19
2013

Briefing

Sustainable Use of Aggregates

1 Introduction

The discussion on sustainability has been given the utmost importance in the construction materials industry over the last decade. The goal of meeting the current demand while ensuring consistent supply for the needs of future markets is a delicate balance which the construction materials industry is constantly striving to achieve through innovation and research.

The scarcity and sustainable supply of natural resources for aggregates has always been borne in mind by the construction materials industry, along with protection and rehabilitation of the natural habitat from which it is extracted.

Concurrently, the industry has identified the need for recycled aggregate to complement the use and performance of naturally sourced aggregate in construction. It is important when specifying recycled material to understand the performance characteristics as compared with those of naturally sourced extracted material. Since the overall performance and durability of the construction needs to be maintained, performance based limits for recycled aggregates must be specified. A number of industry and academically based research projects have been undertaken to ascertain performance limits for recycled, re-used and manufactured aggregates, and provide guidelines for their specification[1, 2, 3]. The level of recycled aggregate substitution which is achievable will depend upon the properties of the recycled aggregate, its availability in the market, the performance criteria of the mix, the whole-of-life sustainability of the product and the economic viability of its inclusion.

This briefing provides guidance on the specification and use of recycled aggregates to produce a truly sustainable product with high performance characteristics.

As the social and environmental elements of sustainability have been championed, and driven, by the needs of a growing population with an increasing environmental conscience, the construction materials industry has faced greater economic and legislative challenges in order to source, extract and supply virgin material. Suburban sprawl has brought residential areas closer to existing quarries which poses operational challenges, while proposed new quarry sites tend to be located further and further away from urban areas. These socially driven requirements result in increased costs for operation, transportation and compliance with regulatory bodies.

These factors are all significant when ascertaining the availability of aggregates, both natural and recycled. Naturally sourced and extracted aggregates are in some cases readily available, albeit from more-remote locations. In other cases, such as natural sand, availability is highly variable from state to state. The supply of recycled aggregates is also highly variable as they are often a by-product of another process or demolition waste. Generating a higher demand for recycled product through incentives in specifications may not necessarily equate to an overall sustainable outcome as the material may have to be obtained from a non-sustainable source.

Factors to consider when sourcing and specifying aggregates for a sustainable outcome are shown in **Figure 1**.

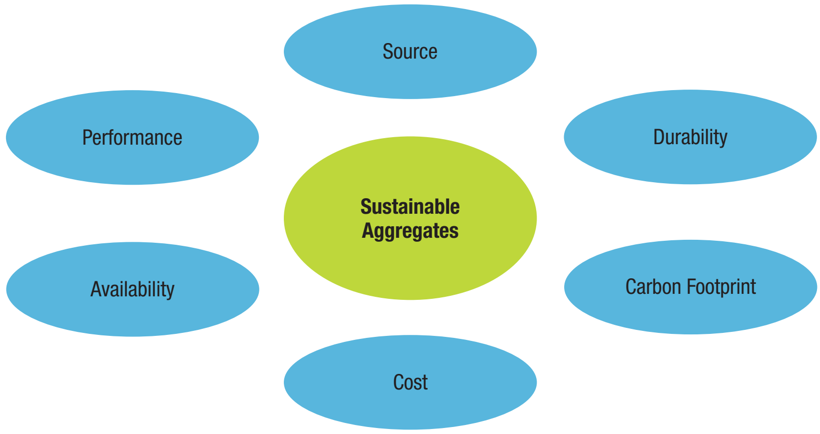

Figure 1 Factors contributing to sustainable specification of aggregates

2 Life Cycle Analysis

The importance of Life Cycle Analysis (LCA) when designing and constructing sustainable structures has been widely studied[4]. ISO 14040 defines Life Cycle Analysis as:

"… a technique for assessing the environmental aspects and potential impacts associated with a product, by compiling an inventory of relevant inputs and outputs of a product system; evaluating the potential environmental impacts associated with those inputs and outputs; interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study."

With the increased emphasis on re-using waste materials and recycled materials, the construction materials industry LCA is primarily concerned with a cradle-to-grave analysis, see **Figure 2**.

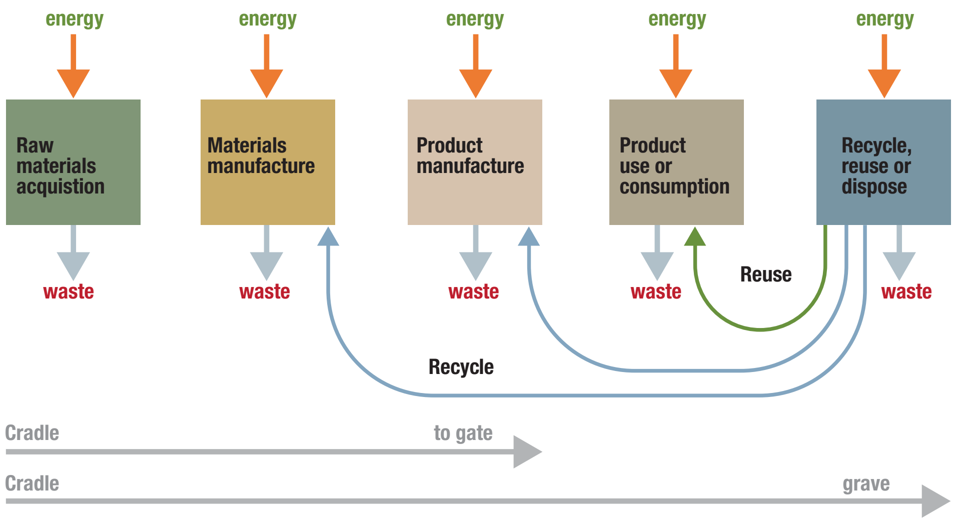

Figure 2 Cradle-to-grave life cycle of construction materials[5]

Most importantly, when designing for sustainability and choosing materials for sustainable construction, it is important to consider the impacts of the construction throughout its design life, see **Figure 3**. Compromising the performance of quality materials by specifying low-grade alternatives may qualify for incentives initially, but may affect the durability and performance of the construction during its design life, leading to costly remediation or the need to re-build.

Similarly, specifying very-high-grade materials for an element that has low or non-critical performance requirements, will lead to unnecessary depletion of valuable resources when a recycled, re-used or manufactured "fit for Purpose" alternative would be adequate.

As with all projects, it is important to consider the environmental as well as the social and economic impacts of material and construction choices from cradle to grave when designing civil or structural works.

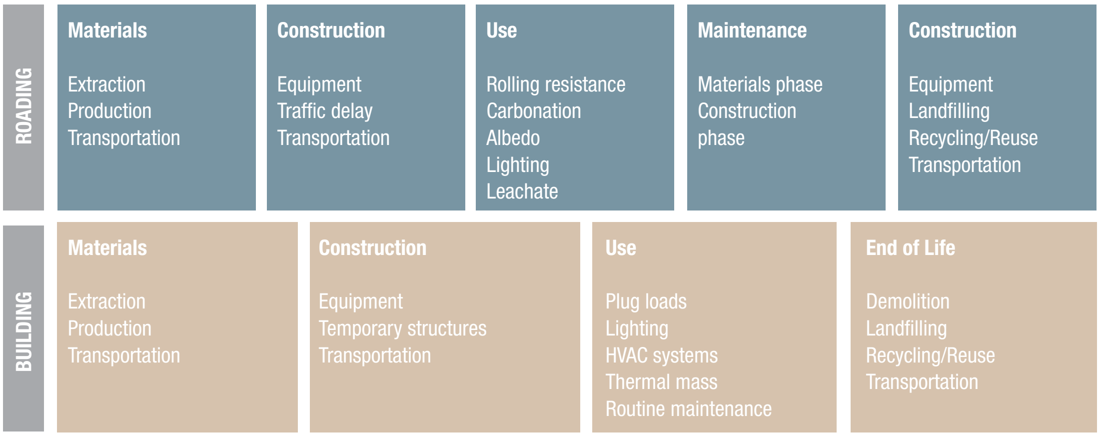

Figure 3 Considerations for the sustainable use of construction materials[6]

3 Sustainable use of aggregates in concrete

All materials, including concrete products, have impacts on the environment throughout their life. These impacts are associated with acquisition of raw materials, processing, transport, construction, maintenance and disposal/recycling at the end of their life. The environmental impacts associated with concrete are outweighed by the benefits that concrete delivers, including:

- Concrete delivers high quality low cost structures.
- Concrete's thermal mass benefits can deliver energy efficient buildings.
- Concrete buildings have low maintenance requirements and support a long design life.
- Concrete can be recycled and reused in numerous ways including in the manufacture of new concrete.
- Concrete has excellent fire resistance properties, providing protection to human life and material assets from the danger of fires[4].

The overall sustainability of concrete is derived from its individual constituent materials, including the cementitious materials, water, admixtures and both fine and coarse aggregates.

The recycling and recovery of waste materials for use as concrete aggregate is seen as a sustainable option, and has been proven practical for low-strength-concrete applications. The benefits associated with recycled concrete aggregates include:

- Preservation of natural raw materials, and reduced impact on natural flora and fauna.
- Reduction in the amount of material going to landfill.
- Economic benefits associated with the use of a waste material/ industrial by-product[7].

Recycled aggregates may not always be the practical or sustainable option. Several constraints to wider use of recycled aggregates include a lack of engineering and performance data along with large variations in properties of recycled materials, leading to low levels of consumer confidence. The cost and energy used for recovering and processing recycled materials can exceed those for raw aggregates. For example, when the recycling plant is remote from the concrete mixing plant, additional cost and fossil fuel use for cartage will result. Site-specific factors should be considered when deciding on aggregate specifications.

An important consideration for the specification of recycled aggregates is the effect they will have on the properties of the concrete. Each category of recycled aggregate will affect the concrete differently. The properties for each category of recycled aggregate will also be highly variable, dependent on the properties of the parent material. For example recycled concrete aggregate made from a 40-MPa parent concrete is likely to have higher strength properties compared with those of a similar aggregate developed from a 20-MPa parent concrete. Demolition of concrete structures will also see inclusion of other demolition waste such as brick and plaster; these materials have significant effects on the aggregate properties and the extent of their inclusion is highly variable. Separation of materials during demolition is one method of overcoming this contamination but will never completely eliminate variability.

The use of 100% recycled coarse aggregate in concrete is likely to negatively impact most fresh and hardened concrete properties, including workability, compressive strength, shrinkage and creep[1]. Appropriate mix design and using a combination of recycled and natural aggregates can overcome most of these negative impacts.

The level of recycled aggregate substitution achievable will depend on the properties of the recycled aggregate, its availability, and the specified performance criteria of the given concrete mix. Performance-based specification should be employed due to the high variability of the material properties and economic viability.

4 Sustainable use of aggregates in roads

A number of state road authority specifications are available and outline specific requirements for the use of recycled aggregates in pavements. A list of these documents is shown in **Table 1**. Properties covered through the specifications include testing requirements, physical and plastic properties, and maximum deleterious material limits.

Table 2 depicts the categories of recycled materials used for road pavements and the range of limits on their use imposed by state road authorities. The limits shown are an example of the range found from different road authorities for a number of pavement classes. For the limits imposed on specific road classes, each individual state specification should be refered to.

State/Authority	Document
NSW	Granular base and subbase materials for surfaced road pavement[8].
IPWEA	Specification for supply of recycled material for pavements, earthworks and drainage[9].
SA	Supply of pavement materials, part 215[10].
QLD	Recycled materials for pavements[11].
VIC	Source rock for the production of crushed rock and aggregates[12]. Crushed rock for pavement base and subbase[13]. Crushed concrete for pavement subbase and light duty base[14]. Aggregate for Sprayed Bituminous Surfacing[15] Recycled Materials Used in Road Construction[16].

Table 1 Relevant State/Authority specifications and guides

Recycled material	State road authority limits
Iron and steel slag	100%
Crushed concrete	100%
Brick	10 – 45%
RAP	20 – 40%
Fly ash	100%
Crushed glass fines	5 – 17%

Table 2 Typical range of limits for the use of recycled materials as constituent materials for surfaced road pavements[9, 10, 11].

Table 3 depicts some standard requirements for strength and deleterious-material limits imposed by several state road authorities. For additional requirements, including specific limits for given road classes, each state specification should be referred to.

State	Range of strength properties for granular products	Range of deleterious-material limits			
		High density materials (a)	Friable materials (b)	Low density materials (c)	Bituminous materials
NSW	Wet Strength: 70 kN min. Dry Strength: 1.7 MPa min. Wet/dry variation: 35 – 40 kN max. Unconfined Compressive Strength: 1.5 MPa	3 – 5%	0.2 –1%	0.1 – 0.5%	_
SA	Resilient Modulus: 250 – 300 MPa min. LA value: 30 – 45% max.	20% max	1%	0.50%	1%
QLD	Wet/dry variation: 35 – 40% CBR: 15 – 80 min. Unconfined Compressive Strength: 0.7 MPa	2 – 3%	1%	0.20%	1%
VIC	CBR: 20 – 100 min. LA value: 35 – 45% max.	2 – 5%	0.5 – 3%	0.1 – 3%	_

(a) Brick, stone, masonry, glass etc.
(b) Plaster, clay etc.
(c) Rubber, plastic, paper, wood, vegetable matter etc.

Table 3 State road authorities' standard requirements for recycled aggregates[8, 9, 10, 11, 14]

5 Types of Aggregates

5.1 Classification

Aggregates are typically classified as follows:[17]

- Virgin and natural aggregate – Aggregate produced from natural source rock.
- Recycled aggregate – Aggregates derived from the processing of materials previously used for another purpose.
- Manufactured aggregate – Aggregates manufactured from select naturally occurring materials, including by-products of industrial processes.
- Reused by-product – Aggregates produced from by-products of industrial processes.

Table 4 lists the types of aggregates by class.

5.2 Virgin and Natural Aggregates

Both fine and coarse aggregates are quarried or dredged for use as natural aggregates in concrete and for road base. The process of quarrying has environmental impacts through its effect on flora and fauna, use of non-renewable resources and impacts on local communities.

Additional energy and carbon equivalent greenhouse gases are expended for ripping, blasting, dredging, crushing, grading and transporting of aggregates. However, the extraction techniques are considered simplistic and the aggregates require no fundamental alteration.

As a result, quarrying operations have low environmental impacts compared to more-energy-intensive operations used for the generation of other materials. For example, the production of clay bricks and cement has high energy requirements due to the need for the generation of high temperatures through the burning of fossil fuels.

Geology ultimately determines the location of virgin material, the availability of material is, however, largely driven by environmental and planning legislation. While good quality material may be available close to main centres, permission needs to be obtained from state governments in order to extract the material. This process, depending on complexity and the required regulatory process, can take 2 – 6+ years for approval[18].

While the majority of hard rock is extracted through the quarrying process (these are referred to as 'virgin' material), there are some regions, particularly in Victoria, where outcrops of basalt rock known as 'basalt floaters' occur extensively and is recovered from the surface. Although classified as a natural aggregate, this material would traditionally have been discarded as waste, often into landfill[3]. This is due to the potential presence of contaminants like heavy clays and leachate which would be detrimental to the properties of concrete and road base. Recently, however, due to improved processing and crushing, some road authorities have allowed limited use of excavated rock for road base following stringent testing[13]. The use of these materials should be governed by adherence to the relevant Australian Standards and/or specification.

Other natural aggregates are sand and river gravel which are extracted through the dredging process.

Specifications for concrete mix design and road base are currently primarily based on the traditional performance characteristics of virgin and natural aggregates. These specifications have been developed through years of research and testing as well as proven in-situ performance. These characteristics currently set the benchmark for the performance requirements of alternative aggregates such as those mentioned below.

Classes of Aggregates	Aggregates
Natural	Crushed rock Sand and gravel Crushed river gravel
Recycled	Reclaimed Aggregate (RA) Reclaimed Asphalt Pavement (RAP) Reclaimed Asphalt Aggregate (RAA) Recycled Concrete and Masonry (RCM) Recycled Concrete Aggregate (RCA) Glass Cullet Scrap Tyres Used Foundry Sand
Manufactured	Manufactured Sand Classified Manufactured Sand Crusher Fines Polystyrene Aggregate (PSA)
Reused by-product	Blast Furnace Slag (Granulated, Foamed, Air-cooled) Coal Ash By-Products Organic Materials Mine Tailings

Table 4 Classes and types of aggregates [17]

Type of Aggregate	Description	Applications	Availability in Australia
Reclaimed Aggregate (RA)	Coarse aggregates reclaimed from returned premixed concrete by separating the aggregates from the water-cement slurry.	Up to 32-MPa concrete with reclaimed aggregates, and as partial replacement of natural aggregate in higher grades up to 80 MPa. Maximum substitution will be governed by agreed performance requirements.	Some available in Victoria, rarely in other states.
	Quarry materials, previously discarded as quarry waste, which are re-processed back into the aggregate supply chain. These may include surface outcrops of naturally occuring rock recovered during the construction process or overburden materials.	Allowable for low grade road bases after special approval from road authorities based on quality and performance requirements. May be used in general concrete – provided required performance requirements are met.	Available in most states.
Reclaimed Asphalt Aggregate (RAA)	Reclaimed coarse aggregate and recycled asphalt granules from waste asphalt concrete.	Concrete – with penalties in mix adjustment.	Not available.
Reclaimed Asphalt Pavement (RAP)	Old asphalt concretes.	New asphaltic concrete pavement. RAP/RCA blends for RCC in flexible pavement and sub-grade material	Available for road construction.
Recycled Concrete Aggregate (RCA)	Crushed sound and clean waste concrete containing at least 95% (by weight) of concrete with typical total contamination lower than 1% of the bulk mass. Class 1A RCA is a well graded RCA with no greater than 0.5% brick content.	Partial replacement (30%) for natural aggregate in concrete for sidewalks, kerbs and gutters. Same for structural concrete with some penalties in mix adjustment, permeability and shrinkage. Maximum substitution will be governed by agreed performance requirements.	Available commercially particularly in the Sydney and Melbourne markets.
Recycled Concrete and Masonry (RCM)	Graded aggregate produced from sorted and clean waste concrete and masonry.	Road base course and subbase material; Unbound and Bound (CTCC)	Available commercially particularly in the Sydney and Melbourne markets.
Glass Cullet	Glass cullet pulverised into a sand-like product.	Partial replacement of fine aggregate (sand replacement) in concrete – small penalties in mix design.	Available in NSW and VIC.
Scrap Tyres	Scrap tyres processed as tyre chips and crumb rubber aggregate.	Crumb rubber in asphalt and sprayed bitumen seals.	Available but largely exported.
Used Foundry Sand	Spent foundry sand.	Partial replacement of fine aggregate in concrete and asphaltic concrete.	Available in NSW.

Table 5 Recycled Aggregates[17]

5.3 Recycled Aggregate

Recycled aggregates are produced from the processing of materials previously used in construction operations. The level of processing can be high and energy intensive, depending on the quality of the recyclable material and the level of contamination. The key types of recycled aggregates are listed in **Table 5**.

5.4 Manufactured and Reused by-product aggregates

5.4.1 General

Manufactured aggregates are purpose-made aggregates, derived from materials with desired properties. An example of a manufactured aggregate is that produced by the crushing and grading of natural rock source material to create a fine aggregate referred to as 'manufactured sand'.

Reused by-product aggregates are aggregates produced from the by-products of industrial processes. Common examples of suitable by-products include slag which is generated from the manufacture of iron and steel, and fly ash which is produced in coal-fired power stations, these by-products will typically require processing before being suitable for use as an aggregate in concrete and pavement applications.

The key types of manufactured and reused by-product aggregate are listed in **Table 6**.

Type of Aggregate	Description	Applications	Availability in Australia
Manufactured Sand	Purpose-made crushed fine aggregate produced from a suitable source material and designed for use in concrete or road construction.	Partial sand substitute in concrete and asphaltic concrete.	Available commercially.
Air-cooled BF Slag (ABFS)	Slowly air cooled crystalline iron slag – crushed and screened. Also available as uncrushed slag.	Concrete aggregates for all structural grades.	Commercially available from Port Kembla and Whyalla.
Granulated BF Slag (GBFS)	Sand-like rapidly quenched iron slag with high volume of water sprays.	Concreting sand with some reservations.	Availability dependent on demand as SCM.
Electric Arc Furnace Slag (EAFS)	Air-cooled steel slag) – crushed and screened.	Road stabilisation and controlled low-strength fill. Asphalt aggregates and high friction surface material.	Commercially available in Melbourne, Sydney and Newcastle.
Steel Furnace Slag (SFS)	Air-cooled steel slag from the Basic Oxygen System (BOS) – crushed and screened.	Asphalt aggregate or for road base and subbase.	Commercially available from Port Kembla and Whyalla.
Fly Ash	Run-of-the-station fly ash from coal-fired power station.	Fine aggregate for concrete, and road stabilisation.	Commercially available in the Sydney market.
Furnace Bottom Ash	Particle or agglomerates of ash collected at the bottom of furnace.	Fine aggregate for concrete products and road base component.	Commercially available in the Sydney market.
Coal Washery Reject	Coal reject or colliery spoil.	Subbase material.	Commercially available in NSW and Queensland.

Table 6 Reused by-product and manufactured aggregates[17]

5.4.2 Manufactured Sand

Manufactured sand is a purpose-made fine aggregate produced by the crushing, classifying and/ or washing of suitable source rock material. Manufactured sand is designed for use in concrete and concrete pavements. The use of manufactured sand is of crucial importance in Australia due to the limited availability of natural river and dune sands.

Currently, the specification limits for manufactured sands in concrete and road base is prescriptive, with upper limits specified by most road authorities. Extensive research has been conducted in Australia by CCAA to provide guidance on the use of manufactured sand in concrete pavements and shed some light on the properties and surface behaviour of concrete pavements incorporating manufactured sand.

CCAA's report[19] suggests that formal limits on manufactured sand are not appropriate, rather than the amount of manufactured sand would be naturally limited by the ability of producers to meet required performance characteristics such as grading, shape, water demand, etc… and its effects on concrete with regard to strength, workability and ease of paving.

5.4.3 Steel and coal ash by-products

The production of iron, steel and electricity generate by-products, which are typically diverted to landfill, if not for their beneficial use in concrete and road applications. Two typical by-products are Blast Furnace Slag (BFS) and Fly Ash (FA) which are commonly used as supplementary cementitious materials (SCMs).They also have their applications as concrete and pavement aggregates, as shown is **Table 6**.

The plastic and hardened properties of concretes incorporating BFS aggregates will in most cases be comparable to virgin-aggregate concrete for key parameters. The vesicular nature of BFS aggregates lead to slightly higher water absorption. This vesicular property is also believed to increase cement-paste/aggregate interaction and provide an additional reservoir of water for hydration[20].

Coal Combustion Products (CCPs) including Fly Ash (FA) and Furnace Bottom Ash (FBA) are by-products from the production of power in coal-fired power stations. The products have pozzolanic properties and are typically used as a SCM to replace cement or as a fine aggregate in concrete and road-base applications[21].

The quality of these by-product aggregates is generally high, and as a result, standards will typically allow a larger percentage of aggregate replacement with BFS and CCPs when compared with other forms of recycled or reused aggregates, see **Table 2**. It is important to note that the availability of these products is variable as they are often in competing demand as SCMs.

5.4.4 Case Study - Use of RCA in Melbourne's Western Ring Road Construction

The use of recycled materials in road construction provides an opportunity to reduce the unnecessary wastage of not only diminishing virgin materials stocks but also valuable land-fill space. Over the past 30 years a combination of diminishing natural aggregate supply and a chronic shortage of land-fill sites has necessitated a growing use of recycled crushed concrete in Japan and Europe. Similar incentives for greater use of recycled crushed concrete are developing in Australia. By the early 1990s, significant use of recycled crushed concrete aggregate was being made by a number of

Figure 4 Work on the M80 Ring Road. (Photo courtesy of Theiss)

Australian municipalities for local road construction and other engineering projects.[22]

The construction of the Western Ring Road Project in 1993 provided the opportunity for field testing the in situ performance of Cement Treated Crushed Concrete (CTCC) as a subbase layer in one of Victoria's major infrastructure projects. Approximately 300,000 tonnes of CTCC was used on the project by three major contractors.

Following laboratory comparisons with Cement Treated Crushed Rock (CTCR) and the successful use of CTCC on the M80 project, VicRoads developed standard specifications for the use of CTCC as a pavement sub base in 1993.[23, 24]

The field tests highlighted some workability differences between CTCC and CTCR, as well as interesting strength development behaviour of CTCC[25] which has since prompted extensive research of the properties both in situ and in the laboratory. The specification requirements for recycled concrete aggregates (RCA) are largely the same as those for subbase quality crushed rock. This encourages manufacturers to consistently produce RCA that meets product quality and performance standards so that it can be successfully and frequently specified for low-traffic roads as well as some major infrastructure projects

6 Conclusion

Recycled Aggregates offer a number of benefits for concrete and pavement applications, both as a sustainable material and an economically viable alternative to raw materials. However, stringent guidelines on large substitution rates would have negative effects on the industry, leading to a reduction in the performance of the product and creating an over demand for recycled products, which are heavily used in other areas such as SCMs.

It is imperative to understand that recycled aggregates may not always be the practical or sustainable option for all applications. This is due to variability in recycled aggregate properties and uncertainty over their effects on structural capacity and durability. Scarcity of supply and site-specific variations, including long haulage can make recycled aggregates less sustainable and more costly than their raw material alternatives.

Performance-based specification is recommended. This will require the producers to determine appropriate mix design using a combination of both recycled and natural aggregates. The level of recycled aggregate substitution will depend on the properties of the recycled aggregate, its availability, performance criteria of the concrete, whole-of-life sustainability of the product and the economic viability of its inclusion.

7 References

1. Cement & Concrete Association of New Zealand, "TR 14 Best Practice Guide for the use of Recycled Aggregates in New Concrete," 2011.
2. CCAA, "Guide to the Specification and Use of Manufactured Sand in Concrete, T60," 2008.
3. T. Aatheesan, A. Arulrajah and e. al, "Crushed brick blends with crushed rock for pavement systems," in *Institute of Civil Engineers, Waste and Resource management 163*, 2010.
4. Cement Concrete and Aggregates Australia, "Concrete – the responsible choice," 2010.
5. W. South, "Concrete Responding to the Challenge - Materials, Standards & Practice for Sustainable Concrete Structures," Industry Presentation, 2011.
6. Concrete Sustainablity Hub@MIT, "Adopting a Life-Cycle Perspective," Special Research Brief, April 2011.
7. Cement Concrete and Aggregates Australia, "Briefing: Sustainable Concrete materials," 2010.
8. Roads and Maritime Services, "RMS 3051 - Granular Base and Sub-base Materials for Surfaced Road Pavement," 2011.
9. Institute of Public Works Engineering Australia, "Specification for Supply of Recycled Material for Pavements, Earthwork and Drainage," 2010.
10. Department for Transport, Energy & Infrastructure, "Supply of pavement materials, Part 215," DTEI SA, 2008.
11. Department of Transport and Main Roads - Qld, "MRTS35, Recycled Materials for Pavements, Queensland Government," 2011.
12. VicRoads, Section 801 - *Source Rock for the Production of Crushed Rock and Aggregate*.
13. VicRoads, Section 812 - *Crushed Rock for Pavement Base and Sub-base*.
14. VicRoads, Section 820 - *Crushed Concrete for Pavement Sub-base and Light Duty Base,* 2009.
15. VicRoads, Section 831 - *Aggregate for Sprayed Bitumous Surfacing*.
16. VicRoads, TN 107 - *Recycled Materials Used in Road Construction.*
17. Cement Concrete and Aggregates Australia, "Report: Use of Recycled Aggregates in Construction," 2008.
18. CCAA, "The Economic Contribution of the Heavy Construction Materials Industry in Victoria," 2012.
19. Cement Concrete and Aggregates Australia, "Research Report: Manufactured Sand, Abrasion resistance and effect of manufactured sand on concrete mortar," 2008.
20. Australian Slag Association, "Blast Furnace Slag Aggregates Properties,characteristics and Applications, Reference Data Sheet 2," 2011.
21. Ash Development Association of Australia, "Pavement Construction and the Role of Coal-Combustion Products, Technical Note 5," 2012.
22. VicRoads, "Investigation Into The Use of Recycled Crushed Concrete for Road Base Use," EcoRecycle Victoria, 1997.
23. VicRoads, Section 820 - *Crushed Concrete for Pavement Subbase and Light Duty Base,* 2011.
24. VicRoads, Section 821 - *Cementitious Treated Crushed Concrete for Pavement Subbase*, 2011.
25. R. Paul and R. Warwick, "Use of Recycled Crushed Concrete for Road Pavement Sub Base," in Proceedings Roads 96 Conference, Part 2, 1996.

19
2013

CCAA OFFICES

SYDNEY OFFICE
Level 6, 504 Pacific Highway
St Leonards NSW Australia 2065
POSTAL ADDRESS
Locked Bag 2010
St Leonards NSW 1590
TELEPHONE (61 2) 9437 9711
FACSIMILE (61 2) 9437 9470

BRISBANE OFFICE
Suite 2, Level 2
485 Ipswich Road
Annerley QLD 4103
TELEPHONE (61 7) 3227 5200
FACSIMILE (61 7) 3892 5655

MELBOURNE OFFICE
2nd Floor, 1 Hobson Street
South Yarra VIC 3141
TELEPHONE (61 3) 9825 0200
FACSIMILE (61 3) 9825 0222

PERTH OFFICE
45 Ventnor Avenue
West Perth WA 6005
TELEPHONE (61 8) 9389 4452
FACSIMILE (61 8) 9389 4451

ADELAIDE OFFICE
Greenhill Executive Suites
213 Greenhill Road
Eastwood SA 5063
TELEPHONE (61 8) 8274 3758

TASMANIAN OFFICE
15 Marana Avenue
Rose Bay TAS 7015
TELEPHONE (61 3) 6491 2529
FACSIMILE (61 3) 9825 0222

WEBSITE www.ccaa.com.au

EMAIL info@ccaa.com.au

CEMENT CONCRETE
& AGGREGATES AUSTRALIA

concrete™
the responsible choice