REVIEW OF STRATEGY FOR RECYCLING AND REUSE OF WASTE MATERIALS

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ABSTRACT. Each year around 400 million tonnes of waste is produced in England and Wales. The UK government document "Waste Strategy 2000" identifies the need to curb the growing quantity of waste produced and sets out the changes needed to deliver sustainable waste management. In order to achieve sustainable waste management, it is not sufficient simply to concentrate on how best to reuse or recycle the waste that is produced, but to minimise the amount of waste that is produced in the first place.

The UK government has set challenging targets; by 2005 the amount of industrial and commercial waste sent to land fill is to be reduced to 85% of 1998 levels. While the issue of hardened concrete waste – as part of the construction and demolition waste stream – has received considerable attention, process waste arising from the manufacture of ready-mixed concrete is relatively unexplored.

It is apparent that initiatives such as the landfill tax have encouraged UK ready-mixed concrete manufacturers to substantially reduce the amount of waste they produce. This paper applies the current UK government waste strategy to this topic, analysing and evaluating current waste management methods.

Keywords: Waste Strategy 2000, Waste minimisation, Ready-mixed concrete.

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INTRODUCTION TO WASTE STRATEGY 2000

The Rio de Janeiro Earth Summit in 1992 saw the formulation of the first series of sustainable waste management options. Sustainable approaches to managing waste in the UK were put forward in the 1994 UK Government publication, 'Sustainable Development: The UK Strategy.' [1] This was replaced in 1995 by the Government White Paper, 'Making Waste Work: A Strategy for Sustainable Waste Management in England and Wales.'[2] This document introduced the 'waste hierarchy' concept. Subsequent Government documents have refined the hierarchy concept, and the current waste strategy for England and Wales, is set out in 'Waste Strategy 2000.'

A key principle of Waste Strategy 2000 is the selection of the Best Practicable Environmental Option (BPEO). Identifying the correct way to deal with particular waste streams is not a simple matter. BPEO will vary from product to product. Determining BPEO requires the consideration of both the waste hierarchy (Figure 1) and the Proximity Principle. The Proximity Principle requires waste to be disposed of as close to the place of production as possible [3]. At the top of the waste hierarchy is reduction (previously termed minimisation). While disposal is the least preferred option, it is important to realise that the most effective waste management decisions can be taken by adopting an integrated approach to waste management, and more than one waste management option from the waste hierarchy, in conjunction with the Proximity Principle, can be used to create the BPEO [4]. The BPEO for a particular waste may gravitate towards the bottom of the waste hierarchy due to the costs and impact of transporting that waste to a reprocessing facility. The BPEO for a waste stream will be a mixture of different waste management methods, as each component material of the waste stream will merit different waste management options. In this paper we consider the ready-mixed concrete plant waste stream.

Figure 1 – Waste hierarchy

READY-MIXED CONCRETE

Concrete is the world's most important construction material. It is an essential part of modern life; our infrastructure depends on it. The UK ready-mixed industry grew rapidly in the 1950s and today the vast majority of concrete originates from a ready-mixed concrete batching plant.

Concrete is a mixture of sand, gravel, crushed rock or other aggregate held together by a hardened paste of cement and water.

One cubic metre of concrete has a mass of around 2400 kilograms. Around 80 per cent of this is aggregate, 12 per cent is cement and 8 per cent is water. Small quantities of chemical admixture may be incorporated.

The production of concrete at a ready-mixed batching plant involves accurately weighing the required quantity of each constituent material and mixing them together either in the drum of a mixer truck or in a static pan-mixer. There are currently 1200 ready-mixed concrete plants in the UK, producing 23.5 million cubic metres of concrete per year.

THE READY-MIXED CONCRETE WASTE STREAM

Process waste from ready-mixed concrete plants is distinct from the hardened concrete waste incorporated in the construction and demolition waste stream, which is said to comprise over 16% of total UK waste arising [5]. In the context of this paper, it also excludes the estimated £400 million of ready-mixed concrete that is dumped in the UK each year because construction sites inaccurately order quantities [6].

It is difficult to estimate accurately the quantity of waste generated by the ready-mixed concrete industry. There is no such thing as a typical ready-mixed concrete plant. Although the UK's 1200 plants are broadly similar, each plant will exhibit individual production practice as a result of local differences in plant design, market, geology, management and personnel. A plant with a large yard and extensive ground storage capacity, for example, may operate differently to a plant with a small yard and no ground storage facility. Estimating waste arising is further complicated by commercial secrecy.

The ready-mixed concrete industry is highly competitive. Producers who have successfully reduced the quantity of waste they produce by the introduction of new technology and management techniques will understandably want to reap the commercial advantage. There is also a prevalent climate of secrecy borne out of the culture of hiding true levels of waste. This is promoted by internal as well as external pressures.

However, a typical plant may create between 20 and 80 tonnes of waste per month. This would suggest that around 0.75 million tonnes of waste is created each year in the UK by the ready-mixed concrete production.

With the current cost of disposal to landfill at around £200 per 20 tonne load, disposal of waste arising from the production of ready-mixed concrete can be estimated to cost the industry around £7.5 million each year. This does not include costs associated with handling this waste at the plant or the loss of materials.

What is the Waste produced by Ready-Mixed Concrete Plants?

Most ready-mixed concrete plant waste arises from two sources:

1. Washing out truck mixer drums at the end of each working day to prevent fresh concrete residue from setting in the drum overnight. Additionally, waste arises from washing down the yard and plant.
2. Occasionally unwanted fresh concrete is returned to the batching plant from site.

The wet waste consists mainly of water, with a variable proportion of coarse and fine aggregates, cementitious powders and chemical admixtures.

The production of ready mixed concrete is not an overtly wasteful process; the amount of waste produced is small in comparison to the quantities of material used. However, wet concrete waste is alkaline and hazardous. Traditionally this waste has been disposed of to landfill. Economic and environmental pressures make landfill an unsustainable option.

Ready-Mixed Concrete Plant Waste is Hazardous

Ready-mixed concrete plant waste has a pH of typically 11.5 or higher (Table 1). The Environment Agency Special Waste Regulations [7] state that any waste with a pH in excess of 11.5 is corrosive (and is therefore hazardous). The active status of waste from concrete plants is acknowledged in the landfill tax regulations. Although hardened concrete waste is classed as inert and qualifies for the lower rate of tax, HM Customs and Excise Notice LFT1 'A general guide to landfill tax', specifically places "concrete plant washings" in the higher tax band [8].

Table 1 Typical chemical analysis of ready-mixed concrete plant waste

PROPERTY	VALUE
Mercury as Hg, dry weight	<0.05 Mg/kg
Arsenic as AS, dry weight	13.97 Mg/kg
Selenium as Se, dry weight	0.41 Mg/kg
pH	**11.83**
Cadmium as Cd, dry weight	<1.70 Mg/kg
Chromium as Cr, dry weight	19.20 Mg/kg
Copper as Cu, dry weight	11.20 Mg/kg
Lead as Pb, dry weight	18.75 Mg/kg
Nickel as Ni, dry weight	16.25 Mg/kg
Zinc as ZN, dry weight	118.80 Mg/kg
Boron as B, hot water soluble, dry weight	1.32 Mg/kg
Cyanide as CH, total dry weight	5.00 Mg/kg
Chloride as CL, water soluble, dry weight	836.17 Mg/kg
Sulfate Total as SO3 by ICP, dry weight	5172.00 Mg/kg

Alkaline substances, including fresh concrete, can cause serious burns to human skin [9].

Water discharged from ready-mixed concrete plants can pollute local watercourses. This can have serious repercussions for the surrounding environment and ecosystems.

CURRENT WASTE MANAGEMENT METHODS IN READY-MIXED CONCRETE PRODUCTION

Description of the traditional method for dealing with waste

Most UK ready-mixed concrete plants have inherited a system for managing waste that dates from an era unaware of environmental pressures and the need to conserve resources.

This system, known as 'washing out', is summarized here (see Figure 2):

1. The empty truck mixer drum is filled with water.
2. The drum is rotated in an effort to wash residual concrete from the interior of the drum.
3. The entire contents of the drum (water and any solids) are discharged into a large pit.
4. Water discharged into the pit is allowed to drain into a separate facility where it may be recovered and recycled. The solids remain in the pit.
5. The pit is emptied periodically – the contents being transferred to a drying out bay.
6. The contents of the drying out bay are disposed of to landfill. The bay is emptied when it is full and when the contents are dry enough to be handled.

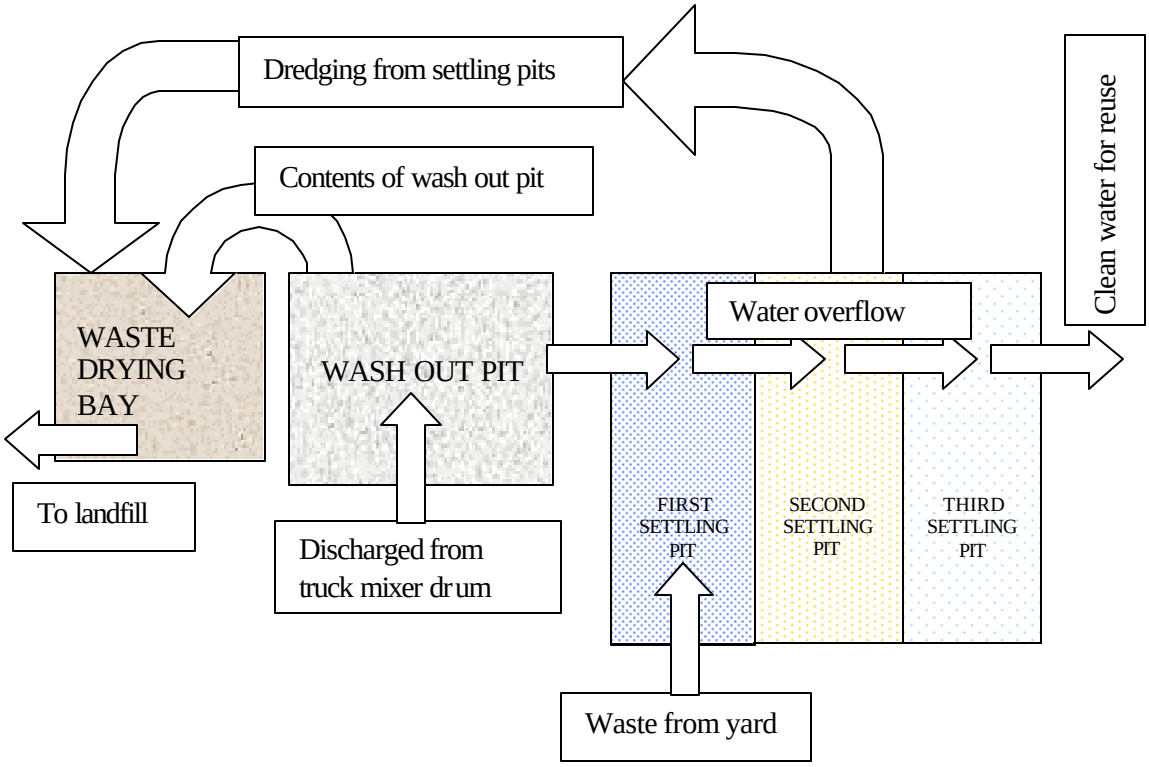

Figure 2 Diagram of traditional method

Washing out the mixer drum is undertaken whenever there is a risk that a residue of fresh concrete may 'set' if it is allowed to remain in the drum. This is usually necessary at the end of each working day.

Although the waste is cementitious, it does not 'set' or harden, as most of the cement has hydrated. The contents of the wash out pit are sludge like, while waste in the drying out bay is similar in consistency to that of a cheesecake base.

The wash out pit, the drying out bay and the settling pits are normally all emptied as one job, all the work being carried out during the course of one working day.

The drying out bay is emptied using a loading shovel and the contents are transported to a landfill site. The contents of the wash out pit are removed to the now empty drying out bay. The settling pits may also be dredged, again using a loading shovel, and the solids placed in the drying out bay.

Recycled Water

Recycling of process water is a common feature of UK ready mixed concrete plants. Water from washing out trucks is recovered from the wash out pit and stored in a settling pit. Run off water from the yard will also drain into this settling pit. The water in the settling pit is allowed to overflow into a second and possibly a third pit. The water in the third pit is relatively clean and free from solids, as most of the solids will have settled at the bottom of the first and second pits. The recovered water may be recycled and used in subsequent batches of concrete, or may be reused to wash out trucks.

Changes in Ready-Mixed Concrete Waste Management

The introduction of the Landfill Tax in October 1996 prompted the UK's ready-mixed concrete industry to evaluate its waste problem. Realising that the waste fell into the standard category and therefore attracted the higher tax rate, producers took the issue seriously. Management of waste – minimizing its occurrence - became a priority. New methods of cleaning mixer drums were sought. The two that have been most widely adopted are 'stoning out' and chemical wash systems. In addition to these new methods of washing mixer truck drums, fresh concrete reclaimers have been installed at a small number of plants.

The ever increasing cost of landfill – and it is clear from the Government's Strategy that these costs are set to increase and landfill will eventually cease to be a viable option – has encouraged ready-mixed concrete companies to continually develop and improve their waste management techniques.

Chemical Wash Out System

This method is relatively new to the UK, ready-mixed concrete companies are increasingly accepting it. The last ten years has seen its introduction, trial, modification and development such that the technique and equipment have been refined and into a usable, effective and efficient system.

A significant amount of research has been published on hydration control admixture, evaluating its practical use, and economic viability [10][11][12][13][14]. The general consensus is that it does work and it is a practical and cost effective system. It has been demonstrated that hydration control admixture, when used appropriately, has no detrimental effect on subsequent batches of concrete.

The procedure involves spraying the truck mixer drum with the admixture and water at the end of the day. In the morning fresh concrete is batched directly into the drum. The amount of water used to 'wash' the drum is typically 300 litres as opposed to 3000 litres. A time

saving of around 18 minutes is gained. The main advantage (Table 2) is the elimination of waste – the residue of concrete and water left in the drum at the end of each working day is simply incorporated into the first batch of the following day.

Table 2 Comparison of current methods of cleaning mixer trucks

Method	Advantages	Disadvantages
Traditional Washing Out	• System already exists at most plants • Easy to operate • Low technology and low maintenance	• Produces a cementitious slurry which is increasingly expensive to dispose of • Requires extensive yard space • Takes a long time to drain waste
Chemical Wash Out	• Requires significant capital investment • Very little space required • Low maintenance	• Relatively high ongoing costs
Stoning Out	• No capital costs • All materials can be reused • Inexpensive	• Requires ground storage • Not suitable after a minority of mixes
Reclaimer	• Little space required • All materials can be reused • Efficient if well managed	• High capital costs • High maintenance costs • Requires good management • Requires a consistently high production plant to work efficiently

Stoning Out

This is a simple and successful method for cleaning concrete truck mixer drums.

Typically two tonnes of coarse aggregate and 200 litres of water are placed in the mixer drum and the mixture brought to the point of discharge four to five times and either placed onto the aggregate stockpile or left in the drum overnight. The next day the aggregate can then be incorporated into a new batch with adjustments made to the mix for the contents of the drum.

Stoning out is the cheapest, simplest way to reduce waste at ready-mixed concrete plants (Table 2), as unlike the chemical wash out system, there is no requirement for new equipment to be installed and maintained and therefore no ongoing admixture costs.

Reclaimers

Washing through a sieve can reclaim the constituent ingredients of fresh concrete. The coarse and fine aggregates can be reclaimed into individual stockpiles and the water and hydrated cement recovered and stored for reuse. Although the principle is simple, the

equipment can be quite complex in design which requires careful management and maintenance, the capital cost is prohibitive for ready-mixed concrete plants (Table 2). This system eliminates wash out waste and has the advantage of reclaiming returned concrete. Plants that have managed to get systems working reliably report savings in waste disposal costs of seventy five per cent.

OBSTACLES IN THE WAY OF WASTE MINIMISATION

The need to change the attitude of ready-mix producers

Recent years have seen waste become a major issue for ready-mixed concrete producers and has been instrumental in initialising a change of attitudes.

The next few years should see a change of emphasis in ready-mixed concrete production with respect to waste management, as a producer will no longer be able to leave waste as an afterthought in the production process. Producers currently put great effort, control and documentation into the technical aspects of concrete production – monitoring the quality of constituent materials and the batched product. A similar level of care, documentation and control of waste – in terms of minimising its creation and its disposal, is required. The Environment Agency, currently novices in monitoring and policing this waste, are gaining expertise and awareness of this waste stream, this in turn will prompt ready-mix companies to improve their performance.

Concrete plants should be properly designed and maintained in order to prevent spillages, unwanted discharges and loss of materials. It seems obvious but it is all too evident at many UK plants that this elementary requirement for effective waste management is ignored. Whilst the UK's main suppliers of ready-mixed concrete have a number of modern, well designed and maintained plants in their portfolio, which they are proud to promote and advertise. For every modern, well designed concrete plant there is an ageing, out of date, badly maintained plant, designed in an era when environmental violations and concerns were given scant consideration.

There is no excuse for a batching plant that spills materials onto the yard floor every time a truck is loaded, or discharges wastewater into the surrounding environment. It is this lax attitude and management that will be punished severely as the Environment Agency gathers experience, expertise and power. It is apparent that there is an economic and commercial advantage in a proactive approach to waste management. Ready-mixed concrete producers should anticipate the impact of these new, increasingly stringent, regulations and by doing so, save money. Savings are to be made through reduced consumption of water, reduced time to wash out and handle waste, reduced waste disposal costs, reduced wastewater discharge costs, reduced build-up in mixer drums and reduced exposure to substantial environmental fines and liabilities.

The attitude of ready-mixed concrete producers needs to change now and the real test of determination will be shown through levels of investment.

The role of regulators in ready-mixed concrete waste

Ready-mixed concrete producers report ambiguity in the requirements to classify their waste. Once the waste has been dried does it represent the same hazard as waste in the wet condition? Does the dried waste require different handling to the wet waste? Producers find that the response of the Environment Agency varies between regions and between plants.

Integrated Planning Pollution and Control (IPPC) is designed to 'reduce pollution by means of integrated processes based on the application of best available techniques' [3]. The IPPC regime is one of the key levers for change identified by the government in Waste Strategy 2000 and will require that waste be recovered unless technically and economically impossible.

The stated primary goal of IPPC "is to achieve integrated prevention and control of pollution in order to secure a high level of protection of the environment taken as a whole." [15]. The intention is to move away from an approach based on "end-of-pipe" technology (i.e. reacting to pollution once it occurs), and adopt an approach where environmental considerations are given greater priority at the design of an installation [16].

The IPPC regime will limit the impacts of concrete batching plants, as it requires the protection of the soil, air and water and the restoration of the site to a clean condition on closure.

Plant Design

Many of the UK's existing ready-mixed concrete batching plants are constrained by their size and locality. Ready-mixed concrete has a very short shelf life, and plants tend to be located within one hours travelling time of customers. Plants are often therefore located in or near urban areas, with associated planning restrictions and constraints. The economics of ready-mixed concrete production do not promote high capital spending. A large proportion of plants were designed and constructed many years ago, and require significant investment to enable effective waste minimisation. However, new, modern plants are greatly improved. It is felt that further advancements in concrete production will be sought and adopted. It seems certain that future years will see the production of ready-mixed concrete become a waste free process.

THE FUTURE

Achieving Waste Minimisation and Reuse

Disposing of waste from ready-mixed concrete plants to landfill is now more expensive and more tightly controlled. These costs and controls will become more prohibitive as disposal resources diminish. Discharges of wastewater not only requires a costly permit, but also opens itself to the possibility of fines for breaching permitted levels.

Therefore there is a need to identify a production process which:

1. Minimises the creation of wet concrete waste

2. Reuses constituent materials

Encouraged by initiatives such as the landfill tax, UK ready-mixed concrete manufacturers have already taken steps to minimise the amount of waste they produce. These methods, including the use of chemical admixtures to wash out, recycling wash out water and the use of concrete reclaimers, have reduced substantially the amount of ready-mixed concrete waste being sent to landfill.

However, all of these methods and operations still result in the creation of a quantity of waste that is not reused or recycled at the concrete batching plant. It is current practice, therefore, to dispose of this waste to landfill.

A zero waste production process is already possible. As Huat [10], has recognised, a combination of chemical wash out and positive reuse of slurry solids waste, for example as sub-grade material for the construction of roads, eliminates waste from ready-mixed concrete production.

It would be preferable to adopt a system of waste management that enables the concrete plant to become totally self contained. As soon as a product, in this case waste, has to be transported from the plant to another location, the costs increase dramatically. In the spirit of the waste hierarchy (Figure 1) and BPEO, therefore, a truly efficient concrete plant would minimise waste by adopting a chemical wash out, stoning out or reclaimer system to wash out trucks. This combined with management practices to limit the amount of returned concrete and a system to recycle water will satisfy the priority of minimising waste. The inevitable, albeit reduced, waste which does arise, would then been reused in a process while remaining on the concrete plant site. This can be achieved by manufacturing a product at the plant that reuses the waste. It seems reasonable to promote the controlled reuse of ready-mixed concrete plant waste in selected concrete mixes, including foamed concrete. There are a number of technical issues that need to be addressed when considering reusing concrete plant process waste in fresh batches, however research is underway to investigate and quantify these factors [17][18][19].

CONCLUSION

Most ready-mixed concrete producers strive to improve their materials reuse and recycling capabilities for financial benefit, however the governments 'Waste Strategy 2000' has given greater emphasis on reducing the waste that is created. This initiative has assisted the ready-mixed concrete producers in accelerating their search for improved methods of waste reduction.

As the cost of disposing of waste becomes more expensive, methods of reusing and recycling waste previously thought to be uneconomic will require revisiting.

It is hoped that the experiences, discussed in this paper, of ready-mixed concrete producers will offer guidance, by example, of the strategy that has been implemented by one sector of the UK industry.

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