

National Highways Sector Scheme 30 for Modular Paving

**Rigid pavement construction using pre-cast concrete pavers
and flags, clay pavers and natural stone slabs and setts laid
without applied vibratory compaction**

Technical Training Manual - Course Framework

NHSS
national highway sector schemes

Contents:

	Page
1. Introduction	2
2. Health & Safety	2
3. Tools required	3
4. Definitions	5
5. Standards	7
6. Inspection of civil engineering works	8
7. Recognising the type of base according to type of paving unit and traffic load	9
8. Setting Out	10
9. Laying pattern	11
10. Joint width	11
11. Cuts and cutting in	12
12. Preparing the base	12
13. Preparing the paving units	13
14. Preparing the Laying Course	13
15. Installation of paving units	15
16. Provision of contraction joints	19
17. Grouting of mortar joints	20
18. Slabs and Flags in pedestrian areas laid using 3:1 sand and cement mortar	23
19. Clay Pavers laid using 3:1 sand and cement mortar	24
20. Protection of freshly laid or freshly jointed paving	24
21. Compliance checks	25

1. Introduction

This manual addresses the procedures for installing a pavement comprising pre-cast concrete pavers or flags, clay pavers, natural stone slabs and setts laid on a mortar laying course where vibratory compaction is not applied to the surface course. Separate manuals cover the installation of flexible modular pavements constructed using unbound aggregate and rigid pavements constructed using natural stone setts, where vibratory compaction is applied to the surface course as part of the installation process.

This manual is to be used as a basic aid for developing training material and presentations for the delivery of training for these materials. Whilst it may be read by and trainees and other interested parties, it intended to provide guidance for those compiling Technical Training Manuals for specific courses. (An accompanying manual - Training Resources Manual - gives addition training resources material, such as images and diagrams).

A separate manual Concrete or clay pavers, concrete or stone flags or sawn stone setts, laid on an aggregate laying course is to be used as a basic aid for developing training material and presentations for the delivery of training for this type of installation.

This manual does not cover the construction of the pavement base below the surfacing.

The installation procedures and properties of materials are based upon the requirements set out in the appropriate British Standards.

An operative trained and qualified to the level described in this training manual should be able to recognise incorrect materials as described in the specification and the delivery documentation or methods being used on site as described in the Quality Plan, and should bring these to the attention of his site supervisor or if not available, the resident engineer or client's representative.

2. Health & Safety

All work should be undertaken in compliance with current health and safety legislation.

Special risks associated with this industry sector should be carefully addressed, in addition to standard current health and safety legalisation.

Paving units might require being machine cut as laying work proceeds.

A specific induction course should include manual handling at work, lifting and carrying, power tools, cutting wheels, working with Portland cement, and appropriate PPE.

In particular, a natural stone sett might weight 15 kg or more.

Information and guidance addressing safety issues associated with this industry sector, such as handling and cutting, can be downloaded (free of charge) from the Interpave website: www.paving.org.uk

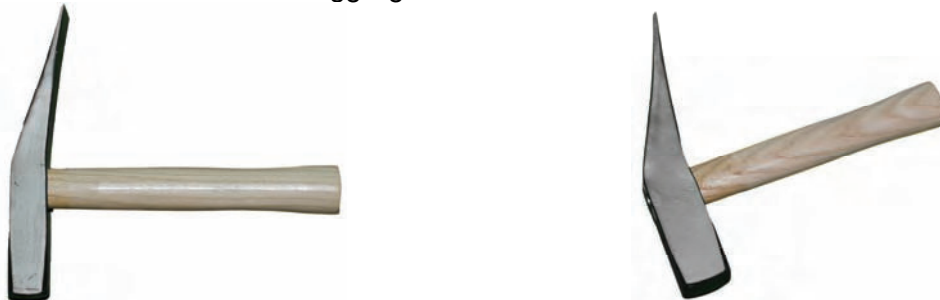
3. Tools required

The correct tools are essential if work is to be competently carried out. A worker not possessing the correct tools shows contempt for the skills demanded by the work expected of them. A craftsman will own and care for his or her tools with pride. The following are those tools which are personal to a skilled worker, unlike such impersonal tools as shovel or broom and powered tools which are often provided by the employer or hired.

Personal Protection Equipment (PPE). A skilled paving worker requires good tactility and vision. Some construction sites might require the use of protective headgear (hard hat) and special care should be taken to choose an item of equipment which is lightweight and which creates least restriction to head movement and field of vision, an unsuitable or ill-fitting hard hat can be more dangerous than none at all. Items such as safety glasses, gloves, knee protectors, reflective clothing, shoes and hard hat should all be carefully chosen and maintained by the worker. A skilled worker is expected to arrive, ready for work, with the essential items of PPE.



Pavior's Hammer. This special tool has evolved over generations for laying setts. Several variations on shape are available according to regional tradition and personal preference, weights vary according to the size of sett being laid, between 900 g and 3,500 g. The forged steel head is on one side a hammer for beating and on the other a blade for placing and moving bedding material, whether mortar or unbound aggregate.



Pavior's Maul. This is a heavy wooden or rubber faced metal hammer used to beat slabs and flags to level.



Mortar trowel. This is used when spreading bedding mortar for laying flags and slabs. A range of shapes and sizes are available and the worker will choose one which is comfortable and effective in use.



Pavior's Stool (optional). This is a one-legged wooden stool which allows the worker to squat comfortably at the ideal height for laying small setts and pavers whilst being able to swivel right and left without placing undue strain on the legs.



Long and short levels. A short level is used both to span more than one paving unit whilst beaten with the Pavior's Hammer in order to ensure uniform densification of the bedding mortar concurrently with achieving uniform levels at the surface. The short level is often and repeatedly slid around the area of freshly laid paving within reach, to check for lips.

The short level is sacrificial and is replaced often, as it becomes worn in use. A short level is typically circa 400 x 45 x 90 mm. The long level must be stiff and perfectly straight, it is very often, in practice, a proprietary spirit level of circa 2 metres in length. The long level is used to check for flatness over a wider expanse of freshly laid paving as work proceeds.



Measuring and marking tools: Tape measure or yard stick, string line and pins, marking chalk or pencils.

Other equipment. Mechanical equipment e.g. rollers or vibrating plates, dumpers, mixers, generators, saws, mortar removers etc. should be checked for safety, correct functioning and adequate fuel, lubricants water etc are present prior to work commencing.

4. Definitions

The following definitions are generally taken from those stated in the relevant British Standards and should be applied specifically to the types of operation described in this document.

paving unit - all types of pre-cast concrete pavers and flags, clay pavers and sawn natural stone slabs and setts

concrete paving block - pre-cast concrete unit, used as a surfacing material, in which, at a distance of 50 mm from any edge, any cross-section does not show a horizontal dimension less than 50 mm and with an overall length which when divided by its thickness is less than or equal to four

clay paver

paving unit manufactured from clay with square edges to all arrisses, having work dimensions of between 200 mm and 215 mm in length, between 65 mm and 215 mm in width and between 30 mm and 65 mm in thickness

concrete flag

pre-cast concrete unit, used as a surfacing material, with an overall length that does not exceed 1.5m and an overall length which when divided by its thickness is greater than four

natural stone slab

unit of natural stone having all unseen sides sawn, in which the working width exceeds 150 mm and also generally exceeds two times the thickness

natural stone sett

natural stone paving block having all unseen sides sawn, work dimensions between 50 mm and 300 mm and no plan dimension generally exceeding twice the thickness

cement

for the purposes of this document cement means an hydraulic binder, whether a CEM1 Portland cement or a CEM2 or other cementitious binder.

hydraulic mortar

a mortar comprising a cementitious binder and aggregate

laying course

layer of mortar on which paving units are bedded

laying face

working edge of the surface course to which paving units are placed

base

layer upon which paving units are bedded, which carries all loads imposed on the pavement into the sub-base, or in the case of suspended slabs, back to the structure.

Note: The base might consist of reinforced or unreinforced concrete, asphalt concrete or compacted unbound aggregate.

surface course

layer of paving units that acts as a wearing surface and forms part of the structure of the pavement.

laying pattern

arrangement of paving units either for structural requirements or for visual effects.

jointing material

mortar applied to fill the joints between paving units.

joint width

distance between adjacent paving units or units and restraints or perimeters.

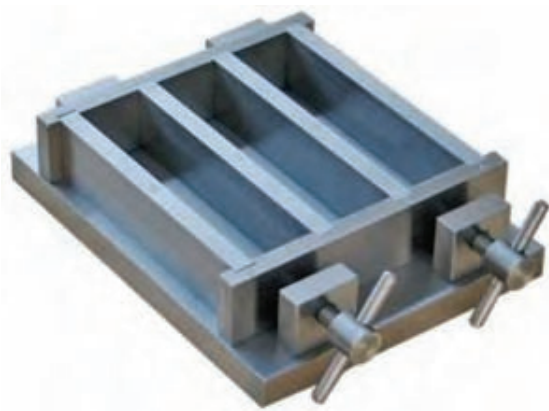
lippage

relative height between adjacent blocks.

Mold (or Mould)

samples of bedding mortar, made on site for quality control purposes, should be made using the prism mold specified in BS EN 1015-11.

The size of the mortar prisms is 40 x 40 x 160 mm.



Small cube molds may be useful for assessing only compressive strength, the standard 50 mm cube mold being used for this purpose.

The use of 100 mm and larger concrete molds is not good practice.

5. Standards

The European Standards relevant to the manufacturing of paving units are shown in table 1

Table 1 Relevant European Standards

European Standard Number	Title
BS EN 1338:2003	Concrete paving blocks. Requirements and test methods.
BS EN 1339:2003	Concrete paving flags. Requirements and test methods.
BS EN 1341:2013	Slabs of natural stone for external paving. Requirements and test methods.
BS EN 1342:2013	Setts of natural stone for external paving. Requirements and test methods.
BS EN 1344:2003	Clay pavers. Requirements and test methods.

The British Standards relevant to installation are shown in table 2

Table 2 Relevant British Standards

British Standard Number	Title
BS 7533 - 4: 2006	Pavements constructed with clay, natural stone or concrete pavers – Part 4: Code of practice for the construction of pavements of pre-cast concrete flags or natural stone slabs
BS 7533 - 7: 2010	Pavements constructed with clay, natural stone or concrete pavers – Part 7: Code of practice for the construction of pavements of natural stone paving units and cobbles, and rigid construction with concrete block paving
BS 7533 - 9: 2010	Pavements constructed with clay, natural stone or concrete pavers – Part 9: Code of practice for the construction of rigid pavements of clay pavers

The key requirements of these British Standards are:-

- Material specifications (laying and jointing)
- Construction procedure
- Bedding depth and joint width
- Laying pattern
- Cutting/edge details
- Joint widths
- Surface level and smoothness
- Tolerances

6. Inspection of civil engineering works

Generally the civil engineering work of providing the structural base is undertaken by a different contractor but, regardless of who is responsible for this work, prior to commencing paving installation the preceding work should be inspected to ensure compliance with the contract specification and drawings. Non compliance must be corrected and reassessed before proceeding with the paving installation.

If the operative is required to prepare the base, reference should be made to the BS 7533 Series for the materials used and the Specification for Highway Works 800 series

Items to be inspected and checked are:

Materials on delivery

Sub base and CBM should be moist but not saturated No dry material should be present

CBM should be able to be pressed into a ball with one hand and caught without crumbling if thrown a foot in the air

Asphalt should be sizzling hot and all look the same with no separated stones

Water permeability of base. Some conventional pavement designs require that the base is water permeable, for reasons of frost protection. A permeable base layer may be formed of unbound, hydraulically or bituminously bound aggregate. An indication of permeability may be confirmed by simple in situ testing. e.g. a minimum of 2 litres of water poured onto a single point on the surface should drain away through the base in less than 5 minutes

Stiffness of an unbound base. The base must be compacted to the contract requirements, these are generally based upon numbers of passes of a roller of given size; the number increasing with increasing base thickness. If possible the stiffness should be confirmed to be in accordance with contract requirements if any. An in-situ testing device such as a portable Falling Weight Deflectometer may be used which is particularly useful at finding soft areas that will need replacement or further compaction. The base should take the load of a small loaded dumper truck or wheelbarrow without deformation and should be completely solid under foot

Competence of CBM base. A visual inspection should be carried out in order to check for warning signs such as cracks, scaling or loose particles. The compacted layer should have a dense smooth uniform finish No pieces should be able to be removed by hand with a screwdriver after 3 days curing under wet sacking.

Competence of concrete base. A visual inspection should be carried out in order to check for warning signs such as cracks, scaling or loose particles. When hit with a club hammer or heavy bar the layer should sound solid and be unmarked.

Competence of asphalt concrete base. A visual inspection should be carried out in order to check for warning signs such as running cracks or loose particles. The compacted layer should have a dense smooth uniform finish. No pieces should be able to be removed by hand with a screw driver.

The tolerance of each layer from the required finish datum, when measured over a 3 m grid, should be as recommended in Table 3. The thickness of the laying course should be assumed to be the target thickness ± 1 mm for the purpose of these calculations.

Table 3 Base and surface level tolerances

	pre-cast concrete pavers and flags	clay pavers and sawn natural stone slabs and setts
Surface Course level tolerance	+ 6 mm - 6 mm	+ 5 mm - 5 mm
Base level tolerance	+ 5 mm - 10 mm	+ 5 mm - 5 mm

To ensure positive drainage, the finished level of the paving above the top surface of gulleys, drainage inlets and drainage channels should be a minimum of 5 mm.

Finished surface levels in relation to damp course levels, standard and deterrent kerbs etc are such that after pavement installation the surface of the paving is compliant with the contract specification as shown on the drawings.

The surface course level tolerance, as shown in Table 3, may be referred to as smoothness.

The falls for surface drainage given in Table 4 can be used to ensure that surface water is removed efficiently from the surface and that ponding is avoided. Drainage should be located so that no puddles will be generated on the finished surface. If this is not the case the operative should bring this to the attention of his site supervisor or if not available, the resident engineer or client's representative. Puddles after rainfall will lead to loss of durability in the pavement in frosty weather.

Table 4 Falls for surface drainage

	Recommended	Extreme limits
Crossfalls	2.5%	1.5% to 7%
Longitudinal falls	1.25%	Max. 8%

Note: Some materials can be laid on slopes steeper than these gradients, but as most paved areas are shared with pedestrians, 8% is considered to be a comfortable maximum.

7. Recognising the type of base according to type of paving unit and traffic load

This is the responsibility of Supervisors.

The base upon which the bedding mortar is to be laid is sometimes referred to as the "roadbase". A rigid modular pavement does is not always required to have a rigid base, this is dependent upon the type of paving unit (slab/flag or paver/sett) and the degree of traffic loading. The relevant British Standards classify traffic loading into six classes, referred to as Site Category. Table 5 describes these:

Table 5 Site categories for typical applications

Site category	Standard axles per day	Typical applications
IB IA	> 1 000 </= 1 000	Adopted highways and commercial developments used by a high number of commercial vehicles
I	</= 200	
II	</= 60	Adopted highways and other roads used by a moderate number of commercial vehicles. Petrol station forecourts Pedestrian projects subjected to regular overrun of commercial vehicles.
III	</= 5	Adopted highways and other roads used by a low number of commercial vehicles, e.g. cul-de-sac on a housing development. Pedestrian projects subjected to occasional overrun of commercial vehicles. Car parks receiving occasional commercial vehicular traffic. Footways regularly overridden by commercial vehicular traffic
IV	0	Car parks receiving no commercial vehicular traffic Footways subjected to domestic vehicular crossover Private drives, paths, patios, hard landscaping Areas receiving pedestrian traffic only, e.g. school playgrounds

This table describes traffic loading using the unit known as "Standard Axles".
The following table 6 is intended to provide a straightforward understanding of this unit:

Table 6 Standard axles per commercial vehicle

Vehicle type	Conversion factor
Buses and coaches	2.6
2 axle rigid	0.4
4 axle rigid	3.0
4 axle articulated	1.7
5 axle articulated	2.9

For rigid pavement laid with slabs and flags it is required to provide a pavement quality concrete (PQC) base in all Site Categories other than Site Category IV.

All pavers and setts with depth less than width must be laid upon a pavement quality concrete (PQC) base.

For full depth pavers and setts (paving units having depth not less than width), a CBM, PQC or bituminous asphalt base may be specified.

For pavers and setts, Table 7 describes the minimum recommended sizes stated in the relevant British Standards:

Table 7 Minimum dimensions of setts and pavers:

Site category	Minimum dimensions of setts or pavers	
IA (special case)	150 mm with minimum depth 180 mm	
IB (special case)	150 mm with full depth	
I	100 mm with full depth	150 mm shallow unit
II	80 mm with full depth	100 mm shallow unit
III	50 mm with full depth	100 mm shallow unit
IV	50 mm with full depth	80 mm shallow unit

8. Setting Out

Consideration must be given to the laying pattern and the orientation of laying pattern. This will normally be provided by the designer and shown on the drawings. However it is often the case with slabs/flags, that a width may be specified and random lengths at the Pavior's discretion. Setting out of datum points is necessary to assist in to achieving falls, straight lines, curves etc.

For dimensionally large projects, to ensure consistent alignment, it may be helpful to set out a reference grid using flush nails or paint, typically on a 10m x 10m grid over the base surface.

Major lines should be set out according to datum points provided by the engineer.

Areas of paving demarcated by boundaries such as change in level, change in pattern or type of paving unit or other perimeter feature should have the lengths of all sides and diagonals measured at final surface levels, to confirm in advance of laying that the effect of longitudinal falls, crossfalls, setting out errors or other unforeseen factors will not prevent the specified paving patterns being achieved using the paving elements provided for the contract.

When perimeters and major lines have been confirmed and feasibility checked, minor lines should be set up at intervals, in advance of laying, to represent a multiple of paving unit width plus joint width. For example, when setting out for paving units 150 mm wide having 10 mm joint width, minor lines might be set up at intervals of 1.6 m or 2.4 m. This prevents the pattern locally overtaking the major lines of the pattern and also prevents joint widths increasing abnormally.

Paving materials should be stored in an appropriate location, to minimise trafficking on the prepared base during installation.

If working in a public area, i.e. refurbishment work to in a public highway, work practices and the safeguarding of workers and the public must be made in compliance with New Roads and Street Works Act. This is a separate skill for which training is provided

All work must be undertaken in compliance with current Health and Safety legislation.

9. Laying pattern

For a rigid pavement construction, laying pattern generally makes a negligible contribution to the overall structural integrity of the pavement. If excessive strain occurs within the pavement surface course, due to thermal contraction or movement of the base, cracks might become focused along a continuous line of joints. However, this is not a problem which laying pattern may prevent.

The laying pattern must conform to that given in the documentation e.g. on drawings. If the Pavior is given discretion some simple rules need to be followed

- If no standard details are provided the client's advice must be sought and no assumptions made.
- A cut is required at any change in surface shape to prevent lipping. It is accepted that this can lead to triangular shapes which contravene the rules about cutting given below
- Straight joints are usually provided in one direction but stepped joints in the other direction.
- Joint widths must be within the permitted range.
- With cropped setts, sufficient space must be allowed everywhere for grout to run easily into the joint.
- The standard details at drainage features and other ironwork must be followed, especially if an expansion joint detail is specified. Expansion joints may or may not be required. Details of suitable joints are given in the relevant British Standards

10. Joint width

When laying a rigid pavement, joint width is an important factor.

The purpose of the mortar joint is to prevent ingress of water during the service life of the pavement and to provide structural integrity to the surface course. Jointing mortar contributes both strength and flexibility to the pavement surface.

Minimum joint width is a function of both the maximum particle size within the jointing mortar and the degree of flexibility it is intended to provide in conjunction with the paving units. For flags and slabs, the recommended joint width is 6 mm to 10 mm. For pavers and setts, guidance is provided in Table 8:

Table 8 Joint width between pavers and setts

Width of paver or sett	Design joint width mm
50 mm	6-10
80 mm	8-12
100 mm	8-12
150 mm	10-15



11. Cuts and cutting in

The paved area should be covered as far as possible with full sized paving units.

It is best practice to employ longer units at ends of rows, in preference to cutting down standard units so that length is less than the shortest specified unit length. For example, alternate rows of setts 100 mm x 100 mm in plan laid with 10 mm wide joints should begin with a longer unit 140 mm x 100 mm in plan.

Where paving units need to be trimmed, cut sizes smaller than a third of the original plan size of the paving unit should be avoided. No plan dimension should be less than 50 mm.

Cut units must be laid concurrently as paving proceeds, without any delay. With rigid paving it is not permissible to leave gaps in the surface course, to be filled at a later time. If this is unavoidable, e.g. because of the unavailability of a cover, all bedding mortar not covered by a unit must be removed.



12. Preparing the base

A rigid pavement requires a sound, strong physical connection between base material and bedding mortar. For a bound base this means an effective adhesion bond, for an unbound base this means an effective frictional connection. Both require cleanliness.

When laying upon a bound base, this should be cleaned of all debris and dust prior to the laying of the bedding mortar. Cleaning with water is the recommended method following the removal of all loose materials. Any contaminants such as hydraulic or fuel oil spillage must be thoroughly removed, using chemical and mechanical means as required.

When laying upon an unbound aggregate base, alien materials such as sand, soil and detritus should be removed. The base surface must comprise only that material intended to be laid as base material.

The base should be checked for level to ensure the laying course will be the correct thickness. If an incorrect base level exceeds the tolerance allowed in the contract specification, the situation must be brought to the attention of the site supervisor or if not available, the resident engineer or client's representative and an instruction sought before work proceeds.

If is too high material must be removed. This might require large scale intervention, such as mechanical planing of the surface.

If it is too low, i.e. the bedding will be too thick; this is a difficult fault to correct. It is likely that the bedding mortar will not receive adequate compaction in the thicker areas, but screeding a thin layer of fine concrete to fill the gap might lead to a plane of weakness. A proprietary product solution may be used at the discretion of the engineer. However, some engineers might require the whole base to be removed and replaced

13. Preparing the paving units

Both natural stone and manufactured products, pre-cast concrete and clay, can vary in colour and shade. The extent of colour variation, despite falling within the limits of contract specification, can create an unacceptable visual contrast and for that reason it might be necessary to mix paving units taken from different packs in order to minimise the effect of colour variation across the surface of the finished pavement. In case of doubt the approval of the Client should be sought prior to laying.

A rigid pavement requires a strong adhesion bond between paving units and both bedding and jointing mortar. Paving units should have all dust and debris removed from all faces. New paving units, as delivered to site, are not sufficiently clean. Dry cleaning is not enough and, even after thorough dry cleaning, cleaning with water is essential. The timing of wet cleaning should be made a sufficiently short time prior to laying, to avoid recontamination.



14. Preparing the Laying Course

The more traffic the pavement carries, the more onerous are the requirements for the bedding mortar. 1:3 Cement sand mortar is permitted in BS 7533-4 for Site Category IV only, i.e. Pedestrian traffic only with NO vehicular use.

For vehicular use two performance classes of bedding mortar are described for rigid paving in BS7533-7:2010, the higher class of which is also described in BS7533-12:2006. Whilst both are specified on the basis of performance and might be supplied as ready-mixed material to the site, it is important to understand the differences between each.

The bedding and laying of clay pavers is different from concrete and stone for reasons as much related to tradition as engineering, though it may be related to the problems of satisfactorily removing mortar from the rough surfaced clay pavers necessary to form a slip resistant surface. Whilst paving units may be laid in accordance with BS 7533 Parts 4 and 7, BS 7533 Part 9 has a different methodology based upon bricklaying techniques. However, for higher traffic levels it is still absolutely essential for the bedding to be in complete contact with the unit and the joints to be fully filled with mortar that has not been wetted too much, as this affects the strength. This requires considerable care on the part of the operative.

The engineering requirements for pavement bedding mortar subject to vehicular trafficking are very different to those for a mortar typically intended for building a wall and the fresh mortar also feels very different in use. Fresh pavement bedding mortar must respond to the Pavior's normal work processes by compacting evenly, without voids, and at the same time must to provide stable support to freshly laid paving units as the next adjacent units are laid in succession. When laid and cured, bedding mortar must be water permeable in service to prevent damage when the inevitable small amount of water, that will penetrate some joints in later life, freezes. It must possess the correct characteristics of strength and flexibility. A good understanding of what constitutes a suitable bedding mortar is an important part of the craftsman's knowledge.

Bedding mortar for paving in pedestrian use only may be mixed to a moist consistency. Bedding mortar for paving in vehicular use is best required to be mixed to a plastic consistency but in some circumstances may be mixed to a moist consistency:

Moist mix - There should be enough water in a moist mix to fully hydrate the cement but not so much as to prevent the paving units being hammered in by hand; this is assessed by squeezing the mix in the hand. When the pressure is released the mix should show no water on the surface and should remain bound together. This is commonly referred to as the "snowball" test. The most common fault is for material



to dry out; this prevents adequate compaction and correct hydration of the cement so that that a weak laying course is produced and rapid failure occurs.

A moist mix is only suitable for situations where sufficient compaction energy can be applied when laying the paving units to adequately densify the bedding mortar. This is typically not possible when laying flags and slabs which are large in plan and relatively thin.

The laying course thickness after compaction should be $40 \text{ mm} \pm 15 \text{ mm}$ for moist mix unless otherwise required by the contract specification.

Plastic mix - The mortar should have a slump of 150 mm in accordance with BS EN 12350-2. The slump test is very easy to carry out, requiring the testing operative to compact the material into a metal cone with a rod, lift off the cone and by placing the cone next to the slumped material measure the amount slumped. After a few tests, the operative will be able to recognise a 150mm slump without further testing. Too wet a material is less of a problem than too dry.



A plastic mix is unsuitable for situations where the depth of the paving unit is so great as to displace the bedding mortar by virtue of its own weight and so disrupt the stability of line and level as work proceeds.

The laying course thickness after compaction should be $30 \text{ mm} \pm 10 \text{ mm}$ for plastic mix unless otherwise required by the contract specification.

Type A bedding mortar, the weaker option, is typically used for pedestrian areas but may sometimes also be used for areas of trafficked setts where the setts are very large. Type A bedding mortar is never used for shallow setts and pavers or for trafficked areas of slab or flag paving.

Type B bedding mortar is the higher performance class, however the operative might not notice any physical dissimilarity when working with a bedding mortar of either class. The significant difference is that Type B mortar must provide a very high adhesion bond and to achieve this it is necessary to apply a slurry coating of an adhesive priming mortar in combination with the bedding mortar. Bedding mortar and priming mortar together comprise a Type B mortar.

Type B bedding mortar is always required for areas of slab or flag paving subjected to vehicular trafficking and for all areas laid using shallow setts or pavers. It is often employed for areas of heavily trafficked setts.

Mortar may be supplied in loose bulk or a silo used for storage, in which case the dry mix is complete unto itself and simply needs water adding. If silo or loose bulk material is transferred to a site mixer in a dump truck it is essential that no segregation of aggregate and cement takes place. This can only be assessed visually with some difficulty. Mortar may also be supplied pre-blended in bags or in separate bags containing aggregate and cement, in which case there is no risk of segregation.

Adhesive priming mortar for use with a Type B bedding mortar is normally supplied as a proprietary product by the mortar supplier but might also be blended on site from a recipe described in the contract specification.

Relatively small quantities are mixed at one time, to maintain freshness and correct slurry consistency.



Mixing should be made using a powered paddle mixer, either hand-held or stationary. Manual mixing is not good practice due to the risk of incomplete blending.

Small "free fall" mixers commonly used for building mortar are unsuitable. The smallest "free fall" mixer which is likely to provide good service is that commonly described in the industry as a "5/3½ cu. ft." model. A "free fall" mixer is not guaranteed to successfully mix all types of bedding mortar that are commonly available. A free fall mixer is a "batch" mixer, which means that it produces a single batch of mortar at one time, this means they can blend a single batch comprising separate ingredients, this might be an important consideration if mortar is produced on site using separate ingredients.

Check that the mixer provided for bedding mortar is suitable to properly blend the mortar and is large enough to deliver the quantity of mortar required to carry out the planned works.

The best type of mixer available is known as a "forced action" mixer, these are commonly available in two variants.

The "Pan Mixer" is a widely available type of "forced action" mixer which may be obtained in a range of sizes, commonly ranging from 80 litres to 300 litres in capacity. For bedding mortar, a capacity of not less than 100 litres is recommended for all but the smallest sites.

Pan mixers are "batch" mixers and so can be used to mix both pre-blended proprietary products and to blend site-batched mortars using separate ingredients.



The "Continuous Mixer" is a "forced action" mixer which comprises a hopper and connected screw-feed blending tube into which water is continually fed and which delivers ready-to-use mortar on demand.

As its name implies, the continuous mixer is just that, it cannot produce batches of mortar comprising separate ingredients, it is only suitable for pre-blended proprietary mortars.



15. Installation of paving units

Prior to mortar being mixed, check that sufficient paving units, dry mortar products and water are close to hand at the point of laying, the base and paving units are clean and have been washed, all major and minor lines have been set out in advance for the area to be laid.

Confirm whether a plastic or soil-moist mix consistency is required in accordance with the contract specification. Operator preference may not override specification requirements.

All work must be carried out on the side of the unlaied face, at no time should operatives stand, work or rest materials or heavy tools on freshly laid paving.

In temperatures of less than 3°C on a falling thermometer or less than 1°C on a rising thermometer it is generally not permissible to work using mortar. Reference should be made to the contract specification or the mortar supplier, to confirm specific requirements.

Rows and patterns are normally set out using string lines, one per row of paving units. Pre-formed templates may be used to form awkward or highly detailed patterns. The use of joint spacers is impractical when laying natural stone or clay paving units, due to the significant dimensional

tolerances which typify those materials. Temporary spacers may be used between pre-cast concrete paving units but must be removed prior to jointing.

Where paving units are required to be cut to size, typically at ends of rows and at obstructions, these must be made as laying proceeds, without delay. On no account must gaps be left for later cutting and filling.

Cleaning of paving units during laying - all mortar contamination must be removed from the surface of paving units without delay, using clean water and a sponge.

Cleaning of paving units following completion of a working shift - areas of freshly laid paving units are to be thoroughly rinsed with clean water at the end of every working shift.

For all bedding mortar types it is good practice to have on site some suitable molds and compact material into them by hand. After curing on site in ambient conditions, these can be sent to a testing house to check compliance with the specification for compressive strength gain.

Shallow Setts and Pavers, full depth Setts and Blocks laid using Type B bedding mortar

Ensure that all necessary tools are prepared, ready for use. The essential tools typically required for this procedure are:

- Mixing machine for bedding mortar.
- Barrow for transporting bedding mortar from mixer to point of laying.
- Shovel for moving bedding mortar and general handling of dry or blended mortar products.
- Trowel for preparing and levelling bedding mortar.
- Tub and mixing equipment for adhesive priming mortar.
- Brush or trowel for applying adhesive priming mortar.
- Tub or bucket for cleaning water.
- Sponge for cleaning.
- Short wooden level.
- Long level.
- Sett hammer – weight relevant to size of paving unit.
- String lines for setting out rows and patterns.
- Cutting equipment if required.

Prepare a small sample area to confirm that a plastic mix, if specified, is suitable for the paving units being laid and to confirm surcharge height.

If a plastic mix is described in the contract specification but a practical test suggests that the paving units are too heavy to be supported by the bedding mortar as laying proceeds, this fact must be brought to the attention of the site supervisor or if not available, the resident engineer or client's representative and an instruction sought before work proceeds.

Bedding mortar is typically laid to a surcharge height of 10 mm to allow for compaction to line and level when tamping down the paving element, however a lower height may be acceptable if the test procedure confirms that full contact has been made between bedding mortar and the underside of the paving unit and that no voids exist in the bedding mortar. A close visual examination of the laid bedding will confirm this fact when a laid paving unit is lifted as a check. This check should be carried out for all types of bedding material. If 100% contact is not made or voids are seen the laying procedure must be revised.

The surface of the concrete base is to be coated with adhesive priming mortar immediately prior to bedding mortar being laid upon it. Priming mortar is normally applied by brushing but a trowel may also be used if preferred. Ensure that the surface of the base is fully wetted out with the adhesive priming mortar and that the surface is fully coated. Adhesive priming mortar is applied to a thickness of 1 mm to 2 mm, unless otherwise stated in the contract specification or mortar manufacturer's instructions.

Bedding mortar should be laid out for a minimum width of two rows of paving units, to the required surcharge height. This is to ensure adequate stability of the freshly laid bedding mortar adjacent to paving units being placed and aligned. Bedding mortar should not at any time be spread in advance of more than 4 rows of paving units. The fresh bedding mortar may be levelled prior to placement of each paving unit using either a trowel or the blade of the sett hammer.

The underside of the paving unit is to be coated with priming mortar immediately prior to the paving unit is being placed onto the fresh bedding mortar. Priming mortar is normally applied by brushing but a trowel may also be used if preferred. In every case it must be ensured that the underside of the paving unit is fully wetted out with the adhesive priming mortar and that the surface is fully coated. Adhesive priming mortar is applied to a thickness of 1 mm to 2 mm, unless otherwise stated in the contract specification or manufacturer's instructions. Adhesive priming mortar must not under any circumstances be applied to one or more paving units in advance of their being placed on the bedding mortar.



Paving units are to be hammered firmly to line and level without delay and thereafter they are not to be disturbed. The sett hammer may be used to strike the head of the paving unit directly if no damage is thus caused. The short wooden level may be placed upon the head of the paving unit and struck with the sett hammer as a preferred method, if desired. The short level is used frequently to slide across the freshly laid paving units, the check for lips and local level. The long level should be frequently used to check level over wider areas.

Full depth Setts and Blocks laid using Type A bedding mortar

Ensure that all necessary tools are prepared, ready for use. The essential tools typically required for this procedure are:

- Mixing machine for bedding mortar.
- Barrow for transporting bedding mortar from mixer to point of laying.
- Shovel for moving bedding mortar and general handling of dry or blended mortar products.
- Trowel for preparing and levelling bedding mortar.
- Tub or bucket for cleaning water.
- Sponge for cleaning.
- Short wooden level.
- Long level.
- Sett hammer – weight relevant to size of paving unit.
- String lines for setting out rows and patterns.
- Cutting equipment if required.

Prepare a small sample area to confirm that a plastic mix, if specified, is suitable for the paving units being laid and to confirm surcharge height.

If a plastic mix is described in the contract specification but a practical test suggests that the paving units are too heavy to be supported by the bedding mortar as laying proceeds, this fact must be brought to the attention of the site supervisor if available or the resident engineer or client's representative and an instruction sought before work proceeds.

Bedding mortar is typically laid to a surcharge height of 10 mm mm to allow for compaction to line and level when tamping down the paving element. however a lower height may be acceptable if this test procedure confirms that full contact has been made between bedding mortar and the underside of the paving unit and that no voids exist in the bedding mortar. A close visual

examination of the laid bedding will confirm this fact when a laid paving unit is lifted as a check. This check should be carried out for all types of bedding material. If 100% contact is not made or voids are seen the laying procedure must be revised.

Bedding mortar should be laid out for a minimum width of two rows of paving units, to the required surcharge height. This is to ensure adequate stability of the freshly laid bedding mortar adjacent to paving units being placed and aligned. Bedding mortar should not at any time be spread in advance of more than 4 rows of paving units. The fresh bedding mortar may be levelled prior to placement of each paving unit using either a trowel or the blade of the sett hammer.

Paving units are to be hammered firmly to line and level without delay and thereafter they are not to be disturbed. The sett hammer may be used to strike the head of the paving unit directly if no damage is thus caused. The short wooden level may be placed upon the head of the paving unit and struck with the sett hammer as a preferred method, if desired. The short level is frequently used to slide across the freshly laid paving units, the check for lips and local level. The long level should be frequently used to check level over wider areas.



Slabs and Flags laid upon a concrete base using Type B bedding mortar

Ensure that all necessary tools are prepared, ready for use. The essential tools typically required for this procedure are:

- Mixing machine for bedding mortar.
- Barrow for transporting bedding mortar from mixer to point of laying.
- Shovel for moving bedding mortar and general handling of dry or blended mortar products.
- Trowel for preparing and levelling bedding mortar.
- Tub and mixing equipment for adhesive priming mortar.
- Brush or trowel for applying adhesive priming mortar.
- Tub or bucket for cleaning water.
- Sponge for cleaning.
- Short wooden level.
- Long level.
- Pavior's maul – weight relevant to size of paving unit.
- String lines for setting out rows and patterns.
- Cutting equipment if required.

For the bedding mortar, a plastic mix is mandatory for this type of works.

Bedding mortar is typically laid to a surcharge height of 6 mm, however a lower height may be acceptable if a practical test confirms that full contact has been made between bedding mortar and the underside of the paving unit and that no voids exist in the bedding mortar. A close visual examination must confirm these facts when the paving unit is lifted at the end of the test.

The surface of the concrete base is to be coated with priming mortar immediately prior to bedding mortar being laid upon it. Priming mortar is normally applied by brushing liberally but a trowel may also be used if preferred. Ensure that the surface of the base is fully wetted out with the adhesive

priming mortar and that the surface is fully coated. Adhesive priming mortar is applied to a thickness of 1 mm to 2 mm, unless otherwise stated in the contract specification or mortar manufacturer's instructions.

Bedding mortar should be laid out to the required surcharge height, for a minimum width of 150 mm more than the width of the row being laid. This is to ensure adequate stability of the freshly laid bedding mortar adjacent to paving units being placed and aligned. The fresh bedding mortar should be levelled prior to placement of each paving unit using a trowel.

The underside of the paving unit is to be coated with priming mortar immediately prior to the paving unit is being placed onto the fresh bedding mortar. Priming mortar is normally applied by brushing but a trowel may also be used if preferred. Ensure that the underside of the paving unit is fully wetted out with the adhesive priming mortar and that the surface is fully coated. Adhesive priming mortar is applied to a thickness of 1 mm to 2 mm, unless otherwise stated in the contract specification or mortar manufacturer's instructions. Adhesive priming mortar must not under any circumstances be applied to one or more paving units in advance of their being placed on the bedding mortar.



Paving units are to be beaten with the maul firmly to line and level without delay and thereafter they are not to be disturbed. The short level is frequently used to slide across the freshly laid paving units, the check for lips. The long level should be frequently used to check level over wider areas.

16. Provision of contraction joints

Whilst expansion joints are a technical requirement which will be fully described in the contract specification, there is sometimes a requirement to install contraction joints and these are normally the work of the Pavior.

When a pavement contracts, either from low temperature or physical shrinkage, cracks might form if the resulting strain exceeds the tensile strength of the pavement surface course. It is common practice to introduce simple contraction joints at intervals across a pavement where cracks may safely form in a controlled manner.

Contraction joints in the surface course of a pavement laid over a concrete base are always located directly above and aligned with contraction joints installed in the concrete base. This requires careful setting out with knowledge of the laying pattern.

Contraction joints in the surface course of a pavement laid over an unbound base or non-rigid bound base, such as an asphalt concrete, may be positioned where it is most convenient for the setting out and laying pattern of the surface course.

Another term commonly used for a contraction joint is an "induced break", which is a useful term in describing the detail. The most common methodology is to introduce a vertical strip of polythene membrane within a line of open joints along the line of the proposed contraction joint. The polythene strip is set within the bedding mortar, for its full depth, and allowed to stand freely upright in the open joint, for its full height. None of the polythene strip is allowed to protrude above the surface of the pavement.

Jointing mortar is allowed to fill the joint void, uncontrolled, finding its own level each side of the polythene membrane. An induced break or contraction joint is thus formed.

17. Grouting of mortar joints

For rigid paving laid in accordance with BS7533-7:2010 two performance classes of jointing mortar are described, to be installed as a self-compacting grout. Both are specified on the basis of performance and might be supplied as ready-mixed material to the site. There is unlikely to be any recognisable difference in the mixing or handling of either class.

For rigid paving subject to vehicular trafficking laid in accordance with BS7533-4:2006 a single performance class of jointing mortar is described, to be installed as a self-compacting grout.

Paving units should have their joints filled to within 2 mm to 3 mm of their top surface. Jointing mortar should not be allowed to rise to be flush with the pavement surface as this will result in damage to the paving elements in hot weather. Flush joints are bad practice.

The engineering requirements for pavement jointing mortar are very different to a mortar typically intended for building a wall and the fresh mortar must also feel very different in use.

Fresh pavement jointing mortar must be a pourable self-compacting grout which, when applied, fills the joint in one operation.

For this method of installation, the forcing of a mortar into a joint, which is not self-compacting, is bad practice. Mortars which do not self-compact will result in voids and poor adhesion between the jointing mortar and the paving units.



Jointing mortars containing admixtures which might cause permanent staining of the pavement surface are to be avoided. Only self-compacting hydraulic mortars are covered by the grouting methodology described in this training manual. A number of proprietary systems exist and if these are used, the manufacturer's method statement should be carefully followed.

Hydraulic mortars are those which employ Portland cement as the binder. These are straightforward to install and clean from the pavement surface.

When cured, jointing mortar must be impermeable in service and resistant to frost and de-icing salts. It must possess the correct characteristics of strength and flexibility. It must also have good adhesion to both sides of the joint and not have undergone shrinkage and cracking.

A good understanding of what constitutes a suitable jointing mortar is an important part of the craftsman's knowledge but the technical requirements must be in accordance with the British Standard for the performance level specified.

The method of application is normally by pouring the grout over the area and using a squeegee to spread and guide the slurry into the open joints. It may also be achieved by using a can with a fine nozzle, or by injecting the joint with a handgun.



It should be noted that the type of squeegee suitable for these operations employs a relatively soft rubber or neoprene blade, the soft material is formed from a closed cell foam material. The squeegee typically takes the form of a folded, twin blade. Squeegees formed of a relatively stiff, hard rubber blade are unsuitable. A craftsman should be able to recognise what constitutes a suitable tool.



Proprietary grout cleaning equipment is in widespread use within the industry. If such equipment is employed the manufacturer's method statement should be carefully followed. There is presently a single manufacturer of such machines and they are commonly known by their trade name "Pergo".



Ensure that all necessary tools are prepared, ready for use. The essential tools typically required for this procedure are:

- Mixing machine for jointing mortar.
- Barrow for transporting jointing mortar from mixer to point of work.
- *Alternatively: Tub and mixing equipment for jointing mortar*
- Suitable squeegee for spreading fresh mortar.
- A pressurised fresh water supply with a flexible hose capable of reaching all extents of the area to be jointed.
- Optional – a "Pergo" grout cleaning machine

Ambient temperature – in temperatures of less than 3°C on a falling thermometer or less than 1°C on a rising thermometer it is generally not permissible to work using mortar. Reference should be made to the contract specification, to confirm specific requirements.

Joints must be clean and cleared of all foreign matter.

The area to be jointed must be thoroughly soaked with clean water and maintained in a wet condition until jointing mortar is applied.

Jointing mortar should be mixed to a free flowing liquid slurry grout.

If using a proprietary mortar product, the manufacturer's method statement should be consulted.

Freshly mixed mortar is spread over the surface whilst the surface is wet and mortar forced into open joints using the squeegee.

The squeegee should be moved across the surface of the pavement at an angle oblique to the open joints.



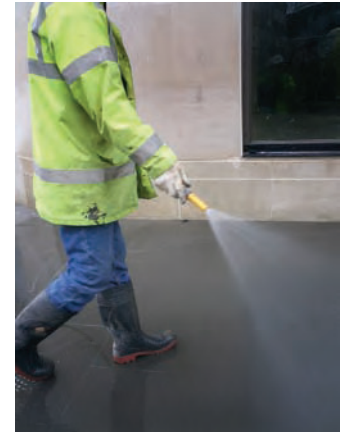
Fresh mortar is allowed to settle within the joints and fresh mortar is drawn across the surface repeatedly until joints are full and further settlement has ceased.

Water should be applied to the surface at any time in the form of a fine spray, to prevent drying of the mortar on the surface.

When further settling of the fresh mortar within the joints has ceased, excess mortar is removed using the squeegee.

Water is immediately applied to the surface in the form of a fine spray, taking care not to disturb the mortar in the joints, until the surface is thoroughly wetted.

Water and excess water is removed using the squeegee.



The process of wetting and removal is repeated, water always being applied to the surface in the form of a fine spray, taking care not to disturb the mortar in the joints. The surface is thereafter maintained in a damp condition by periodic application of water in the form of a fine spray. It should never be allowed to dry, even in small places, until final cleaning is effected.

The surface may be rinsed clear with clean water after sufficient time has elapsed for joint mortar to have become sufficiently stable to resist action of cleaning

If using a proprietary grout cleaning machine, manufacturer's method statement should be carefully followed.



18. Slabs and Flags in pedestrian areas laid using 3:1 sand and cement mortar

Ensure that all necessary tools are prepared, ready for use. The essential tools typically required for this procedure are:

- Mixing machine for bedding mortar.
- Barrow for transporting bedding mortar from mixer to point of laying.
- Shovel for moving bedding mortar and general handling of dry or blended mortar products.
- Trowel for preparing and levelling bedding mortar and to apply jointing mortar.
- Jointing iron for compacting and finished jointing mortar.
- Tub or bucket for cleaning water.
- Sponge for cleaning.
- Short wooden level.
- Long level.
- Pavior's maul – weight relevant to size of paving unit.
- String lines for setting out rows and patterns.
- Cutting equipment if required.

For the bedding mortar, a plastic mix is usual for this type of works. However, a moist mix might be considered acceptable if tests confirm that full contact has been made between bedding mortar and the underside of the paving unit and that no voids exist in the bedding mortar. A close visual examination of the laid bedding must will confirm this fact when the a laid paving unit is lifted as a check. This check should be carried out for all types of bedding material. If 100% contact is not made or voids are seen the laying procedure must be revised

Bedding mortar is typically laid to a surcharge height of 6 mm, to allow for compaction to line and level when tamping down the paving element. However a lower height may be acceptable if a practical test confirms that full contact has been made between bedding mortar and the underside of the paving unit and that no voids exist in the bedding mortar. A close visual examination must confirm these facts when the paving unit is lifted at the end of the test.

Bedding mortar should be laid out to the required surcharge height, for a minimum width of 150 mm more than the width of the row being laid. This is to ensure adequate stability of the freshly laid bedding mortar adjacent to paving units being placed and aligned. The fresh bedding mortar should be levelled prior to placement of each paving unit using a trowel.

Where flags/slabs are laid on a cement- sand mortar for pedestrian use only (Cat IV BS 7533-4), the mortar should be spread on the side of the laid paving unit, the next unit presented to it and any surplus mortar struck off.

Paving units should be laid to line and level on a full bedding layer compacted down using a Pavior's maul. The units should not rock after bedding. Any rocking flags should be lifted and re-laid as necessary.

The mortar should then be firmly pressed into the joints with a trowel or suitable rod to within 2-3mm of the surface.

The joint should be well compacted, using a jointing iron to create a bucket handle profile, to give a dense upper surface.

Any mortar on the surface should be cleaned off immediately to avoid staining if this is an important consideration.

19. Clay Pavers laid using 3:1 sand and cement mortar

Ensure that all necessary tools are prepared, ready for use. The essential tools typically required for this procedure are:

- Mixing machine for bedding mortar.
- Barrow for transporting bedding mortar from mixer to point of laying.
- Shovel for moving bedding mortar and general handling of dry or blended mortar products.
- Trowel for preparing and levelling bedding mortar and to apply jointing mortar.
- Jointing iron for compacting and finished jointing mortar.
- Tub or bucket for cleaning water.
- Sponge for cleaning.
- Short wooden level.
- Long level.
- Sett hammer – weight relevant to size of paving unit.
- String lines for setting out rows and patterns.
- Cutting equipment if required.

Where clay paving is laid in accordance with BS 7533-9 the most satisfactory method of laying involves simultaneous bedding and jointing; each paver should be mortared on the vertical face and pushed into the mortar bed. Additional mortar should be carefully placed in the joints as necessary using a trowel, ensuring that the vertical joints are fully filled to avoid impact damage and frost damage to the joint.

The joint should be well compacted, using a jointing iron to create a bucket handle profile, to give a dense top surface. The profile should be formed level with the top surface of pavers to provide support to arrises of paver units otherwise chipping can occur as debris enters the joint.

Surplus mortar should be quickly removed and a tooled joint profile formed using an appropriate tool. The surface of the paver should be wiped clean, with care being taken not to allow excess mortar or slurry to stain by entering the surface texture.

20. Protection of freshly laid or freshly jointed paving

This applies to all types and methods of rigid pavement construction.

During hot, dry weather and where there is a risk of heavy rainfall it is advisable to protect freshly laid or freshly jointed paving. Waterproof polythene sheeting is typically laid over the pavement, taking care not to disturb the paving elements. On no account must personnel stand on freshly laid or freshly jointed paving when carrying out such operations.

The freshly laid paving should be fully quarantined to allow sufficient strength gain before being accessed for any purpose, this includes site personnel. This might typically be a period of 24 hours but careful reference should be made to the contract specification or mortar supplier's information, which might instead state a strength gain figure instead of time.



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