THE GREEN CONSTRUCTION BOARD

REPORT 020

Ready-Mixed Concrete Resource Efficiency Action Plan

February 2014

A contribution to delivering the targets in the joint government and industry Strategy for Sustainable Construction and the ambitions of the Green Construction Board

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Ready-Mixed Concrete: a Resource Efficiency Action Plan

February 2014

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Executive summary

This resource efficiency action plan was developed by the ready-mixed concrete sector to assist its supply chain, which ranges from raw material extraction to the demolition and deconstruction of buildings, in identifying and creating an actionable strategy for improving resource efficiency. The plan identifies the key challenges and actions that the ready-mixed concrete sector and its associated supply chain need to address in order to make improvements in resource efficiency.

Given the extensive work already completed by this sector through the strategy created by the Sustainable Concrete Forum, this Resource Efficiency Action Plan (REAP) addresses a wide range of resource efficiency issues and impact areas of waste, water, carbon (energy usage and emissions), materials (primary raw materials and secondary/recycled materials) and biodiversity. It aligns with the current resource efficiency, low carbon and general sustainability themes being promoted by the Green Construction Board (GCB) and Construction 2025 Industry Strategy: government and industry partnership.

It has been developed in association with two other plans, for clay bricks and clay blocks and for precast concrete. Collectively, the plans underpin the approach these three related heavyweight construction materials sectors are taking to address sustainability issues and provide resource efficient products and solutions to the construction sector in the UK.

The plan was developed with the input of a stakeholder group formed of a range of professionals drawn from the ready-mixed concrete supply chain, including raw material suppliers, ready-mixed concrete manufacturers, logistics suppliers, designers and main contractors, and demolition and recycling contractors. In addition to providing the funding for this project, the Waste and Resources Action Programme (WRAP)[1] has supplied valuable links with other sectors and other REAPs, and its contribution is duly acknowledged.

In the UK, ready-mixed concrete is one of the main construction product sectors, with an annual turnover of around £1 billion, and is a crucial supplier to the £110 billion construction industry. The UK ready-mixed concrete industry, represented by members[2] of the British Ready-Mixed Concrete Association (BRMCA), produced around 14.2 million cubic metres of concrete from just over 800 ready-mixed concrete plants in 2012, around 75% of the UK market.

The concrete industry's overall Sustainable Construction Strategy, created by the Sustainable Concrete Forum (SCF) [3], looks at a variety of sustainability principles and measures the industry performance against a number of key performance indicators (KPIs). The scheme set targets to 2012 and now proposes targets and objectives to 2020 and beyond. It allows the industry to collect information on resource efficiency and waste generation. But only limited detailed information beyond the factory gate is so far available, and no detailed analysis of the drivers and implications of product use, transport and logistics, wastage or end of life has ever been conducted. Specific resource efficiency issues being considered include those associated with over-ordering, the peaks in demand for ready-mixed concrete, and continuing to promote reductions in embodied carbon in concrete mixtures.

[1] Waste and Resources Action Programme (WRAP) http://www.wrap.org.uk
[2] See Appendix 3 for member link
[3] Sustainable Concrete Forum Strategy http://www.sustainableconcrete.org.uk/

One of the beneficial outcomes of this REAP is in addressing shortfalls in the data collection and evaluation process. Through the 'actions' presented here, the aim is also to develop a way of setting objectives and reporting progress against 2020 targets. The REAP will be reviewed annually as part of the concrete sector's annual performance report, with a major review due after five years (2018)[4].

During the development of this REAP, more than 40 challenges and potential actions were identified by the stakeholder group, encompassing all aspects of the supply chain. These preliminary actions were subsequently reviewed and prioritised, resulting in 23 high priority and SMART (Specific, Measurable, Realistic, Achievable, Time-bound) actions. When put into practice, it is believed that these actions will bring about measurable improvements in resource efficiency, not only when first instigated but continuing over time.

The actions generated provide a range of approaches to addressing continual improvement of the sector. These include the need to gather and evaluate data and to transfer knowledge in the form of guidance documents, exemplars and case studies in order to change resource inefficient practices in the production, specification, distribution and use of ready-mixed concrete. Other actions relate to the assessment of and, where appropriate, investment in equipment and infrastructure that will deliver resource efficient improvements.

The basic concept is that this report reinforces the journey towards continual improvement in the sector, resulting in resource efficiency improvements in the manufacture, supply, placement at the construction site and recycling of ready-mixed concrete in the UK, thus contributing to the UK Government's requirements for a low carbon, sustainable construction sector.

The development of the plan will enable the ready-mixed concrete sector to develop and deliver the most appropriate actions to improve resource efficiency across the sector's supply chain and logistics network.

[4] Concrete Sector Annual Sustainability Performance Report, 6th Report: 2012 performance data http://www.sustainableconcrete.org.uk/

Summary of actions

The following is a summary of actions within the report, including information regarding the lead on action delivery and proposed timescales.

Proposed action	Lead	Deliverable action (and timescale)
Manufacturing		
Standardised prescribed (ST) concretes have higher cementitious content than equivalent designated mix concrete and hence higher embodied CO_2. BRMCA to gather data on the percentage of ST concrete supplied. The volume of ST concretes currently supplied to the market requires investigation.	BRMCA	Conduct survey to assess volumes of ST concrete supplied by ready-mixed concrete companies (complete survey by 31 December 2015).
Collection of data on total waste associated with manufacturing. Ready-mixed concrete does not go to landfill but, nevertheless, wasted material goes back to the plant and is reworked or reused on site. There is a need to collect data, develop targets and promote best practice to achieve reduction in the amount of the total waste associated with the manufacture of ready-mixed concrete.	BRMCA	Review resource wastage from reworking and reuse of concrete. Collect waste data and subsets of metrics and develop target of total waste from manufacturing of ready-mixed concrete (by 31 December 2016).
Establish metrics against which to measure reduction in the use of water (mains and permitted groundwater) in the manufacture of ready-mixed concrete	BRMCA with Mineral Products Association (MPA) Water Group	BRMCA to continue to participate in the development of, and adopt the agreed sector water strategy for, manufacturing and associated guidance notes on best practice (completed strategy by 31 December 2016).
Review all questionnaires and guidance in respect of the data capture in association with Key Performance Indicator (KPI) annual data surveys.	BRMCA	In collaboration with MPA and SCF, BRMCA to review all questionnaires and data collection processes associated with the annual KPI data surveys (by 31 December 2015).
Promote appropriate use of recycled and secondary aggregates in ready-mixed concrete (or, where appropriate, in other construction applications) to reduce extraction of primary raw materials.	BRMCA, The Concrete Centre (TCC*)	BRMCA and TCC to provide an agreed factsheet as guidance for the promotion of best practice with use of recycled and secondary aggregates in ready-mixed concrete (by 31 December 2016). First draft by December 2014, final draft by December 2015. Promotion 2016.
Promote greater use of low CO_2 cements and combinations to save on embodied CO_2 in concrete.	BRMCA	BRMCA and member companies to make generic available information to customers on the embodied CO_2 of concretes (by 31 December 2016).

Proposed action	Lead	Deliverable action (and timescale)
Promote greater use of low CO_2 cements and combinations – to save on embodied CO_2 in concrete and substitute for mineral resource use.	TCC	Raise awareness among designers (through factsheets: 'This is Concrete') of circumstances where additions, such as fly ash and ground granulated blastfurnace slag (ggbs), can be included in concrete to optimise carbon and resource impacts and keep the advice up to date (factsheets by 31 December 2016).
Promote appropriate use of fly ash and ggbs to (i) save on embodied CO_2 in concrete, (ii) reduce extraction of raw materials and (iii) avoid the possibility of their going to landfill.	UK Quality Ash Association (UKQAA) and Cementitious Slag Makers Association (CSMA)	Raise awareness among designers through articles and case study exemplars illustrating opportunities for high volume additions of fly ash or ggbs in ready-mixed concretes. Publish at least 12 articles/exemplars by 31 December 2016 in magazines, journals and on CSMA and UKQAA websites.
Transport and logistics		
Transport of ready-mixed concrete represents a high proportion of total fuel use. To enable reduction of fuel consumption, an assessment of the availability of data and feasibility of data collection is required.	BRMCA and member companies	Establish availability of data from truck operators and propose metrics (likely to be proxy data such as distances). Report on feasibility of gathering and interpreting this data for benchmarking (by 31 December 2018).
Driver behaviour and training are believed to have a large impact on driving fuel efficiency. Continue to undertake driver training and promote fuel efficient driving techniques (as part of MPA initiative).	BRMCA and member companies	BRMCA and its member companies to continue to promote driver awareness and training in relation to fuel efficient driving techniques. Report on proportion of drivers who have received training (by 31 December 2016).
Initiate BRMCA-wide gathering of data on concrete deliveries and patterns of demand and assessment of results from study. In particular, consider if further data (e.g. wastage rates) is required and/or assess if generic customer guidance on ordering would be useful.	BRMCA and member companies	Issue BRMCA recommendations with respect to gathering additional data and/or the usefulness of any generic guidance on ordering ready-mixed concrete (by December 31 2016).
Design for use and reuse		
Develop a standardised, Building Information Modelling (BIM) compliant resource efficiency data set including how to incorporate the six key elements of Environmental Product Declaration (EPD) data.	BRMCA	BRMCA to promote the use of standard formats for resource efficiency BIM data (and, where appropriate, EPD data sets) through guidance notes to the membership (publish guidance notes by 31 December 2016).
Raise awareness among customers of extent of adoption of responsible sourcing by ready-mixed concrete producers. 90% of ready-mixed concrete producers have adopted responsible sourcing (BES 6001) but this is not widely recognised by customers. The benefits of responsible sourcing to customers (gaining BREEAM credits) are also not widely appreciated.	TCC	BRMCA to work with the Materials Task Group of the UK Contractors' Group (UKCG) to raise awareness of the wide adoption and benefits to customers of certified responsible sourcing by ready-mixed concrete producers (implement communication plan by 31 December 2016).

Proposed action	Lead	Deliverable action (and timescale)
For concrete to resist reinforcement corrosion and aggressive ground, the designer should check the performance of locally available concreting materials, as the limiting value concrete proportions may well exceed the strength classes indicated in BS 8500.	TCC	TCC to raise awareness and remind designers that the performance of locally available materials should be part of the design process by inclusion in the next revision of 'Specifying Sustainable Concrete' (by 31 December 2015).
There is evidence that designers commonly specify large volumes of ST concretes for kerb backing and other applications that have to be supplied by ready-mixed concrete companies. ST concretes have a high cementitious content and, if the concrete is supplied by a Quality Assured ready-mixed concrete company, a more resource efficient alternate designated mix concrete can be used.	TCC	TCC to raise awareness that this is an issue at the design stage by inclusion of text (targeted at designers) in the next revision of 'Specifying Sustainable Concrete' (by 31 December 2015).
The industry needs to guard against legacy issues that may restrict recycling of concrete. Maximise opportunities for appropriate recycling of crushed concrete by raising awareness of any new materials or practices that could adversely affect capacity to recycle ready-mixed concrete at end of life.	TCC	Raise awareness and promote best practice among designers (by updating the Sustainable Concrete Design Guide) on designs, materials and practices that could reduce ability to recycle ready-mixed concrete at end of life (update Design Guide by 31 December 2018).

Construction process

Reduce waste of timber from temporary formwork. There is a commonly held view that the complexity of formwork and fair face finishes leads to an increase in the amount and waste of temporary formwork (timber).	TCC	TCC to consult with formwork suppliers to gather evidence and benchmark data on the level of timber waste associated with formwork. Develop a communication plan to give evidence of, and develop, best practice for designers and concrete subcontractors (communication plan by 31 December 2016).
To deliver carbon reductions, assess the scope for reduction in emissions associated with transport, placement and other processes related to the movement and placement of concrete within construction sites (e.g. cranes, pumps, delivery delays).	UKCG	TCC and UKCG to establish a new working group within the framework of the SCF and establish and maintain on-going dialogue. Under this working group, UKCG (with TCC) will work with specialist trade contractors to identify issues where there is scope to deliver carbon reductions associated with site processes (with ready-mixed concrete) to develop actions to achieve best practice (agree action plan by 31 December 2018).
Reduce water use and risk of groundwater contamination by promoting best practice in the use of water for washout on site.	TCC	Raise awareness of existence of BRMCA good practice sheet on water use/washout to TCC and UKCG working group for dissemination to specialist contractors (complete dissemination to specialist contractors by 31 December 2016).

Proposed action	Lead	Deliverable action (and timescale)
Reduce water use and risk of groundwater contamination on site by evaluating opportunities for improving practice in the use of water for washout on site to minimise water use.	TCC	TCC to establish a new working group with UKCG within the framework of the SCF and develop an agreed cross-industry solution (with buy-in from the Environment Agency). The solution will address issues such as the costs, practicalities and benefits of different methods of handling wash-down water on site, legislative (waste) issues and how any given method should be paid for (agreed solution by 31 December 2018).
Reduce total waste by identifying causes of waste associated with ordering practices for ready-mixed concrete on site and develop strategies to achieve reduction.	UKCG	TCC and UKCG to establish a new working group within the framework of the SCF and establish and maintain on-going dialogue. Under this working group, UKCG (with TCC) will work with its specialist trade contractors to gather data, estimate volumes of ready-mixed concrete ordered, analyse data, identify causes of wastage (if any) and develop an action plan (by 31 December 2018).

Demolition

Maximise opportunities for appropriate recycling of crushed concrete by looking out for any new materials or practices that could adversely affect capacity to recycle ready-mixed concrete at end of life. There is a need for the ready-mixed concrete sector to work with the National Federation of Demolition Contractors (NFDC) in the development and updating of Demolition Refurbishment Information Data Sheets (DRIDS).	TCC	Raise awareness among demolition contractors by providing on-going comments and dialogue (in collaboration with the precast concrete sector) with NFDC on new issues and practices that could affect concrete at end of life, suitable for revision and improvement of DRIDS (on-going contributions to revisions of DRIDS by 31 December 2016).
Raise awareness of opportunities and circumstances under which foundations and concrete frame can be beneficially reused (in resource efficiency terms).	TCC	Continue to gather exemplars of the reuse of ready-mixed concrete structural frames and foundations and publish as best practice case studies, one per year (2014, 2015 and 2016) to 31 December 2016. The Materials Task Group of UKCG has offered its active involvement.

Note: TCC is an industry-recognised abbreviation for the Concrete Centre.

Contents

1. Introduction

This Resource Efficiency Action Plan (REAP) has been created by the Sustainable Concrete Forum, in partnership with WRAP, BRE, the British Ready-Mixed Concrete Association (BRMCA), the REAP Brick, concrete block and Precast concrete groups and engagement with their stakeholders. This sector is aware of the growing concern for reducing waste and making more efficient use of resources, which had been highlighted by the pan-Concrete Industry Sustainable Construction Strategy[5]. The REAP will enable the ready-mixed concrete sector to deliver improved resource efficiency across the sector's supply chain. It will also help the sector to deliver KPI targets and objectives for 2020 within the envelope created by the Concrete Industry Sustainable Strategy, Cement Industry Carbon Strategy[6] and Green Construction Board's Low Carbon Routemap[7]. In the context of this action plan, resource efficiency covers the following headline areas:

- Materials
- Carbon emissions
- Water
- Waste
- Biodiversity.

Ready-mixed concrete is a factory produced construction material, locally supplied and transported as a flowable material ready for placing and compacting into any desired shape and size on construction sites. Greater resource efficiency within the concrete sector (including ready-mixed concrete) is an ongoing commitment entered into by the Concrete Industry Strategy (first published in 2008 and updated to cover the period to 2020 and beyond). The commitments within the strategy are now being realised by the ready-mixed concrete sector with the publication of this REAP.

The ready-mixed concrete industry has already made great strides in resource efficiency, as covered in the annual performance report[8]. As a construction material, ready-mixed concrete has some inherent advantages:

- Concrete is supplied by volume where the exact amount of concrete required can be ordered. Most ready-mixed concrete includes by-products of other industries such as fly ash from coal-fired power stations or ground granulated blastfurnace slag (ggbs) from iron and steel manufacture. Both reduce embodied carbon and divert potential waste from the waste stream.
- Thermal mass properties. When used appropriately in UK buildings, concrete reduces the need for both heating and cooling (e.g. air conditioning) and so saves energy and CO_2 emissions (see Figure 1)[9].

[5] Concrete Industry Sustainable Strategy (Concrete Centre – Mineral Products Association) http://www.concretecentre.com/sustainability/sustainable_strategy.aspx
[6] Cement Industry Carbon 2050 Strategy (Mineral Products Association) http://cement.mineralproducts.org/current_issues/climate_change/carbon_strategy.php
[7] Green Construction Board – Low Carbon Routemap for the Built Environment http://www.greenconstructionboard.org/index.php/resources/routemap
[8] Concrete Sector Annual Performance Report, 6th Report: 2012 performance data http://www.concretecentre.com/online_services/publication_library/publication_details.aspx?PublicationId=801
[9] Reproduced from: Thermal Mass Explained – The Concrete Centre 'http://www.concretecentre.com/online_services/publication_library/publication_details.aspx?PublicationId=781

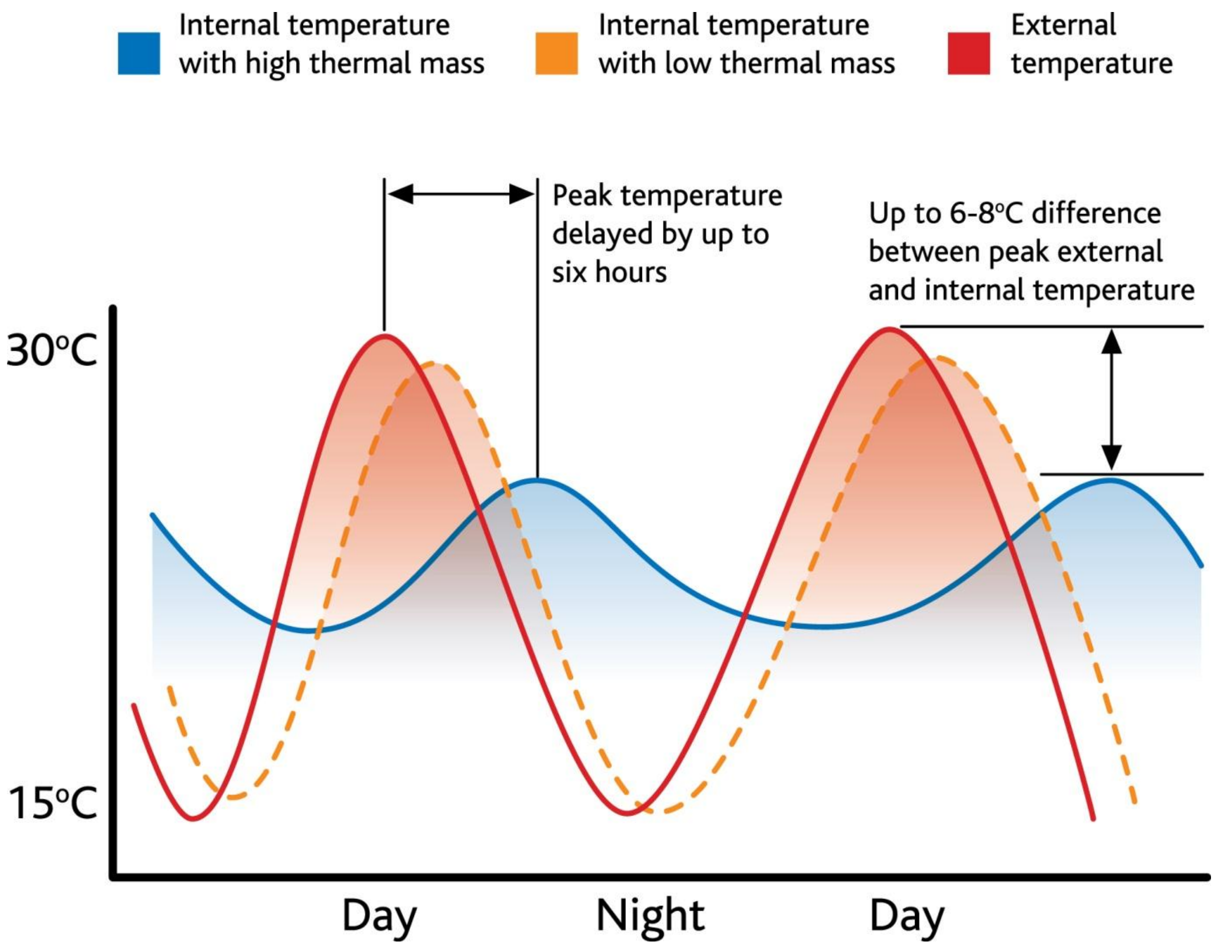


Figure 1: The stabilising effect of thermal mass on temperature (*reproduced from Thermal Mass Explained – The Concrete Centre*[9])

- Ready-mixed concrete is locally supplied. The average delivery distance from the production site to the construction site is 12km and thus the environmental impact as a result of delivery is small.
- Packaging is not needed for ready-mixed concrete (it is therefore not addressed in this REAP).

Notwithstanding these inherent advantages, the ready-mixed concrete industry is committed to both continuous improvement and holding a leadership role in sustainable construction solutions. The SCF and BRMCA are grateful for the support and input from its stakeholders, BRE and WRAP, in the compilation of this REAP.

As to the aspirations of the ready-mixed concrete sector over the coming decades, the linear ''take, make, dispose'' model, which relies on large quantities of easily accessible resources and energy, is being critically reassessed by the UK Government and others. Current activity towards a closed loop circular economy[11] where materials and components are recycled within industrial economies with minimal loss in quality are suitable for concrete. Ready-mixed concrete contributes to the circular economy over the long term from cradle to grave and rebirth, when crushed and incorporated as construction aggregates at end of life.

[11] http://www.greatrecovery.org.uk/

Product durability allows for use over the long term, thus delaying the end of life scenario and halving the carbon footprint of the building at each reuse. The resources used by the sector (water, limestone, clay and aggregates) are relatively abundant and responsibly sourced, with over 90% of BRMCA concrete accredited to the responsibly sourcing standard BES 6001.

2. Scope of the REAP

The REAP is aimed at assisting and supporting the wider construction industry, especially the organisations involved with the specification, procurement, manufacture, distribution, installation, maintenance and deconstruction of ready-mixed concrete components. This will play a part in enabling the industry to make the best use of materials, water and energy over the whole lifecycle of built assets to minimise embodied and operational carbon. The aim is to:

- Minimise materials consumption and waste
- Minimise waste to landfill
- Reduce environmental impact (water and CO_2) in production and use
- Maximise reuse, recycling and recyclability
- Define these in terms of SMART actions and targets.

Lifecycle stages covered by the REAP

The REAP includes the whole lifecycle for ready-mixed concrete (from the environmental impacts of materials used to make the concrete, through the use of the structure during its life, to demolition and recycling/reclamation of the concrete). Any regulations and statutory requirements relevant to the REAP are referenced in the text where appropriate.

Supply chain included within the scope of the REAP

The REAP includes:

- UK ready-mixed concrete manufacture in permanent batching plants and site batching plants.
- The whole UK supply chain (from manufacturing, design for use and reuse to logistics, construction and demolition).

What's not included in the REAP

- Concrete produced by builders on small sites, where the materials are likely to be proportioned (batched) by volume.
- Packaging: there is no packaging supplied or associated with delivery of ready-mixed concrete to the construction site or with the main ingredients for the concrete (aggregates, cement, additions, bulk admixtures and water). There may be some packaging associated with some of the minor components used at the batching plant (some admixtures and fibres) but this is reusable or recycled.

Review period for the REAP

- The REAP and actions will be reviewed annually as part of the concrete sector's performance reporting activities. They are scheduled for a full review in 2020.

The REAP and carbon

The language and terminology surrounding carbon can be confusing. Terms commonly used include 'capital carbon', 'embodied carbon' and 'embedded carbon'. The glossary (Appendix 1) provides definitions. For the purposes of this plan, the figures referred to are embodied carbon, and emissions are referred to as such throughout.

Embodied carbon is the carbon dioxide emitted at all stages of a manufacturing process, from the mining of the raw materials, through the distribution process, to the final product provided to the user. Depending on the calculation, the term can also be used to include other greenhouse gases. SCF Benchmarks relate to CO_2 emissions ($kgCO_2$/tonne of product) rather than greenhouse gas emissions (CO_2e or CO_2 equivalent).

3. Background to the ready-mixed concrete industry

The UK ready-mixed concrete industry (represented by BRMCA members) produced around 14.2 million cubic metres of concrete from just over 800 ready-mixed concrete plants in 2012[12]. Ready-mixed concrete can actually be considered as a 'family' of products with a wide range of engineering performance from relatively low strength concrete to high performance concrete for heavily loaded columns or elements exposed to aggressive environments.

The materials used in the manufacture of ready-mixed concrete are:

- Aggregates (coarse crushed rock or gravel aggregate and sand)
- Cement, including combinations of Portland cement and additions such as ggbs (from iron and steel manufacture) or fly ash from coal-fired power stations
- Water
- Chemical admixtures, such as water-reducing, plasticising, air entrainment agents and viscosity modifying products
- Polymer or steel fibres to give specific properties.

The proportions and type of materials used in individual concrete mixtures depend on the end use and performance required of the concrete. Non-optimal specification (for example, using more cement in the concrete mixture than its hardened performance requires) can unnecessarily increase the environmental impact of the concrete.

A large proportion of ready-mixed concrete is placed within formwork to achieve a required shape or 'form'. Consideration of the materials used for the formwork and the way they are specified/used (reused)/designed is required to minimise waste to landfill at end of life. Formwork may be permanent (left in place within the structure) or temporary. Where concrete is placed against ground, there is a benefit in removing the need for formwork but this may require additional concrete to fill dug excavations. Concrete may either be unreinforced or placed around reinforcement (i.e. embedded steel). Steel reinforcement has a high recycled content and is generally recycled at end of life.

Ready-mixed concrete is ideally suited for the construction process because it is available in large quantities and often at limited or short notice. For smaller volumes, almost no notice is required because the UK network of ready-mixed concrete suppliers can meet a full range of concrete performance requirements. Where larger volumes are required with a guarantee of no break in supply, the ready-mixed concrete suppliers can allocate back-up plants and call in extra ready-mixed concrete trucks to cover peaks in high demand. Ready-mixed concrete is used most appropriately for on-site casting of large volumes of concrete, particularly where placement is possible directly from the truck or through a concrete pump. It is less efficiently used for small volumes of concrete, particularly where it is transported on site by wheelbarrows or small skips and dumpers. Ready-mixed concrete is largely supplied with third party product conformity certification, which is essential to the use of the materials-efficient range of designated concretes (see Appendix 1) and gives the contractor his assurance of minimum strength and other specified requirements.

[12] Ready-mixed concrete statistics: 2012 ERMCO (European Ready-Mixed Concrete Association), 2013, p20.

4. The ready-mixed concrete supply chain

Figure 2 illustrates the main features of the supply chain for ready-mixed concrete. The manufacturing process, transport, placement on site and product lifecycle are shown in more detail in Appendix A4. These schematic diagrams collectively outline the primary routes to market for ready-mixed concrete and where some of the resource efficiency opportunities lie.

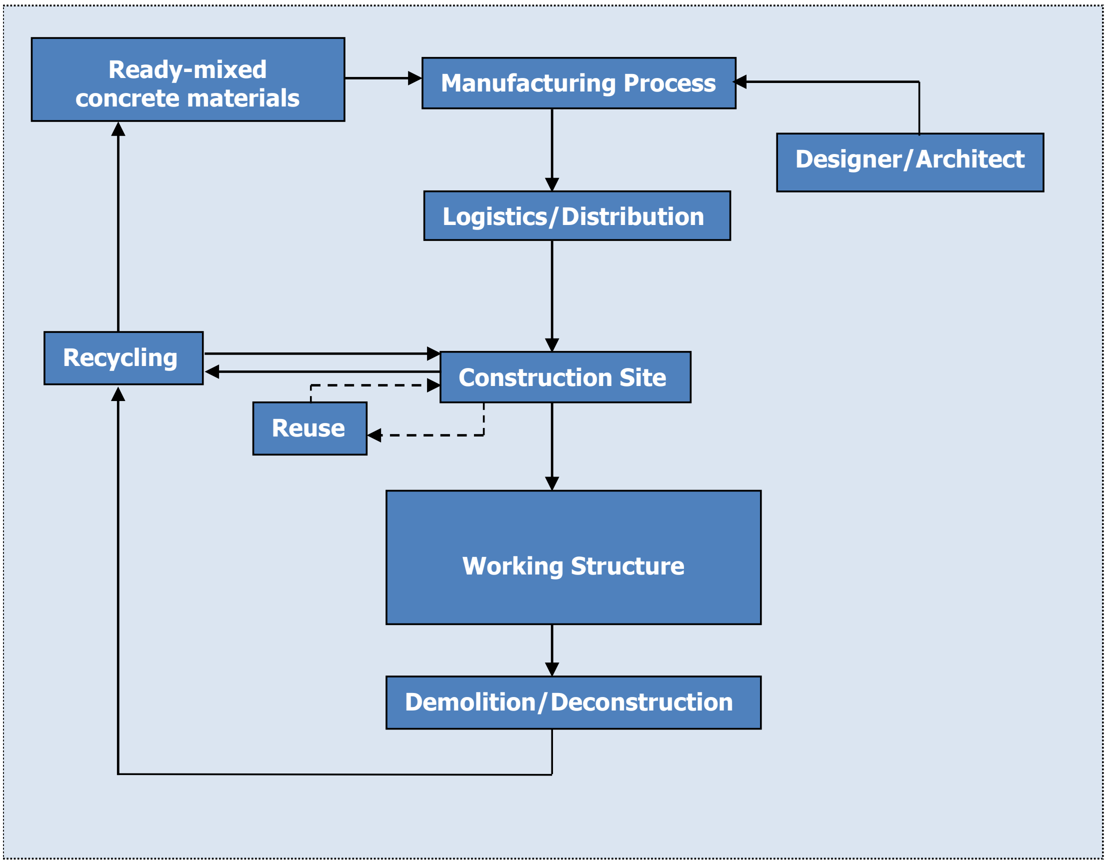


Figure 2: Schematic of the supply chain for ready-mixed concrete products

5. Resource efficiency challenges facing the ready-mixed concrete industry in the UK

The REAP stakeholder group identified a number of resource efficiency challenges faced by the ready-mixed concrete sector. Several have also been targeted by the stakeholder groups producing the REAPs for precast concrete and for clay bricks and clay blocks, and they are also highlighted in documents such as the Low Carbon Routemap[13]. The main top-level resource efficiency issues and challenges faced by the sector are summarised in Box 1. Table 1 further divides and groups these main issues and challenges by supply chain or lifecycle stage.

Box 1: Summary of main impacts/resource efficiency challenges of the ready-mixed concrete sector in the UK (including its supply chain)

- Reducing and optimising embodied CO_2 (referred to as 'capital carbon' in Low Carbon Routemap)
- Reducing and optimising water use
- Minimising wastage
- Reducing energy use (in manufacture and transport)
- Material efficiency in design/specification
- End of life – encouraging reclamation/reuse

Table 1: The main issues and challenges facing the ready-mixed concrete sector and its supply chain

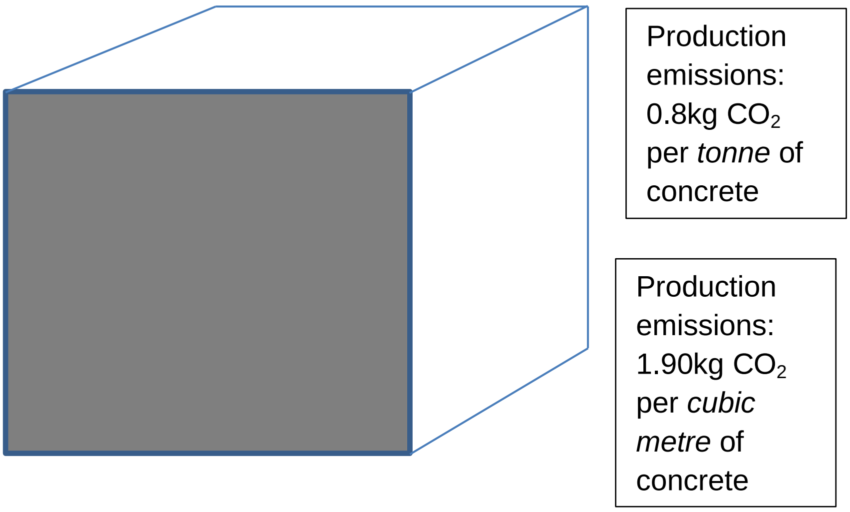
Supply chain stage	Issues
Manufacturing of concrete	• Energy and associated emissions • Waste • Water usage • Raw materials – binders • Raw materials – aggregates • Definition of metrics and availability of data (e.g. production water and energy) • Communication of the high level of adoption of responsible sourcing by ready-mixed concrete producers and limited awareness of this among clients
Logistics and packaging	• Timing of deliveries • Demand smoothing
Design for use and reuse	• Material efficiency in design • Flexible design to envisage reuse of core structure for refurbishment • Over-specification or non-optimal specification of concrete (e.g. standard prescribed concrete)

[13] Low Carbon Routemap http://www.greenconstructionboard.org/index.php/resources/routemap

Supply chain stage	Issues
Construction	• Methods of work (workmanship) • Over-ordering
Demolition	Improving resource efficiency at end of life through the Demolition and Refurbishment Information data sheet (DRIDS) system from the National Federation of Demolition Contractors and measures such as: • Appropriate reuse of foundations or structural frame • Processing into recycled aggregates – maximising value • Minimising inappropriate low value uses/downcycling

6. Resource efficiency impact indicators for the ready-mixed concrete sector in the UK

Since the publication of Environmental Product Declaration standard BS EN 15804 2012[14], there has been a European level standardised assessment methodology for the measurement of resource efficiency and environmental impact indicators for construction products. Where possible, the resource efficiency indicators and principles of BS EN 15804 have been used in identifying relevant factors in assessing the resource efficiency and measurement methodologies adopted in this REAP, specifically in respect of the development of targets and progress towards them. Many of the necessary metrics for the REAP are already within the Concrete Industry Sustainability Performance Report[15]. Current metrics and benchmarks for the ready-mixed concrete sector are given in Table 2. KPIs for production emissions are typically reported as kg of CO_2 per tonne of concrete. However, embodied CO_2 from production, expressed per cubic metre of concrete (based on a concrete density of 2,380 kg/m^3), are also included in Table 2 and Figure 3. The embodied carbon of the raw materials is not included in these metrics.



1 cubic metre of concrete:

- Kg CO_2/tonne from production of concrete (using current emission factors): 0.8
- Kg CO_2/cubic metre from production of concrete (using current emission factors): 1.90
- Weight (1 cubic metre): 2.38 tonnes
- Volume: 1,000 litres
- Density: 2,380 kg/m^3

Figure 3: Schematic illustrating weight, density and embodied CO_2 associated with production of one cubic metre of ready-mixed concrete *(based on 2012 industry data)*

[14] BS EN 15804: 2012 Sustainability of construction works, Environmental product declarations, Core rules for the product category of construction products, BSI.
[15] Concrete Sector Annual Performance Report, 6th Report: 2012 performance data http://www.concretecentre.com/online_services/publication_library/publication_details.aspx?PublicationId=801

Throughout the supply chain, the principal resource impact areas fall within the following:

- **Materials** – cements, additions, aggregates, water and admixtures being used in the manufacturing process (including recycled materials).
- **Carbon (energy and carbon emissions)** – including both direct and indirect energy consumption associated with the manufacture, transportation and installation and demolition of ready-mixed concrete, including natural gas, electricity and other fuel oils and gas.
- **Water** – consumption of water, either through utilisation of mains water or via abstraction from lagoons or boreholes on site as well as collected rainwater. Water in the manufacturing process (embodied water in the concrete) and water for washing out (at the plant or at the point of delivery) are also included.
- **Waste** – waste generation either through the manufacturing process or during site processes. The sector needs to identify and measure sources of wastage of concrete, which could be associated with incorrect order and delivery or waste recovered and recycled through recycling schemes (surplus concrete returned to plant). Based on UK Government statistics, waste to landfill is minimal[16].
- **Biodiversity** – mineral workings, including quarries, lagoons and decommissioned production facilities can provide the opportunity to develop and enhance the biodiversity of a site following its restoration. Such actions are typically identified within the restoration plans for all the mineral industries' extractive and production operations. Conserving the UK's biodiversity is an essential requirement for sustainable development. Stakeholders expect the ready-mixed concrete sector to reflect this in the way it carries out its business. At the same time, industry increasingly recognises the importance of its role in conserving biodiversity, with the mineral industries being among the leaders in demonstrating how it can be done through the implementation of Biodiversity Action Plans (BAPs). The most exciting opportunities lie in quarry management and restoration, where there is great scope to recreate habitats and encourage species that were once more common in the wider countryside and are targeted in the UK BAP. Built environment assessment schemes such as BREEAM[17] and CEEQUAL[18] are also helping to raise awareness of biodiversity with clients, architects and contractors and ensure that opportunities are taken to integrate biodiversity into the built environment. Biodiversity is a developing area, in particular with the work being done on ecosystem services, which assign a financial benefit to natural resources, and on future opportunities for a biodiversity credit scheme, where the impacts of development are offset at another location.

Table 2: Average ready-mixed concrete industry resource efficiency indicators *(UK averages unless otherwise stated*)

		2008	2009	2010	2011	2012
Energy	KWh/tonne concrete	**1.7**	**1.7**	**2.5**	**2.5**	2.0
Production emissions (*see Note 1*)	Kg CO_2/tonne concrete using current conversion factors	**1.0**	**0.9**	**1.1**	**1.1**	0.8
	Kg CO_2/cubic metre of concrete using density of 2,380 kg/m^3	*2.38*	*2.14*	*2.62*	*2.62*	*1.90*

[16] Review of the factors causing waste soil to be sent to landfill, 2007 to 2011, CIS101-301, WRAP, 2013 http://www.wrap.org.uk/sites/files/wrap/CIS101-301%20Final%20Report%20final%2017%20april%2013.pdf
[17] BREEAM http://www.breeam.org/
[18] CEEQUAL http://www.ceequal.com/

		2008	2009	2010	2011	2012
Binder	Tonnes of all cementitious content/tonne of product	135	127	132	135	137
	Fly ash/ggbs etc. substitute (% of total cementitious material)	**34.1**	**30.8**	**28.6**	**33.0**	32.6
Aggregate	Tonnes of all aggregate/tonne of concrete produced	814	803	795	789	802
	Recycled + secondary aggregate (% of total aggregate used)	**0.3**	**0.4**	**1.4**	**0.8**	0.2
Water	Litres total water/tonne of product	63.2	75.0	73.3	76.2	74.5
	Litres mains water/tonne of product	**63.0**	**75.0**	**65.4**	**64.4**	62.8
	Litres controlled groundwater/tonne of product	0.2	0.0	7.9	11.8	11.7
Waste	Waste to landfill (kg/tonne of product)	**2.28**	**2.28**	**0.93**	**0.84**	0.44
Delivery	Average truck load (tonnes of product delivered)	n/a	12.4	13.1	14.8	14.0
(see Note 1)	Average delivery distance by road (km/delivery)	n/a	11.5	10.5	10.0	12.0
	Transport CO_2 emissions (kg/tonne concrete)	**n/a**	1.41	1.24	1.05	1.29
Environmental Management Systems	Production sites covered by a UKAS certified EMS (%)	**68**	**80**	**86**	**89**	91
Responsible sourcing	Production certified to BES 6001 Responsible Sourcing Standard (%)	**n/a**	**87.1**	**93.9**	**95.9**	95.1

Data sources in Table 2:

Bold values	Disaggregated ready-mixed concrete data from annual SCF data collection, 2008-2011, November 2012 (unpublished).
Normal values	From 2008-2012 concrete industry data collation sheets.
Italic values	Calculated from kg CO_2/tonne KPI figures based on average concrete density of 2,380 kg/m^3.

Note 1: Production emissions are CO_2 emissions derived from concrete production (mixers, silos, aggregate handling etc.). All the figures for carbon (energy and carbon emissions) in Table 2 exclude embodied CO_2 of the constituents because these are outside the control of the ready-mixed concrete industry. The embodied values are orders of magnitude higher than processing and transport values and their inclusion would make it impractical to monitor effectively and hence reduce carbon emissions from processing and delivery.

7. A Resource efficiency action plan for ready-mixed concrete

The primary aim of this action plan is to identify, clarify and define actions that will improve the resource efficiency of the activities involved with the specification, procurement, manufacture, distribution, installation, maintenance and deconstruction of ready-mixed concrete products. The plan was developed and created in association with the Clay Bricks and clay blocks and Precast Concrete REAP's to ensure that this REAP aligned with these plans and with the overall concrete industry strategy.

This REAP brought together contributors and stakeholders representing the entire supply chain and end users including manufacturers, materials producers, demolition contractors and construction. The full list of contributors and stakeholders are listed in Appendix 2.

The actions within the REAP have, where possible, been developed to be SMART (Specific, Measurable, Achievable, Realistic, Time-bound) to enable periodic review and refinement of performance against the actions. Each action has a clearly defined industry lead. The approach has allowed the actions to be developed and managed with clear ownership and meaningful outcomes.

This report is part of a larger industry series of resource efficiency initiatives in the construction industry providing an envelope for the development of the REAP are the Concrete Industry Strategy, Cement Industry Carbon Strategy and Green Construction Board's Low Carbon Routemap.

7.1 Manufacture of concrete

Within the manufacturing process and supply of raw materials into the manufacturing process, the main focus on resource efficiency was associated with the use of the physical resources, energy, materials, water, reducing the (limited) amount of waste generated as a result of the manufacturing process and collecting data on the volumes of different concrete types supplied into the market.

- **Energy (and associated carbon emissions)** – Energy consumption in ready-mixed concrete plants is associated with the movement and conveyance of raw materials (diesel fuel and electrical energy) and mixing of the concrete. Data needs to be collected and consideration given to how to drive down energy usage within the sector and development of targets as part of overall concrete industry strategy and KPIs.
- **Packaging and waste** – There is very limited waste of concrete per se generated at the manufacturing stage, with surplus fresh and hardened concrete being recycled. Surplus concrete may be returned from the construction site to the manufacturing site but there is a need to collect data and develop targets for reduction. Ready-mixed concrete does not require packaging. Admixtures and additions are mainly delivered in reusable containers.
- **Water** – There is a need for a better understanding of water use in the sector and ultimately to reduce mains water use. System boundaries and metrics relating to water are being defined by the Mineral Products Association Water Group. They will report on an industry-wide basis on water consumption (from mains and other sources) and develop performance indicators.
- **Cement and additions** – There is a general awareness of the utilisation of additions such as fly ash and ggbs in combination with Portland cement and their broad benefits to resource efficiency in terms of reduced embodied carbon, diversion of materials from landfill and reduced extraction of primary materials, as well as their other technical benefits (including opportunities for application in high volume uses). Portland limestone cements (PLC) are used in ready-mixed concrete and are within the scope of the REAP. There is a role for such cements to help further reduce the embodied CO_2 in concrete mixes.

Also, there is a need to gain a better understanding of the volume of standardised prescribed concrete supplied and (if appropriate) to identify opportunities to encourage the use of more resource efficient designated concretes.

- **Raw materials: aggregates** – Recycled and secondary aggregates can be used (under controlled conditions and with care) in the manufacture of ready-mixed concrete, and best practice guidance exists for their use. However, under many circumstances, other end uses (e.g. as unbound materials) may provide more resource efficient construction solutions. Better promotion and awareness raising of best practice and the most resource efficient circumstances for their use in ready-mixed concrete is required.
- **Data** – Refinement of the way data is requested and guidance given in order to maximise the accuracy of annual data collected for the KPIs would be beneficial. This data refinement will be used in the development of targets for 2020, based on the analysis of the 2007-2011 results.

Table 3: Actions identified relating to the supply of raw materials and the manufacturing process for ready-mixed concrete

Proposed action	Lead	Deliverable action (and timescale)
Standardised prescribed (ST) concretes have higher cementitious content than equivalent designated mix concrete and hence higher embodied CO_2. BRMCA to gather data on the percentage of ST concrete supplied. The volume of ST concretes currently supplied to the market requires investigation.	BRMCA	Conduct survey to assess volumes of ST concrete supplied by ready-mixed concrete companies (complete survey by 31 December 2015).
Collection of data on total waste associated with manufacturing. Ready-mixed concrete does not go to landfill but, nevertheless, wasted material goes back to the plant and is reworked or reused on site. There is a need to collect data, develop targets and promote best practice to achieve reduction in the amount of this total waste associated with the manufacture of ready-mixed concrete.	BRMCA	Review resource wastage from reworking and reuse of concrete. Collect waste data and subsets of metrics and develop target of total waste from manufacturing of ready-mixed concrete (by 31 December 2016).
Establish metrics against which to measure reduction in the use of water (mains and permitted groundwater) in the manufacture of ready-mixed concrete	BRMCA with Mineral Products Association (MPA) Water Group	BRMCA to continue to participate in the development of, and adopt the agreed sector water strategy for, manufacturing and associated guidance notes on best practice (completed strategy by 31 December 2016).
Review all questionnaires and guidance in respect of the data capture in association with Key Performance Indicator (KPI) annual data surveys.	BRMCA	In collaboration with MPA and SCF, BRMCA to review all questionnaires and data collection processes associated with the annual KPI data surveys (by 31 December 2015).

Proposed action	Lead	Deliverable action (and timescale)
Promote appropriate use of recycled and secondary aggregates in ready-mixed concrete (or, where appropriate, in other construction applications) to reduce extraction of primary raw materials.	BRMCA and The Concrete Centre (TCC)	BRMCA and TCC to provide an agreed factsheet as guidance for the promotion of best practice with use of recycled and secondary aggregates in ready-mixed concrete (by 31 December 2016). First draft December 2014, final draft Dec 2015. Promotion 2016.
Promote greater use of low CO_2 cements and combinations to save on embodied CO2 in concrete.	BRMCA	BRMCA and member companies to make generic available information to customers on the embodied CO_2 of concretes (by 31 December 2016).
Promote greater use of low CO_2 cements and combinations – to save on embodied CO_2 in concrete and substitute for mineral resource use.	TCC	Raise awareness among designers (through factsheets: 'This is Concrete') of circumstances where additions, such as fly ash or ground granulated blastfurnace slag (ggbs), can be included in concrete to optimise carbon and resource impacts and keep the advice up to date (factsheets by 31 December 2016).
Promote appropriate use of fly ash and ggbs to (i) save on embodied CO_2 in concrete, (ii) reduce extraction of raw materials and (iii) avoid the possibility of their going to landfill.	UK Quality Ash Association (UKQAA) and Cementitious Slag Makers Association (CSMA)	Raise awareness among designers through articles and case study exemplars illustrating opportunities for high volume additions of fly ash or ggbs in ready-mixed concretes. Publish at least 12 articles/exemplars by 31 December 2016 in magazines, journals and on CSMA and UKQAA websites.

7.2 Transport and logistics

- **Ordering/scheduling and transport/deliveries of concrete** – The stakeholder group has identified a potential role of programming and demand smoothing to improve resource efficiency. A particular challenge is presented by the typical pattern of demand, where concrete placement tends to be scheduled towards either a Wednesday or Thursday of each working week. For resource efficiency (potentially less idling time, fuel consumption and reduced waste), it is preferable to programme concrete placing for periods of least average demand. The potential benefits include improved customer service and a reduction in idle time (for trucks), resulting in savings in site operating costs and energy consumption. The actions are to gather data and to assess the potential impacts of changes in demand on resource efficiency (fuel, waste and carbon). The use of Building Information Modelling (BIM) with the latest generation of building design software is aimed at better development of a bill of quantities. Better communication within the supply chain and use of tools such as BIM are expected to improve the proportion of deliveries on time/on spec and reduce over-ordering etc. (BIM is also included in the sections of the REAP on design for use and reuse below.)
- **Driver awareness/training** – Although MPA implements driver training programmes, there are perceived to be significant benefits in continuing and enhancing driver awareness and training in order to optimise fuel efficiencies. The actions are to continue to promote best practice and to establish the availability of data from third party operators to set benchmarks.

There are no specific actions relating to safety, health and well-being in the REAP, but the sector will continue actively to support the activities of the MPA Cycle Safe Campaign and strategy (launched in 2011), which seeks to prevent collisions between cyclists and lorries.

Table 4: Actions identified relating to the transport of ready-mixed concrete

Proposed action	Lead	Deliverable action (and timescale)
Transport of ready-mixed concrete represents a high proportion of total fuel use. To enable reduction of fuel consumption, an assessment of the availability of data and feasibility of data collection is required.	BRMCA and member companies	Establish availability of data from truck operators and propose metrics (likely to be proxy data such as distances). Report on feasibility of gathering and interpreting this data for benchmarking (by 31 December 2018).
Driver behaviour and training are believed to have a large impact on driving fuel efficiency. Continue to undertake driver training and promote fuel efficient driving techniques (as part of MPA initiative).	BRMCA and member companies	BRMCA and its member companies to continue to promote driver awareness and training in relation to fuel efficient driving techniques. Report on proportion of drivers who have received training (by 31 December 2016).
Initiate BRMCA-wide gathering of data on concrete deliveries and patterns of demand and assessment of results from study. In particular, consider if further data (e.g. wastage rates) is required and/or assess if generic customer guidance on ordering would be useful.	BRMCA and member companies	Issue BRMCA recommendations with respect to gathering additional data and/or the usefulness of any generic guidance on ordering ready-mixed concrete (by December 31 2016).

7.3 Design for Use and Reuse

The stakeholder group includes representatives of the interests of designers of buildings and structures and specifiers of concrete. It is recognised that this segment of the supply chain can have a significant influence, not only on the decision-making process to use ready-mixed concrete but also in optimising the specification of performance and strength and the environmental credentials of the concrete. It can also affect the ease with which the concrete is reused, reclaimed or recycled. Design[19] can also have a bearing on the amount of formwork (timber) waste generated during the construction process.

Specification of concrete

- **Specifying concrete quality** – An important aspect of ensuring resource efficiency is that the concrete supplied is as specified. For this reason, there should be a requirement for the concrete supplier to have product conformity certification, either from the Quality Scheme for Ready-Mixed Concrete (QSRMC) or, as an equivalent, the BSI Kitemark Scheme. Membership of the QSRMC or equivalent is mandatory for BRMCA members, and the BRMCA will continue to seek to maintain the membership level at 100%.

- **Optimum strength and materials efficiency** – The performance of concrete is a function of both the strength and durability of the concrete. Optimisation of strength, durability and materials resources must take into account factors including criteria for the performance of concrete over its intended design life. The relationship and structural interaction with adjacent construction elements are also important to achieve an efficient structure. In addition, the use of materials resource per structure may not be the most significant factor if the design increases the functionality and social value, such as the lettable area[20].

[19] http://www.wrap.org.uk/content/designing-out-waste-design-team-guide-buildings-0
[20] The Concrete Centre, Concrete Structure 7, Commercial savings 2007, p4-5.

Guidance on materials efficiency is already available from The Concrete Centre document entitled 'Material efficiency'[21]. This document sets out material resource and waste issues of using concrete at different stages including design. It provides guidance to designers and specifiers on optimising performance. The Low Carbon Routemap also refers to the scope for more material efficient designs and proposes metrics and indicators.

There are several new actions in the REAP to raise awareness of approaches to reduce embodied CO_2 in each cubic metre of concrete and concrete elements. The British Standard for concrete (BS 8500) can be applied to optimise concrete mixtures for resource efficiency by:

a) Assessing the actual performance of the locally available materials in concrete manufacture and utilising the findings to develop or modify the design of the structure to save on the volume of concrete used.
b) Appropriate use of designated concrete instead of standardised prescribed concretes to save on embodied carbon in each cubic metre of concrete.

- **Responsible sourcing** – 90% of ready-mixed concrete producers have adopted responsible sourcing (BES 6001) but this is not widely recognised by customers. The benefits of responsible sourcing to customers (gaining BREEAM credits) are not widely appreciated by designers and specifiers.

- **Building Information Modelling (BIM)** – The use of BIM with the latest generation of building design software is aimed at better development of a bill of quantities. BIM also allows for the inclusion of specific information relating to the environmental impact of the building materials in the database. There is therefore a need for the sector to provide data in a BIM compliant form with complete resource efficiency and Environmental Product Declaration (EPD) data sets. There are a number of routes to producing EPDs. The sector is moving towards a commitment to the provision of generic EPDs for ready-mixed concrete that enables integration of LCA/BIM etc.

- **Avoiding legacy issues** – There is a need to maximise opportunities for appropriate recycling of crushed concrete by raising awareness (through updating guidance) among designers of any new materials or practices which could adversely affect capacity to recycle ready-mixed concrete at end of life.

[21] The Concrete Centre, Material efficiency, 2010.

Table 5: Actions identified relating to the design for use and reuse of ready-mixed concrete

Proposed action	Lead	Deliverable action (and timescale)
Develop a standardised, BIM compliant resource efficiency data set including how to incorporate the six key elements of Environmental Product Declaration (EPD) data.	BRMCA	BRMCA to promote the use of standard formats for resource efficiency BIM data (and, where appropriate, EPD data sets) through guidance notes to the membership (publish guidance notes by 31 December 2016).
Raise awareness among customer base of extent of adoption of responsible sourcing by ready-mixed concrete producers. 90% of ready-mixed concrete producers have adopted responsible sourcing (BES 6001) but this is not widely recognised by customers. The benefits of responsible sourcing to customers (gaining BREEAM credits) are also not widely appreciated.	TCC	BRMCA to work with the Materials Task Group of the UK Contractors' Group (UKCG) to raise awareness of the wide adoption and benefits to customers of certified responsible sourcing by ready-mixed concrete producers (implement communication plan by 31 December 2016).
For concrete to resist reinforcement corrosion and aggressive ground, the designer should check the performance of locally available concreting materials because the limiting value concrete proportions may well exceed the strength classes indicated in BS 8500.	TCC	TCC to raise awareness and remind designers that the performance of locally available materials should be part of the design process by inclusion in the next revision of 'Specifying Sustainable Concrete'[22] (by 31 December 2015).
There is evidence that designers commonly specify large volumes of ST concretes for kerb backing and other applications that have to be supplied by ready-mixed concrete companies. ST concretes have a high cementitious content and, if the concrete is supplied by a Quality Assured Ready-Mixed Concrete company, a more resource efficient alternate designated mix concrete can be used.	TCC	TCC to raise awareness that this is an issue at the design stage by inclusion of text (targeted at designers) in the next revision of 'Specifying Sustainable Concrete' (by 31 December 2015).
The industry needs to guard against legacy issues that may restrict recycling of concrete. Maximise opportunities for appropriate recycling of crushed concrete by raising awareness of any new materials or practices that could adversely affect capacity to recycle ready-mixed concrete at end of life.	TCC	Raise awareness and promote best practice among designers (through updating the Sustainable Concrete Design Guide) on designs, materials and practices that could reduce ability to recycle ready-mixed concrete at end of life (update Design Guide by 31 December 2018).

[22] The Concrete Centre, Specifying Sustainable Concrete, 2011
http://www.concretecentre.com/online_services/publication_library/publication_details.aspx?PublicationId=758

7.4 Construction

The stakeholder group includes representatives of contractors. Their primary interest relates to the construction process itself and thus entails a significant amount of co-ordination of both materials and human resources. Since 2008, site waste management has improved significantly. However, as a result of the development of this REAP, several outstanding issues relating to waste generation were identified as requiring more development:

Waste (concrete and formwork) – Waste/surplus fresh or hardened concrete is generally returned to the plant for reintroduction into the production process. However, there is a need to develop a better awareness of the actual value of the raw materials and of how site management and best practice can be used to minimise wastage of materials on site. Temporary concrete formwork is a significant source of (timber) waste on construction sites. The complexity of design detailing of the concrete may affect the potential to reuse formwork multiple times on site (for example, if there are a large number of custom formwork shapes for a complicated structure). Falsework (which supports the temporary formwork) is generally reused. There are actions in the REAP for the Concrete Centre to consult with formwork suppliers to gather evidence on the amount and causes of waste.

Some forms of non-traditional permanent formwork can affect the demolition process by causing logistical issues with segregation at end of life. Mitigation needs to be considered at the design stage and there is a need to enhance awareness among designers of the potential influence of formwork type on waste.

Site processes and methods of work (workmanship) – There may be scope for carbon reduction of processes associated with the placement and compaction of concrete, which will be assessed through a joint Concrete Centre/UKCG Working Group. The REAP stakeholder group itself did not develop any actions regarding issues such as workmanship, logistics on site, ordering lower slump concrete than required, the uncontrolled addition of water on site, inadequate compaction and poor curing, which are covered by up-to-date guidance and are a matter of continuing to encourage best practice.

Wash water – Current practice is to wash out the chutes on delivery trucks and ancillary equipment at the delivery site following discharge of the concrete. Guidance on best practice with water use and discharge on site is already provided in an MPA/BRMCA good practice sheet[23]. Clients and suppliers are considering alternative means for collecting and recovering wash water (e.g. self-contained tanks), although there are issues associated with waste transfer licences, ownership of the waste and cost. More analysis into the costs and benefits of different methods of handling wash-down water on site is required, and it was agreed that a working group under the auspices of the Concrete Forum would be established to develop a robust, agreed cross-industry solution. Then best practice can be identified and encouraged through the industry.

Over-ordering of concrete – A major waste issue with ready-mixed concrete (for the contractor) is the practice of over-ordering concrete to ensure that a pour can be finished. This is even more significant when pouring ground floor slabs and foundations because of the undulating nature of the substrate, so the part load ordered at the end of a pour will always need to be a significant overestimate. One solution adopted currently is for concrete suppliers to take back part loads of concrete that are not used and reuse them at the batching plant. The most efficient solution could be to have a Plan B on the construction site to deal with over-ordering but the issue (and relevant metrics) needs to be developed and examined by an industry working group. The relevant metric is wastage (concrete) per/100 m^2 or £100,000 of cost.

[23] Managing concrete wash waters on site, BRMCA Best Practice Sheet: 31 October 2012.

Table 6: Actions identified relating to the construction process and use of ready-mixed concrete on construction sites

Proposed action	Lead	Deliverable action (and timescale)
Reduce waste of timber from temporary formwork. There is a commonly held view that the complexity of formwork and fair face finishes leads to an increase in the amount and waste of temporary formwork (timber).	TCC	TCC to consult with formwork suppliers to gather evidence and benchmark data on the level of timber waste associated with formwork. Develop a communication plan to give evidence of, and develop, best practice for designers and concrete subcontractors (communication plan by 31 December 2016).
To deliver carbon reductions, assess the scope for reduction in emissions associated with transport, placement and other processes related to movement and placement of concrete within construction sites (e.g. cranes, pumps, delivery delays).	UKCG	TCC and UKCG to establish a new working group within the framework of the Sustainable Concrete Forum (SCF) and establish and maintain on-going dialogue. Under this working group, UKCG (with TCC) will work with specialist trade contractors to identify issues where there is scope to deliver carbon reductions associated with site processes (with ready-mixed concrete) to develop actions to achieve best practice (agree action plan by 31 December 2018).
Reduce water use and risk of groundwater contamination by promoting best practice in the use of water for washout on site.	TCC	Raise awareness of existence of BRMCA good practice sheet on water use/washout to TCC and UKCG working group for dissemination to specialist contractors (complete dissemination to specialist contractors by 31 December 2016).
Reduce water use and risk of groundwater contamination on site by evaluating opportunities for improving practice in the use of water for washout on site to minimise water use.	TCC	TCC to establish a new working group with UKCG within the framework of the SCF and develop an agreed cross-industry solution (with buy-in from the Environment Agency). The solution will address issues such as the costs, practicalities and benefits of different methods of handling wash-down water on site, legislative (waste) issues and how any given method should be paid for (agreed solution by 31 December 2018).
Reduce total waste by identifying causes of waste associated with ordering practices for ready-mixed concrete on site and developing strategies to achieve reduction.	UKCG	TCC and UKCG to establish a new working group within the framework of the SCF and establish and maintain on-going dialogue. Under this working group, UKCG (with TCC) will work with its specialist trade contractors to gather data, estimate volumes of ready-mixed concrete ordered, analyse data, identify causes of wastage (if any) and develop an action plan (by 31 December 2018).

7.5 Demolition

The stakeholder group focused on maximising the opportunities for reuse of concrete foundations and frames, minimising the possibility of legacy issues associated with some materials and practices and continuing to promote best practice in the production and use of recycled and secondary aggregates.

Currently, many buildings are demolished (rather than deconstructed), resulting in end of life ready-mixed concrete ending up in construction, demolition and excavation waste, which is predominantly reprocessed and used as recycled aggregate. Some case studies[24] indicate that the potential for high levels of recovery of demolition arisings, in excess of 95%, include significant levels of concrete recovery. In such projects, little if any processed (crushed) concrete leaves site and goes to landfill. Material excess to a site's redevelopment is normally utilised on other sites, though typically as fill type, which reduces the use of virgin materials.

The current practice commonly applied to ready-mixed concrete at end of life is recycling of construction and demolition waste by processing and using as recycled aggregates or general fill materials.

The National Federation of Demolition Contractors has introduced the Demolition and Refurbishment Information Data Sheets (DRIDS) system. The DRIDS have been developed to provide the demolition industry with relevant knowledge and practicable information on the individual materials and products they manage, or will be required to manage, in the future: http://www.nfdc-drids.com/. The site also allows processors to indicate materials they are actively accepting for reuse, recovery or recycling at particular processing facilities/locations.

- **Recovery of ready-mixed concrete** – Concrete structures made from ready-mixed concrete can be well suited to refurbishment and reuse (as an entire structural frame – see below). In contrast to some types of precast concrete elements, there is, however, limited scope for the recovery and reuse of individual ready-mixed concrete elements because of the way cast in-situ concrete forms an integral part of a structure, generally with limited accessibility.

- **Reuse of foundations and structural frame** – This can be attractive, particularly in urban areas, where reuse of existing foundations can be logistically and commercially attractive (RUFUS project[25]). Strip-back of a building to the concrete frame for refurbishment may also be viable and yield a range of resources efficiency and business benefits. Exemplars/case studies and guidance are available[26,27] but more are needed.

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[24] ICE Demolition Protocol Case Study Brent W01 Development
http://www2.wrap.org.uk/downloads/WRAP_Case_Study_WO1_formatted_050307.512ccaf8.4654.pdf

[25] A P Butcher, J J M Powell and H D Skinner (editors), Reuse of foundations for urban sites: Proceedings of the International Conference, Oct 18, IHSBRE Press, Bracknell, 2006
http://www.brebookshop.com/details.jsp?id=286883

[26] Concrete Centre Case Study – 55 Baker Street, London
http://www.concretecentre.com/default.aspx?page=1083)

[27] 'This is Concrete' case study – Angel Building, Islington
http://www.thisisconcrete.co.uk/home_page/case_studies/the_angel_building.aspx)

- **Awareness of influence of new materials and practice on recycling end of life** – There is concern from the demolition industry about the potential influence of unfamiliar construction practice and materials on end of life. The sector needs to look out for any new materials or practices that could adversely affect capacity to recycle ready-mixed concrete. Some forms of non-traditional permanent formwork can have an impact on the demolition process and this possibility needs to be considered at the design stage through education of designers.

Table 7: Actions identified relating to the demolition of structures containing ready-mixed concrete and reuse

Proposed action	Lead	Deliverable action (and timescale)
Maximise opportunities for appropriate recycling of crushed concrete by looking out for any new materials or practices that could adversely affect capacity to recycle ready-mixed concrete at end of life. There is a need for the ready-mixed concrete sector to work with the National Federation of Demolition Contractors (NFDC) in the development and updating of Demolition Refurbishment Information Data Sheets (DRIDS).	TCC	Raise awareness among demolition contractors by providing on-going comments and dialogue (in collaboration with the precast concrete sector) with NFDC on new issues and practices that could affect concrete at end of life, suitable for revision and improvement of DRIDS (on-going contributions to revisions of DRIDS by 31 December 2016).
Raise awareness of opportunities and circumstances under which foundations and concrete frame can be beneficially reused (in resource efficiency terms).	TCC	Continue to gather exemplars of the reuse of ready-mixed concrete structural frames and foundations and publish as best practice case studies, one per year (2014, 2015 and 2016) to 31 December 2016. The Materials Task Group of UKCG has offered its active involvement.

8. Next steps/implementation/formalising of follow-on stakeholder group

The REAP will be implemented, reviewed and updated through the following approaches:

- Continued engagement and collaboration with the contributors and stakeholders to review the REAP.
- An annual review process by the above stakeholder group, with a major review after five years (2018).
- To maintain focus on the on-going development and delivery of the actions identified within this REAP, reviews will be aligned and coordinated in twice yearly meetings with the joint clay bricks and clay blocks and precast concrete REAP's. This is expected to move the three REAP's towards greater alignment and promote cross-fertilisation of ideas as well as optimising the use of time and management resources.

9. Conclusions and recommendation

This REAP tackles a broader range of issues than previous REAPs, encompassing waste, energy, carbon and water and lifecycle stages from raw materials to demolition and reuse. The ready-mixed concrete industry has already made great strides in resource efficiency, does not require packaging and produces low levels of waste to landfill. However, the REAP process has identified areas where there is potential for continuous improvement.

Several of the actions developed have focused on gathering and assessing evidence where the availability of data and/or the scope for improvement needs to be evaluated. Examples include the volumes of concrete supplied, wastage rates, water use, logistics, ordering behaviour and transport fuel consumption.

A common review process will be adopted to coordinate between REAP documents and that of the concrete industry sustainable construction strategy in order to maximise synergies.

Appendices

A1 Glossary

Term	Definition
Additions	Materials such as fly ash, ggbs or limestone fines used in combination with CEM I (Portland cement) at the concrete plant in accordance with the standard for concrete BS 8500-2.
Admixtures	Admixtures are ingredients other than water, aggregates, hydraulic cement, and fibres that are added to the concrete batch immediately before or during mixing. Chemical admixtures are added to concrete in very small amounts, mainly for the entrainment of air, reduction of water or cement content, plasticisation of fresh concrete mixtures, or control of setting time.
Aggregate	The general term for any granular material used in construction. 'Primary aggregate' is material such as sand, gravel and crushed stone, taken from natural sources specifically for use as aggregate. 'Recycled aggregate' is material produced by the processing of selected inorganic material previously used in construction. 'Secondary aggregates' are generally by-products of mining, quarrying or industrial processes.
Batching plant (concrete)	A device that combines various ingredients to form concrete, some of which include sand, water, aggregates, fly ash and cement. Concrete batching plants are widely used to produce various kinds of concrete, including flowing concrete and non-flowing concrete, suitable for large or medium scale building works, road and bridge works and precast concrete plants.
Biodiversity Action Plans (BAPs)	A biodiversity action plan (BAP) is an internationally recognised programme addressing threatened species and habitats and is designed to protect and restore biological systems.
Building Information Modelling (BIM)	Building information modelling (BIM) is a process involving the generation and management of digital representations of physical and functional characteristics of a facility. The resulting building information models become shared knowledge resources to support decision-making about a facility from the earliest conceptual stages, through design and construction during its operational life, to eventual demolition.

Term	Definition
Capital carbon	All greenhouse gas (GHG) emissions associated with construction and demolition activities in the United Kingdom, including those embodied within imported construction materials and products, and those associated with the provision of professional support services (e.g. architecture and engineering). They include direct and indirect process emissions from manufacture and transport of UK and imported construction materials and products, emissions from professional services in support of construction, and all construction and demolition works on site (as defined in the Green Construction Board's Low Carbon Routemap for the UK Built Environment).
Cement	A building material made by calcining limestone and clay, grinding to a fine powder, which can be mixed with water and poured to set as a solid mass or used as an ingredient in making mortar or concrete.
Combinations	A blend of cement and addition, which when combined in the concrete mixer counts fully towards the cement content, in accordance with the standard for concrete BS 8500-2.
CPA	Construction Products Association
Designated concrete (GEN)	A concrete mix selected from a restricted range given in BS 8500, where the producer must hold product conformity certification.
Designed concrete	A concrete mix with a requirement for strength. This requirement may be satisfied by using a designed concrete where the specifier states the limitations on the mix design (e.g. in industrial ground floor slabs) or a designated concrete, where a supplier accredited by a third party designs the mix to suit the requirements of the designation given by the specifier (e.g. designated mix or RC, as defined in the concrete standard BS8500).
Embedded carbon	See embodied carbon.
Embodied carbon	Refers to carbon dioxide emitted at all stages of a goods manufacturing process, from the mining of the raw materials, through the distribution process, to the final product provided to the user. Depending on the calculation, the term can also be used to include other greenhouse gases. Embodied carbon is sometimes referred to as 'embedded carbon'.
Fill	Ground that has been formed by material deposited by human activity rather than geological processes. It is alternatively termed 'made ground' and 'man-made ground'. When used to fill an excavation or placed behind a retaining wall, it is called 'backfill'. When placed within an enclosed space, it is 'infill'.

Term	Definition
Fly ash	The residual solid material from the combustion of coal (at high temperatures, in excess of ~1,000°C) in coal-fired power stations. Fly ash is the fine ash composed mainly of spherical, glassy particles recovered from the gas stream. Furnace bottom ash (FBA) is the coarse ash recovered from the bottom of the furnace. Fly ash can also be known as 'pulverised fuel ash' (pfa) or 'coal fly ash' within standards and scientific literature. Fly ash is a pozzolan and reacts chemically with lime and water to form cementitious products, thereby being used as a partial replacement for Portland cement in concrete. It is quite different from, and must not be confused with, fly ashes from other industrial processes (such as incineration of municipal waste).
Formwork	Formwork is a structure, usually temporary, used to contain poured concrete and to mould it to the required dimensions and support until it is able to support itself. It consists primarily of the face contact material and the bearers that directly support the face contact material.
Ground granulated blastfurnace slag (ggbs)	A by-product from the blast furnaces used to make iron. The slag is periodically tapped off from the smelting process as a molten liquid. If it is to be used for the manufacture of ggbs, it is rapidly quenched with water. Quenching produces granules similar in appearance to coarse sand. This 'granulated' slag is then dried and ground to a fine powder, which can be used partially to replace conventional cement (typically replacing between 40% and 70% of the cement).
Logistics	The management of the flow of resources between the point of origin and the point of consumption in order to meet some requirements. The logistics of physical items usually involves the integration of information flow, material handling, production, packaging, inventory, transportation, warehousing and often security. The complexity of logistics can be modelled, analysed, visualised, and optimised by dedicated simulation software. The minimisation of the use of resources is a common motivation.
Mineral Products Association (MPA)	The trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries.
Prescribed (ready-mixed) concrete (see British Standard BS 8500-1)	A mix for which the purchaser prescribes the exact composition and constituents of the concrete and is responsible for ensuring that these proportions produce a concrete with the required performance. Effectively, the purchaser selects the materials and mix proportions to satisfy the required strength and durability needs but does not specify these parameters. The mix is ordered by its constituent materials and the properties or quantities of those constituents to produce a concrete with the required performance. The assessment of the mix proportions will form an essential part of the conformity (compliance) requirements if the purchaser so requires.

Term	Definition
Primary aggregates	Granular material used in construction produced from natural materials.
Quality Scheme for Ready Mixed Concrete (QSRMC)	The QSRMC provides product conformity certification for the design, production and supply of ready-mixed concrete. The certification standard for ready-mixed concrete is the QSRMC Quality and Product Conformity Regulations. The QSRMC sets the highest certification standards for ready-mixed concrete and it is the preferred certification scheme of almost all the major UK suppliers and a large number of smaller producers.
Recycled aggregate (RA)	Recycled aggregate (RA) principally comprising crushed masonry. The concrete standard BS 8500-2 gives further details on compositional requirements for RA.
Recycled concrete aggregate (RCA)	Recycled concrete aggregate mainly composed of crushed concrete. The concrete standard BS 8500-2 gives further details on compositional requirements for RCA.
Slump	The concrete slump test is an empirical test that measures the workability of fresh concrete. More specifically, it measures the consistency of the concrete in that specific batch. The current terminology for the property in standards is 'consistence'.
SMART	Actions that are Specific, Measurable, Achievable, Realistic, Time-bound.
Standardised prescribed concrete	A concrete mix selected from a restricted range given in BS 8500, where the purchaser is to ensure that the concrete is not used where other aggressive chemicals are present in the ground.
Sustainable Concrete Forum (SCF)	The Sustainable Concrete Forum is a group of concrete industry trade associations and companies that have signed up to the Concrete Industry Sustainable Construction Strategy.
The Concrete Centre (TCC)	The Concrete Centre is the central development organisation for the UK concrete sector.
Thermal mass	Thermal mass is a concept in building design that describes how the mass of the building provides 'inertia' against temperature fluctuations, sometimes known as the thermal flywheel effect. Concrete and masonry are generally regarded as having a high thermal mass.
UKCG	The UK Contractors Group (UKCG) is the primary association for contractors operating in the UK. The group represents more than 30 leading contractors operating in the UK on construction specific issues. Its mission is to promote the UK construction industry and to support its members in delivering excellence by encouraging contractors to work together with their clients and supply chains to promote change and best practice.

A2 List of stakeholders and contributors

Table A2.1: Joint Clay Brick and Clay Block, Precast Concrete and Ready-Mixed Concrete Project Management Team

Name	Company/Organisation	Sector
Richard Sawyer	AMEC	Administrative Secretariat
Simon Hay	Brick Development Association (BDA)	Trade Association
Andrew Smith	Ceram	Technical Specialist
David Manley	Hanson; pre-cast concrete REAP Chair	Manufacturer
Emma Hines	Lafarge Tarmac; ready-mixed concrete REAP Chair	Manufacturer
Guy Thompson	Mineral Products Association (Concrete Centre)	Technical
Mike Leonard	Modern Masonry Alliance	Trade Association
Hafiz Elhag	The British Precast Concrete Federation	Trade Association
John Sandford	Wienerberger; clay bricks and clay blocks REAP Chair	Manufacturer
Gareth Brown	WRAP	WRAP
Malcolm Waddell	WRAP	WRAP

Table A2.2: Ready-Mixed Concrete Stakeholder Group

Name	Affiliation
Kim Noonan	Building Research Establishment (BRE)
Chris Clear	British Ready-Mixed Concrete Association (BRMCA)
Andrew Dunster	Building Research Establishment (BRE)
Emma Hines	Lafarge Tarmac; Chair of the ready-mixed concrete REAP stakeholder group
Guy Thompson	The Concrete Centre (TCC)
Gareth Brown	WRAP
Malcolm Waddell	WRAP
Rob Carroll	UK Quality Ash Association (UKQAA)
John Dransfield	The Cement Admixtures Association (CAA)
Lance Higgs	Cemex
Leanne Laughton	John Sisk & Son Limited
David Manley	Hanson UK
Karen McWalter	Kier Construction

Name	Affiliation
Emily Townsend	Lafarge Tarmac
Jenny Burridge	The Concrete Centre (TCC)
Denis Higgins	Cementitious Slag Makers Association (CSMA)
Terry Quarmby	Dorton Group
Howard Button	National Federation of Demolition Contractors (NFDC)

A3 Background on the British Ready-Mixed Concrete Association

The British Ready-Mixed Concrete Association (BRMCA) is an association of member companies dedicated to representing the interests of British ready-mixed concrete producers to the UK Government, technical and industry bodies, the general public and other key audiences.

Its main aims are to improve innovation, product development and client/contractor liaison in the concrete industry. BRMCA focuses on a wide range of topics, such as sustainability, technical and environmental issues, health and safety, industry legislation and government policy, as well as promotion of building systems using ready-mixed concrete.

BRMCA operates through task groups, made up of members and specialists who study specific issues; seminars and workshops, to help disseminate information and encourage discussion; and the publication of best practice guides and key information. BRMCA also works closely with the rest of the concrete sector in the promotion of the sustainable production and use of concrete. It currently represents 85% of ready-mixed concrete production and 80 companies. BRMCA is part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries.

A list of BRMC members is available via its website:

http://www.brmca.org.uk/members.php

A4 Process flow diagrams for ready-mixed concrete production and subsequent lifecycle

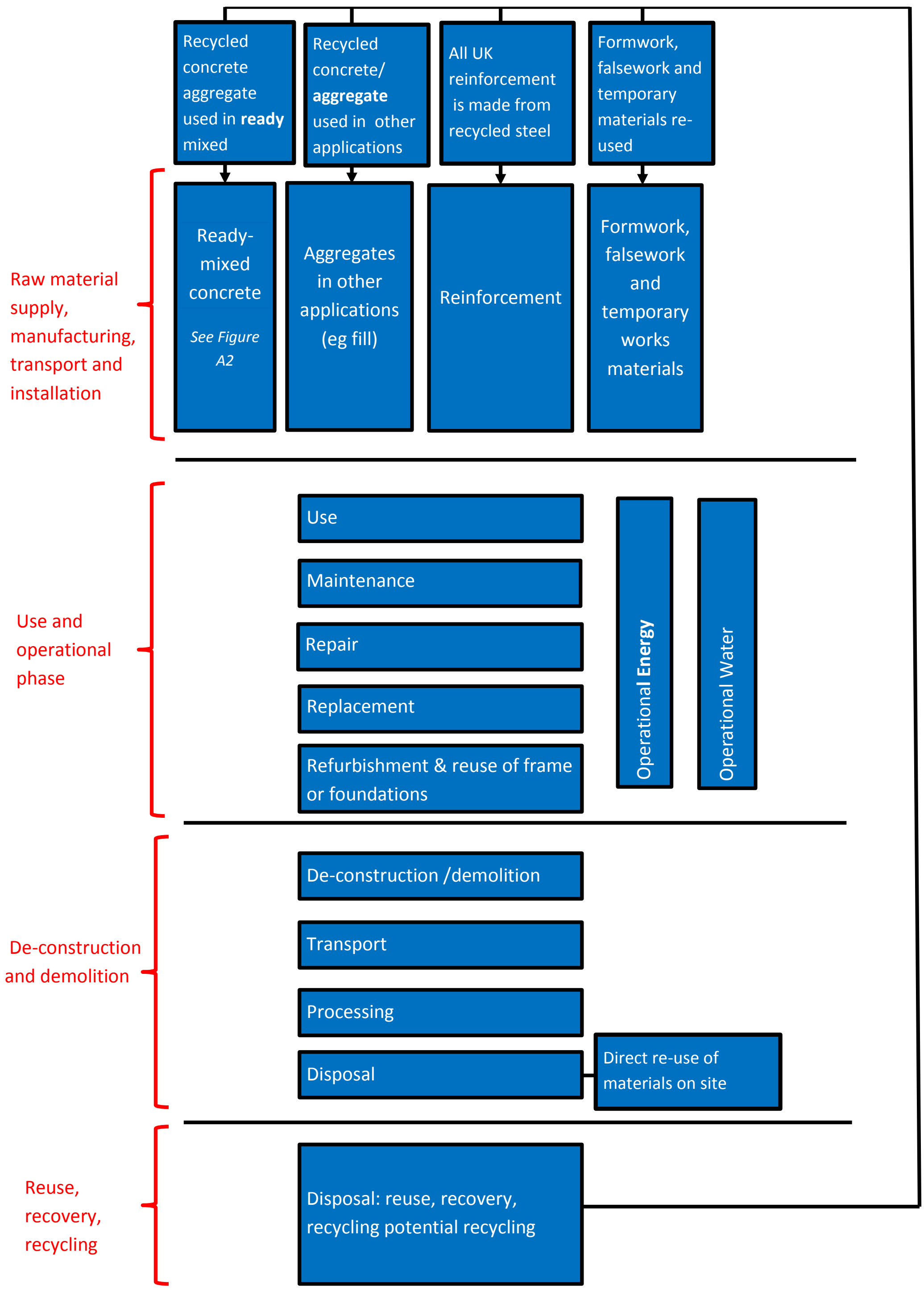

Figure A1: **Process flow diagram showing concrete manufacture, use, deconstruction and reuse phases of ready-mixed concrete**

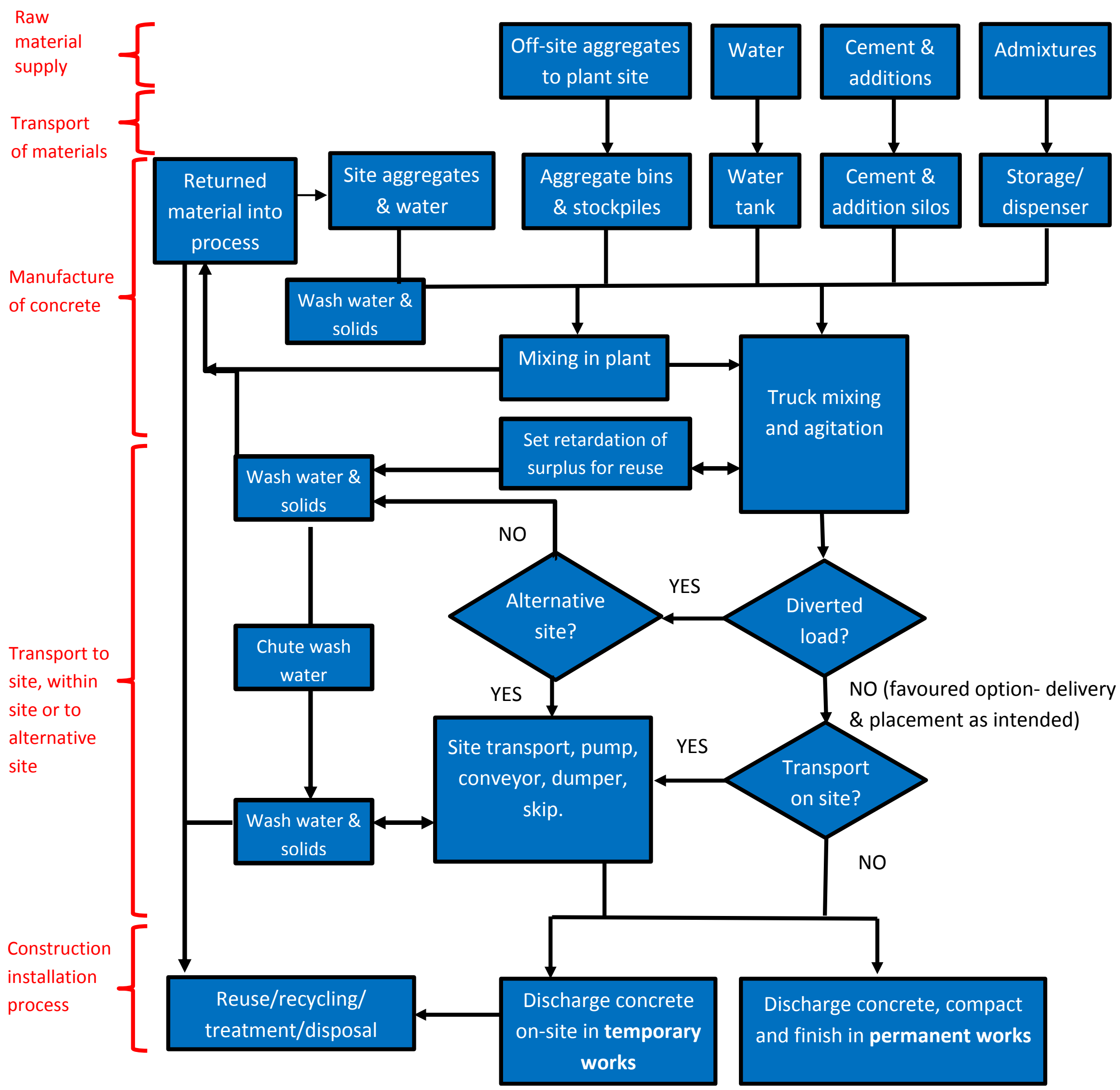

Figure A2: Process flow diagram showing manufacturing, transport and placement of ready-mixed concrete