CANDLEBARK SCHOOL LIBRARY

GENERAL DESIGN INTENT AND SITE CONTEXT

The Federal school building programme (BER) launched in early 2009 provided Candlebark School the opportunity to build a new library, obviously something dear to the heart of it Principal John Marsden who is also acclaimed author of many books for young and not so young readers. This government funding ($850,000) was announced only a few months after the Black Saturday fires when there was a lot of anxiety in the bush.

The school is located in a designated bushfire prone area at the edge of forest in the eastern foothills of the Macedon Ranges. So the aim of having a new library building also serve as a wildfire refuge of last resort emerged.

The school clearing generally falls at some grade from northwest to southeast, and as such the bulk of vacant land on it is deeply shaded by the surrounding tall messmate forest through the colder months of the year. Also planning overlays regarding wildfire management and environmental significance ruled out any tree removal or exposed cut and fill site works in the school clearing, and any construction close to the forest edge. Only a patch of south sloping land below the school dining and meeting hub was available for a new building. This open ground formed the grassy foreground to an exquisite view from the school hub into a valley of oaks, elms and pasture.

So the aim to site the new library there, preserving the view from the school hub above, and providing some wildfire protection internally, provided the motivation to consider an underground building.

MATERIALS AND STRUCTURE

The Candlebark School library sits on a concrete slab that lies 4.5 metres below natural ground at its northern edge and meets natural ground level at its southern edge. The external retaining wall, of 290mm thick core reinforced concrete block construction, is curved to a full half circle. This shape provides considerable restraint against the horizontal load of retained earth. The south wall is curved to broader radius, and consists mainly of tall counter-balanced double hung windows and glazed doors that open to intimate courtyards, open terrace and that gorgeous valley view beyond. Above this glazing the curved south wall is framed in seasoned pine, sheathed both sides with structural grade seasoned pine plywood (again to retain the edge of earth laid over the roof), and clad with 10 thick fully compressed cement sheet.

The library's roof structure supports some 500-600mm of earth relaid over it. This soil depth effectively:
- shields the building below against radiant heat exposure from high summer sun and potential wildfire.
- ameliorates otherwise extremely low external surface temperatures encountered at the insulated roof skin on a winter's night in this southern mountain climate.
- stores sufficient moisture and nutrient to feed the grass and native ground cover plants growing on the roof.

Despite advice from the structural engineer that such roof loads (effectively 2.5 tonnes per square metre when self-weight and live loads are included) need to be carried by concrete and/or steel structures, the architect held with some stubbornness to the dream of an all timber roof frame because of the carbon sequestered in it from the atmosphere, its easy workability and potential aesthetics. He proposed massive post and beam portals that carpenters could fabricate off site in seasoned pine laminated veneer lumber (LVL). 12m long x 1.2m wide x 35 and 45mm thick slabs of LVL (the stock from which LVL beams are normally cut to size) were specially intercepted from the LVL production line at Wesbeam in WA, and delivered by train to Melbourne and by truck to the builder's shed in Gisborne. There these huge LVL slabs were shaped (guided by CAD templates) and themselves vertically screw laminated into near 12m long x 600mm deep x 205mm thick roof beams that span continuously over posts of same section. These portal members were then erected on site in around 16 hours by 4 men, with the aid of the delivery truck's loading crane. There was virtually no timber wasted from the original LVL slabs, because all off-cuts were ripped into 140 deep purlins that span between roof beams. 25 thick structural grade seasoned pine plywood was laid over roof purlins to complete what turned out to be an economical and attractive roof structure for an earth covered building.

Internally the timber portal frames are exposed forming a visually dramatic gently barrelled fan-like structure. The underside of purlins between these portals is lined with 6 thick hoop pine (Araucaria cunninghamii) plywood sourced from substantial plantations in Queensland.

Windows and external doors are framed in select recycled blackbutt (Eucalyptus pilularis) - a dense, durable and highly fire resistant hardwood. And the chunky pergola embracing the south terrace is constructed from salvaged Monterey Cypress (Cupressus macrocarpa) – an exotic tree species that has served as windbreak for stock in much of Victoria's higher rainfall farmland for many years. As some of it now approaches declining age, it's being removed (some salvaged by small local sawmillers) and replaced by more locally indigenous windbreak plantings.

WATERPROOFING SYSTEMS

Waterproofing and perimeter drainage of an habitable earth covered building needs to be of very high quality both as a material system and in its installation detailing. It cannot afford to fail for the life of the building, because if a leak were to appear internally, it would be extraordinarily difficult and expensive to locate and rectify. After much research and liaison with prospective installation contractors, we chose the following composite systems that together represented a significant portion (approx. 10%) of the total construction cost.

For the roof:

	Grass struck from mixed pasture seed to match that on adjacent slopes.
Over	450mm thick topsoil relaid from excavation stockpile. (sheds surface water run-off and absorbs moisture to support grass)
Over	50mm thick coarse sand. (to allow free drainage of excess moisture from soil layer above)
Over	Geofabric (360g/m2). (allows water but not sand to pass down to drainage cell)
Over	“Elmich Versiflex” 30 thick polypropylene drainage cell (provides cavity for excess moisture to drain freely to roof edge rather than welling on waterproofing membrane.
Over	Geofabric (360g/m2). (serves as cushioning to protect membranes below)
Over	“HomeGuard TMB” 0.2mm thick polymer termite and moisture barrier. (first line of defence)
Over	“Wolfin Cosmofin” 1.5mm thick reinforced PVC sheet membrane with welded lap joints. (primary waterproofing membrane)
Over	Geofabric (360g/m2). (serves as cushioning to protect membranes above)
Over	25 thick LOSP treated CD face seasoned pine plywood. (structural roof sheet)

For the walls:

	Subsoil backfill from excavation stockpile.
Outside	Geofabric (360g/m2). (allows water but not soil to pass in to drainage cell)
Outside	“Atlantis FloCell” 30 thick drainage cell. (provides cavity for excess moisture flowing off roof edge in roof drainage cell or penetrating Geofabric to drain freely down to 2No. “Atlantis” 100x80mm strip filter pipes, which in turn discharge all subterranean water collected by drainage cells to downslope ground outlets)
Outside	“HomeGuard TMB” 0.2mm thick polymer termite and moisture barrier. (first line of defence)
Outside	“Isoboard VVH” 75 thick expanded polystyrene insulation sheet (EPS). (R4.7 non-moisture-absorbent thermal insulation)
Outside	“Ausblick” two-part four-coat reinforced rubberised spray-on waterproofing membrane. (primary waterproofing membrane)
Outside	290 thick core-reinforced concrete block wall. (structural external/retaining wall)

THERMAL PERFORMANCE

With an earth covered building, questioning whether to couple (or provide direct contact between) the interior environment with the earth or whether to insulate between the two makes for interesting learning. And the answer lies very much in the regional location of the building.

Underground below roughly 2 metres, the earth rests at reasonably stable temperatures that approximate the average (between day and night, and between winter and summer) annual external ground surface temperature. And in a good portion of Australia's interior, external ground surface temperatures range considerably between day and night and/or between winter and summer, and are reasonably balanced either side of the internal air comfort range of say 17-25ºC. Underground buildings in this region maintain relatively stable internal temperatures throughout the year because the earth they're directly coupled to rests in this comfortable temperature range, cooling internal air when external air is hot, and warming internal air when external air is cold. So in places like Cooper Pedy, underground opal mines simply fitted with doors and windows at shaft heads, make for wonderfully comfortable interiors for homes, churches and pubs alike.

But in locations like southern Victoria, and particularly with altitude as at Candlebark School, annual external ground surface temperatures average, and deeper earth temperatures rest, at maybe 13-15ºC, so well below the internal comfort range. And in tropical Australia, external ground surface temperatures average, and deeper earth temperatures rest, well above the comfort range. So in the Cutta Cutta Caves near Katherine NT for example, internal air temperatures are stable but oppressively in excess of 30ºC. Earth covered buildings in such locations should not have their external walls and roofs directly contacting the earth beyond, or the earth will continuously absorb radiant and convected heat from the internal air in cool temperate climates, and will similarly emit heat to internal air in hot tropical climates. This is certainly the case where such walls and roofs are of materials that conduct heat well, like concrete and masonry.

Because of the structural loads surrounding them, earth covered buildings are typically constructed with a good quota of concrete and masonry, at least in floors as well as in external and internal walls, as is the case with the Candlebark School library. The thermal mass (or temperature smoothing potential) of these materials can be well harnessed in cool southern and hot tropical climates without the problem described above, provided they're located internal to an insulative skin. The logic in thermal performance applies equally to solid (fired, rammed or sun-dried) clay brick wall construction as compared to reverse brick veneer construction, except that earth coupled to roofs and external walls of underground buildings transfers heat by conduction much more efficiently (whether beneficial or not) than does air convecting against the same external surfaces of above-ground buildings. Hence the importance of insulating earth covered buildings in these parts of Australia.

So although the land slope at Candlebark School limited opportunity for including expansive north facing glass in the library's design, computer simulations of the building's thermal performance revealed that active heating (provided by highly efficient LPG wall heaters) would be required for only an hour or so on winter mornings, consuming less than one tenth of the annual energy allowance for heating and cooling set by the new BCA energy efficiency standards for buildings of this type. And internal summer temperatures would never rise above the comfort range, even when the building is heavily occupied with one person per square metre. This excellent thermal performance is achieved because of R3.5 roof insulation, external R4.7 EPS insulation of thermally massive external walls, thermally massive internal walls, double glazing with 12 thick argon-filled air gap, and meticulous door and window weather-stripping.

Whilst the EPS wall insulation extends to the very base of external slab footings, insulating against heat loss to what could well be a moist environment around the subterranean perimeter drains, the floor slab is otherwise not insulated. Direct coupling of concrete floor slabs to deep earth that hovers around 13-15ºC can only be beneficial for summer cooling. And in winter, there is little heat loss through an un-insulated slab resting on such relatively warm earth. This is because, as the thermal stratification and surface tension of the internal air film contacting the floor is likely to be in the order of 3-5ºC cooler than the air at sitting chest level (say 1.0m above floor) where thermal comfort is measured and regulated, there won't be a sufficient temperature difference between the slab and the low interior air to effect substantial heat loss to the floor.

The air can get thick in a school classroom, so the library has a three-stage ventilation strategy. Firstly, fresh air is readily accessed by opening of the counter-balanced double-hung windows in the south window wall. Secondly, if the outdoor air is very still, further natural cross and stack ventilation can be activated by opening electrically controlled butterfly dampers just below the head of large concrete vent shafts, which in turn extend up from the ceiling in the rear northern part of the building through the earth roof cover to above ground level where they are capped with "CondorKinetic" venturi cowls. And finally, if the building interior were to warm up beyond the comfort range as a result of very high occupancy and unusually hot weather over many days, the windows but not the roof vent shafts are closed and mechanical fans built into concealed wall plenums adjoining south courtyards can be switched on overnight. These fans flush the interior with cool mountain night air, and purge the building's internal thermal mass of the heat it has absorbed during the day.

NATURAL AND ARTIFICIAL LIGHTING

Whilst unable to offer passive solar heat gain, the Candlebark School library's expansive south-facing windows provide a superior softer daylight for reading, free of much of the direct glare associated with sun penetration through north-facing windows. And a series of ten "Solatube 750DS" (530mm dia.) and "Solatube 290DS" (350mm dia.) tube light shafts flood the rear northern sections of the library with an extraordinary level of daylight. So on sunny days, there is a respectable balance of interior daylight between the south window side and the deeply buried north side of the building, without supplementary artificial light. And the four skins of glazing in these light shafts makes for minimal unwanted summer heat gain.

On overcast days and at night, artificial light is provided by way of energy-efficient LED lighting with good colour rendering index (CRI) and colour temperature.

CRI is a quantitative measure of the ability of a light source to reproduce the full colour spectrum faithfully in comparison with an ideal or natural light source. Lights with high CRI (say above 80) allow us to read and undertake other visually exacting work under lower light intensity than would be the case with lights of lower CRI. Colour temperature (measured in degrees Kelvin) of light is often more readily understood and listed as warm white (below about 2000K), natural white (around 4000K) or cool white (above about 5000K). Whether LED or fluorescent, a cool white lamp is generally considerably more energy efficient than a warm white lamp. But we often find the light emitted from cool white lamps to be too blue, harsh or cold. Unsurprisingly then, cool white lamps have a lower CRI than warm white lamps. So finding a good balance between energy efficiency and CRI is a challenge, and the intended use of illuminated space will of course inform the decision. For example, cool white lighting might be appropriate in a science laboratory or technical workshop. But in a lounge or café, warm white light is generally preferred despite the luminous efficiency measured in lumens per watt of electricity consumed.

In the general reading and stack areas of the library, pendant lamps with effective and visually appealing heat sinks hang bare (without shade fittings) between and just below the underside of the deep roof beams, bringing the light source down closer to the reading plane. These lamps are "AltLED Asteria" 35W LED lamps with Cree XM-L chipsets, 100° beam angle, 4100K colour temperature, CRI 80, and output efficiency of 51 lumens/watt.

Even more impressive are the surface mounted flat disc lamps fitted to the lower ceilings of the digital media room, quiet reading area, workroom/store and WC. These smart little "ICX FP06" 6W lamps have 4200K colour temperature, a CRI 87, and output efficiency of 87 lumens/watt!! The lamps themselves emit almost no heat. A young man from Fairfield Victoria has developed these and other amazing LED lamps in the Silicon Valley, manufactures in China, and sells worldwide.

A lot of time went into selecting and trialling artificial lighting for the library, but we're all very pleased with the result.

BUSHFIRE SAFETY

Candlebark has a formal understanding with its parent community that the School will be closed on days when a Total Fire Ban or Code Red Bushfire Warning applies to the area. This dramatically reduces bushfire risk to students and staff upfront. At other times through the bushfire season, the School closely monitors local CFA and DSE radio activity and will if necessary, as directed by the CFA, make an early evacuation using buses kept on site throughout the school day. So the library will serve as a refuge of last resort only in the very unlikely event that the above emergency plans fail to remove students and staff from an imminent bushfire threat.

The school is located in an area that State planning policy has designated to be of high bushfire risk. In July 2011 the Victorian Building Regulations enacted an interim amendment to direct construction of community fire refuges. Until then, two years after Black Saturday and well after the library had been completed, there were no Australian standards or regulatory requirements for the design of community bushfire refuges, nor for the design of any non-residential building. So with regard to bushfire protection, design of the Candlebark School library was unregulated, but informed by AS 3959 – 2009 *"Construction of buildings in bushfire prone areas"* (although that formally applies only to residential buildings), by other technical reference on buildings and wildfire, by advice from CFA officers and two private wildfire management consultants, and by the understanding that the main wildfire risk to the building is likely to come from large and small ember attack.

The roof, as well as the north, east and west sides of the building are buried underground and therefore well shielded from wildfire (certainly fire resistant beyond 40kW/m2 or BAL-FZ).

Coincidently after the library was completed, a third wildfire management consultant studied fuel loads in the immediate surrounds the building (the zone of *"classified vegetation"* under AS 3959), as well as fuel loads, topography and wind patterns in the forest environment beyond. Through this analysis he calculated that the exposed south window wall of the library would be subject to radiant heat flux of only 6.16kW/m2. This wall is clad externally with 10 thick fully compressed cement sheet (fire resistant to 40kW/m2 or BAL-40 under AS 3959). External doors and windows in the wall are framed in recycled Blackbutt (fire resistant to 29kW/m2 or BAL-29), have BAL-29 thermally toughened sealed insulating glass units installed, and are fitted with custom-made heavy-duty BAL-29 stainless steel insect screens.

AS 3959 lists deemed-to-comply construction standards that don't recognise water drenching as a supplementary means for protecting building fabric against radiant heat and ember attack. But the Building Code of Australia (BCA), by reference to the new interim amendment to the Victorian Building Regulations, requires that construction and service systems in community fire refuges be assessed and certified on a performance basis, which logically then recognises the value of water drenching.

Designed but not yet installed for the library is a south wall drencher system which includes 15 “Techpro BDQ T1 1740” X-vane square-cone brass spray nozzles. These would be fitted to a 50mm copper supply pipeline, in turn fixed to the underside of pergola beams out 500mm from doors and window heads. At 300kPa supply pressure, these nozzles can douse 7.4 litres of water per minute over each door and window unit, to amply protect against radiant heat and ember attack. The drencher system can be controlled via a gate valve located by the southeast corner of the library, being the main building approach by foot or vehicle. A 25mm fire hose will also be installed at this point to facilitate dousing of embers by school staff after the main fire danger passes.

Static water storage required for drenchers amounts to around 6.7kL per hour. In providing 2 hour drencher protection (ample according to the wildfire management consultant) and a supply for the fire hose, around 22kL of dedicated water storage would be required. This water will be stored in an above ground concrete tank situated somewhat higher on the school property but clear of large tree limbs that could otherwise damage the tank if they were to fall in a wildfire event.

A small diesel pump will deliver fire water from the storage tank to the library. The pump will be housed in a fire-resistant shelter, and will be fitted with automatic (via pressure controller) and manual (via button) battery start. The elevation (static head) of the storage tank and generous pipe diameters (minimising friction loss) will provide a 200kPa supply pressure at the library drencher and fire hose nozzles by static head alone. Therefore, even if the pump is not operating for some reason, the volume of water dousing door and window glass by gravity flow alone will provide reasonable protection.

The southward orientation of the library’s tall window wall ensures that the northward and downward trajectory of drenchers is not compromised by fire winds.

Skylights on the library roof are fire-resistant to BAL-29 because they have 8mm thick thermally toughened glass fitted just below their dome tops. And metal dampers inside rooftop ventilators protect against ember ingress. Furthermore all light and vent shafts are fire-resistant to BAL-FZ, in that the shafts themselves are min. 50 thick reinforced concrete pipe. And fire shield bags have been sewn to order from a reflective fabric with BAL-40 rating by "Wildfire Protection Services". These bags will be stored in the library ready for covering shaft tops if a bushfire threatens, and possibly also through the summer holidays as a precautionary measure.

INTERNAL FIT-OUT

Modular book shelving, both mounted on wall and freestanding on mobile trolley, is flexible and practical. But the proprietary powder-coated steel systems commonly found in school and public libraries are expensive, clinical and imported. So modular shelving has been provided for Candlebark by purchasing from proprietary shelf systems supplier Dexion only some components. All shelves, whether shallow for novels, deep for folios, divided for magazines, or tilted for display, have been fabricated from hoop pine plywood by a local cabinetmaker to a modular 900mm width, and hooked to Dexion wall channels and trolley frames via quadrant plates. This approach has engaged a more sustainable and locally sourced balance of material and labour. It's actually more robust and serviceable than the proprietary steel option, less expensive, and certainly more attractive in its architectural setting.

John likes learning in the round. And some years ago he had a fallen Blackwood (Acacia melanoxylon) tree milled for some future use. So recently he commissioned a local craftsman to design and construct a huge (4.8m long x 1.8m wide) oval table for a class to gather around in the library's digital media room. The exquisite blackwood table top sits over beautifully curved legs of hoop pine plywood laminated with detail to echo the massive roof beams over the general reading area just beyond.

Otherwise the interior of the Candlebark School library is unconventionally relaxed and eclectically furnished with some delightful acquisitions, including circular pods of rattan chairs, a large antique medicine cabinet, an aisle of old movie house chairs, and yes - a Russian WW2 motorbike for the boys to lounge and read on. *"It's no different to having a shelf of books in a motorbike shop"* is John's justification. And the entire quiet reading area is currently transformed into a set from Enid Blyton's *"The Magic Faraway Tree"*.

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