

Concrete and not so concrete impacts

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Snapshots

1.
It's spring. In suburban streets the bottle brush trees bloom bright and fast, their show is over almost as soon as it begins, the red blossoms falling and breaking down into tiny filaments that gather in the cracks in the concrete forming blood veins along the footpaths.

2.
The days are getting warmer, you can feel the heat bouncing back up at you as you walk down the street at midday.

3.
Now it's summer. In the evenings an old woman comes out, supposedly to water the garden, but her real pleasure is hosing down the concrete path that runs from the front gate down the side of the house to the concrete back yard that also gets a thorough going over, washing away the dust of the day, and releasing that reassuring first-shower-of-rain-on-hot-streets smell.

The overlooked

Concrete - it's as if it's always been there. We don't notice it. It just sits there being itself, impassive, solid as a rock, the strong, silent type. We think we're pretty aware of the systems that connect things up and make our world - the smart systems, the info-webs, air travel and other technologies that abolish distance. But concrete? It hardly compares. It's the dumb substrate of everyday life, the stuff of cities and suburbs - just background material. When it does intrude into our presence it's the effects we notice as they impinge on our bodies, senses, memories. Sore feet after a day walking the streets, a crack that trips us up, coldness underfoot in winter, heat radiating from surfaces in summer. Concrete, the stuff itself, remains withdrawn.

Of course the reverse is true for engineers and builders. Concrete is one of their tools of trade, a material with very specific and controllably variable properties that can be tweaked according to the requirements of the job. In fact it's their skill in tweaking that makes concrete do its job with the invisible efficiency which means that it disappears into the background for the rest of us. Mostly when lay people notice it, it's because it's not doing what it's supposed to do - because it has collapsed, is cracked, damp, too hot, too cold, etc. But even then we won't think about concrete - we'll talk about the floor being too cold, the ground hard, the footpath cracked and so on.

Concrete is concrete is concrete - but its not!

A central drive of designed modernity has been to make the world increasingly seamless. Modern materials seek to disappear in effortless functionality. We have seen how this has occurred with plastics ('Everywhere and Nowhere: an Introduction to Plastics', *Information Ecology*, August 1998). It is also a feature of concrete (the two materials also share an inherent formlessness). What

this also means is that the world as materiality becomes divided into two perceptual registers existing at opposite points along an imaginary line - that of those who design and engineer towards the desired state of invisibility and that of those on the receiving end of their designing. But it's never just one line; expertise and ignorance are distributed along many cross cutting axes that mark out relative knowledges of technologies, structures and materials. What this does indicate however is the modern world is a composite construction - niche expertise unwittingly producing widespread ignorance in its accommodating design of the material and immaterial infrastructure of the everyday.

It is in fact by teasing out these two different dispositions that we can come to a deeper understanding of concrete's impacts, rather than by simply assembling an environmental checklist. This article presents the environmental impacts associated with concrete by exploring these questions: What are its essential characteristics? What impacts flow from these? What does it do as a material? What does it create? What does it destroy?

Concrete origins

The invention of concrete goes back to the ancient Romans who mixed mortar with small stones to create a monolithic mass, which was laid in courses rather than poured. Slow drying mortars were invented in the first century AD - combined with the arch and vault they enabled the construction of large spaces without internal support, plus flexibility of form. This early form of concrete construction appears to have been forgotten until the 18th century. The earliest use of reinforced concrete was in mid 19th century France with some examples of concrete floors with embedded iron. Andrew Ure (who was a major source for Karl Marx's study of labour processes) gives us this picture of concrete technology as it was used for building foundations in the mid 19thc:

The best mode of making concrete is to mix lime, previously ground, with the ballast in a dry state; sufficient water is now thrown over it to effect a perfect mixture, after which it should be turned over at least twice with shovels, or oftener; then put in the barrows, and wheeled away for use instantly. It is generally found advisable to employ two sets of men to perform this operation, with three in each set, one man to fetch the water etc, while the other two turn over the mixture to the second set, and they, repeating the process, turn over the concrete to the barrow men. After being put into barrows, it should at once be wheeled up planks, so raised as to give it a fall of some yards, and thrown into the foundation, by which means the particles are driven closer together, and greater solidity is given to the whole mass. (Ure, p.462)

What we see here in rudimentary form is one of the key features of concrete, which is that it is more than a material, it is **system of construction**. It has been as much the elaboration and refinement of a standardised system for mixing, delivering, pouring and finishing that has made concrete such a widely used material as the properties of the material itself. This is further borne out by another historical instance. Now it's eighty years later and the place is the construction site for the Soviet Union's first automobile factory, being built by Russian peasant workers but designed by American engineers of the Austin Company which specialised in standardised systems for constructing

industrial buildings. The writer is a Russian engineer lamenting the inefficiency of Soviet bureaucrats:

There are on the dock 15,000 tons of gravel, pyramids of sand, stone, cement, machines, lumber. Buildings cry out and demand all this. Have you thought about the plan of their delivery and transportation to the different districts? Every day workers on the dock receive new instructions from you. Every day you make people destroy and remake what was done yesterday. Valuable summer days pass and you sigh softly while young Communists from all districts are carrying the gravel on their shoulders; while the moveable conveyors rust in storage; while a misplaced pump is being carried from one place to another because you did not clearly indicate its proper place; while an expensive crane, which can replace the work of 200 workers, stands unassembled on the dock because there was nobody who could be spared to assemble it when it arrived; while tons of concrete was mixed - by hand - even though a concrete mixer stood unused for three months, waiting

His description registers the incompatibility between the American capitalist system of production and the Soviet socialist system, and points to a key requirement as well as a driver of industrial modernisation, which is design for standardisation. And here we come to an important point. The developmental direction of modernisation has largely been towards unsustainability. Clearly concrete is deeply implicated in this, it is a nodal element in the structure of the modern world, both a driver of, and driven by, unsustainability. Here are the truly significant environmental impacts of concrete. But to further understand this, its essential characteristics have to be elaborated.

Formless and dependent

Cast your eyes across the skyline of any modern city and the dominant image is of massive concrete structures. Solid, impassive, immovable, strong, durable, ubiquitous - these are the immediate impressions. But appearances are not always what they seem. Concrete is made up of cement, sand and aggregate mixed with water, beginning life as a wet, fluid material. Like plastic, it is inherently formless, depending on other materials to give it its final shape, usually timber or steel formwork. This interface with other materials also determines its surface appearance, whether it will be rough or smooth - thus even a supposedly 'raw concrete aesthetic' is not the result of the inherent properties of concrete, but of how the forming materials impress themselves upon it. Once it has set and cured, concrete has excellent compressive strength, but tensile strength, and thus the ability to span large spaces, only arrives courtesy of the steel reinforcing set into it.

Concrete always has a relation to other materials

These observations suggest that the environmental impacts of concrete are always relational - they involve impacts of the materials used with it. A dramatic example is that of timber formply - a very smooth finish, a Class 1 or 2 job, requires the use of plywood with a fine-grained face layer, and fine wood grain is generally a characteristic of old growth trees from tropical regions - thus

rainforests in Brazil, Malaysia and Indonesia have been felled in response to the formply industry, which in turn is driven by the decisions of concrete specifiers.

Impacts of concrete production

Concrete is extremely strong, massive and durable. These properties are due to its ingredients. Sand and aggregate (mixed in varying proportions and grades according to the specification of use requirements) make up its mass, while cement (mixed with water) binds the mixture together. There are environmental impacts associated with extracting and processing the materials, with the production of cement being the most complex and most environmentally impacting process. We will now diverge for a moment to elaborate these (more conventional) impacts of manufacture, before continuing the story of how concrete's inherent properties are responsible for truly big picture impacts.

- *Mining* is required to obtain aggregate and sand as well as limestone, the main raw material for cement. Depending on how well or badly it is managed the impacts of mining can include habitat destruction, erosion, and pollution of waterways.
- *Energy* is used in mining and in transporting mined materials to mixing sites, but the most significant energy expenditure is in the production of cement. Limestone is heated in high temperature kilns to form clinker which is ground and mixed with gypsum.
- *Greenhouse gas emissions* (CO²) are produced by the fossil fuels used to power mining equipment and to provide the heat source for cement kilns. The latter are fuelled either by coal, natural gas and sometimes by using waste products such as spent engine oils, lubricants and used tyres. There are also CO² emissions associated with the electricity used to grind the clinker, run fans, motors and drives.
- But it is not just the energy used to produce cement that results in greenhouse emissions. Significant amounts of CO² are released by the nature of the process itself, specifically the *calcination process* (i.e., when the calcium carbonate in limestone is changed into calcium oxide). Cement manufacture is responsible for about 1% of Australia's greenhouse gas emissions (Greenhouse Challenge); worldwide the cement industry accounts for 8-10% of greenhouse gas emissions, second only to fossil fuels (*Green Building Digest*, 1995). Cement makes up 10-15% of the concrete mix.
- *Other atmospheric pollutants* are released in cement manufacture: heavy metals, organic hydrocarbons and carbon monoxide. Sulphur dioxide is produced in the kiln but is mainly reabsorbed in the process, however nitrogen oxides are released. After manufacture cement dust may contain free silicon dioxide crystals (the cause of silicosis), the trace element chromate (a cause of stomach cancer and skin allergies) and the lime content may cause skin burns.
- *water consumption and effluent*: large amounts of water are needed for concrete production, also a great deal of alkaline waste water is generated during production and use, therefore

building sites should be carefully managed to prevent run-off leaving the site and contaminating waterways and nearby vegetation.

Reducing environmental impacts of production

Regulatory authorities and the concrete and cement industries are aware of impacts and in most cases are making attempts to reduce them. There are also actions that can take be taken by engineers, architects and builders such as specifying recycled materials for aggregate.

- ***Cement substitution***

Greenhouse emissions can be reduced by substituting a proportion of the cement binder with alternative cementitious materials such as fly ash or ground and graded blast furnace slag.

Fly ash is a waste product from power stations fuelled with black coal - the coal is pulverised and blown into the burning chamber where it ignites to heat boiler tubes, heavier ash particles settle to the bottom, the lighter particles (fly ash) remain suspended in the exhaust gases - they are filtered and collected before the gases pass through the stack into the atmosphere. While not cementitious in itself, when mixed with cement it takes up some of the 'free lime' and so acts as a cementitious material. Thus it works as a cement 'extender' as well as having other claimed benefits such as reducing the heat of hydration, increasing the ultimate strength of the concrete, and of course reducing cost.

Slag is a waste by-product of the smelting of metals. Its properties differ according to the smelting process and how the slag is solidified and crushed. Slag is produced from iron blast furnaces, BOS steel making, electric arc furnace steel making and copper smelting. As a ground cementitious material, granulated iron blast furnace slag can be used as a substitute or an enhancer of ordinary Portland cement (OPC). A prominent project in which it has been used is the Sydney Harbour Tunnel in which slag cement replaced 65% of the OPC. The environmental benefits of both fly ash and slag come from utilisation of a waste material which otherwise gets dumped and the reduction on greenhouse emissions due to OPC substitution.

- ***Aggregate substitution***

Blast furnace granulated slag can also be used as an aggregate in concrete. Slag is indeed a versatile waste! Another example of aggregate substitution is the recycling of concrete to make concrete: crushed concrete can be used as aggregate for new concrete. To use recycled aggregates is to conserve natural resources - it should have the result of slowing down the rate of rock quarrying. On large construction projects, such substitutions can be significant.

Limits to environmental benefits

While large amounts of slag are produced from Australia's iron and steel industry, its reuse is still limited. Slag has been used for cement replacement in concrete in Australia since 1966, but usage is only about 5% while in many other countries slag accounts for between 20% and 50% of all cement production. The story is similar with slag aggregate - it has diverse applications in road works, yet

still many engineers do not specify it - despite the inclusion of slag in the Australian Standard for concrete aggregates (AS 2758.1 - 1985) as well as other standards applying to its use. Not surprisingly the most extensive use of slag is found in the steel making cities of Newcastle and Wollongong. Sometimes transport costs make its use uneconomical, but there are other economic factors at work. Supporters of slag (yes there is even an Australasian Slag Association!) point out that a major barrier is the tightly integrated construction material supply industry which "has given rise to complacent and narrow promotion of a valuable resource" and "the inherent conflict with naturally occurring stone, sand and cement sources." (The Steel Sand Group: 1992).

Crushing concrete for reuse is a very crude form of recycling, requiring a huge amount of mechanical strength to be thrown against a material that has been designed to endure. But even if all unwanted concrete was recycled, the difference this would make is variable, if not negligible in the case of still growing cities where there are far fewer structures being demolished than built. At Boral's quarry in Western Sydney, the source of most of the aggregate which has been used to build Sydney itself, concrete collected from demolition sites is crushed and mixed with newly quarried aggregate, extending the life of the quarry. But even if this facility were to receive concrete from *all* Sydney's demolition sources, this could only supply about 8% of Sydney's total aggregate demand - so the quarrying of new rock continues and the gigantic hole gets deeper and deeper, wider and wider!

- ***Process innovations***

There are some concrete products that use less energy in their production than others. Developments here are motivated as much by cost saving as by the desire to reduce greenhouse gas emissions. Lightweight concrete, or to be more precise autoclaved aerated concrete (AAC) requires less energy to produce than conventional precast concrete, plus it has the benefit of better thermal insulation properties than brick or conventional concrete, meaning buildings that are cooler in summer and warmer in winter, thus reducing utilisation energy. AAC concrete is available as building blocks, wall and floor panels. Australia's CSIRO has gone one step further in process energy saving, having introduced a Low Energy Accelerated Process (LEAP) for precast concrete products which uses microwaves for heat curing (BPN, Nov/Dec, 1998), the process being applicable to lightweight or conventional concrete products (wall, floor, roof panels; pavers; roof tiles; concrete pipes and poles).

Concrete desirability

The environmental improvements discussed so far are all within 'concrete logic'. But there is a different order of impacts to consider which come from concrete's inherent characteristic and the kinds of applications these afford. Consider:

- ***Strength and Durability***

Concrete is a highly durable material, but this in itself is not an environmental benefit - it may be where concrete is used for a very long lifespan structure or application, the reverse is true when the 'cultural life'* of the structure is shorter than afforded by concrete's durability. Unwanted concrete buildings cannot be disassembled, they have to be demolished or blown up (to be more accurate, imploded or exploded). They can only be reduced to a pile of low grade rubble which has three fates: (i) clean fill for further construction (ii) crushed as aggregate to make another concrete structure or (iii) simply dumped in landfill. This is what happens to no longer wanted in situ concrete structures, but the situation can be different where precast elements have been used, because if still in good condition they can be dismantled and reused elsewhere, though this in turn depends upon how they have been interfaced with other materials and how accessible they are for removal without damage - which suggests that future relocation and reuse needs to be considered at initial design stage.

Concrete's strength means that crushing it to make aggregate requires heavy machinery and the process generates a lot of dust and noise. This limits the situations in which such activity can occur on site for further reuse.

**cultural life is being used here to contrast with 'design life' the term used by ISO and Australian Standards to indicate functional lifespan. 'Cultural life' refers to the period of time for which something is valued - it is less predictable, more subject to fashion and other socio- economic factors.*

- ***Fire resistant, resilient and low cost - ambiguous advantages***

These are three other factors that have made concrete so popular. Embedding steel reinforcing *inside* concrete was looked on favourably after the many fires that plagued 19th century cities, in which timber structures got raised to the ground and exposed steel members were reduced to a twisted mass. Concrete's low cost is due to widespread availability of raw materials and continual improvements in mixing and delivery services.

Concrete is resilient to chemical attack and therefore stable - in fact even after curing its strength continues to increase over many years. It can take a lot of abuse and just be hosed down afterwards.

- ***A schizophrenic aesthetic***

Concrete has become the material of choice when practicality is the key factor - factories, warehouses, storage areas, prisons and other functional buildings (apart from all the civil engineering applications). This in turn has decreased its aesthetic appeal. The industry's response has been to add value to precast concrete products, often by imitating a 'natural' aesthetic of brick and stone - e.g., concrete pavers or concrete masonry units which are honed and coloured to look like sandstone. Another approach is an aesthetics of concealment - a great deal of multi-unit residential developments in Australia are made of concrete ('Besser') blocks, rendered and painted over.

This tendency of concrete pretending it's not concrete marks the failure of the 'brutalist aesthetic' exemplified by Le Corbusier's raw concrete *Unite D'Habitation*, (Marseilles, 1948-54) which was much admired by post WW2 British architects such as Peter and Allison Smithson who designed a series of uncompromisingly unadorned public buildings (such as the Hunstanton school, 1954) with exposed services, plain brick and raw concrete finishes. While their inspiration may have been high architectural ideals of 'truth to materials', as their aesthetic got taken up by other architects in other places, it converged with the condition of post-war austerity, which meant that the brutalist style became coded in the public mind as basic functionality, that precisely which is sought to be transcended in the stylistic excesses of much domestic

architecture and 'leisure structures' - shopping centres, theme parks, etc - which use a great deal of concrete, but that's not what hits you in the eye (as it is intentionally designed into invisibility).

There are other approaches to the aesthetics of concrete. Types of finishes are classified according to degree of smoothness, with Class 1 and 2 being the 'top grade', and as already mentioned these desirably even surfaces are generally only achieved with the use of formwork faced with rainforest timbers (which are fine grained). Some construction authorities (e.g., NSW Department of Public Works and Services) has banned the use of tropical timber formwork on its jobs.

- ***Imperviousness and uniformity***

Concrete is the ultimate enabling material, the infrastructure that creates infrastructure. Its imperviousness and uniformity have made it one of the ground rules (literally!) of urban living. It delivers smooth surfaces that facilitate the flow of people, vehicles and stormwater in huge volumes across urban spaces (we're also including asphaltic concrete used in road construction here). A fundamental expectation of urban living is being able to walk about without having to traverse rough or muddy ground (this in turn has designed the designs of the footwear industry, which mainly produces shoes for walking on city streets). One of the lesser known desires that fuelled the rise of concrete were the campaigns of 19th century health reformers for clean streets. Paving, kerbing and guttering were the advocated solutions, allowing accumulated dirt and waste matter to be flushed into subterranean drainage systems and carried away to distant watercourses.

With these benefits have come long term cumulative impacts. Paved surfaces (including roads) now account for significant percentages of the total land area of many bioregions. These are some effects:

- large areas of earth and soil are rendered inert; soil exposed after having been concreted over for some time is virtually useless as a growing medium — it is dead.
- alteration to the biophysical ecology of waterways . Concreted surfaces speed up the flow of rainwater, directing it into gutters, drains and subsurface pipes (which are often also concrete) to gather and discharge into rivers, lakes and sea; also the gradients of paved surfaces are designed to facilitate overland flow. These measures result in larger volumes of water entering natural watercourses at faster rates, carrying pollutants with them, thus changing their composition and what lifeforms they can and cannot support.

A dramatic example of this is the Central Coast of NSW (less than two hours drive north of Sydney) which has growing population attracted to it because of its pristine bushland and extensive system of lakes. But suburban development, specifically the imposition of paved surfaces, has increased run-off and silt build-up in the lakes to such an extent that they will disappear entirely within a few years. Dredging will ameliorate the situation, but this will be the imposition of another (third) ecology, not a restoration of the 'natural environment' which drew people there in the first place, and which has now vanished forever.

- ***Formability***

While concrete depends on other materials to give it form, with steel reinforcing the variety of shapes it can be moulded into are almost limitless, many, such as suspended and cantilevered structures, seem to defy gravity. The possibilities of using concrete to create this huge variety of forms inspired architects often well before all the technical problems had been solved. In the early 20th century French style leader Tony Garnier envisaged a plan for a model city of 35,000 people in which all the buildings would be concrete, the major ones with far-projecting cantilevers made possible by reinforced concrete. In the 20th century some of these visions were realised in architecture (the massive and soaring forms of Italian architect-engineer, Pier Luigi Nervi's stadia and airport hangars are probably the best known) but also most dramatically in the concrete (ised) dreams of civil engineers - such as clover leaf freeways and vast dam projects (like the Tennessee Valley Authority scheme of 1930s USA, which delivered not only water for irrigation and hydro electricity but was the means by which rural lifestyles and economies were modernised).

- ***Speed of construction***

Timing is crucial when working with in situ concrete - from the time the ingredients are blended and mixed with water through to the final placement, once the process has started it must finish within a set time. There are also time pressures on cement utilisation as cement structurally deteriorates prior to use (but goes on gaining strength after use). The development of subordinate technologies - formwork systems, equipment for pouring and vibration have also bonded this flowing material into a flowing system of delivery. Concrete necessitates both speed and system, this in turn has speeded up construction in general, propelling concrete structures across the globe. Wartime in particular accelerated advancements in concrete technology - rapid prefabrication systems were pioneered during World War 2, as well as repeatable structures that used standard formwork such as air raid shelters and bunkers; concrete also proved useful for the quick laying of runways for aerodromes.

Speed, strength, durability, uniformity, imperviousness, formability - looking at all these desirable characteristics of concrete, gives us a sense of the significance of its impacts in use. It is what concrete makes possible (the physical infrastructure of the modern world - roads and freeways, multi-storey buildings, bridges, dams, etc) that has had the largest, most transforming, complex, relational (and therefore virtually incalculable) impacts. It is a 'genie out of the bottle' material - once its possibilities were recognised there was no holding it back. More concrete has been produced during the past two decades than in the rest of human existence (Doran, 1994, p. 134). 'Materials substitution' is an impossible corrective to throw in front of a major civil engineering project such as a freeway or dam!

Snapshots: Japan 1997, Fred Pearce observes*

1.

“Travelling around Japan last autumn, I saw an entire country being systematically covered in concrete. Coastlines and hillsides, flood plains and river beds. And dams, of course - roughly a thousand dams in the past fifty years.”

2.

“Once you start pouring concrete there is no end to it. Witness the Japanese coastline. Dams on almost every river stop the flow of the sediment to the coastline ... with no sediment supply, beach erosion is accelerating, so they concrete the coast to protect it.”

3.

“By paving the Tokyo metropolitan area - the biggest expanse of concreted land on Earth - the city has stopped rainwater infiltrating the underground strata, where it could be pumped up to provide the city with drinking water. Instead, the water races into rivers, where more dams will have to be built to stop it rushing into the sea, and direct it into the city’s taps.”

* ‘Land of the rising concrete’
New Scientist 11 Jan 1997.

Using concrete to make sustainments

What are the implications then for the sustainable use of concrete - is this impossible to achieve? Only if the implication’s of concrete’s characteristics are more carefully thought about at design stage. And here a shift needs to be made from prioritising attempts to reduce concrete’s impacts (e.g. by reducing its embodied energy by specifying aggregate or cementitious substitutes) to asking ‘how can concrete be used to make a sustainment?’ This requires using its qualities in order sustain something else that sustains. Let’s take three examples.

- ***Taking advantage of lifespan***

Its clear that concrete when properly specified, in appropriate conditions is an extremely long lifespans material - once in place its difficult to budge! Therefore in situ concrete should only be used for very long lifespan applications - the long term viability of the use to which it is being put needs very careful consideration , e.g., if a building, it should be capable of having many uses well into the future. It is also possible to design a concrete in-ground slab for later removal. Stutchbury and Pape’s Archery Centre at Homebush Bay Olympic site (a simple timber structure designed for disassembly) has rings inset into the slab to allow for removal to another site if necessary.

- ***Limiting the use of impervious concrete paving***

We have already identified the negative impacts of concrete’s imperviousness, i.e., increased run-off and resultant gathering of pollutants that flow into waterways. Where there are large unpaved areas the picture is different - rainwater soaks into the ground recharging groundwater supplies which is beneficial for vegetation, lessens overland flows, and as water percolates through soil and subsoil, some of it eventually making its way to water courses, pollutants are filtered out along the way. It needs to be asked - **just how often is an impervious surface really necessary ?** There is a need to increase non paved areas (e.g. gravelled or planted with grasses and groundcovers) in urban

environments close to watercourses. But concrete and other paving materials can still play a part, especially the use of porous paving systems. These come in many forms - e.g.:

- do-it-yourself - concrete or clay pavers laid with enough space between each unit to allow for the growth of ground covers or
- manufacturer-designed concrete pavers which interlock to form a regular pattern of small drainage holes across the surface. These can be flexibly laid on a sand course (rather than cemented in place), with base course construction appropriate to loads and traffic, and where plantings are incorporated, the use of engineered soils. Porous paving has been used successfully along the Olympic Boulevard at Homebush Bay, Sydney eliminating the need for irrigation of several hundred transplanted semi-mature fig trees.

- ***Taking advantage of concrete's thermal mass***

Concrete has very good ***thermal mass*** or heat storage capacity which can be used to enhance the of a building's thermal performance, cutting down on the energy used to heat and cool it. The process by which thermal mass provides thermal comfort is via 'thermal time lag'. We are familiar with this. But concrete's potential to contribute to a comfortable building that doesn't rely on heating and/or air conditioning systems only happens when the principles of passive design have been applied, which include most crucially, the building's solar orientation and how glazing is used, as well as which materials are used where, how passive ventilation is designed in, what measures are taken to seal the building in winter, whether additional shading is needed in summer, and a number of other factors. There are advantages if the thermal mass of a building, particularly the floor, is in contact with the stable geothermal mass of the earth - this is where a concrete slab comes into its own. It is an irony that the predominant type of housing construction in Australia, brick veneer on a concrete slab, rarely uses the slab to enhance thermal comfort and the building's energy performance. And while housing energy rating schemes (such as Australia's NatHers) are changing this scenario (with greater awareness by builders and local authorities of the importance of the relation between orientation and glazing), householders (and display home interior designers!) also need to play their part by, for example, not laying carpets or other insulating wall-to-wall floor coverings over concrete floors in living areas that have been designed for solar heat gain (tiles or slate on the other hand will work in harmony with the slab's heat storage and time lag radiation capacity, to keep rooms warm in winter after the sun's gone down).

Passive design is a complex area - approaches vary according to climatic region as well as according to building type and size - the principles applied will be different for a single storey dwelling and a multi storey office building. We direct readers to the publications by CCAA and Hollo listed below, as well as recommending the UK published *Building Services Journal* which carries regular in depth reviews of passively designed buildings.

Conclusion

Availability of raw materials combined with the development of fast and reliable construction methods have made concrete the most commonplace and taken-for-granted of all construction materials. It is so easy to use it without thinking: just go with standard applications and reach for off-the-shelf specifications (often provided by concrete suppliers). Yet the consequences of concrete's ubiquity have been in the main, cumulatively unsustainable. Concrete needs to be used by architects and engineers with far greater selectivity. Its capacity for permanence needs to be respected by only using it for structures that warrant a very long life. The fact that it can be crushed and re-used as aggregate needs to be regarded as a low, grade, last resort rather than an environmental benefit. What concrete does throughout its very long functional life also needs more consideration – whether it will be contributing to the thermal performance of a long-life building, whether it has the possibility of multiple lives as an element in a transportable construction system, whether it is being used to direct water (as run-off) to sustain sustainable ecologies – or whether spread over acres of ground it will kill the soil and contribute to pollutant loads in waterways as it surreptitiously does its job of keeping our feet mud-free.

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Australian Standards and other guides

There are many Standards pertaining to concrete in the Australian Standards catalogue, listed here are only those that have some direct environmental advantage.

AS 3582 Supplementary cementitious materials for use with portland cement

AS 3582.1 - 1991 - Fly ash

AS 3582.2 - 1991 - Ground granulated iron blast-furnace

AS 2758 Aggregates and rock for engineering purposes

AS 2758.1 - 1995 Concrete aggregates

Self-compacting concrete (SCC) is a special type of concrete which can be placed and consolidated under its own weight without any vibration effort due to its excellent deformability, and which at the same time is cohesive enough to be handled without segregation or bleeding. From: Construction and Building Materials, 2015. Related terms: Admixture. Cementitious Material. Compressive Strength. Durability.