Cycle Path Surface Options

Technical Information Note No. 8

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Introduction

General requirements for path surface materials for cycle routes would be a smooth riding surface, good drainage properties, long–term durability, low maintenance, use of sustainable and / or recycled materials and suitability to sensitive locations.

Not each path material will suit every location – steep hills, waterlogged sites, poor ground conditions and environmentally sensitive locations each require particularly careful consideration, and often bespoke designs. Also the presence of utilities below the path may influence the choice of surface.

Path surfaces suitable for cyclists may not be suitable to equestrians – dust paths tend to get chewed up by horses, and while cyclists normally prefer a smoother surface, horses fare better with more grip and surface texture. Having a parallel grass path for equestrians might be more useful rather than finding a surface material suitable to both cyclists and equestrians.

Standard surface options

Sustrans default path surface option is a bound surface, either dense bitumen macadam (DBM) or hot rolled asphalt (HRA). For situations where either of these two surface options is not suitable, alternative options are outlined later in this document.

Asphalt is a combination of bitumen and aggregate used for road and path construction. It relies for its strength on the mortar binding together the aggregates (where the mortar is the bitumen + fines + filler). The aggregate content can vary. Asphalts are more difficult to lay than bitmacs (experienced contractors must be used), however they offer advantages for simple cycle path construction: asphalt can be more flexible and therefore tends to deform rather than break should the path base subside or wash out.

Bitumen–macadam (“bitmac”) is the other combination of bitumen and aggregate used in road and path construction. It relies for its strength on the stability of the aggregate throughout its grading. As with asphalt however, the bitumen content can vary and thus bitmacs may have less aggregate than asphalts. DBM (dense bitumen macadam) is one type of this material.

Standard path cross sections are provided in the Design and Construction section of the Sustrans website. Thicknesses of each layer of the path construction need to be adapted to each individual location.

The bitumen used in making the blacktop can vary slightly in hardness. This is measured in terms of the bitumen “penetration grade”, which is a measure of how deep a standard needle penetrates the hardened bitumen at a standard temperature under a standard pressure. Higher penetration grades (where the needle penetrates deeper) are softer and generate a smoother and more forgiving cycle path surface. Typical penetration grades for cycle paths are 160/220 pen (softer) or 100/150 pen (harder). The typical penetration grades for road construction is 100/150 pen. Occasionally harder penetration grades are used for roads, e.g. for nearside lanes on a motorway (trucks).

The other main variant in blacktop design is the aggregate size that is used. Typically well-graded aggregate (i.e. a good size distribution down to fine particles) is used. Larger aggregate sizes make a rougher path surface, which is useful to allow rainwater to trickle through rather than flow across the surface, but may also allow the accumulation of dust with moss / vegetation growth particularly in wooded areas. Smaller aggregate gives a smoother riding surface, which is usually preferred by most cyclists. For HRAs, the percentage aggregate content must be specified when ordering (typical percentages are 55%, 35% and 30%). Standard maximum aggregate sizes are 20mm, 14mm, 10mm and 6mm.

Asphalts and bitmacs are produced according to BS EN 13108 “Bituminous mixtures. Material specifications”. Part 1 of this standard covers DBM, part 4 covers HRA.

This standard also prescribes how to describe a product, as follows:

Type / Aggregate Size / Layer / Penetration grade

The words “surface course” and “binder course” now replace the old terminology of “wearing course” and “base course”. The term “asphaltic concrete” (AC) is used instead of DBM.

Thus:

AC / 20 / Surf / 100/150 is asphaltic concrete (DBM) with 20mm max aggregate size (down to fines) for a surface course with 100/150 penetration grade bitumen.

HRA / 30/10 / Surf / 160/220 is hot rolled asphalt (HRA) with 30% aggregate content (10mm max size) for a surface course with 160/220 penetration grade bitumen.

Alternative surface options

The following table summarises situations where alternatives to the two standard path surface options (DBM and HRA) mentioned above might need to be considered.

Path surface problem	**Possible alternative surfaces (in order of preference)**
Appearance / colour of “blacktop” not suitable	Coloured bitmac / asphalt ‘Clear’ bitmac / asphalt Foamed bitumen products Resin bonded surface treatment Some self-binding surfaces
Sealing of ground is undesirable (creating more impermeable surfaces, additional runoff, etc)	Pathside drains (open or closed) – see standard drawings for details Porous asphalt Some self-binding surfaces Reinforced grass
Sustainable sources are desirable / environmental concerns	Blacktop with recycled contents Foamed bitumen products Some self-binding surfaces Vegetable based binders in blacktop Some self-binding surfaces
No easy access for trucks carrying hot asphalt / extended laying time is needed	Coldlay asphalts / cutback bitumen asphalts Foamed bitumen products Self-binding surfaces

Path surface problem	Possible alternative surfaces (in order of preference)
	Vegetable based binders in blacktop Reinforced grass Forestry paths
Surface too slippery for horses	Provide parallel grass track Roll grit into path surface when it is laid Resin bonded surface treatment
Path close to trees or other reasons that prevent excavation	Realign further from trees No dig construction

These alternatives are described in Appendix A, but should only be considered where the standard options are not suitable. The Appendix covers:

- Coloured surfaces
- Foamed bitumen products
- Porous asphalt
- Asphalt with recycled content
- Asphalt with vegetable binders
- Coldlay asphalt
- Grit rolled into newly laid surface
- Surface dressing: resin bonded / tar spray and chip
- Self-binding surfaces
- Reinforced grass / reinforced sand
- No dig construction

All photos are taken from relevant supplier's web pages or by Sustrans, unless otherwise stated. Examples are included of suppliers and products but these are not exhaustive and the omission of a particular product should not be taken to mean that it is any less suitable.

Whilst sealed surfaces are more expensive to construct, their future maintenance costs are appreciably lower than unsealed surfaces. A comparison of the whole life cost of these two options is included as Appendix B. Based on a whole life comparison, unbound surfaces are at least 50% more expensive than bound surfaces. There are many factors that can accelerate the rate of wear on an unbound path, which would make the cost difference even greater.

Summary

Sustrans' default path surface is machine-laid DBM or HRA, however we recognize that this is not always possible or desirable, for a variety of reasons. This guide aims to provide an overview of suitable alternative path surfaces. It is intended to guide negotiation and decision making, however more detailed guidance must be sought before specifying these materials for construction projects.

Using easily and locally available materials that are easily laid is recommended for all situations. Not every supplier operates across the whole of the UK and Ireland, and transporting path surface materials over any distance tends to be very expensive. The same applies to coloured aggregate that might only be locally available in some regions of the UK.

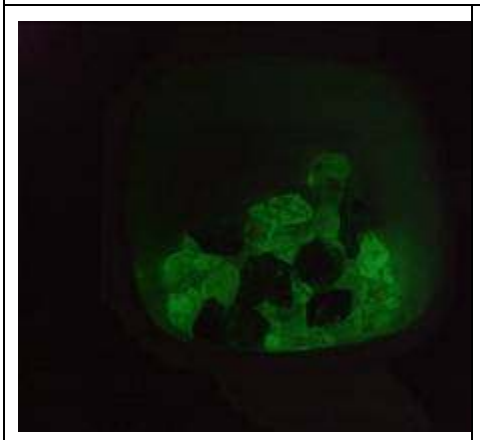
APPENDIX A: Alternative Surface Options

Coloured surfaces	
Description	There are two main methods to create coloured bituminous surfaces: 1. Painting the surface – cheap and easy to apply once the surface is laid, however the colour tends to peel off over time, leaving the typical black / grey colour of normal asphalt surfaces. Once the peeling starts, this becomes unsightly. Slurry seals are the most common paint used. Any colour is possible. This method is not recommended. 2. The asphalt / bitmac is prepared using a clear binder and coloured aggregate. To enhance the finished colour, colour pigments may be added to the mixture, creating a strongly coloured finished product. This will fade over time to the colour of the aggregate used, as bitumen is worn from the riding surface. Possible colours include red, green, brown, golden, yellowish and blue tones. Aggregate Industries produces a green fluorescent aggregate (see picture below). Asphalt made with clear binder and no pigment will show the natural aggregate colour. This method lasts longer.
Benefits	Coloured asphalt has the same ride quality and strength as black / grey asphalt
Suitability	Coloured asphalt is useful for highlighting cycle facilities in urban areas (typically red or green is used). In rural areas, clear or coloured asphalt can be used to blend the path surface with its surroundings (typically brown, red or golden tones)
Suppliers / brands	Most large asphalt suppliers stock clear binders and offer to add colour pigments as required. Coloured aggregate usually needs to be transported long distances, typically only one colour is available from local quarries, depending on local rock types.
Cost	Cost varies depending on the availability of coloured aggregate, and necessary transport. Clear bitumen can be up to double the cost of black bitumen, however it is only a minor constituent of the path surface. Typical material cost is 1 ½ - 2 times that of black/grey asphalt. Laying costs are the same as black asphalt.

Coloured surfaces







Fluorescent aggregate



Coloured asphalt samples

Foamed bitumen products	
Description	Foamed bitumen has been developed as a method of recycling road planings to become a new path surface. Bitumen is foamed to increase its volume, and to more effectively coat aggregate materials. It is then mixed with carefully screened road planings. The bitumen already present in the road planings adds to the strength of the finished product. Foamed bitumen surfaces can be laid cold or hot. Cement or pulverized fuel ash is sometimes added to increase the strength of the surface. The surface needs to be machine laid and rolled and compacted properly to bond.
Benefits	When designed to be laid cold, this material can be stored on site for up to several weeks This material has a high recycling content. Portable mixing plants are available.
Suitability	Material with added cement has a grey (cementious) colour rather than bituminous black Suitable where road planings and foaming plant is available locally. This material is very durable.
Suppliers / brands	Roadstone Recycling produces “Foamix” Ringway produces “Foambase” Tarmac produces “FoamMaster”
Cost	Less or similar to “normal” DBM, depending on the availability of road planings
	

Foamed bitumen products	
	
Foamed bitumen path with added cement.	

Porous asphalt	
Description	Asphalt can be made porous by eliminating finer particles from the aggregate mix. This way voids are created in the asphalt where water can seep through. The underlying path base will need to be made porous as well to allow better drainage, by also eliminating fine particles. This makes the base more difficult to compact properly, and the paver might create ruts while running over the base.
Benefits	Rainwater can seep through the path surface and so pathside drainage provision can be reduced. This is particularly beneficial in dense urban environments, or where drainage would otherwise be difficult.
Suitability	Porous asphalt should not be relied upon in the long term, as the water pathways tend to clog with dust particles and mud, particularly in low trafficked or wooded areas, allowing moss / vegetation growth. High-pressure water jetting cleans the pores somewhat, but never returns to the original state. Porous asphalt has a rougher surface than normal asphalt.
Suppliers / brands	Any supplier can create porous asphalt.
Cost	Similar to normal asphalt.



Porous asphalt at back, normal asphalt at front (picture from supplier)

Porous asphalt	
 Open pores (fresh porous asphalt)	 Clogged pores due to dust and mud

Asphalts with recycled content	
Description	When mixing asphalt there is no real difference in material quality between asphalt made with freshly quarried or asphalt made with recycled aggregates. There are several options: Replace part of the aggregate with road planings. This can be done provided the asphalt supplier adjusts the bitumen content accordingly, and tar-based planings are avoided (they are carcinogenic). Replace quarried aggregate with recycled aggregate – see Technical Information Note 7 on aggregate. Provided aggregate meets the same quality standard, there is no problem. There are many other ideas of mixing recycled or waste products into asphalt. It is advisable to test each one on their individual merit. Using tyre rubber for cycle paths is not recommended, as the rubber does not bond well with the bitumen.
Benefits	Where recycled products are locally available using these materials can save on transport (cost) and reduces quarrying. The finished surface looks and feels the same as asphalt mixed with non-recycled contents.
Suitability	Unless porous asphalt is used, leaching is not normally a problem.
Suppliers / brands	Most asphalt suppliers now have products with recycled contents available.
Cost	Same or similar than the non-recycled product it replaces

Asphalt with vegetable binders	
Description	This is asphalt where the bitumen is replaced by a vegetable-based binder. It is laid as conventional asphalt, however the laying temperature tends to be lower.
Benefits	The oil-based bitumen is avoided, and replaced with a (renewable) plant-based binder. Strength and surface smoothness are the same as with bitumen-based asphalts. The binder is colourless, therefore colour pigments can be added to create any path colour that is wanted, and the aggregate colour will show.
Suitability	Suitable as replacement for any other bound surface.
Suppliers / brands	Colas produces and exclusively lays “Vegecol” Shell produces “Floraphalte”
Cost	Comparable to coloured bituminous surfaces



Vegecol at Basingstoke Canal, Woking



Vegecol at Basingstoke Canal, Woking

Coldlay asphalt	
Description	Coldlay products are designed asphalts for difficult situations, in particular where it is necessary to deal with long delivery routes or where the asphalt needs to be stored on site before laying. Oils are added to the bitumen when the asphalt is batched (called “cutback bitumen”), with the effect that the asphalt remains workable at lower or ambient temperatures. Within days the oil evaporates from the finished surface, so that the asphalt hardens at ambient temperatures.
Benefits	The asphalt can be stored on site for hours or even days, allowing slower construction methods. Larger quantities of asphalt can be delivered to site, rather than calling off small volumes when a section of path is ready.
Suitability	The oils in the cutback bitumen should evaporate over time, so that the finished product is the same as ‘normal’ blacktop. This never works 100%, meaning that the asphalt is softer. Use of the path (especially to heavy vehicles and horses) must be limited until the path has initially hardened. The finished surface looks and feels the same as hot asphalt
Suppliers / brands	Most asphalt suppliers have coldlay / cutback products available. One example is “pathmaster” (by Tarmac), but choose what is available closest to you.
Cost	Comparable to hot asphalt. Transport costs may be less if deliveries to site can be optimised.

Grit rolled into newly laid surface	
Description	After initially laying a bituminous surface approx 1kg / m2 of 3mm grit is sprinkled on the path surface and rolled in using motorised rollers. Excess grit to be swept from path surface and reused at further sections of path.
Benefits	Can be very effective method to slightly alter colour of surface (if coloured grit is used). If not swept properly after application, this surface can be dangerous.
Suitability	This method is particularly useful for generating surface grip that is useful for horses Surplus grit must be swept from the path surface before the path is opened for use by cyclists, walkers and equestrians.
Suppliers / brands	Any aggregate supplier can provide grit
Cost	Depending on colour and quantity used. Less than resin-bonded surface treatment.



Gritted path surface



Detail of gritted surface, wth some loose stones

Surface dressing: resin bonded / tar spray and chip	
Description	This treatment is applied to an existing bound surface, and comprises a thin layer of chippings applied to a surface dressing adhesive. It can also be directly applied to a stone base. It works by gluing small aggregate particles onto an already existing or newly laid asphalt surface or stone base using a resin or a hot sprayed coat of bitumen emulsion, and thus provides the appearance of loose gravel (in the colour of the gravel). The aggregate however is not loose but firmly held in place, and adds grip. This surface treatment is increasingly seen on roads, including on the approach to traffic lights or roundabouts, where increased skid resistance is wanted. Similarly it improves the grip for horses.
Benefits	This can be used to change the colour or grip of an existing (grey) asphalt path. The finished look of the resin bonded surface treatment will depend on the colour of the aggregate used (typically yellows, browns or light greys).
Suitability	This method only works on surfaces that are smooth and even, as the finished surface treatment has only minimal thickness; it can be laid on any sound constructed surface in good condition, however, concrete, steel and timber will require additional preparation. Loose aggregate must be swept from the finished path before opening it to cycle traffic. We have had some problems due to the chippings being laid too thickly in the first place, which should be avoided. If the surface treatment is applied directly to a stone base, then two layers of the surface treatment are required (lower layer 6mm stone, upper layer 3 – 6mm stone). This type of surface has been frequently used in the early days of the NCN. Where an unbound surfacing has been specified, localised use of a resin boded material is recommended on particularly vulnerable sections such as: • where erosion is likely to take place such as on steep slopes, sharp corners, junctions or under bridges, • with difficult drainage or where water is present, • where heavy traffic uses a path • where equestrians use a path. Surface dressing may also be used to increase skid resistance on a gradient or round a bend.
Suppliers / brands	Available form most contractors or aggregate / asphalt suppliers There is a wide variety of products available so best to check with the contractor / supplier what products are recommended to address the specifics of the site. As products vary in nature and application it can be worth using a product the contactor is familiar with so they are practiced in the correct techniques. The specific product is usually the resin and a variety of stone can be

Surface dressing: resin bonded / tar spray and chip	
	used to suit the environment / local availability. For example British Waterways in Scotland use Ayton Products – Aquagrip because their contractor is fully trained in the application of the resin. It is used along with a 6mm Whin stone chip to conform to Historic Scotland Requirements Product such as Prismo Textureflex are used to highlight areas it increase skid resistance and have chip of up to 3mm. These have excellent skid resistance and a range of colours; they tend to be applied as a slurry with the chips already mixed. Resins can be very susceptible to failure if they are laid in the incorrect conditions, usually when it is cold or wet. Always check with the supplier and ensure the contractor works with in the specified temperature and moisture ranges. Fibredec is a specific surface treatment combining bitumen emulsion, chopped glass fibres and aggregate, produced by Colas. Sustrans staff should liaise with the technical department if they are considering using this product.
Cost	Surface dressing may cost between £15 - £35 / m2 (material & labour) in addition to the construction cost of the original asphalt surface, depending on aggregate and supplier used.
 Rhyl Promenade (Roy Spilsbury, CTC)	
	

Self-binding surfaces	
Description	Self-binding gravel paths are versions of the standard limestone dust surface. All options require a 100 – 150mm thick aggregate base. There are many different products available, and most are only marketed regionally – contractors and builder's merchants should have local information available. Self-binding materials may be based on limestone, slate waste or granite waste and others. The material is spread and levelled using a paving machine whilst damp/moist and then compacted using a roller or vibrating plate. The material 'sets' when dry, but not to the same extent as would a concrete or bitmac. The surface remains loose-ish and dusty, but does 'harden' to the point of becoming impermeable in some heavily trafficked projects. Each material is different and therefore it is important to visit a site where the desired material has been laid several years ago to see how it performs.
Benefits	This range of products is suitable for lightly trafficked environmentally sensitive areas. It does not harden quickly after delivery, therefore allowing time to get the material into difficult work sites (it can be stockpiled for a few days on site before laying).
Suitability	Suitable as alternatives to limestone dust surfaces, and where a bound surface is not acceptable. Self-binding surfaces tend not to work very well in areas • where erosion is likely to take place such as on steep slopes, sharp corners, junctions or under bridges, • with difficult drainage or where water is present, • where heavy traffic uses a path • where equestrians use a path. Where this type of surface is chosen, localised use of resin bonded or other sealed surfaces is recommended for such vulnerable sections. The life-cycle of self-binding surfaces tends to be significantly shorter than for bound surfaces (see Appendix B), and there is a continuous problem with overgrowing vegetation, ponding and pothole development, which very quickly make paths unacceptable to many cyclists and walkers (unless repaired quickly). Self-binding path surfaces can be easily repaired. The quality of the surface is sensitive to the workmanship with which it is laid so effort must be put into ensuring a high level of quality control, and it is important to select a contractor with sound experience of the particular product to be used.
Selection of suppliers / brands (not exhaustive)	**Breedon Gravel** (supplied by Breedon Aggregates) – the material laid across Queen Square in Bristol (on route between Temple Meads and Sustrans head office). Golden / amber colour **Cedec** (supplied by Ced Ltd) – can be grey, gold or reddish. Should not

<table>
<tr><th colspan="2">Self-binding surfaces</th></tr>
<tr><td></td><td>be laid too deeply.

Centrac (supplied by Central Construction Services Ltd) – buff colour

Coxwell Gravel - slightly reddish colour. It has been used on various sections of the NCN and is best suited to paths that are level and lightly used.

Finepath (supplied by Tarmac) is made of recycled blast furnace slag, steel slag and secondary dusts, with added colour pigments. There have been frost-heave problems when laid in cold weather, otherwise the material is very frost resistant. This material has been used by British Waterways in the West Midlands (NCN 54)

Goldpath (supplied by builder's merchants) – golden / amber colour.

Hoggin – composed of a well graded mixture of gravel, sand and clay, producing a buff colourer surface.

Toptrec (supplied by Tarmac) - 100% recycled pathway material. It has in the past been used on NCN 5 in Kidsgrove (Staffs), but has now been overlaid with a bituminous surface. Used on NCN 767 in Clackmannanshire as a demonstration of different surfaces.</td></tr>
<tr><td>Cost</td><td>Varies from product to product, but generally slightly cheaper to install than bituminous surfaces. Whole-life costs are generally more expensive than for bituminous surfaces (see Appendix B)</td></tr>
<tr><td colspan="2">
Toptrec (NCN 5 in Staffordshire)</td><td>
Breedon Gravel</td></tr>
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Self-binding surfaces	
Finepath in Birmingham	Finepath (NCN 54 in Wolverhampton)
 Coxwell Gravel (NCN 6, Dunstable)	 Coxwell Gravel
 Goldpath	 Goldpath
 Hoggin	

Reinforced grass / reinforced sand	
Description	Interlocking plastic grids laid on top of a type 1 (or similar) base. The plastic grids are typically around 1 foot square in size, and are connected to each other like puzzle pieces. The grid sections are then filled with soil / sand / gravel, and can be seeded if necessary.
Benefits	Useful for paths along beaches or dunes, or where a grass surface must be maintained. Reinforcing sand or grass allows developing cycle or walking routes where any imported surfacing material would not otherwise be permitted. Reinforced grass / sand / gravel surfaces are permeable. The path adapts very well to ground undulations. The finished surface allows trafficking by light vehicles. This surface can work in areas that are prone to flooding.
Suitability	Suitable for short sections of path where the path needs to blend in completely with nature. Needs regular maintenance (to cut grass or to combat sand / soil erosion), otherwise the path can quickly become buried in sand or overgrown by grass. The surface is not perfectly smooth to cycle over. Heavy or turning vehicles can cause damage, as can livestock hooves. Some products are made from 100% recycled plastic.
Suppliers / brands	“Netpave” has been successfully used by Sustrans for some paths along beaches. Other suppliers are also available. Not all products are well suited to forming bends in the path alignment.
Cost	Approx £20 / m2 on NCN 7 southwest of Glasgow (material and labour)





Reinforced grass / reinforced sand	
	
NCN 7 in Lochwinnoch	Grass surface in Leighton Linslade

'No dig' construction	
Description	In locations where ground conditions prevent excavation for the sub base, such as over tree roots, the path may need to be constructed on the existing ground surface. Interlocking plastic grids are laid on top of the existing ground and are filled with Type 1 sub base; the path is then finished with a base course and porous wearing course.
Benefits	In recognition of the fact that trees are sensitive to disturbance, normal construction methods should not be used within the root protection area. Above ground, no dig, construction avoids tree root severance or soil compaction, which can be seriously detrimental to tree health. The three dimensional cellular confinement system distributes the vertical load on the sub soil and protects tree roots. Only surface vegetation need be removed. The finished surface allows trafficking by light vehicles. These cellular retention systems can be also built up over several layers to construct steep embankment slopes
Suitability	Paths over tree roots should maintain a porous surface, such as reinforced grass, porous asphalt, gravel or block paviors.
Suppliers / brands	**CellWeb** marketed by Geosynthetics Ltd has been used on the Cheshunt Connect2 scheme **Terram Geocell System** is an alternative no dig system.
Cost	*To follow*



Terram Geocells



CellWeb

APPENDIX B: Whole Life Costs Comparison for Paths

Sustrans initially surfaced many off-road sections of the National Cycle Network with unbound limestone or granite dust surfaces, which were considered most economic and more environmentally friendly at the time. Experience over the last 15-20 years or so has shown however that already significant path sections have suffered erosion, rutting, ponding or other damage that make these paths very unattractive and unusable in very wet weather conditions. Annual maintenance requirements for unbound surfaces are generally higher than for bound surfaces.



This Appendix provides an example of how the whole life costs of a path, including construction, routine maintenance and major repairs, varies between different surface types.

Rural Paths

Path construction for bound surface: £30/m² without ancillaries. Path surface lasts 25–30 years, then major repairs and additional wearing course required (approx £15/m²). Annual maintenance cost £1-2/m²/year. Therefore total cost for 50 year life-cycle per m² of path construction (at current cost):

- Initial construction £30
- Repair after 25 yrs £15
- Annual maintenance (50 x £1.50) £75
- **TOTAL £120/m²**

Comparable construction with limestone dust - £25/m² without ancillaries. Path surface lasts 12 years, then requires thorough repair / resurfacing (approx £15/m²). Annual maintenance costs are higher than for bound surfaces, around £2/m²/year. Therefore total cost for 50 year life-cycle per m² of path construction (at current cost):

- Initial construction £25
- Repairs after 12, 25 & 37yrs £45
- Annual maintenance (50 x £2) £100
- **TOTAL £170/m²**

This total could increase considerably if the path wears at a faster rate, possibly needing a complete rebuild after a shorter period. This may be due, for example, to an exposed position, heavy usage, inadequate drainage, under bridges, at junctions, on gradients or use by horses.

Urban Fringe and Urban Paths

Similar comparisons could be demonstrated for urban fringe and urban routes. Where paths are more heavily used, unbound surfaces require proportionally more repair and maintenance than in the above example.

Conclusions

Bulk material consumption for the initial path construction is similar for unbound and bound surfaces; however over a 50 year life-cycle unbound surfaces will require more additional aggregate for repair than bound surfaces.

Based on a whole life comparison, unbound surfaces are at least 50% more expensive than bound surfaces. However, there are many factors that can accelerate the rate of wear on an unbound path, which would make the cost difference even greater.