Construction Handbook.* RawlhousePublishing Pty Ltd.

RICS (2009) *RICS Awards 2009 winners revealed.* Royal Institution of Chartered Surveyors. http://www.rics.org/site/scripts/documents_info.aspx?documentID=688&pageNumber=12

Ryan, D. (2009) Australian Steel Institute. Personal communication.

Stiles, G. (2009) Boral Construction Materials. Personal communication.

Woolloongabba Demolitions (2009) www.gabbademolitions.com.au/