

Key points about access and paving

- The main functions of paving in upgrading areas are to provide a firm all-weather access and to improve drainage. Brick and unreinforced concrete will generally be the best materials for paving local streets and lanes.
- Gravel, hardcore and waterbound macadam provide relatively cheap short-term surfacing options but are likely to deteriorate quickly, particularly where there are periods of heavy rainfall.
- The preferred options for surfacing through routes are bituminous carpets and surface dressing.
- Brick pavements should be sand grouted and laid with no cross-fall in streets where the available longitudinal fall is less than about 1 in 300. Bricks grouted with cement mortar are also commonly used.
- The key to good construction is the preparation of the subgrade. For heavily loaded pavements poor quality subgrade material should be replaced with compacted sand or other selected fill material.
- An appropriate structural design method for pavements carrying through traffic is presented which allows for variations in design load.

Section 4d

Access and Paving

Tool P1 Access and paving: Objectives and options

Access

Access provision takes account of the needs of people, vehicles and services. Access routes enable the inhabitants of a site to move freely from their homes to other areas of the site and to major adjoining thoroughfares. A balance must be struck between:

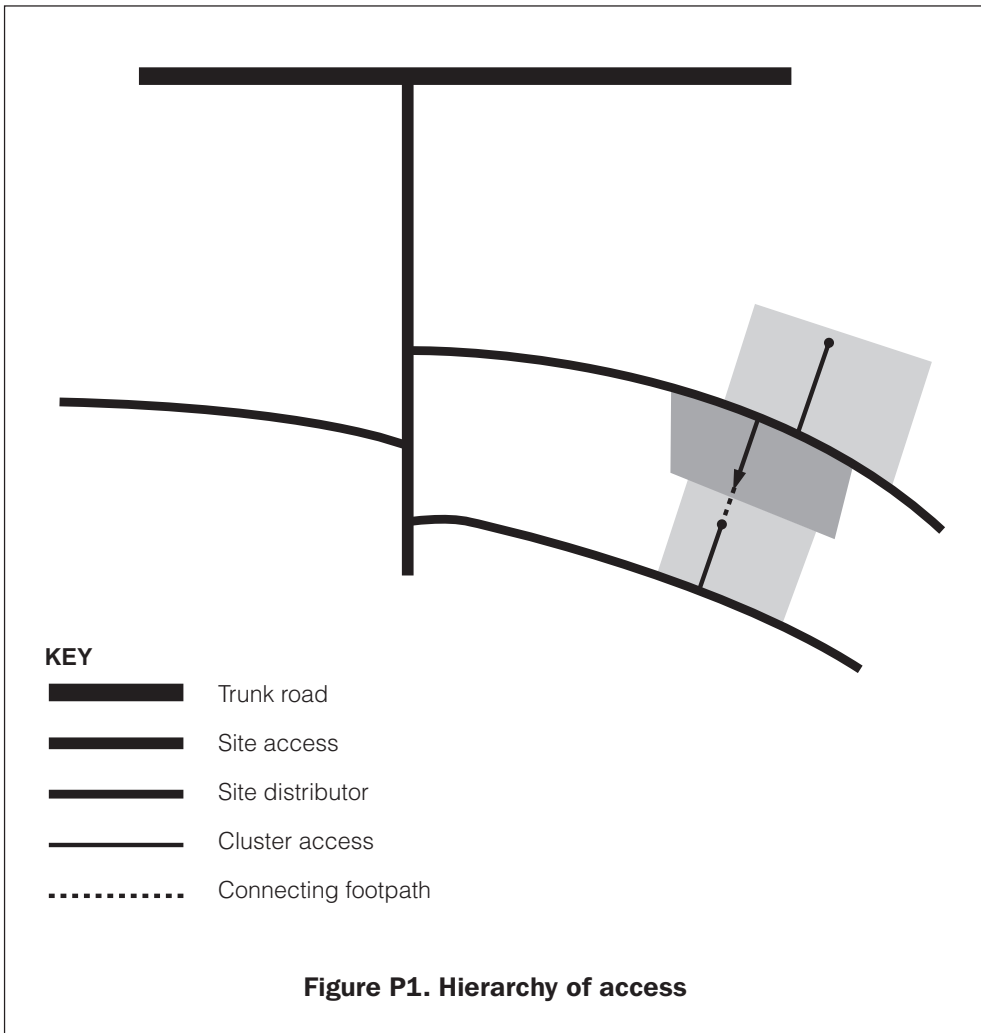
- desirable planning standards which may specify large access widths, thereby taking up valuable land; and
- the need to adopt small plot sizes and high housing density to cope with the demands for shelter.

People require access to their houses; consideration should be given to both front and rear access. Whilst walking distances to main trunk routes should be minimized, some access restrictions to other parts of the housing area may be desirable to enhance security and community awareness within subsections or clusters of the housing site.

Vehicles do not necessarily need to be able to reach every house. In low-income upgrading areas which are predominantly residential, pedestrian and small vehicle (rickshaws, bicycles, carts) movements tend to dominate. Design of all roads for substantial movements of conventional vehicles is unnecessary, however, it is desirable to allow small vehicle access to all houses for occasional personal transportation and to permit delivery of building materials. Small buses and paratransit vehicles should be able to travel freely on site distributor roads, but do not need access to each house. Similarly, emergency vehicles and vehicles for services (for example, solid waste collection) do not require access to every house.

Services: it is common practice for service lines to follow the street alignment. Many services require space and full account must be taken of the needs of water supply and sewerage pipes, open channel drains and power lines.

Consideration of these requirements leads to designs for a hierarchy of access. There may be one or more site access roads leading off a trunk route; a site distributor then connects all the housing clusters to the site access road. A cluster road gives access to individual households and finally pathways may be used to interconnect clusters. This is illustrated in Figure P1.



Paving

Paving has three basic functions:

- to provide a hard, dry access to residential, commercial and industrial areas;
- to improve the drainage of built up areas; and
- to provide a smooth running surface with adequate skid resistance for vehicles.

Any access route for pedestrians or vehicles requires a smooth surface, free of obstructions or holes, which is passable in wet weather. The consequent improvements to drainage are usually a high priority, whilst skid resistance is of importance mainly on primary routes.

Paving must have sufficient strength to resist the loads which are imposed on it and transmit them to the underlying ground (known as the subgrade). Therefore an important attribute of paving is structural strength, which depends upon the materials used and the pavement thickness. Failure to consider the drainage implications of street paving work may lead to rapid deterioration of the surface.

Options for pedestrian and lightly trafficked areas (i.e. those carrying some cars but few if any commercial vehicles) include:

- hardcore/murrum/granular fill;
- sand grouted bricks/concrete blocks;
- cement grouted bricks/concrete blocks;
- in-situ unreinforced concrete; and
- hand-laid asphalt.

Options for through routes carrying commercial traffic include:

- surface treatment;
- bituminous carpet; and
- concrete (this is uncommon).

The type of pavement to be used is influenced by the location, the expected traffic, the ground conditions and the durability of the various options. Where stormwater run-off is to be carried on the pavement surface, its effect on the durability of the construction must be considered. Other factors to be considered include the availability of equipment and skills and the accessibility of

the area to be paved. There is no point in specifying surfacing methods which require equipment which is either not available or cannot work effectively in the area to be surfaced.

Cost calculations need to take into account the design lives of the options considered and their requirement for maintenance. A gravel or hardcore surface will be much cheaper in capital cost but will have higher maintenance costs and require a greater maintenance effort than other options. Bituminous carpet and surface treatment surfaces are more susceptible than concrete and brick surfaces to damage by stormwater. They may thus have higher maintenance costs if used in situations where storm water is to be allowed to run on the road surface.

Tool P2 Access & Paving: Planning

Background

In many situations, paving is carried out in a piecemeal, uncoordinated manner with no overall planning; the full benefits of improved overall access and drainage are not realised. At the planning stage, decisions have to be made about the type and width of paving, the methods and materials to be used and the role that the paving is to play as part of the drainage system. These decisions are to some extent inter-related. In particular, the materials to be used and the pavement levels adopted will be influenced by the way in which the paving is to be incorporated into the drainage system.

Hierarchy of access

The first task is to decide the hierarchy of access; through streets must be distinguished from those that will be used for purely local access. In many cases, the hierarchy will be obvious with the wider streets taking through traffic. In others, it may be appropriate to prevent through traffic from using certain streets, using bollards or other forms of barrier to prevent access. It is important that any schemes to restrict access are discussed with the local community as part of the action planning process (see Section 3a) before the detailed design stage.

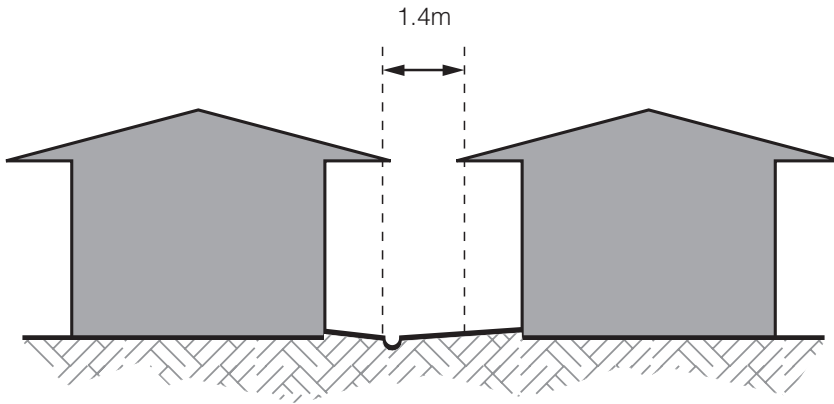
Access and pavement width

The pavement width required depends on the width of the street and the traffic to be carried by the street. For streets up to about 5m in width, it will usually be advisable to pave the whole width, other than that required for any drains. For wider streets, paving should usually be provided only to accommodate access needs. Suggested minimum standards are shown in Table P1.

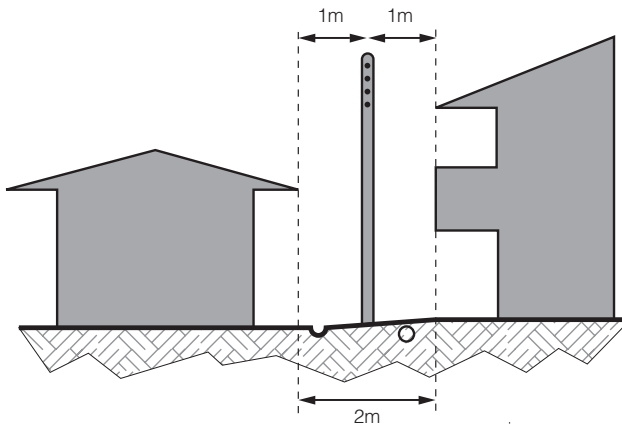
Some requirements for land-take for services for different access hierarchies are suggested in Figures P2 to P5.

Table P1. Minimum paved width standards

Type of traffic	Paved width
Pedestrians only	1.4 metres
Light local traffic	3.5 metres
Tonga/minibus routes	6 metres
Routes for commercial/public transport vehicles	7.5 metres

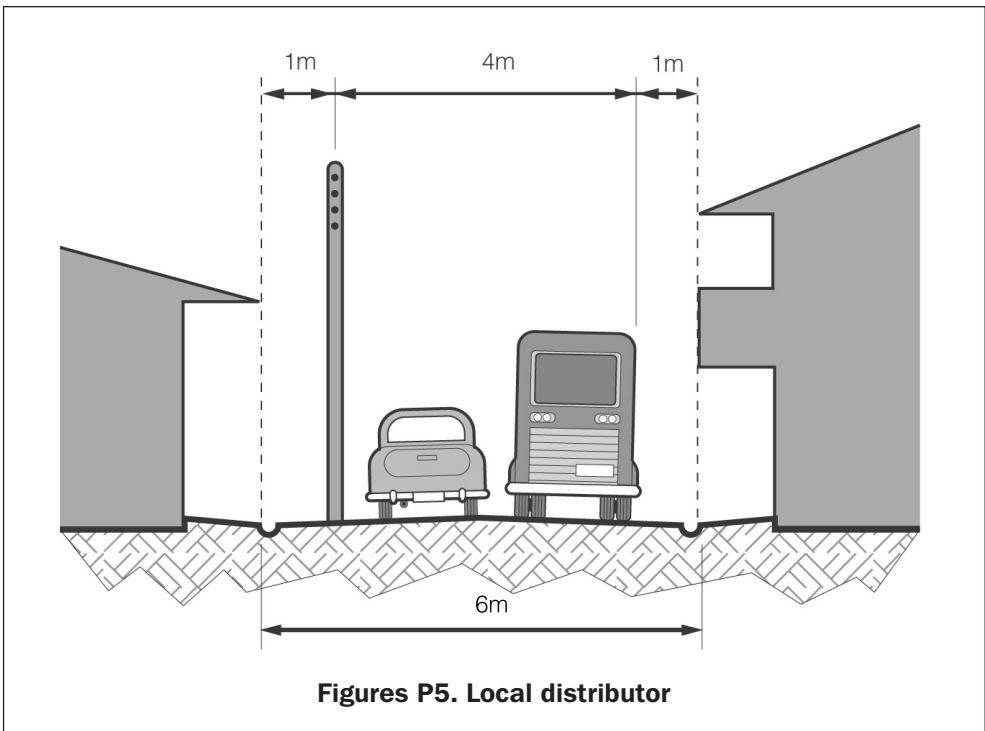
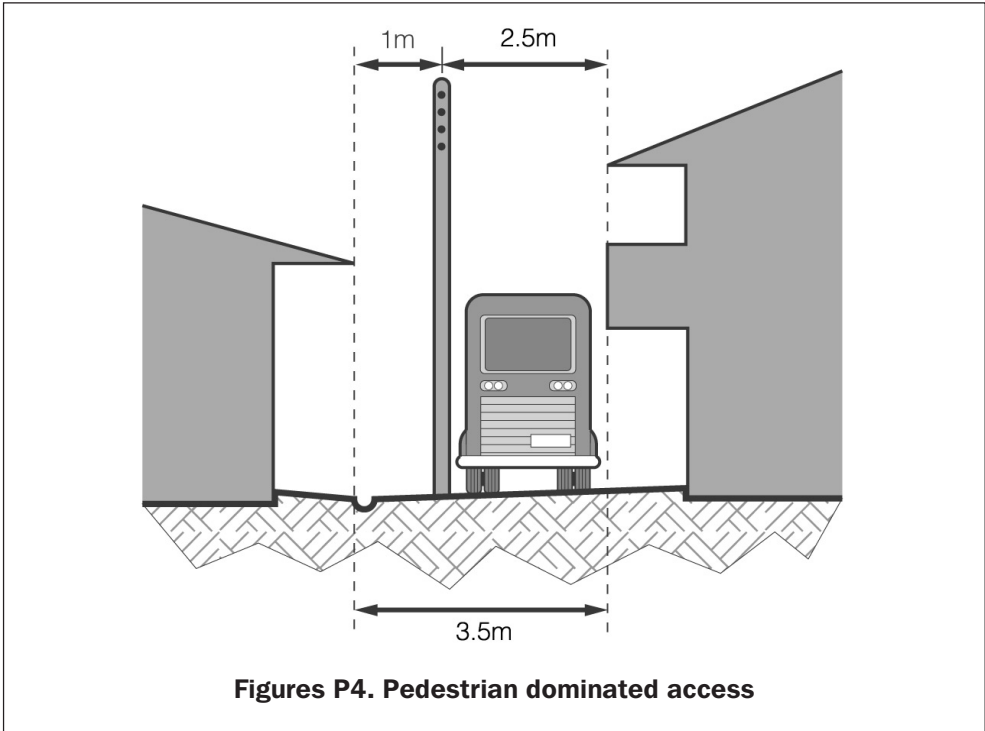


Figures P2. Minimum access widths



Figures P3. Minimum access to include overhead powerlines

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Pavement levels

Pavement levels should always be taken into account when planning and executing upgrading schemes. At the very least, the relationship between the proposed pavement levels and those of adjacent plots should be considered. *Upgrading works should avoid raising pavement levels to a point where water can flow from the pavement onto adjacent plots.* There will be instances where levels will have to be raised above the levels of some low lying plots, for instance where subsequent development has been raised to a level which makes it impractical to work from the levels of the lowest plots. However, the decision to accept levels above those of the lowest plot levels should only be taken after searching for alternatives and discussing the options with community members. Often, the owners of low lying plots will say that they are willing to raise levels on-plot.

The detailed determination of levels is a design task but the overall scheme for street levels should be considered at the planning stage in conjunction with drainage proposals. In general, the levels of main through streets should be established first, wherever possible in relation to the national datum but in any case in relation to the levels of the main outfall drain or drains serving the area. The levels of local streets and lanes can then be fixed in relation to those of the main streets to which they connect.

Typical cross-sections

The cross section adopted for a particular street will be influenced by the street width, the traffic to be carried and the proposed drainage system. A range of typical cross-sections are shown in Figure P6.

It is advisable to provide a cross fall except where either:

- the lane width is less than about 2m; or
- the longitudinal fall is less than about 1 in 300.

For narrow lanes, the benefits derived from a cross-fall are not great enough to justify its provision. Where there is little longitudinal fall and the surface is impervious, irregularities in the surface will result in standing water after rain. The water will remain for longer if it is concentrated in one spot by the cross-fall, especially where infrequent street cleaning allows dirt and rubbish to gather at the low point of the cross-section. With a flat cross-section, water will stand over a wider area but the depth will be less and the speed with which

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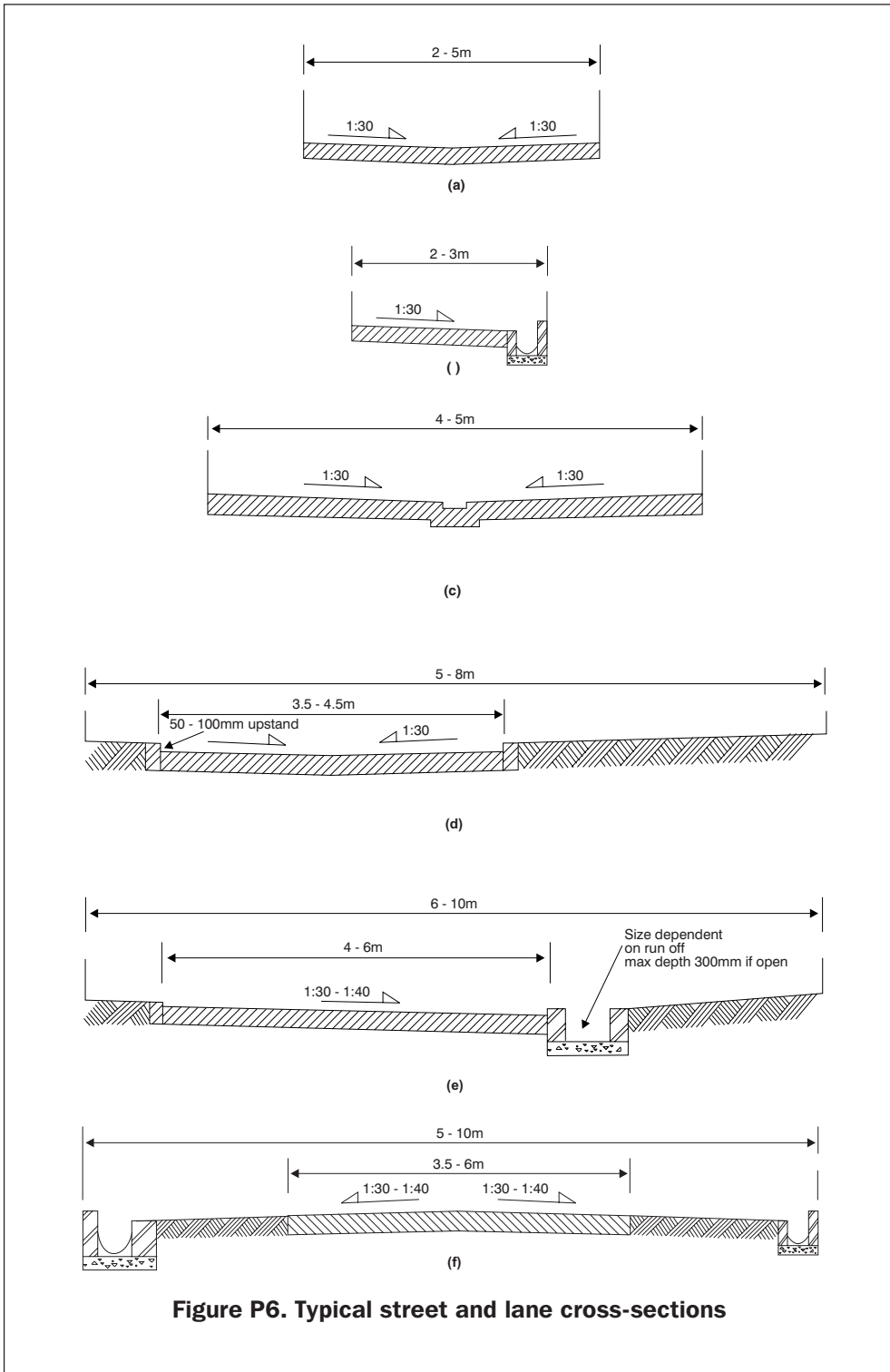


Figure P6. Typical street and lane cross-sections

the water will either evaporate or percolate away will be greater. Standing water problems will be further reduced if joints in brick and block pavements are grouted with sand rather than cement mortar.

Cross-section (d) also removes the need for drains by allowing water to run on the road surface. The size of the area which can be drained by this method will depend on the rainfall, catchment characteristics and longitudinal fall. The remarks already made about standing water where there is limited longitudinal fall also apply to this cross-section.

Cross-section (e) shows a conventional arrangement with a cross-fall to a drain. This will be required where run-off flows are too great to be carried on the road surface alone but the size of the drain may be reduced by allowing for the drainage capacity of the road in the design.

Note that in unsewered areas, sullage needs to be removed through open drains if the plots are too small for on-plot soakage pits. Sullage drains can ideally run along the backs of plots, this means that site distributor roads require open channel sullage drains.

Tool P3 Access & Paving: Design

Unbound pavements

Unbound pavements can be formed from gravel, hardcore or water-bound macadam.

Gravel roads consist predominantly of stones in the size range 6mm-20mm, with about 10% of fine material to act as a binder. Where washed gravel is used, fine river sand may be used as the binder. For lightly trafficked roads with up to about 100 vehicle movements per day, the total compacted thickness should be at least 150mm. For more heavily trafficked roads, the total thickness may be increased up to about 300mm.

Water-bound macadam consists of coarse aggregates, mechanically interlocked by rolling and bound together by screenings and/or stone dust and water. Whichever material is used, it should be rolled to achieve compaction, using a 6-8 tonne roller. This will not be possible in narrow streets and lanes although reasonable results might be obtained using a small vibrating roller. When considering the provision of unbound pavements by community action, the need to roll the pavement must be remembered.

For lightly trafficked roads a water-bound macadam thickness of 115mm, laid on 75mm of gravel or clinker, will be appropriate. The maximum size of aggregate should not exceed three quarters of the total consolidated thickness of any one layer of construction. Suggested size ranges for different types of aggregate are:

- soft stone/broken brick 40-63mm
- hard stone 20-50mm

The first stage in constructing a waterbound macadam road is to spread and roll the dry aggregate until it is well compacted. Screenings of crushed rock, brick kiln dust or similar, graded from about 12mm down, are then spread over the surface, brushed into the gaps between stones, sprinkled with water and rolled until the coarse aggregate is well bonded and firm for its whole depth. For hard aggregates, fine grained binding material should be spread, watered and rolled into the surface after application of the screenings.

‘Black-top’ roads: flexible pavements

Conventional black top roads consist of a weather-proof surface layer laid over a granular base; it is the road base which provides structural strength. The base is usually laid over a sub-base. Surfacing materials fall into two main categories.

Surface dressings consist of a layer of stone chippings bonded to the road surface by a thin continuous film of bitumen. They can be used for surfacing new roads, when it is usual to apply two or occasionally three layers, and for rehabilitation of existing road surfaces. Surface dressing is frequently used to pave through roads in informal areas. It is cheaper than bituminous surfacing but has a shorter design life, typically about 6 years as opposed to 10 years or more for a bituminous carpet. Surface dressing will not normally be an option for narrow lanes, partly because other pavement options are cheaper and partly because the rolling which is essential if the surface is to be of good quality will be difficult or impossible.

Premixed bituminous surfacings are usually coated macadams, where graded aggregate is coated with a bituminous binder with the aggregate interlock providing most of the strength of the material. Dense bitumen macadam is sometimes referred to as asphalt concrete. Premixed material is produced by special equipment; it is usually possible to achieve reasonable quality control. A single bituminous layer, laid by a mechanical paving machine, is normally specified with a granular base and sub-base. It is not suitable for use on small contracts in narrow streets and lanes because of its cost and the physical difficulties involved in using mechanical equipment in restricted areas. Movable small scale ‘donkey’ plants may be used to prepare coated macadams on site but it is difficult to ensure quality control of site mixed material. For this reason, brick and block pavements are a better option than bituminous pavements for tertiary streets and lanes.

Concrete pavements

Rigid pavements must have sufficient beam strength to bridge localised failures of the subgrade and withstand the stresses that develop. They must also be able to withstand the stresses caused by the concrete curing and temperature variations. Jointed unreinforced concrete is relatively inexpensive in many parts of South Asia; it is long lasting and is widely used to pave pedestrian access ways and lightly trafficked streets.

The concrete slab itself should be cast in lengths not exceeding 4.5m in length so that the construction joints can function as contraction joints. Alternate slabs should be cast and the intervening slabs filled in later. For pavements less than 150mm deep, contraction joints are basically the same as construction joints.

Brick and block pavements

Where they are readily available, bricks are often used to pave lightly trafficked areas. Such pavements are durable, reasonably cheap and have the advantage that they can be laid without expensive equipment. Sand grouted bricks can easily be removed and reinstated to allow installation of services and will permit some infiltration of stormwater. Bricks grouted with cement mortar are more rigid; sand grouted bricks have some rigidity if they are placed close together to prevent rotation of individual blocks under load. Where bricks are not available, the option of using commercially produced concrete block pavers should be considered.

Where anything more than light traffic is expected, bricks should be laid in a herringbone pattern (see Figure P7). Running bond and basketweave bond are frequently used in practice. The former is preferable where there is to be occasional light traffic, with the long axis of the pavers being laid across the street or lane.

If a sand bed is used, this should be placed in layers of about 35mm compacted to 25mm. Bricks should be laid dry with joints not more than 5mm wide. They should then be grouted either with sand brushed into the joints or a 1:4 cement:sand slurry.

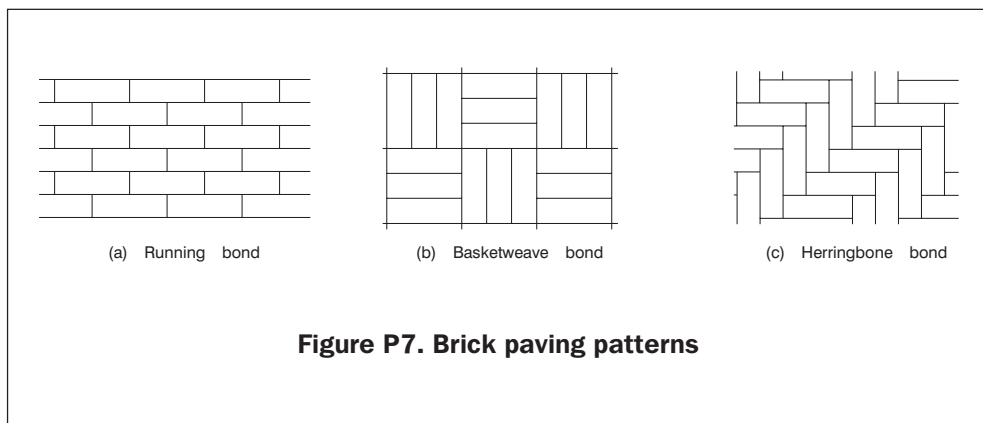
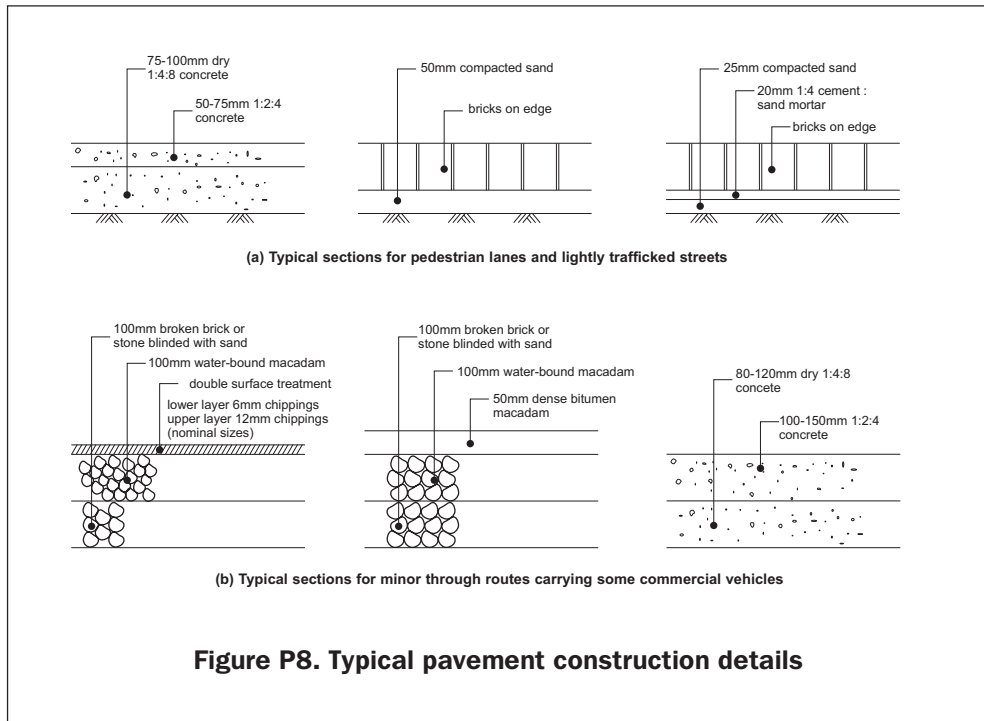


Figure P7. Brick paving patterns

Pavement design

Pavement depth

The first step in pavement design is to determine the overall depth of pavement required. This depends on the loading, the subgrade strength and whether the pavement is intended to be rigid or flexible. In general, the overall depth of a flexible pavement will be more than that of a rigid pavement in the same situation. The depth and construction details for pavements in most upgrading schemes are decided on the basis of experience and on what ‘feels right’. This is reasonable given the fact that most conventional design methods are intended primarily for more heavily trafficked roads, indeed the typical pavement structures given in Figure P8 were all developed empirically and have proved successful in practice.



The pavement depths given in Table P2 are related to the subgrade strength as measured by the Californian Bearing Ratio (CBR) test. It will not be practical and should not be necessary to carry out CBR tests for every scheme. The aim should rather be to obtain representative values for various areas and to incorporate these in design guidelines. CBR results for low strength materials

Table P2. Minimum pavement thickness

Location	Traffic Intensity	California bearing ratio(%)					
		1.5	2	3	5	8	12
Lanes < 3.5m	Light	150	125	100	75	60	50
Local access lanes and streets > 3.5m	Light	210	170	130	100	75	55
Minor through routes	Medium	325	275	230	160	125	90
Major through routes	Heavy	610	525	425	300	225	175

tend to be very variable. In many informal areas, streets and lanes have been made up using a variety of materials including, in some cases, solid waste. In such instances, it will be difficult to obtain a reliable overall CBR value. In the absence of reliable field data, assume a CBR of 3 for natural material and 1.5 for fill material containing solid waste.

It can be seen that the pavement depth required can theoretically be less than 50mm for subgrades with a high CBR. In practice, a minimum depth should be specified. For example:

- for access streets and lanes carrying little traffic 100mm
- for minor through routes 150mm

Once the overall pavement depth has been determined, the details of the pavement construction must be decided. Suggested minimum construction standards are given in Table P3.

Table P3. Minimum construction standards
<i>Lanes less than 3.5m wide</i>
<ul style="list-style-type: none"> ■ 50mm 1:2:4 concrete on 60mm 1:4:8 dry concrete base. ■ Bricks laid on 20mm mortar on 25mm sand. <p>Note that bricks laid on edge are preferable; bricks laid flat give a rather uneven surface</p>
<i>Streets and lanes greater than 3.5m wide</i>
<ul style="list-style-type: none"> ■ Brick-on-edge on 50mm sand bed. ■ Brick-on-edge on 20mm mortar on 25mm sand. ■ 50mm 1:2:4 concrete on 100mm 1:4:8 dry concrete base.
<i>Minor through routes</i>
<ul style="list-style-type: none"> ■ 50mm dense bitumen macadam on 100mm rolled stone base on 100mm rolled stone or broken brick sub-base. ■ Double surface treatment on 200mm rolled stone base. ■ 125mm 1:2:4 concrete over 80mm stone base.

The pavement construction for major through routes will be dependent on the amount of traffic carried and should follow National or State standards for highway design.

Figure P8 shows typical pavement construction details for a range of situations and using a variety of materials.

Edge details

Most street pavements in upgrading areas are bounded by either property walls or brick masonry drains. Where this is the case, no special edge detail is required other than to perhaps provide a raised strip or tega to contain stormwater. Such raised strips are typically a half brick (112mm) wide and 75-100mm high. There are places, however, where streets run alongside unbuilt plots and public open spaces which may be at a lower level than the pavement itself. In such cases, the pavement must be contained by a continuous edge strip which prevents local failure when either heavy loads are imposed at the pavement edge or there is local erosion. Figure P9 gives some typical edge details.

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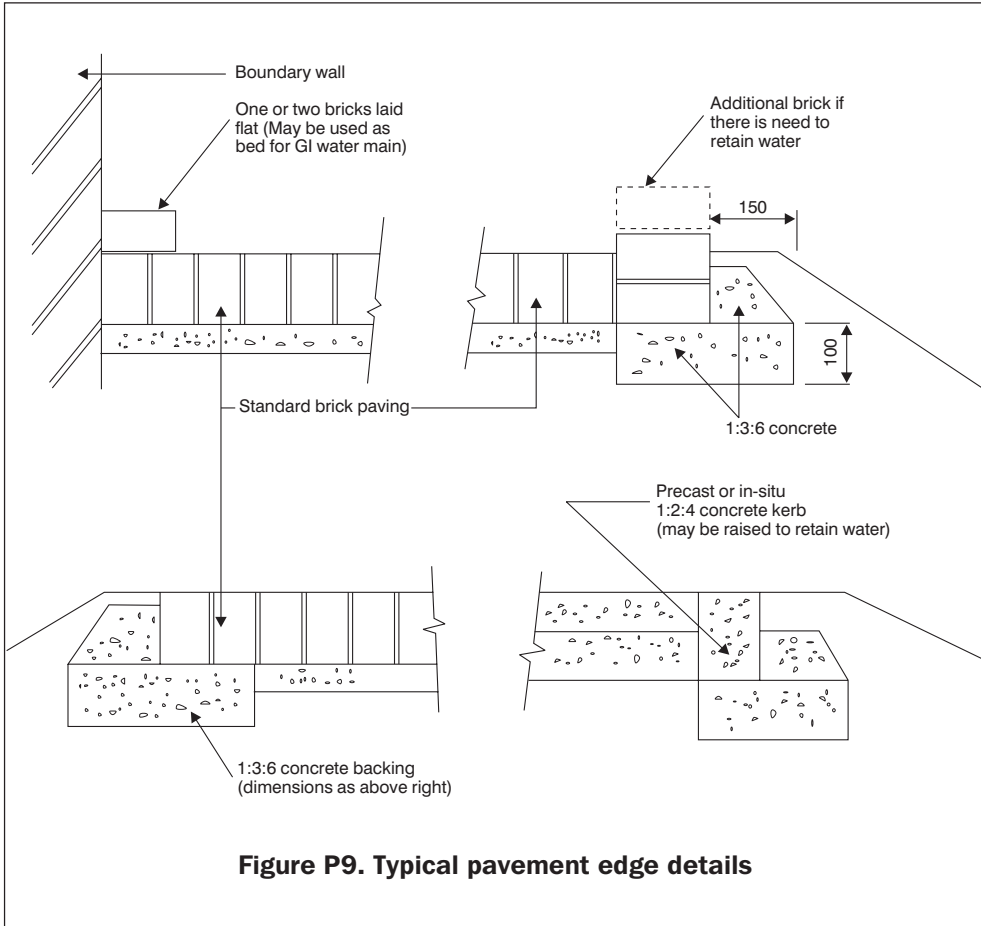


Figure P9. Typical pavement edge details

Structural design of black top roads

Pavement design is empirical. The design method used in this manual is based on that developed by the American Asphalt Institute. This has the advantage over other methods that it makes allowance for a range of design axle loads. It is strictly applicable to flexible pavements but, in the absence of similar methods allowing for a range of axle loads, may also be used for concrete and brick/block pavements. The method requires information on the design load and the subgrade strength as measured by the CBR value.

Loading

Most conventional design methods specify the design loading in terms of the number of standard 8200kg (18000lb) axle loads that the pavement can carry before failure. This relates to heavy commercial vehicles and is clearly inappropriate for the design of a lane used only by pedestrians, motorcycles and perhaps motor-rickshaws. It also seems unnecessarily conservative for access streets where the largest vehicles regularly passing will be cars. Bearing in mind that the laden weight of a private car is less than 2000kg, the following design axle loadings are suggested:

- for lanes less than 3.5m in width - 1500kg
- for access lanes and streets, 3.5m-6m in width - 3000kg
- for minor through routes, up to 7.2m road width - 5000kg
- for through routes carrying buses, trucks daily - 8200kg

Subgrade strength

The CBR test is the commonly accepted method of measuring subgrade strength. The testing procedure is described in standard textbooks. Typical CBR values for a range of soil types are given in Table P4.

Table P4. Typical CBR values

Soil Type	Plasticity Index	CBR Value (%)	
		Ground water depth < 600mm	Ground water depth > 600mm
Heavy clay	70	1.5	2
	50	2	2.5
	40	2.5	3
Silty clay	30	3	5
Sandy clay	20	4	6
	10	5	7
Silt (unconsolidated)	-	1	2
Sand (poorly graded)	Non-plastic	10	20
Sand (well graded)	Non-plastic	15	40
Sandy gravel	Non-plastic	20	60

Procedure for determining pavement depth

Once the design loading and the CBR value of the subgrade have been determined, the pavement depth can be obtained from Figure P10. The procedure for using the figure is as follows:

1. Select the appropriate CBR value for the subgrade.
2. Draw a vertical line to the curve which represents the loading appropriate to the location of the pavement.
3. Draw a horizontal line from the intersection point obtained from (2) to the left hand side of the chart.
4. Decide whether the likely volume of traffic can be classified as light, medium etc. This will require some judgement as traffic figures will not normally be available. The volume of traffic in access streets can almost always be assumed to be light and anything more than a medium volume of traffic will be unlikely in most through streets in upgrading areas.

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- Draw a line from the point on the left-hand margin obtained from (3) through the appropriate pivot point obtained from (4). The required overall pavement thickness can be read off from the scale on the right-hand side of the chart.

The dashed line on Figure P10 shows the process for a CBR value of 3 and a 4m wide lane carrying occasional light vehicles.

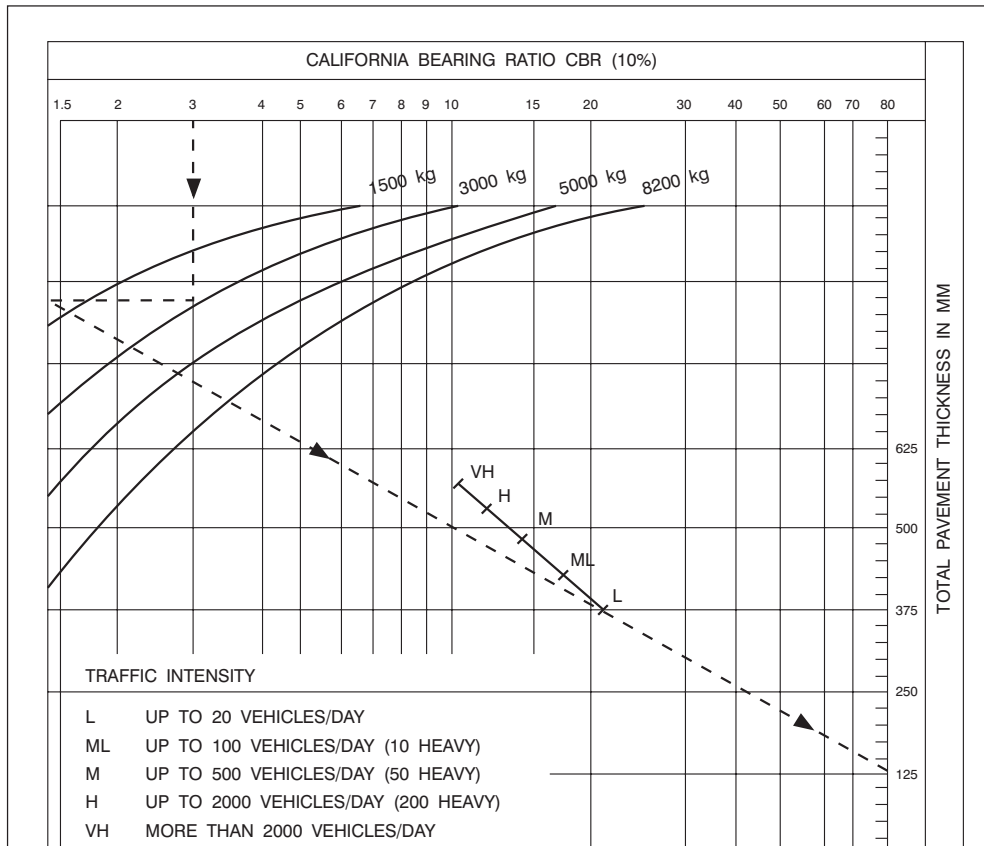


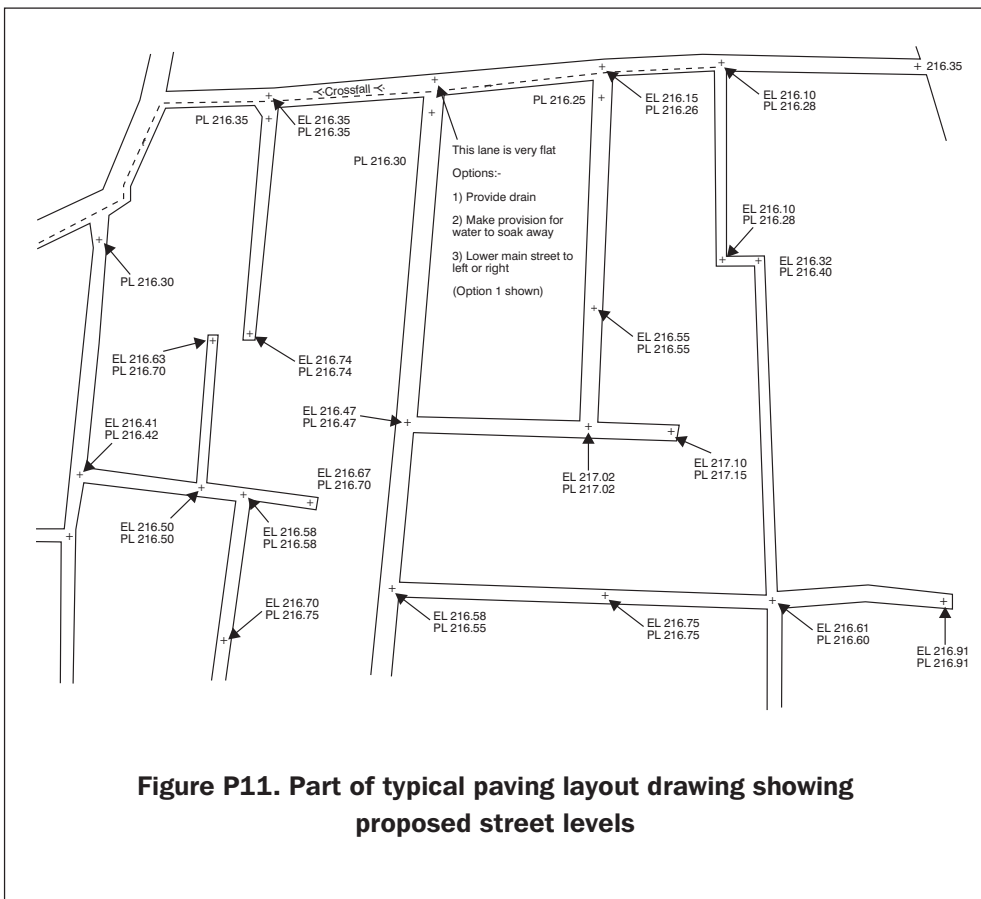
Figure P10. Design chart for calculation of pavement thickness

Preparing plans for paving

Most paving proposals can be represented by standard cross-sections, typically at a scale of 1:20 to 1:50, together with plans at 1:500 or 1:1000 which show the streets to be paved and the required pavement levels. It is probable that pavement levels as such will not be required where there are good average falls, say greater than 1:50 on average. It is also possible that levels can be omitted from drawings for individual lanes less than about 150m long even in flatter areas, provided that a fall is provided towards the outlet point.

Figure P11 shows a typical paving drawing for part of North East Lahore. Both the existing ground level and the proposed pavement level are shown, enabling quantities for fill and excavation to be calculated.

For small schemes, it should be possible to decide levels relative to the point at which the tertiary level streets or lanes to be paved meet a through street.



Tool P4 Access and Paving: Handy Tips

Preparation of subgrade for all paved surfaces: construction tips

- Compact the subgrade well before construction begins; failure to do so will result in premature pavement failure because of excessive settlement.
- Excavate to the correct levels; work from levels marked on the walls bounding the street or lane.
- Make sure subgrade is correctly profiled.
- A profile board with a horizontal upper surface and a lower surface cut to the correct profile can be used where a cross-fall or camber is required.
- In dry weather, water the subgrade before compaction.
- Where a sewer or water main has been laid before paving the street, make sure that the trench backfill material has been properly compacted.
- Where pavements are laid on poor quality fill, remove the poor quality material to a depth of 100-300mm and replace it with compacted sand or hard-core; this is not necessary with lightly loaded cement-grouted brick pavements.

Gravel surfaced road: where to use it

- Do not use in areas subjected to frequent flooding.
- Good for formation of new access ways.
- Only when less than 100 vehicles per day.
- Easily upgraded.
- Suitable where good gravel readily available locally.

Gravel surfaced road: construction tips

- Lines and levels need to be set out by a technician.
- Use gravel with some clay content (plasticity) to assist binding and setting.
- Cross drainage: may be cost effective to use RCC pipe culverts at appropriate locations.
- Transverse sand drains can remove subsurface water rapidly.
- Compact in 100 - 200mm thick gravel layers.
- Suitable for community based works; filling and compacting can be done by unskilled labour.

Gravel surfaced road: operation and maintenance tips

- Regular maintenance to replace lost gravel (30mm per year per 100 vehicles using road per day).
- Deep rut holes and holes due to settlements need pre-filling with stones.
- Communities can manage total maintenance; requires minimum tools.
- Keep some stocks of gravel locally.

Block paving: where to use it

(including stone flags and precast concrete blocks)

- Very good for 'pedestrians only' and two-wheeler access.
- Very attractive; beautifies the area if laid to a pattern.
- Easily made good after disruption e.g. excavation for service lines.
- Useful where there is a lot of sub-soil settlement; very flexible, does not crack; it is easy to lift, reprofile and replace blocks.
- Can be used for road-as-drain; assists drainage, as water percolates through sand grouted joints.
- Easy to lay in irregular pathways.
- Can be upgraded to a stronger pavement.
- Salvage value in blocks.
- Lasts for 5-10 years; may require total removal and refixing any time after this.

Block paving: construction tips

- Use sand bedding for normal use.
- For extra bearing capacity if there is some vehicular traffic, use lean concrete bedding.
- Make sure there is a gradient/profile towards drains.
- Use blocks of uniform thickness, minimum 50 mm thick.
- Grout joints with sand or cement mortar.
- Suitable for community based works; requires only basic skills, no machinery or plant.
- Difficult to monitor and control the quantities of materials used, particularly when refixing or replacing old or worn out paving; subject to abuse by untrustworthy contractors.

Block paving: operation and maintenance tips

- Periodic maintenance is necessary.
- Communities can manage total maintenance; requires minimum tools.
- Keep some blocks locally in store to replace as and when necessary if maintenance is by community groups.
- After excavations for service lines, only those blocks on the trench line need to be re-fixed.
- When major settlements occur or when most of the stones are broken, it is advisable to refix entirely using undamaged and new blocks to a corrected profile.

Brick on edge paving: where to use it

The above points for block paving also apply

- Good where sub-soil is loose and lanes are likely to be upgraded after compaction into flexible or rigid pavements.
- Recommended where bricks are cheaper and available in abundance.
- This pavement can be retained as base for surfacing with concrete or bitumen.
- Bricks are susceptible to theft.
- Not desirable when subjected to frequent flooding if bricks are not well-burnt.

Brick on edge paving: construction tips

The above points for block paving also apply

- Use good quality bricks if pavement is used as a drain.
- Bonding: avoid straight joints and ensure proper overlaps.
- It is desirable to provide some support at the pavement edges.
- Start paving from a straight edge which may be an edge restraint or a string-line.
- Place sand bedding in layers of about 35mm compacted to 25mm.
- Lay bricks dry, with joints not more than 5mm wide and grout either with sand brushed into the joints or a 1:4 cement:sand slurry.

Brick on edge paving: operation and maintenance tips

The above points for block paving apply

Cement concrete paving: where to use it

- Provides a strong durable, low maintenance surface.
- Financing may be important: high initial cost but low O&M cost.
- Suitable for pedestrian and light vehicular traffic.
- Widespread application e.g. hill slopes, weak soils, flood prone areas.
- Lasts for over 20 years.
- Reinstatement is difficult (patchwork does not give adequate strength); do not use if there is a likelihood of excavation for service trenches in the near future.
- Good for road-as-drain.
- Unsuitable if road level is likely to be raised in the near future.
- Construction is relatively quick; adjacent CC drains can be done at the same time.

Cement concrete paving: construction tips

- For courtyard paving use cement concrete (M15) 25 to 40 mm thick on lean concrete of 75 mm.
- Use machine mix for local roads wherever possible; for hand mix, cement quantity should be increased to compensate for the loss of strength as a result (concrete codes of practice specify the quantities to be compensated).
- Vibration using a flat vibrator after ramming avoids unwanted voids and gives better finish.
- Good form-work is necessary to obtain clean, sharp edged construction joints.
- Expansion joints are not needed on thin slabs for pedestrian and light vehicular traffic.
- Keep a rough finish to the surface to safeguard against skidding.
- Concrete needs to be cured; no traffic to pass until it attains 90% of design strength.
- Correct mix proportion is essential; aggregates need to be clean and free from clay and organic matter.
- Do not use over-sized aggregates; the surface looks uneven and mortar is easily lost.
- Where possible use a dry, lean-concrete sub-base as it is easy to handle and does not require shuttering.
- Cast the concrete slab in lengths not exceeding 4.5m in length so that the construction joints can function as contraction joints.
- Cast alternate slabs and fill in the intervening slabs later.
- Small roads are suitable for community-based works; requires unskilled labour, skilled masons; mixing machines can be hired; good quality control is simple but essential.

Cement concrete paving: operation and maintenance tips

- Durable and almost maintenance free.
- Joints should be inspected at regular intervals and filler material should be replenished whenever required.
- If surface wears out, either concrete or bitumen overlay can be provided; this is skilled work requiring close supervision and appropriate tools.
- Frequently dug out roads require concrete resurfacing of adequate thickness.
- Regular cleaning; surface is easy to sweep.
- Where too little cement has been used in a particular batch, that part of the surface absorbs moisture and weakens over time; this needs to be removed and replaced with good concrete.

Water Bound Macadam (WBM): where to use it

- Lasts for five years for up to 100 vehicle movements per day; actual life depends on quality of aggregate, filler materials and watering.
- Not suitable for areas subjected to frequent and prolonged flooding.
- Easily upgraded by addition of bituminous surface dressing; a good base for flexible or rigid pavement.
- Used from 0.5 to 2 years prior to surfacing (bituminous or cement concrete) to allow full compaction of underlying soil; new formations undergo seasonal variations in strength.

Water Bound Macadam (WBM): construction tips

- Requires a sub-base of compacted gravel and sand, or stone soling.
- Use aggregate from approved quarries.
- Aggregate needs to be well-bonded without voids; filler material for binding requires some clay content as this resists being washed away by rainfall and runoff.
- Develop the profile/camber during WBM construction; it cannot be done during final surfacing.
- Compact by rolling in layers of about 100mm loose thickness, applying water as a lubricant to help road metal lock together; easier to construct during the rainy season.
- Close supervision is important for profiling, dry rolling, spreading of aggregate and blinding.
- Not well-suited for community-based works; skilled workmanship is important.
- Before construction, remove organic matter such as roots etc. to avoid settlements due to decay; for trafficked roads remove soft soils with little strength.
- Requires good cross drainage.

Water Bound Macadam (WBM): operation and maintenance tips

- Annual maintenance costs 5% of original capital cost; renewal of surface after five years costs about 50% of original cost.
- Occasional spreading of sand or other non cohesive soils over surface improves performance if there is vehicular traffic.
- Regular repair of pot-holes with aggregate.
- Spread gravel or filler material whenever surface is worn out or aggregate is exposed.
- Maintenance requires mainly unskilled labour (unlike construction) and is suitable for community involvement.
- During rains, aggregate may be exposed if the binding material washes out; this needs immediate replenishment.

Bitumen surfacing ('black top'): where to use it

- Suitable where there are more than 100 vehicle movements per day; use design procedure outlined in Tool P3.
- Not suitable for narrow lanes.
- Whilst not suitable for community-based works, surface dressing can be undertaken by small contractors.
- Bitumen surfacing is rapidly destroyed by petrol, kerosene and diesel; problems arise near automobile repair shops.
- The life of the road depends on the strength of the base; good drainage is essential and the base must not become saturated by water.
- More prone to damage by extreme conditions such as floods and cyclones than are concrete roads.

Bitumen surfacing ('black top'): construction tips

- The surface of the road base should be thoroughly cleaned before applying the tack coat.
- Provide the final surfacing as quickly as possible after the base has been laid and rolled to avoid the build up of mud on the surface of the road base.
- In places of heavy rain fall, it is better to use a different option or else provide more camber and seal coat. Also use right type of bitumen (viscosity). Suitable bitumen should be selected depending on the prevailing conditions (rainfall, temperature variations etc.).
- Kerosene should not be added to improve the workability of bitumen as it reduces its life; instead, bitumen should be maintained at the appropriate temperature to achieve workability.
- Good camber is essential and the surface should be without undulations as water stagnation even for few hours is detrimental to the bitumen surfacing. Use cross drainage to reduce the water content of the road.
- It is essential to use the correct quantity of bitumen to achieve good durability; for example too much bitumen leads to 'bleeding out' of bitumen in hot weather and the weakened surface ruts under traffic load.

Bitumen surfacing ('black top'): operation and maintenance tips

- Bitumen surfaced roads have a 15 year life for up to 3000 vehicle movements per day; annual maintenance costs are 2% of capital costs with a new seal coat required after no more than five years costing 25% and renewal of the road after 15 years costing about 85% of the original capital cost.
- Regular sweeping and removal of accumulated earth which restricts good drainage off the surface is necessary; this is one of the main causes of rapid deterioration.
- Regular 'patching' for the repair of pot-holes and spots which have settled.
- Before resurfacing, make sure that the camber is adequate; remember to allow for this in the cost estimates.
- Following heavy storms and continuous flooding the base may need to be strengthened at considerable cost; the existing surfacing needs to be removed.
- A trained labour gang is required to undertake regular maintenance.
- Adequate supplies of aggregate and bitumen need to be available.
- Resurfacing may raise the road level; manhole covers and frames must also be raised.
- Trench excavations for services must be rapidly reinstated to the necessary pavement standard.

