Construction of Concrete Flag Pavements (Flexible and Rigid Construction)

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Interpave
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Introduction

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 the PDF download Structural Design of Flag Pavements available on www.paving.org.uk) and correctly constructed, a flag pavement will provide long service with low maintenance costs.

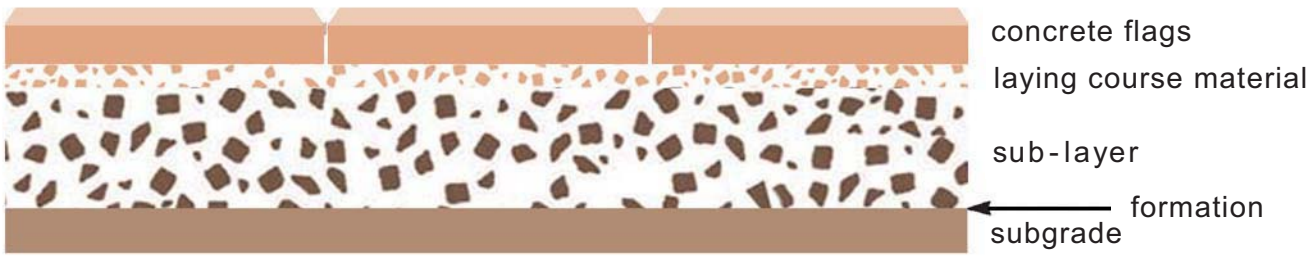
Successful construction of a concrete flag paved area depends on five main operations:

- 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

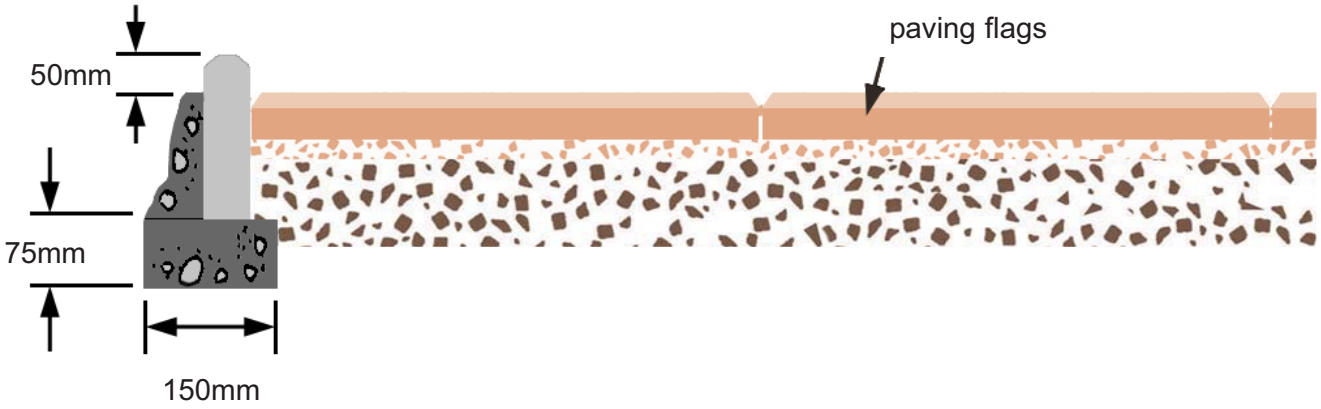
Where flags are to be laid over existing roads or other paved areas, it may be necessary to correct levels of the existing pavement to ensure final surface tolerances within +10 mm and -10 mm. Any excess material should be removed, using a planing process, to allow installation of the required laying 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

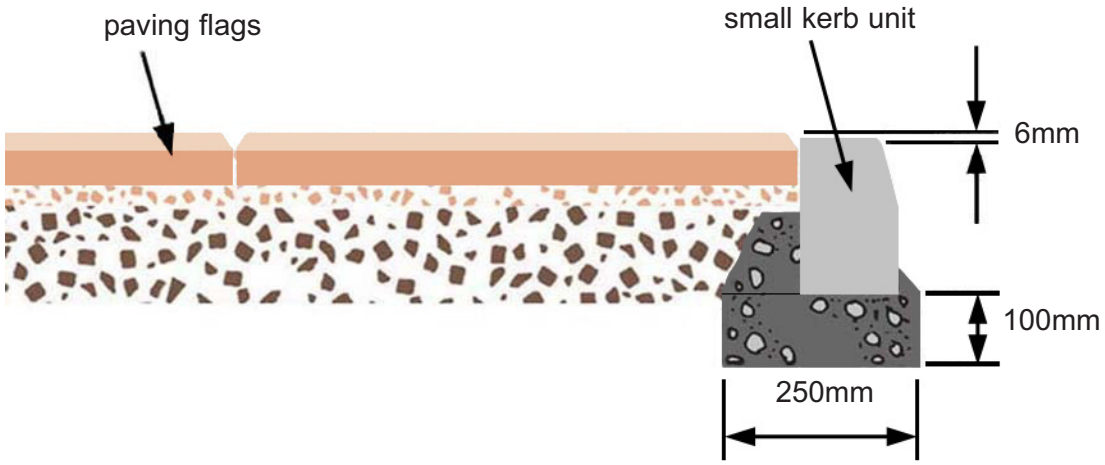
Edge Restraints

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.

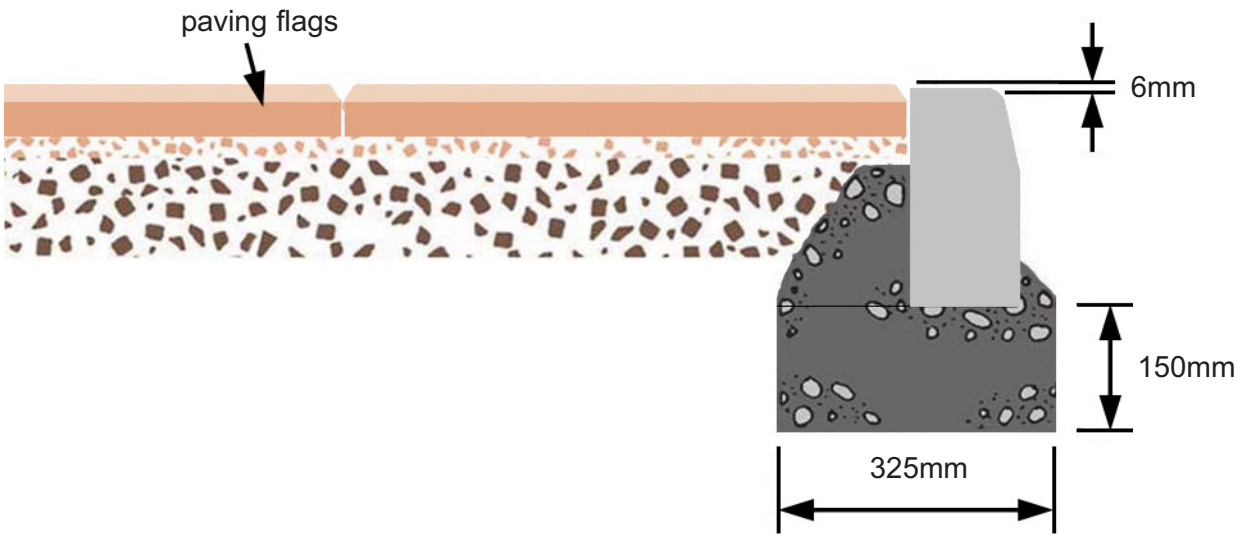
precast concrete edging
(not suitable for vehicle overrun)



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.

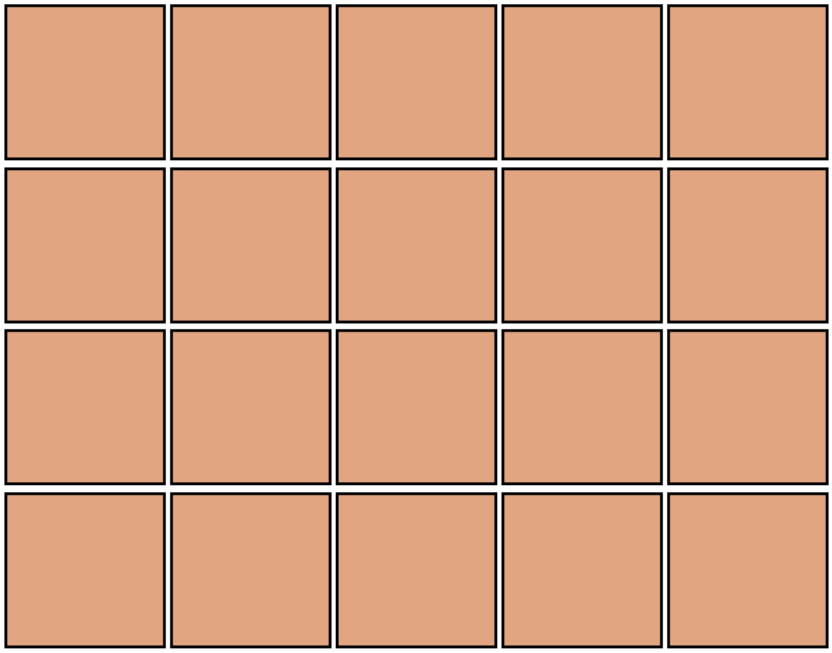
Jointing flags on a mortar laying course

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.

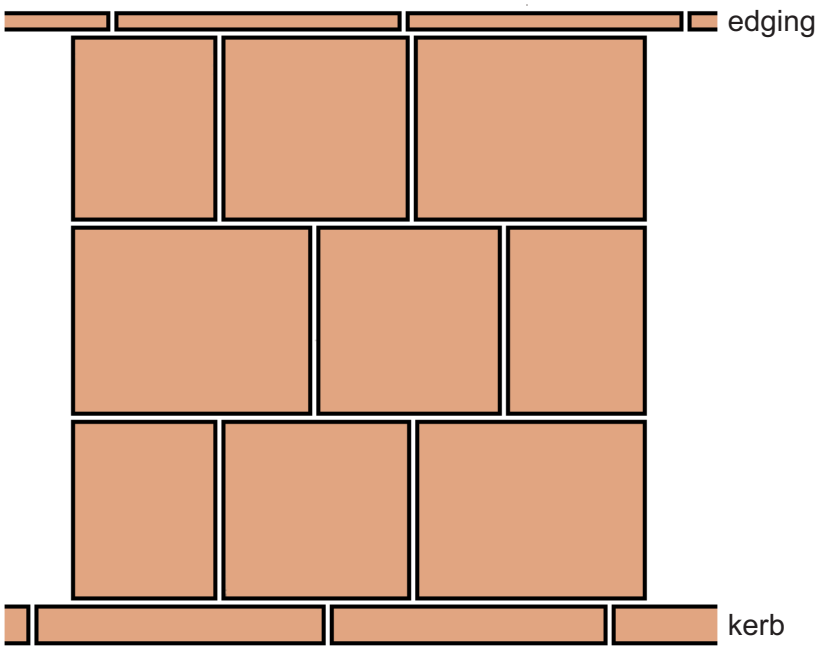
Selection of flag bond

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.

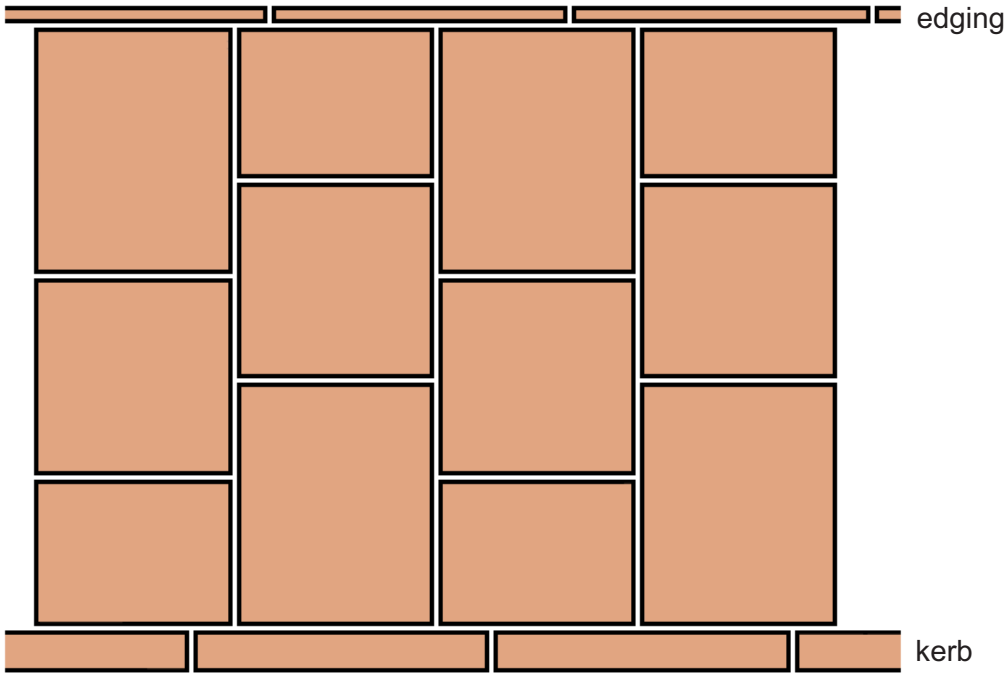
stack bond



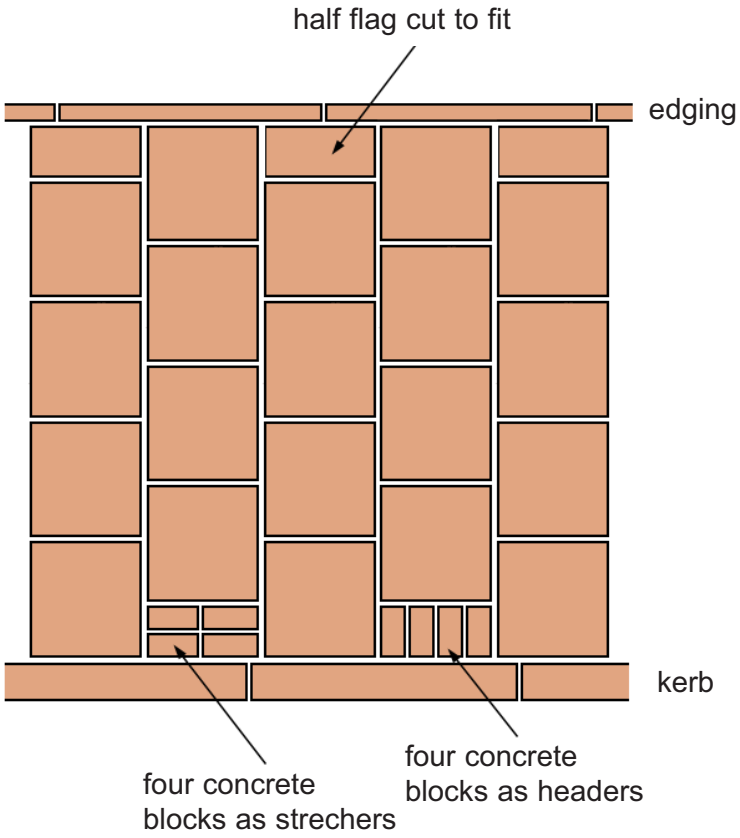
longitudinal broken bond



transverse broken bond



broken bond with block or half flag infill

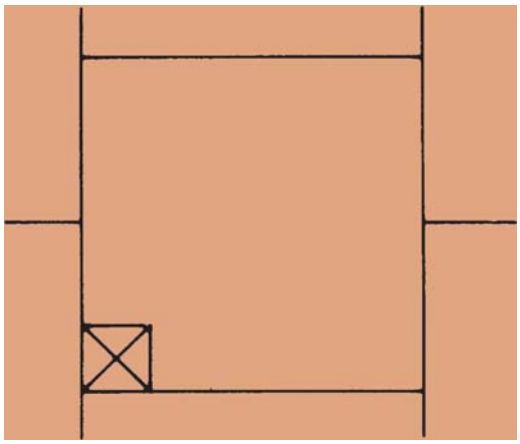


Flag installation

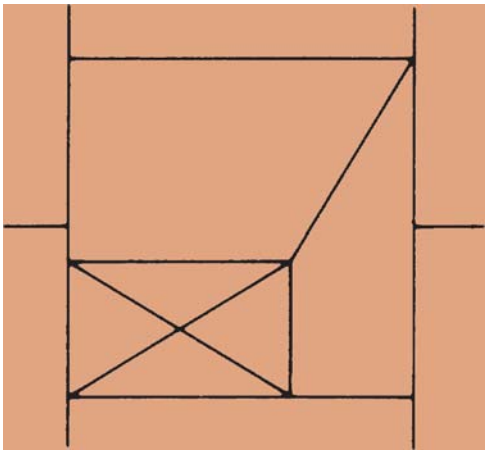
Flag laying should normally start at a fixed edge restraint. However, any edge restraint is unlikely to be perfectly straight or at 90° to the intended flag pattern. Therefore, a string line should be set up a short distance from the edge restraint and used to align the first "row" of flags. A second 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.

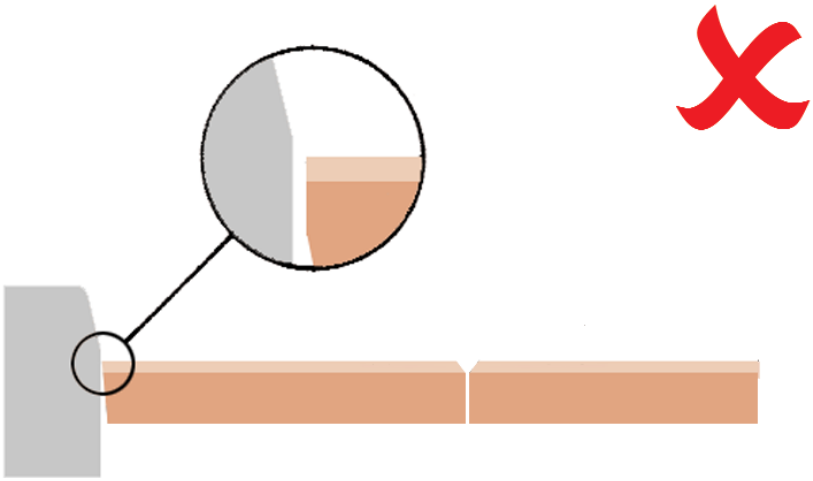


Where more than 25% of the flag has to be cut away then the remaining shape should be mitred from the internal corner of the cut-out to the external corner of the flag as shown below.

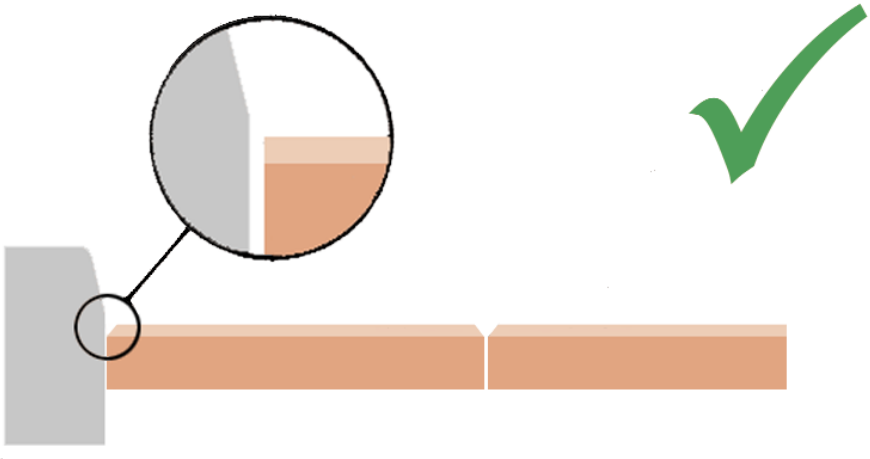


Detailing

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



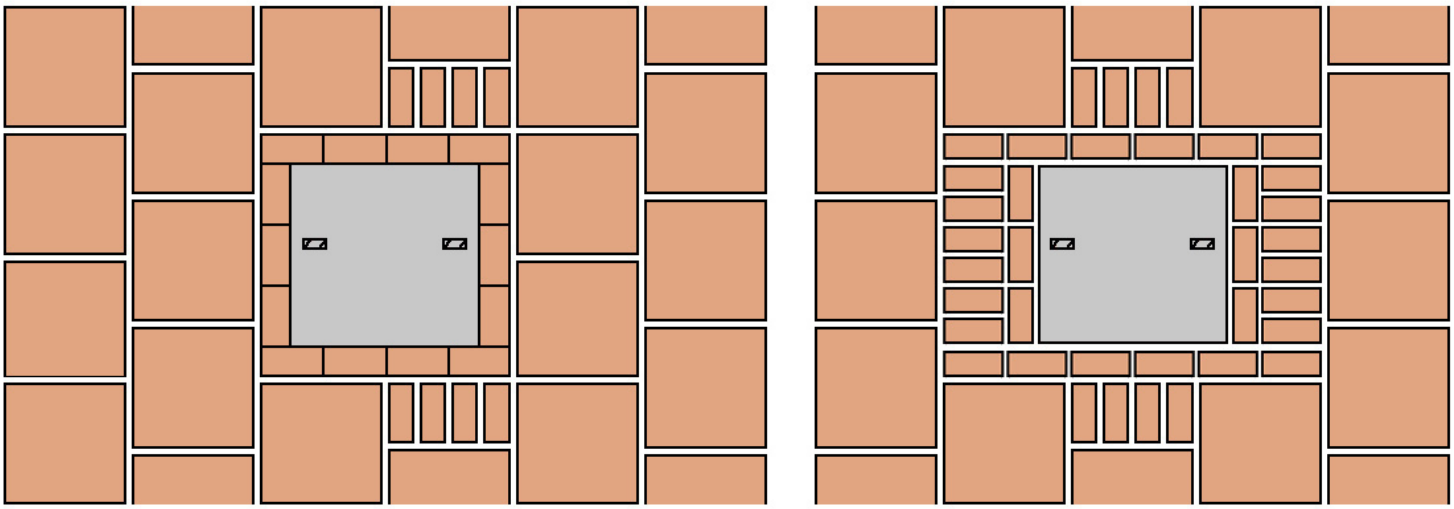
Cut faces should be positioned against an adjacent flag to reduce the visual intrusion of the square cut edge.



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.

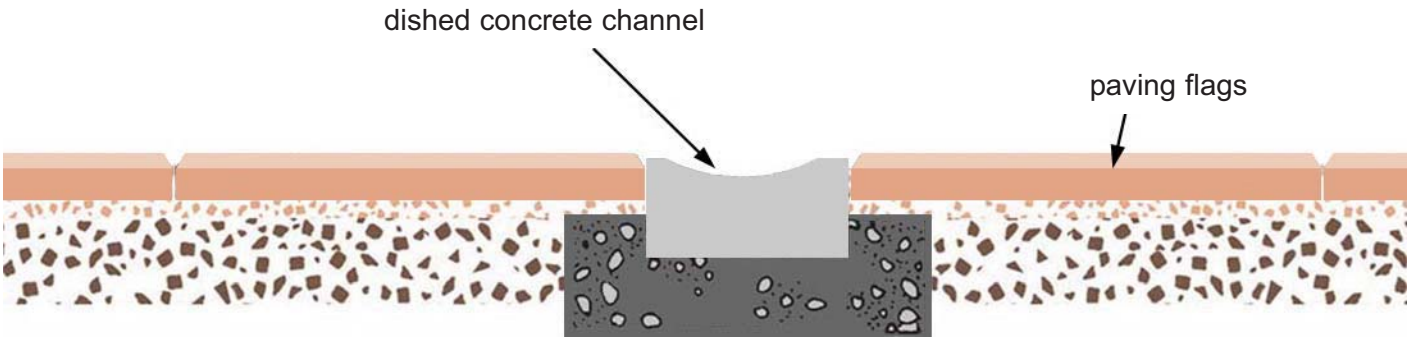
Details for manholes in flagged pavements



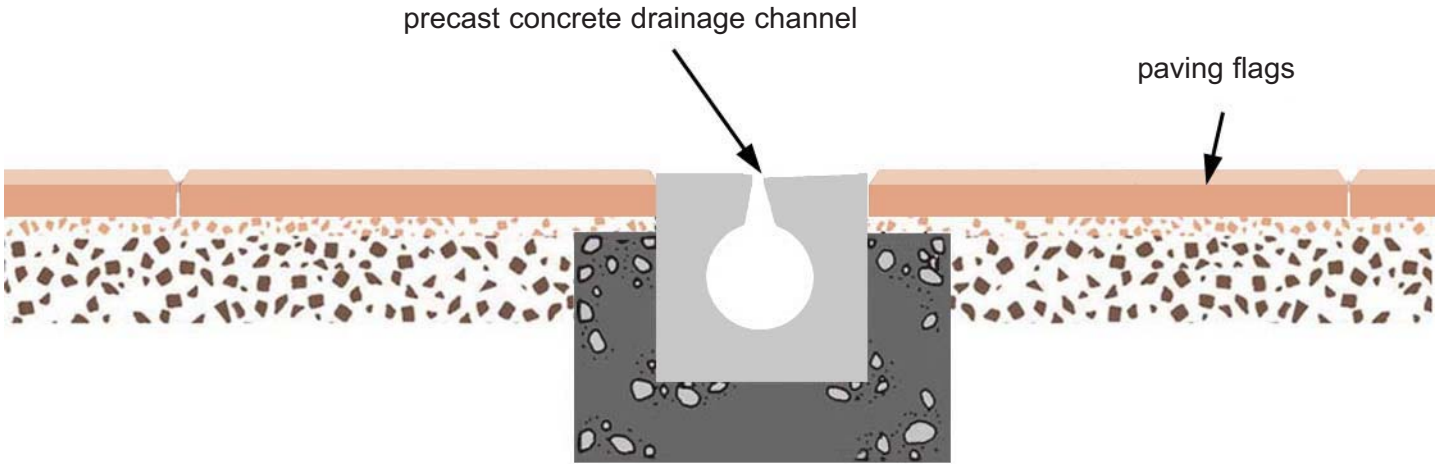
If a manhole cover or gully frame without straight sides is used, which will not allow the paving to directly abut the frame, then a surround of C35 air entrained concrete to BS EN 206-1 should be incorporated. It should be laid to the full depth of the flag and laying course. A stretcher course of blocks 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.

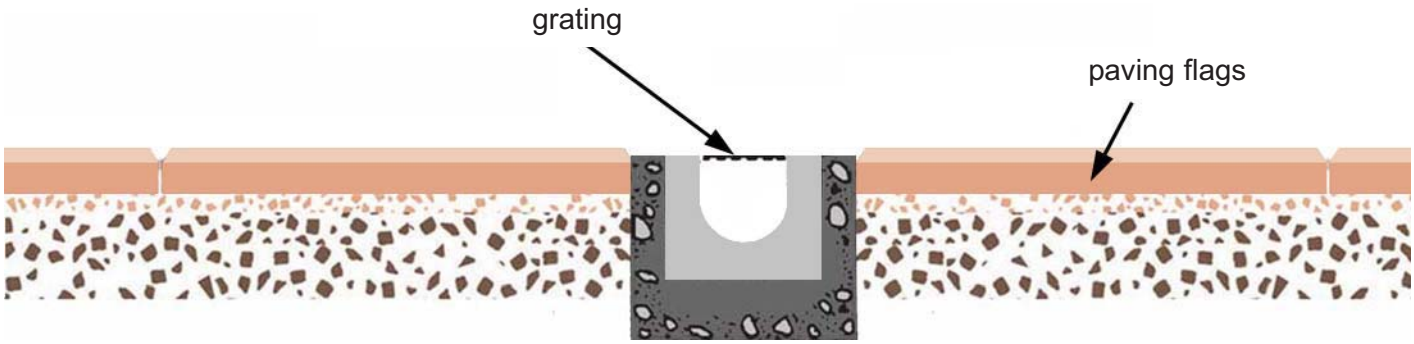
dished concrete channel



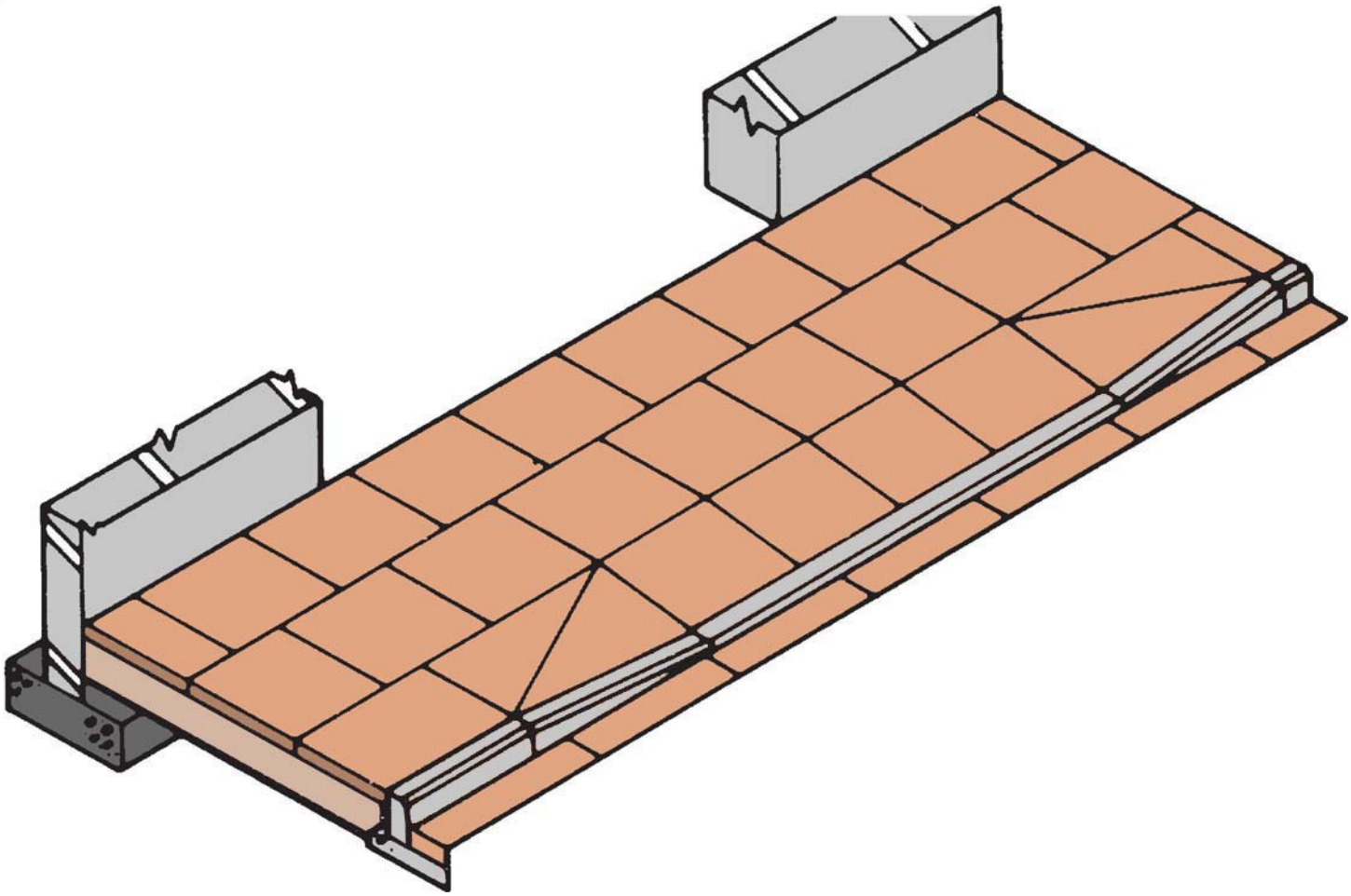
drainage channel with concrete haunching



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.