Guide 1: Simple Windrow Facilities

Introduction

The purpose of this guide is to provide a basic introduction to the engineering design of the simplest composting system of all – open windrow slab composting. Further guides will be produced if this guide is well received and proves successful.

The guiding principle of this guide is that the best value from long term infrastructure design of any composting facility will be most likely to obtained by applying a high-quality design, using high quality materials and complying with international codes and standards, wherever applicable.

Clearly, not every compost facility developer will have the ability to finance an entire project at this level of investment from the outset, in which case short term expedients such as the use of lower quality pavement materials such as unbound macadam, protected by materials such as wood chip may be feasible, nevertheless, in the long-term concrete materials based slabs will normally provide the longest service and ultimately the best value.

The actions of compost handling and turning plant places a very high level or abrasion and repetitive loading stresses on the slabs. Wear can be remarkably rapid if materials are not to a high standard of hardness, to resist abrasion during deposition and turning

If pavements are proposed which will be permeable to surface water and the run-off from composting materials, great care must be taken to ensure that these organically polluted leachates do not escape to contaminate watercourses or groundwater. Advance consultation with the environmental regulator is recommended before construction starts, lest such drainage related issues prove unacceptable to the environmental regulator after construction, and additional remedial costs are then incurred as a result.

In some instances, Windrow Composting facilities, especially in wet locations, have required modification to avoid polluting leachate emissions, and some sites have, in rare cases, even been closed by regulators, due to the unacceptably severe impact of leachate pollution.

So, early attention to ensuring acceptably low pavement permeability, appropriate to your site conditions, is a major consideration. However, ensuring that pollutants will not pass through the slab, will mean that in wet climates/seasons, considerable volumes of contaminated run-off (leachate) will then need to be collected and disposed of.

Disposal of leachate may be: -

- to an odour sealed on-site tank, where rainfall is low relative to evaporation potential and the period of production of leachate will be short and replaced by a period of water deficit when the presence of stored water may be very welcome for spraying to raise the water content in the maturing windrows to the required optimum minimum.
- by tankerage to a sewage or private industrial effluent treatment plant.
- to an on-site Leachate Treatment Plant from which discharge may be to a watercourse, or smaller sized rural sewer – subject to provision of suitable consents as administered by the water regulator.

Whatever the leachate disposal route, developers are advised to research the costs and availability of tankerage, and relative merits of on-site tank storage, at an early stage.

Sometimes, a water storage system may be installed beneath the windrow slab. At other sites on-site storage and treatment has been unavoidable due to the local water company being unwilling, or unable, to accept the leachate at public sewage works – or may charge an uneconomic price.

Also, when considering leachate management, we recommend that operators do not underestimate the very high nuisance level of the odour which can be generated by the open storage of highly organically contaminated compost leachate. On occasions the odour produced may be far stronger and more unpleasant than that produced by the whole windrow area, unless early plans incorporate suitable measures.

Sizing your Windrow Slab Area

The first stage is to decide on the area of windrow slab you will need, and there are calculation methods available for this, such as that provided by the Composting Association (UK) for its members.

Each operator will have his own preferred loading rate/unit area of windrow slab, and these lie in the range somewhere in the range from half a tonne per m^2/annum to three times that amount.

Newcomers would do well to assume a loading rate for the production of a high-quality compost of between 0.50 and 0.75 tonne per square metre. Actual loading rates achieved per square metre will vary greatly, due to the very many variables ranging from the types of organic waste being composted, degree of balance of materials in C:N composition, open ventilating texture, temperature/moisture content, effect of mixing, shredding and screening, plus others.

Many composting facility operators start at the lower range of loading intensity, and then by experience and the careful choice of turning and pile depth/shape, attain higher density compost production rates over a period of time.

We suggest a back-to-basics approach whereby the designer considers the route of the compost material through the system, the loss of mass as the compost material progresses through sanitisation and maturations stages, the actions required to be undertaken on the composting materials to achieve the processing requirements, and typical pile shapes/sizes generated by the chosen plant.

Space will be needed for composting processing actions such as:-

- reception and weighing
- storage for suitable C:N ratio mixing (ie green and woody materials)
- shredding and screening areas (considered both before, and after, composting)
- oversize materials
- composting (allow for both sanitisation and maturation stages)
- collection of loads of “contrary materials” ready for off-site disposal
- storage of products ready for sale or onward dispatch
- any bagging plant, and again storage of bagged product.

Higher intensities of windrowing are achieved based upon pile height and geometry. Turning by front end loader, with allowances for access ways between pile, will give one characteristic loading rate, and might be suitable for early site life, whereas as the business grows and throughput tonnage increases, investment funds may then come available for the use of the most slab area/intensity efficient dedicated compost turning machines.

Common low-cost front-end loaders sold for general farm use are the entry level for composting use. These may by used to build long 3m high triangular piles.

The best of such machines can efficiently aerate and turn compost to achieve a completely flat topped and continuous pile up to 5 metres deep over the full slab area – less a turning strip width.

Consideration of all these factors, and possibly a few more site-specific factors, enables the total slab area requirement to be calculated.

Slabs and Drainage Systems

Once that all-important decision has been made on slab area requirements, for the required compost throughput identified in the business plan, it will be necessary to consider the design of composting area slabs, and drainage.

Largely out of sight for most of their useful lives, these all-important elements of any successful composting facility often receive far less thought than the composting processes, or the plant and machinery. However, "getting it wrong" in this area can disrupt composting businesses, entail hefty repair bills, and greatly shorten the life of slabs, and often of the associated drainage as well, with financial consequences at least as severe as in these other areas.

Every slab depends for its design on the assumed ground stiffness and the bearing capacity and the material directly beneath it. Softer ground will require a stronger slab to compensate, and therefore establishing the ground conditions is an essential next step in the windrow slab design process.

Understanding Ground Conditions

Ground conditions vary enormously from undisturbed (high bearing capacity) soils, and well drained granular sub-soils, to the very weakest clays, silts and even peat which may be present.

All too frequently the sites chosen for composting are in poor ground or are low lying and tend to lie below or close to the water table. For slabs on known well-drained virgin ground it may be reasonable to omit a site investigation, but this is rare and requires experienced geotechnical experience to judge (unless the base is hard virgin rock of course!), and not recommended for the inexperienced.

If in doubt at all about the bearing capacity of the ground, and in all cases where any structural loads, beyond simple hardstanding areas, are planned, a **trial pit site investigation** (SI) will be a minimum requirement. Trial pit site investigations will be limited in the depth which can be investigated by:

- the maximum downward reach of the machine bucket,
- and, by health and safety considerations relating to the presence of unsupported excavations.

For heavier building structures, where complex geologies may be present, and where the loads imposed may alter the stress pattern in the underlying strata to some depth, the SI will need to include deeper **trial boreholes** drilled and logged to below the depth of load influence.

For a firm, undisturbed ground bearing, site a trial pit SI may typically be undertaken within one day with a 360-degree excavator. It will and require in resource terms, no more than the presence of an experienced engineer to direct the machine driver, log, and photograph the strata encountered, any water seepages, and any rest water levels and to write a report on his findings. The engineer may also take simple in-situ soils strength (vane & SPT) tests and send characteristic strength samples to a soils laboratory for strength testing. Plate bearing tests may also be undertaken to establish the CBR ("California Bearing Test") load rating of the site sub-soils.

For a poor ground condition site, the same exercise often requires the additional construction of boreholes driven from a specialist rig by a specialist SI Contractor, similarly logged and reported, and may take several days to complete. Again, this work is likely to include off-site laboratory soil strength analysis.

Spending on an adequate SI is expensive, but very important. History is littered by the unfortunate examples of those that thought they understood their ground conditions without the need for further investigation, but didn't, and wasted a great deal of money as a result.

For all but the simplest good ground bearing sites it is recommended the developers employ experienced Design Consultants, Site Investigation Contractors, and Geotechnical Laboratories.

Drainage

Drainage may be required for three purposes: sub-soil drainage (“French drains”), surface water drainage, and compost run-off/leachate drainage.

Sub-soil drainage: The need for sub-soil drainage, and in particular for a permanently drained sub-base below the slab, should be identified by the Site Investigation. In principle sub-base and slab design will be based on the assumption that these materials will at all times be drained. If water is present and the inter-granular spaces are filled with water beneath a slab a “pore water pressure” will develop. Pore water pressure in a soil effectively prevents each particle transferring its load by resting upon its neighbour in free air, and instead each particle begins to “float” in the water around it, greatly reducing the material strength. For this reason, drainage failure is a primary cause of slab failure. Neglect site sub-soil drainage below low-lying sites at your peril!

Sub-soil drainage may be either led to soakaway or discharged to surface water. Similar discharge quality and peak flow requirements will exist for any sub-soil drainage, as will apply to surface water discharges.

Surface Water Drainage: Surface water (S/W) drainage will be required, and the size chosen should be based on estimation of peak storm flow rates. Although a number of simplified methods are available, UK designers are recommended to use the storm data provided by the Institution of Hydrology Flood Estimation Handbook which has been updated to account for recent increases in storm intensity. Other national guides should be used elsewhere.

All S/W drains should be to a minimum nominal diameter of 150 mm and should be laid to a minimum gradient of not less than 1 in 80, although steeper gradients are preferred. The provision of a suitable backfill stone pipe surround to all pipework is essential to avoid pipe ovality and loss of pipe capacity. Nevertheless, where site soils are suitably sized and granular, the backfill may comprise selected excavated material.

It may make economic and environmental sense to store run-off for dry periods when shredded materials will need additional wetting prior to commencement of windrowing or in later sanitisation stages.

Your local Environment Agency (EA) inspector will provide guidance on permissible peak flow rates for discharges to watercourses of clean uncontaminated surface water and should be contacted at the commencement of the surface water drainage design. The EA will require that any discrete surface water discharge to watercourse is licensed, and regularly analysed, and will advise on suitable application terms.

Some manufacturers (eg Hepworth, in the UK) also provide information on pipe size selection and flow calculation.

Access for Cleaning Surface Water Drainage: It is inevitable that the S/W drains within composting facilities will require regular cleaning against the gradual build-up and eventual blockage of pipework with sediment and organic materials.

Although jetting companies nowadays possess remarkably flexible equipment, and can jet successfully through very long pipe runs, this is at a cost. Longer pipe runs between access chambers, also mean longer jetting gang time spent, at the operator’s cost, working to flush out the accumulated materials.

We recommend the Access Points, suitably designed for Jetting Access, and pipe flushing (Washout Points) be provided at a maximum 50 metre spacing interval on pipelines, and at each change of direction in both gravity drains and pressure pipes.

Compost Run-Off/Leachate Drainage: It is normally preferable to keep access road drainage and roof drains separate from contaminated compost area flows, to minimise the quantity of contaminated water generated. The quantity and contaminant strength of this run-off varies enormously between different sites.

MBT composting produces a far stronger “leachate” than green waste, and a careful watch needs to be kept on ammoniacal nitrogen (commonly referred to as just “ammonia”) in this leachate. It is the most difficult contaminant to treat biologically and rapidly without creating process instability. It’s presence in compost leachate can lead to severe treatment plant reliability problems – and resulting odours.

The amount of run-off from open slab composting varies enormously, as does the need to wet screenings in summer. Sites in East Anglia will suffer substantial annual water deficits, whereas sites exist in the west of Ireland exist where they could never hope to store all winter excess leachate flows, and where in the absence of large local sewage treatment plants results in a requirement for on-site leachate treatment.

Estimation of compost run-off leachate strength and volume is site specific, and so variable, that no guidelines or good practice assumptions have yet been established. For slab extensions the best recourse is to monitor existing run-off and then extrapolate. For new facilities and process changes we recommend that operators seek out the experience of other composting site operators running comparable windrow systems, or other composting technologies in their region, or engage experienced consultants with their own data resource derived from previous design work completed.

For compost facilities which produce significant net annual excess leachate, the cost of disposal can be high, as stated in our introduction. We recommend contacting the local Water Service PLC to find out whether (a) they will accept compost run-off discharges to sewer, or if not (b), allow your excess leachate/run-off to be tankered to a suitably licensed Sewage Treatment Works. Expect sewer discharges to be charged at between £0.35/m^3 and £1.25/m^3 dependent upon strength and region, and tankered leachate/run-off cost to be in the range £130 to £240/30,000 gallon tanker load (prices current Spring 2006).

On-site Leachate/Run-Off Treatment

Compost contaminated water can be readily treated biologically, however care is necessary with the possible high ammoniacal nitrogen contaminant levels which may be present.

Normal water treatment (sewage) package plant suppliers usually decline to offer the provision of their systems for compost run-off due to the much higher contaminant (especially worst case ammoniacal nitrogen) concentrations, so bespoke on-site Leachate Treatment Plant designs are usually necessary.

On-site Leachate Treatment should be considered to be a last resort solution for composting sites, and is rarely needed, nevertheless, it may be covered in a later Technical Guide.

Meanwhile, consultants such as Enviros Consulting (www.leachate.co.uk) have been designing leachate treatment plants since 1980 and provide a Compost Facility Design service.

Slab Design

Slab design is normally based upon two or three structural components, which must act together in unison with the soils below. Weaker sub-soils require greater sub-base thicknesses. If any component fails, the whole slab will fail. The components are:-

- sub-base: a compacted granular material (possibly recycled)
- slab or wearing course.

In the case of asphalt designs, in addition to the sub-base a third further layer may be provided below the wearing course, which is known as the base-course.

Many local, national and international construction contractors have gangs available which are highly skilled in specialist slab construction and including asphaltic pavement laying skills.

Sub-base & Base Course*;* The purpose of these layers is to spread the loads from the activities above so that the bearing capacity of the underlying soils is never exceeded.

Wearing Course: This provides the running surface and needs to be capable of withstanding the high degree of scuffing, and scraping forces exerted by compost site plant. Special asphalts have been developed for composting surfaces to withstand not only the abrasion and potential corrosion experienced by compost slabs, but also to retain strength at the prolonged high temperatures beneath compost piles.

Asphalt solutions will normally be cheaper than concrete slab solutions, but just as in highways scheme uses, the longevity of asphalt paving is normally considered to be less than for concrete. Asphalt being a fully flexible pavement is susceptible to localised soft spots and “tramlining” whereas a reinforced concrete pavement is more forgiving as it will span localised sub-standard or saturated areas. The experience of front-end-loader drivers often reflects in the degree of scuffing of asphaltic surfaces.

It is recommended that the designer should obtain cost estimates for both the concrete slab and asphalt alternatives, and then carry out a cost benefit analysis based upon the design life and required duty for both options. Of course, for start-up projects initial capital cost may have to be minimised and in such cases the asphalt option may be selected for initial economy alone.

Corrosion of concrete for compost slabs is not normally a problem, although the designer should obtain worst case leachate quality data and look for the main corrosive substances know to attach Ordinary Portland cement concrete, and to a much lesser extent the pozzolanic OPC replacement mixes readily available in the UK. Of these, the most important corrosive agent is sulphate. However, the most that will be required will be to adjust the concrete mix design in the event that stated threshold values for the mix category are exceeded. The mix design requirements are documented in the Eurocode: European Standard BS EN 206 for concrete design. The Concrete Hardstanding Design Handbook (BP/107-August 2005) is the most current publication (available from the Concrete Bookshop (Tel: 01276 608778) or visit www.concretebookshop.com) and concrete construction advice is also available in the publication titled; “Ground Bearing Concrete Slabs”, by John Knapton, (Thomas Telford, 2003, www.thomasytelford.com).

Concrete slabs

Concrete slabs will normally be reinforced by high yield steel mesh to spread point loads, and to prevent surface cracks. Dowel bars are used to prevent differential vertical movement between bays while allowing the concrete bays both to shrink during curing and to expand and contract with temperature variations. A thin plastic (usually polythene) membrane is laid below the slab which prevents excessive moisture loss on the base of the slab during curing. It also forms a slip plane, allowing large slabs to shrink and move slightly in so doing, relative to the ground beneath, without cracking. The joint details are designed to allow for the necessary degree of movement, and dowel bars which are placed through movement joints will be de-bonded on one end to allow the necessary free movement for the joints to open and close slightly as ambient temperatures change.

The spacing of joints will be related to the degree of movement, and all these requirements are documented within the design codes, and other guidance used by the experienced engineer.

Impact and abrasion resistance of concrete slabs can be enhanced by the addition of fibres, and air entrainment may be used to improve frost damage resistance (particularly when cement to concrete ratio is at a minimum - for economy).

Ensure that care is taken during hot and cold weather to protect from extremes of temperature, and cure each and every bay with care after casting, in accordance with good practice guidelines. Spray-on curing agents are essential and are to be applied approximately 24 hours after casting, and then seal the surface from desiccation. The appearance of a soft white sometimes powdery surface layer should be avoided as it indicates that the concrete surface has dried out before the essential cement to concrete hydration reaction has been able to complete. Long term serviceability depends on good curing and is greatly reduced without suitable curing.

Other hard surfaces:

It is possible to use surfaces other than concrete and asphalt where the base is proven to be sufficiently impermeable. Samples of clay, for instance, should be independently tested in a laboratory for permeability, linked to the geology of the area and a risk assessment undertaken to satisfy the EA. The roller compacted clay base should then be protected by a membrane before hardcore is added on top. The working surface can be finished off with crushed stone and a sacrificial layer of compost to avoid contaminating product with stones. This may be a method of getting started at lower cost but still involves a considerable amount of ‘groundwork’ to justify its use.

Slab Permeability Issues and EA requirements

The EA frequently require a very high degree of groundwater protection below composting sites. They are required to do so, by the EU Groundwater Directive. No engineering structures built at this scale can be made completely impermeable, although we have seen compost facility waste management licences containing this unachievable requirement.

In practice, both concrete and asphalt slabs have finite measurable permeabilities. If the site lies within a groundwater protection zone, and is of high risk of contamination (ie is laid in permeable soils not clays), possibly not far from a groundwater abstraction point, the concrete slab option may be required by the EA. In such circumstances the asphalt option may not be suitable, due to its greater permeability than concrete. Of course, this is only the case provided that high quality joint seals are installed between each slab, and maintained.

If, ultimately, problems are experienced in obtaining EA approval for a particular proposed slab type and jointing solution, it may be beneficial to propose a groundwater risk assessment-based approach. Water engineering consultants are in the provision of this service, and it may be possible to demonstrate a minimal impact risk when groundwater flux and dilution effects are considered.

Slab Joint Seals:

Permanent joint seals are introduced into movement joints in concrete slabs by the insertion of a 20mm by 30mm plastic strip which is glued against the hardened edge of the previously cast bay. These are removed after casting and replaced by sealant supplied by a specialist sealant supplier. All sealant materials must be resistant to biological attack, nevertheless, suitable sealant ranges are available for this duty, and have been developed and rigorously tested for the sewage treatment industry. The specialist sealant manufacturers will provide expert advice on the selection of the most suitable products for this application.

Geotextiles

Geotextiles are used to strengthen sub-bases in very poor low bearing capacity soils and perform an important role as soil separation membranes. Soil separation membranes are used to separate granular base materials from clayey and silty underlying soils. Their purpose is to prevent clay or silt particles entering the interstices of the material above and contaminating it, leading to a progressive loss of strength in the granular material especially under cyclical plant wheel loading.