NEW CONCRETE TECHNOLOGY IN CONSTRUCTION

AGGREGATES - THEIR ROLE IN CONCRETE AND THE 'GREEN AGENDA'

Christopher Andrew Clear
BSc PhD CEng MICE FICT FIMMM

British Ready-Mixed Concrete Association

Christopher Andrew Clear, is Technical Director of the British Ready-Mixed Concrete Association (BRMCA). His early career (1980-1989) was in Research and Development at the Cement and Concrete Association, which became the British Cement Association (BCA) in 1985. Later (1989-2003) he held Technical and Marketing roles for Civil and Marine Slag Cement Limited before returning to the BCA in 2003 as Research Manager. The Quarry Products Association (QPA), including BRMCA, merged with BCA and The Concrete Centre (TCC) to become the Mineral Products Association in 2009.

ABSTRACT: Sustainability of construction works is such an important topic that it should not be discussed by rather imprecise and emotive terms such as 'The Green Agenda'. Therefore this paper deals with the sustainability assessment of building with respect to their environmental, social and economic performance before briefly covering how concrete and its aggregate constituent play a part in sustainable construction.

Keywords: aggregates, building, concrete, construction, standards, sustainable

INTRODUCTION

For a concrete technologist the term ‘Green Agenda’ is a rather more difficult concept to understand than either ‘Aggregates’ or ‘Concrete’. Having said this it is the authors opinion there is a degree of ambiguity associated with all three terms. This paper sets out what ought to be considered important to consider with respect to sustainable construction and a brief consideration of how aggregates and concrete support such an initiative.

The Green Agenda

A problem with the green agenda is that it is often not presented as a list of important environmental, social and economic considerations but as a banner around which those affected by some form of change to their environment gather to resist the change.

However, with respect to building construction the position is changing as a comprehensive technical description of the green agenda is being set out across a set of International and European Standards. EN 15643-1[1] entitled ‘Sustainability of construction works — Sustainability assessment of buildings — Part 1: General framework’. This European Standard forms part of a suite of the European Standards that set out a system for the sustainability assessment of buildings using a life cycle approach. The sustainability assessment is quantified to assess the environmental, social and economic performance of buildings using quantitative and qualitative indicators but benchmarks or levels of performance are not set. It should be noted that currently it is only buildings that are covered by the EN 15643-1 framework, but there are proposals for standards to cover the sustainability assessment of civil engineering and other construction works.

In carrying out assessments, scenarios and a functional equivalent are determined at the building level. This level means that the descriptive model of the building with the major technical and functional requirements has to be been defined in the client's brief or in the regulations as illustrated in Figure 1, abstracted from EN 15643-1.

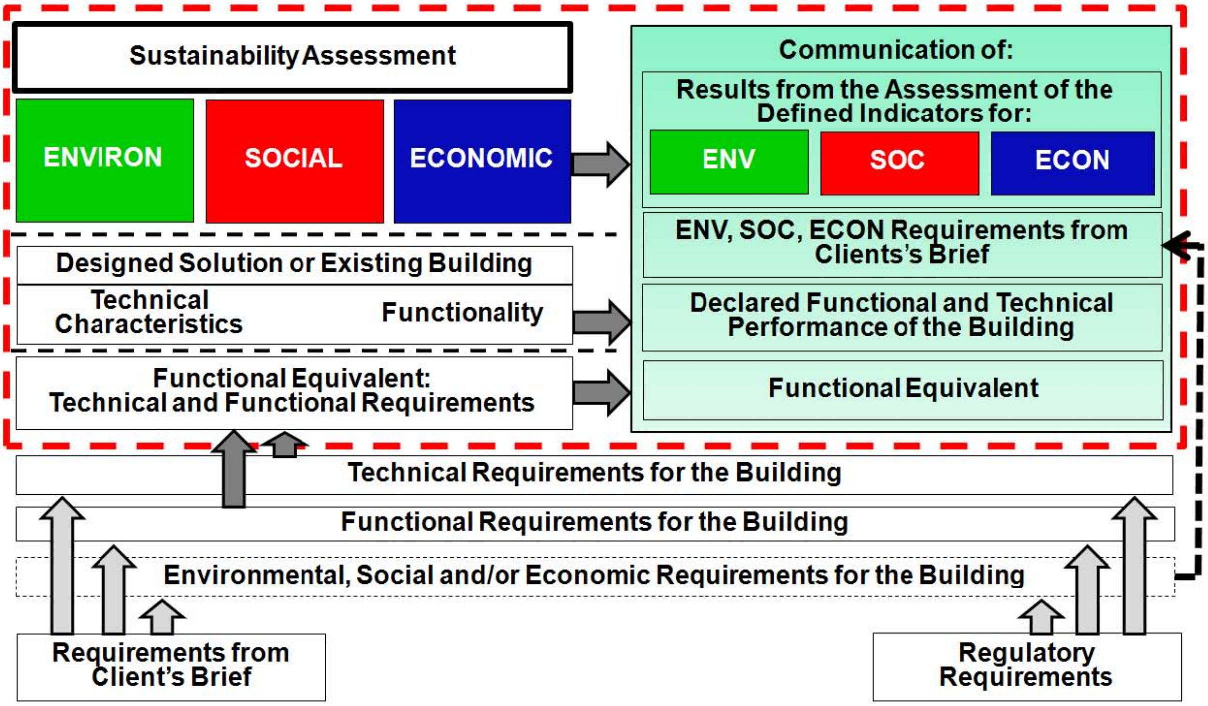

Figure 1: EN 15643 concept of sustainability assessment of buildings

EN 15643 Part 1 is the general framework, and Parts 2[2], 3[3] and 4[4] the individual frameworks for environmental, social and economic performance respectively. All four parts contain a version of Figure 1, and in their draft stages the 'Environmental' box was coloured green, the 'Social' box coloured red and the 'Economic' box coloured blue. The use of colour in what might otherwise be considered rather dull documents such as standards is to be applauded, however it is unfortunate that in this case it reinforces the misconception that 'The Green Agenda' is concerned only with Environmental issues, whereas it should encompass Social and Economic issues as well.

In Figure 1 the boxes within the thick red dashed box are those covered by the European Technical Committee entitled 'Sustainability of construction works', CEN/TC 350. As the EN 15643 standards state when describing the integrated building performance at the concept level, the environmental, social and economic performance are one part, and the technical and functional performance are another. Both parts are intrinsically related to each other as shown in Figure 2, where the CEN/TC 350 work programme is represented by the boxes shaded grey as set out in EN 15643-1.

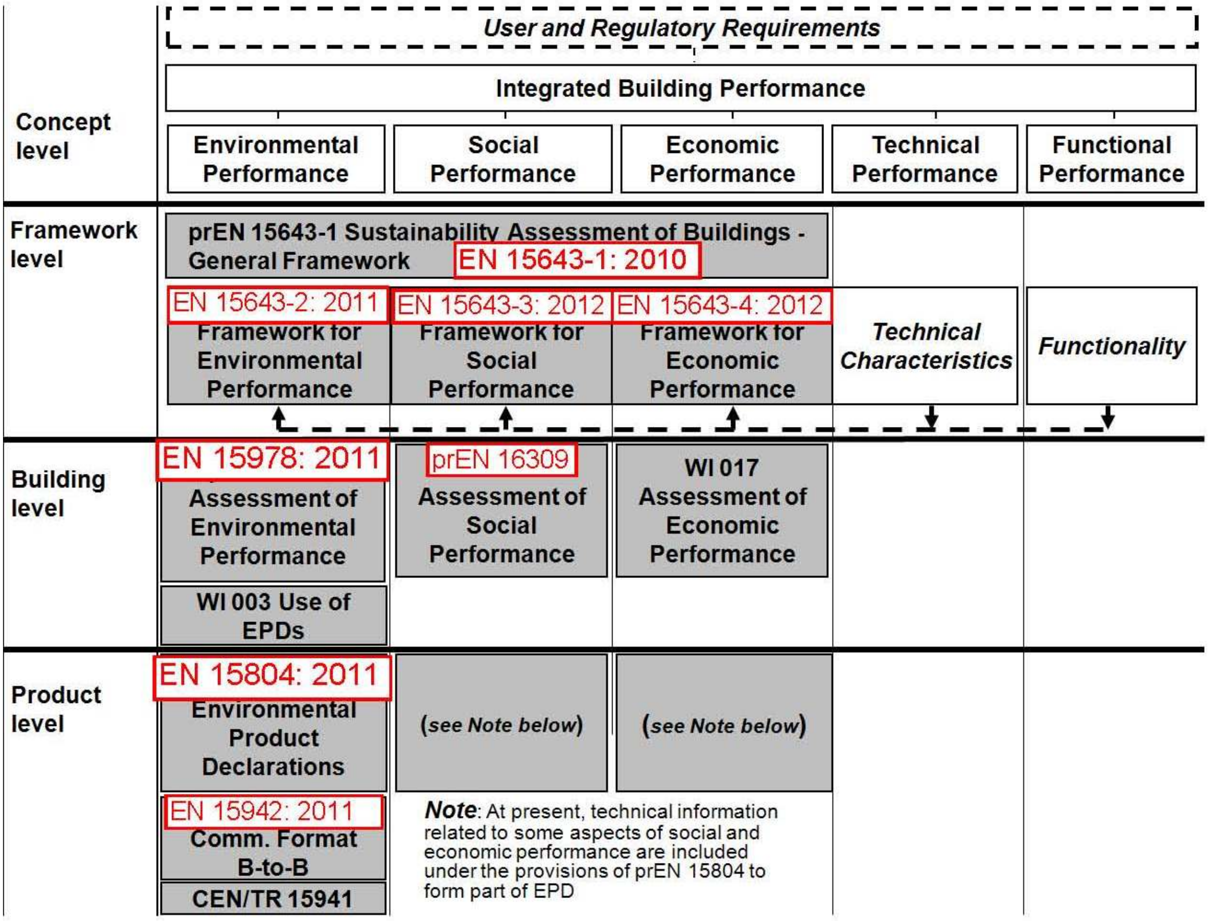

Figure 2: Work programme of European Technical Committee CEN/TC 350 Sustainability of construction works

Sustainability assessments can be undertaken for the whole building, for parts of the building which can be used separately, or for elements of the building. This is in a complete contrast to some simplified interpretations of the 'Green Agenda' which may largely restrict consideration to just the environmental impacts of the various building products from which the building is made.

Although the evaluation of technical and functional performance is beyond the scope of CEN/TC350 standards, the technical and functional characteristics are considered by reference to the functional equivalent. The functional equivalent of a building or an assembled system (part of works) shall include, but is not limited to, information on:

- building type (e.g. office, factory, school)
- pattern of use (e.g. occupancy)
- relevant technical and functional requirements (e.g. regulatory framework and client's specific requirements);
- required service life

There is an explicit requirement that the assessments shall be established on the basis of specified realistic scenarios that represent the whole building life cycle.

To ensure the results of the assessment of environmental, social and economic performance can be readily understood they need to be presented in a systematic and transparent method, where Figure 3 shows the groups of information required.

	BUILDING LIFE CYCLE INFORMATION				SUPPLEMENTARY INFORMATION BEYOND THE BUILDING LIFE CYCLE
Stages	**BEFORE USE STAGE**		**USE STAGE**	**END OF LIFE STAGE**	BENEFITS & LOADS BEYOND THE SYSTEM BOUNDARY
	Product Stage	Construction Stage			
Impacts and aspects specific to building fabric and site during the building life cycle	1) The results from the product stage (cradle-to-gate)	2) The results from the construction process stage	3.1) The results from the use stage excluding building operation	4) The results from the end of life stage	Reuse – Recovery – Recycling – potential
Impacts and aspects specific to the building operation			3.2) The results from building in operation		

Figure 3: The organisation of the result of the assessment in accordance with EN 15643-1 life-cycle stages and the information groups

The standard EN 15643-1 makes it explicitly clear that tin the assessment report the results shall be expressed with all the defined indicators set out in EN 15643-2 for Environmental performance, EN 15643-3 for Social performance and EN 15643-4 for Economic performance. The indicators included in EN 15643 Parts 2 to 4 are summarized in Table 1. It should be noted that the items in the middle column come from a pre-Standard dated 2010, and the final lists within EN 15643 parts 2 and 4 changed significantly from the equivalent listings in their pre-Standards.

Environmental indicators **EN 15643-2: 2011** **Annex B.1** (informative)	***Categories for social aspects prEN 15643: 2010***	**Economic Indicators** **EN 15643: 2012** **Annex C** (informative)
environmental impacts (LCIA impact categories) — abiotic depletion potential (elements and fossil fuels) — acidification of land and water resources — destruction of the stratospheric ozone layer — eutrophication — formation of ground-level ozone — global warming potential **resource use (environmental aspects)** — use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials — use of renewable primary energy excluding renewable primary energy resources used as raw materials — use of non-renewable primary energy resources used as raw materials — use of renewable primary energy resources used as raw materials — use of secondary materials — use of non-renewable secondary fuels — use of renewable secondary fuels — use of freshwater resources **other environmental information (environmental aspects)** — components for reuse — materials for recycling — materials for energy recovery — non-hazardous waste to disposal — hazardous waste to disposal (other than radioactive waste) — radioactive waste to disposal — exported energy	***Health and comfort*** *— Thermal performance* *— Humidity* *— Quality of water for use in buildings* *— Indoor air quality* *— Acoustic performance* *— Visual comfort* ***Accessibility*** *— Accessibility for people with specific needs* ***Maintenance*** *— Maintenance requirement* ***Safety/security*** *— Resistance to climate change* *— Fire safety* *— Security against intruders and vandalism* *— Security against interruptions of utility supply* ***Loadings on the neighbourhood*** *— Noise* *— Emissions* *— Glare* *— Shock/vibrations*	**Cost** — economic performance expressed in cost terms over the life-cycle **Financial value** — economic performance expressed in terms of financial value over the life-cycle

Table 1. Indicators listed in EN 15643-2 for Environmental performance, prEN 15643-3 for Social performance and EN 15643-4 for Economic performance

Table 1 is not a complete list as and EN 15643-2 includes a list of further environmental indicators, and these are listed in Table 2.

Further Environmental indicators EN 15643-2: 2011 Annex B.2 (informative)
environmental impacts (LCIA impact categories) — biodiversity — ecotoxicity — human toxicity — land use change **resource use (environmental aspects)** — use of non-renewable resources other than primary energy — use of renewable resources other than primary energy **other environmental information (environmental aspects)** — use of environmentally sustainably managed materials (grouped per material type e.g. PEFC, FSC, responsibly sourced materials BS 8902:2009) — use of environmentally sustainably managed fuels (grouped per fuel type e.g. Sustainability criteria for bio-fuels ISO 13065)

Table 2. Further indicators listed in EN 15643-2 for Environmental performance

The detailed calculation method for the environmental performance of buildings using the environmental indicators set out in EN 15643-2, is set out in EN 15978[5] entitled 'Sustainability of construction works — Assessment of the environmental performance of buildings — Calculation method.' This standard sets out a methodology on how to calculate and most importantly how to display the modular information for the different stages of building assessment. Figure 4 shows the general format for the output where for each stage A1, A2, A3, B1… there will be a number required for each of the environmental impacts as listed in column 1 of Table 1, and those in Table 2 where appropriate. The natural extension is to list the social and economic impacts as well but the Standards for these have yet to be drafted. It is important to remember that the eventual Table of results is for the whole building for its whole life, so a scenario has to be developed to cover the construction, use and end of life stages.

BUILDING ASSESSMENT INFORMATION															
BUILDING LIFE CYCLE INFORMATION															SUPPLEMENTARY INFORMATION BEYOND BUILDING LIFE CYCLE
A 1-3			A 4-5		B 1-7						C 1 - 4				D
Product			Construction		Use						End of life				Benefits/Loads BSB
A1	A2	A3	A4	A5	B1		B2	B3	B4	B5	C1	C2	C3	C4	D
Raw Material Supply	Transport	Manufacturing	Transport	Construction-installation process	Use		Maintenance	Repair	Replacement	Refurbishment	De-construction	Demolition	Waste processing	Disposal	Reuse – Recovery – Recycling – Potential
			S	S	S		S	S	S	S	S	S	S	S	
					B6	Operational energy use									
					S = Scenario										
					B7	Operational water use									
					S = Scenario										

Figure 4: Display of modular information for the different stages of building assessment in accordance with EN 15978: 2011

On the specific challenge with respect to Global Warming Potential impact (measured by CO_2 equivalent) the concrete options to meet the demand for low-energy housing specific research was commissioned and reported[6]. Figure 5 shows an example of the results where the cumulative CO_2 emissions, embodied and operational, have been modelled for a 60 year period for both lightweight (timber) and medium weight (blockwork walls) simple semi-detached house. Due to predicted increase in summer temperatures resulting from climate change , the lightweight house needs air-conditioning by 2021, whereas for a medium weight home it would not be needed until 2041. A typical concrete and masonry house with a medium level of thermal mass has about 4% more embodied CO_2 than a lightweight house, but this could be offset in as little as 11 years due to energy savings provided by its thermal mass.

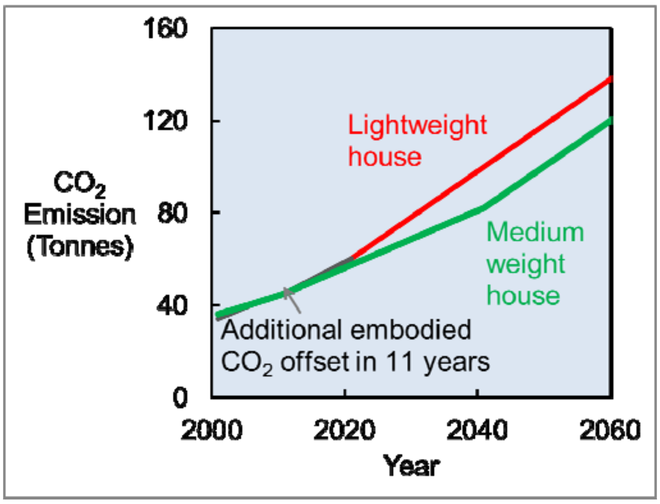

Figure 5: Cumulative Global Warming Potential, CO_2 emissions (air-conditioned)

The simple semi-detached house is the sort of scenario required for the EN 15978 analysis, but for a complete EN 15978 analysis then a further 20 environmental impacts should be considered in addition to the single Global Warming Potential shown in Figure 5. The EN 15978 standard is clear that the communication of results may be limited to a selection of indicators, and so the use of a single indicator is within scope and the standards notes that the graphical representation of results like that shown in Figure 5 may be useful to communicate results. It is also evident that trying to carry out an assessment to encompass all or even just a majority of the indicators may be an overly cumbersome exercise and so a client may wish to restrict the range to those considered of greatest importance.

What the EN 15643 series of standards clear state is that the *'The results of possible further aggregation of these indicators shall be clearly separated from the assessment results as additional information'*. This is an important facet as it is evident that where environmental indicators are normalised and/or weighted it is possible to present the assessment results in a way that appears to represent the just the bias of those responsible for the manipulation system. Figure 6 below shows the results of a particular 'E-points' system as applied to a tonne of coarse aggregate and a tonne of CEM I (Portland cement), where the higher the E-points the less environmentally desirable is the material.

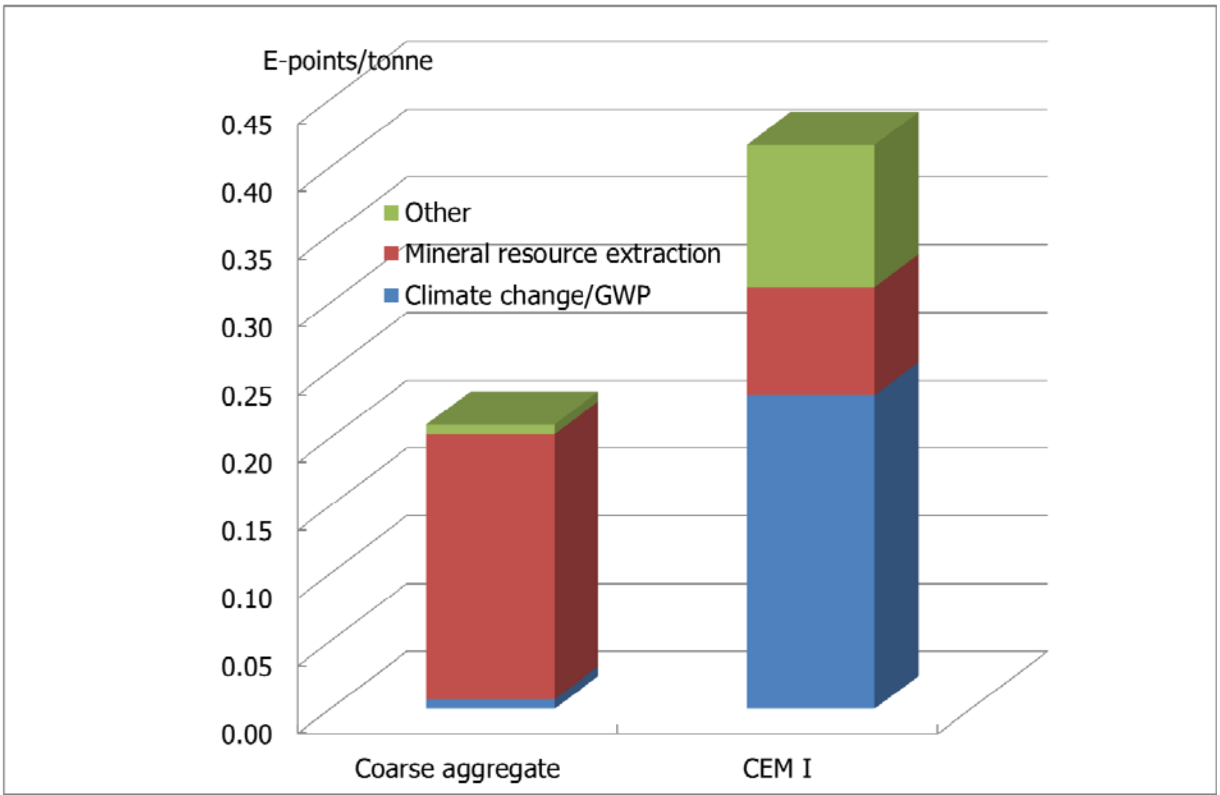

Figure 6: E-points for coarse aggregate and CEM I showing contribution for mineral resource extraction and climate change (Global Warming Potential)

Unfortunately, many clients want to be seen to be complying with a green agenda and as all the tools and expertise to carry out a comprehensive sustainability assessment are not readily available the temptation is to go down a simplified route. Such a simplified route, like those based on an E-points type system, can give arguable results. For example we know that the cement represents a global warming potential equivalent to about 850 kg of CO_2e/tonne[7], and that such emissions considering world production of over 3,300,000,000 tonnes of cement a year is generally considered to have a negative impact on the environment. According to the E-point system the extraction and use of one tonne of coarse aggregate in concrete is about as half environmentally damaging as the production and use of one tonne of cement, or say two tonnes of coarse aggregate is equivalent to the environmental impact of a tonne of cement. This cannot be sensible as a tonne of cement will initially put about 850 kg of CO_2e into the atmosphere whilst even if the two tonnes of coarse aggregate is used to make concrete it is still available. That is the aggregate is still aggregate through the service life of the building but also be an aggregate in a subsequent life where as part of recycled concrete it is likely to be used either as an unbound or bound aggregate application.

The important conclusion is that the term 'Green agenda' is the wrong term and its use should be deprecated. Indeed 'Green Agenda' is often regarded as synonymous with 'Environmentally friendly' and even this is the wrong term. The correct term to use is 'Sustainability of construction works' and until the necessary standards are developed for civil engineering works the more appropriate term is 'Sustainability assessment of buildings' in accordance with the EN 15643 series and supporting standards.

Aggregate

There is a suspicion that as far as a large number of Engineers are concerned aggregates for concrete are natural aggregates, and should be in accordance with BS 882: 1992[9] entitled 'Specification for aggregates from natural sources for concrete'. To these engineers it may be a bit of a shock that BS 882 was withdrawn on 1 June 2004, when it was replaced by EN 12620 'Aggregates for Concrete' which was first published in 2002 but was subsequently amended in 2008[10]. To the European Standard aggregate is *'granular material used in construction. Aggregate may be natural, manufactured or re-cycled'* where it is evident that the widest range of usable materials is included. This type of standard supports sustainable construction as it means that any suitable materials can be used to make concrete, but it is up to the specifier to ensure that the correct aggregate and concrete properties are specified to suit a particular application.

In the past it may have been considered reasonable to specify a high performance natural gravel or crushed rock for even the lowest grades or performance concrete classes, and where environmentally, socially and economically a high performance natural aggregate can be justified then that is perfectly acceptable. However, it should be equally acceptable that where there is a technically sound but lower grade of aggregate available to make a particular concrete then this will normally be the more sustainable option. If nothing else it would help preserve the resources of higher quality aggregates for more demanding concrete performances or other applications.

Sometimes it may be possible to use Recycled Concrete Aggregate (RCA) or Recycled Aggregate (RA) providing the source and quality meet all the necessary limits with respect to particular impurities and other materials that may be deleterious to concrete performance. Recycled aggregates are produced in conformity with the 'Quality Protocol for aggregates produced from inert waste'[11] where the material produced must also conform to EN 12620. To help ensure that aggregate for concrete is specified in the most appropriate manner guidance is available as BSI Published Document PD 6682-1[12] entitled 'Aggregates – Part 1: Aggregates for concrete – Guidance on the use of BS EN 12620.'

Concrete

The European Concrete Standard, EN 206-1[13], and its complementary UK counterpart, BS 8500[14], are increasingly being made more flexible, and hence supportive of sustainable construction. The general concept will be that general suitability is established at European level for; natural normal-weight aggregates, heavy-weight aggregates and air-cooled blast furnace slag conforming to EN 12620 as well as lightweight aggregates conforming to EN 13055[15] and aggregates reclaimed by the concrete producer. In addition at National level recycled and manufactured aggregates with an identified history of use may be used as aggregate for concrete if the suitability is established. In summary sustainable construction is supported by widening the range of materials deemed suitable for use in concrete, but the specifier may have to give some additional consideration to ensure that the materials specified are suitable for a particular application.

CONCLUSIONS

Sustainability is an issue of increasing importance to everyone, and sustainable construction is of particular importance to all those involved in the construction industry. Sustainable construction is not well served by the use of ill-defined jingoistic terms like ‘green-agenda’ and it use of this term should be deprecated by the construction industry and its suppliers. Concrete and aggregates have a role to play in sustainable construction, but the sustainability assessment needs to be in environmental, social and economic terms at the building level.

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