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concrete flag paving

GUIDE TO THE PROPERTIES, DESIGN, HANDLING, CONSTRUCTION, REINSTATEMENT AND MAINTENANCE OF CONCRETE FLAG PAVEMENTS

Interpave
THE PRECAST CONCRETE PAVING AND KERB ASSOCIATION

www.paving.org.uk

CONCRETE FLAG PAVING

guide to the properties, design, handling, construction, reinstatement and maintenance of concrete flag pavements

EDITION 4

Addendum - April 2022

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Addendum

With the publication of **BS 7533-101:2021** ***Pavements constructed with clay, concrete or natural stone paving units – Part 101: Code of practice for the structural design of pavements using modular paving units***, designers may wish to refer to that standard for the latest advice. Alternatively, the guidance provided by this Interpave document, with its long track record, remains valid.

In 2022, Interpave became a part of MPA Precast, part of the Mineral Products Association.

1 PROPERTIES

Concrete flag paving offers a clean, hardwearing and aesthetically pleasing surface. Flags are produced in a wide range of square or rectangular sizes of different thicknesses, offering a wide choice of patterns. Concrete flag paving is available in a wide variety of colours and textures, enabling it to be used to delineate different functions. Sizes range from 300 x 300 to 900 x 600 mm, offering designers the potential to use elements of a larger scale than block paving.

Applications

Used either on its own or in conjunction with block paving, concrete flag paving provides an attractive surface suitable for:

- pedestrian footways and precincts
- forecourts and entrances to public buildings
- approaches and surrounds to residential and industrial buildings
- areas surrounding shops and offices
- school playgrounds
- public and private gardens
- swimming pool surrounds
- footways where vehicular overrun is unavoidable
- home zones and urban regeneration
- and other areas where a durable external surface is required.

Colours and Finishes

Flags can be finished to produce a variety of surfaces including textured and profiled ground, with or without chamfers. Stable pigments are used to provide a range of permanent colours further increasing designer choice. Flags are also manufactured to reproduce the colour and texture of natural stone paving in various finishes including split, sawn and tooled. They are particularly useful for pedestrian surfaces in historic towns and conservation areas, matching the appearance of stone but with greatly improved stability and slip resistance, providing a cost-effective alternative. Full details of special products and finishes can be obtained from individual Interpave manufacturer Members.

Concrete flag paving is also manufactured with specific textures designed to assist the accessibility of blind and partially sighted people. These units, known as 'tactile' paving, have surfaces incorporating raised blisters or bars and specific colours which warn partially sighted or bind people of approaching hazards or other situations such as at pedestrian crossings, steps, cycle paths and rail platforms. Full details are available in the Interpave brochure *Accessible Paving* which can be downloaded from www.paving.org.uk.

Sizes

Flags can be divided into three main categories: standard, small element and decorative. All but decorative are manufactured to BS 7263 part 1/ BSEN 1339 in standard sizes in controlled factory conditions.

The level and type of pedestrian and vehicular use on a pavement determine the size and thickness of the flag, the selection of laying courses, the jointing materials and the depth of pavement construction below the flag. Guidance on the structural design of Small Element concrete flag pavements for occasional trafficking is available in Section 2. Reinforced flags are also now available which offer superior performance: please seek advice from Interpave Member manufacturers for specific information and recommendations.

The following table gives a guide to the type and thickness of flag which should be used for various applications.

Suitability of flags for various applications

Designation	Nominal Size	Thickness	Pedestrian Only	Vehicular 1	Vehicular 2	Vehicular 3
A	600 x 450	50 or 63	✓	✓	✓63 mm	✗
B	600 x 600	50 or 63	✓	✓	✓63 mm	✗
C	600 x 750	50 or 63	✓	✓63 mm	✗	✗
D	600 x 900	50 or 63	✓	✓	✗	✗
E (small element)	450 x 450	50 or 70	✓	✓	✓70 mm	✓70 mm
F (small element)	400 x 400	50 or 65	✓	✓	✓65 mm	✓65 mm
G (small element)	300 x 300	50 or 60	✓	✓	✓60 mm	✓60 mm

Key:

Vehicular 1 - very occasional use by cars and light mechanical sweepers, e.g. unprotected footways in no parking areas or where overrun is not a problem. These flags can be laid on either a sand or mortar laying course.

Vehicular 2 - footway where vehicles cross to access house driveways. The preferred laying course is sand.

Vehicular 3 - footways where cars and occasional commercial vehicles run over; unprotected pedestrian precincts with about 25 commercial vehicles each day; fire tender access ways. These flags to only be laid on a sand laying course.

Performance

The new European Standard BS EN 1339: 2003, *Concrete Paving Flags - Requirements and Test Methods* has introduced a different approach to the old British Standard that will give specifiers and suppliers more confidence in the use of concrete paving flags. Whereas the BS EN stipulates that the manufactured concrete must conform to a wider range of performance characteristics, determined on actual manufactured concrete paving flags. Additionally, instead of having "one size fits all", all the performance characteristics are classified into classes, which the manufacturer must declare, so that the specifier and supplier has the relevant information needed to make informed selections.

Before any product is launched it is subjected to the rigours of 'Initial Type Testing' which demonstrates conformity to the BS EN for a product family. A family of product types is best described as paving flags manufactured to give a similar surface using the same equipment, process and raw materials, e.g. a paving flag manufactured with a natural river gravel will belong to the same surface family (same performance characteristics) as a paving flag manufactured with crushed granite/limestone. Each manufacturer will declare their definitions of product families when asked.

The continuing conformance of the concrete paving flag to the BS EN is supported by 'Routine Type Testing' and additional measures established under 'Factory Production Control'. The BS EN describes how the performance characteristics are to be assessed with detailed test methods and procedures, as described below. These methods are to be used in all cases of dispute resolution. Other methods can be used routinely to check compliance with the BS EN provided correlation is established with the standard method.

Strength - is a measure of the ability of the concrete paving flag's ability to withstand load. It is determined under laboratory conditions applying bending strength. The paving flag is supported by two parallel and rigid bearers rounded to a radius of 20±1 mm and a load uniformly applied to its length until failure is reached within 45±15 sec. For each flag, the individual strength in MPa is determined by calculation. Both the final breaking load in kN and bending tensile strength in MPa are recorded to check compliance with the BS EN. The number of flags per sample will vary depending on previous production performance assessed statistically by attributes or variables.

Weathering Resistance - is a measure of the ability of the concrete paving flag to withstand weathering where specific conditions exist such as frequent contact of the surfaces with de-icing salt under frost conditions. It can be assessed under laboratory conditions by measuring the amount of spalled material from a surface under the cycle of freezing/thawing action using a de-icing salt solution. Or, if no de-icing salt is used, then the measurement of the porosity by measuring the water absorption of the flag should be used.

Abrasion Resistance - is a measure of the ability of the concrete paving flag to withstand erosion caused by trafficking in service. It is assessed under laboratory conditions by abrading the surface of the flag with a flow of a hard abrasive material while applying a known force. The resulting loss of material from the flag surface is measured by determining the abraded width.

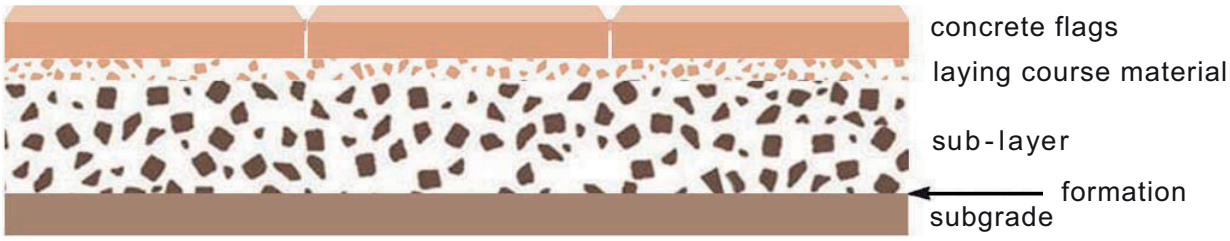
Slip/Skid Resistance - is a measure of the ability of the concrete flag paving laid in service to withstand slipping for pedestrians and skidding for vehicles. The unpolished slip resistance value is determined using a "standard rubber" material attached to a Pendulum Friction Tester and tested under wet conditions. To determine the polished paver value (PPV) for all paving units, BS 7932: 1998 should be used. This standard has formed the basis for the European Test Method DD ENV 12633:2003. The test method measures the slip resistance of the flag paving after it has been synthetically trafficked (or polished) under laboratory conditions to replicate the performance of flag paving during it's life under traffic conditions. For more details please contact Interpave.

Domestic paving

Flags currently manufactured for use in domestic situations are not included in the scope of British and European standards. However, many are manufactured to the requirements of current standards but are outside the dimensions required.

2 STRUCTURAL DESIGN (FLEXIBLE CONSTRUCTION)

This section offers detailed guidance based on BS 7533-8 for the design of flexible pavements surfaced with precast concrete flags and laid on a 30 mm sand laying course with sand filled narrow joints. It applies to pavements subject to occasional overrun by no more than 15 commercial vehicles per day at speeds not exceeding 50 kph (30 mph).



The fundamental objective is the assessment of the thickness of base material to be used beneath precast concrete flags to ensure that the allowable stresses in the paving units or sub-grade are not exceeded. The design of the pavement should be based on the assumptions that the construction conforms to BS 7533-4.

Suitability of flags for various applications

Designation	Nominal Size	Thickness	Pedestrian Only	Vehicular 1	Vehicular 2	Vehicular 3
A	600 x 450	50 or 63	✓	✓	✓63 mm	✗
B	600 x 600	50 or 63	✓	✓	✓63 mm	✗
C	600 x 750	50 or 63	✓	✓63 mm	✗	✗
D	600 x 900	50 or 63	✓	✓	✗	✗
E (small element)	450 x 450	50 or 70	✓	✓	✓70 mm	✓70 mm
F (small element)	400 x 400	50 or 65	✓	✓	✓65 mm	✓65 mm
G (small element)	300 x 300	50 or 60	✓	✓	✓60 mm	✓60 mm

Key:
Vehicular 1 - very occasional use by cars and light mechanical sweepers, e.g. unprotected footways in no parking areas or where overrun is not a problem. These flags can be laid on either a sand or mortar laying course.

Vehicular 2 - footway where vehicles cross to access house driveways. The preferred laying course is sand.

Vehicular 3 - footways where cars and occasional commercial vehicles run over; unprotected pedestrian precincts with about 25 commercial vehicles each day; fire tender access ways. These flags to only be laid on a sand laying course.

STEP 1

The bearing strength of the subgrade should be obtained as this determines the overall thickness of the sub-base. The strength of the subgrade is described as the 'California Bearing Ratio' (CBR). The CBR of the underlying materials may be provided by a site investigation report. If there is no report or the CBR has not been obtained then it may be estimated using the following table:

Estimated CBR values for British soils

Type of subgrade	**Plasticity index**	**CBR per cent**
heavy clay	70	2
	60	2
	50	2
	40	3
silty clay	30	4
sandy clay	20	5
	10	5
silt		1
poorly graded sand		20
well graded sand		40
well graded sandy gravel		60

The following information has been extracted and summarised from BS 7533: Part 2. For sub-base design, the subgrade strength can be estimated using simple field tests (after initial compaction of the trimmed ground) to give the sub-base thickness:

Identification of materials and CBR values using a simple field test

Rock or soil		Simple field test	CBR
Type	**Condition**		
Rock	Hard	Requires mechanical pick for excavation	Above 5%
Sand Gravel	Compact	50mm square peg hard to drive in 150mm	>5%
Clay Sandy clay	Stiff	Cannot be moulded by fingers Need pick for excavation	5%-2%
Clay Sandy clay	Firm	Can be moulded by fingers Need spade for excavation	5%-2%
Sand Silty clay Clayey sand	Loose	Dry lumps easily broken down 50mm square peg driven in easily	2%
Silt Sandy clay Silty clay Clay	Soft	Can easily be moulded by fingers	<2%
Silt Sandy clay Silty clay Clay	Very soft	Exudes between fingers when squeezed	Seek specialist advice
NOTE 1 This table is based on the principles in BS 8103-1. NOTE 2 The CBR of the rock or soil is significantly affected by moisture content			

For loose, soft and very soft materials comprising sand, silt and clay, specialist advice should be sought. The above guidance applies where the water table is 300 mm or more below formation level. Specialist advice should be sought where this is less, standing water is present or there are any doubts about the ground conditions. Any soft spots should be dug out and replaced with good fill or sub-base material and fully compacted. On sites where the CBR varies from place to place then the lowest recorded value should be used.

STEP 2

An evaluation is needed of the total number of commercial vehicles using an area during the design life of the pavement. In the absence of more reliable information, an estimate may be made based on the following table.

Number of commercial vehicles

Location	Commercial vehicles per day
Residential areas	1
Small shopping areas	5
Large shopping areas	10
Precincts and pedestrianised areas	15

For pavements subject to normal vehicle loads, it may be assumed that each commercial vehicle per day is equivalent to one standard axle per day. Otherwise, where the actual traffic mix is known, determine the standard axles per day. The design life for flag pavements is normally a minimum of 20 years.

Vehicle Type	Number of standard axles/commercial vehicle
2 axle rigid	0.34 sa per vehicle
3 axle rigid	1.70 sa per vehicle
4 axle rigid	2.60 sa per vehicle

The number of standard axles using the pavement in its design life can be obtained by multiplying the number of standard axles per day by the required design life.

STEP 3

Determine the sub-base or roadbase thickness. Two thicknesses must be determined - one to prevent the paving flag cracking, the other to prevent overstressing the subgrade. The thicker of the two values is adopted to avoid premature pavement failure. The procedure is as follows:

Select the type of flag to be employed:

Type E 450 x 450 x 70 mm
Type F 400 x 400 x 65 mm
Type G 300 x 300 x 60 mm

Select which of the three types of recommended sub-base or roadbase is to be used:

Type 1
Type 2
CBM

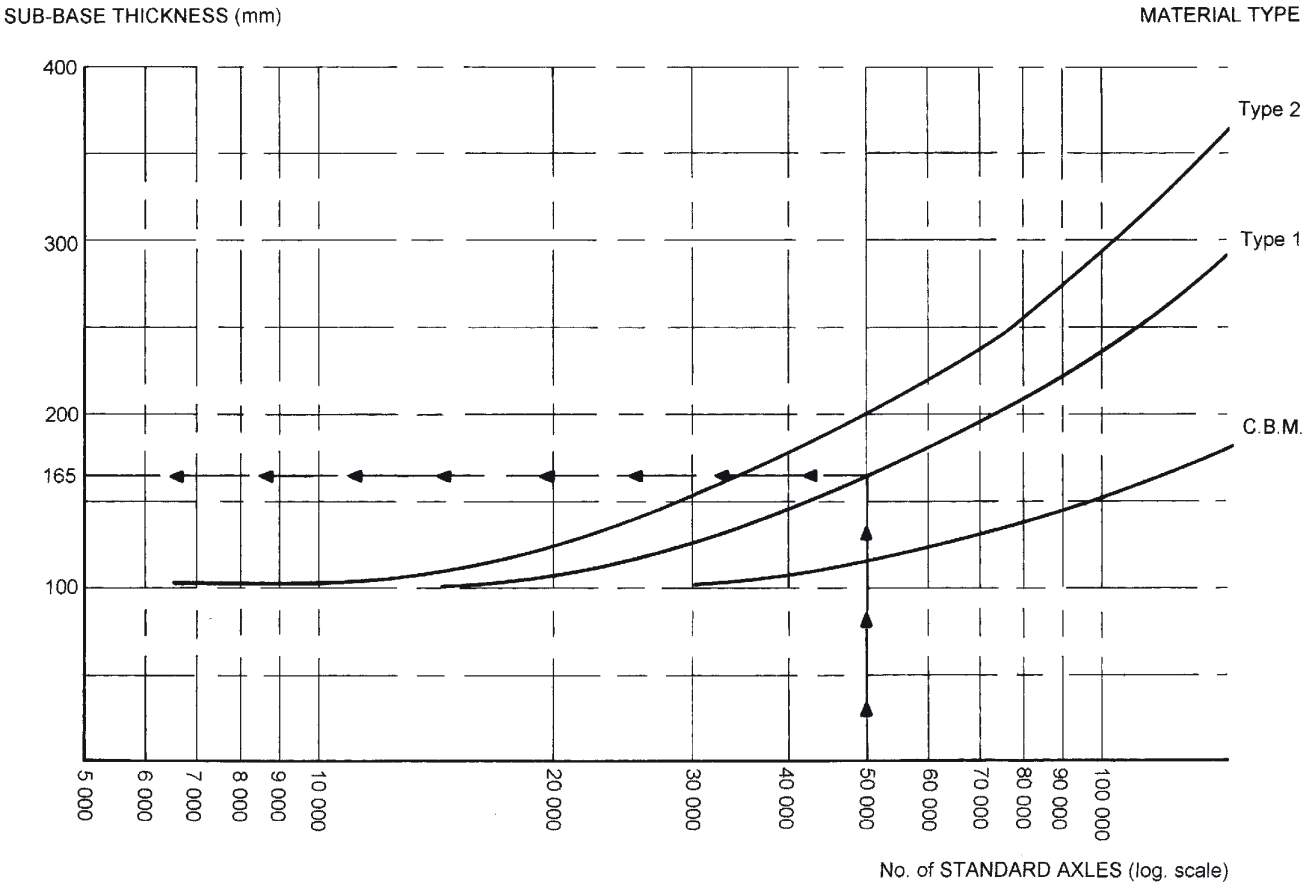
From the number of standard axles evaluated above and the sub-base or roadbase selected use Graph 1 to obtain the sub-base thickness required to prevent overstressing of the paving flag.

From the number of standard axles evaluated above, the CBR of the subgrade and the sub-base or roadbase selected, use either:

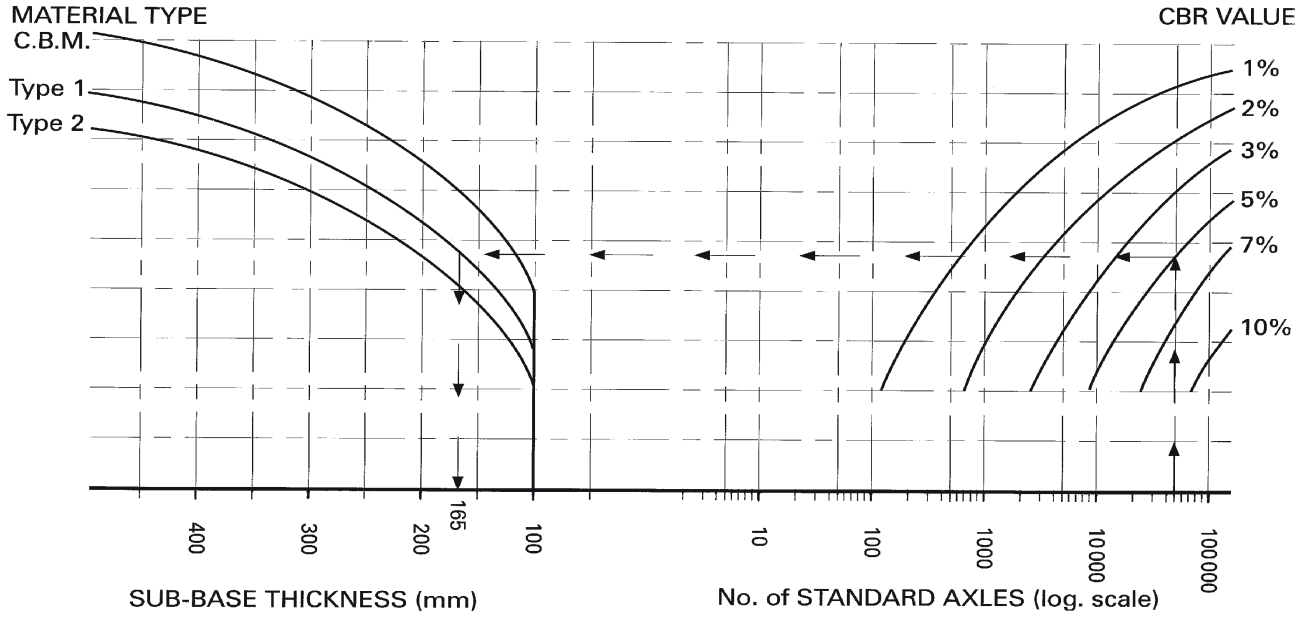
- Graph 2 for Type E (450 x 450 x 70 mm) and Type F (400 x 400 x 65 mm) flags, or
- Graph 3 for Type G (300 x 300 x 60 mm) flags

to obtain the sub-base thickness required to prevent overstressing the subgrade. The greater of the two sub-base thicknesses obtained is adopted as the design thickness.

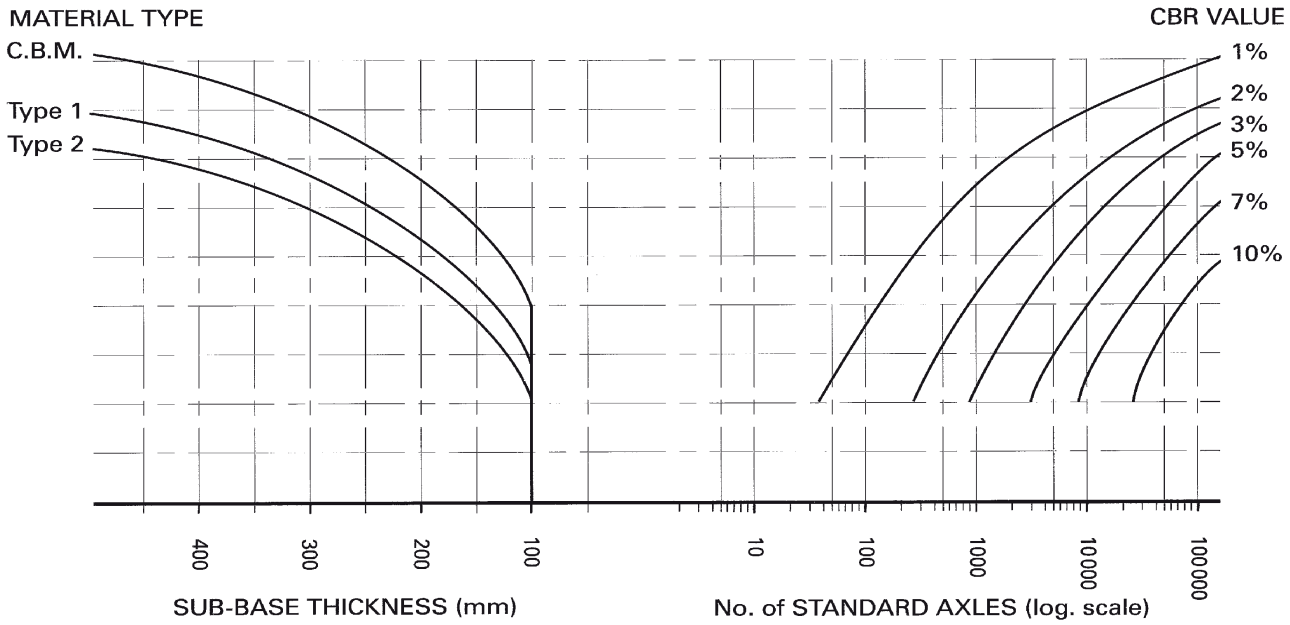
Graph 1; Sub-base thickness to prevent paving flag overstressing



Graph 2; Sub-base thickness to prevent subgrade overstressing [Type E and Type F flags]



Graph 3; Sub-base thickness to prevent subgrade overstressing



A DESIGN EXAMPLE

A pavement in a new shopping centre is to be constructed using Type E (450 mm x 450 mm x 70 mm) paving units. It is estimated that for six days per week there will be eight commercial vehicles per day servicing the shops. Servicing will take place fifty weeks a year over a twenty-year design life. A site investigation indicates the CBR of the subgrade is 3 % and the base material to be used is CBM. Commercial vehicles assumed to be 1 sa.

The total number of standard axles in the 20-year design life:
= 6 x 8 x 50 x 20 = 48 000

From Graph 1 for flag overstressing using CBM material
Base thickness = 120 mm

From Graph 2 for base overstressing using DBM material
Base thickness = 175 mm

The construction thicknesses:

Base CBM	= 175
Laying course material	= 25 mm
Flag	= 450 mm x 450 mm x 70 mm

Design Notes

- The minimum thickness of any sub-base or roadbase material required is 100 mm.
- When using Type 2 material care should be taken in the selection as some Type 2 materials are frost susceptible.
- Construction complies with the procedures outlined in BS 7533:Part 4.
- The laying course sand complies with BS 7533:Part 4.
- The nominal sand thickness is 25 mm.
- The sand moisture content is approximately 5% - 7%.
- The joints are filled with sand complying with BS 7533:Part 4.
- The joint widths are between 2 and 4 mm.

Pavement Overlays

Use BS 7533-8, Annex B to determine the depth of construction. In pedestrian schemes, paving units are often used as an overlay to existing bituminous pavements. If vehicles are to use the area, then it is first necessary to estimate the residual life of the existing pavement to determine the overlay depth needed to give the required design life. The existing pavement should be inspected for surface cracking and rutting and an assessment on the residual life should be made. By using one or both of the factors, the equivalent thickness can be calculated.

The existing construction thickness should be multiplied by the Condition Factors CF 1 and CF2, where applicable. This equivalence value should then be compared with the base design thickness, excluding flag and laying course, obtained by the design method given in this standard.

If the base design thickness exceeds the equivalence value of the existing pavement then the new design is adequate.

If the base design thickness is less than the equivalence value of the existing pavement then the base thickness should be increased.

Where the new base material is different from the existing base material both base thicknesses should be converted to an equivalent thickness of DBM (dense bitumen macadam).

3 HANDLING

This section provides guidance on safe handling of kerbs and flags, and illustrates examples of available equipment. The following guidelines comply with HSE Construction Information *Sheet No 57, Handling Kerbs: Reducing the risk of musculoskeletal disorders (MSDs)*.

Concrete kerbs have been in use for around 70 years and concrete flag paving for even longer. Regulations have been in place for some time to protect workers from risks associated with musculoskeletal disorders and work related upper limb disorders resulting from manual installation of these products. They include the Health and Safety at Work Act, etc., 1974, Manual Handling Operations Regulations 1992 (as amended 2004) and 2007 CDM Regulations. There has been continuing growth in the use of mechanical lifting devices in the UK over recent years.

Some contractors and designers may not be aware of their responsibilities and how to minimize risk. In addition to health and safety considerations, mechanical installation regimes offer greater efficiency than manual handling, saving time and money.

These new guidelines are intended to help with the reduction of risk resulting from installation of highway kerbs and paving flags, and relate to currently available equipment. They do not replace the contractor's obligations to carry out risk assessments in accordance with the Construction (Design and Management) Regulations 2007 and work should be carried out in accordance with all relevant, current legislation.

Health and Safety Considerations:

Precast Concrete Kerbs

Concrete kerbs are generally supplied horizontally laid on pallets.

They can be divided into three categories: BS EN 1340 standard kerbs, BS EN 1340 accessories (e.g. quadrants, angles and radii) and non-BS products (e.g. containment and combined drainage kerbs). BS standard kerbs are 450 - 915mm long. The following weights are for 915mm length straight standard kerbs:

Profile Designation	Weight kg
Half battered HB1	97
Half battered HB2	69
Half battered HB3	42
Splayed SP	64
Bullnosed BN (150x305mm)	100
Bullnosed BN (125x255mm)	70

The weights of other specific products should be provided by the manufacturer. For example, traffic containment kerbs and combined drainage kerbs units can weigh in excess of 250 kg.

Precast Concrete Paving Flags

Each Interpave member has its own method of packaging but it is common for paving flags to be stacked vertically. The majority of packs are supplied palletised, although some are supplied in strapped packs.

Flags can be divided into three main categories: Standard, Small Element and Decorative. Traditionally the range of sizes of flags has remained consistent and the following units are recognised as the British Standard preferred sizes. As a guide to calculating individual weights of different size paving units a density of 2300kg/m^2 is used here.

Designation	Nominal Size mm	Thickness mm	Weight kg
A	600 x 450	50 or 63	32 or 39
B	600 x 600	50 or 63	43 or 52
C	600 x 750	50 or 63	53 or 65
D	600 x 90	50 or 63	64 or 78
E (small element)	450 x 450	50 or 70	23 or 33
F (small element)	400 x 400	50 or 65	19 or 23
G (small element)	300 x 300	50 or 60	11 or 13

Risk Assessment:

The Manual Handling Operations Regulations 1992 (as amended 2004) apply to all construction work. They set out a framework for employers to tackle the risks from manual handling. Under these regulations, if employers cannot avoid manual handling where there is a risk of injury, they must assess their manual handling operations and take steps to reduce the risk of injury to the lowest level reasonably practicable.
Kerb and flag laying by hand, particularly if repetitive, involves a serious risk of injury to those who are doing the work. Therefore employers need to take action to control this risk. When tackling the risk, the best solutions will be those which address all three main hazards: the weight of the kerb or flags; the repetitive nature of the operation; and posture during work. To help find the best solution, the following 'hierarchy of control measures' is suggested. You should try to adopt the solutions nearest the top of the hierarchy first, as these will give the best level of risk control.

Hierarchy Control Measures

- **Elimination** - Eliminate manual lifting of kerbs and flags at the design stage.
- **Total Mechanical** - ensure kerbs and flags are always handled and laid mechanically (e.g. using vacuum devices, mechanical grabs, etc). This is the preferred solution for new build and refurbishment work.
- **Partial Mechanical** - ensure that the maximum amount of the kerb or flag handling process is undertaken mechanically (e.g. using mechanical solutions to get the kerb or flag near its final position). Using smaller/lighter kerbs or flags, or substituting with block paving, or using handling aids will further reduce the risks from any residual manual handling.
- **Manual Handling** - in rare cases where it is not possible to use any of the above solutions, short stretches of kerb and flags may be laid manually. Where this is necessary, workers should be trained in good handling techniques. The use of lighter weight kerbs or devices that allow two people to share the lift will reduce the risk of injury.

Precautions:

All those involved in the specification, manufacture, supply and installation of kerbs and flags can help to reduce the risk from manual handling.

Designers, CDM Co-ordinators and Clients

The design and planning stage should consider:

- Solutions which eliminate repetitive manual handling.
- When kerbs or flags are used they are compatible with mechanical handling solutions.
- Identify the risks during the lifetime of the product including issues relating to maintenance and repair.
- Plan the work to allow the maximum number of kerbs or flags to be laid at one time to realise the economies of scale and promote the practicability of mechanical handling.

Contractors

Contractors need to plan the work to ensure risk is kept to an acceptable level. This may involve the following actions:

- Rethink the phasing of the installation to maximise the number of kerbs or flags being laid at one time.
- Lay direct from the pack or pallet rather than double handling.
- Use mechanical solutions for the handling of non-standard kerb details such as feature kerbs, transition kerbs, drop kerbs, quadrants (cheeses) and radius kerbs.
- Provide for the safe storage and secure transport of kerbs and flags.
- Ensure that workers are trained in the safe use of mechanical lifting equipment.
- Provide training in safe lifting techniques.

Mechanical Lifting Equipment Summary - Flags:

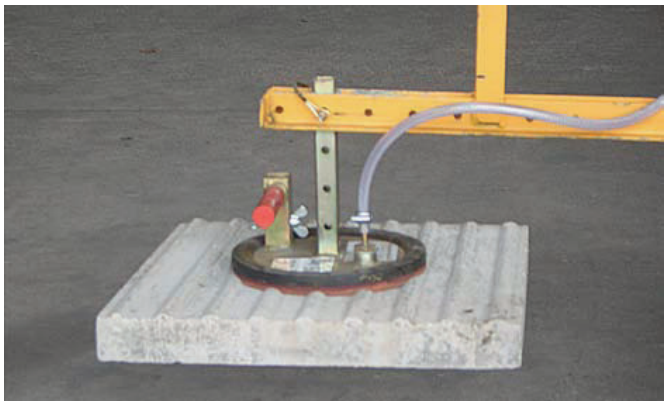
The following table illustrates examples of lifting equipment currently available for use with precast concrete flags.

	TYPE	ILLUSTRATION
MECHANICAL HANDLING EQUIPMENT	Self contained vacuum lifter. Self contained trailer unit with vacuum system - swinging boom arm - efficient and cost-effective - particularly suited to larger areas	
	Vacuum attachment. Vacuum operated lifter attachment for a suitable fork lift or excavator with suitable capacities - hydraulics powered by host machine - swinging beam arm - flags for use carried by the equipment	
	Vacuum lifter - trailer or truck mounted. Vacuum operated self powered lifter - trailer or lorry mounted - swinging boom arm - flags carried on board trailer or lorry	
	Self powered vacuum lifting attachment. Vacuum operated lifter attachment to an existing construction machine, self powered	

Mechanical Lifting of Tactile and Textured Surfaces Flags:

Various types of vacuum lifting heads are available to lift any tactile, riven or other textured surface paving flags, such as the examples that follow. It is essential to select the appropriate head for the flag and surface involved.

Tactile – Corduroy Hazard Warning



Tactile – Platform Edge (Off-street)

Tactile – Platform Edge (on-Street)

Textured Surface Flag

Mechanical Turning of Stacked Flags:

Attachments are available to pick up flags vertically stacked on a pallet and rotate them to a horizontal position ready for installation.

Lifting Equipment:

Lifting equipment is generally based on mechanical or hydraulically operated clamps, or vacuum lifting systems. Suitability should be determined through a risk assessment of the operation. Equipment is available from Associate Members of Interpave: details available on www.paving.org.uk

Scissor Clamps

A simple clamping attachment fitted to existing site plant designed for lifting, or used manually by two operatives. Manual clamps are lifted and controlled by handles which must be located safely away from pivot points to avoid risks of trapped fingers. Scissor clamps are generally only used for handing kerbs, but clamps are available to handle and lay flags. The clamping action relies on the kerb mass to activate the gripping action. Gripping may be assisted by rubber blocks fixed to the clamps.

Hydraulic Clamp Systems

A simple clamping attachment to existing site plant designed for lifting. The clamping action relies on the kerb mass to activate the gripping action. Gripping is assisted by rubber blocks fixed to the clamps.

Vacuum Lifters

A simple suction lifting system suitable for a two-man lifting device (battery driven) or an attachment to existing site plant designed for lifting or mounted on a lorry or trailer. Vacuum lifters utilise a motorised pump to generate suction through a pad that attaches to the kerb or flag. It is essential to ensure that the suction pad type is suitable for the kerb or flag type to be lifted. Vacuum equipment may incorporate filters that require cleaning and replacement to ensure efficient running.

Maintenance and Safety

Although all of these options offer safe methods to move heavy product on site, the equipment must be well maintained. The failure of any equipment during lifting operations could cause serious injuries if the load is allowed to drop. Particular attention should be paid to the maintenance requirements of those areas that are most prone to wear and tear and which require repair or replacement from time to time. Care should also be taken with the handle grips which, when worn or loose, may allow operatives' hands to slip on the equipment.

Selecting Lifting Equipment

- Consider the various differences between equipment available in the context of the proposed work.
- Check for the appropriate manufacturer's certification / guarantees to ensure that the equipment has been designed for the intended use and determine the lowest safe working load of any component of the equipment.
- Ensure that the equipment is in good working order and not damaged.
- For vacuum lifting equipment, vacuum heads/ pads are available to suit different kerb

and flag sizes/weights and surface profiles. Ensure that the lifting vacuum heads/pads are suitable for and compatible with the kerbs or flags to be lifted.

- Ensure that the equipment is the most appropriate for the job before purchasing or hiring. If the equipment is used inappropriately or not in accordance with manufacturers' recommendations, accidents may occur.
- For manual lifting equipment, make sure that it will allow the worker(s) to lift and lower the load without undue bending or twisting and to hold the equipment comfortably without excessive wrist deviation.
- Equipment continues to be developed with increased adoption by the industry and discussions with the equipment manufacturers before purchase may enable modifications to be made to suit any specific requirements.

Practical Considerations

- Make sure that the work is appropriate for powered machines, e.g. that the machinery can manoeuvre around the site.
- Check with the kerb or flag manufacturer that products can be delivered to site packed and loaded in a way that is compatible with the operational characteristics of the equipment, i.e. with drainage channels or tactile/riven/textured paving the right way up.
- Operators of the equipment must complete training as laid down by the equipment supplier. Manual handling training is also required to deal with any unforeseen manual handling of products and pallets.
- When manually handling ensure personnel have received training on team lifting and manual handling, and carry out the work in such a way as to reduce manual handling risks to an absolute minimum.

Use and Maintenance of the Equipment

- The equipment must be used, maintained and tested strictly in accordance with the equipment manufacturer's and supplier's requirements.

Manual Lifting Equipment Summary - Flags:

The following table illustrates of lifting equipment currently available for use with precast concrete flags.

	TYPE	ILLUSTRATION
MECHANICAL HANDLING EQUIPMENT	One person manual lifting vacuum system. Battery driven vacuum lifter – no manual lifting is necessary as raising and lowering the boom is powered.	
	Single person vacuum lifter Manual operation both to control and to lift is achieved by the operative pushing down via a long lever-arm to minimise the effort needed.	
	Two person vacuum lifting system. Battery driven vacuum lifter - may be used as an attachment to existing construction plant, or manually as illustrated.	
	Two person manual lifting clamp. Simple scissor action operated by two persons.	

General Guidance:

It is important that work procedures are drawn up before commencement to identify any hazards. Failure to do this can result in lack of co-ordination of materials and multiple handling of product. Correct Personal Protective Clothing should be used.

Planning the work

- Work should be planned and coordinated to avoid unnecessary handling.
- For operations where it is proposed to carry products around site, forklift vehicles are used, kerbs and flags should be delivered on timber pallets. Ensure that pallets are robust as the failure of a pallet could allow kerbs or flags to fall.
- Strapping and wrapping of packs should only be removed just prior to use of the kerbs or flags.
- Care should be taken when cutting bands and/or removing wrapping to avoid kerbs or flags falling.
- Accurate placement of the laying course will minimise shovelling operations
- Accurate preparation of the concrete bed and any excavated trench will reduce the amount of adjustment to kerbs once laid.
- Consideration should be given to avoiding on-site cutting and, if it is necessary, to its safe execution. Comprehensive guidance is available for both kerbs and flags via **http://www.paving.org.uk**

Return to work

Employers should consider how to manage workers who have suffered manual handling injury, in particular their work. For most lower back injuries, staying mobile can assist recovery. With an employer's good management, including a 'back-to-work' plan, in most cases the affected person will be able to return to work. Good management would include reviewing the risk assessment and obtaining medical advice. Further information is available on the *HSE Back Pain and Sickness absence* web pages.

Further Information:

Publications

- Health and Safety at Work Act etc 1974
- Management of Health and Safety at Work Regulations 1999
- Manual Handling Operations Regulations 1992 (as amended 2004)
- Construction (Design and Management) Regulations 2007 (CDM)
- Lifting Operations and Lifting Equipment Regulations 1998
- Provision and Use of Work Equipment Regulations 1992
- HSE leaflet MISC 383, the Manual Handling Assessment Chart
- HSE booklet L23 - Manual Handling; The Manual Handling Operations Regulations 1992 (as amended)

Websites

- http://www.hse.gov.uk/msd/backpain/index.htm
- http://www.hse.gov.uk/sicknessabsence/index.htm

4 DETAILING AND CONSTRUCTION

The following installation guidance should be adopted for all areas with flexible construction surfaced with concrete flag paving. The guidance is based on BS 7533: Part 4, 'Code of practice for the construction of pavements of precast concrete flags or natural stone slabs.'

A flag paved area is primarily designed for pedestrian use. However by careful selection of the appropriate flag in conjunction with the correct method of bedding, 'small element' flags can sustain trafficking by light vehicles and frequent overrun by commercial vehicles. If adequately designed (as described in Section 2) and correctly constructed, a flag pavement will provide long service with low maintenance costs.

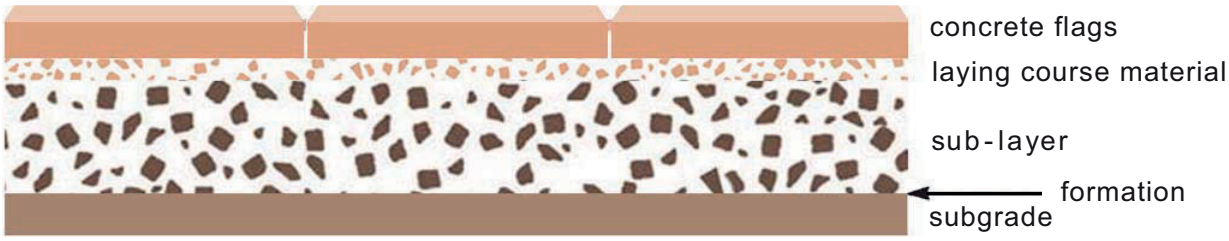
Successful construction of a concrete flag paved area depends on five main operations:

- Preparation
- Detailing
- Compaction of sub-layers
- Bedding of flags
- Jointing

Any pavement requires an appropriate foundation. The underlying sub-layers below the flag surface course and laying course need to be correctly designed and prepared to accommodate the anticipated applied loads. Good detailing by minimising cutting will ensure an aesthetically acceptable flag wearing surface able to protect the laying course and sub-layers and transmit any vehicular loads to the structural elements of the sub-layer. The appropriate level of compaction of each sub-layer of the flag pavement, particularly when overrun by vehicles, should prevent flags becoming displaced and rocking or developing trips between adjacent flags.

Flags require bedding on a laying course to provide even support and prevent excessive local stresses being transmitted to the flag by high points in the underlying sub-layers. For lighter trafficked, mainly pedestrian areas a mortar laying course is sufficient but for areas subject to regular vehicular overrun small element flags bedded on a sand laying course, with sand joints, are necessary. It is essential to maintain the structural integrity of the surface course to prevent water penetration leading to deterioration of the sub-layers and subgrade or loss of interlock resulting in direct wheel loading to the underlying sub-layers.

The main elements of a typical flag pavement construction are as shown in the pavement cross-section shown below.



Compaction

Compaction plant for sub-layer

Type of compaction plant	Mass	Minimum number of passes for compacted sub-base thickness	
		100 mm	150 mm
Vibrating plate	1400 kg/m^2 to 1800 kg/m^2	6	Not suitable
	1800 kg/m^2 to 2100 kg/m^2	4	8
Vibrating roller	700 kg/m^2 to 1300 kg/m^2	12	Not suitable
	1300 kg/m^2 to 1800 kg/m^2	5	12
Engine driven vibro-tamper	50 kg to 65 kg	4	8
	65 kg to 75 kg	3	6
	Over 75 kg	2	4

Preparation of sub-grade

Any soft spots should be excavated and back-filled with well-compacted suitable material. The subgrade or original ground formation should then be prepared by trimming to level and compacting to a tolerance within +20 mm and -30 mm, in accordance with the Specification for Highway Works. It may also be necessary to introduce drainage into the sub-grade to lower the water table and improve the bearing capacity of the sub-grade.

Construction of sub-layers

Construction of sub-layers should be undertaken in accordance with BS7533: Part 4: 1998. It should be noted that this standard is under review and it is anticipated that it will be re-published in 2005. The sub-layer material(s) should comply with the materials listed in the table.

Materials for sub-layer construction

Material	**Clause reference in the *Specification for Highway Works***
Granular sub-base material type 1	803 (except that 100 % should pass a 37.5 mm sieve
Granular sub-base material type 2	804
Cement-bound material category1 (CBM 1)	1036
Cement-bound material category2 (CBM 2)	1037
Cement-bound material category3 (CBM 3)	1038
Wet-lean concrete	1030
Concrete grade C25P in accordance with BS 5328[NH23]	-

Where the sub-layer contains cement the appropriate minimum time should be allowed to elapse before starting to lay the surface course.

Minimum curing time between layers

Sub-base material (see Table)	**Minimum time for surface course compacted with maul**	**Minimum time for surface course compacted with vibrator]**
	h	h
Natural ground	0	0
Granular sub-base material type 1	0	0
Bitumen-bound material	0	0
Cement-bound material categories 1, 2 or 3	0	72 (at ambient temperatures above 4°C)
Wet-lean concrete	40 (at ambient temperatures above 4°C)	72 (at ambient temperatures above 4°C)
Structural concrete	40 (at ambient temperatures above 4°C)	72 (at ambient temperatures above 4°C)

Preparation of existing bases as the sub-layer

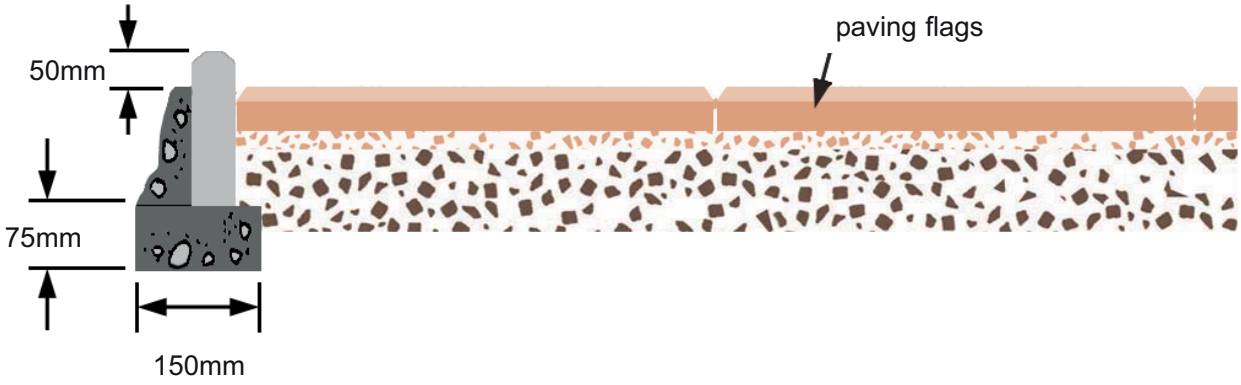
Where flags are to be laid over existing roads or other paved areas, it may be necessary to correct levels of the existing pavement to ensure final surface tolerances within +10 mm and -10 mm. Any excess material should be removed, using a planing process, to allow installation of the required laying course thickness. Where levels need to be built up, suitable material complying with the table “Materials for sub-layer construction” should be used, laid and compacted in accordance with the *Specification for Highway Works*. Care should be taken to ensure that existing drainage will continue to function after any adjustments to levels.

Preparation of restraints

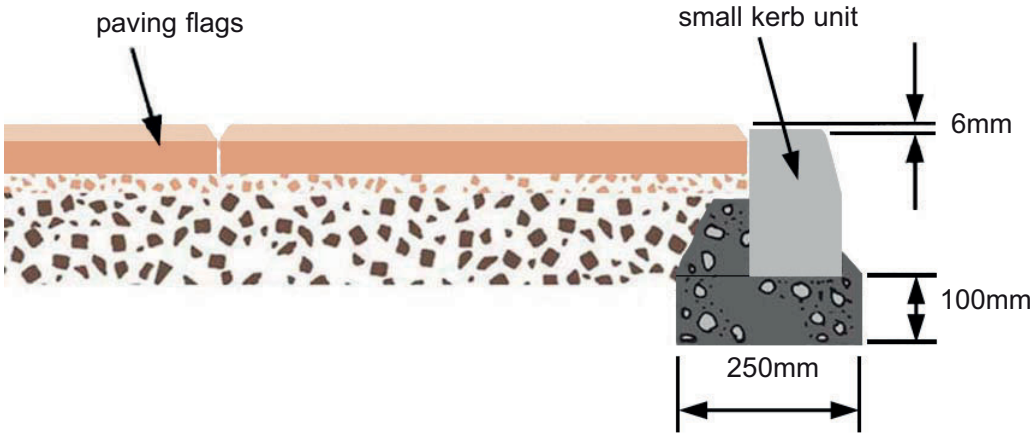
Edge Restraints

Flag paved areas must be restrained at their edges to prevent movement - either progressive movement of the whole paved area or individual flags. Edge restraints resist lateral movement and restrict loss of laying course material at the boundaries.
Edge restraints should be laid at all boundaries of the paved area including where the flag pavement abuts different flexible materials, such as bituminous bound material. They should be suitable for the relevant application and sufficiently robust to resist displacement if likely to be overrun by vehicles. It may be necessary to extend sub-layers to support the edge restraint and any base and haunch. Compaction of pavement layers near edge restraints should be delayed until any concrete bed and haunch has gained sufficient strength to prevent movement of the edge restraint.

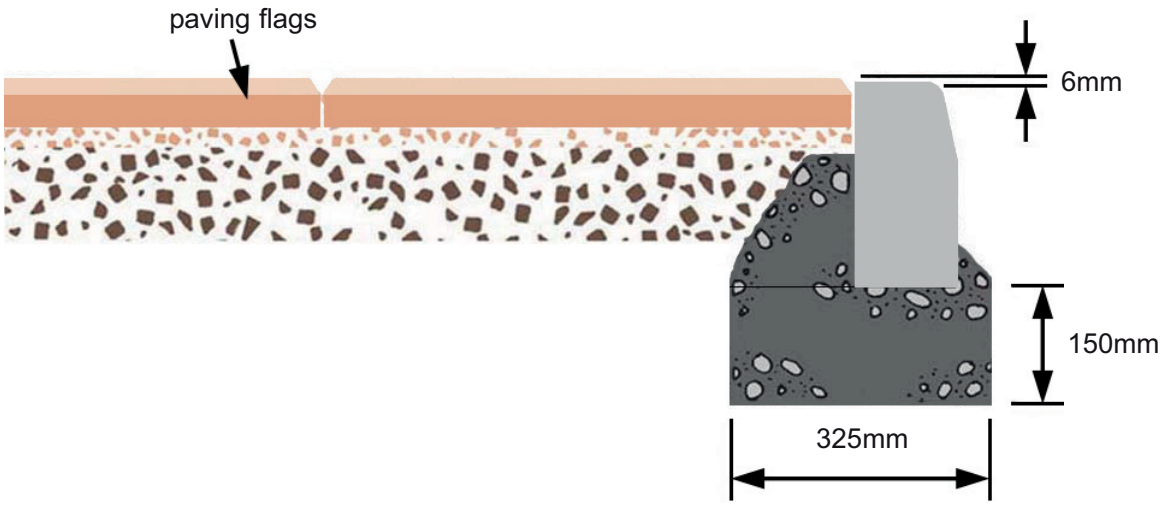
precast concrete edging
(not suitable for vehicle overrun)



small kerb unit edging
(suitable for vehicle overrun)



precast concrete kerb edging
(suitable for vehicle overrun)



Temporary Restraints

During construction it may be necessary to construct temporary restraints on the laying face of the flag paved area to prevent movement of laid flags, ingress of water to the laying course or help protect mortar from frost. This may be done at the end of the working day or due to site constraints or because the paving has to be trafficked temporarily. Temporary restraints should be constructed to resist lateral movement during full compaction of the paving and subsequent trafficking.

Construction of surface course - Bedding, Laying and Jointing Flags on a Sand Laying Course

Laying course material

Sand laying course material should be naturally occurring sand, and should not incorporate cement. The sand should be graded in accordance with the following table.

Laying course material gradings

Sieve size mm	Percentage by mass passing %
8	100
6.3	95 - 100
4	85 - 99
0.5	30 - 70
0.063	0 - 3

As a guide to moisture content, after the material has been squeezed in the hand and the hand is opened the sand should bind together without showing free moisture on its surface. Where laying course material is stored on site it should be covered to reduce moisture loss due to evaporation, or saturation from rainfall.

If the laying course material becomes saturated after laying then it should be removed and replaced with laying course material having the correct moisture content. Alternatively the laying course can be left in place until it dries sufficiently to allow flag laying to proceed.

Sand laying course thickness:

Laying course material that conforms to the Jointing Material table (shown later), should be spread to give a thickness of 25 mm after being placed and fully compacted. A thickness of 30 mm of uncompacted material is usually found to be suitable. A trial area should be used to determine the required surcharge.

Preparation of the sand laying course

The laying course should be prepared only to the extent that work can be completed during the working day or before the onset of inclement weather. Areas of prepared laying course should not be left overnight. The laying course material should be screeded and prepared using one of the following methods:

Pre-compaction
Spread out the laying course sand to a depth sufficient to give the required compacted nominal thickness after compaction of the sand and flags (the uncompacted thickness of sand will depend on the nature and moisture content of the sand and a trial area may be necessary to ascertain the surcharge). Compact with a vibrating plate compactor and screed to level the surface, then loosen the top 10mm with a rake.

Partial pre-compaction
Spread out the uncompacted laying course material to a depth approximately equal to the required compacted nominal thickness after compaction of the sand and flags. Compact with a vibrating plate compactor, then lay and screed approximately a further 10-15 mm of loose material before laying flags.

Details of compaction plant are given in the table. Where concrete block paving is laid in combination with small element paving flags, the compacted sand thickness should be determined by the requirements of the flags. It will be necessary to incorporate a geotextile filter to prevent the laying course material migrating into drainage systems.

Where screed rails are used they should be carefully removed to avoid disturbing the screeded surface of the laying course. Any depressions left by the screeding rails should be made good. If the prepared laying course is disturbed or damaged prior to flag laying it should be re-screeded to the required tolerances.

Vibrating Plate Compactor Requirements

Site category	**Min plate area m^2**	**Min effective force per unit area of plate (kg)**
I & II	0.25	75
III & IV	0.2	60

Laying flags

Flags should be laid to line and level and bedded down using a pavior's maul or, for small element paving flags, a vibrating plate compactor as described in the table “Vibrating Plate Compactor Requirements”.

It may be necessary to use a vibrating plate compactor fitted with a neoprene sole plate to protect some flags with special finishes. The installer should work from flags already placed, taking care not to disturb them. Laid flags should not be trafficked within 1.0 m of an unrestrained edge.

Jointing flags on a sand laying course

Flags should be laid with joints 2 to 5mm wide and fine dry jointing sand, complying with the table below, brushed in to completely fill joints. Additional sand may be added to top up the joints as necessary after the flags are compacted with the vibrating plate compactor.

Jointing Sand Grading

Sieve size mm	**Percentage by mass passing %**
2	100
1	85 - 99
0.5	55 - 100
0.063	0 - 2

Jointing sand should preferably be kiln dried. Care should be taken to select jointing sand which does not stain the surface of the flags, where it would be detrimental to the aesthetic appearance of the pavement. Joint filling and final compaction should be completed on the same day as laying or before inclement weather. It may be necessary to add additional jointing sand during the early life of the pavement. The pavement should not be cleaned by vacuum sweepers for a minimum of three months to prevent loss of jointing sand or until the joints seal up with detritus. Joints may be stabilised with joint sealants to reduce sand loss from vacuum sweepers.

Preparation of surface course - Bedding, Laying and Jointing Flags on a Mortar Laying Course

Laying course material

The mortar should consist of freshly mixed, moist 1:3 cement-sand mortar (proportions by volume) or 1:3 lime-sand mortar (proportions by volume), using sand complying with BS EN 12620:2002. Retarded, plasticized and pre-mixed mortars may be used.

Mortar laying course thickness

The mortar laying course should be spread out to a depth of 30-35 mm to provide a nominal 25 mm thickness after compaction.

Preparation of a mortar laying course

Areas of prepared mortar laying course should be paved as soon as possible. Cement based mortar that has begun to set or has been mixed for more than two hours should be discarded.

Laying flags on a mortar laying course

The flags should be carefully laid on a full mortar bed and bedded down to line and level with a pavior's maul. The installer should not stand in freshly laid mortar nor on freshly laid flags unless suitable action is taken to prevent movement of the laid flags.

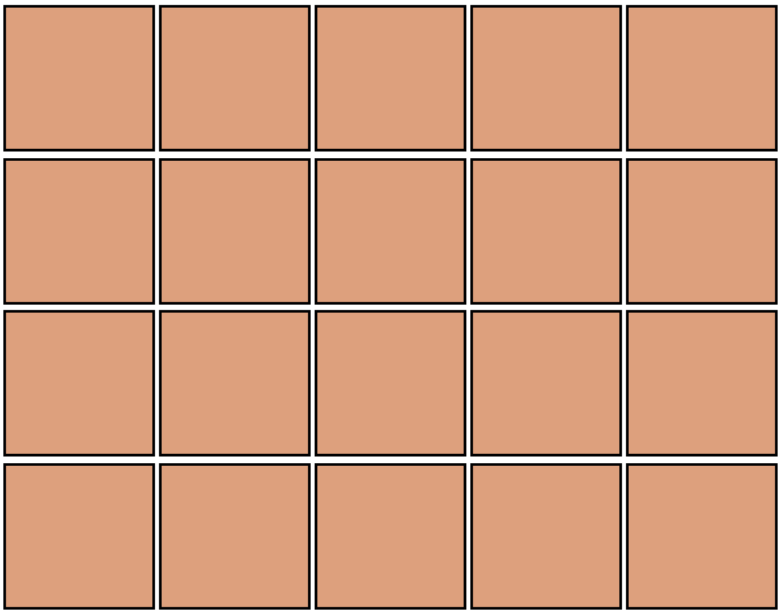
Jointing flags on a mortar laying course

Flags are laid with wide joints (i.e. 5 to 10 mm wide) and the whole of the joint should be filled with a compacted mortar to within 2 to 3 mm of the flag surface using a 1:4 cement-sand (proportions by volume) mortar, containing sand complying to BS EN 12620:2002. Flag paving containing mortar joints and/or mortar laying courses should be protected from pedestrian traffic until the mortar has achieved a working strength.

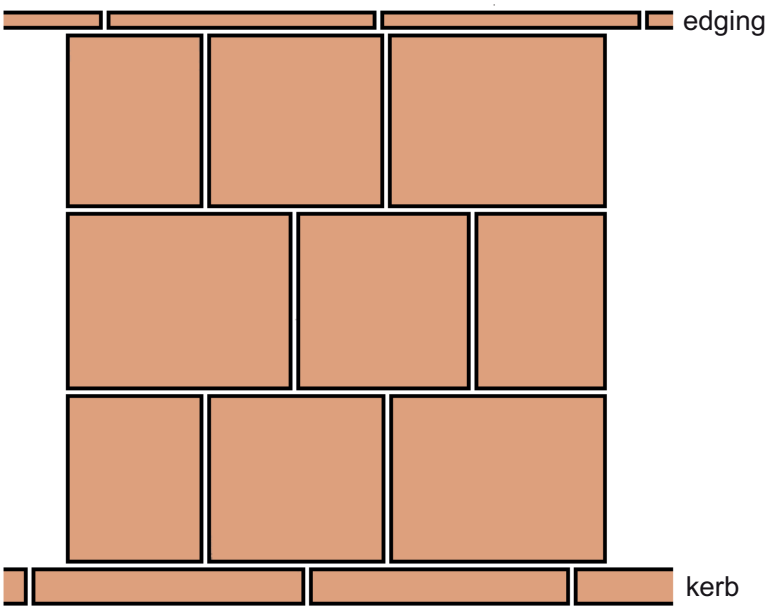
Selection of flag bond

The two most common flag paving patterns are 'Stack Bond and 'Broken Bond'. Broken Bond can be further sub-divided into 'Transverse Broken Bond' and 'Longitudinal Broken Bond, all as shown below. Broken Bond should be used in areas subject to vehicular trafficking, with the straight unbroken joints at 90° to the main direction of travel of the vehicles.

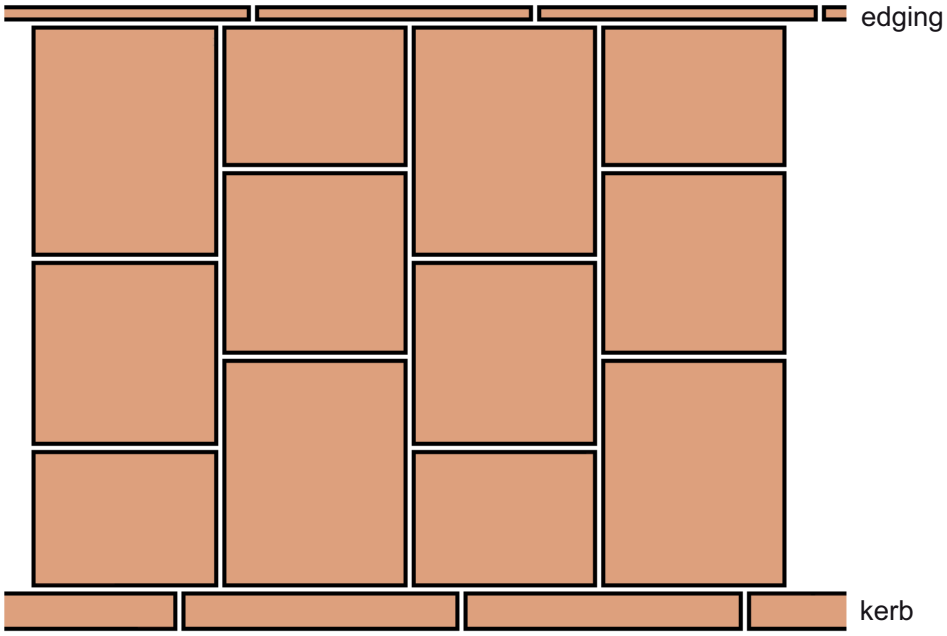
stack bond



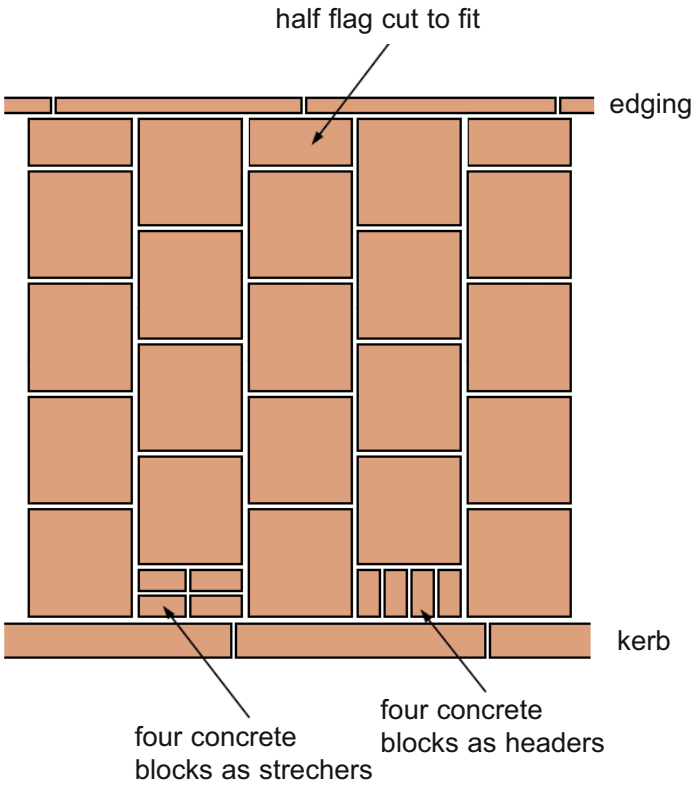
longitudinal broken bond



transverse broken bond



broken bond with block or half flag infill

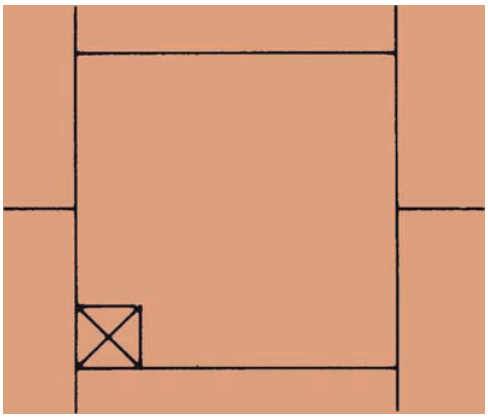


Flag installation

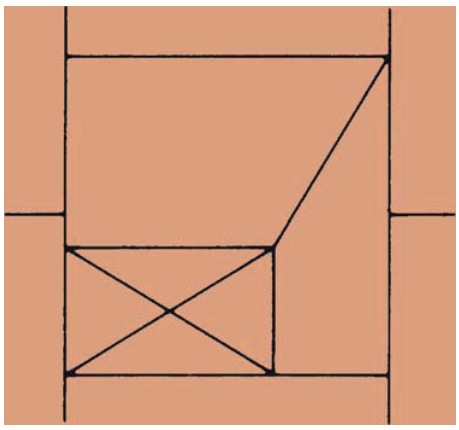
Flag laying should normally start at a fixed edge restraint. However, any edge restraint is unlikely to be perfectly straight or at 90° to the intended flag pattern. Therefore, a string line should be set up a short distance from the edge restraint and used to align the first "row" of flags. A second string line at 90° to the first will ensure that the flag bond does not "wander." The area between the first string line and edge restraint can then be infilled with cut flags or concrete blocks, cut to fit as necessary. It is important to continue to use string lines during laying of the paved area to ensure joints appear visually straight or in line.

Flag Cutting

As work progresses, the paved area should be completed with any necessary cut flags inserted and bedded, followed by compaction and jointing. Flags may be cut using a saw, bolster and chisel or a suitable disc cutter. Small element paving flags may also be cut using a suitable mechanical flag splitter. Care should be taken to ensure a safe working environment during any cutting operation and that all procedures conform to the relevant safety legislation. Where less than 25% of a flag needs to be cut away it may be left as a single flag as shown below.

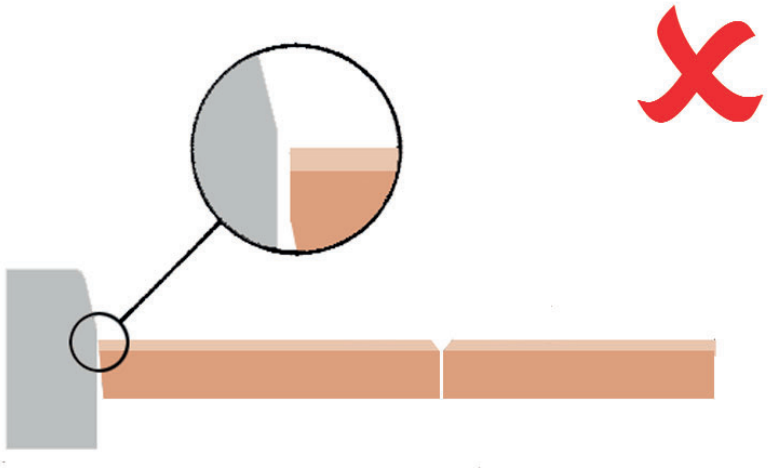


Where more than 25% of the flag has to be cut away then the remaining shape should be mitred from the internal corner of the cut-out to the external corner of the flag as shown below.

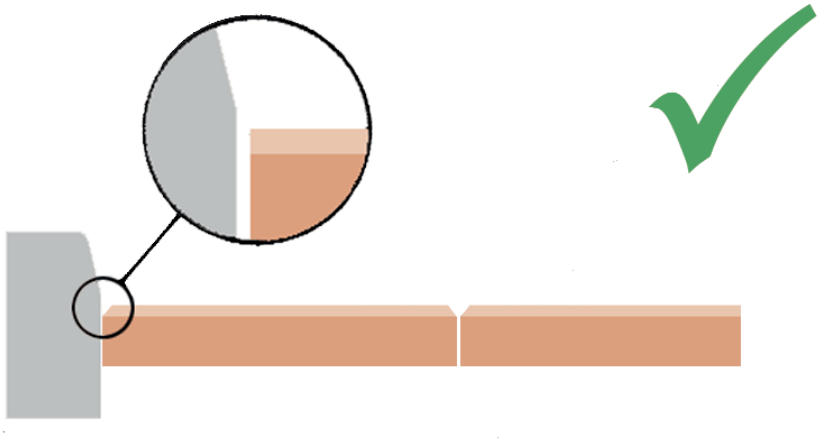


Detailing

Wherever possible avoid placing the cut face of a flag against an adjacent edge restraint, as shown below.



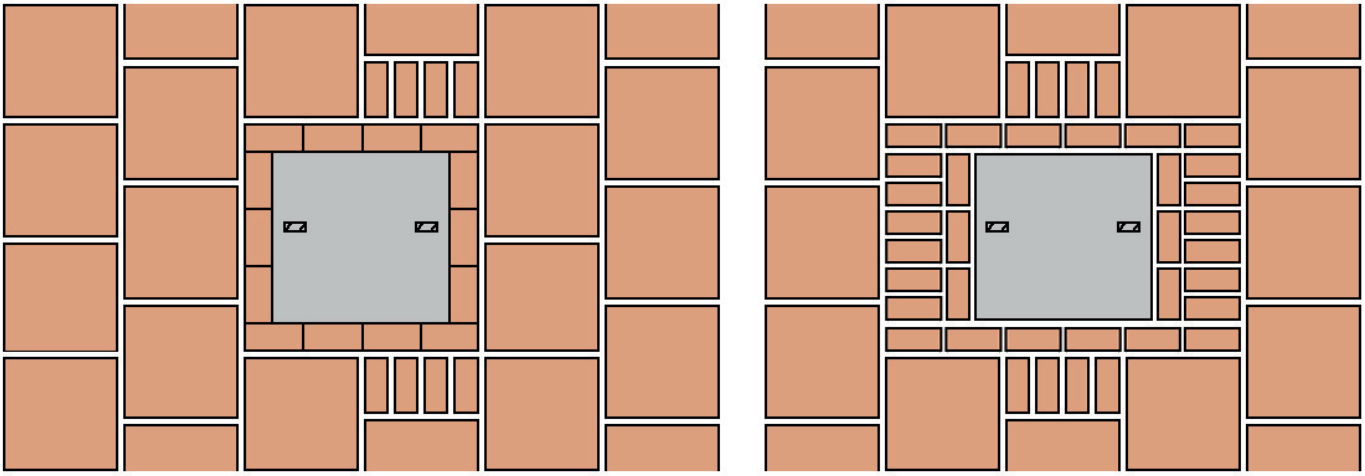
Cut faces should be positioned against an adjacent flag to reduce the visual intrusion of the square cut edge.



This is particularly important with chamfered edge flags to reduce the visual intrusion of a straight cut face directly against the flat vertical side of the edge restraint. The above detail can be adopted as shown where the flag pattern is square to the edge restraint. With curved edge restraints or where the flag pattern is not square to the edge restraint, block paving infill comprising a single stretcher course, double stretcher course or a header/soldier course can be introduced between the flags and the kerb or edge restraint. Alternatively the area of flag paving can be "picture framed" with a single stretcher course, double stretcher course, header/soldier course or a combination of these block courses, cut to suit any irregularities in the edge restraints. Cut faces of flags can then be positioned against this block course to reduce the visual impact of the cut.

Manholes or other similar intrusions into the paved area can be treated in a similar manner. Ideally, manhole covers or gully frames which have straight sides should be used to allow the paving to directly abut the frame. A stretcher course of blocks at this point, around the manhole, avoids cut edges of flags directly against the frame and ensures any cut edges are less intrusive. This stretcher course may be laid on a mortar bed where there is a possibility of bedding sand migrating beneath the manhole surround. Alternatively, cut flags may be replaced with concrete blocks. After compaction the flag surface level should be 3 to 6 mm above the manhole cover and frame to allow for any future settlement.

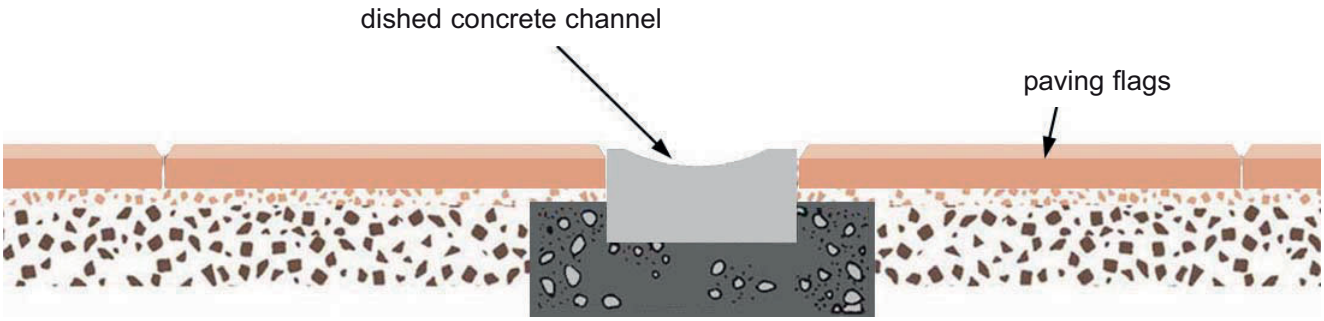
Details for manholes in flagged pavements



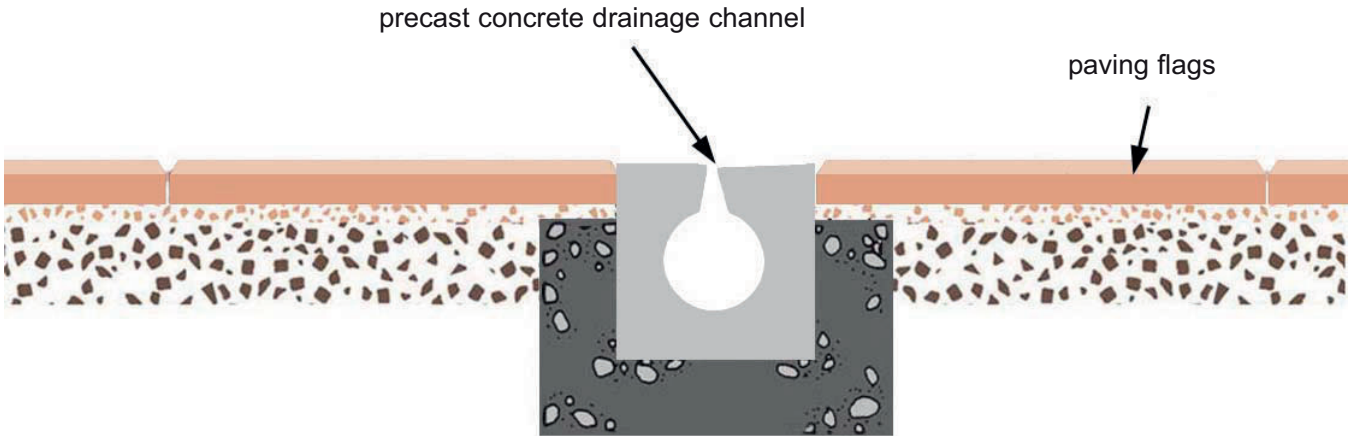
If a manhole cover or gully frame without straight sides is used, which will not allow the paving to directly abut the frame, then a surround of C35 air entrained concrete to BS EN 206-1 should be incorporated. It should be laid to the full depth of the flag and laying course. A stretcher course of blocks should be introduced to minimise the width of concrete surround. Careful selection of the raw materials for the concrete and/or the addition of suitable colour pigments can help reduce the visual impact of the concrete surround.

Where proprietary drainage channels are used in a flag paved area, after compaction the flag surface level should be 3 to 6 mm above the edge of the drainage unit to allow for positive drainage and any future settlement. As an alternative they may be treated as manholes and "picture framed" with stretcher or header courses to allow cut edges to abut a block chamfer.

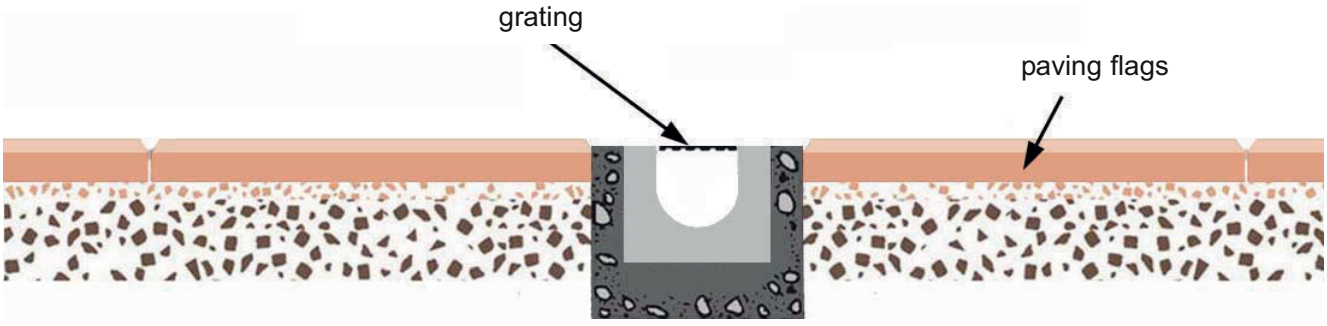
dished concrete channel



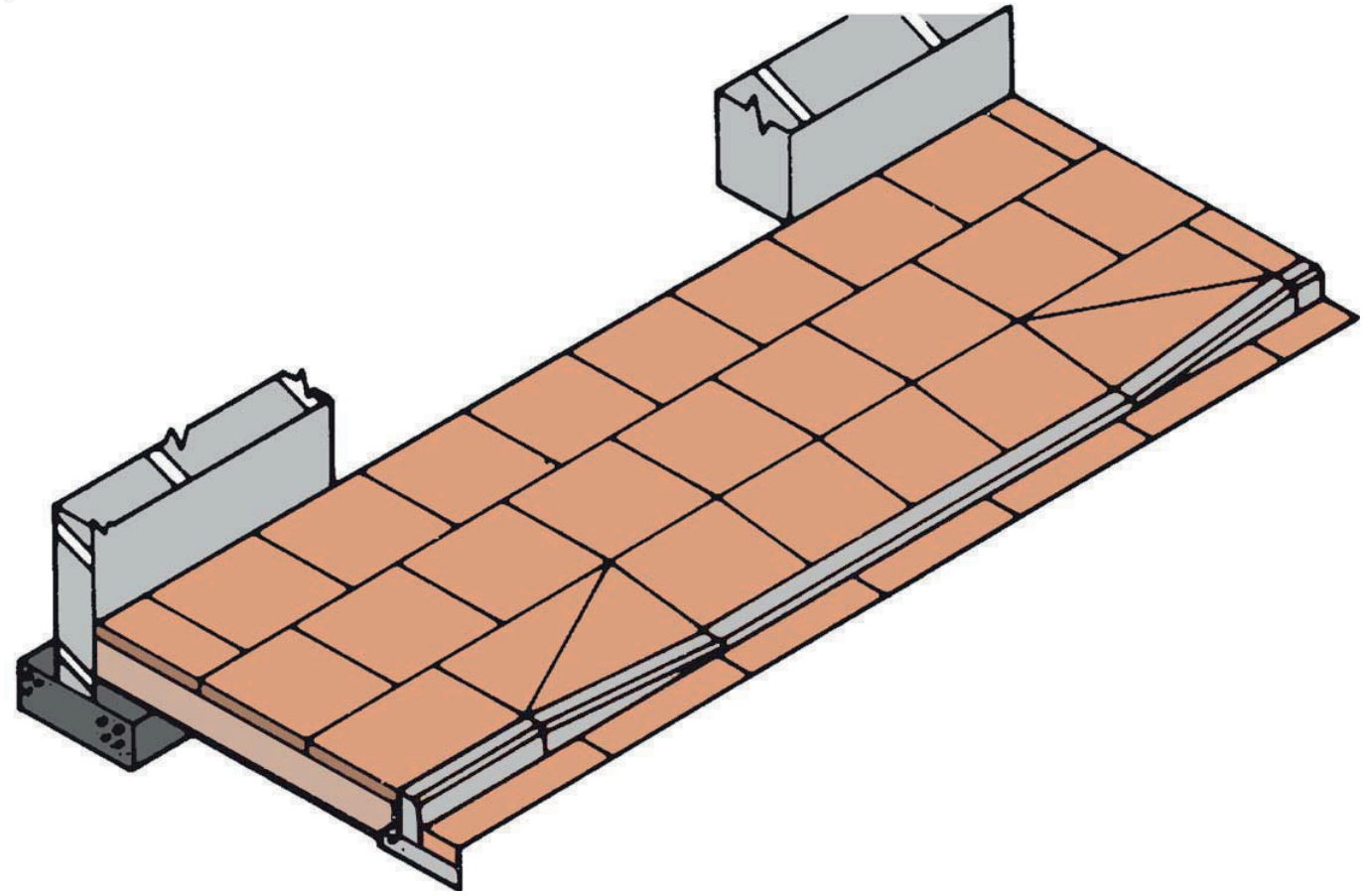
drainage channel with concrete haunching



drainage channel with concrete surround



A ramped crossing may be formed in a flag footpath where the footpath and drive threshold are at similar levels. Two corner flags have to be cut to accommodate the change of level at the kerb.



Falls

Flag paving provides a paved surface that is virtually impermeable. Flags with mortared joints are resistant to water penetration immediately after setting. Sand filled joints develop water resistance in early life. A flag pavement therefore requires gradients for drainage of surface water. Minimum crossfalls of 2.5% (1:40) and longitudinal falls of 1.25% (1:80) are recommended, wherever possible.

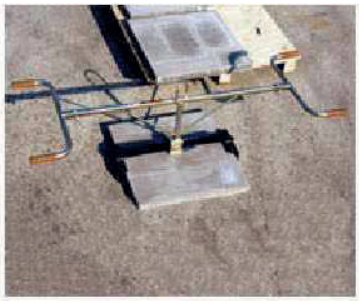
Tolerances

The flag pavement should be laid to the following tolerances. The finished surface level tolerance from the design level of the flag pavement should be ± 6 mm. Adjacent flags should not differ in level by more than 3 mm.

5 REINSTATEMENT

This Guide is intended to help with the opening up and reinstatement of concrete flag paving – for access to underground services or repairs to the pavement. Unlike other pavement materials, with concrete flag paving using sand filled joints it is possible to complete reinstatement work with no visual evidence that a repair has been undertaken. This Guide combines information from BS 7533-11: 2003, 'Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone' with 'hands-on' experience to provide practical advice for flag paving with sand filled joints. Although suggestions on appropriate equipment are listed, these are not exhaustive and do not personal protective equipment or other health and safety measures required by current legislation. All health and safety measures are the responsibility of those undertaking the work.

Vacuum lifting device



Flag lifting tool

Equipment List:

- *Bricklayer's small trowel*
- *Large flat-bladed screw drivers or other levers*
- *Flag lifting tools or vacuum lifting device (see Handling, Section 3)*
- *Wire brushes and/or stiff hand brushes*
- *Timber spacing pieces*
- *Hand shovels*
- *Broom and hand brush*
- *Hand rammer (50 x 50mm timber or hammer shaft)*
- *Aluminium or notched wood screeding board with length to suit*
- *Screed rails, 25, 30, 35 and 50mm thick (usually steel hollow section or bar)*
- *String line*
- *Steel float*
- *Pavior's rubber maul*
- *String line*
- *Replacement flags as needed*
- *An appropriate plate compactor (1400 – 2100 kg/m2) which may need a neoprene sole plate to protect special surfaces (as recommended by the flag manufacturer)*

Remove the paving flags:

Equipment Checklist

- *Bricklayer's small trowel*
- *Large flat-bladed screw drivers or other levers*
- *Flag lifting tools or vacuum lifting device (see Handling section)*
- *Wire brushes and/or stiff hand brushes*
- *Timber spacing pieces*

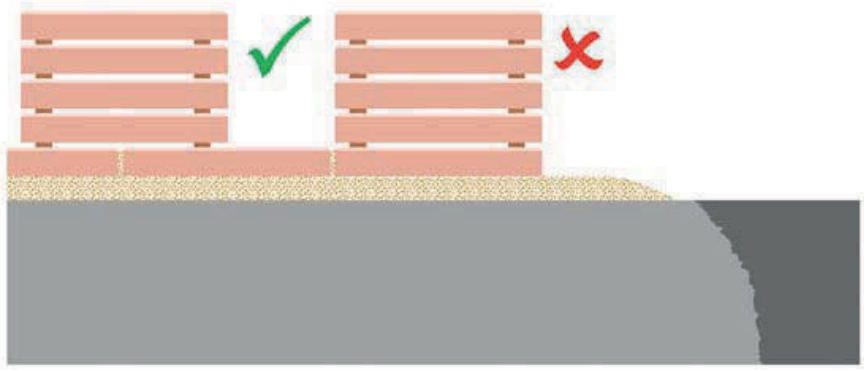
1. Rake out the joints around the first flag using a bricklayer's small trowel or other suitable tool. Lever out the first flag using screwdrivers or other suitable levers
   - *Selecting a broken flag (if there are any) first may make this easier*

2. After the first flag has been removed take out subsequent flags and lift clear. Continue until an area of paving has been removed to give a minimum of one complete row (depending on bond) beyond the excavation area

3. For the lifting and handling of flags, the recommendations in the Handling Section should be adhered to and flag lifting tools or vacuum lifting devices used, as described

4. Clean the joint material and detritus from the flags before stacking or re-use

5. Stack damaged and undamaged flags separately in a position that will be convenient for relaying but at least 0.5m away from the excavation. Place timber spacing units between flags to minimise surface contact and damage
   - *damaged flags can be kept for re-use as cut units*



Remove laying course:

Equipment Checklist

- *Hand shovels*

Take up and dispose of the laying course material, which must not be re-used

Repair/Reinstate the lower pavement layers:

1. Carry out the required work to services or lower pavement layers
2. Reinstate to give a finished level so that the laying course will be the correct thickness

Although BS 7533-11: 2003 suggests that reinstatements should have a cambered surface with flags slightly proud of the existing for future settlement, experience shows this to be unnecessary if material selection, construction and compaction are all carried out correctly

Place the new laying course:

Equipment Checklist

- *Flag lifting tools or vacuum lifting device*
- *Wire brushes and/or stiff hand brushes*
- *Timber spacing pieces*
- *Broom and hand brush*
- *Hand shovel*
- *Hand rammer (50 x 50mm timber or hammer shaft)*

1. As it is likely that the edge flags and underlying sand will have been disturbed, a further row or so of flags (depending on bond) at each edge should be removed, cleaned and stacked

2. Cut back the existing laying course and remove, then scrape away the caked jointing sand from the exposed flag edges

3. Ensure that remaining flags are fully supported on the laying course with some level existing laying course exposed in front

4. Select the correct laying course material grading and thickness shown in the table on page 29.

5. Place and spread the correct laying course material

6. Compact (hand ram) the new material against the existing to ensure there are no voids where they meet

Screed the laying course:
- for areas up to 3.0m wide

Equipment Checklist

- *Aluminium or notched wood screeding board with length to suit the area width*
- *Steel float*

1. Screed the laying course to approximately 5mm above the underside of the adjacent blocks using a notched screeding board running on top of the existing blocks as shown

   - *Although BS 7533-11: 2003 suggests that reinstatements should have a cambered surface with blocks slightly proud of the existing for future settlement, experience shows this to be unnecessary if material selection, construction and compaction are all carried out correctly*

2. Use a rectangular steel float to hand screed areas that can't be screeded with the board

   - *For areas of any width, it is advisable to undertake a small trial of laying course screeding, block laying and compaction to ensure the right thickness of laying course material for the reinstated blocks to be at the same level as the surrounding blocks. If necessary make adjustments to the screed before proceeding with any more work*

Screed the laying course:
- for areas over 3.0m wide

Equipment Checklist

- *Aluminium or notched wood screeding board with length to suit the area width*
- *Steel float*

1. Screed the laying course to approximately 5mm above the underside of the adjacent flags using a notched screeding board running on top of the existing flags as shown
   - *Although BS 7533-11: 2003 suggests that reinstatements should have a cambered surface with flags slightly proud of the existing for future settlement, experience shows this to be unnecessary if material selection, construction and compaction are all carried out correctly*

2. Use a rectangular steel float to hand screed areas that can't be screeded with the board
   - *For areas of any width, it is advisable to undertake a small trial of laying course screeding, flag laying and compaction to ensure the right thickness of laying course material for the reinstated flags to be at the same level as the surrounding flags. If necessary make adjustments to the screed before proceeding with any more work*

Lay the flags:

Equipment Checklist

- *Flag lifting tools or vacuum lifting device (see Handling section)*
- *String line*
- *Replacement flags as needed*

1. The original cleaned flags and any new replacements needed are laid to line and level, and joints adjusted to suit (2-5mm wide). A pavior's rubber maul may be used to tap the final flags into place

2. For the laying and handling of flags, the recommendations in the Handling section should be adhered to and flag lifting tools or vacuum lifting devices used, as described

Cutting Flags:

Equipment checklist

- *Saw, bolster or suitable disc cutter*

When necessary, flags may be cut using a saw, bolster or suitable disc cutter. Where less than 25% is to be cut away, the remainder may be left as a single flag but for larger cuts, the flag should be divided with a mitre cut from the internal corner of the cut-out to the external corner of the flag (see page 35).

Compact the laying course:

Equipment Checklist

- *An appropriate plate compactor (1400 – 2100 kg/m^2) which may need a neoprene sole plate to protect special surfaces (as recommended by the flag manufacturer)*

1. Compact the laying course by running the plate compactor over the laid flags at least twice

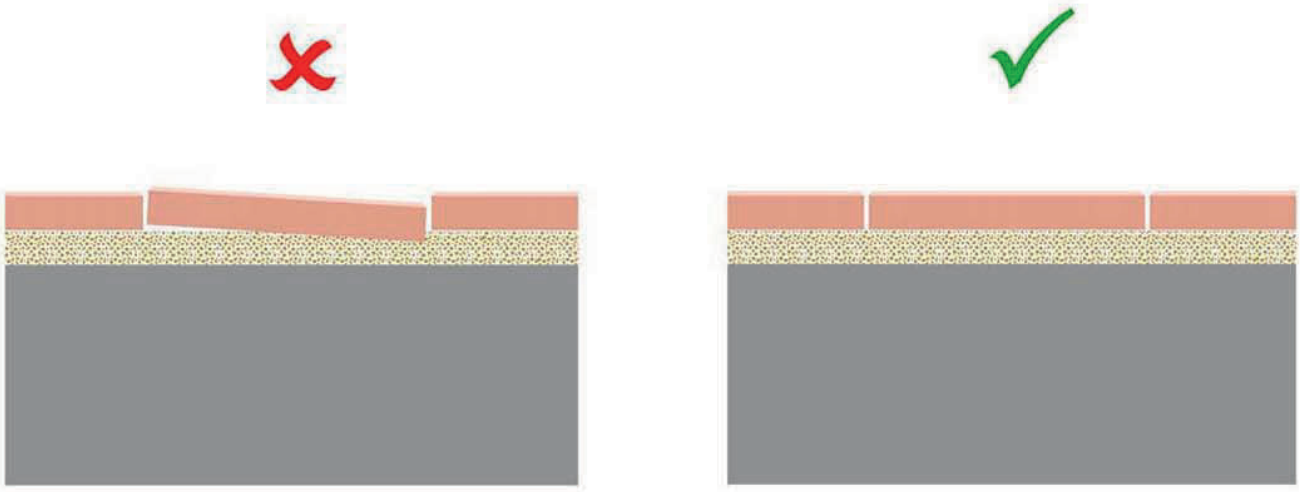
2. Around the perimeter of the reinstatement, ensure that the compactor traverses half on the existing and half on the newly laid flags

Check joint widths and flag levels

Equipment Checklist

- *Large flat-bladed screw drivers*

1. Check flag alignment and joint widths (which should be 2-5mm): adjust with screwdrivers if necessary
2. Check for broken and damaged flags and replace if necessary
3. Check for any protruding flag corners and adjust the height as necessary by removing and correcting the level of the laying course. If the laying course has been disturbed, re-compact after replacing the flag(s)



Fill joints

Equipment Checklist

- *An appropriate plate compactor (1400 – 2100 kg/m^2) which may need a neoprene sole plate to protect special surfaces (as recommended by the flag manufacturer)*
- *Broom*

1. **Only proceed if the flags, alignment, joint width and flag levels have been checked and are acceptable**

2. Select the correct joint filling material grading from the table on page 31

3. Place and sweep the joint filling material into joints

4. Compact the joint material by running the plate compactor over the laid flags at least twice

5. Around the perimeter of the reinstatement, ensure that the compactor traverses half on the existing and half on the newly laid flags

Final check:

Equipment Checklist

- *Large flat-bladed screw drivers*
- *General cleaning equipment*

Check alignment, joint width and flag levels are all OK and correct if necessary.
Remove debris and sweep the area clean

6 CLEANING AND MAINTENANCE

The following notes are intended for general guidance on the cleaning and maintenance of precast concrete paving and are not intended to be exhaustive.

Any surfacing material may suffer from staining or marking, due to general trafficking or contamination from other sources. There may also be some vegetation growing in joints or on the paving itself in shaded areas or areas subject to long periods of dampness.

Regular maintenance and good cleaning practice will enhance the overall appearance of the paving.

Health and Safety advice:

Some of the cleaning methods described involve the use of chemicals which must be used correctly and strictly in accordance with the suppliers/manufacturers' recommendation. The following precautions should also be noted:

- Appropriate protective clothing such as gloves, goggles, ear defenders, boots and overalls should be worn.
- Adequate ventilation is required in confined spaces when using chemicals.
- When using flammable materials, cigarettes, naked flames and other sources of ignition should be avoided.
- When diluting acid based cleaners, ALWAYS add acid to water and not water to cleaner.
- Any clothing which is contaminated with chemicals should be disposed of safely.
- Care must be taken not to damage, contaminate or stain any adjoining material.
- Personnel operating in the area of the cleaning must be protected from any hazard created by the cleaning. (Risk Assessments and COSHH)

It is particularly important with all cleaning methods that trials should be carried out on a small, preferably inconspicuous area, to determine the effect of the treatment before commencing work on a larger area.

Cleaning of paving:

General dirt and detritus:

To remove general dirt and detritus, regular brushing is recommended. If the colour of the paving becomes masked it may be re-established by scrubbing with soap and warm water, either by hand or by using an industrial cleaner.

Ensure all the soap has been thoroughly washed from the surface on completion of the cleaning and carefully channelled in the resulting run-off to either drainage points or containers where it can be safely disposed of.

If a power hose is used then care must be taken to avoid the removal of the jointing material (sand or mortar). After completion the pavement should be inspected and the joining material replaced as required.

Moss, lichens and algae:

Moss, lichens and algae should not grow on concrete unless the area is heavily shaded, is under trees or is not adequately drained. If such growth does occur and is considered undesirable then the area should be treated with a proprietary cleaner suitable for the purpose, used in accordance with the manufacturer's instructions. Some treatments leave a residue to discourage the regrowth of the moss and algae, but this will only be of limited value if the surrounding conditions leave the paving damp and in shade.

Rust stains:

Action must be taken to eliminate the sources of staining. To remove the rust stain, the surface should be wetted and the affected area treated with an acid based concrete cleaner (no stronger than an equivalent 5% Hydrochloric acid solution or similar). However acid in cleaners attacks concrete. It may leave a slightly roughened surface or leach out some of the pigment from the concrete, so care must be taken when using acid based cleaners. After application of the cleaner any residue should be washed off the surface of the concrete with copious quantities of water to avoid staining. Care should be taken to dispose of the run-off safely. All manufacturers instructions must be strictly followed and after cleaning is completed, any chemical residue should be disposed of carefully.

Oil stains:

Oil penetrates readily into concrete, but it should not stain if any spillage is removed promptly with an absorbent material e.g. paper towels or cloth. Do not wipe as this will drive the oil into the concrete and spread the contamination over a larger area.

If the stain persists, a cleaner suitable for the purpose should be used in accordance with the manufacturers' instructions.

Alternatively the surface can be scrubbed with a strong detergent and the residue washed away with hot water. However, care must be taken as this method might also result in the leaching out of some pigment from the concrete product and discolouration due to surface abrasion of the concrete.

Bitumen stains:

Bitumen does not penetrate concrete readily. The bitumen should be left until it has cooled. It can then be removed using a paint scraper or similar mechanical device. If it is particularly resistant, the use of ice to make the bitumen even more brittle may be required, prior to scraping it from the paving. Any residue should be removed with an abrasive powder and finally the whole area rinsed with clean water.

Certain proprietary cleaning agents are available to remove bitumen, but these should first be tested on an inconspicuous area of the paving.

Chewing gum:

Chewing gum is one of the most difficult substances to remove from any surface. Newly discarded gum can be scraped off using a scraper. Hardened gum can be removed by chiselling it off the surface of the paving, using a hot water/steam cleaner or by chemical means.

There are contract cleaning companies who specialise in this type of cleaning, and it is recommended that they be contacted directly for further details.

Scuff marks from vehicle tyres:

These can normally be removed by steam cleaning or by scrubbing the area with hot water and a strong detergent.

Graffiti and paint stains:

Both paint and graffiti are difficult to remove. Fresh wet paint should be soaked up with an absorbent material without wiping the paint, as this will spread the stain. It should then be treated with a suitable solvent, for the paint involved, and the area washed with a concentrated detergent, taking care with the disposal of the run-off material. Most paint strippers are Sulphuric Acid based and attack the concrete.

Dried paint should be scraped off as far as possible and an appropriate paint remover applied, used in accordance with the manufacturer's instructions. Paint manufacturers may be able to give more detailed advice on the removal of graffiti and it may be necessary to consult them if there are large areas of vandalism.

Epoxy and polyester stains:

Areas of solidified epoxy or polyester resin can be removed by carefully burning off with a blowtorch. Care must be taken not to inhale any fumes given off or to overheat the concrete sufficient to cause explosive fracture of the coarse aggregate.

If black stains remain after burning, this can be removed by scrubbing with soap and water. For larger areas, grit blasting may also have to be considered. This will not affect the durability of the material but may affect the micro-texture of the surface. It is advisable to test a small area before any large scale operation is undertaken.

Smoke, fire and tobacco stains:

Normally these stains can be removed by scrubbing with soap and water. Where stains persist a mixture of scouring powder and household bleach can be used. When using bleach, it is important the bleach is washed from the area once cleaning is completed and the run-off disposed of carefully. Bleach is detrimental to plant life so care should be taken to protect adjacent lawns and borders.

Beverage stains:

These can normally be removed by scrubbing with hot soapy water. If the stain is persistent, apply mild bleach solution and then rinse the area with clean water, taking care to dispose of the run-off safely.

Initial maintenance of non mortared joints:

Refilling joints:

Jointing material may be lost from paving joints in early life during both dry and wet weather. In dry weather dry jointing material on the surface of the joint can be lost before it can consolidate. Particularly on steep slopes, the material can be washed from the surface of the joints during heavy rain in its early life. It is therefore important to inspect areas of new paving regularly in their early life and top up joints if necessary.

Sweeping:

Until joints have become stabilised (naturally or chemically) the paving should only be brushed by hand. Mechanical sweepers, (see following section) and in particular sweepers with high suction forces should not be used in the early life of the pavement. If they are used, there is a real risk of loss of jointing material from between the paving units. This is particually important for permeable pavements that have enlarged joints or voids.

Mechanical sweepers on paved areas:

Important considerations:

The following recommendations deal with vehicles and associated equipment and their use in sweeping and washing paved and flagged footways, footpaths, pedestrian areas and roads:

- Equipment should be purpose designed to sweep the particular area. If there is any doubt about suitability the vehicle manufacturer should be consulted.
- Where possible, low pressure tyres should be fitted to reduce the risk of breaking or cracking flags.
- Tyres should be inflated according to the manufacturers recommendations, again to ensure minimum weight per unit area.
- Polypropylene, rather than wire, brushes should be used.
- Sweeping brush pressures should be set to the minimum required to suit the particular task, i.e. surfaces swept regularly will require a lower setting than those swept infrequently or covered with heavy deposits.
- Tyre and brush pressures should be regularly checked.
- When sweeping, engine speed should be set at the minimum required to maintain vacuum (suction) pressure.
- Operators, including reliefs, should be trained to operate machinery in accordance with manufacturers recommendations.
- When equipment is stationary or left unattended, suction, brush rotation and water jetting equipment should be switched off to avoid the risk of damage to the paved area below the stationary equipment.
- For conventional block pavements or flag pavements in new or re-laid areas, agreement should be reached with the local highway authority on a period of manual cleaning to allow flags and block paving to become established, and the joints to seal with detritus. This period may be reduced by using either a water based bonding agent or elastomeric prepolymer sealant, and by agreement with the cleansing authority on an appropriate sweeping and sealant replacement regime.
- When water jetting equipment is used to wash areas, the jets or hand held lance should be directed at the surface at an angle not greater than 30° to the horizontal and diagonally across the joints (i.e. not parallel) using a high concentrate detergent solution. The area should be inspected after cleaning to ensure that joints remain full with any required jointing material replacement carried out after the pavement is dry.

Efflorescence:

White patches appearing on the surface of concrete paving naturally cause concern. However, such concern is rarely justified in the long term, as the appearance is normally the result of '*efflorescence*'.

Forms of Efflorescence

The term 'efflorescence' is also frequently used to describe whitish deposits or stains on building materials. However there are many forms of efflorescence, which have little in common, other than the fact that they result in a white discolouration. Efflorescence, as generally found on concrete paving products, is known as 'lime bloom.' It is a surface deposit on the concrete, seen either in the form of white patches or as a more general lightening in colour. When the latter effect is seen it is often misinterpreted as a fading or 'washing out' of the colour of pigmented concrete.

Formation of Lime Bloom

Lime bloom, when it occurs, is a natural phenomenon brought about by the normal chemical reaction between cement and water. A product of this reaction is calcium hydroxide, 'lime,' which is slightly soluble in water. Under certain conditions it can migrate through damp concrete to the surface where it in turn reacts with atmospheric carbon dioxide to produce a deposit of calcium carbonate crystals.

This deposit gives rise to the white patches or the overall lightening referred to earlier. It is normally extremely thin, and when wetted, the deposit becomes transparent and seems to disappear.

Occurrence

The occurrence of lime bloom on the surface of concrete paving products is a spasmodic and unpredictable phenomenon not associated with poor quality manufacture. The weather is a significant factor with lime bloom forming more readily when concrete becomes wet and dries slowly; therefore occurrences are more frequent in winter months. Generally it only occurs in the early life of concrete paving products, and materials which have been in place for a year or more, without experiencing lime bloom, are unlikely to be affected. The phenomenon is temporary and superficial and will generally disappear in time without affecting concrete strength or durability.

Block paving showing efflorescence

The same blocks after weathering

Removal of Lime Bloom

Introduction

Lime bloom can generally be expected to disappear over a period of time, depending on the environment to which the paving is subjected. Rainwater, being slightly acidic, dissolves the surface deposit. Where paving is fully exposed to the weather any efflorescence would normally be expected to disappear within the first year or two, although it might be longer for a sheltered site. Removal would be accelerated by abrasion caused by foot or vehicular trafficking.

Treatment

Equipment:

The following minimum equipment is required:

1 Protective gloves and goggles
2 Appropriate footwear
3 Brush with soft bristles/plastic watering can for application
4 Supply of clean water

Procedure

Proprietary cleaners can be used for more immediate removal of lime bloom. Most proprietary cleaning treatments contain acids and detergents, so it is important to ensure that the manufacturers' instructions and all relevant environmental regulations are followed. Incorrect or careless cleaning may result in injury or damage and discolouration to the surface of the concrete paving. It is advisable to carry out a test on a small and inconspicuous area of paving before undertaking cleaning over the complete area.

The procedure is best carried out in cool conditions. When the paving is hot, rapid evaporation may lead to recurrence of deposits. Care should be taken when applying acid based cleaners to concrete. Acid attacks concrete and over application may alter the appearance of the paving.

Wash off the residue and inspect the paving. In the case of stubborn or heavy deposits repeat the application as necessary.

After final application of the cleaner wash off any residue with plenty of water to prevent staining, taking care to dispose of the run-off safely. Allow the paving to dry and inspect the surface and joints and resand/replace mortar to joints as necessary.

Long term experience suggests that it is unlikely that lime bloom will recur after removal with acid based treatments. It is not possible, however, to give a guarantee against recurrence.

Preventing recurrence:

A further possibility, which may be considered after successful cleaning, is the use of a sealant to minimise recurrence, see Paving Sealants.

Advice on the use of such treatments can be obtained from specialist companies.

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