Waste Reduction Potential of Precast concrete Manufactured Offsite

Precast concrete manufactured off-site negates the need for temporary works and reduces material wastage resulting in a more efficient use of material.
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Executive summary

Offsite construction methods are increasingly popular in the construction industry. Offsite construction, also referred to as Modern Methods of Construction (MMC), offers many advantages in terms of quality of construction, cost control, construction time and environmental credentials. It is also seen as a means to help reduce the amount of waste generated on site.

Precast concrete manufactured offsite for structural and ornamental elements have been extensively used for a wide variety of projects, from railway sleepers to bridge elements, housing and stadia. Precast concrete products are reported to potentially reduce waste on construction site by as much as 50% when compared to more traditional approaches.

The nature of concrete and of the production methods allows manufacturers to produce standardised elements using pre-set forms and shutters that are endlessly reused. Furthermore, the design and the manufacturing process does not require the temporary supports and scaffolding that are, on more conventional construction sites, waste generating, time consuming and a health and safety hazard.

Bison Concrete Products Ltd, as an exemplar manufacturer, has provided data and information that demonstrate the environmental and waste reduction benefits of offsite precast concrete. This case study shows that a modern precast concrete factory can both decrease the demand on natural resources, efficiently reuse and recycle materials in the production chain, and limit waste to sent landfill to less than 1% of the material used.

Table 1: Summary of saved materials and waste generated (Bison as an example)

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1.0 Introduction

Offsite construction relates to construction activities that are carried out in a factory environment away from the site. Due to the set up of the offsite production facilities, and the possibilities offered to the manufacturers to improve the assembly process, offsite construction has a range of advantages compared to traditional build.

The importance of offsite construction methods, also referred to as Modern Methods of Construction (MMC), has increased since the mid-1990’s. These efforts were most pre-eminent in the housing industry where the housing associations established guidelines to facilitate the integration of light construction forms and offsite methods of construction. Offsite precast construction methods have been in use for over a century for a wide range of construction, from floors to high rise buildings, from single components to building systems.

Like other offsite methods of construction, precast concrete offers the known advantages in terms of efficiency of the construction process, improved construction programme, better budget controls, and improved quality. However, due to the manufacturing process, precast concrete also brings in important reductions in materials needed and in turn waste on site. This case study reviews the manufacturing and erection processes of precast concrete and highlights the impact of using precast concrete elements on construction waste.

2.0 Precast Concrete

Precast concrete solutions for structural and ornamental elements have been extensively used all over the world both for large construction projects such as bridges and stadia, as well as for modest size dwellings. Precast concrete is the most commonly used offsite construction method, precast provides the builders with:

- Quick erection times
- Reduced need for plant on site
- Easier management of construction sites
- Better overall construction quality
- Ideal fit for simple and complex structures

Precast concrete solutions can provide construction elements that are made of recycled materials that generate small amounts of waste through the manufacturing and erection phases.

Annually, the precast concrete industry produces over 35millions tonnes of products. These products are widely used in the following sectors:

- Residential (floors)
- Stadia
- Infrastructure (roads, railways, bridges, sewage)
- Prisons
- Medium and high rise building
- Hospitals
- Commercial and industrial buildings

The main forms of precast concrete in the UK include:

- Railway sleepers
- Floors elements (either beams and blocks or hollow core sections)
- Wall elements (with or without insulated core)
- Roof elements
- Stairs
- Structural elements for stadia
- Portal frames for industrial buildings
The precast processes allows the steel re-enforcing bars to be pre-stressed which, in most cases, reduces the amount of steel required.

This case study will look into the design, manufacturing and erection processes of the products manufactured by Bison Concrete Products, with a particular focus on Hollow Core floors and precast concrete walls.

2.1 The Products

Unlike other offsite construction methods, the manufacturing process of precast concrete relies on shuttering that is either standard built (e.g. hollow floor section) or customised to suit the specific geometry of the construction elements (e.g. bridge elements). As a result of this precast concrete elements are more economical where there is repetition within a project.

Precast concrete offers construction elements that can be used in the following ways:

1. **Stand alone elements.** These elements are mostly standard construction components that are held in stock by manufacturers and delivered to site on demand. Examples of such elements are precast concrete beams, standard sized hollow sections for floors and in-fill wall panels, etc.

2. **Building Systems.** Some manufacturers of precast concrete have developed standardised concrete building systems that are used to build small to medium size buildings (dwelling, flats, prisons, etc.). These building systems rely on precast elements that are bolted together on site through galvanised or stainless steel bolting systems and grouting.

3. **Assembly package.** For large projects, such as stadia or bridges, the design breaks the structure into smaller elements that can be transported and assembled together on site. Although there is a fair amount of standardisation, the connection systems as well as the dimensions of the elements are carefully designed to ensure safe and easy installation procedures.

The use of precast concrete requires significantly less resource on site as all elements are designed and manufactured in conditions that are not affected by weather, or distances to the concrete plant, therefore the required operations on site are then limited to:

- Preparation of the foundations
- Cranage of the elements to position
- Sliding junction re-bar in loops
- Grouting

Therefore, the amount of waste generated on site is significantly reduced compared to more traditional methods of construction.

2.2 Market

The British Precast Concrete Federation claims that the industry delivers annually over 35m tonnes of precast products for the construction sector (estimated at £2 billion).

In the UK, the major market players in 2006 were (in alphabetic order):

- Bell & Webster
- Bison Concrete Products
- Buchan Concrete
- Hanson Building Products
The precast concrete market is mature and based on simple manufacturing methods. Nevertheless, the industry invests in Research and Development in order to improve on its environmental credentials as well as to improve the industry’s records in waste management.

2.3 Precast Concrete and Waste

Precast concrete manufacturers offer their clients technical support, design capabilities and erection crews. Depending on the type of precast concrete product used by the builder on site, the involvement of the manufacturer might be limited to technical guidance on standard products, to complete design and construction projects. Overall, this approach ensures that the production and use of precast concrete limits the generation of waste on site and is resource efficient.

Precast concrete elements do not require packaging and are designed for easy handling. Therefore erection of the elements on site will generally not produce waste except, in some instances some timber edge shuttering and unused grout.

It is estimated that the amount of waste that could be saved by using precast concrete elements is between 20 and 50% of what might be generated on similar site using more traditional construction approaches.

3.0 Bison

Bison is a leading manufacturer of precast concrete floor and wall components. Recent development in the company’s factory procedures and approach to environmental issues has helped Bison to develop strategies and procedures that are exemplar in the industry. This case study highlights some of the important aspect of Bisons procedures and stresses their positive impacts on management of waste.

From its origins in 1919, Bison has led the way in precast concrete technology. Focussed on the construction industry, Bison’s history has been one of strong growth with market leading positions in all the sectors in which it operates.

Bison offer the design, offsite manufacture and installation of precast, pre-stressed hollow core flooring, precast concrete staircases, precast multi-storey wall panel structures and other bespoke solutions for stadia.

Bison’s commitment to sustainability has led the company to rethink its design procedures and manufacturing process in order to reduce the impact of its activities on water, material and energy resources. A £50 million investment programme started 3 years ago has brought new manufacturing technology and processes across its factories which are now able to reuse most of the water and recycle the waste that is produced.

3.1 Bison’s attitude towards waste

Bison’s manufacturing process generates less than 1% waste, generally timber.

Like most of the major players in the construction industry, Bison is committed to ensuring that its activities, and those of its clients, will have minimal impact on the environment. Therefore, the company has been modifying its procedures and process in order to ensure that the:

- manufacturing process has minimal impact on the environment;
- waste generated by its activities are recycled; and
- that the company as a whole adopts recycling procedures for all non-industrial waste generated.

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Document available on www.wrap.org.uk
Bison has, therefore, embarked a review of its activities, from design to installation on site, to identifying where generation of waste and utilisation of resources could be reduced. The immediate effectiveness of these steps, as outlined below, has also increased the productivity of the operations and reduced the overall manufacturing costs:

**Involving the supply chain.** The manufacturing process relies on materials being delivered on a just-in-time basis. Negotiations with suppliers led Bison to ensure the quality and the sustainability credentials of the materials bought, but also to ensure that the materials are prepared and delivered to the factory in such a way that there is no need for further modifications or adjustments.

**Continuous improvement.** Any environmental issues are dealt with in a responsible approach which is shared with the whole of the workforce. Committees are regularly formed in order to identify areas where improvements could bring even further reduction of waste.

**Monitoring and informing.** All materials delivered to the factory are rigorously weighed and recorded. The automated production lines also provide the management team with up-to-the-minute information on the performance of the manufacturing facilities in terms of productivity, waste generation and resource utilisation. This information is then analysed in order to rapidly rectify the parameters of the plant process that produced waste levels outside the set targets.

**Working with the other manufacturing facilities.** Bison has four manufacturing facilities throughout the UK which are all linked together by advanced IT technology. It is then possible for Bison to manufacture at the facility nearest to the construction site. This allows Bison to spread its production and to reduce the journey lengths to construction sites, hence reducing the production of CO2 associated to transportation. Furthermore, new and successful procedures implemented in one factory are shared between the other manufacturing sites in order for the whole company to benefit from the same efficiencies.

**Ensuring continuity of the factory approach to the construction site.** All of Bison’s products are designed to take into consideration the need for an easy and safe installation of the elements on site. Safer and better designed elements for erection on site also decrease the time needed for the construction, improve on the requirement for safety equipment on site, and avoid waste due to errors or accidents on site.

The investments made in the recent years, and the continuous improvement procedure through the company has helped Bison to develop an energy efficient factory in Swadlincote that recycles and reusing all materials, except for a limited amount of timber.

### 3.2 Precast v In-situ concrete

Although precast concrete manufacturers use the same basic components as onsite, the manufacturing methods allow the production of the precast elements to happen at a safe height and under optimal conditions. Therefore, precast concrete methods represent a substantial advantage in terms of the following items required for the equivalent construction site work:

- Elimination of needs for supports / scaffolding
- Elimination of temporary structures
- Reduced health and safety risks
- Reduction in lorry traffic and traffic management
- Easier management of steel procurement
- Elimination for long and continuous pouring operations
- Significant reduction/elimination of temporary shuttering
- Controlled curing of concrete
- Improved quality controls performed at the factory
- Process not subjected to weather conditions

Furthermore, due to the refined design, the Hollow Core and the use of pre-stressed steel re-bars in floor sections Bison can manufacture hollow core floor sections using less steel (30% in average compared to traditional) and concrete. For example, for the same floor conditions (spans, loading, etc.), eight cubic metres (8m³) of concrete would produced the following floor areas:

- **On-site traditional methods:** 63m²
- **Offsite – Bison’s hollow core:** 808m²
Considering that the production of Bison’s Hollow Core does not produce waste sent to landfill, the offsite solution offers a floor system that is easier to install, uses less resources, does not require expensive and time consuming shutter systems on site, and, more importantly, does not produce waste.

3.3 Estimation and Design Stage

Bison engineers all its products to suit the requirements of the specific construction sites where the precast concrete elements are used. Doing so allows Bison to value engineer and optimise the design of all the components to ensure that, where applicable, the actions of all components once assembled on site produce a sound and solid structure.

Because each component manufactured at Bison is somewhat bespoke, the final manufacturing drawings are complete once the clients have approved the scheme drafted by Bison’s engineers. An engineer uses a CAD-CAM based system which has a tri-dimensional module that allows personnel to review the interfaces between the precast elements and the steel structures, when applicable. This state-of-the-art computer software helps the designer to avoid overseeing important details that, in the past, have resulted in fabrication errors and, consequently, in loss of materials, time and resources.

In the near future, the CAD-CAM system will be improved by the addition of a detail checker that will ensure - particularly for the floor hollow core sections - that the design developed by the engineer does not include fabrication elements that can not be manufactured. Again, once in place, this piece of software will reduce the risk of errors that normally result in large concrete elements being discarded, new design to be drafted and new elements to be manufactured.

Once the design has been approved by the clients, the manufacturing drawings are completed and directly fed into the computers controlling the manufacturing process. As much as possible, the company avoids printing out drawings in an effort to reduce the waste of paper. Therefore, all working stations are linked by computer to the main frame server, and, accordingly to the daily production programme, fed on screen with the appropriate drawings and instructions.

3.4 Production of Precast Concrete Elements

The manufacturing facilities in Swadlincote consist of:

1- Hollow Core floor production hall
2- Batching plant for concrete to Hollow Core production and Batching plant for self compacting concrete for bespoke elements
3- Recycling centre for wet wastes and dry waste streams
4- Walls and other bespoke pre cast elements fabrication hall.

Whilst the production of the Hollow Core floor elements is highly automated, the production of bespoke pre cast and other elements is more specifically skilled and therefore labour intensive.

3.4.1 Hollow Core Floors

The manufacture of the Hollow Core floor sections is fully automated. The facilities were designed as a carousel to allow a continuous production flow. Furthermore, the production facilities have the following special features:

- The process of recycling generates sufficient water to manufacture all of the concrete without having to use any “Mains supply” and in the first year of operation has saved over 21,000ltrs per week
- A framework agreement with Lafarge who supply the cement to the factory. The level of materials in the silos is monitored from Lafarge’s offices. Lafarge is responsible for ensuring that the cement levels are kept above a set minimum, and has free access to the factory. This system further allows Lafarge to re-route cement consignments that can not be delivered to other clients and that would, in normal
cases, sent back to the cement factory. This procedure, therefore, is beneficial to both Bison and Lafarge environmental credentials.

- Drag chain canals collect all fresh concrete that is lost during the concrete process. The water and slurry are reused in the concrete process to ensure that no material is lost or wasted.
- All dry waste that is considered unusable (either due to cutting patterns or errors) are sent to a crush plant. The steel is separated out and sent for recycling, whilst the crushed concrete is either used as aggregate for production of concrete, or sold as class 1 aggregates for roads or other fill material.

Considering that the production of hollow core sections at the factory does not use any shutter systems, and that all waste is either reuse or recycled, the utilisation of offsite precast concrete floor elements on construction sites certainly reduces the amount of waste generated in comparison with more traditional approaches.

Furthermore, new automated machinery has been recently added to the concrete plant. This new equipment installs specially designed hooks in each unit, within the Hollow Core. This new system helps the handling of the concrete slabs at the factory and on site as the hooks allow units to be installed direct into their final bearing without the need to bar them into position and removes the potential for damage compared with traditional handling methods. This new hook system not only facilitates the handling of the concrete elements, but also improves the health and safety on site.

Finally, each of the floor elements has a transponder which can be read by electronic handheld equipment. This tagging method allows the computerised equipment to make the appropriate cuts at the right place. These cards store design and manufacturing information that can be retrieved at a later stage when the owners of a building wish to undergo modifications that affect the floor design.

### 3.4.2 Walls

The production of walls is more labour intensive. Wall panels are of different sizes and structural performance. Therefore, the production of walls requires framing solutions that can easily adapt to the dimensions of the walls being produced, and the need for openings.

Bison has adopted a manufacturing process using both vertical casting methods and horizontal steel pallets on which shuttering is attached to the main plate by means of magnets. All opening frames are prepared in a separate workshop and positioned onto the pallet prior to the re-enforcement being laid.

Most of the walls reinforcement steel is delivered to the factory on a just-in-time basis in the form of welded mesh that has been manufactured to the right dimensions. The steel mesh is then laid onto the pallet and the lifting hooks and connections pieces installed where required.

Once measurements and dimensions of the wall panels, openings, and re-enforcement have been checked, self compacting concrete is poured into the vertical and horizontal forms. The concrete is left to set, then, the panels are lifted and stored in the yard or direct on transport specially designed frames, waiting for delivery to site.

The wall manufacturing process requires a significant reduction in shuttering, when compared to walls formed on construction sites. By using steel pallets and angles, Bison eliminates the need for plywood based shutters to be built and supported, and steel reinforcement to be assembled on site. Not only do the offsite operations reduce the amount of activities required to form the walls, but the shuttering systems are continuously reused.

The use of self compacting concrete also reduces the number of activities required. On traditional construction sites, the construction of concrete walls would require a concrete pump and the use of concrete vibrators. These vibrators are used in order to ensure that the concrete reaches the required compaction ratio.

Wall panel fabrication at the factory generates a small amount of timber waste that can not be recycled because it is spoiled by concrete. In 2006, around 200 tons of timber was discarded to landfill with a further smaller volume being offered to wood burning facilities local to the plant. In order to achieve a waste free manufacturing
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Bison is currently trying alternative products to form the openings in the wall panel. These alternatives are reusable and can be recycled. If these trials are conclusive, this new material will replace timber in all Bison’s facilities.

The waste produced by the production of wall panels is kept to a minimum due to the use of re-usable steel shutter forms. Resources are also carefully managed to avoid unnecessary waste of materials and time. The wastes generated are:

- Small amounts of concrete which is crunched and re-mixed into new concrete batches as aggregate;
- Small amounts of timber which are reused where possible, otherwise discarded to landfill. Bison is currently trying alternative materials to eliminate timber from the production.

### 3.4.3 Other Precast Concrete Elements

Bison produces precast concrete elements for large construction projects such as stadia, hospital, high rise buildings, etc. These constructions require heavier and stronger structural elements which need special forms and plant for manufacture.

Depending on the geometry of the element to be fabricated, Bison engineers and workforce will choose the factory set up that generates the least amount of waste, using reusable steel shutter systems, and completing with multi-use plywood and polystyrene blocks.

For the wall panels, self compacting concrete is used ensuring a continuous level of quality in the concrete poured and formed.

The steel reinforcement structures are pre-manufactured and delivered to the factory ready to be installed in the shutters without further alterations. This just-in-time delivery mechanism ensures that there is no waste generated by the reinforcement activities.

Whilst every effort is made to ensure that the shutters and forms fabricated for this activity are reused as much as possible, the generated waste level is slightly higher than for the walls. The increase complexity of the elements being manufactured impacts on the quantity of timber to be used in the preparation of shutters and forms for non-standard concrete components. However, Bison, through its continuous improvement programme, has been assessing the waste produced and has engaged the pertinent resources ensuring that:

- all wasted concrete is recycled as aggregates for new concrete batches or for class 1 road sub-surface aggregate;
- all steel is separated out and sent for recycling; and
- all timber is, where possible, reused.

Nevertheless, the waste produced by such a manufacturing process represent a significant reduction when compared to the resources and materials wasted on traditional construction sites where scaffolding, shutters, supports, reinforcement, etc need to be built on site prior to the concrete being poured. This often leads to delays related to errors or deliveries, slow down of activities due to adverse weather conditions, and wastage of materials such as timber products, steel, etc. which are often sent directly to landfill.

### 3.5 Delivery to site

The manufacturing period for a set order is relatively short. However, the elements manufactured are heavy and require heavy equipment to move and load them onto the lorries. Bison has developed two methods that best suit the two streams of products manufactured.

The Hollow Core floor units are moved directly from the production line into set areas in the stack yard where they are combined with other units in the correct sequence for erection and laid onto specially design pallets.
The Forklift truck reads the transponder cards inserted onto the floor units. The information appears on the driver’s screen who then delivers the floor section on the right pallet. Once complete, Bison use a straddle crane to pick up the completed pallet and transfer it minimising the vehicle movements to a pre designated location in the yard. The same crane moves the pallet and its load onto a flat bed lorry ready for delivery. The pallets are returned to the factory after delivery to site. This method has proven to be efficient and generated savings in terms of truck journeys and on waiting time of drivers.

The wall elements are stored in racks within the stockyard in the right order for the assembly on site. specially designed frames are used to transport the finished product to site, once on site the product is craned off directly into its position within the building and the frames are returned to the factory for reuse.

Bison has also carried out some investigations on site in order to identify the areas where unnecessary waste could be eliminated. In the case of the floor system, the joints and the edges of the floors have to be grouted to give the whole floor the performance criteria specified by the engineers. Until recently, this involved the temporary installation of timber shutters at the end of the floor to prevent grout leakage. This operation was both time consuming and generated waste. This observation resulted in Bison devising a special reusable end-of-floor and which are removed once the grouting has set. This method not only saves time on site and improves on the safety of work, but also eliminates the waste created by the fabrication and the use of temporary timber shutter.

4.0 Conclusion

Precast concrete solutions can help the construction industry to reduce the waste generated on site by up to 50% compared to more traditionally managed construction sites. Used for over 150years, precast concrete has gained an impressive market share that, in terms of annual turn over, equals the sum of the cement and ready-mix markets.

Precast concrete has the advantage over traditional onsite concrete methods as there is no need for elaborate scaffolding or temporary works. Moreover, precast concrete does not require the fabrication of bespoke shutters on site and their subsequent discard to landfill after use.

Bison manufactures precast concrete elements for floors (Hollow Core sections), walls and for special constructions, such as stadia. Bison sells its products to a wide variety of clients and is involved in residential construction as well as institutional, educational, commercial, industrial, civil engineering, leisure and sport facilities.

Bison’s manufacturing process generates less than 1% waste, generally timber.

At the design stage, procedures ensure that design errors are rapidly identified to prevent fabrication errors that would otherwise result in wasted time, resources and, ultimately, materials. The design system uses tri-dimensional modelling software that allows the design engineer to check the interfaces between the different construction elements. A further development of the software will soon indicate to the designer where choices made in the specifications and design of elements can not be manufactured. Hence, implementing waste reduction techniques from as early as possible prior to manufacturing and construction on site.

The manufacturing process put in place by Bison is altogether environmentally responsible and almost waste-free. For example, the manufacturing process for hollow Core floor sections uses water harvested through the process. So far, the water harvested has been sufficient to supply Bison with the one million litres of water needed annually for the
production of the concrete. More over, all wasted water and wet concrete is recovered and re-used in the mixing process of concrete. Dry concrete is crushed to create aggregates that is then used either in the concrete or sold as class 1 aggregate for road construction. Therefore, the production of Hollow Core floor sections at Bison does not generate any waste that is sent to landfill and does not draw on valuable treated water resources.

The manufacturing process of walls and special elements is more labour intensive. Because of the need to create openings, and to produce special geometries, this operation generates timber based waste that, when not reused, is disposed of as waste because it is spoiled by concrete. However, Bison is currently testing new materials that will enable the crews to form the frames for openings in walls and other special elements. As for the floor, all concrete waste is collected and reprocessed into the concrete mix or as aggregate for road construction. The reinforcement (steel bars and mesh) is normally pre-assembled and delivered to the factory ready to be integrated into the concrete forms. Therefore, there is no steel wasted at the factory. However, when modifications are required, the steel wasted is recovered and sent for recycling.

As shown in Table 1, Bison’s process limits the waste sent to landfill to less than 1% of the total material weight processed (generally timber).

Considering that the introduction of reusable end caps further reduces the timber waste that was generated on site by the erection crew for containing the grout poured in the intersections, precast concrete manufacturing and erection processes can significantly help construction managers to better control waste management on site.

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</table>