Handout

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Refuse, Reuse & Recycle: A Guide to Material Substitutions for Sustainable Concrete

INTRODUCTION

This handout presents a novice framework for methodologies in reducing, reusing and recycling commonly discarded waste products. By utilising such problematic waste as substitutions to conventional concrete materials. The aim is to outline the possibilities that this can offer to create eco-friendly alternatives within Australia and compare to abroad. Australian companies were contacted to establish what the industry is currently doing to achieve sustainable concrete by utilizing waste during production.

BACKGROUND

"70% of the world's population lives in a structure that contains concrete." [1]

Concrete is no new revolution. For many years it has been an integral material for our built environment, with strong links to economic and social security by provides jobs and shelter. It shapes our cities, taking many forms including bridges, roads, hospitals, schools, homes, businesses, and water and energy infrastructure. It is low cost, strong, durable, versatile, flexible in application, fire resistant and provides thermal mass. [2] It comes as no surprise that it is the second most widely used building material in the world, following water. [3] In recent decades, concrete use has shown resurgence, facing the pressures from growing demands in property development to offset the extreme growth in population that is still relentless. [4] Despite its many benefits, manufacturing concrete has had significant environmental impacts that contribute to greenhouse gas emissions and global warming, ranking third place; cement production alone contributes to 4-5% of worldwide CO2 emissions. [8] Aggregates (coarse and fine) alone make up roughly 60-75% of a concrete batch and Australia is estimated to be extracting roughly 200 million tonnes of aggregates yearly and rising (refer figure 2). [9] Although impressive, this causes land degradation that impairs natural environments and has a history of habitat destruction, including exacerbating the already depleting natural resources, such as sand and water. [10]

Concrete manufacturing involves an enormous amount of embodied energy and creates various pollutant by-products, such as noise, dust and emissions from fuel transporting the materials. [11] Cement, the binder in concrete is a dry combination of limestone, clay, shells and silica sand. [12] Limestone is the predominant ingredient, and when intensely heated to combine the materials it produces high levels of CO2 emissions. Estimating that for every tonne of clinker (nodular material produced in the kilning stage), 700-1000kg of CO2 is emitted. [13] Finally, concrete contributes to waste accumulation which puts significant pressures on limited space left in landfill, to no surprise governments are incentivised to introduce levies in order to reduce waste being sent to landfill. [14]

Figure 1: Limestone quarry illustrating the impact that excavating for materials used in concrete production has on the environment, such as land depletion. Source: Davalle, Sofia, "The growth in the mining sector and the use of limestone guide the performance of the lime market in Australia." (Australia Heavy Quip Journal, Nov 18, 2019), https://www.australiahqj.com/2019/11/18/the-growth-in-the-mining-sector-and-the-use-of-limestone-guide-the-performance-of-the-lime-market-in-australia/.

RECYCLING IN AUSTRALIA

"By 2050, 95% of all sea birds will have plastic in their gut." - CSIRO [15]

The need for appropriate long-term solutions could not be more urgent - Australia is in a waste crisis, especially after China placed restrictions on waste imports and tightened limits on contamination. [16] This has effectively forced Australia to find alternative means of discarding its own waste, with the hopes that alternatives to exporting or landfill can be realised. [17] In 2017, Australia exported almost 600,000 tonnes of plastic; a short-sight and unsustainable practice that allowed the complete absence of a domestic plastics recycling industry. [18] Australia's construction industry generated 20.4 million tons of construction and demolition waste in 2017, contributing to 40% of the total waste accumulation.[19] Queensland has been reported as the highest source of waste, 41% higher than the national average with over 430,000 tonnes from plastic alone in 2013. [20]

The question is, what are we really doing about it? Currently Australia has 193 material recovery facilities with the vast majority hand-sorted; only 18 are automated or semi-automated. [21] This is far from sufficient to deal with Australia's accumulating waste problem. The other common waste solution is the establishment of kerbside collection, which mixes the waste and takes it to sorting facilities – proving to be one of the least successful solutions, only a marginal improvement on dumping directly at landfill. Other forms of recycling have shown more promise, such as deposit systems where people are rewarded small change for recyclables. This is still simply sorting however, and the effectiveness of such systems ultimately relies on how the sorted waste is processed (which in Australia is extremely limited and difficult to track and quantify). [22] Several construction companies have established a take-back scheme, in which helps decreasing the amount of construction waste being sent to landfill.

What are Australian concreting companies currently doing and what is the progress on sustainable concrete?

CONCRETE MANUFACTURING IN AUSTRALIA

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Company	Recycled Aggre-gates	Industrial By-prod-ucts	Manufac-tured Agg.	Chemical Additives
Hanson	NO.	YES	YES	YES
Holcim	YES	YES	YES	YES
Boral	NO.	YES	YES	'Would not disclose'
Zeobond	YES	YES	YES	YES

Table 1: What waste materials Australian companies are using.

RECYCLED AGGREGATE SOURCES

Figure 2: Representing the locations for various recycled aggregates, manufactured aggregates and waste by-products within Australia. Designed by Richter, E. Original/ Information source: Use of Recycled Aggregates in Construction. Cement Concrete & Aggregates Australia (2008).

CONCRETE MANUFACTURING IN AUSTRALIA

Many efforts using recycled aggregates, particularly in Australia have proven practicality for low-strength concrete applications and to a limited degree some structural grade applications. Australian companies were surveyed and the results showed little interest in implementing recycled aggregates in concrete. There were various reasons given for this disinterest, with one company citing the 'lack of reliable and consistent source at this stage,' for recycled aggregate to be worth the time or money invested. On the other hand, pure disinterest was justified as 'not much demand for recycled aggregate use in concrete' and that the 'high-water absorption makes their use problematic and requires extra cement use.' In contrast to this, Holcim appealed this statement, affirming there is in fact 'a market for the use of recycled aggregates.' The level of transparency these companies have shown is commendable, with only minor details exempt from the findings, mostly economic factors or chemical additives were 'not disclosed.' The most common sustainability measure in concrete production is the use of waste by-products, greatly exceeding the use of recycled aggregates. Consistently, by-products like fly ash and blasted furnace slag are commonplace for concreting companies, as they are celebrated for success in reducing CO2 emissions, acting as a partial substitution to Portland Cement.

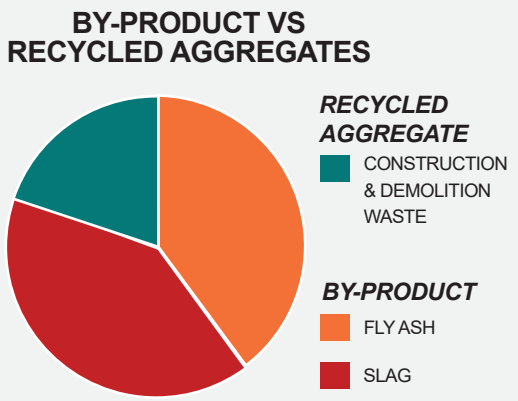

Figure 4: Percentage reflects what waste products are currently observed in the Australian concreting industry. Designed by Richter, E.

CONCRETE MANUFACTURING IN AUSTRALIA

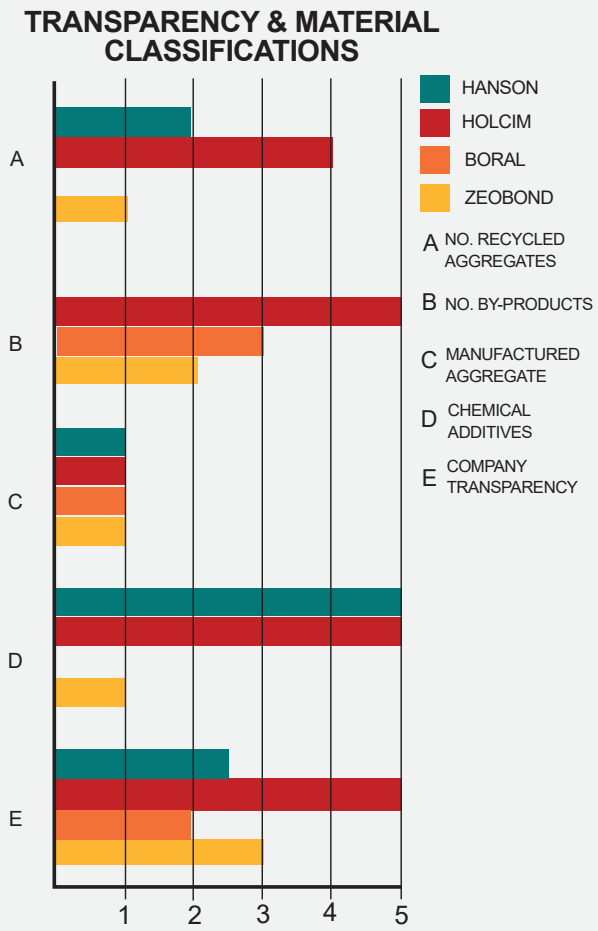

Figure 3: Illustrates the level of transparency the concreting company showed based on a number of responses. Additionally the number of materials under classifications used in each companies concrete. Designed by Richter, E.

CONCRETE 'PRIOR ART'

WHAT DOES THE PRESENT AND FUTURE OF CONCRETE LOOK LIKE?

Recycled roads are on the rise in Australia, becoming almost commonplace as governments desperately find ways to increase material recovery and divert stockpiles of recyclables from landfill. This application uses construction and demolition waste, which contributes to 40% of overall waste. It is withdrawing to think that with all the promising results from ongoing research on recycled aggregates in concrete (addressed below) ramming waste into roads is the only widely practiced outcome.

AUSTRALIAN INNOVATION
RECYCLED GLASS

"Lightweight concrete with glass fines is cost-effective and has a high strength-to-weight ratio, which is very important for the prefab industry." - Prof. Tuan Ngo, The Project Manager at The University of Melbourne.

Australian researchers from the University of Melbourne effectively produced eco-friendly concrete with glass waste, showing promising results that could potentially be superior to traditional concrete.

Figure 5: Glass waste. Source: "Eco-friendly concrete made from glass waste? Sustainable Building." TPM Builders (2017), https://tpmbuilders.com.au/concrete-made-glass/

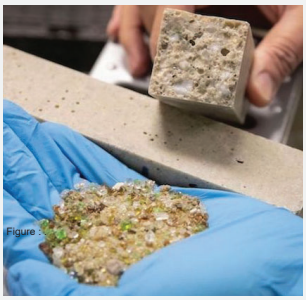

Figure 6: Australian researchers from the University of Melbourne produced eco-friendly concrete from glass waste. Source: Ngo, Tuan; Kashani, Ali; Hajimohammdi, Ailar; and Crough, Damien, "Case study – Using recycled glass fines in light weight concrete," Published by Sustainability Victoria, (April, 2018)

AUSTRALIAN INNOVATION
RECYCLED RUBBER

Researchers from the University of South Australia were approached by Tyre Stewardship Australia (TSA) to develop and test Crumbed Rubber Concrete (CRC) for potential use in residential construction.

Figure 7: Researchers from the University of South Australia developing crumbed rubber concrete, after being approached by Tyre Stewardship Australia (TSA). Source: "Recycled rubber looks promising for residential construction," (Architecture & Design, 2019), https://www.architectureanddesign.com.au/news/recycled-rubber-looks-promising#

INTERNATIONAL INNOVATIONS
RECYCLED TIMBER, PLASTIC AND PAPER

Researchers from the Swiss National Forrest Programme have established an approach for greener, lighter and easier to recycle concrete by substituting gravel and sand with more than 50% of sawdust .

Research conducted by The University of Bath in India demonstrated favourable results for reducing excessive amount of plastic waste, with a partial replacement to sand in concrete production; which would potentially save up to 820 million tonnes of sand annually.

Figure 8: Researchers from the Swiss National Forrest Programme developing a concrete that substitutes conventional aggregates with more than 50% sawdust. Source: Aliento, Willow, "Concrete made from wood. How about that!" The fifth state, (July, 2017), https://www.thefifthestate.com.au/innovation/materials/concrete-made-from-wood-how-about-that/

Figure 9: Plastic waste (resin pellets) in reference to the research being conducted by the University of Bath in India by incorporating plastic aggregates in concrete. Source: "Cement's solution to plastic waste," (2018)

The Carriage House by Kelly Hart located in New Jersey, this project substituted traditional aggregates with large pulped paper fibres (waste) in concrete production (papercrete).

[For more information on the project refer to: Kelly Hart (Director, Producer, Writer), Kelly Hart, Rosana Hart, Peter B. Rice (Actor) , Building with Bags: How We Made Our Experimental Earthbag / Papercrete House, 2010]

Figure 10: Papercrete - The Carriage House by Kelly Hart located in New Jersey. Source: Hart, Kelly, "Papercrete," (Kelly Hartworks LLC, established in 2001), http://www.greenhomebuilding.com/papercrete.htm

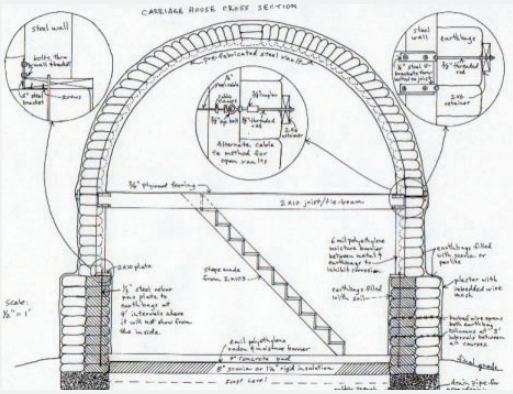

Figure 11: Detailed section through The Carriage House by Kelly Hart located in New Jersey, design utilizes earth-bags plastered with papercrete. Source: Hart, Kelly, "Papercrete," (Kelly Hartworks LLC, established in 2001), http://www.greenhomebuilding.com/papercrete.htm

Conclusion

In conclusion, concrete has remained largely unchanged since the introduction of Portland cement. Traditional processes significantly contribute to greenhouse gas emissions, degrade and destroy habitats and consume large quantities of natural resources such as sand and water. While there has been some progress towards the use of recycled materials in concrete, primarily as substitutes for the traditional quarried aggregates, this avenue is only beginning to be explored, and there is still significant potential for progress in the near future.

Conclusion Cont.

With a poor sustainability record (especially with respect to sand mining), a rapidly growing waste/recyclables problem, and an innovative construction industry capable of utilising these advanced hybrid concrete materials Australia is in a position to see major benefits from the use of waste products in concrete production. Multiple Australian companies and universities are currently researching, trialling and beginning to implement more sustainable concrete products, and these trials as well as personal experimentation demonstrate the feasibility of the process. Further, some of these ingredient substitutions are able to change and even improve the material properties of concrete, showing that sustainability does not have to come at the cost of function. The primary contemporary use of recycled aggregates in Australia is in roads, however even in standard concrete, up to 3% recycled construction materials in the place of aggregates are already in commercial use. Promising results have been shown using up to 50% substitution with materials such as sawdust and glass, although these have yet to see commercial use.

THANKS

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