Piling, retaining walls and tunnels

This section includes summary sheets for the following technical solutions:

- Precast concrete rather than cast in-situ;
- Precast tunnel lining segments on site;
- Recycled/secondary aggregates in concrete;
- Reuse of piled foundations;
- Plastic sheet piling;
- Steel with high recycled content;
- pfa or ggbs as cement replacement materials;
- Recycled aggregates and/or HBM for working platform; and
- Incorporate working platform into permanent works.
TECHNICAL SOLUTION: Piling, retaining walls and tunnels

Precast concrete rather than cast in-situ
Precast tunnel lining segments on site

Application: Various structural elements for highways, railways, utilities, harbours, docks and waterways, and power generation.

Designing out Waste Principle: Design for Off Site Construction.

What is it?
The benefits of off site factory production, or controlled prefabrication on site or at a nearby location, are well documented. Assembling the precast units on site and then moving them into place has the potential to significantly change operations on site, reducing the number of site activities and changing the construction process into one of a rapid assembly of parts that can provide many environmental, commercial and social benefits. Generally a better quality product can be produced by precast techniques and the need for temporary works may be reduced.

Assembling structures in this way is one of a group of approaches to more efficient construction sometimes called Modern Methods of Construction that also include prefabrication, improved supply chain management and other approaches. It should be noted that these techniques are already extensively applied in the building construction industry from which many lessons can be learned.

Where can I use it?
Precast beams and bridge units are frequently used for constructing road, rail and foot bridges and box culverts are precast prior to jacking them beneath embankments. In replacement situations, the new structure is built alongside the existing one, which is then demolished and the new structure moved into place as a unit. The main driver for this method of construction is that it minimises closure or disruption of the road or railway, but it also allows more efficient construction of the new structure with reduced waste compared to constructing it in stages while keeping the road/railway functioning. In all cases, the methods of construction need to be considered at the preliminary design stage.

The use of precast units for rapidly constructing low height modular retaining walls, such as those needed for slope retention and silo installation, is already well established in the civil engineering industry. Precast pipes are also extensively used.

How do I apply it?

For concrete structures, the Concrete Centre and the British Precast Concrete Federation are amongst those organisations providing advice on off site construction and precasting techniques.


Why should I use it?
- **Waste reduction:** has the potential to significantly reduce waste produced on site.
- **Cost reduction:** efficient precasting techniques may reduce costs.
- **Recycled content:** opportunities may exist for increasing the recycled content during prefabrication.
- **Programme:** rapid on site assembly of the structure reduces construction timescales.
- **Carbon footprint:** minimises delay to road, rail and other users so improving fuel efficiency.
- **Other environmental benefits:** less disruption in terms of noise, dust, and vibration because of faster construction.
**TECHNICAL SOLUTION: Piling, retaining walls and tunnels**

**Recycled/secondary aggregates in concrete**

**Application:** Construction and maintenance of piling, retaining walls and tunnels.

**Designing out Waste Principle:** Design for Reuse and Recovery.

**What is it?**

At the moment recycled aggregate is restricted to replacing coarse aggregate (>4mm) which precludes the use of most secondary aggregates. It is likely that suitable recycled aggregate will be obtained from two main supply streams, either preconsumer waste from concrete production (precast or ready-mix concrete plants) or from demolition projects such as disused airfield structures, concrete framed or clad buildings. This ensures a relatively high quality material with < 5% brick and <1.0% impurities. Potential sources need to be able to provide sufficient quantity, consistent quality and usually be fairly close to the site where the concrete is to be used to ensure that the economics are viable.

**Where can I use it?**

The use of recycled aggregate in structural grade concrete is relatively new. Hence, the usage of Recycled Concrete Aggregate (RCA) is not advised for use in particularly sensitive or critical structural elements or structures until it has a longer track record. In some applications RCA is used as a partial replacement for primary aggregate and may be used up to the 20% replacement level; however, it may be possible to use it up to the 60% replacement level with the overseeing engineer’s approval.

**How do I apply it?**

Requirements for RCA for use in concrete in general are indicated in **BS 8500-2:2006**.

The **SHW 1702.2** states that ‘Unless otherwise specified in Appendix 17/4, aggregates shall conform to the British Standards listed in 4.3 of BS 8500-2 except that recycled concrete aggregate (RCA) and recycled aggregate (RA) shall not be used’. However, this is dated May 2004 and conflicts with **BA 92/07** dated May 2007. It is advised that a departure should be applied for use of RCA and RA in accordance with Chapter 7 of BA 92/07.

**Why should I use it?**

- **Waste reduction:** the use of recycled aggregates reduces the quantity of waste disposal to landfill.
- **Cost reduction:** is usually cheaper than using primary aggregates.
- **Recycled content:** increases the recycled content of the scheme.
- **Programme:** no significant impact on programme.
- **Carbon footprint:** the use of recycled materials are usually available locally, therefore there is a saving on transport in lorry movements and fuel.
- **Other environmental benefits:** reduction in congestion, noise, vibration and fumes by reduction in lorry movements. Reduced resource depletion.

BA 92/07 is an Advice Note in the Design Manual for Roads and Bridges entitled **The use of recycled concrete aggregate in structural concrete** and provides information on the use of RCA as a replacement for coarse natural aggregates in structural grade concrete. [www.standardsforhighways.co.uk/dmrb/vol2/section3/ba9207.pdf](http://www.standardsforhighways.co.uk/dmrb/vol2/section3/ba9207.pdf)

It encourages designers, contractors and concrete suppliers to consider the use of RCA.

The WRAP Research Report on **Mix design specification for low strength concretes containing recycled and secondary aggregates** provides guidance.

**TRL PPR36 The use of recycled aggregate in structural concrete** gives details of performance testing to determine engineering properties and durability.
TECHNICAL SOLUTION: Piling, retaining walls and tunnels

Reuse of piled foundations

Application: Construction of deep foundations for buildings, bridges and other structures in highways, railways, airports, harbours, docks and waterways, power generation and in the development of brown- and greenfield sites.

Designing out Waste Principle: Design for Reuse and Recovery.

What is it?
The reuse of foundations for a new superstructure is technically feasible and is increasingly becoming part of standard practice. The concept of reusing foundations is being developed in response to increasing pressure on land availability for city re-development and to find more cost effective and sustainable methods of construction.

Where can I use it?
Redevelopment of buildings in city centres frequently occurs and, in confined spaces such as these, there are often few options in terms of foundation location and reuse is particularly viable. In some cases, a mixed foundation solution may be adopted with new foundations used in conjunction with existing foundations. The main benefits are in the reuse of deep piled or diaphragm wall foundations, however the principles are applicable to shallow foundations although cost and environmental benefits are then small.

How do I apply it?
The key to reuse of foundations is identifying the foundation locations, dimensions and load carrying capacity with a high degree of reliability. CIRIA Report C653 gives guidance on how foundations can be reused, the technical considerations, and advice on allowing new foundations to be reused in the future.

There are risks inherent in the reuse of foundations, but these can be controlled by risk assessment and careful design. Various guidance has been produced under the RuFUS project which was European Union partially funded research. This includes a best practice handbook on the reuse of foundations for urban sites [BRE EP75, 2006] which gives guidance on technical risks, decision models and the legal and financial issues. Case history studies where the reuse of foundations has been employed are given in the Proceedings of the International Conference [BRE EP73, 2006].

Why should I use it?
- **Waste reduction**: avoids the use of virgin materials for the construction of new piles.
- **Cost reduction**: removing old piled foundations to make way for new foundations can cost significantly more than the construction of new piles.
- **Recycled content**: increases the recycled content of the scheme.
- **Programme**: transfer of load to existing piles reduces the extent of the new piling programme and hence speeds construction.
- **Carbon footprint**: reduction in lorry movements in removing debris and importing new concrete and steel. The latter take significant energy to produce and reuse therefore improves “carbon accountancy” balance.
- **Other environmental benefits**: significant benefits in reducing noise, dust and vibration both from heavy plant required to demolish the old foundations and also from more extensive new piling operations which would otherwise be required. Reduced resource depletion.
TECHNICAL SOLUTION: Piling, retaining walls and tunnels

Plastic sheet piling

**Application:** Soil retention, slope stabilisation, water retention or cut-off for highways, railways, utilities, harbours, docks and waterways, power generation and in the development of brown- and greenfield sites.

**Designing out Waste Principle:** Design for Reuse and Recovery.

**What is it?**

Plastic sheet piling manufactured from either polyvinyl chloride or fibre reinforced polymer has been extensively used for soil retention in North America and Europe particularly for waterway and marine applications. Recent innovations in the UK plastics industry have included the production of sheet piling from recycled polyvinyl chloride. This product is being increasingly used in the UK for highways and waterways related applications and offers a cost effective solution to the provision of low height soil retaining or water cut-off walls.

**Where can I use it?**

Plastic sheet piling has been successfully employed and is expected to be increasingly used for permanent highway works and retention of the banks of waterways. The various products are mainly suited for structures with a low retained height because of the limitations in bending moment resistance, driveability and creep performance. For a cantilevered structure these issues become critical as the retained height approaches 2m and consideration then needs to be given to providing support at the top by anchoring or nailing the structure.

Other identified uses include temporary works (e.g. for deep trenching), stabilising slopes against shallow failures, noise barriers, construction of water channels, scour protection around bridge foundations, balancing pond and flood control walls to mitigate against the increasing number of flooding incidents caused by climate change, and cut-off walls to prevent the movement of groundwater/sea water.

**How do I apply it?**

Guidance on the structural use of plastic sheet piling is given in TRL Report 533 and further information on performance and durability can be obtained from manufacturers. Plastic sheet piling produced from recycled material is more appropriate for use when designing out waste.

Monitoring of driveability trials for the particular application may be appropriate to convince the client of the suitability of the product. As specialised lightweight equipment has been developed for driving plastic piles, a specialist contractor should be engaged for the trial. There may be further merit in monitoring overall performance of the piling in the trial area to provide confidence in its serviceability.

**Why should I use it?**

- **Waste reduction:** avoid sending large quantities of PVC to waste from other manufacturing processes.
- **Cost reduction:** it will generally be up to 50% cheaper than steel sheet piling.
- **Recycled content:** increases the recycled content of the scheme (100% of the pile material is recycled).
- **Programme:** advantages include ease of handling and transportation of the lightweight piles which reduces costs of delivery and no craneage is required.
- **Carbon footprint:** reduction in lorry movements as more linear metres can be carried per delivery.
- **Other environmental benefits:** good corrosion resistance to both fresh and salt water, and chemicals. Can be produced in aesthetically pleasing colours.
TECHNICAL SOLUTION: Piling, retaining walls and tunnels

Steel with high recycled content

Application: Steel usage in the construction of highways, railways, utilities, harbours, docks and waterways, power generation and in the development of brown- and greenfield sites.

Designing out Waste Principle: Design for Reuse and Recovery.

What is it?
In general, there is a highly developed market for steel recycling and about 40% of the steel produced in the world is from recycling. This means that steel purchased for construction is likely to have a high recycled content and also that steel scrap arising on site will have a market value.

Steel can sometimes be reclaimed from site and put to direct use elsewhere without recycling.

Why should I use it?
- **Waste reduction**: surplus or waste steel is normally sold to a scrap merchant for recycling.
- **Cost reduction**: there is an associated cost recovery in the reclamation or recycling of steel.
- **Recycled content**: increases the recycled content of the scheme.
- **Programme**: no impact on programme.
- **Carbon footprint**: the recycling process requires lower levels of resource than primary steel production.
- **Other environmental benefits**: no waste generation. Reduced resource depletion.

Where can I use it?
A high proportion of the steel used in the construction industry is already produced by recycling and there are generally no limitations on its use for any purposes.

All steel has a recycled content that varies between 10% and 100% and steel construction products are highly recycled. Recent research by the Steel Construction Institute has found that on average, 84% of the UK’s construction steel is recycled and a further 10% reused.

The location of scrap merchants is readily researched on the internet and many websites are available to identify the nearest merchant to a particular UK postcode.

How do I apply it?
The properties of the recycled steel are the same as those of the virgin material and the relevant British Standard specifications apply, e.g.

- **BS EN 10293:2005** Steel castings for general engineering uses.
TECHNICAL SOLUTION: Piling, retaining walls and tunnels

pfa and ggbs as cement replacement materials

**Application:** Construction of deep foundations for buildings, structures and tunnels for highways, railways, airports, harbours, docks and waterways, power generation and in the development of brown- and greenfield sites.

**Designing out Waste Principle:** Design for Reuse and Recovery.

**What is it?**
Composite cement concretes reduce early-age thermal cracks in thick concrete sections because of the low heat evolution during hydration. Cements containing materials such as pulverised fuel ash (pfa) and ground granulated blastfurnace slag (ggbs) have been used for many years and both act to limit the temperature rise during hydration and hence thermal cracking. There is potential for their increasing usage in pile and retaining wall construction. Although the strength gain with time is slower than with conventional concrete, in the longer term higher strengths are attained.

**Where can I use it?**
Pozzolans, like pfa and ggbs, have not gained popularity in fast track construction because of their slower strength gain at standard curing temperatures – however for below ground construction this may not be an issue. Yet in some circumstances their properties may be advantageous. For example cement replacement is considered to enhance resistance to sulphate attack and to alkali-silica reaction. In addition there is some evidence that pfa or ggbs have the effect of reducing permeability to both gases and liquids so encouraging their usage for cut-off walls.

**How do I apply it?**

**BS EN 197-1:2000 (Composition, specifications and conformity criteria for common cements)** gives the allowable compositions of cements incorporating pfa or ggbs. The ICE specification for *piling and embedded retaining walls* permits the use of cement replacement materials provided they can be shown to have no deleterious effects.

**Why should I use it?**
- **Waste reduction:** the use of waste/by-product materials for cement replacement reduces the quantity of cement used.
- **Cost reduction:** some reduction in the cost of procuring cement.
- **Recycled content:** increases the recycled content of the scheme.
- **Programme:** no significant impact on programme.
- **Carbon footprint:** the use of waste/by-product materials reduces the embodied carbon associated with cement.
- **Other environmental benefits:** obviates need to dispose of waste materials by other means. Reduced resource depletion.
TECHNICAL SOLUTION: Piling, retaining walls and tunnels

Recycled aggregates and/or HBM for working platforms
Incorporate working platform into permanent works

**Application:** Working platforms for piling rigs and cranes for the construction of highways, airports, utilities, tunnels, railways, harbours, docks and waterways, power generation and in development of brown- and greenfield sites.

**Designing out Waste Principle:** Design for Reuse and Recovery.

**What is it?**
A working platform provides a safe and durable working surface from which construction plant, such as piling rigs and cranes, can operate. Recycled aggregates can be used to form the platform. Alternatively hydraulically bound materials (HBM) made using lime, cement and other binders are a cost effective method of stabilising weak on site soils (or imported recycled aggregates).

**Where can I use it?**
- Clear economic and environmental benefits can be derived from the use of platforms, particularly where increased use can be made of either site won or recycled materials,
- when platforms can be used and reused for a variety of purposes throughout the construction process,
- when platforms can be reused for permanent works.

**How do I apply it?**

General advice on the use of stabilised soils is given in the Specification for Highway Works 600 and 800 Series.

Further advice is given in TRL Contractor Report 151 [Stabilized capping layers using either lime, or cement, or lime and cement].

**Why should I use it?**
- **Waste reduction:** the use of site won materials reduces the waste sent to landfill, particularly if the working platform can be incorporated into the permanent works.
- **Cost reduction:** reduced costs compared with the option of importing primary aggregates for the platform.
- **Recycled content:** reuse of site won materials and/or recycled aggregates.
- **Programme:** no significant impact on programme.
- **Carbon footprint:** use of site won materials can lead to significant savings in lorry movements.
- **Other environmental benefits:** obviates need to dispose of waste materials by other means. Reduced resource depletion.
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