Creating markets for recycled resources

Waste Tyres Case Study

Bryn Posteg: Baled tyre substitution of aggregate for landfill sites

Product:	Baled tyres as landfill leachate layer
Material:	Waste whole tyres
Application:	Bound
Project Type:	Barrier
Location:	Wales
Date:	Current
Specification:	The use of baled used tyres as a substitute for primary aggregate in the construction of a Municipal Solid Waste landfill site.

Waste Tyres Case Study

Overview

Waste tyres can be used as a substitute for aggregate and the product is known as Used Tyre Derived Aggregate Replacement (UTDAR). Potters Waste Management, at their Bryn Posteg landfill site in Wales, use baled tyres as an UTDAR for the base of their landfill site. The site is licensed for receipt of Municipal Solid Waste (MSW) and, together with the local community, is very "environmentally aware" and eager to be a "carbon neutral" zone.

The tyres are usually received in the unbaled form and are delivered as road freight. They are baled on site. The bales are positioned at the bottom of the landfill cell by the use of heavy plant and machinery, as shown in Figure 1.

Source: Potters Waste Management

Fig. 1: Landfill cell construction with baled tyres.

The bales are very stable and can withstand the load of the plant and machinery typically found in a landfill site. Furthermore, the deformation of the bales is such that even if the retaining wire strands fail, the bales do not catastrophically expand and only show a very small increase in volume.

The advantages of using tyres as an aggregate substitute in landfill cell construction are:

- Used tyres can be safely used to replace primary aggregate raw material
- The process offers a beneficial use for waste tyres
- The operation is economically advantageous to the operators
- Baled tyres are very easy to position in a landfill cell
- Bales can be used for other temporary constructions around the site.

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Technical Details

Description	Units
Size of bale	1.5 X 1.2 X 0.7m
Weight of bale	0.75-0.8 tonnes
Bulk volume of bale	1.26 m^3
Bulk density of bale	0.64t/m^3
Approximate number of tyres per bale	100
Approximate number bales used	2,500
Approximate area covered by bales	4,000m^2
Approximate weight of total tyres used	1,600 tonnes
Approximate number of total tyres used	250,000
Permeability (bale)	0.14-0.04m/sec
Permeability (80-10 mm coarse gravel)	0.1 m/sec
Porosity of bale	42-55%
Porosity of aggregate (coarse gravel)	13-25%
Aggregate equivalence	300 mm
Binder strand material	Hot dip galvanised high carbon wire
Binder strand diameter	4 mm
Binder strand tensile strength	150-170 N/mm^2

Background

Traditionally, aggregate has been used for the base of the leachate layer in the construction of a landfill cell. The thickness of aggregate is required to be between 300 and 500mm and at most sites the aggregate has to be brought in. The use of primary aggregate is being discouraged as it is a waste of a primary natural resource; furthermore, as an incentive to reduce its use still further, an aggregate levy tax of £1.60 per tonne has been imposed. This came into force in April 2002 and has not been changed since. Meanwhile the Landfill Tax in 2006 is £21 per tonne for active waste and this is on a £3 per annum escalator.

It is estimated that approximately 120 million waste tyres are put into landfill annually, but after July 2006, this practice will be prohibited under the EU Council Directive on landfill(1).

However, waste tyres have been shown to offer an excellent alternative to aggregate and, where permitted by the Environment Agency, it is possible to use them in the construction of a landfill cell. In October 2005 NISP(2) reported that the likely domestic consumption of used tyres as a substitute for aggregate in 2005 was 59,000 tonnes. The tyres can be used in three forms; whole tyres laid in a herring bone pattern, shredded tyres and baled tyres. However, certain performance criteria need to be met by the tyre layer.

The Landfill Directive[1] prescribes the regulations with which landfill sites must comply, and one of the key features is the thickness of gravel. The Directive requires an "equivalence" of 500mm thickness drainage media assumed as part of the ground water risk assessment, although the Waste Management Licensing Regulations only require 300mm thickness. This level of performance can be met by a barrier layer constructed from tyres.

A 300 mm equivalence can be achieved with whole tyres being hand placed in a herring bone pattern to a depth of about 1.4 metres, but if 500 mm equivalence is required, the barrier would need to be about 2.3 metres deep[2] and would severely limit the mode of tyre utilisation. This thickness is considered to be impractical and wholly unsafe[2].

At the other extreme is the use of tyre shred. This has been the subject of some discussion, since the Landfill Directive will prohibit the disposal of tyres in landfill during 2006 and it was initially interpreted that all tyre shred would also be prohibited. However, it has been agreed that the use of tyre shred for cell construction will still be permitted on a case by case basis. Furthermore, it is the view of the HM Customs and Excise[3] that tyres brought onto landfill sites for use in cell construction will not be liable to Landfill Tax. However, permission must be obtained for the Environment Agency to use tyres in cell construction.

The use of tyre shred in a landfill site has been documented[2] in another case study based on the Roxby landfill site and an extensive a cost comparison between using aggregate, whole tyres and UTDAR (Used Tyre Derived Aggregate Replacement) has been made. It is concluded that total site savings of £53,113 can be made by using whole tyres and savings of £34,020 can be made using tyre shred, compared with using approximately 4,480 tonnes of primary aggregate. There are also other savings to be made from reduced transport costs and other environmental impacts associated with transport.

Figure 2 shows the substitution of primary aggregate by tyres shred at Roxby.

Source: NISP

Fig. 2: UTDAR shred being used at Roxby

The third option for using waste tyres in landfill is to construct the cell using bales. This has been successfully demonstrated by Potters Waste Management in their landfill cells at Bryn Posteg Landfill site, Tylwch Road, Llanidoes, Powys, Wales SY18 6JJ. Figure 3 shows one of the cells at Bryn Posteg during construction.

Source: Potters Waste Management

Fig. 3: Baled tyres used in cell construction at Bryn Posteg

Traditional landfill cell construction at Bryn Posteg would require between 300 and 500 mm of aggregate to be transported to the site, where time and effort would also be put into placing and grading it out. There can also be a supplementary herringbone assembly of pipework to assist leachate drainage.

As an example of an aggregate based cell construction, Figure 4 shows a typical gravel base in the area of the leachate sump.

Source: Potters Waste Management

Fig. 4: A conventional aggregate base in a landfill cell

However, the Bryn Posteg landfill site has been using baled tyres as an aggregate substitute for some time and the site's current owners, Potters Waste Management, are continuing to do so. This case study focuses on the use of baled tyres at the Bryn Posteg site.

In the past, Bryn Posteg has also used whole uncompressed tyres in cell construction, but it took five men between 4 and 6 weeks to lay the tyres and construct the cell. The assembly was very time consuming and unpleasant for the operatives.

Specification, Quality Assurance and Design

Landfill operating permit

Bryn Posteg is only licensed to landfill Municipal Solid Waste (MSW) and every week it receives between 1,000 and 2,000 tonnes of refuse from Powys and Ceredigion County Councils. The lower tonnage is typical of winter receipts whilst the higher is peak summer season and is attributed to tourism and increased gardening activities. There is no facility for hazardous waste or security disposal. Some of the MSW receipts, such as plastics and metal, are suitable for further reclamation and these are used as backloads for some of the vehicles delivering tyres.

Cell construction

The natural geology of Bryn Posteg is boulder clay and the land is of little current value other than for agricultural grazing. Cells at the site are constructed using a 1000mm layer of clay as a geological barrier onto which is laid a fully impermeable GeoSynthetic Clay Liner (GSCL). This liner comprises two fabric sheets between which is a layer of bentonite clay. Bentonite clay is well known for its absorbing and swelling characteristics and is used in the creation and repair of ponds and other waterways; it is also used in babies' nappies. The preferred bentonite clay for landfill applications is sodium bentonite, as on exposure to water it will swell up to 15 times its dry volume and retain about ten times its volume of water. Calcium bentonite does not swell as much and is not used in landfill cell construction.

A protective 2mm thick sheet of high density polyethylene (HDPE) is applied on top of the GSCL and acts as another impermeable membrane. The sheet is fully welded and has a very high inspection level to ensure the welds are continuous. The HDPE is then covered with a protective permeable layer to minimise the risk of the sheet being punctured when other materials are placed on top. Finally, a single layer of baled tyres is placed on the barrier layer. The cell is then suitable for receiving licensed and landfillable waste material. This layer replaces the aggregate normally used in cell assembly.

The cell has a 1:50 fall off to a sump, where the leachate is collected and processed through a biological treatment plant prior to discharge to sewers.

Tyre bales are used as a replacement for aggregate only at the base of the cell, the area of which is approximately 4,000m^2; this requires 2,500 bales of approximate size 1500mm x 1200mm X 700mm high. Bales are not used up the cell sides, which are constructed using conventional cell assemblies. Figure 5 shows baled tyres being placed onto the HDPE sheet in the base of a cell. The sheet is also positioned on the side of the cell, where it is retained by other loose tyres.

Source: Potters Waste Management

Fig. 5: Tyre bales being placed in the cell base

The heavy machinery used in placing the bales is based on equipment designed for use in the forestry industry. Unlike loose tyre cell construction, baled tyres provide a base onto which heavy machinery can be easily and safely driven, as can be seen in Figure 5. Being able to use the bales as a working platform to continue the cell assembly significantly reduces the risk of damaging the HDPE membrane and helps keep the integrity of the cell intact.

The cell, shown in Figure 6, is being constructed during the winter of 2005/6 and will take between 12 and 16 weeks to construct and will hopefully be active for about three years.

Source: Oakdene Hollins Ltd

Fig. 6: The new MSW cell under construction

Baled tyre porosity and permeability

Important criteria in landfill cell assembly include the porosity and permeability of the base; any substitute for aggregate must have equivalent performances. Studies conducted by HR Wallingford[4] have shown that tyre bale porosity is comparable with that of aggregates such as gravel. Using bales of very similar construction to those employed at Bryn Posteg, they showed that tyre bales have an effective porosity of between 47 and 55% for a small bale and 42 to 50% for a large bale; this compares with a range between 13 and 25% for coarse gravel. “Effective porosity” is defined as the amount of interconnected pore space available for fluid transmission. However, it can be expected that the porosity of bales will decrease with the influx of sediments into its structure.

Also of importance is the permeability of the bale; this is a measure of the ability of a fluid to pass through the structure and it has been shown by HR Wallingford[4] that this is very similar to that for gravel or very coarse sand. Trials were conducted with bales of similar construction to those used at Bryn Posteg. The typical permeability of a tyre bale is between 0.14 and 0.04m/sec depending on the orientation and geometry of the bale, as shown in Table 1.

Table 1: Comparison of tyre bale permeability by geometry.

Bale number	Length (metres	Height (metres)	Width (metres)	Permeability (length wise axis) m/sec	Permeability (heightwise axis) m/sec
1	1.38	0.65	0.61	0.019	0.19
6	1.54	0.7	0.55	0.0443	0.09
9	1.06	0.66	0.37	0.0533	0.13

Source HR Wallingford [(4)]

For comparison, the permeability of gravel (80-10mm) was found to be 0.10 m/sec and this is comparable with that found for the permeability of tyre bales in their heightwise axis. For further comparison, very coarse sand is approximately 0.01m/sec.

It can therefore be concluded that tyre bales have very similar permeability to gravel or very coarse sand. Despite the large size of the tyres, they have a similar surface area and create a long flow length. As would be expected, the permeability is inversely proportional to the path length, so the longer the path, the less permeable the assembly becomes. However, as would be expected from further consideration of the permeability concept, the orientation of bales also affects its porosity. When the pathway is long, the tyre rims act as obstacles creating a long flow path and reduce the permeability of the structure. However, when the bale axis is smaller, the path length is also reduced, resulting in an increased permeability, as shown in Table 1.

From these data, it has been shown that the performance of a 700mm thick baled tyre assembly can be considered equivalent to approximately 300mm of 20-40 stone gravel.

Baling

Potters Waste Management specify that tyres for use in baling should be with rim diameters of between 15 and 18 inches; this covers virtually all car and most 4X4 vehicle tyres. Baling is carried out on site at Bryn Posteg.

The size of the bale is determined by the chamber size of the baler and the length of the wrapping wires or straps. About 100 tyres are placed into the bale chamber in a herringbone pattern, as shown in Figure 7.

Source: Potters Waste Management

Fig. 7: Loading the baler

The hydraulic compactor compresses the tyres with a load of about 65 tonnes pressure for 10 to 20 seconds; this deforms the tyres into a rectangular block measuring approximately 1500mm X 1200mm X 700mm and weighing about 0.75 to 0.8 tonnes. While in the press, the compressed tyre block is 'baled' by binding it together with five 4-metre long bands of 4mm thick hot-dip galvanized high tensile high carbon wire, as shown in Figure 8.

Source: Potters Waste Management

Fig. 8: A completed bale in the press

These wires have a tensile strength of 150 to 170N/mm^2. It is believed that other balers also use stainless steel wires. The ends of the wire are joined together using an "easy-to-tie" design, as shown in Figure 9.

Source: Oakdene Hollins Ltd

Fig. 9: Wire connection ends

After compression, the bales are usually dimensionally very stable, as shown in Figure 10.

Source: Potters Waste Management Ltd

Fig. 10: A single, stable tyre bale

After the tyres have been baled, they are stacked and stored until required for further use in either cell or wall construction, as shown in Figure 11.

Source: Oakdene Hollins Ltd

Fig 11: Baled tyres awaiting use.

Bales safety

Concern has been raised about the risk of baled tyres bursting apart if the baler strands fail. It has been confirmed by trials that even when the strands do fail, the tyres do not explosively release their compressed energy. Strand-released bales have been shown to only expand by a few centimetres over an 18 month duration[(5)]. This is equivalent to an expansion of about 5%.

The long term stability of the retaining wires has not been fully clarified, but it has been shown that they are very stable for the period over which they would be stored prior to use and used in an open landfill site. Once the bales have been installed in the landfill cell and MSW deposited on top, they are structurally sound. Unless the wire strands are mechanically damaged while the landfill cell is in use, they will last longer than the operating lifetime of the cell.

In the case of Bryn Posteg, the full cell will be about 30 metres deep, so the bales will be extremely well compacted. The compressive forces exerted on tyres in landfill sites have been the studied elsewhere[(6,7)] but predominantly on unbaled tyres. With a waste height of 5 metres, the tyres are exposed to a load of about 40kPa, whilst if the waste depth is increased to 75 metres, the load increases to about 600kPa. With a 5 metre MSW header, the tyre volume is decreased by 70%, whilst at 75 metres, they are compressed by 87%. As the tyres become more compressed, the porosity decreases, as does their permeability.

Unlike unbaled tyre barrier assemblies, baled tyres offer a safe surface onto which heavy machinery can be driven. However, when the cell is being filled with MSW, it is usual for the site's heavy refuse moving plant to use the refuse for building a feeder roadway onto the exposed bales on the cell base. This enhances the stability of the structure. Where unbaled tyre assemblies are used, this practice is essential. The inherent instability of the unbaled barrier layer was considered to have such a level of risk associated with it that alternative options should be considered.

Technical Benefits

The benefits of using tyres as a direct replacement for aggregate are shown elsewhere. From a technical aspect, benefits are gained in using baled tyres by way of using a stable leachate layer onto which heavy plant and machinery can safely operate. This is not the case with loose tyre assemblies.

Secondly, the bales are constructed in a consistent and known manner, so their size and performance are established prior to installation. This is not the case with tyre shred, where thickness monitoring is required to ensure an adequate layer.

Thirdly, the bales are considered easier to handle and locate in the cell than is shred.

Cost Benefits

Cost benefits derived from using baled tyres as a replacement for aggregate can be only estimated, as much of the information is commercially sensitive. Since Bryn Posteg uses only one layer of baled tyres, it can be assumed it is replacing a 300mm depth of aggregate.

Currently Potters Waste Management charge about £30 per tonne for tyres, or approximately 25p per tyre. In comparison, the tyre baling process costs about £15 per tonne, or £12 per bale.

For the construction of a 4,000m^2 base to the cell, using an aggregate depth of 300mm will require approximately 2,160 tonnes of aggregate, at a total cost (including Aggregate Levy, but excluding transport) of about £18,576.

Transport costs for bulk material can be estimated at about £0.08 per tonne per mile. For the delivery of 2,160 tonnes of aggregate, this would be an estimated £172.8 per mile.

In comparison, Bryn Posteg receives an average of £30 per tonne for tyres; the 4,000m^2 base requires approximately 2,000 tonnes of tyres, baled into 2,500 units. The income obtained from tyre receipts is approximately £60,000, whilst baling costs are an estimated £30,000. Transport costs are normally met by the tyre supplier, so no expenditure is incurred by Bryn Posteg on the delivery of tyres. By using tyres as a substitute for primary aggregate, Bryn Posteg makes a net gain of approximately £30,000, excluding the costs incurred by aggregate usage.

Hence, it can be estimated that the use of baled tyres saves the Bryn Posteg landfill site in excess of £48,500 plus transport costs for the aggregate. For comparative purposes only, if it is assumed the delivery distance of the aggregate is 40 miles, the total transport costs will be almost £7,000, so total savings would be in the region of £56,000.

Environmental Benefits

Benefits of using UTDAR

Used Tyre Derived Aggregate Replacement (UTDAR) offers many opportunities for improving environmental issues relating to landfill. Firstly, the use of tyres in the barrier construction reduces the industry's dependence on primary aggregate and removes the aggregate levy tax of £1.60 per tonne. Secondly, the use of tyres as a construction material offers an acceptable, stable and benign route for the disposal of a significant number of waste tyres. Thirdly, because of significant differences in the bulk density of tyres and aggregate, the net tonnage per unit area of cell is reduced by approximately half, even when the differences in permeability are taken into account. This not only reduces the amount of traffic required at the landfill sites, but is also provides secondary benefits such as reduced CO_2 emissions and other wastage of energy[(2)].

The baled tyres are also an integral part of the cell assembly and must remain intact for the duration of any potential adverse environmental impacts by the cell. It is therefore essential that the baled tyres continue to provide their benefits during this period and remain operationally stable. The bales do not offer a major source of pollution within the cell and will remain intact for many years after the cell has been closed. Even if the cell is redeveloped for another use, such is the stability of the bales that there would be no need to extract them prior to the site's change of use, unless it presented a structural hazard in subsequent development of the site.

In the case of Bryn Posteg, aggregate savings amount to approximately 2,160 tonnes for a 4,000m^2 base of a 6,000m^2 landfill cell. This is equivalent to 1,200m^3 of aggregate.

Furthermore, both the Bryn Posteg site and the local area are endeavouring to be a carbon neutral environment and the use of tyres as a substitute for aggregate is positively contributing to this policy.

Supply Chain

Tyre size, sourcing and delivery

Potters Waste Management specify the tyres for baling should be car-sized tyres with rim diameters of between 15 and 18 inches. This includes both car and 4X4 vehicle tyres. During the winter period of 2005/06 the site was receiving approximately 30 tonnes of tyres per week, equivalent to approximately 4,400 tyres, and was baling about 75-80 tonnes per week. The difference between the net delivery tonnage and the baling tonnage was taken up by stockpile depletion.

The Bryn Posteg site receives most of its tyres as unbaled from A J Recycling Ltd of Meigan Wells, Bonarth, Pembrokeshire. A J Recycling Ltd conducts an extensive tyre recycling operation and hand sort their feedstock. Any tyres that are not suitable for specialised recycling (ie retreading etc) are processed for other end uses, and tyres suitable for baling are hand loaded onto curtain trailers for delivery to Bryn Posteg.

Bryn Posteg has also received, through an agent (Black Ram Recycling of Somerset), about 500 bales from Outline Waste Management, near Southampton, Hampshire. These bales were obtained from a large stockpile of approximately 1 million tyres held at the Ashfield Sawmills, Romsey, Hampshire SO51 9NJ.

Other sources include Quarry Tyres Group, who operate in North Wales as well as the Liverpool / Manchester area.

Transport

Suitable tyres are received from collectors covering a wide area. Most sources supply the tyres in the unbaled form; a typical load of such tyres would be between 10 and 15 tonnes and would be up to 1,800 units. For a typical load of about 13 tonnes, it would take about four hours to manually load them into a curtain sided trailer; such loading is done from the rear and the curtain walls used to support the load.

Unloading takes significantly less time: Figure 12 shows the tyres being unloaded using a mechanical back-hoe. A full load can be safely unloaded in a matter of 20 minutes.

Source: Oakdene Hollins Ltd

Fig. 12: Unloading loose tyres

When correctly loaded the loose tyres maintain very good stability, as can be seen in Figure 13, where most of the load has been removed from the trailer, leaving behind a stable load.

Source: Oakdene Hollins Ltd

Fig. 13: Partially unloaded delivery

When tyres have been received in the already baled state, there is an increase in tonnage and subsequent reduction in transport costs per tyre unit. A typical baled tyre load would be slightly less than 25 tonnes, comprising a typical tare of 37 bales, each of approximately 100 tyres. Loading has to be carefully carried out, with two rows of eight bales being stacked two high. Another five bales can be put on top to help stabilise the load. Greater loading is not recommended because the lower bales tend to be pushed outwards. When already baled tyres are supplied, they are delivered on a flat bed articulated lorry rather than a curtain sided trailer; this is because the baled tyres create handling problems and could damage the trailer.

Transport costs are a significant issue with suppliers to Bryn Posteg. To minimise costs, backloading the transport is a very important option. Deliveries of pre-baled stock came from a stockpile of tyres at Romsey, Hampshire and it was even more important that backloading was possible. Llanidloes is in a non-industrial area of Central Wales and opportunities for backloading towards Southampton are limited and seasonal. More localised transport does offer the opportunity of backloading recyclable materials to other processing plants. These are collected at Bryn Posteg and stored in small cells made from walls comprising tyre bales, as seen in Figure 14.

Source: Oakdene Hollins Ltd

Fig. 14: Recyclable material stored in baled tyre cells

Deliveries from A J Recycling Ltd are transported about 60-70 miles from West Wales; backloading is often done with recyclable waste that has been segregated either at the landfill site or by the public at the point of collection.

Regulatory Issues

Used tyres and landfill

Under the EU Directive[(1)] the use of landfill for tyre disposal is to be prohibited after July 2006. However, both tyre shred and whole tyres can be used in cell construction if the Environment Agency permit allows it. Furthermore, tyres used in the engineering construction of the landfill cell are not liable to the Landfill Tax.

Leachate discharges

Bryn Posteg has few problems with meeting the discharge limits. The biggest issue is meeting the ammonia levels, where 200m^3 per day leachate discharge is permitted if the ammonia level is less than 50ppm, but this is reduced to 100m^3 per day if the level increases to 150ppm. The problem arises during winter when there is a high rainfall and the ambient temperature is low; this can result in increased levels of ammonia production within the cells. The problem of heavy metals being released by the tyre bale layer is insignificant compared to the amount already present in the MSW material.

Other environmental aspects

Currently the gases produced in the landfill site are fed into a generator where they produce about 1MW of power. Since the site only requires an average of 100kW to operate, the surplus power is fed into the National Grid. Bryn Posteg is considered a progressive landfill site and is considering feeding gas directly into the national system. To do so requires further processing of the gases to make them acceptable for use in the National Grid system and such processing is being actively pursued. The local community is endeavouring to be a carbon neutral community and Bryn Posteg is contributing to this effort.

Conclusions

The use of baled tyres as a leachate layer in the construction of a landfill site has been shown to be an economically sound proposition. If approximately 100 car-sized tyres are baled into about 1.26m^3, the resultant structure has similar permeability and porosity characteristics to about 300mm of aggregate. Savings made in not using primary aggregate and receipts from the supply of waste tyres can make this use a very attractive option in landfill sites.

However, one of the major factors to be taken into account in the supply chain assessment is that of transport costs.

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