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THE POTENTIAL USE OF ALTERNATIVES TO PRIMARY AGGREGATES IN COASTAL AND RIVER ENGINEERING

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Abstract

This paper reports on a recent CIRIA study, carried out in collaboration with HR Wallingford, to assess the potential for using recycled/re-used (secondary) aggregate and construction and demolition waste as aggregate for coastal and river engineering.

The objectives were to:

- Reduce the impact of river and coastal construction on natural resources by promoting the use of alternative materials in place of primary aggregate and other materials.
- Enable the construction industry to provide more sustainable and cost-effective solutions for river and coastal engineering.
- Raise awareness of the potential use of secondary aggregate and recycled/reused materials as aggregate.
- Reassure designers and constructors of the appropriateness for use of alternatives to aggregates.
- Help overcome barriers to the use of alternatives to aggregates in a strategic and co-ordinated way.
- Produce a best practice guide on the above.

The demand from coastal and river engineering works for primary aggregate is increasing and is expected to expand further. It is recognised that this demand will need to be met, in part, by alternatively sourced aggregate. This paper reviews the availability of secondary and waste materials for application to river and coastal engineering and how designers and engineers can apply them.

1. Introduction

1.1 Materials and the construction industry

Construction is the largest consumer of natural resources in the UK, with over 90 percent of non-energy minerals extracted in the UK supplying the construction industry with materials. This represents, on average, nearly 300 million tonnes per year of primary materials (Smith, Kersey & Griffiths, 2002), the majority of which (some 214 million tonnes per year) is in the form of aggregates. If the demand for aggregates in the UK increases by the 1 percent per annum, as presently expected, then by 2012 an extra 20 million tonnes of aggregates will be needed annually (http://www.aggregain.org.uk).

There are growing concerns regarding the environmental consequences and the long-term sustainability of providing this large amount of construction material.

In response to these current levels of use, the Government introduced an Aggregates Levy in April 2002 as an environmental tax on the commercial exploitation of aggregates in the UK. Presently set at £1.60 per tonne, the aim is to reduce the demand for primary aggregates and encourage the use of alternative materials (see http://www.hmce.gov.uk/ business/othertaxes/agg-levy.htm).

The UK is already a leading user of alternative materials in Europe and can be proud of the fact that we have already established large and successful markets for alternatives to primary aggregates. In England alone, some 50 million tonnes of construction materials per annum are already derived from recycled or secondary sources (see http://www.aggregain.org.uk). Increasing the use of alternative, and recycled construction materials could provide a more sustainable option for meeting future demands. In addition to being a major consumer of natural resources, the construction industry is also one of the largest generators of waste in the UK, producing approximately 150 millions tonnes of waste per annum (Smith, Kersey & Griffiths, 2002). This, coupled with limited available landfill space has contributed to the Government's introduction of the landfill tax and the waste strategy to help secure changes to behaviour and to meet new waste targets (for further information see: www.hmce.gov.uk/business/othertaxes/landfill-tax.htm and www.defra.gov.uk/environment/waste/strategy/cm4693). However, some inert construction and demolition (C&D) materials are still going into landfill. Increased recycling of such materials would further reduce the demand for primary aggregates for new construction projects.

This study reviews the potential use of "secondary aggregates", defined as those construction materials produced from by products of industrial processes (manufactured aggregates) in river and coastal engineering. These include waste glass, metallurgical slags, Pulverised Fuel Ash (PFA) etc. and aggregates produced as by products from other mineral extraction processes, e.g. from china clay or slate production. It also examines the use of "Recycled aggregates", defined as those derived from the processing of inorganic material previously used in construction, for example construction and demolition (C&D) waste.

1.2 Alternative Materials in River and Coastal Engineering

Each year in the UK, coastal and river engineering schemes use a large volume of primary aggregates (e.g. excavated or dredged gravel and sand) not only in concrete structures but also for beach recharge and the construction of embankments. In seeking to improve the sustainability of such schemes it is important to consider how such demands on the Earth's natural resources could be reduced.

The potential consequences of climate change for the UK include accelerated sea level rise, and greater risk of extreme weather conditions that may lead to more frequent and more severe floods, increased erosion of coastal areas and higher maintenance costs for flood defences. The current annual average damage arising from flooding and coastal erosion is around £400 million and without investment in mitigation measures this could rise to as much as £2 billion per annum (Environment Agency 2001).

In a survey conducted for the Environment Agency's 2001 *Flood Defence Investment Strategy for England* (Halcrow Maritime, 2001), regional Environment Agency (EA) offices gave their spend in the 1999/2000 financial period for maintenance and replacement of river and sea defences. For river and related defences, maintenance costs amounted to over £35m, and replacement costs of just under £122m. For sea and tidal defences, maintenance costs equated to over £17m and replacement costs of just under £97m. This totals a yearly spend for

maintenance and replacement of coastal and river defences of over £271m. This excludes the expenditure incurred by local authorities, for example on coast protection schemes, and on schemes carried out in other parts of the UK.

The need to improve and upgrade many defences means that the above costs are likely to rise. It is therefore important that coastal and river engineers, in particular, address their resource usage and reduce consumption of primary materials wherever possible. The Environment Agency has introduced targets to encourage the use of alternatives to primary aggregates to this end.

In addition there is also a clear opportunity for river and coastal engineers to lead the wider construction industry in adopting good practice. If we can use "alternatives" to primary materials in these challenging situations they also provide good case study example for other uses which are less demanding. Indeed, there are already examples of this use, for example where rock is not available locally, innovative use of tyres etc. The recent CIRIA research project *Potential use of alternatives to aggregates in coastal and river engineering* has provided guidance to assist this process. Extending the use of alternatives to these demanding applications is seen as important because most coastal/river engineering requires materials that are:

- Very durable - to cope with abrasion/ harsh weather/wave/water conditions;
- Environmentally acceptable, avoiding pollution (e.g. From release of fine-grained sediments and other contaminants) and aesthetic issues; and
- Low cost, in the light of budgetary restraints on many coastal / river engineering schemes.

The project has also provided guidance for the construction industry on making material usable for applications and for designers and engineers on applying recycled and re-used construction waste and secondary aggregates.

2. Alternative materials and possible applications

2.1 Material Availability

In 2001 in England and Wales, the construction industry produced an estimated 93.91mt of construction and demolition (C&D) waste, of which 38.02mt was recycled as aggregate by crushing and/or screening and 7.05mt was recycled as soil. Of the remaining 48.84mt:

- 2.68mt comprised uncontaminated hard C&D waste and heavily mixed and/or contaminated hard C&D waste with varying potential for recycling as aggregate;
- 5.51mt was mixed construction and demolition excavation waste (CDEW), which was primarily soil but mixed with some hard C&D waste. This had limited scope for recycling as aggregate, and,
- 40.65mt was wholly or mainly accounted for by waste soil and excavation waste with little or no scope for recycling as aggregate.

Table 1 (Environment Agency 2003) shows that the South East, including London, handles the most C&D waste and recycled and reused the largest. The North West region was the next largest producer followed by the "Yorkshire and the Humber" region (see source for details of regions). Wales and the North East of England produced the least C&D waste.

Table 1 Destinations of construction and demolition wastes in England and Wales, 2001 (000s of tonnes)

Region	Recycled Soil & Aggregate	Re-used on Landfills	Recovered inert at exempt sites	Landfill Disposal	Used to backfill quarry voids
East of England	5,912	1,186	519	475	1,294
East Midlands	4,859	1,048	3,129	431	1,113
London	4,859	218	444	151	379
North East	4,247	739	1,217	323	937
North West	5,352	917	3,366	381	1,039
South East	5,843	1,792	2,828	779	2,202
South West	3,579	854	6,328	479	1,375
Wales	1,788	662	1,279	352	937
West Midlands	4,277	1,042	1,808	400	1,097
Yorkshire & the Humber	4,353	950	2,764	451	1,158
Total	**45,069**	**9,408**	**23,682**	**4,222**	**11,531**

In addition to the above, data gathered in 2001 by the Office of the Deputy Prime Minister, and research by others (such as WRAP), has identified the locations, volumes of arisings, usage and stockpiles of secondary aggregates in England and Wales (Table 2). This included materials from existing industrial and construction processes. The scale of reuse/recycling of materials was also recorded where known.

2.2 Potential Material Applications

The study has also developed preliminary assessments of the potential uses of the materials identified above in a range of river and coastal engineering applications. A summary of the suggested uses is presented in Table 3. It must be stressed, however, that this list is neither presciptive nor proscriptive. Material use will also be subject to availability (some materials are already highly utilised and generally scarce (e.g. BFS, PFA and BOF steel slag)), cost and (as with all materials) they must be checked to ensure that they meet the standards and specifications required by each application. Case studies of past uses website alternative materials can be found on the Aggregain website at http://www.aggregain.org.uk. This tool also helps specifiers and buyers choose the right aggregate for the right application and then download detailed technical notes and purchase orders.

Table 2 Tonnages of materials in England, Wales (2001) and Scotland (1998)

Resource Type	Material	Annual Arisings		Potential Aggregate Portion		Actual Aggregate Use		Non-Aggregate Use		Stockpiles	
		England & Wales	Scotland	England & Wales	Scotland	England & Wales	Scotland	England & Wales	Scotland	England & Wales	Scotland
Metallugical Slags	Blast Furnace Slag	3.0mt	0	3.0mt	not known	0.9 - 1.2mt	90kt	1.8 - 2.1mt	not known	No reliable estimates	0
	BOF Steel Slag	1.0mt	not known	1.0mt	not known	0.98mt	not known	0.02mt	not known	No reliable estimates	0
	EAF Steel Slag	0.28mt	not known	0.28mt	not known	0.28mt	not known	0	not known	No reliable estimates	not known
	China Clay	22.60mt	0	20.01mt	0	2.28mt	0	0	0	45 – 100mt	0
Mine & Quarry	Slate	6.33mt	not known	6.33mt	not known	0.58mt	not known	0	not known	456.5mt	not known
	Colliery Spoil	7.52mt	150 kt	7.52mt	150 kt	0.81mt	65 kt	0	0	10 – 20mt	not known
	Pulverised Fuel Ash	4.87mt	780 kt	4.87mt	780 kt	1.66mt	228 kt	0.83mt	not known	55mt	not known
Other	Furnace Bottom Ash & Clinker	0.98mt	44 kt	0.98mt	44 kt	0.97mt	40 kt	0	0	No reliable estimates	not known
	Incinerated Refuse	0.62mt	not known	0.62mt	not known	0.38mt	not known	0	not known	No reliable estimates	not known
	Spent Railway Track Ballast	1.3mt	102 kt	1.3mt	102 kt	1.24mt	77 kt	0	not known	No reliable estimates	not known
	Spent Foundry Sand	0.9mt	not known	0.9mt	not known	0.09 - 0.18mt	not known	0	not known	No reliable estimates	not known
	Glass Waste	2.20mt	not known	2.20mt	not known	85kt	not known	0.65mt	not known	20 – 30kt	not known
	Fired Ceramic Waste	100kt	not known	100kt	not known	90 – 100kt	not known	0	not known	Working only	not known
	Scrap Tyres	400kt	not known	400kt	not known	90kt	not known	170kt	not known	~14million tyres	not known

Note that for many of these secondary aggregates, e.g. slag and railway track ballast, there is already a high percentage of re-use, leaving little scope for further applications in coastal or river engineering projects. However, the large quantities of inert materials arising from slate and china clay production, in particular, do offer an opportunity for reducing the demand for primary aggregates.

Table 3 Suitability of alternative materials for common coastal/ river engineering scheme elements

	Concrete Seawalls*		Coastal Revetment/Ba-	Gabions e.g.	Geobags	Beach	Cliff drains	Saltmarsh	Embankments		Flood walls	Riverbed protection*
ALTERNATIVE MATERIALS	Fill	Prom. surface	Core/Under- layers						Fill	Revet-ment		
RECYCLED AGGREGATES												
Granular materials	3	C,B	3	3	3	3	3	3	3	C,B	C	3
Maintenance Dredgings (muddy)	X	X	X	X	X	3	X	3	X	X	X	X
Capital Dredgings (sand, gravel)	3	C,B	3	3	3	3	3	3	3	C,B	C	3
Spent Railway Ballast	3	X	3	3	3	3	3	3	3	3	3	3
Recycled Concrete rubble	3	B	3	3	X	3	3	3	3	3	3	3
Kerbstones	X	X	3	3	X	X	X	X	X	3	3	3
Railway Sleepers	X	X	X	X	X	X	X	X	X	3	3	3
SECONDARY AGGREGATES												
Burnt colliery spoil	U,C	C	3	X	?	3	3	3	U,C	C,B	C	C,B
Unburnt colliery spoil	U,C	C	3	X	?	X	X	X	U,C	C	C	C
Steel slag (EAF/ BOF)	3	C,B	3	X	?	3	3	3	3	C,B	C	C,B
Blast Furnace Slag	3	C,B	3	X	?	3	3	3	3	C,B	C	C,B
Furnace bottom ash (FBA)	C	C	3	X	?	X	X	X	C	C	C	C
China clay sand	3	C,B	3	X	3	3	X	3	3	C,B	C	C,B
Slate aggregate	3	C,B	3	X	3	3	3	3	3	C,B	C	C,B
Foundry sand	3	C,B	?	X	3	3	X	3	3	C,B	C	C,B
Recycled glass	3	C,B	?	X	?	3	3	3	3	C,B	C	C,B
Incinerator bottom ash (IBA)	3	C,B	?	X	?	X	3	X	3	C,B	C	C,B
Recycled tyres (in bales etc.)	3	X	3	3	X	?	?	?	3	3	X	?
Pulverised fuel ash (PFA)	3	C,B	3	X	X	X	X	X	3	C,B	C	C,B

Key: 3- generally suitable: C –Suitable if bound in concrete, B - suitable if bound in bitumen/ asphalt, U – suitable if unbound, X – Unsuitable.

* Large mass units or structures are required for most exposed locations, e.g. concrete armour units can be made using secondary aggregates. For sheltered locations, some recovered C&D waste may be suitable, e.g. concrete railway sleepers or kerbstones.

3. CONCERNS AND CHALLENGES IN REPLACING PRIMARY AGGREGATES

A range of potential barriers to the use of these materials in river and coastal engineering has been identified during this study. These barriers include:

- Perceived quality and specifications of materials;
- Availability, transport and economics;
- Environmental concerns;
- Policies, legislation and regulations; and
- Perceptions of risks and liability.

Whilst there are a number of genuine concerns about the use of alternatives to primary aggregates in coastal and river engineering projects, there appear to be some false perceptions about these materials despite the considerable advances have been made in recent years to improve their quality, consistency and availability. A series of recommendations have been developed, alongside guidance for key stakeholder groups to help overcome these problems. These include:

- A better interchange of information is required, involving all parties, to bridge the gap between perceptions and the reality of alternative materials
- The development of clear specifications of the type of materials required for even relatively common forms of coastal and river engineering, e.g. the construction of flood embankments.
- More active marketing of alternative materials by suppliers, with assistance from public sector bodies, e.g. Defra, Environment Agency, local authorities.
- The provision of better information on the types, availability and location of recycled or secondary aggregates to enable those planning and designing schemes to change the type of a structure, or adjust its dimensions, to make best use of these materials.
- Better review and dissemination of case history information from past schemes and additional new pilot projects to highlight the use of the most promising recycled or secondary aggregates and ensure that any lessons in their application are learned.
- A reduction of the costs of alternative materials should be sought where possible, particularly by investment in cheaper and more environmentally friendly methods of delivery, e.g. by sea or rail.
- There may be a case for "positive discrimination" in favour of alternative materials, by setting targets or incentives for their use or by sharing any extra risks in their usage.
- The public need to be better informed about the use of some alternatives to primary aggregates to allay safety concerns and to confirm that they are compatible with local requirements for amenity, recreation and aesthetics, and provide a net benefit to the environment.

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5. References

SMITH, R.A., KERSEY, J.R. and GRIFFITHS, P.J. (2002). *The Construction Industry Mass Balance: Resource use, wastes and emissions*. Viridis Report VR4.

ENVIRONMENT AGENCY (2001). *Flood defence investment strategy for England*. Environment Agency

HALCROW MARITIME (2001). *Environment Agency's flood defence investment strategy for England – Final Report*. Halcrow Group Ltd, Swindon

ENVIRONMENT AGENCY (2003) http://www.environment-agency.gov.uk/yourenv/eff/water. [Accessed 22/03/04]

http://www.hmce.gov.uk/business/othertaxes/landfill-tax.htm
[Accessed 22/03/04]

www.defra.gov.uk/environment/waste/strategy/cm4693
[Accessed 22/03/04]

http://www.aggregain.org.uk
[Accessed 22/03/04]

http://www.hmce.gov.uk/business/othertaxes/agg-levy.htm
[Accessed 22/03/04]

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