Implementing employment intensive road works

A cidb practice manual

Contributing to contractor development in job creation

MANUAL 3
Gravel pavement layers

cidb
development through partnership

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cidb is a public entity established in terms of the CIDB Act, 2000 to provide strategic direction for sustainable growth, reform and improvement of the construction sector and its enhanced role in the country's economy. In pursuit of this aim cidb partners with stakeholders and regulates the construction industry around a common development agenda underpinned by best practice procurement and project processes.

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Constructing shared growth

This set of practice manuals for employment intensive road construction, draws on the experience of the South African Construction Industry in the development of road building contractors, supervisors and designers, in implementing road works and creating jobs; and builds upon the labour-based best practice guidelines that have been published by the Construction Industry Development Board. (cidb) (see www.cidb.org.za):

"…..with the right construction technology, South Africa can successfully address infrastructural backlogs in a cost-efficient way and to acceptable engineering standards. We are saying we can do this while maximising job opportunities.…"
(Ms Thoko Didiza, Minister of Public Works. Vuk'uphile learners welcoming ceremony, Nkangala, Mpumalanga, 29 June 2006.)

In assembling this publication, the cidb has collaborated with the Council for Scientific and Industrial Research (CSIR), and the International Labour Organisation (ILO) in fulfilment of the cidb's mandate to promote *"national social and economic objectives, including the labour absorption in the construction industry"*. (CIDB Act 38 of 2000). The cidb is committed to further partnerships with industry and stakeholders, to promote the use of these manuals and the training of SME contractors within the framework of the National Contractor Development Programme and the Construction Charter.

These manuals are supported by the Expanded Public Works Programme (EPWP), which directs a significant and increasing proportion of South Africa's public investment towards a labour intensive programme of construction, drawing the unemployed into productive work and providing access to skills development.

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ILO

Implementing employment intensive road works

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OVERVIEW of the practice manuals

The South African White Paper *Creating an Enabling Environment for Reconstruction, Growth and Development in the Construction Industry* (1999), expresses a vision for public-sector delivery aimed at optimising employment opportunities through labour-intensive construction. This can be realised in the delivery of infrastructure through the adoption, where technically and economically feasible, of

- labour-based methods of construction and manufacture where labour, utilising hand tools and light equipment, is preferred to the use of heavy equipment for specificactivities,
- labour-based technologies where there is a shift in balance between labour andequipment, in the way the work is specified and executed for selected works components.

This ci**d**b practice manual for *Implementing Employment Intensive Road Works* follows on from the ci**d**b's guide to best practice for *Labour-based Methods and Technologies for Employment-Intensive Construction Works*. The latter covers a broad spectrum of construction works. It establishes desirable and appropriate standards, processes, procedures and methods; relating to the design and implementation of labour-based construction technologies, methods for earthworks and for materials manufacture. This first set of guidelines provides sufficient technical information to enable those, responsible for the design of projects, to make confident and informed choices on their use in projects.

Implementing Employment Intensive Road Works aims to provide practical and technical guidance to small and medium sized (SME) contractors, supervisors and designers who are involved in the construction and upgrading of roads using labour and light plant. The need for these technical manuals was identified during the training of SME contractors, involved in the Gundo Lashu programme in Limpopo Province – a programme of labour-based upgrading of rural roads, promoted by the Department of Public Works, Roads and Transport in collaboration with the International Labour Organisation (ILO).

The development of this series of manuals is based on:

- experience gained in South Africa over the last ten years, including that of the Gundo Lashu project presently being implemented by the Road Agency Limpopo, with technical assistance from the ILO,
- best practices implemented by a number of Sub-Saharan countries,
- the relevant ci**d**b best practice guidelines, in its series of *Labour-based Methods and Technologies for Employment-Intensive Construction Works.*

These manuals support the objectives of South Africa's Expanded Public Works Programme (EPWP), and are aligned with the *Guidelines for the Implementation of Labour-intensive Infrastructure Projects under the Expanded Public Works Programme (EPWP)* of the Department of Public Works, obtainable on www.epwp.gov.za.

Acknowledgements

These manuals were compiled by the CSIR in collaboration with, and funding from, the ILO and cidb to promote the implementation of employment intensive road works.

A cidb Focus Group of industry specialists and stakeholders has further reviewed and refined these manuals.

The contribution of these individuals whose passion, commitment and knowledge has enabled the development of this publication as a common resource in the fight against poverty and joblessness, both in South Africa and globally, is acknowledged. Special thanks to:

- Adrian Bergh and Alex McKay of the CSIR.
- Jon Hongve of the ILO.
- Rob Little, Bryan Westcott, Ian van Wyk and Ron Watermeyer of the cidb Focus Group.
- Maikel Lieuw Song, Basotho Seetsa and Mpayo Kasure of the Department of Public Works, as members of the cidb Focus Group.
- The many organisations and individuals referred to in the references quoted in these manuals.

MANUAL 3: Gravel pavement layers

Contents

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Introduction

1. Aim

The aim of this manual is to provide contractors, involved in the labour-based construction of gravel pavement layers, with a detailed description of the materials, plant and equipment and processes involved in the construction of this work.

The procedure followed is that of a systematic approach. The first step is the preparation of the existing sub-base layer, to serve as the foundation for the remainder of the pavement, followed by

- the gravel wearing course for unsealed roads; and
- the base course for sealed roads.

2. Composition

The manual comprises the following modules:

Module 1:	Safety during construction
Module 2:	Setting out
Module 3:	Construction of unstabilised gravel pavement layers (excluding base)
Module 4:	Construction of a gravel wearing course
Module 5:	Construction of a stabilised base course
Module 5.1:	Emulsion-treated base course (ETB)
Module 5.2:	Composite emulsion-treated base
Module 6:	Indicative production and task rates

3. Notes to designer/consultant

A set of 'Notes to designer/consultant' is included at the end of the modules comprising this manual, where applicable. These notes are provided to highlight important aspects, applicable to the particular module, which the designer/consultant should take into account.

4. Supplementary manuals

Manual 1:	The fundamentals of road construction
Manual 2:	Planning and contract management
Manual 4:	Bituminous seals
Manual 5:	Concrete and masonry drainage works and structures

5. Bibliography

Technical manual for labour based road rehabilitation works. March 1999: Lusaka: Republic of Zambia; Ministry of Works and Supply.

Guidelines for low-volume sealed roads. July 2003: South African Transport and Communications Commission (SATCC).

Labour Intensive Construction Techniques Volume 7: Upgrading techniques for low volume roads/streets. August 1996: Pretoria: Department of Transport (LICT 7).

Course material. Civil Engineering Industry Training Scheme (CELTS) - For more information on available CELTS training courses contact 011 455 1700.

MODULE 1: Safety during construction

1. General

A number of parties are involved with safety during construction namely:

- The travelling public using the facility/road under construction.
- The contractor executing the work.
- The client/consulting engineer responsible for designing, specifying and supervising the contract.

The Occupational Health and Safety Act – Act 85/1993 has important implications for the contracting parties and it is important that the parties are conversant with the act and its implications, as it affects the execution of the work; and that the necessary Health and Safety Plan is in place in accordance with the client's Health and Safety Specifications. Refer also to Manual 2: Module 4: Health and safety issues.

Main objectives of this act are:

- To provide for the health and safety of persons at work, and for the health and safety of persons in connection with the use of plant and machinery.
- The protection of persons, other than persons at work, against hazards to health and safety arising out of, or in connection with, the activities of persons at work.

2. Safety of road users/public

The safety of the public is materially affected by the actions of the contractor and his staff i.e. the manner in which traffic is accommodated during construction, the erection of suitable road signs and warning devices and adherence by the workers to these road signs and other safety arrangements.

Requirements for the accommodation of traffic are laid down in the relevant specifications, referred to in the scope of the work in the contract documents.

Construction based on methods to promote job creation means that more people will be involved in the execution of the contract for a greater length of time, as would normally be the case with conventional methods, and it is therefore even more important to comply with any safety requirements.

3. Health and safety of workers

The health and safety aspects of the workers are largely governed by the *Health and Safety Act – Act 85/1993*.

Compliance with the requirements for the accommodation of traffic, set out in point 2 above, is not only intended for the wellbeing of the public but also to protect the workers involved on the road.

The following minimum practical requirements are, however, drawn to the contractor's attention:

- The issue of protective clothing, boots, gloves, overalls, etc. to the workers is essential.
- Use of diesoline by workers to clean hand arms and tools, when working with bitumen, must be discouraged – the use of paraffin is preferable.
- A properly equipped first aid kit must be available at all times.
- Transportation of workers on open trucks/trailers must be controlled e.g. all passengers must be seated with no legs hanging over the side of the truck/trailer.

- No children must be allowed on the construction site or contractors camp.
- Fire extinguishers in good working order must be available, especially when working with hot binders.

4. Points to note

The contractor should take particular note of the following:

- Competent staff must be used for controlling traffic, as their actions can affect the safety of both the road users and road workers.
- For the same reasons no short cuts must be attempted for the establishment of road signs.
- Detailed attention to staff safety increases productivity and staff harmony.

5. Notes to consultants

According to the *COLTO Specifications*: Section 1500, the contractor is responsible for the accommodation of traffic.

Depending on the size and experience of the contractor involved in the labour-based construction of the road works, capacity problems may be experienced, if he has to construct and maintain by-passes to accommodate the traffic during the construction of the works.

In such cases consideration should be given to executing the construction of by-passes, either departmentally or by a separate contract, prior to the commencement of the work. This departmental team or contractor would then also be responsible for the maintenance and, where necessary, watering of the by-pass.

All other items/activities pertaining to the accommodation of traffic would still remain the responsibility of the road contractor i.e. the erection of the necessary signage including deviation signs, and the actions and safety of his work force.

MODULE 2: Setting out

1. Materials and equipment

The materials and equipment for setting out the work include:

- Metric tapes
- Ranging rods
- Boning rods
- Spirit level
- Line level
- Steel pegs of various lengths (Y 10)
- 3 mm white string or sisal
- Gut line
- Cross-fall template (camber board) of 2%, 3% or 3,5% as specified (Workshop drawing LIC 006)

2. Horizontal alignment (centre line of road)

The horizontal alignment (centre line of the road) is established, using ranging rods, from the pegs (fixed in concrete) provided by the consulting (design) engineer, at the points of intersection of straight sections.

Having established the centre line of the road, 500 mm steel pegs (Y 10) are hammered firmly into the ground so that exactly 400 mm is left above ground at 10 m intervals. (Figure 3.1)

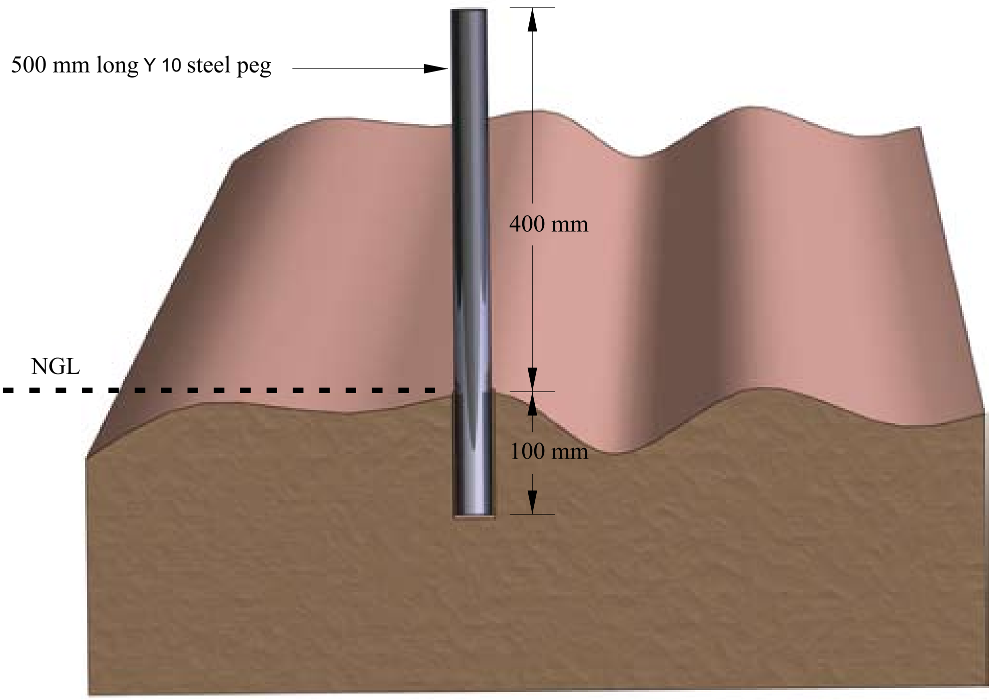

Figure 3.1: Centre-line pegs

3. Vertical alignment (to a rolling grade)

Tie a 3 mm white string (sisal) to the top of each peg along the centre line of the road (Figure 3.1), so that the visual grade line of the centre line of the road can be seen. (Figure 3.2)

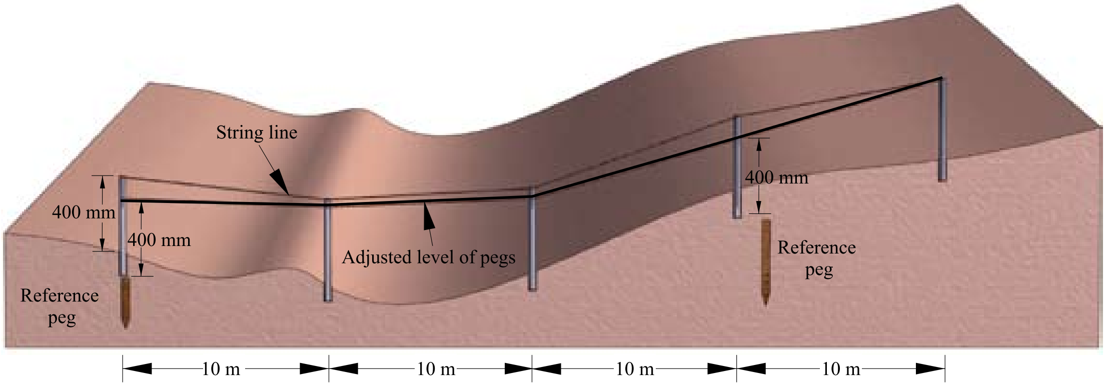

Figure 3.2: Setting of levels

Standing to one side, knock in or lift the pegs, so that a smooth rolling grade line is seen by the eye. This is used as the reference line.

Once the most economical line has been selected, with minimum cut and fill, reference pegs are placed 400 mm below the top of the adjusted steel pegs along the centre line of the road at 10 m intervals.

4. Setting out of cross-fall

Using a template (camber board) with a built-in cross-fall of 2% or 3% as specified, and a spirit level on the edge of the riding surface, for each side of the road, a reference peg is established at A (Figure 3.3 a). String lines can be used for checking intermediate levels. (Figure 3.4)

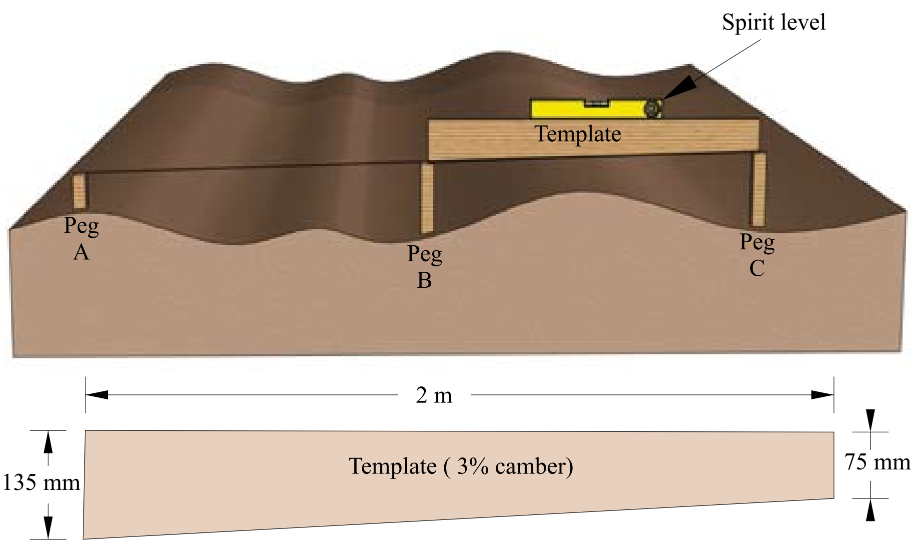

Figure 3.3 a: Setting out 3% cross-fall with template (camber board)

The intermediate peg at B can be removed, once the peg at A has been established.

Figure 3.3 b and Table 3.1 a, give the dimensions of the template for a range of cross-falls (cambers).

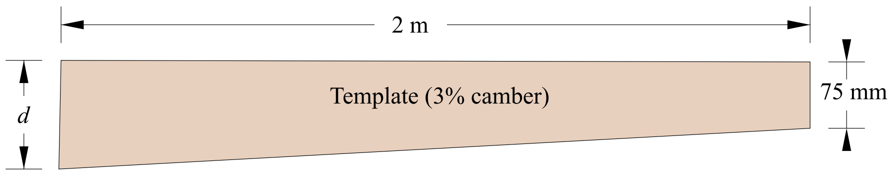

Figure 3.3 b: Camber template (camber board)

Camber (cross-fall) %	*d* mm
2,0	115
3,0	135
3,5	145

Table 3.1 a: Dimensions for d in mm

Alternatively, once the level of the centre-line peg (C) has been established, the edge of the road pegs can be established using a string and spirit bubble, tape and boning rod (Figure 3.4 and Table 3.1 b). One boning rod must be adjustable.

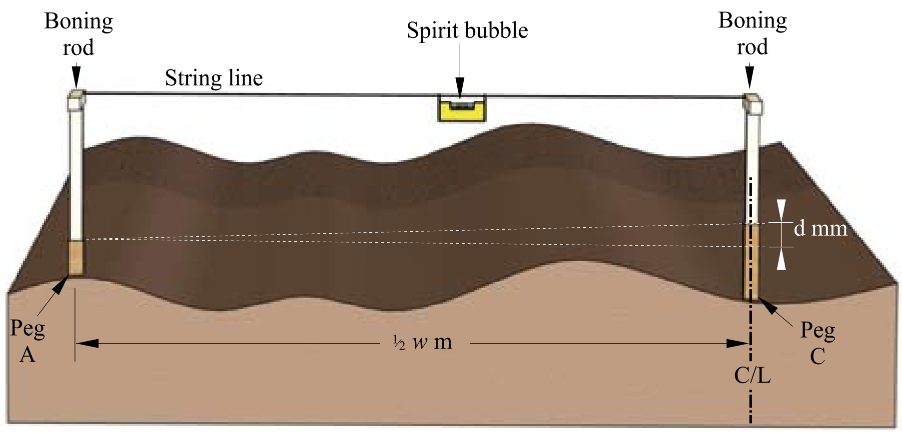

Figure 3.4: Setting out 3% cross-fall

Half width of road – ½*w* in (m)	Fall to edge of road – *d* in (mm)		
	2% cross-fall	3% cross-fall	3,5% cross-fall
2,0	40	60	70,0
2,5	50	75	87,5
3,0	60	90	105,0
3,5	70	105	122,5
4,0	80	120	140,0
4,5	90	135	157,5

Table 3.1 b: Fall to edge of road for 2% and 3% cross-falls

5. Horizontal curves

Five methods for setting out horizontal curves between two straights are described with reference to the figures below, together with restrictions and limitations to the methods.

5.1 String method (suitable for curves with a radius < 30 metres and intersections)

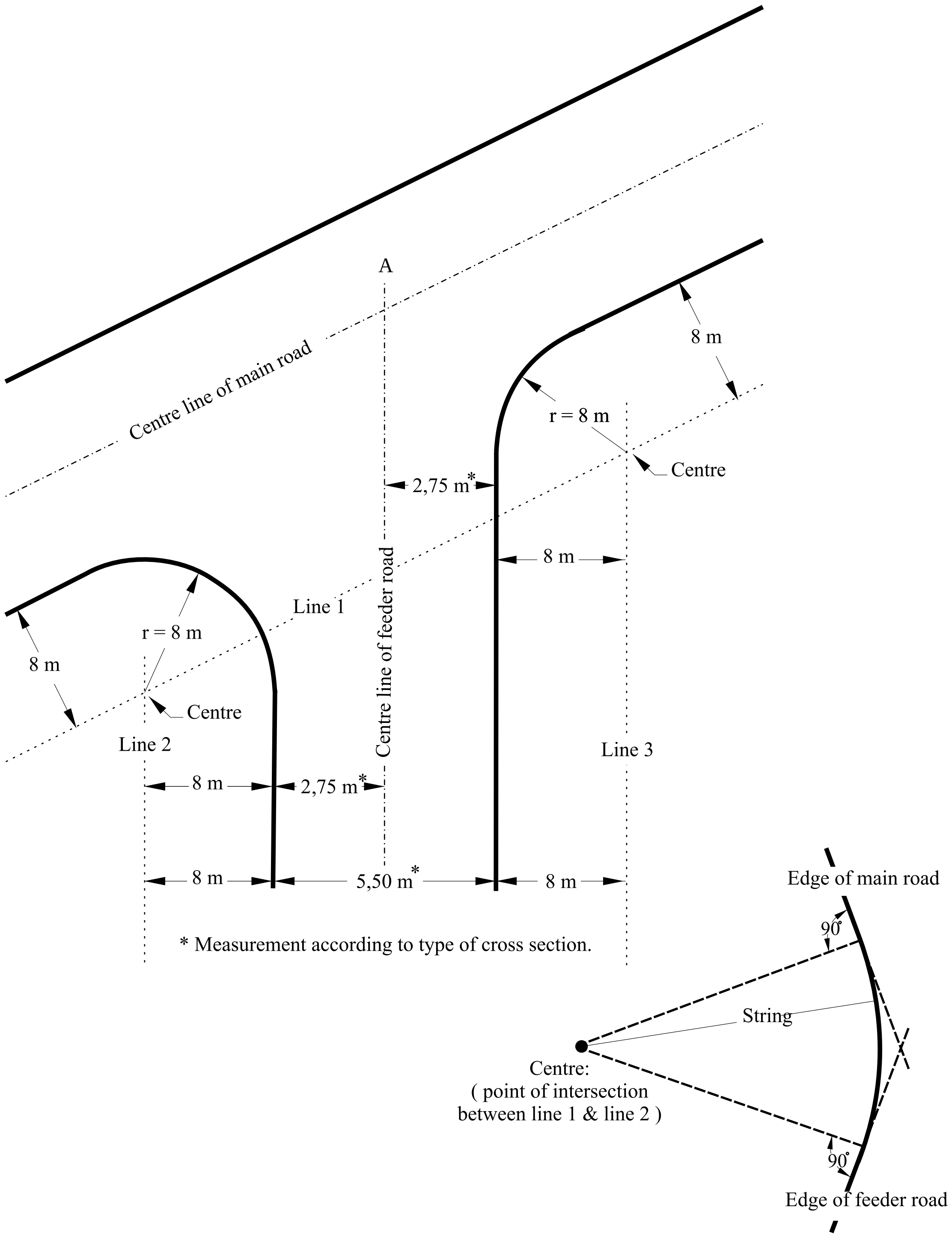

Figure 3.5

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1. Determine the edge of the main road. Mark with a string line.
2. Set out line 1, parallel to the edge of the main road at the required radius (e.g. 8 m in example) from it. Mark this line with a string line.
3. Set out the edges of the feeder road. Mark with string lines.
4. Set out line 2, parallel to the edge of the feeder road at the required radius (8 m) from the left edge of the road. Mark with a string line.
5. Repeat for the right edge of the road (line 3).
6. The points of intersection between line 1 and 2 and between line 1 and 3, are the centre points for the curves.
7. Use a string line of the required length of the radius (8 m) and from the centre points set out the curves.

5.2 Quarter point method (suitable for short curves where a string line (AB) can be stretched between the ends of the two straights)

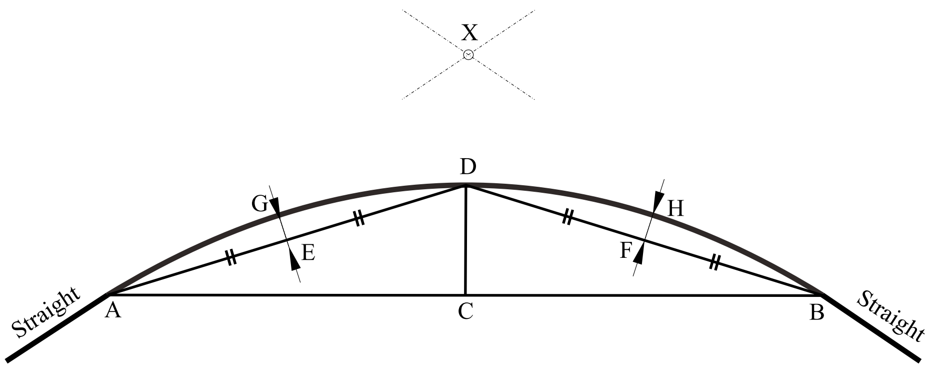

Figure 3.6

1. Extend the two straights to meet at point X (the point of intersection).
2. Determine the ends of the straights points A and B, at equal distances from X.
3. String a line between A and B and establish point C halfway between A and B (AC = CB).
4. Establish point D directly opposite point C, on the desired centre line of the curve.
5. Measure the distance between C and D (*a* metres).
6. String a line between A and D and establish point E halfway between A and D (AE = ED)
7. Establish point G directly opposite point E and ¼ *a* metre from E.
8. String a line between B and D and establish point F halfway between B and D (BF = FD).
9. Establish point H directly opposite point F and ¼ *a* metre from F.
10. If the radius is too sharp, move A and B further apart and restart.
11. Place intermediate pegs if necessary with a smooth curve with a string line.

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5.3 Tangent and chord method (the intersection point for the straights, and the area between it and the road, must be flat and free of obstructions)

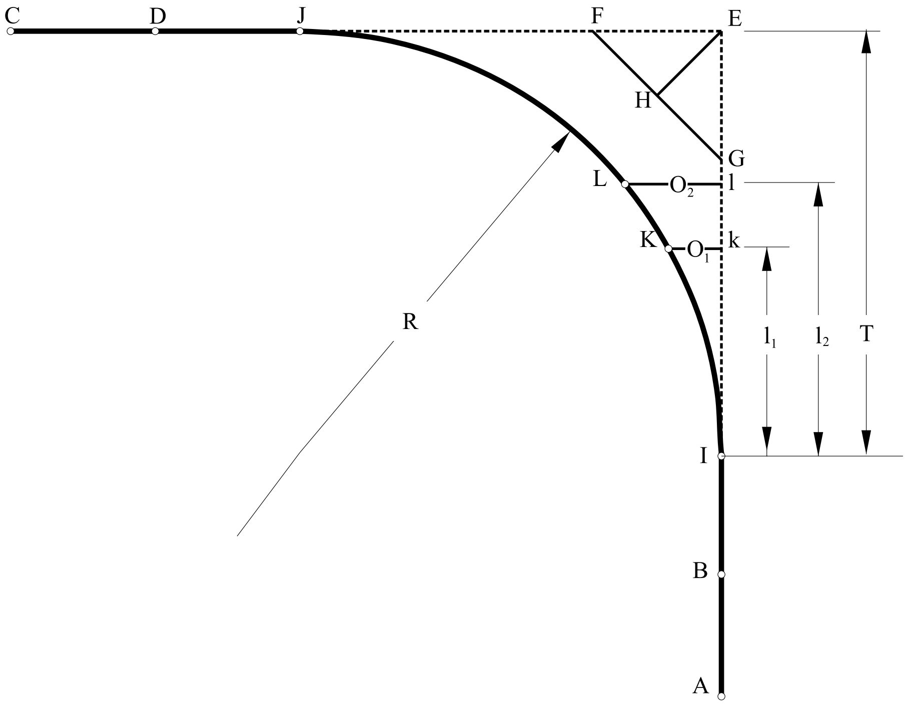

Figure 3.7: Setting out horizontal curve of radius R

1. Location of tangent points (beginning and end of curve)

1.1 Extend the two straights AB and CD to meet at E, and knock in a peg. String a line ABE and CDE.

1.2. Measure off two points F and G (that are inter-visible), along ABE and CDE that are of an equal distance from E. Knock in 2 pegs at F and G.

1.3. Measure the distance between F and G and divide it in half, to give point H. Knock in a peg at H.

1.4. Measure EH, FH and GH. (FH = GH)

1.5. The beginning and end points of the curve (I and J) between the two straights can be calculated from the formula:

$$T = EH/FH \text{ (or GH) } \times R$$

1.6. Measure the distance T from E, along the string lines EBA and EDC, to give points I and J. Knock in a peg at each of these points. I and J are the points that mark the beginning and end of the curve.

2. Determine the points on the curve

The points on the curve can be determined from the formula:

$$O = \frac{l^2}{2R}$$

2.1. Point K

From I measure off l_1 along ABE and knock in a peg. Calculate the distance O_1 from the formulae. Measure O_1 from k, at right angles to give point K on the curve. Knock in a peg. Remove the peg at k.

2.2. Point L

Repeat as above to determine point L.

5.4 Tangent method (the intersection point for the straights, and the area between it and the road, must be flat and free of obstructions)

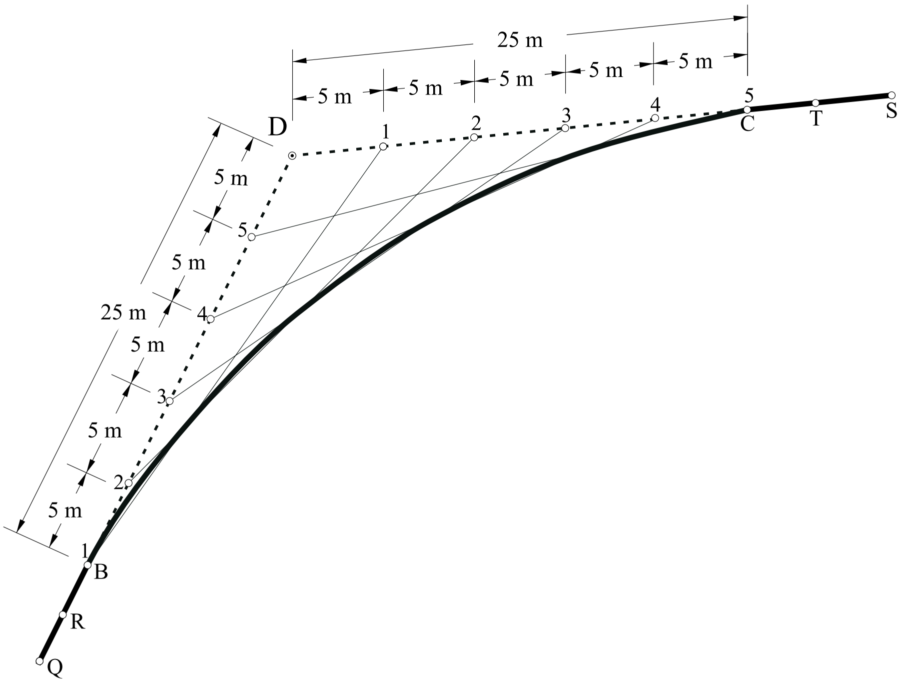

Figure 3.8

1. With the help of ranging rods, establish the point of intersection D by extending QR and ST.
2. Choose the most suitable tangent lengths (equal lengths, and establish points B and C. (In the example BD =DC = 25 metres).
3. Establish points B and C with pegs.
4. Divide BD and DC into an equal number of parts (in the example, 5 parts and number them as shown above. Place a peg at each point.
5. String a line between the two points marked 1 (1-1) on each tangent. Repeat with points 2 (2-2), 3 (3-3), 4 (4-4) and 5 (5-5).
6. The points on the curve lie at the intersection of 1-1 with 2-2; 2-2 with 3-3; 3-3 with 4-4; 4-4 with 5-5. Knock in pegs at these points and remove the pegs along the tangents.
7. If the radius is too sharp move B and C further apart and start again.

5.5 Off-set method (suitable for any curve – it does, however, require a trial and error approach)

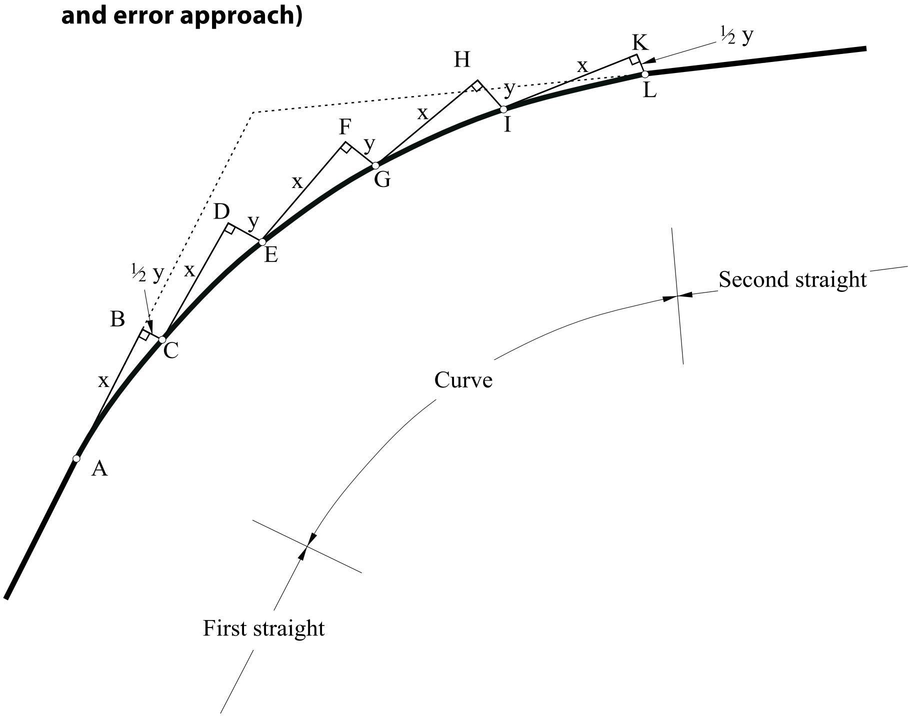

Figure 3.9

(Note that this is a trial and error approach, where the intersection point between the two straights cannot be established.)

1. Choose the beginning of the curve on one of the straights (Point A) as a trial.
2. Assume a distance x (normally 10 m) and a trial offset y (use the table below as a guideline).
3. Set out point B at a distance x from point A, on the extended straight (tangent).
4. Set out an off set at distance ½ y from B, to get point C on the curve. Knock in a peg.
5. Set out point D at a distance of x on the extension of line AC.
6. Set out an off set at distance y from D, to get point E on the curve. Knock in a peg.
7. Repeat until you reach the other extended straight (tangent) point I, and set out an offset of ½ y. This point L should be on the second straight.

If you do not reach the other tangent (point I), you will have to repeat the setting out, using another offset y and starting point A.

Radius (R) (metres)	x (metres)	y (metres)	Remarks
200	10	0,50	If a larger radius is
100	10	1,50	required reduce the
40	10	2,50	offset y.
40	5	0,60	Do not increase the
15	5	1,65	distance x.

For any given radius and assumed distance x, the offset y as reflected in the above table, can be calculated from $y \sim \frac{x^2}{R}$

MODULE 3: Construction of unstabilised gravel pavement layers (excluding base)

1. Specification

The specification will call for the construction of a 150 mm-thick unstabilised pavement layer, constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2. Materials

Materials required for the construction of the layer are:

- Gravel – approved from in-situ source or gravel pit (quarry)
- Water

3. Construction plant and equipment

The following specialised plant and equipment is recommended to promote the construction of the layer by labour intensive methods:

- Suitably sized (approximately 1 ton) tandem vibratory pedestrian roller, having two equally sized drums – both drums driven, each drum to have a separate eccentric shaft (e.g. Bomag 75 or equivalent)
- 150 × 100 mm × 8 mm thick steel angle formwork (steel shutters)
- (3 m, 2 m and 1 m lengths) (Figures 3.17 and 3.23 – Section 4.3 and Workshop drawing LIC 002)
- 75 × 8 mm steel spacer plates (bulking rails), (Figure 3.23 - Section 4.3 and Workshop drawing LIC 003), (3 m, 2 m and 1 m lengths)
- Builders' wheelbarrows (Capacity + 65 – 67 litres)
- Steel squeegees (Workshop drawing LIC 005)
- Screeding boards (Workshop drawing LIC 004)
- Plastic sheeting
- Cross-fall template of 2% or 3% as specified (Workshop drawing LIC 006)
- Steel pegs of various lengths (Y 10)
- 3 mm white string or sisal
- 1 000 litre water tank on LDV or mounted on trailer – with pump

4. Construction

4.1 Setting out

Refer to Module 2.

4.2 Preparatory work

4.2.1 Preparation of roadbed (sub grade)

Existing alignment

Once the horizontal and vertical alignment and cross-fall of the road have been set out as described in Module 2, and before the pavement layer gravel can be placed, the existing sub grade (roadbed) must be prepared.

The pegs at the centre line C and edge of riding surface A, to the left and right of the centre-line (section 4 – Figures 3.3 and 3.4) will determine the levels of the top of sub grade (roadbed).

Construction procedure sub grade preparation

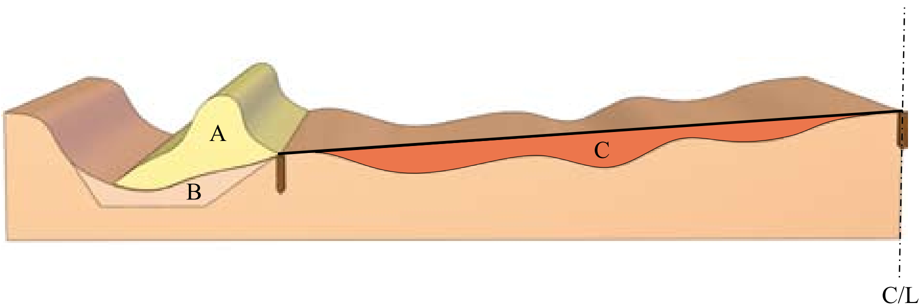

Figure 3.10: Reshaping sub grade (roadbed)

The type/quality of the materials will govern what the most practical treatment would be for the road.

In most cases, the work would be carried out under traffic and construction would be done in half widths.

In Figure 3.10 the material at A has been bladed or ridden into large windrows over a period of time from the road surface, and the road levels are now below surrounding ground levels.

The material at B probably is a soil loam, finely graded with a CBR of probably between 15 and 25. The PI is also relatively low – probably of the order of 5 to 8 but certainly below 10. (This can be confirmed by a few laboratory tests.)

Before any labour-based construction can proceed for pavement layers, i.e. for sub-base or base, whether for surface or unsurfaced roads, the rutting/unevenness at C must be rectified.

The in-situ material at B below the non-plastic coarse gravel must be considered for filling any ruts or rectifying any unevenness, and be taken from the road reserve. (Laboratory tests are required to assess the quality of this material.)

Don't use coarse gravel

The non-plastic coarse gravel at A must not be used. This should be stockpiled for use in the pavement layer.

The amount of material required for filling the ruts must be determined by using a string/line and tape. By taking the average of the dips measured × the width × 12 m (which is the practical length that the pedestrian roller can efficiently roll) × 1,5 (to allow for bulking/compaction of the material).

Average dips	=	50 mm
Width of formation	=	4 m
Section to be rolled	=	12 m
Bulking factor	=	1,5
Quantity required	=	$\frac{4 \times 12 \times 50 \times 1{,}5}{1\,000}$
	=	3,6 m^3

Prepare heaps of say 3½ m^3 every 12 m along the side of road. (Figure 3.11)

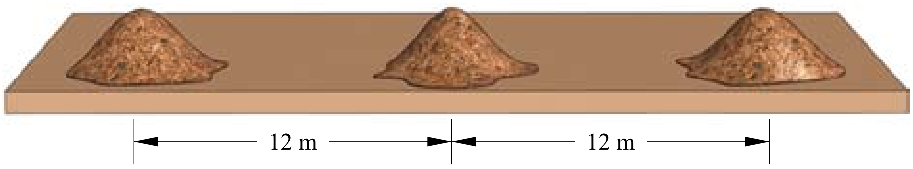

Figure 3.11: Spacing of heaps

No compaction should/must be attempted of dry material.

Most efficient compaction is achieved when material is mixed with its optimum moisture content (OMC) of water, as determined in the laboratory.

Uniform mixing of water and material is a major problem, and the following method overcomes most of these difficulties:

- Prepare a platform for each heap.
- Preferably measure out the quantity required, e.g. 14½ wheelbarrows = 1 m^3.
- Place material in a neat heap and form a dam at the top of the heap (Figure 3.12).

Figure 3.12: Addition of water to heaps

- Approximate amount of water required per 1 m^3 = 150 to 170 litres. Pour this water slowly into the dam.
- Cover the dam with plastic sheeting.
- Allow water to soak through material for approximately 24 to 36 hours.
- Draw off only the damp material in wheelbarrows – use a plastic sheet to cover wheelbarrow. (A small amount of water can be added by watering cans as the wheelbarrows are being loaded, if some of the material appears too dry – do not attempt to compact dry material.)

- Only dump material from wheelbarrow when labour is ready to spread and screed the material, using steel squeegees and screed rail.
- It is recommended that the surface be watered before material is dumped.
- After spreading and screeding the damp material, the surface must be covered with plastic sheeting, which is rolled out systematically as the work progresses, to reduce evaporation of water.

Compaction

> **Note**
>
> The treatment of the stockpiles of fill material, i.e. making and filling the dam must only be for one day – maximum two days ahead of sub grade preparation.
>
> Any excavation of the sub grade, to achieve required levels, can be added to the stockpiles in measured amounts for the addition of water.
>
> Because the depth of the fill required is not uniformly 50 mm thick, but varies from 0 to > 50 mm, there will be differential settlement when compacting the fill and extra fill may be required or cut away to meet the desired levels, but a smooth longitudinal surface is required between the reference pegs, and must be checked with boning rods and string lines.

It is advisable to lay the fill material 50% higher than the required compacted thickness and trim back any excess material. Once approximately 12 m of sub grade (roadbed) is completed and covered with plastic sheeting, rolling can commence with the roller in vibratory mode.

- Roll back the plastic sheeting.

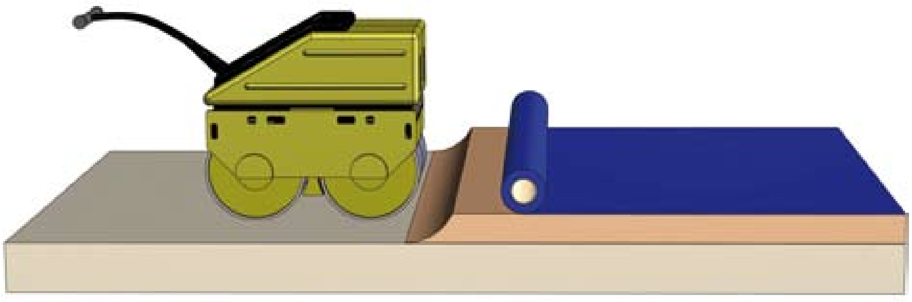

Figure 3.13: Compaction of sub grade (roadbed)

- Follow the rolling back of plastic sheeting with pedestrian roller.
- After one complete half-wheel pass of the roller, check the levels and trim back and remove excess material.
- Complete rolling and final trimming.
- Stop rolling immediately should the drums start to bounce.
- Generally 2 to 3 half-wheel passes are sufficient on thin layers (< 50 mm).

4.2.2 New alignment (example based on two in-situ sub grade layers being required to obtain desired controlled compaction depth of 550 mm). (Figure 3.14)

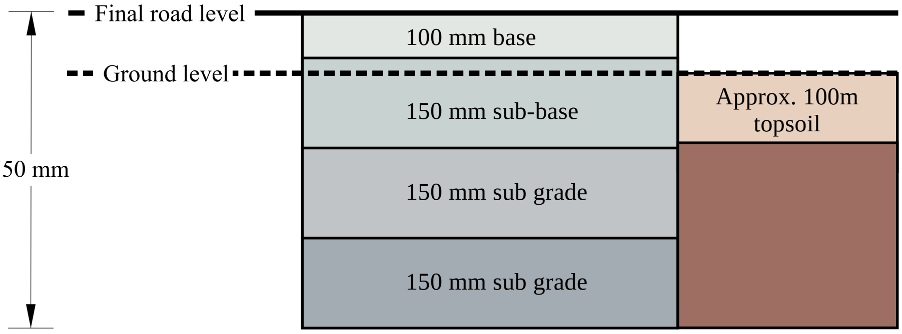

Figure 3.14

- Clear and grub including removal of ± 100 mm of topsoil and stockpile for later use in finishing off drains, slopes etc. as directed by the engineer.
- Excavate sub grade to 400 mm below final road level, for width of sub grade (600 mm wider than final sub-base width), and stockpile excavated material along edge of road at E1. (Figure 3.15)

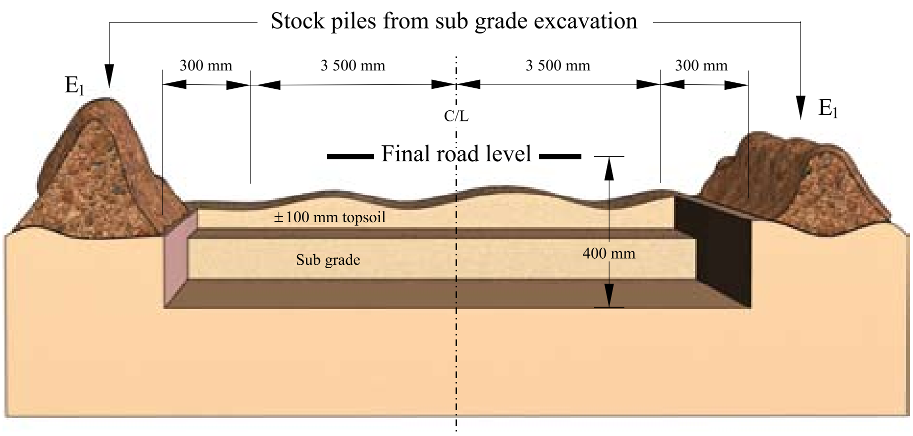

Figure 3.15

- Excavate a half-width of the road (3,8 m wide) for a length of 12 metres (A, B, C, D), 150 mm deep and stockpile on open half of road. (Figure 3.16 a)

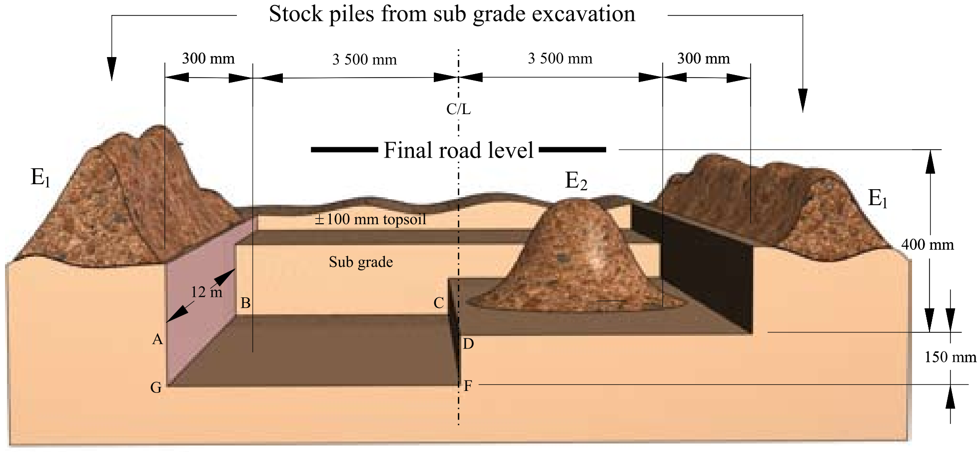

Figure 3.16 a

- Prepare a dam on stockpile E2, and slowly fill with ± 1 000 litres of water. Allow to stand till water has seeped through stockpile. Cover with a plastic sheet to stop evaporation of water.
- Construct 150 mm-thick compacted lower sub grade as described in Section 4.3.3 for the half width of the road in sections of 12 metres, using 150 × 100 mm steel shutters, with material from E2.
- Due to working in a confined space, there will be a gap between the compacted layer and the edge of the excavation once the shutters have been removed. Ensure that this area is efficiently filled to a depth of 225 mm with loose material and then compacted to the same level as the previously compacted material. (Figure 3.16 b)

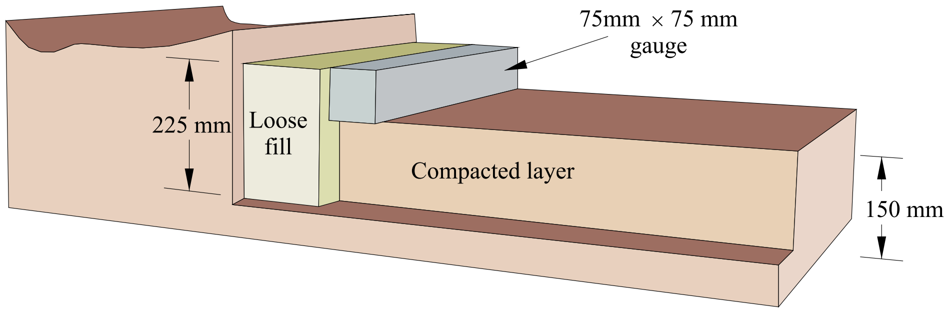

Figure 3.16 b: Compaction of edges of layer

- The same process is followed for constructing the second half of the lower sub grade of the road.
- Thereafter, the second sub grade is constructed in exactly the same manner, using material from E1 stockpiles. It may be necessary to add material of an equal quality to make up any shortfall.
- Thereafter, the sub-base is constructed as described in Section 4.3, and the base as described in Module 5.

4.3 Construction of gravel pavement layer

4.3.1 General

Tolerances

Steel side forms (steel shutters).

Steel formwork (shutters) for the placing of the pavement layer should be 150 × 100 mm × 10 mm thick angle, and be available in 3, 2, and 1 metre lengths. The shorter lengths should be used for small curves.

It is recommended that the steel formwork (shutters) should conform to the dimensions and thickness shown in Figure 3.17 and Workshop drawing LIC 002.

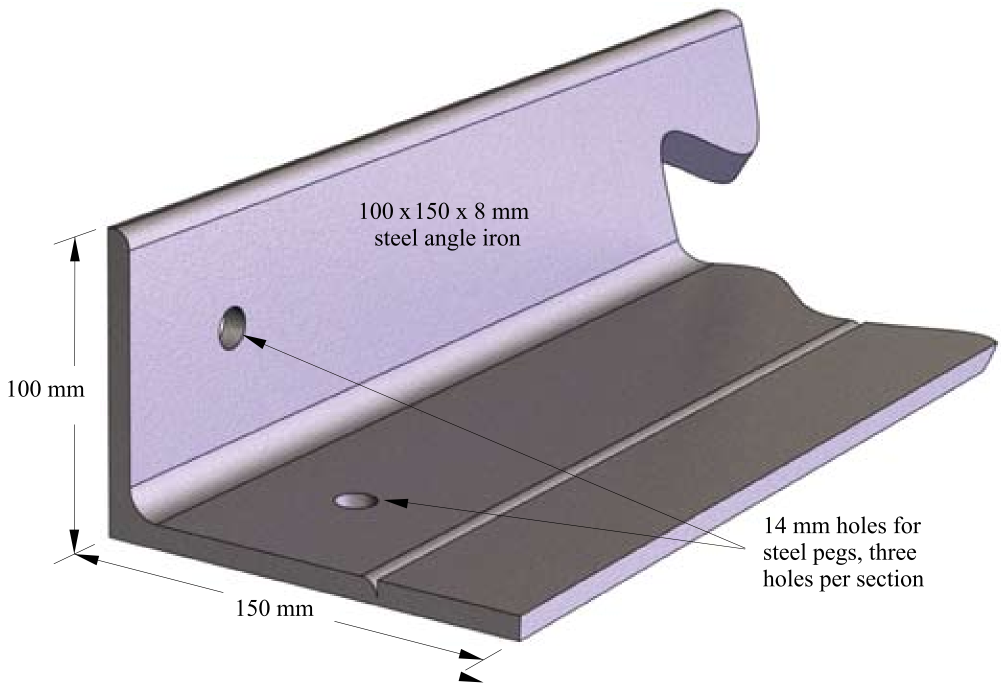

Figure 3.17: Side forms (shutters) for 150 mm pavement layers

Sufficient quantities of formwork should be available for a day's work.

4.3.2 Tipping and treatment of gravel stockpiles along road

Control of spacing of gravel heaps along the side of the road (for a 150 mm-thick compacted layer – 225 mm loose)

In order to minimise the distance over which material must be carted from the stockpiles to be placed on the road, it is essential to measure the size of the truck capacity. Preferably, the capacity of the trucks must be the same, e.g. all 6 m^3, 7 m^3 or 8 m^3, etc.

From the table (Table 3.2) or graph (Figure 3.18), the spacing for the truck deliveries can be established or calculated, based on the loose thickness on which the material must be placed (1.5 compaction factor).

Calculation of spacing of heaps	
Based on loose thickness of layer	**Based on compacted thickness of layer**
$\frac{\text{Volume of truck } (m^3)}{\text{Layer width } (m) \times \text{ loose depth of layer } (m)}$	$\frac{\text{Volume of truck } (m^3)}{\text{Layer width } (m) \times \text{ layer } (m) \text{ depth}} \times \frac{1}{\text{Compaction factor}}$
Note: Depth of layer in mm divide by 1 000 = Depth in metres (e.g. 225 mm = 0,225 m)	

Truck volume (m^3)	**6**			**7**			**8**		
Road width (m)	6	7	8	6	7	8	6	7	8
Gravel thickness (mm) **Loose/compacted**	225 150	225 150	225 150	225 150	225 150	225 150	225 150	225 150	225 150
Spacing (m)	4,44	3,80	3,33	5,18	4,44	3,88	5,92	5,06	4,44

Table 3.2: Spacing for various road widths and truck volumes

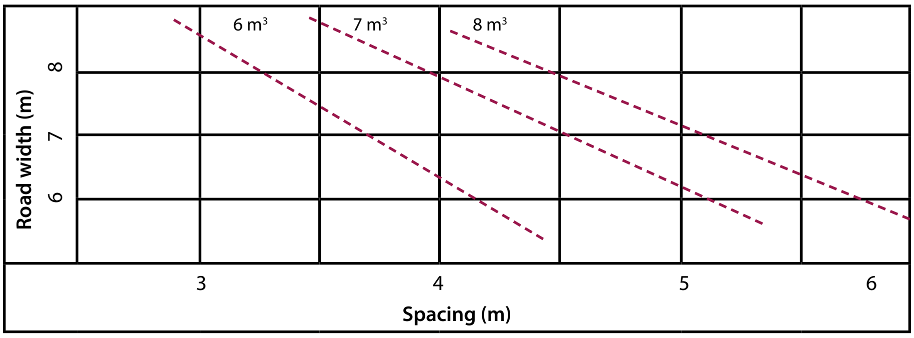

Figure 3.18: Spacing for various road widths and truck volumes

> **Note**
>
> As the road is to be built in half widths, the spacing in the above tables and graphs must be doubled.

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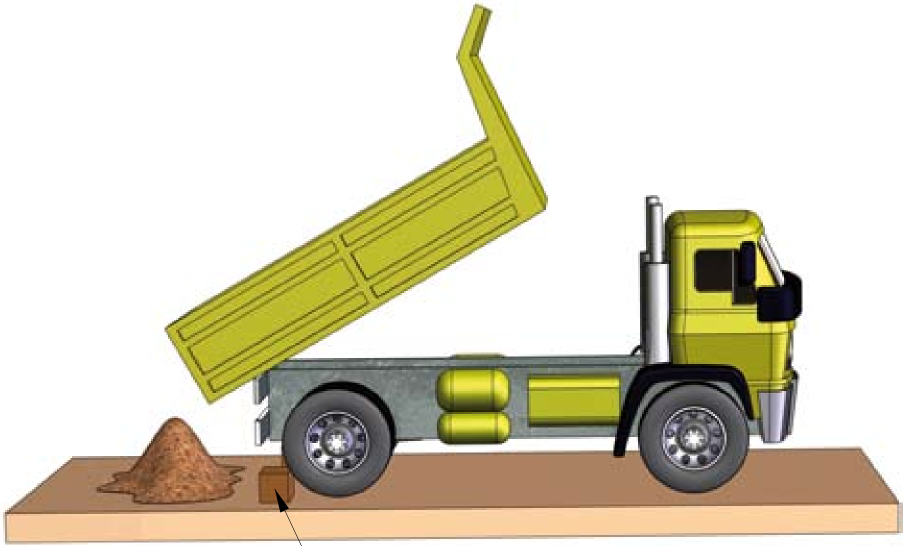
By means of stop blocks (Figure 3.19) the spacing for each truck load must be controlled.



Place timber stopper to get truck placed accurately for tipping at required spacing
(Use rope of correct length for spacing, not tape)

Figure 3.19: Spacing of heaps

Where deviations are in place, the material can be dumped on the half-width of the road on which construction is not taking place. If traffic is using this half-width, the material must be dumped on a prepared area along the side of the road. The material must not be dumped on the half-width that is being constructed.

The dumping of material must allow for working space in the vicinity of the heap.

No compaction of dry material should/must be attempted

The most efficient compaction is achieved when material is mixed with its optimum moisture content (OMC) of water, as determined by laboratory tests.

Addition of compaction water

When constructing the pavement using labour-based methods, the uniform mixing of water and material is a major problem, and the following method overcomes most of these difficulties.

Figure 3.20: Addition of water to heaps

- Shape the loads, tipped by the trucks, into relatively flat heaps and form a dam on these heaps.
- Using a 2 000 litre trailer, these dams should be filled with water to seep through the stockpile.
- Approximate amount of water required per 1 m^3 = 150 to 170 litres. Pour this water slowly into the dam.
- Cover the dam with plastic sheeting.
- Allow water to soak through material for 24 to 36 hours.
- Once the water has soaked through the material, the material can be hauled by wheelbarrow to the final position. (A small amount of water can be added by watering cans as the wheelbarrows are being loaded, if some of the material appears too dry – do not attempt to compact dry material.)
- Only 3 – 4, eight m^3 loads (24 m^3 – 32 m^3 of loose material), can be placed and screeded between steel shutters and rolled (as described in Section 4.3 - Construction of gravel pavement layer) per day, by a team of 12 labour units.
- If greater production is required, the number of teams will need to be increased.

4.3.3 Construction process

Placing of steel side forms (shutters)

In placing and fixing the formwork (shutters), care must be taken to ensure that no bumps are built into the surface, and that a smooth vertical and horizontal alignment and the correct cross-fall (camber) is obtained.

Care must be taken to check the vertical and horizontal alignment of the formwork, as well as the camber (cross-fall), and to ensure that the side forms are firmly and correctly positioned before placing the material.

Once the shutters are in place, the camber can be checked by using the screed board and the camber board, or a camber block and a spirit level.

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Using camber board

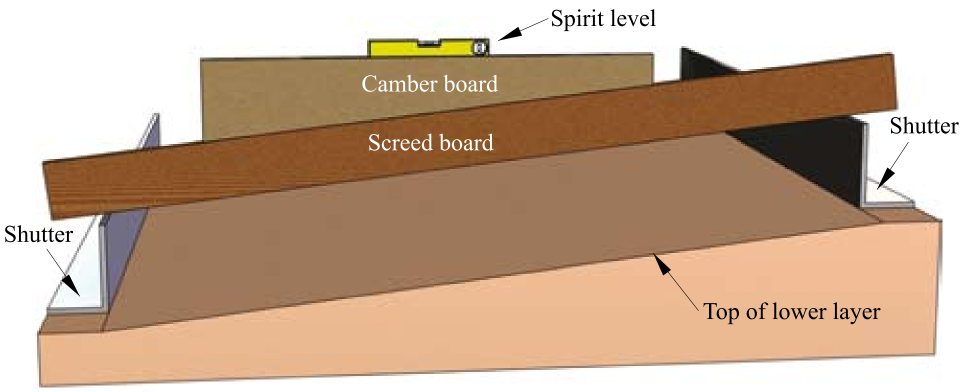


Figure 3.21 a: Use of camber board

Span the screed board between the centre-line shutter and the lower shutter (edge of road). Place the camber board for the correct cross-fall (camber) on top of the screed board. Check that the bubble is in the centre with a spirit level on top of the camber board. The road will then be at the correct cross-fall (camber).

Using a camber block

Place a camber block of the correct height for the specific camber and road half-width, on top of the vertical leg of the lower shutter (edge of road). A spirit level can then be placed on top of a screed board, spanning from the centre-line shutter to the lower shutter, to ensure that there is no fall between the top of the camber spacer and the centre-line shutter. (Figure 3.21 b)

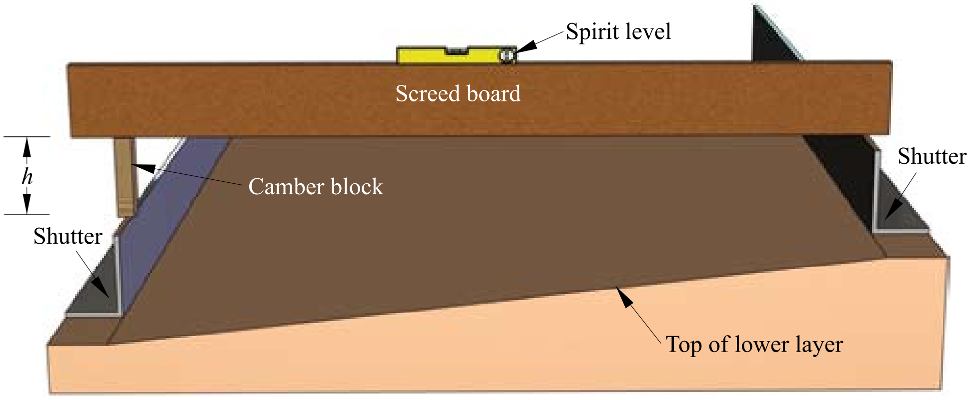


Figure3.21 b: Use of camber block

The height (h) of the camber spacer for various cambers is given in Table 3.3.

Half width of road – ½ *w* in (m)	Height of camber spacer – *h* in (mm)		
	2% cross-fall	3% cross-fall	3,5% cross-fall
2,0	40	60	70,0
2,5	50	75	87,5
3,0	60	90	105,0
3,5	70	105	122,5
4,0	80	120	140,0
4,5	90	135	157,5

Table 3.3: Height of camber spacer for 2%, 3% and 3,5% cross-falls

(A drawback of this method is that different height camber blocks are required for different road widths and cross-falls.)

Once the side forms have been placed, the levels must again be checked (by string lining across the tops of the side forms), and the surface trimmed to ensure that the correct thickness of pavement layer (150 mm) is laid. Slacks or depressions in the sub-base will not only result in an increase in the amount of base material required, but also differential settlement, causing an uneven ride.

Placing of the layer

Before placing the layer, the lower layer should be lightly watered. Placing of the material should be done as uniformly as possible, by placing the wheelbarrow loads at a uniform spacing, between the side forms to achieve the minimum amount of movement for levelling the loose material for a 225 mm loose layer. (Figure 3.22 a)

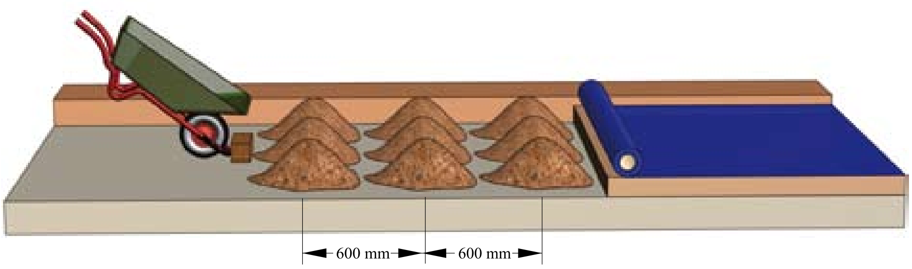


Figure 3.22 a: Placing of gravel

Calculation of spacing for 225 mm loose (150 mm compacted) layer for half width of 3,5 m

A width of 3,5 metres will allow 7 wheelbarrow loads to be tipped at a spacing of 0,5 metres.

Assuming the capacity of a wheelbarrow is 0,067 m³ the spacing between rows of wheelbarrows to obtain a loose depth of 225 mm (0,225 m) is then:

$$\frac{7 \times 0{,}067\ (m^3)}{3{,}5\ (m) \times 0{,}225\ (m)}$$

$= 0{,}6$ m

= 600 mm (Figure 3.22 b)

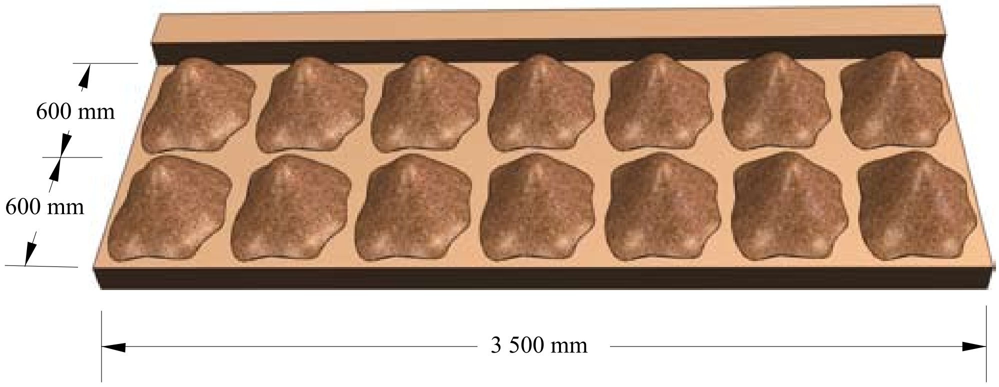


Figure 3.22 b: Spacing of barrow loads

Place the 75 mm × 10 mm thick steel spacer plate, as detailed in Figure 3.23, on top of the 150 mm leg of the side forms. Using the steel squeegees and steel screed bar, spread the material to obtain a 225 mm loose layer. (Less segregation of the material is attained by using steel squeegees in place of rakes.) Walking must not be allowed on the un-compacted/loose layer before screening and rolling.

Where the layer is being constructed adjacent to previously constructed work (e.g. half width construction), a 75 mm × 75 mm spacer must be placed on top of the existing work, to obtain the correct loose thickness for the new work.

Spacer plate (bulking rail)

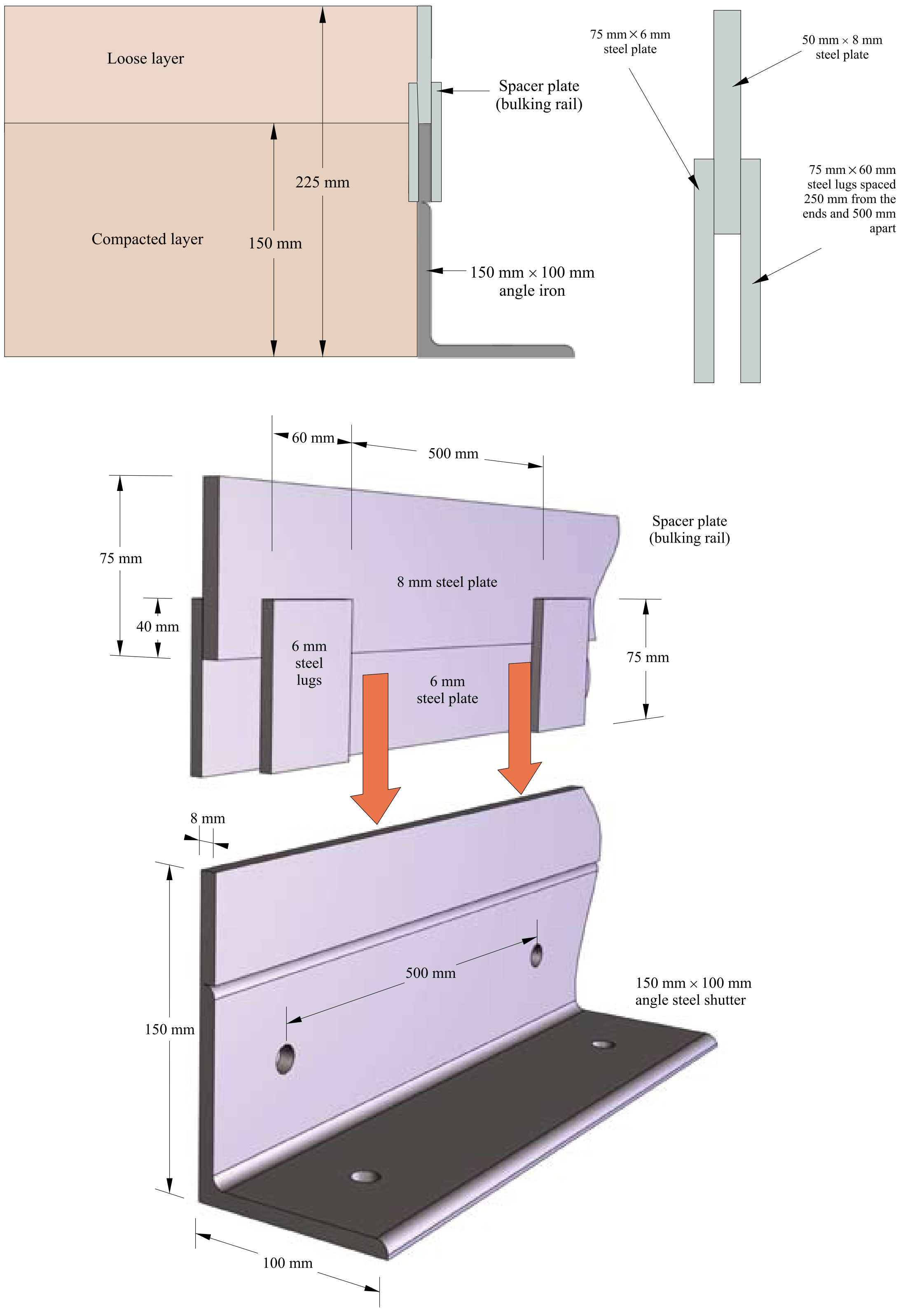


Figure 3.23: Sketch of spacer plate (bulking rail) to place 225 mm loose material
(Refer to Workshop drawings LIC 002 and 003 for details)

When using a coarse material, the judicious removal of the large fractions from the surface and their replacement with finer material will result in a smoother finish. Large fractions can be placed on the floor of advancing work.

As the work progresses, a black plastic sheet should be rolled out over the work to inhibit the material drying out. Once some 8 – 10 metres of layer has been placed, the cover can be rolled up, the spacer plates removed and rolling commenced.

Compaction of layer

The spacer plates (bulking rails) are removed before compaction of the layer commences.

Rolling, with the roller in vibratory mode, is continued until the 225 mm loose layer has been compacted to the top edge of the 150 mm leg of the side form. Incorrect rolling can result in the building of undulations in the surface.

In order to eliminate undulations, rolling should commence at 45° to the edge line of the shutters. Thereafter rolling should be undertaken in such a manner, that the roller is always supported, over approximately a half of its width, as indicated in Figures 3.24 a and 3.24 b initially either on an existing surface or the steel side forms.

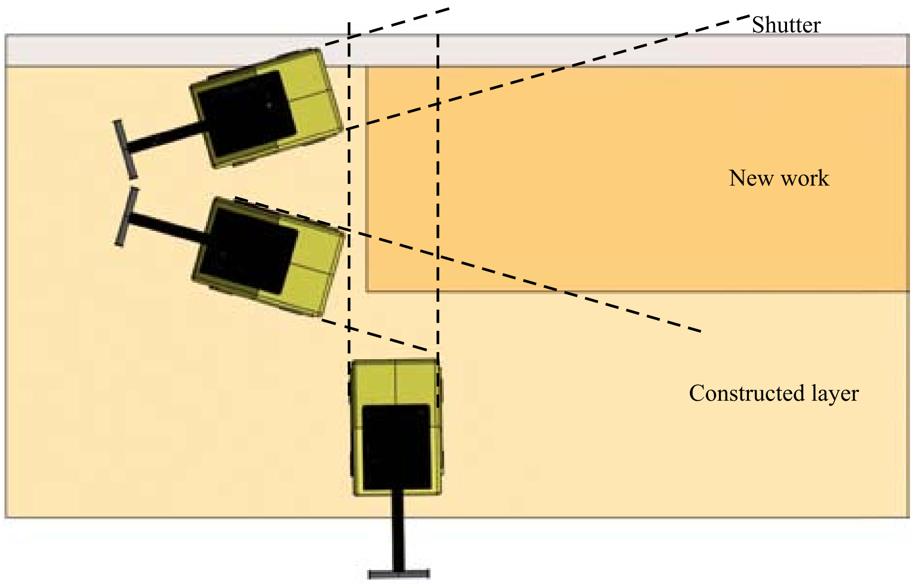


Figure 3.24 a: Initial rolling at 45° and across joint

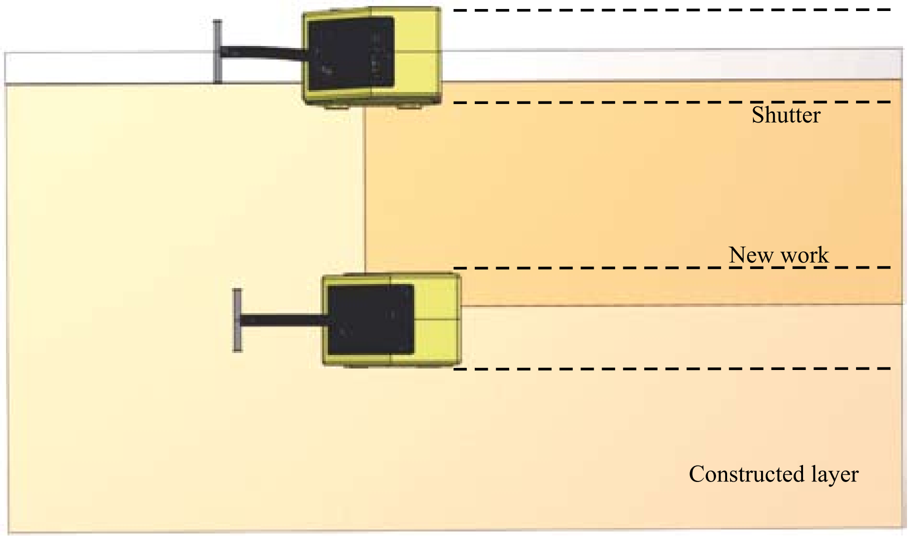


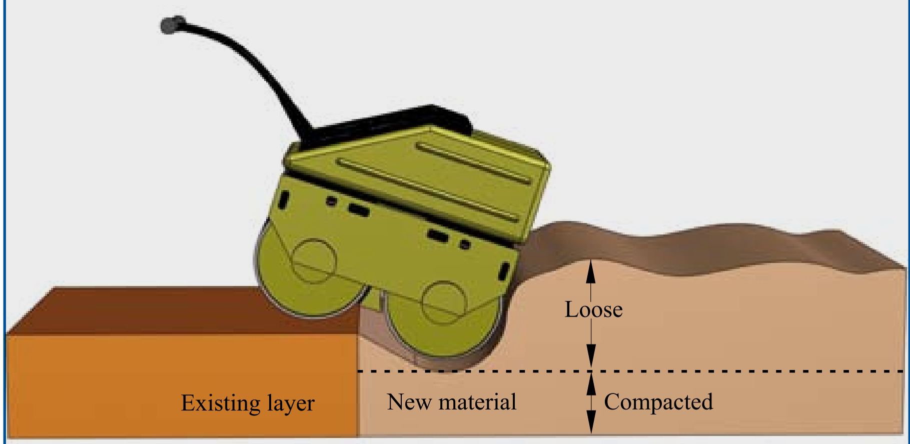
Figure 3.24 b: Rolling parallel with shutters from outside inwards

Always roll, in vibratory mode, parallel with the shutter lines. Move from both sides towards the middle of the layer, in a little less than ½ the width of the roller after each pass of the roller. Continue to roll the section until the layer is level with the shutters.

1. **Reason for operating roller in vibratory mode**

   The reason for operating the roller in vibratory mode from the outset is to overcome the problem of sealing air in the voids of uncompacted material. This makes it difficult to attain the required density, which is the case if the uncompacted material is initially rolled in non-vibratory mode.

2. **Reason for commencing rolling at 45°**



   Where construction starts when approaching the new work, parallel with the centre line of the road, approach the uncompacted material from the existing compacted material, initially at 45° with the roller. This overcomes the problem of creating/ constructing a bump in the road, between the existing and new work.

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5. Notes to designer/consultant

5.1 Materials survey

5.1.1 General

Before any work is commenced on the design of the road layers, it is advisable to determine:

- The quality of gravel available in the area.
- The quality of gravel on the road:
  - Establish the average depth of the gravel.
  - Establish the average width of the gravel.
  - What the CBR, Grading modulus (GM) and PI of the material is.
- The quality of the sub-base/sub grade materials.
- The drainage conditions of the system.

5.1.2 Centre-line survey

The quickest and most economical means of establishing the bearing capacity of the in-situ material, is by means of the DCP test.

DCP tests should be done in the middle of the wet season or just at the end of the wet season. This will introduce a safety factor in the design.

It is recommended that DCP tests are done every 50 metres along the route and, in the case of short lengths of road/street; at least three tests should be done every 80 – 100 metres.

It is recommended that physical tests, i.e. PI and grading, be done at selected points of similar material. Road material can be classified/similarities established, visually or the DCP tests could be used for testing the points.

From the DCP tests, the CBRs can be established for the in-situ materials. However, it is advisable to do CBR tests on selected samples after completion of the indicator tests.

5.1.3 Quarry (borrow pit survey)

It is advisable or recommended that, before funds are expended on opening/preparing a quarry site for winning gravel, a proper investigation is undertaken, comprising:

- The establishment of possible sites from geological knowledge of the area, and/or study of the local vegetation, cutting faces and discussions with locals.
- Trial pits to establish the extent of the deposit/existence of possible suitable material.
- The preparation of a plan of the area, showing the location and systematic establishment of further trial pits and showing these on the plan with test results.
- Testing. The minimum tests required for gravel roads and earthworks are the indicator tests i.e. grading and Atterberg limits.

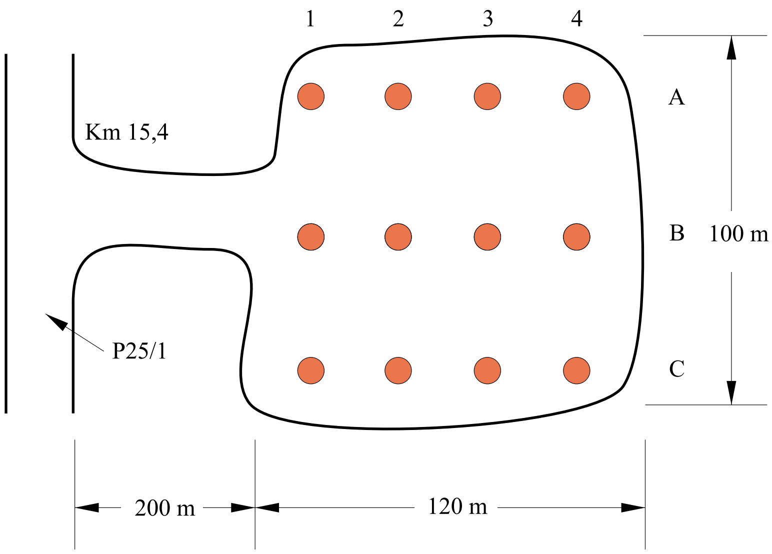


Figure 3.25: Quarry plan

Normally where large trees occur, the topsoil is deep and the material is finely graded soil. Stunted vegetation often indicates relatively shallow deposits and coarsely graded material.

The grass growing over gravel deposits is less intense/concentrated/lush. This is not always true as the overburden may be thick enough to encourage grass growth.

It is important to establish the depth of suitable material. Often ouklip/laterite/ferricrete deposits overly clay deposits which are unsuitable.

Each area has its own vegetation characteristics e.g. Protea bushes usually occur on granite deposits, and Bobbejaanstert over quartzitic gravels.

5.2 Winning gravel in approved gravel pit (quarry)

5.2.1 Management of quarry sites

Once the preliminary investigations have been expanded; the detailed investigations completed; and the quarry plans and test results, including the estimated material quantities available at each site, the planning/management of the site is possible.

It is generally uneconomical to win gravel at the quarry face using hand labour. It is therefore recommended that the material is won and stockpiled by machine, as a separate contract, for loading using only hand labour.

> **Note**
>
> - As the work is about to be contracted out, it is essential that this information of the quarry site is readily available, including the estimated quantity of material.
> - Before any site is tested, the owner must be consulted and permission to enter obtained – power of compensation/expropriation is normally covered in the relevant Road Ordinance.

5.2.2 Overburden

It is necessary to strip the soil and vegetation (overburden) before working the quarry for the following reasons:

- The topsoil is not always suitable for the layer for which it is required. The this can be assessed from the test results.
- The grass and roots in the overburden are not suitable for layer work.
- Reinstatement of the quarry is most important – top soil, seeds and grass roots must be stockpiled for this exercise.

> **Cost effective practice**
>
> As a dozer is required for this work – delivered to site by low-loader, it may be policy/effective to use it for stockpiling gravel, depending on the depth of the suitable material.

5.2.3 Stockpiling of gravel

In many areas of the country, suitable material occurs in shallow lenses of alluvial or secreted deposits, less than ± 1½ metres deep.

Why rip and stockpile gravel?

- It speeds up the process for loading by hand later.
- Better control of the quality of the material won in the quarry – the dozer operator can avoid any suspect/clay deposits. (The foreman/superintendent must supervise this work – using the quarry plan and test results to guide the operator.)
- The uniformity of material will be more easily obtained, if the quarry survey has been carried out efficiently.
- If the gravel consists of coarse and over-size material e.g. weathered dolerite or quartzitic boulder material, it is advisable to allow for crushing the material using a mobile primary crushing plant.
- The winning and stockpiling of material can be carried out under a separate contract. The dozer can complete its work at a specific quarry and move on to the next quarry for loading of the material by hand later, as required in the road layers. (This saves the cost of keeping the dozer on-site for extended periods.)

5.2.4 Method of stockpiling gravel

1. Move the vegetation and specified amount of topsoil, neatly into a stockpile/windrow, on either edge of the demarcated area indicated on the quarry plan. Rip the cleared area to the depths approved on the quarry plan.

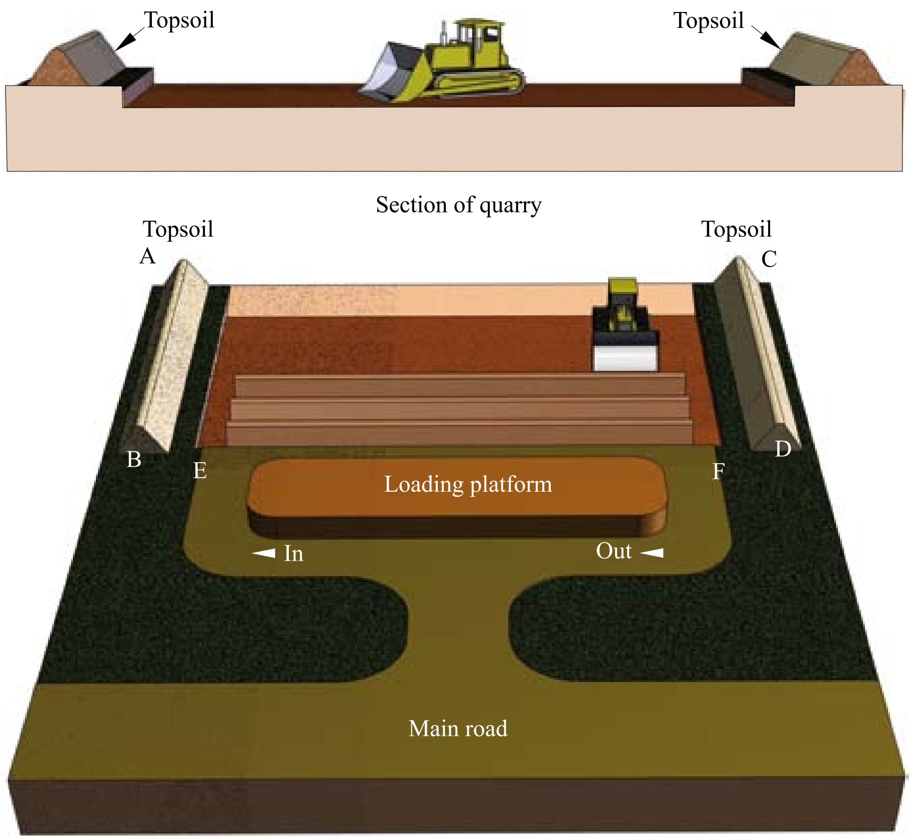


Figure 3.26: Management of quarry site

N.B. Road signs and flagmen must be used for controlling traffic, at junction of access to quarry, from main road.

2. At right angles to the line of topsoil stockpiles AB & CD, stockpile the gravel to a height of 1½ – 2 m in approximately parallel lines.

3. Shape, water and compact the access road from the main road to the quarry. This road must be wide enough for passing of trucks (6 – 8 m), or preferably two access roads 4 m wide – one IN and one OUT.

   Prepare the loading platform in front of the gravel stockpile for loading by hand, before commencing with the loading.

   When loading the trucks or trailers by hand, the management of the quarry stockpiling is essential for efficient loading: slots, with a depth approximately equal to the diameter of the wheels of the truck or trailer, must be provided in the stockpile area (Figure 3.27):

   – Gravel must be stockpiled on either side of the slot to allow for loading the truck or trailer from both sides.
   – More than one slot can be provided to expedite the work.
   – Gravel should be stockpiled in heaps of ± 20 cubic metres.

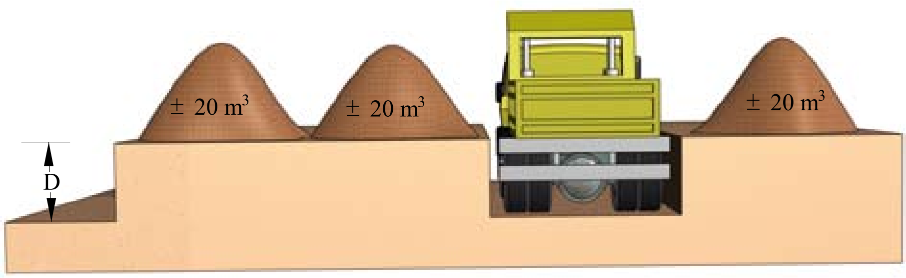


Figure 3.27: Stockpiling of gravel for loading by hand

4. The quarries must be reinstated at the end of the regravelling operation, by returning the vegetation and topsoil from AB and CD to neatly cover the area.

   – This can be undertaken by hand labour.
   – If possible, the reinstated area should be watered to encourage the growth of vegetation.
   – N.B. The quarry must be properly drained for health reasons – especially in malaria areas.

Stockpiling gravel

The above approach is particularly applicable to flattish areas or low rolling hills. In hilly or mountainous country, the process will have to be modified but the principles remain the same e.g. winning and stockpiling by suitable machines and loading platform, properly prepared prior to loading by hand.

The plant used may be changed e.g. a face shovel instead of a front-end loader for working a hard face.

The use of explosives is very effective in certain types of material.

5.3 Preparation of sub grade on new alignment

Special treatment is required on new alignments.

As a guideline, a minimum of 500 mm – 600 mm of controlled compaction is required below the final road level, on all new alignments i.e. assuming allowance for one 100 mm base and one 150 mm sub-base, two in-situ layers of 150 mm will be required in flat and rolling country.

> **Note**
>
> Heavy earthworks and excavation in hard material are not appropriate, nor cost effective for excavation by hand.

5.4 Road alignment

In view of the nature of the roads (low volume rural roads which mostly follow existing alignments), and method of construction (labour based), roads should be set out to a rolling grade to minimise earthworks and therefore costs, and to promote the use of labour.

Vertical curves should, however, be checked for safety sight distances.

Horizontal curves should also be checked e.g. do not introduce isolated sharp bends in a 120 km terrain.

MODULE 4: Construction of a gravel wearing course

1. Specification

The specification will call for the construction of a 150 mm-thick gravel wearing course, constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2. Materials

Materials required for the construction of the layer are:

- Gravel – approved from along the road or gravel pit (quarry)
- Water

3. Construction plant and equipment

The following specialised plant and equipment is recommended to promote the construction of the layer by labour intensive methods:

- Suitably sized (approximately 1 ton) tandem vibratory pedestrian roller having two equally sized drums – both drums driven, each drum to have a separate eccentric shaft (e.g. Bomag 75 or equivalent)
- 150 × 100 mm × 8 mm thick steel angle formwork (steel shutters) (3 m, 2 m and 1 m lengths) (Figures 3.35 and 3.41 – Section 4.3 and Workshop drawing LIC 002)
- 75 × 8 mm steel spacer plates (bulking rails) (Figure 3.41 - Section 4.3 and Workshop drawing LIC 003) (3 m, 2 m and 1 m lengths)
- Builders' wheelbarrows (capacity + 65 – 67 litres)
- Steel squeegees (Workshop drawing LIC 005)
- Screeding boards (Workshop drawing LIC 004)
- Plastic sheeting
- Cross-fall template of 2% or 3% as specified (Workshop drawing LIC 006)
- Steel pegs of various lengths (Y 10)
- 3 mm white string or sisal
- 1 000 litre water tank on LDV or mounted on trailer – with pump

4. Construction

4.1 Setting out

Refer to Module 2.

4.2 Preparatory work

4.2.1 Preparation of roadbed (sub grade)

Existing alignment

Once the horizontal and vertical alignment and cross-fall of the road have been set out as described in Module 2, and before the pavement layer gravel can be placed, the existing sub grade (roadbed) must be prepared.

The pegs at the centre line and edge of riding surface to the left and right of the centre line (Module 2.4 – Figures 3.3 and 3.4), will determine the levels of the top of sub grade (roadbed).

Construction procedure sub grade preparation

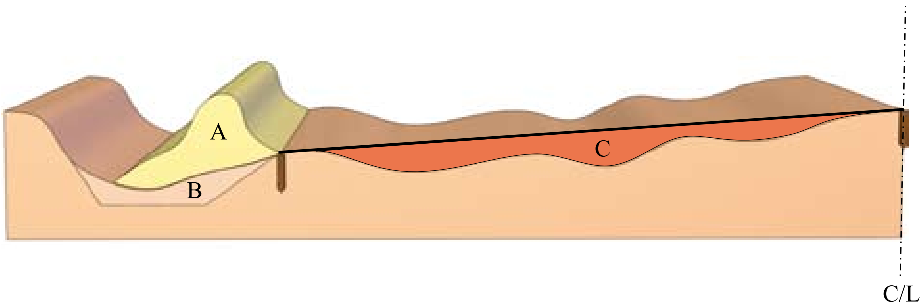


Figure 3.28: Reshaping sub grade (roadbed)

The type/quality of the materials will govern what the most practical treatment would be for the road.

In most cases, the work would be carried out under traffic and construction would be done in half widths.

In Figure 3.28, the material at A has been bladed or ridden into large windrows from the road surface over a period of time, and the road levels are now below surrounding ground levels.

The material at B is probably a soil loam, finely graded with a CBR of most likely between 15 and 25. The PI is also relatively low – possibly of the order of 5 to 8, but certainly below 10. (This can be confirmed by a few laboratory tests.)

The quality of both A and B material must be checked by determining the indicators and classification.

> **Note**
>
> The non-plastic coarse gravel at A must not be used. This material should be stockpiled for use in the pavement layer.

Before any labour-based construction can proceed for pavement layers i.e. for sub-base or base; whether for surface or unsurfaced roads; the rutting/unevenness at C must be rectified.

The in-situ material at B, below the non-plastic coarse gravel, must be considered for filling any ruts or rectifying any unevenness, and be taken from the road reserve. Laboratory tests are required to assess the material quality.

The amount of material required for filling the ruts must be determined by using a string/line and tape. By taking the average of the dips (measured every ½ metre, in lines 1 metre apart, at right angles to the road) x the width x 12 m (which is the practical length the pedestrian roller can efficiently roll) x 1,5 (to allow for bulking/compaction of the material).

Average dips	=	50 mm
Width of formation	=	4 m
Section to be rolled	=	12 m
Bulking factor	=	1.5
Quantity required	=	$\frac{4 \times 12 \times 50 \times 1.5}{1\,000}$
	=	3, 6 m^3

Prepare heaps of say 3½ m³ every 12 m along the side of road. (Figure 3.29)

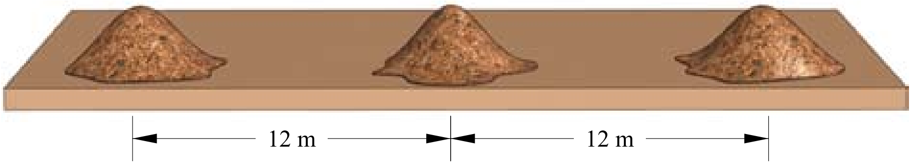


Figure 3.29: Spacing of heaps

No compaction should/must be attempted of dry material.

Most efficient compaction is achieved when material is mixed with its optimum moisture content (OMC) of water, as determined by laboratory tests.

Uniform mixing of water and material is a major problem, and the following method overcomes most of these difficulties:

- Prepare a platform for each heap.
- Preferably measure out the quantity required, e.g. 14½ wheelbarrows = 1 m³.
- Place material in a neat heap and form a dam at the top of the heap. (Figure 3.30)

Figure 3.30: Addition of water to heaps

- Approximate amount of water required per 1 m³ = 150 to 170 litres. Pour this water slowly into the dam.
- Cover the dam with plastic sheeting.
- Allow water to soak through material for approximately 24 to 36 hours.
- Draw off only the damp material in wheelbarrows – use a plastic sheet to cover wheelbarrow (a small amount of water can be added by watering cans as the wheelbarrows are being loaded, if some of the material appears too dry – do not attempt to compact dry material).
- Only dump material from wheelbarrow when labour is ready to spread and screed the material, using steel squeegees and screed rail.
- It is recommended that the surface be watered before material is dumped.

- After spreading and screeding the damp material, the surface must be covered with plastic sheeting, which is rolled out systematically as the work progresses, to reduce evaporation of water.

Note

The treatment of the stockpiles of fill material, i.e. making and filling the dam must only be for one day – maximum two days ahead of sub grade preparation.

Any excavation of the sub grade, to achieve required levels, can be added to the stockpiles in measured amounts for the addition of water.

Because the depth of the fill required is not uniformly 50 mm thick, but varies from 0 to > 50 mm, there will be differential settlement when compacting the fill and extra fill may be required or cut away, to meet the desired levels but a smooth longitudinal surface is required between the reference pegs, and must be checked with boning rods and string lines.

Compaction

It is advisable to lay the fill material 50% higher than the required compacted thickness, and trim back any excess material. Once approximately 12 m of sub grade (roadbed) is completed and covered with plastic sheeting, rolling can commence with the roller in vibratory mode.

- Roll back the plastic sheeting.

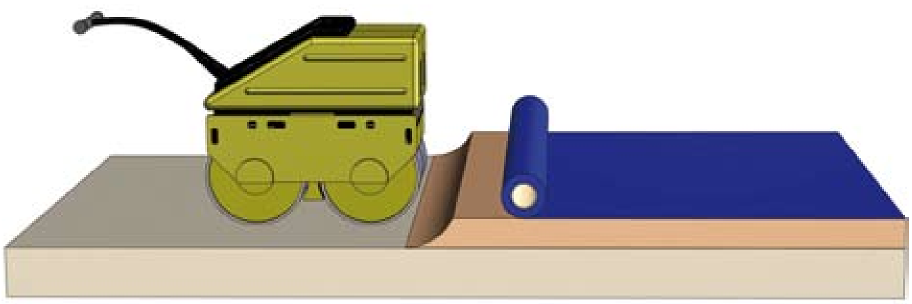


Figure 3.31: Compaction of sub grade (roadbed)

- Follow the rolling back of plastic sheeting with pedestrian roller.
- After one complete half-wheel pass of the roller, check the levels and trim back and remove excess material.
- Complete rolling and final trimming.
- Stop rolling immediately should the drums start to bounce.
- Generally 2 to 3 half-wheel passes are sufficient on these layers (< 50 mm).

New alignment

Method 1 (Road unlikely to be upgraded in foreseeable future)

- Clear and grub including removal of ± 100 mm of topsoil and stockpile for later use in finishing off drains, slopes, etc. as directed by the engineer.
- Shape roadbed to correct cross-falls, using template and method described in Module 2 Section 3.
- Thereafter, the gravel wearing course is constructed as described in Section 4.3.

Method 2 (Example road on final alignment for upgrading, based on two in-situ sub grade layers being required, to obtain desired controlled compaction depth of 550 mm). (Figure 3.32)

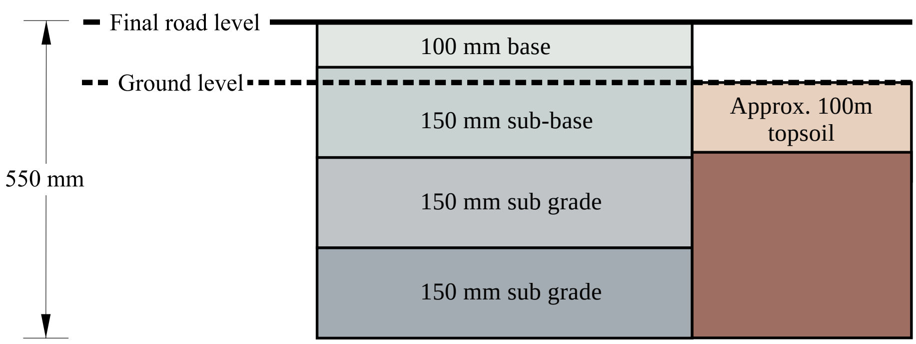


Figure 3.32

- Clear and grub including removal of ± 100 mm of topsoil and stockpile for later use in finishing off drains, slopes, etc. as directed by the engineer.
- Excavate sub grade to 400 mm below final road level, for width of sub grade (600 mm wider than final sub-base width), and stockpile excavated material along edge of road at E1. (Figure 3.33)

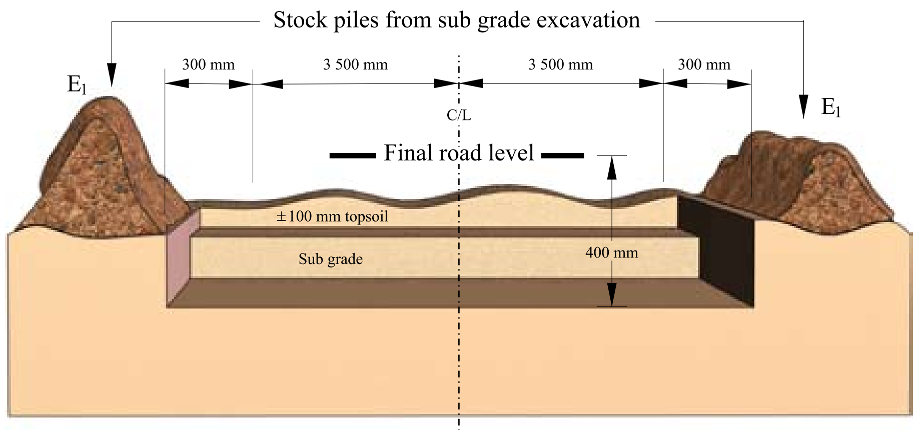


Figure 3.33

- Excavate a half width of the road (3,8 m wide), for a length of 12 metres (A, B, C, D), 150 mm deep and stockpile on open half of road. (Figure 3.34 a)

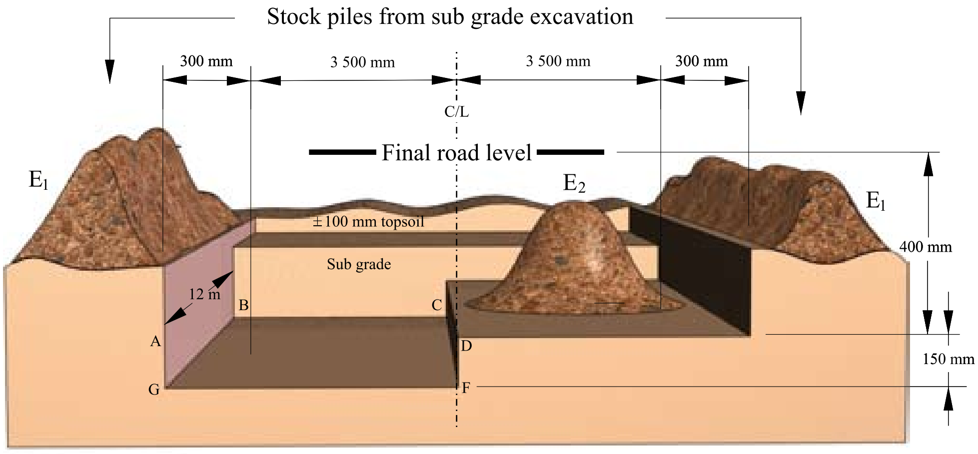


Figure 3.34 a

- Prepare a dam on stockpile E2 and slowly fill with ± 1 000 litres of water. Allow to stand till water has seeped through stockpile. Cover with a plastic sheet to stop evaporation of water.
- Construct 150 mm-thick compacted lower sub grade for the half width of the road in sections of 12 metres, using 150 × 100 mm steel shutters, with material from E2, as described in Section 4.3.3.
- Due to working in a confined space, there will be a gap between the compacted layer and the edge of the excavation once the shutters have been removed. Ensure that this area is efficiently filled to a depth of 225 mm with loose material and then compacted to the same level as the previously compacted material. (Figure 3.34 b)

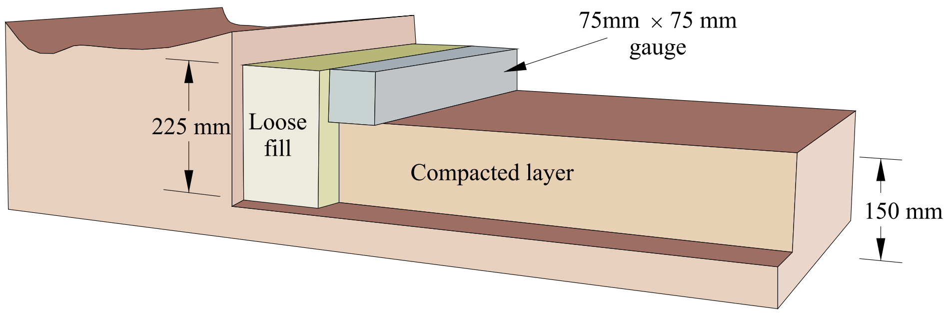


Figure 3.34 b: Compaction of edges of layer

- The same process is followed for constructing the second half of the lower sub grade of the road.
- Thereafter, the second sub grade is constructed in exactly the same manner, using material from E1 stockpiles. It may be necessary to add material of an equal quality to make up any shortfall.
- Thereafter, the gravel-wearing course is constructed as described in Section 4.3.

4.3 Construction of gravel wearing course

4.3.1 General

Tolerances

Steel side forms (shutters).

Steel formwork (shutters) for the placing of the wearing course, should be 150 × 100 mm × 10 mm thick angle, and be available in 3, 2, and 1 metre lengths. The shorter lengths should be used for small curves.

It is recommended that the steel formwork (shutters) should conform to the dimensions and thickness shown in Figure 3.35 and Workshop drawing LIC 002.

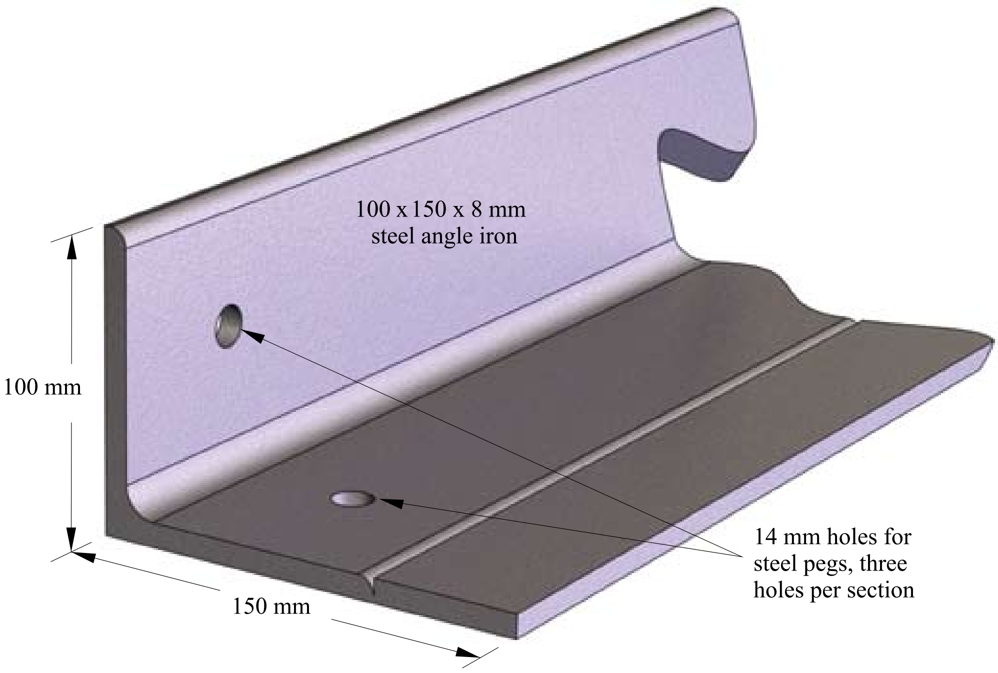


Figure 3.35: Side forms (shutters) for 150 mm gravel-wearing course

Sufficient quantities of formwork should be available for a day's work.

4.3.2 Tipping and treatment of gravel stockpiles along road

Control of spacing of gravel heaps along side of road (for a 150 mm thick compacted layer – 225 mm loose)

In order to minimise the distance over which material must be carted from the stockpiles to be placed on the road, it is essential to measure the size of the truck capacity. Preferably, the capacity of the trucks must be the same, e.g. all 6 m^3, 7 m^3 or 8 m^3, etc.

From the table (Table 3.4) or graph (Figure 3.36), the spacing for the truck deliveries can be established or calculated, based on the loose thickness on which the material must be placed (1.5 compaction factor).

Calculation of spacing of heaps	
Based on loose thickness of layer	**Based on compacted thickness of layer**
$\frac{\text{Volume of truck } (m^3)}{\text{Layer width } (m) \times \text{loose depth of layer } (m)}$	$\frac{\text{Volume of truck } (m^3)}{\text{Layer width } (m) \times \text{layer } (m) \text{ depth}} \times \frac{1}{\text{Compaction factor}}$
Note: Depth of layer in mm divide by 1 000 = Depth in metres (e.g. 225 mm = 0,225 m)	

Truck volume (m^3)	**6**			**7**			**8**		
Road width (m)	6	7	8	6	7	8	6	7	8
Gravel thickness (mm) **Loose/compacted**	225 150	225 150	225 150	225 150	225 150	225 150	225 150	225 150	225 150
Spacing (m)	4,44	3,80	3,33	5,18	4,44	3,88	5,92	5,06	4,44

Table 3.4: Spacing for various road widths and truck volumes

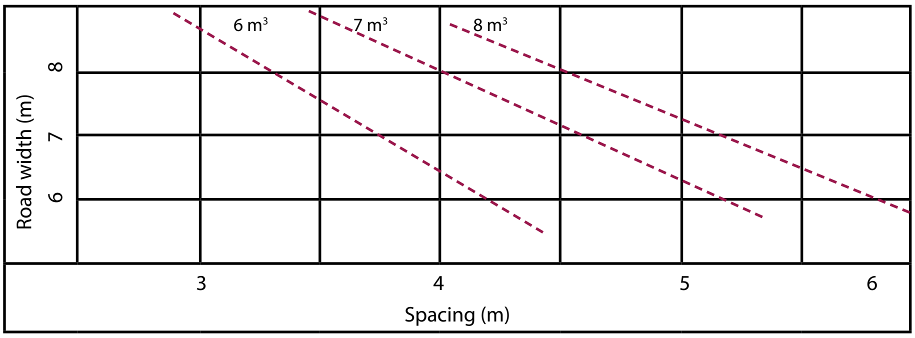


Figure 3.36: Spacing for various road widths and truck volumes

> **Note**
>
> As the road is to be built in half widths, the spacing in the above tables and graphs must be doubled.

The spacing for each truck load must be controlled by means of stop blocks. (Figure 3.37)

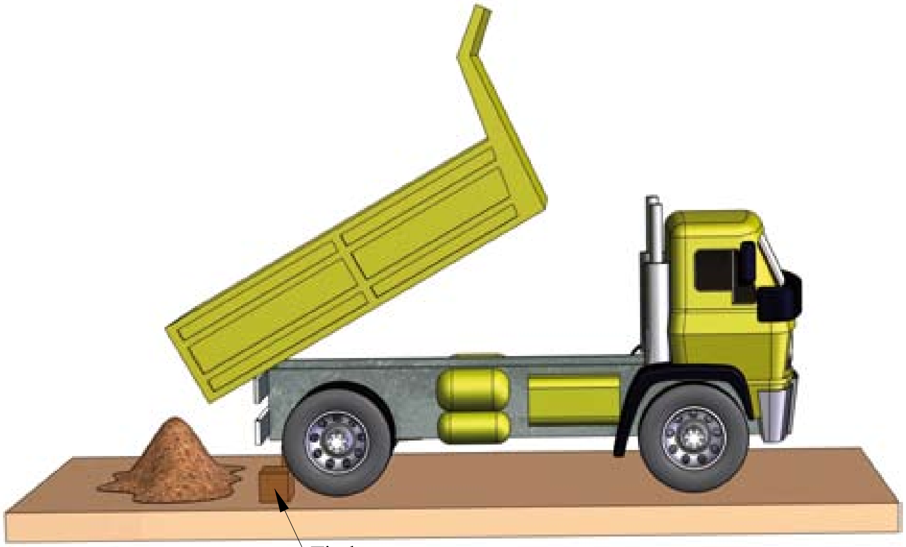


Figure 3.37: Spacing of heaps

Where deviations are in place, the material can be dumped on the half-width of the road on which construction is not taking place. If traffic is using this half-width, the material must be dumped on a prepared area along the side of the road. The material must not be dumped on the half-width that is being constructed.

The dumping of material must allow for working space in the vicinity of the heap.

Addition of compaction water

When construction the pavement using labour-based methods, the uniform mixing of water and material is a major problem, and the following method overcomes most of these difficulties.

> **Note**
>
> No compaction of dry material should/must be attempted.
>
> The most efficient compaction is achieved when material is mixed with its optimum moisture content (OMC) of water, as determined by laboratory tests.

Figure 3.38: Addition of water to heaps

- Shape the loads, tipped by the trucks, into relatively flat heaps and form a dam on these heaps.
- Using a 2 000 litre trailer, these dams can be filled with water to seep through the stockpile.
- Approximate amount of water required per 1 m^3 = 150 to 170 litres. Pour this water slowly into the dam.
- Cover the dam with plastic sheeting.
- Allow water to soak through material for 24 to 36 hours.
- Once the water has soaked through the material, the material can be hauled by wheelbarrow to the final position. (A small amount of water can be added by watering cans as the wheelbarrows are being loaded, if some of the material appears too dry – do not attempt to compact dry material.)
- Only 3 – 4, eight m^3 loads (24 m^3 – 32 m^3 of loose material), can be placed and screeded between steel shutters and rolled (as described in Section 4.3 - Construction of gravel pavement layer) per day, by a team of 12 labour units.
- If greater production is required, the number of teams will need to be increased.

4.3.3 Construction process

Placing of steel side forms (shutters)

In placing and fixing the formwork (shutters), care must be taken to ensure that no bumps are built into the surface, and that a smooth vertical and horizontal alignment and the correct cross-fall (camber) is obtained.

Care must be taken to check the vertical and horizontal alignment of the formwork, as well as the camber (cross-fall), and to ensure that the side forms are firmly and correctly positioned before placing the material.

Once the shutters are in place, the camber can be checked by using the screed board and the camber board, or a camber block and a spirit level.

Using camber board

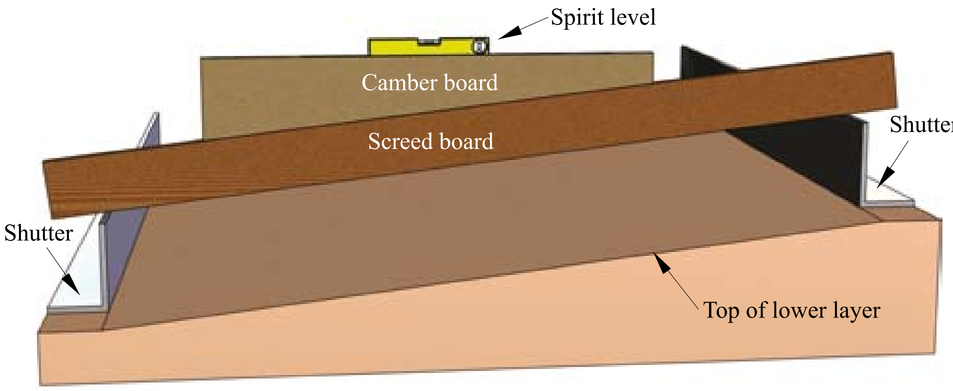


Figure 3.39 a: Use of camber board

Span the screed board between the centre-line shutter and the lower shutter (edge of road). Place the camber board for the correct cross-fall (camber) on top of the screed board. Check that the bubble is in the centre with a spirit level on top of the camber board (Figure 3.39 a). The road will then be at the correct cross-fall (camber).

Using a camber spacer

Place a camber spacer of the correct height for the specific camber and road half-width, on top of the vertical leg of the lower shutter (edge of road). A spirit level can then be placed on top of a screed board, spanning from the centre-line shutter to the lower shutter, to ensure that there is no fall between the top of the camber spacer and the centre-line shutter. (Figure 3.39 b)

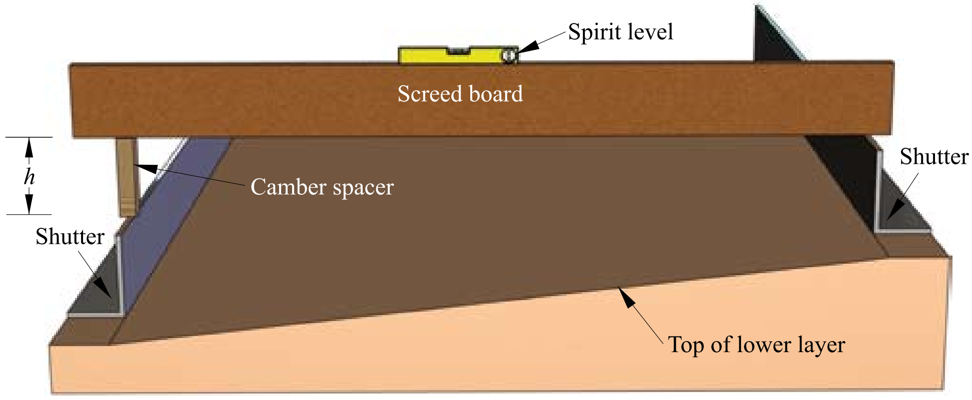


Figure 3.39 b: Use of camber spacer

The height (*h*) of the camber spacer for various cambers is given in Table 3.5.

Half width of road – ½*w* in (m)	Height of camber spacer – *h* in (mm)		
	2% cross-fall	3% cross-fall	3,5% cross-fall
2,0	40	60	70,0
2,5	50	75	87,5
3,0	60	90	105,0
3,5	70	105	122,5
4,0	80	120	140,0
4,5	90	135	157,5

Table 3.5: Height of camber spacer for 2%, 3% and 3,5% cross-falls

(A drawback of this method is that different height camber blocks are required for different road widths and cross-falls.)

Once the side forms have been placed, the levels must again be checked (by string lining across the tops of the side forms), and the surface trimmed to ensure that the correct thickness of pavement layer (150 mm) is laid. Slacks or depressions in the sub-base will not only result in an increase in the amount of material required, but also differential settlement causing an uneven ride.

Placing of the gravel wearing course layer

Before placing the layer, the lower layer should be lightly watered.

Placing of the material should be done as uniformly as possible, by placing the wheelbarrow loads at a uniform spacing, between the side forms to achieve the minimum amount of movement for levelling the loose material for a 225 mm loose layer. (Figure 3.40 a)

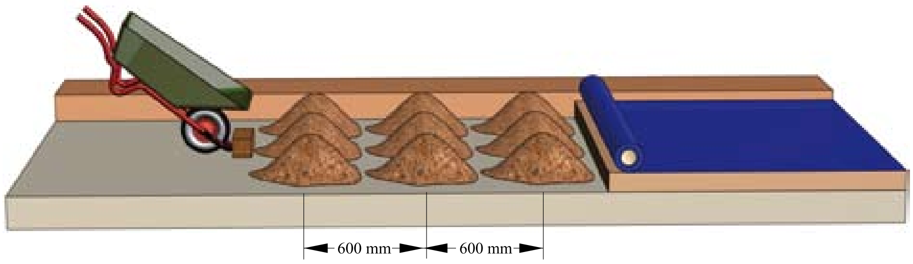


Figure 3.40 a: Placing of Gravel

Calculation of spacing for 225 mm loose (150 mm compacted) layer for half width of 3,5 m

A width of 3,5 metres will allow 7 wheelbarrow loads to be tipped at a spacing of 0,5 metres.

Assuming the capacity of a wheelbarrow is 0,067 m³ the spacing between rows of wheelbarrows to obtain a loose depth of 225 mm (0,225 m) is then:

$$\frac{7 \times 0{,}067\ (m^3)}{3{,}5\ (m) \times 0{,}225\ (m)}$$

$= 0{,}6$ m

$=$ 600 mm (Figure 3.40 b)

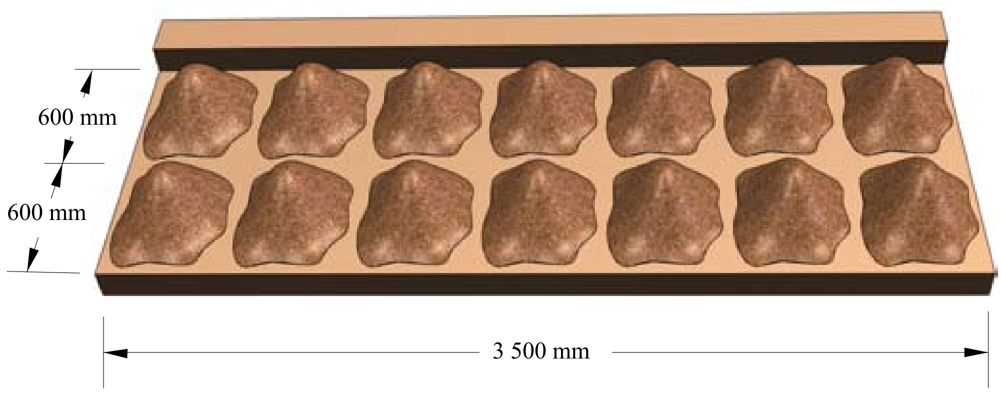


Figure 3.40 b: Spacing of barrow loads

Place the 75 mm × 10 mm thick steel spacer plate (bulking rail), as detailed in Figure 3.41, on top of the 150 mm leg of the side forms. Using the steel squeegees and steel screed bar, spread the material to obtain a 225 mm loose layer. (Less segregation of the material is attained by using steel squeegees in place of rakes.) Walking on the uncompacted/loose layer before screeding and rolling, must not be allowed.

Where the layer is being constructed adjacent to previously constructed work (e.g. half width construction), a 75 mm × 75 mm spacer must be placed on top of the existing work, to obtain the correct loose thickness for the new work.

Spacer plate (bulking rail)

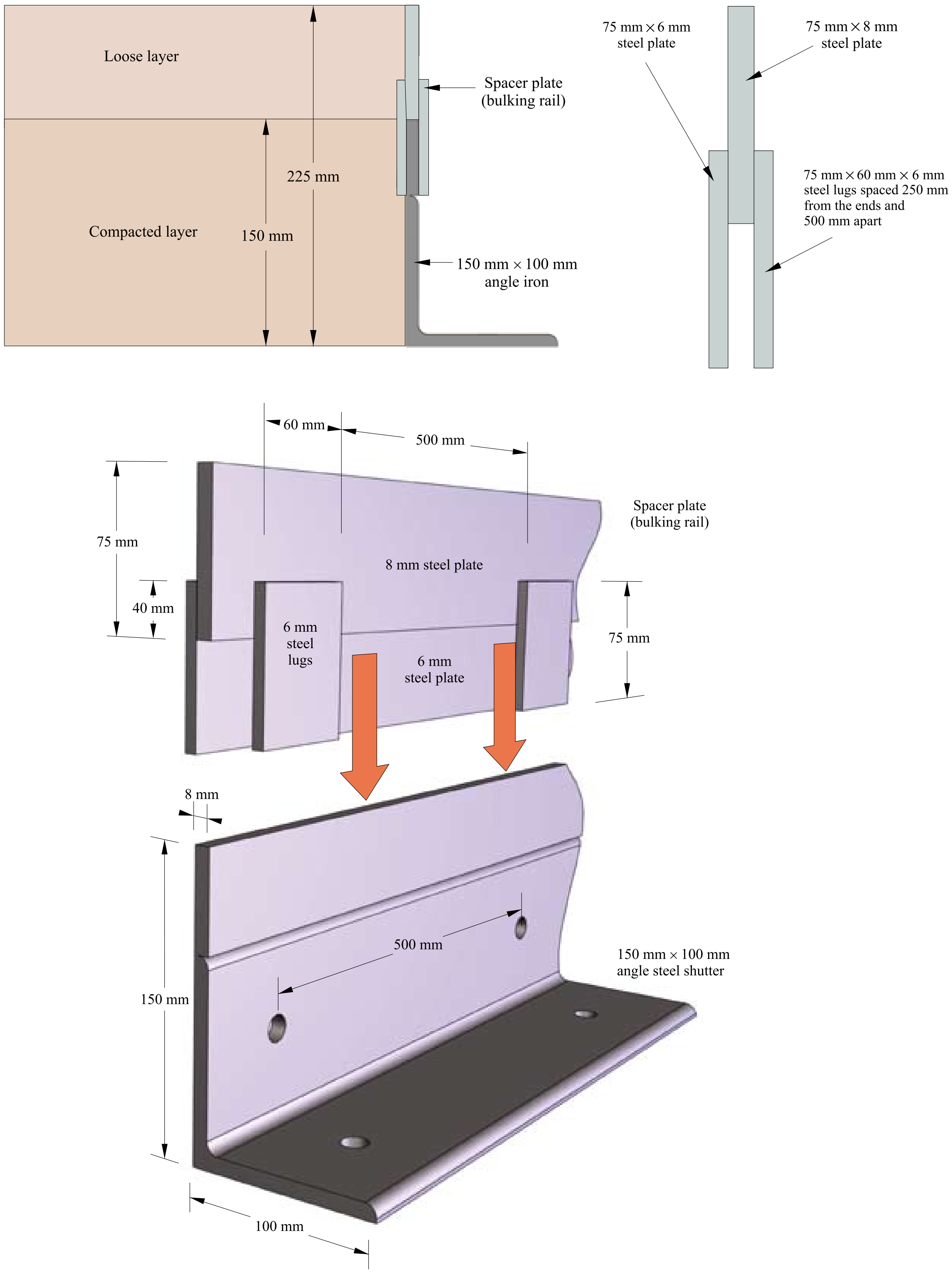


Figure 3.41: Sketch of spacer plate (bulking rail) to place 225 mm loose material

(Refer to Workshop drawings LIC 002 and 003 for details)

When using a coarse material, the judicious removal of the large fractions from the surface and their replacement with finer material will result in a smoother finish. The large fractions can be placed on the floor of advancing work.

As the work progresses, a black plastic sheet should be rolled out over the work to inhibit the material drying out. Once some 8 – 10 metres of layer has been placed, the cover can be rolled up, the spacer plates removed and rolling commenced.

Compaction of layer

The spacer plates (bulking rails) are removed before compaction of the layer commences.

Rolling, with the roller in vibratory mode, is continued until the 225 mm loose layer has been compacted to the top edge of the 150 mm leg of the side form. Incorrect rolling can result in the building of undulations in the surface.

In order to eliminate undulations, rolling should commence at 45° to the edge line of the shutters. Thereafter rolling should be undertaken in such a manner that the roller is always supported over approximately a half of its width, as indicated in Figures 3.42 a and 3.42 b, initially either on an existing surface or the steel side forms.

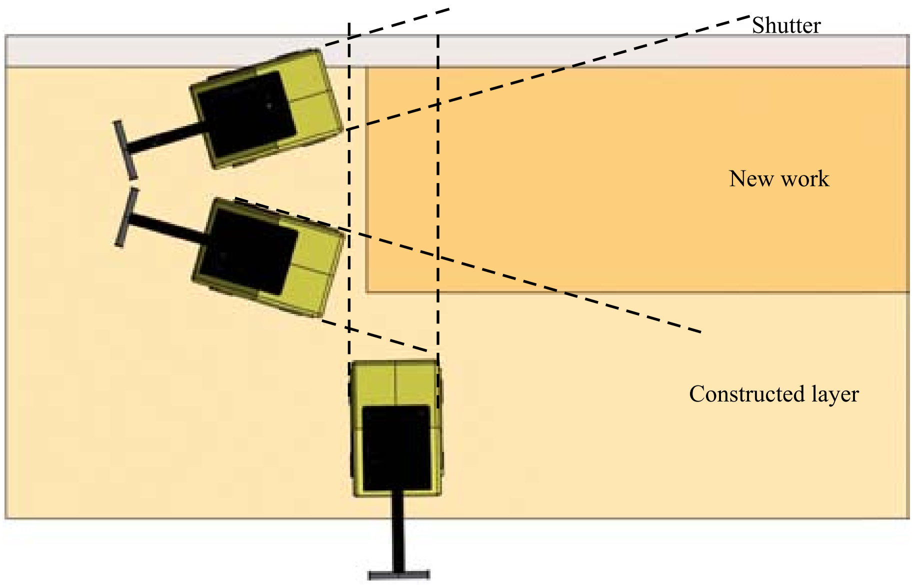


Figure 3.42 a: Initial rolling at 45° and across joint

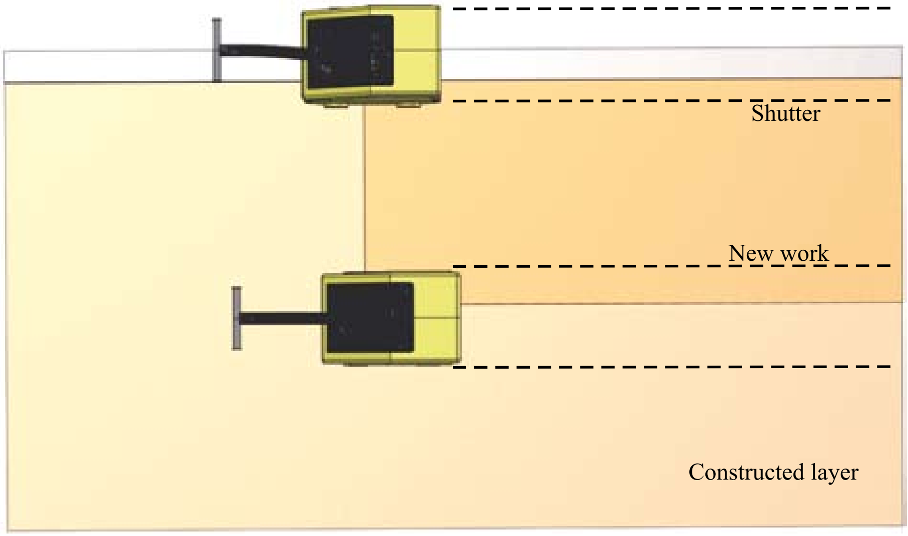


Figure 3.42 b: Rolling parallel with shutters from outside inwards

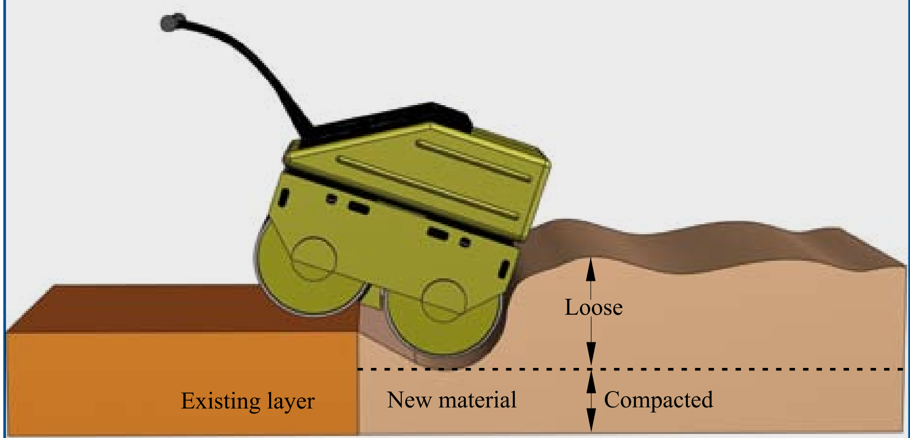
Always roll, in vibratory mode, parallel with the shutter lines. Move from both sides towards the middle of the layer, in a little less than ½ the width of the roller after each pass of the roller.

Continue to roll the section until the layer is level with the shutters.

1. **Reason for operating roller in vibratory mode**

   The reason for operating the roller in vibratory mode from the outset is to overcome the problem of sealing air in the voids of uncompacted material. This makes it difficult to attain the required density, which is the case if the uncompacted material is initially rolled in non-vibratory mode.

2. **Reason for commencing rolling at 45°**



Where construction starts when approaching the new work, parallel with the centre line of the road, approach the uncompacted material from the existing compacted material, initially at 45° with the roller. This overcomes the problem of creating/ constructing a bump in the road, between the existing and new work.

5. Notes to designer/consultant

5.1 Preparatory work

5.1.1 Centre-line survey

Before any gravelling work is commenced, it is advisable to determine:

- The quality of gravel available in the area.
- The quality of gravel on the road:
  - Establish the average depth of the gravel.
  - Establish the average width of the gravel.
  - What the CBR, grading modulus (GM) and PI of the material is.
- The quality of the sub-base/sub grade materials.
- The drainage conditions of the system.

5.1.2 Preparation of existing roadbed

It is recommended that the roadbed is prepared to a rolling grade longitudinally, and the cross-fall corrected, prior to placing of the gravel wearing course. The shape of the drainage system must also be rectified where required.

The source of material is not normally a problem, as very little material is required to shape the roadbed.

Most of the material can be obtained from within the carriageway. Extra material can be obtained from within the road reserve by reshaping the flat bottom side drains where these are required, or even widening these drains – if the material is suitable. (Figure 3.43)

Under extreme conditions, the odd load of gravel may be required from the nearest quarry or by widening nearby cuttings.

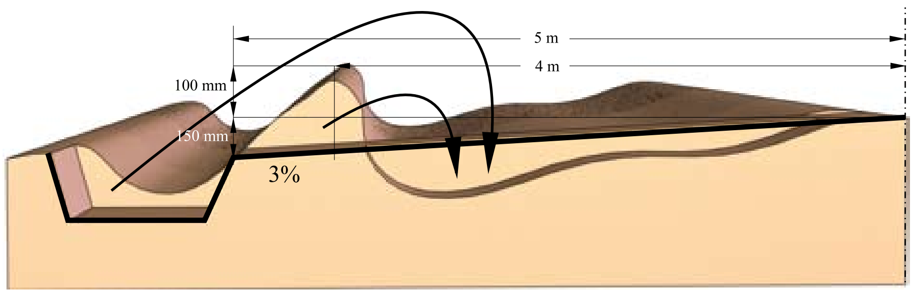


Figure 3.43: Reshaping roadbed

Preparation of roadbed where gravelling is to be carried out on new alignment

Where it is unlikely that the road is to be upgraded in the foreseeable future, the new alignment should merely be cleared and grubbed, whereafter the road can be shaped as required. (Method 1 – Section 4.2.1.)

Where the road is likely to be upgraded in the foreseeable future, the sub grade layers should be provided as described in Method 2 – Section 4.2.1.

5.1.3 Quarry (borrow pit) survey

It is advisable/recommended that, before funds are expended on opening/preparing a quarry site for winning gravel, a proper investigation is undertaken, comprising:

- The establishment of possible sites from geological knowledge of the area, and/or study of the local vegetation, cutting faces and discussions with locals.
- Trial pits, to establish the extent of the deposit/existence of possible suitable material.
- The preparation of a plan of the area, showing the location and systematic establishment of further trial pits and showing these on the plan with test results.
- Testing. The minimum tests required for gravel roads and earthworks are the indicator tests i.e. grading and Atterberg limits.

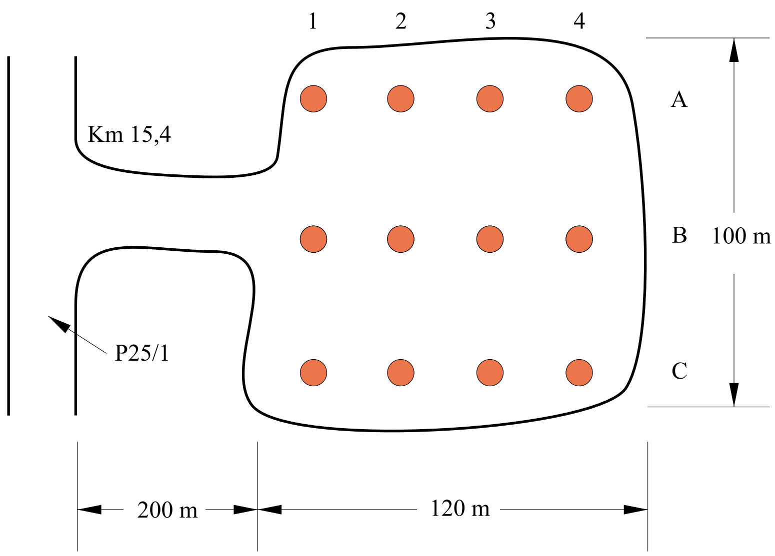


Figure 3.44: Quarry plan

Normally where large trees occur, the topsoil is deep and the material is finely graded/ soil. Stunted vegetation often indicates relatively shallow deposits and coarsely graded material.

The grass growing over gravel deposits is less intense/concentrated/lush. This is not always true as the overburden may be thick enough to encourage grass growth.

It is important to establish the depth of suitable material. Often ouklip/laterite/ferricrete deposits overly clay deposits which are unsuitable.

Each area has its own vegetation characteristics e.g. Protea bushes usually occur on granite deposits, and Bobbejaanstert over quartzitic gravels.

Selection of material

The following tables are recommended as guidelines, to be used in the selection of borrow pits for materials in the construction of a gravel-wearing course.

Note

- As the work is about to be contracted out, it is essential that this information of the quarry site is readily available, including the estimated quantity of material.
- Before any site is tested, the owner must be consulted and permission to enter obtained – power of compensation/expropriation is normally covered in the relevant Road Ordinance.

MODULE
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Please note these tables are only guidelines and it is advisable to inspect roads on which similar selected materials have been used, to establish its performance.

Maximum size:	37,5 mm
Oversize Index (I_o):	< 5%
Shrinkage Product (S_p):	100 – 365 (max. of 240 preferable)
Grading Coefficient (G_c):	16 – 34
CBR:	> 15 at > 95% Mod. AASHO compaction and OMC

Table 3.6: Recommended material specifications for unpaved rural roads

Maximum size:	37,5 mm
Oversize Index (I_o):	0
Shrinkage Product (S_p):	100 – 240
Grading Coefficient (G_c):	16 – 34
CBR:	> 15 at > 95 % Mod. AASHO compaction and OMC

Table 3.7: Recommended material specifications for unpaved roads in urban areas

Where: I = % retained on 37,5 mm sieve
S_p = Linear shrinkage x % passing 0,425 sieve
G_c = (% passing 26,5 mm - % passing 2,0 mm) x % passing 4,75 mm/100

Tested immediately after compaction.

In comparison with the limits for rural roads, it can be seen that the limits for the Oversize Index (I_o) have been reduced to eliminate stones, whilst the Shrinkage Product (S_p) has been reduced to 240 to reduce dust as much as possible. This lower limit reduces the probability of unacceptable dust from about 70% - 40%.

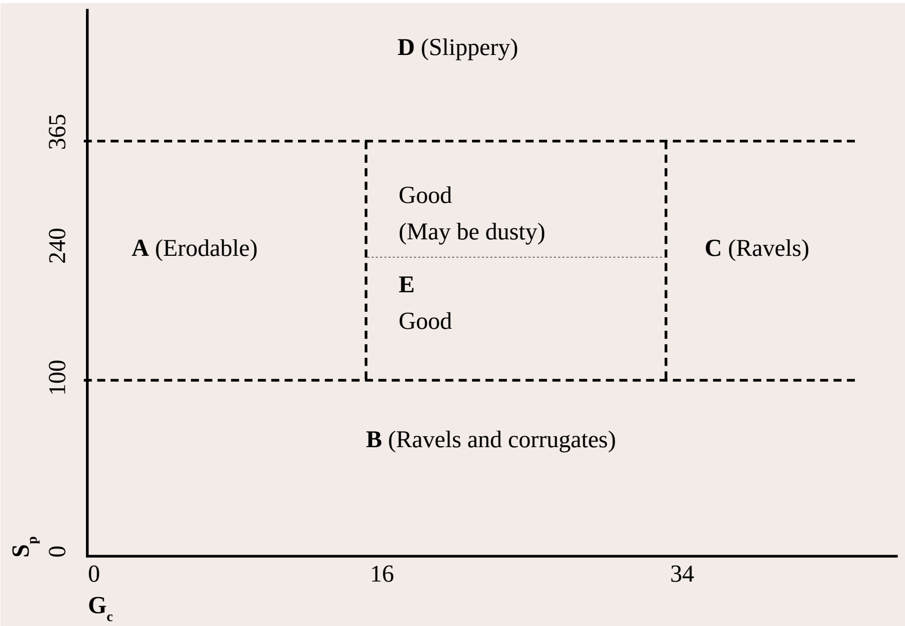

Figure 3.45: Relationship between Shrinkage Product (S_p); Grading Coefficient (G_c) and performance of unpaved wearing course gravels

The specifications for Shrinkage Product (S_p) and Grading Coefficient (G_c) are shown schematically in Figure 3.45. The following conclusions can be drawn about each zone in the following table:

Zone	Material description
A	Materials in this area generally perform satisfactorily but are finely graded and particularly prone to erosion by water. They should be avoided if possible, especially on steep grades and sections with steep cross-falls and super-elevations. Most roads, constructed from these materials, perform satisfactorily but may need periodic labour-intensive maintenance over short lengths and have high gravel losses due to water erosion.
B	These materials generally lack cohesion and are highly susceptible to the formation of loose material (ravelling) and corrugations. Regular maintenance is necessary if these materials are used and the roughness is to be restricted to reasonable levels.
C	Materials in this zone generally comprise fine, gap-graded gravels lacking adequate cohesion, resulting in ravelling and the production of loose material.
D	Materials with a shrinkage product in excess of 365, tend to be slippery when wet.
E	Materials in this zone perform well in general, provided the oversize material is restricted to the recommended limits.

The specifications accept a number of materials which are likely to be unacceptably dusty, but many materials which perform well, would be eliminated by lowering the shrinkage product to 240. This was considered unnecessarily harsh for rural roads. However, attempts should be made to locate materials with a shrinkage product of less than 240, as far as possible.

By plotting the shrinkage and grading properties of potential wearing course gravel in Figure 3.45, an indication of the suitability and any potential problems will be obtained. However, personal judgement should be used. In flat dry areas, materials falling into zones A and D may be acceptable if the potential to erode or become slippery is not excessive.

If no laboratory facilities are available, there is the 'Look, see and decide' method, which is a very effective manner to select the best performing gravels/or similar materials in your area.

It is recommended that the roads in your district/area of activity are inspected in wet and dry weather, and the following features of the material observed and noted:

- The binding qualities of the material.
- The loose sandy corrugations.
- The firm/compacted corrugations.
- The tendency to erode – on shoulders and longitudinally in the carriageway.
- Potholes and rutting in the wet season – signs of skidding.

- Is the surface smooth, shiny and cracked in the dry season?
- The size of windrows on the shoulders, due to inappropriate maintenance grading.

Typical good sources of gravel

Source	Comments
Blue shales	When broken down with grid rollers and compacted, it forms an excellent gravel riding surface and improves with traffic use.
Laterites	Low PI laterites/ferricretes tend to corrugate but the high PI laterites/ferricretes, although a little slippery during the first wet season, settle down to form good gravel surfaces. The normal good laterite/ferricrete has a PI of approximately 17 – 23. Mixtures of quartzitic material and laterites/ferricretes work very well.
Weathered granites	Weathered granites, if non-plastic, tend to corrugate in the dry season and erode in the wet season. If the weathered granite has a PI of 12 – 14, a very smooth, good gravel surface can be achieved.
Weathered dolerites	Weathered dolerites vary considerably but there are fine sugar dolerites and cubical-shaped dolerites, which break down under grid rolling to form good gravel-wearing courses. Coarse rounded dolerite is difficult to maintain.
Quartzitic gravels	Quartzitic gravels tend to corrugate when non-plastic, but can be improved by adding red loamy soil with a PI to the material in different proportions.
Red loamy soils	There are many red loamy soils with PIs < 8 which, if compacted, make good riding surfaces. They often occur in dolomitic areas.
Chert gravels	Chert gravels often contain lateritic material and make sound gravel roads, if the PIs are not too low.
Calcrete	Calcrete occurs in some of the drier areas and can be used efficiently for gravel roads. (Problems with dust.)

5.2 Winning gravel in approved gravel pit (quarry)

5.2.1 Management of quarry sites

Once the preliminary investigations have been expanded; the detailed investigations completed; and the quarry plans and test results, including the estimated material quantities are available at each site, the planning/management of the site is possible.

It is generally uneconomical to win gravel at the quarry face using hand labour. It is therefore recommended that the material is won and stockpiled by machine, as a separate contract, and for loading using only hand labour.

5.2.2 Overburden

It is necessary to strip the soil and vegetation (overburden) before working the quarry for the following reasons:

- The topsoil is not always suitable for the layer for which it is required. This can be assessed from the test results.
- The grass and roots in the overburden are not suitable for layer work.
- Reinstatement of the quarry is most important – top soil, seeds and grass roots must be stockpiled for this exercise.

> **Cost effective practice**
>
> As a dozer is required for this work – delivered to site by low-loader, it may be policy/ effective to use it for stockpiling gravel, depending on the depth of the suitable material.

5.2.3 Stockpiling of gravel

In many areas of the country, suitable material occurs in shallow lenses of alluvial or secreted deposits, less than ± 1½ metres deep.

Why rip and stockpile gravel?

- It speeds up the process for loading by hand later.
- Better control of the quality of the material won in the quarry – the dozer operator can avoid any suspect/clay deposits. (The foreman/superintendent must supervise this work – using the quarry plan and test results to guide the operator.)
- The uniformity of material will be more easily obtained, if the quarry survey has been carried out efficiently.
- If the gravel consists of coarse and over-size material e.g. weathered dolerite or quartzitic boulder material, it is advisable to allow for crushing the material using mobile primary crushing plant.
- The winning and stockpiling of material can be carried out under a separate contract. The dozer can complete its work at a specific quarry and move on to the next quarry for loading of the material by hand later, for use as required in the road layers. (This saves the cost of keeping the dozer on-site for extended periods.)

5.2.4 Method of stockpiling gravel

1. Move the vegetation and specified amount of topsoil, neatly into a stockpile/windrow, on either edge of the demarcated area indicated on the quarry plan. Rip the cleared area to the depths approved on the quarry plan.

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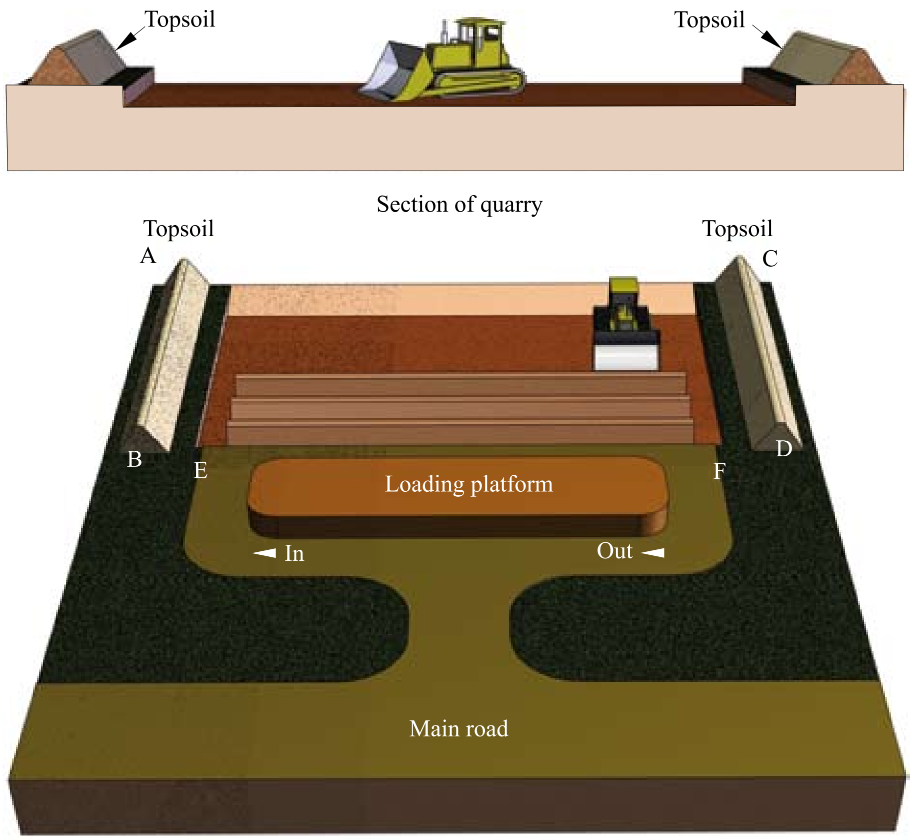

Figure 3.46: Management of quarry site

N.B. Road signs and flagmen must be used for controlling traffic, at junction of access to quarry, from main road.

2. At right angles to the line of topsoil stockpiles AB & CD, stockpile the gravel to a height of 1½ - 2 m in approximately parallel lines.

3. Shape, water and compact the access road, from the main road to the quarry. This road must be wide enough for passing of trucks (6 – 8 m), or preferably two access roads 4 m wide – one IN and one OUT.

   Prepare the loading platform in front of the gravel stockpile, as described below for loading by hand, before commencing with the loading.

   When loading the trucks or trailers by hand, the management of the quarry stockpiling is essential for efficient loading: slots with a depth approximately equal to the diameter of the wheels of the truck or trailer must be provided in the stockpile area (Figure 3.47):

   – Gravel must be stockpiled on either side of the slot to allow for loading the truck or trailer from both sides.
   – More than one slot can be provided to expedite the work.
   – Gravel should be stockpiled in heaps of ± 20 cubic metres.

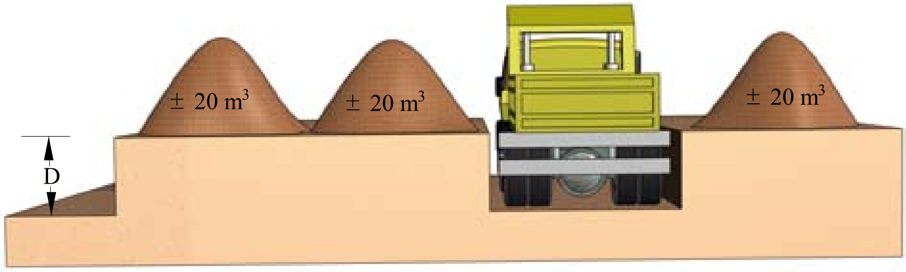

Figure 3.47: Stockpiling of gravel for loading by hand

4. The quarries must be reinstated at the end of the regravelling operation by returning the vegetation and topsoil from AB and CD to neatly cover the area.
   - This can be undertaken by hand labour.
   - If possible, the reinstated area should be watered to encourage the growth of vegetation.
   - N.B. The quarry must be properly drained for health reasons – especially in malaria areas.

The above approach is particularly applicable to flattish areas or low rolling hills. In hilly or mountainous country, the process will have to be modified but the principles remain the same e.g. winning and stockpiling by suitable machines and loading platform, properly prepared prior to loading by hand.

The plant used may be changed e.g. a face shovel instead of a front-end loader for working a hard face.

The use of explosives is very effective in certain types of material.

5.3 Preparation of sub grade on new alignment

Special treatment is required on new alignments

As a guideline, a minimum of ± 450 mm of controlled compaction should be incorporated below the final road level, on all new alignments i.e. assuming allowance for one 150 mm gravel wearing course, two in-situ layers of 150 mm will be required in flat and rolling country.

> **Note**
>
> Heavy earthworks and excavation in hard material are not appropriate, nor cost effective, for excavation by hand.

5.4 Road alignment

In view of the nature of the roads (low volume rural roads which mostly follow existing alignments) and method of construction (labour based), roads should be set out to a rolling grade to minimise earthworks and therefore costs, and to promote the use of labour.

Vertical curves should, however, be checked for safety sight distances.

Horizontal curves should also be checked e.g. do not introduce isolated sharp bends in a 120 km terrain.

MODULE 5: Construction of a stabilised base course

1. General

This module covers the preparatory work, materials plant and equipment, and construction process for the construction of a stabilised base course.
It comprises:

- Module 5.1: Emulsion-treated base course (ETB)
- Module 5.2: Composite emulsion-treated base

2. Preparatory work

2.1 Setting out

2.1.1 On newly constructed sub-base

The newly constructed sub-base will have been set out to the correct horizontal and vertical alignment as well as camber/cross-fall.

All that needs to be done, after placing the side shutters used for constructing the base, is to check the surface of the sub-base for any irregularities due to damage. Place a straight edge across the shutters as shown in Figure 3.48, as the accuracy of these levels will affect the riding qualities of the final surface to a large extent.

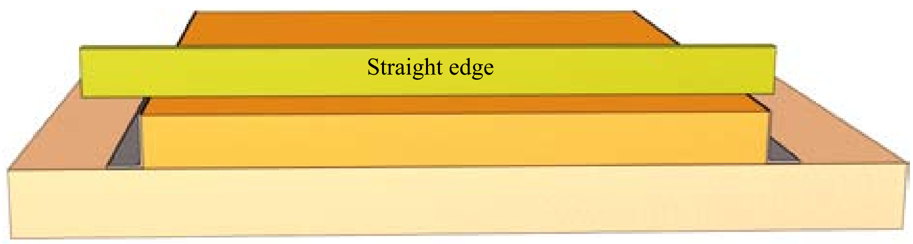

Figure 3.48: Method of checking sub-base levels

The consistency of the depth, between the bottom of the straight edge and top of the sub-base, is then measured for consistency and irregularities corrected.

2.1.2 Where existing road layer forms sub-base

Refer to Module 2

2.2 Preparation of sub-base

2.2.1 Newly constructed sub-base

After placing the side shutters used for constructing the base, surface of the sub-base should be checked for any irregularities due to damage, with a straight edge across the shutters as shown in Figure 3.48.

The accuracy of these levels will affect the riding qualities of the final surface to a large extent.

The consistency of the depth, between the bottom of the straight edge and top of the sub-base, is then measured for consistency and irregularities corrected.

2.2.2 Where existing road layer forms sub-base

Once the horizontal and vertical alignment and cross-fall of the road have been set out as described in Module 2, and before the base course gravel (ETB) can be placed, the existing road layer in which it is to be placed must be prepared.

The pegs at the centre line C and edge of riding surface A to the left and right of the centre line (Module 2.4 – Figures 3.3 and 3.4), will determine the levels of the bottom of the base.

Construction Procedure: Preparation of existing road layer

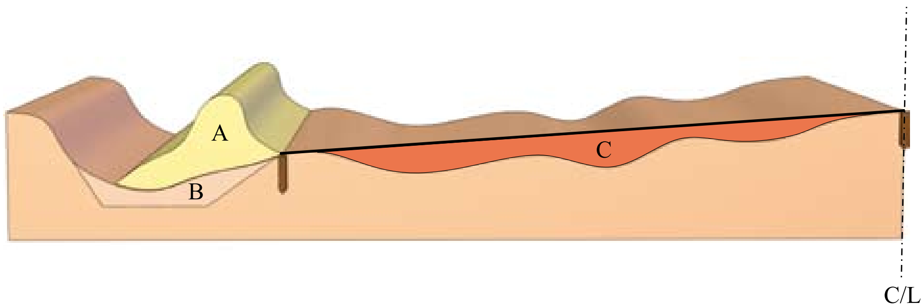

Figure 3.49: Reshaping sub grade (roadbed)

The type/quality of the materials will govern what the most practical treatment would be for the road.

In most cases the work would be carried out under traffic and construction would be done in half widths.

In Figure 3.49 the material at A has been bladed or ridden over a period of time from the road surface into large windrows, and the road levels are now below surrounding ground levels.

The material at B probably is a soil loam, finely graded with a CBR of most likely between 15 and 25. The PI is also relatively low – possibly of the order of 5 to 8 but certainly below 10. (This can be confirmed by a few laboratory tests.)

Before any labour based construction can proceed for the base, the rutting/unevenness at C must be rectified.

The in-situ material at B, below the non-plastic coarse gravel must not be considered for filling any ruts or rectifying any unevenness.

The non-plastic coarse gravel at A must be used.

The amount of material required for filling the ruts must be determined by using a string/line and tape. By taking the average of the dips measured × the width × 12 m (which is the practical length the pedestrian roller can efficiently roll) × 1,5 (to allow for bulking/compaction of the material).

Average dips	=	50 mm
Width of formation	=	4 m
Section to be rolled	=	12 m
Bulking factor	=	1,5
Quantity required	=	$\frac{4 \times 12 \times 50 \times 1,5}{1\ 000}$
	=	3,6 m^3

Prepare heaps of say 3½ m^3 every 12 m along the side of road. (Figure 3.50)

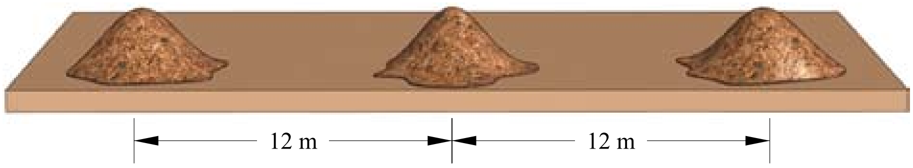

Figure 3.50: Spacing of heaps

No compaction of dry material should/must be attempted.

Most efficient compaction is achieved when material is mixed with its optimum moisture content (OMC) of water, as determined by laboratory tests.

Uniform mixing of water and material is a major problem and the following method overcomes most of these difficulties.

- Prepare a platform for each heap.
- Preferably measure out the quantity required, e.g. 14½ wheelbarrows = 1 m^3.
- Place material in a neat heap and form a dam at the top of the heap. (Figure 3.51)

Figure 3.51: Addition of water to heaps

- Approximate amount of water required per 1 m^3 = 150 to 170 litres. Pour this water slowly into the dam.
- Cover the dam with plastic sheeting.
- Allow water to soak through material for approximately 24 to 36 hours.
- Draw off only the damp material in wheelbarrows – use a plastic sheet to cover wheelbarrow (a small amount of water can be added by watering cans as the wheelbarrows are being loaded, if some of the material appears too dry – do not attempt to compact dry material).

- Only dump material from wheelbarrow when labour is ready to spread and screed the material, using steel squeegees and screed rail.
- It is recommended the surface be watered before material is dumped.
- After spreading and screeding the damp material, the surface must be covered with plastic sheeting, which is rolled out systematically as the work progresses, to reduce evaporation of water.

Note

The treatment of the stockpiles of fill material, i.e. making and filling the dam must only be for one day – maximum two days ahead of sub grade preparation.

Any excavation of the sub grade, to achieve required levels, can be added to the stockpiles in measured amounts for the addition of water.

Because the depth of the fill required is not uniformly 50 mm thick, but varies from 0 to > 50 mm, there will be differential settlement when compacting the fill and extra fill may be required or cut away, to meet the desired levels but a smooth longitudinal surface is required between the reference pegs, and must be checked with boning rods and string lines.

Compaction

It is advisable to lay the fill material 50% higher than the required compacted thickness, and trim back any excess material. Once approximately 12 m of the layer is completed and covered with plastic sheeting, rolling can commence with the roller in vibratory mode:

- Roll back the plastic sheeting.

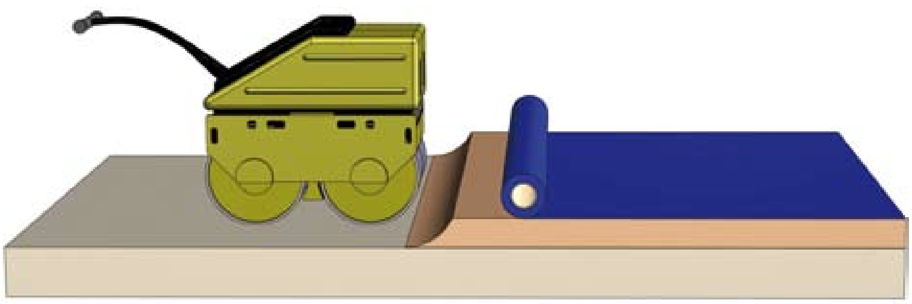

Figure 3.52: Compaction of sub-base

- Follow the rolling back of plastic sheeting with pedestrian roller.
- After one complete half-wheel pass of the roller, check the levels and trim back and remove excess materials.
- Complete rolling and final trimming.
- Stop rolling immediately should the drums start to bounce.
- Generally 2 to 3 half-wheel passes are sufficient on these layers (< 50 mm).

MODULE 5.1: Emulsion-treated base course (ETB)

1 Specification

The specification will call for the construction of a 100 mm emulsion-treated base, constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2 Materials

Materials required for the construction of the ETB are:

- Gravel – approved from in situ source or gravel pit (quarry)
- 60% Anionic stable-grade emulsion (vinzyl resin emulsifier) decanted from 210 litre drums. (Emulsion, made with vinzyl resin as emulsifier, has less tendency to settle than other emulsifiers.)
- Cement – pockets
- Lime – pockets (if required to adjust PI)

3 Construction plant, equipment and tools

The following specialised plant and equipment is recommended to promote the construction of the ETB by labour-intensive methods:

- Steel-framed stand with steel or timber ramps for emulsion drums (Photo 3.1)
- Ball valve (75 mm diameter)
- Measuring containers – 25, 20 and 5 litre (for dry and wet materials)
- Drum handles for 20 and 25 litre drums (Workshop drawing LIC 009)
- Dipstick (Workshop drawing LIC 001)
- Suitably sized concrete mixer (14/10 or 400/300)
- Builders' wheelbarrows (capacity ± 65 – 67 litres)
- Suitably sized (approximately 1 ton) tandem vibratory pedestrian roller, having two equally sized drums – both drums driven, each drum to have a separate eccentric shaft (e.g. Bomag 75 or equivalent)
- 150 x 100 mm x 8 mm thick steel angle formwork (steel shutter) (3 m, 2 m and 1 m lengths) (Figure 3.53 and Workshop drawing LIC 002)
- 50 x 8 mm steel spacer plates (bulking rails) (Figure 3.55 and Workshop drawing LIC 0031) (3 m, 2 m and 1 m lengths)
- Steel pegs (Y10) for securing formwork
- Steel squeegees (Workshop drawing LIC 005)
- Screeding boards (Workshop drawing LIC 004)
- Plastic sheeting
- 1 000 litre water tank on LDV or mounted on trailer – with pump
- 210 litre drums for storing water
- 25 litre container with clip-on lid to store balance of cement from cement pocket

4 Construction

General

Emulsion

The emulsion to be used must be anionic stable-grade 60% emulsion (vinzyl resin emulsifier), decanted from 210 litre drums.

Before using the drums of emulsion, they should be rolled backwards and forwards to ensure that the emulsion is properly mixed. When stockpiled for any length of time, the bitumen in the emulsion tends to settle. (Full drums should be stored flat and empty drums upright.)

For neat and accurate workmanship, it is essential that the drums are placed on a steel frame and that a ball valve is fitted to the drum (Photo 3.1). The ball valve should be soaked and cleaned in paraffin at the end of each shift. Measuring containers with calibrated dipsticks should be available for accurately measuring the required amount of emulsion for each mix.

Photo 3.1: Emulsion drum stand
(Note ramps for easy handling and ball valve for decanting emulsion)

Steel side forms (steel shutters)

Steel formwork (shutters) for the placing of the ETB should be 150 x 100 mm x 10 mm thick angle, and be available in 3 m, 2 m and 1 metre lengths. The shorter lengths should be used for small curves.

It is recommended that the steel formwork (shutters) should conform to the dimensions and thickness shown in Figure 3.53.

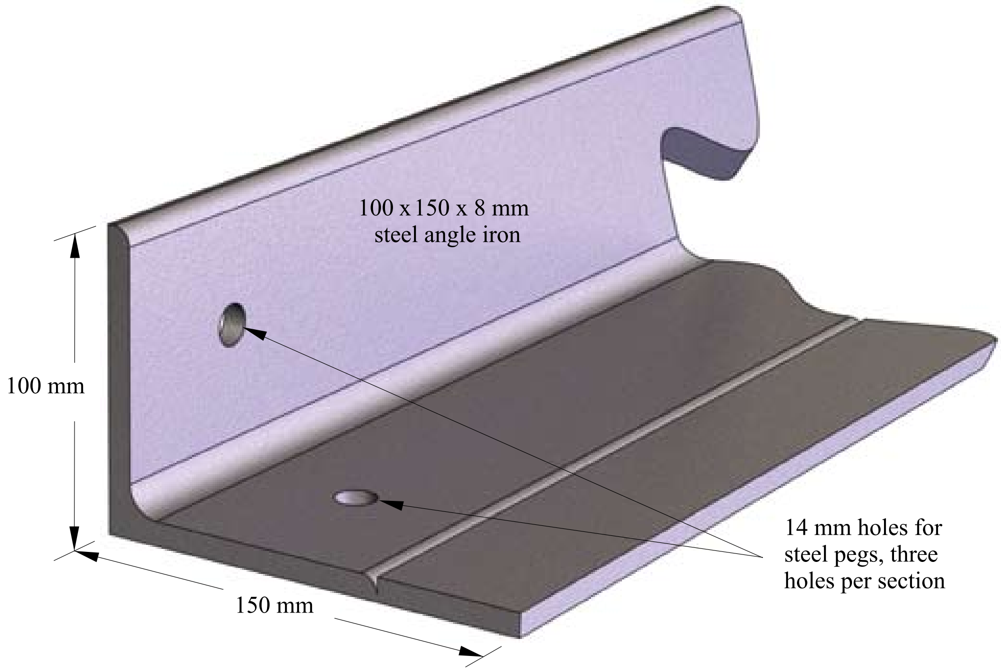

Figure 3.53: Side forms (shutters) for ETB

Sufficient quantities of formwork (shutters) should be available for a day's work.

(For one construction unit i.e. one 400/300 concrete mixer, and the associated team, approximately 30 m of formwork (shutters) is required.)

Construction process

Tolerances

In view of the relatively thin surfacing being placed, the ETB base should be constructed to levels to accommodate the surface within 6 mm of designed level.

Placing of steel side forms (shutters)

In placing and fixing the formwork (shutters), care must be taken to ensure that no bumps are built into the surface, and that a smooth vertical and horizontal alignment and the correct cross-fall (camber) is obtained.

Care must be taken to check the vertical and horizontal alignment of the formwork, as well as the camber (cross-fall), and to ensure that the side forms are firmly and correctly placed before placing the material.

Once the shutters are in place, the camber can be checked by placing a camber spacer of the correct height for the specific camber, on top of the vertical leg of the lower shutter (edge of road). A spirit level can then be placed on top of a screed board spanning from the centre-line shutter to the lower shutter, to ensure that there is no fall between the top of the camber spacer and the centre-line shutter. (Figure 3.54)

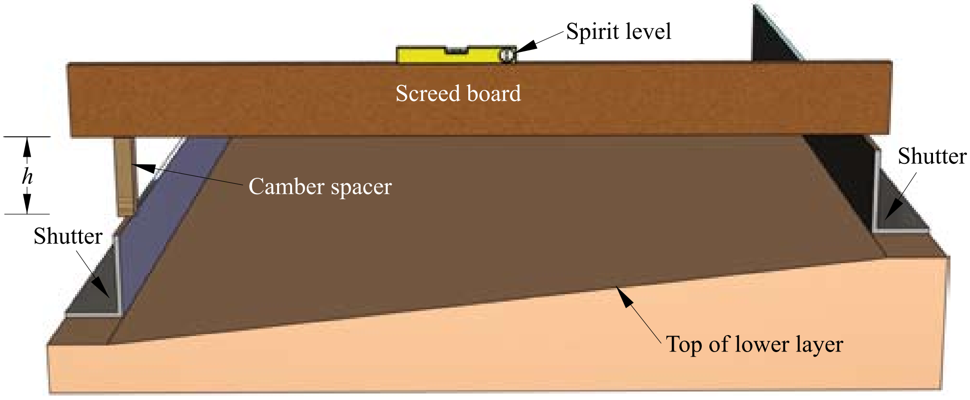

Figure 3.54: Use of camber spacer

The height (*h*) of the camber spacer for various cambers is given in Table 3.7.

Half width of road – ½ *w* in (m)	Height of camber spacer – *h* in (mm)		
	2% cross-fall	3% cross-fall	3,5% cross-fall
2,0	40	60	70,0
2,5	50	75	87,5
3,0	60	90	105,0
3,5	70	105	122,5
4,0	80	120	140,0
4,5	90	135	157,5

Table 3.7: Height of camber spacer for 2%, 3% and 3,5% cross-falls

Once the side forms have been placed, the levels must again be checked (by string lining across the tops of the side forms), and the surface trimmed to ensure that the correct thickness of ETB (100 mm) is laid. Slacks or depressions in the sub-base will not only result in an increase in the amount of ETB required, but also differential settlement.

Work site planning

It is essential that the planning of the delivery and stockpiling of gravel from the quarry sources is carefully planned and controlled.

Example

Assume:

Material is delivered in 8 ton trucks.
Road is being constructed in half width (3,5 metres).
Layer thickness 100 mm compacted (150 mm loose/uncompacted).

Then:

1. Spacing of stockpiles is:

Volume = length × width × thickness (uncompacted/loose)

$$8\ m^3 = \text{length} \times 3{,}5\ m \times \frac{150}{1\ 000}\ m$$

$$\text{Length (spacing of stockpiles)} = \frac{8\ m^3}{3{,}5\ m \times 0{,}15\ m} = 15{,}24\ m\ \text{(say 15 metres)}$$

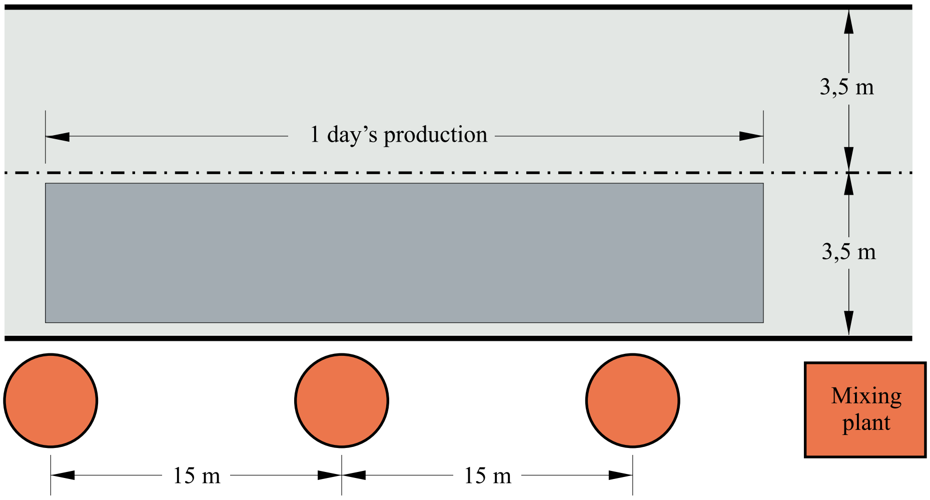

Figure 3.55: Placing of mixer (work site)

2. Placing of mixing plant

The mixing plant is placed one day's production ahead of the gravel stockpiles (Figure 3.55), so that it only needs to be moved every second day.

3. Quantities of emulsion and cement

Emulsion:
Assuming 42 litres of emulsion is required for each m³ of compacted material, then the amount required for an 8 m³ stockpile is:

$$\frac{8}{1,5} \times 42 = 224 \text{ litres}$$

For 3 loads the amount is thus 3 × 224 = 672 litres = 3,2 drums (1 drum = 210 litres).

Therefore, approximately 3 drums of emulsion per day are required to be placed at the mixing plant.

Cement:
Assuming 1% by mass of cement is required for each kg of gravel, and the density of the gravel is 2 000 kg/m³ compacted.

The compacted mass of one stockpile is therefore:

$$\frac{8}{1,5} \times 2\,000 = 10\,666 \text{ kg}$$

For 3 stockpiles the mass is 3 × 10 666 = 31 998

1% cement = 319,98 kg, say 320 kg

One pocket of cement is 50 kg, therefore, approximately 6 pockets of cement are required at the mixer per day.

If the rate of production is too slow, the number of units producing ETB must be increased accordingly.

> **Note**
>
> The amount of emulsion and cement (lime) to be used must be determined by an approved materials laboratory.

Mixing of ETB

Mixing of the ETB should be done in appropriately sized concrete mixers.

Material to be used in the ETB should be stockpiled as closely as possible to the work area, as described above.

The mixing of materials should take place in the following order (Photos 3.2 – 3.7):

- The dry materials, aggregate, cement and lime (if required) should be added first and mixed well.
- This is followed by adding one third of the water and mixing well.
- Lastly the emulsion, diluted with the remaining two thirds of the water, is added to the contents of the mixer and mixed to a uniform consistency.

> **Note**
>
> The photos depict the gravel (aggregate) being added to the mixer in a container. For larger mixers (400/300), struck-off wheelbarrow loads (± 67 litres) of aggregate are added to the mixer – 4 wheelbarrows per mix.

The amount of liquid to be added must be approximately 1 – 1½% over the optimum moisture content required for the Mod. AASHTO density.

> **Typical mix proportions**
>
> Aggregate – 1 wheelbarrow (loose)
>
> Cement – 1 kg (⅔ litres)
>
> Emulsion – 2 litres
>
> Water (approximate) – 5½ litres

Process of mixing of ETB in concrete mixer

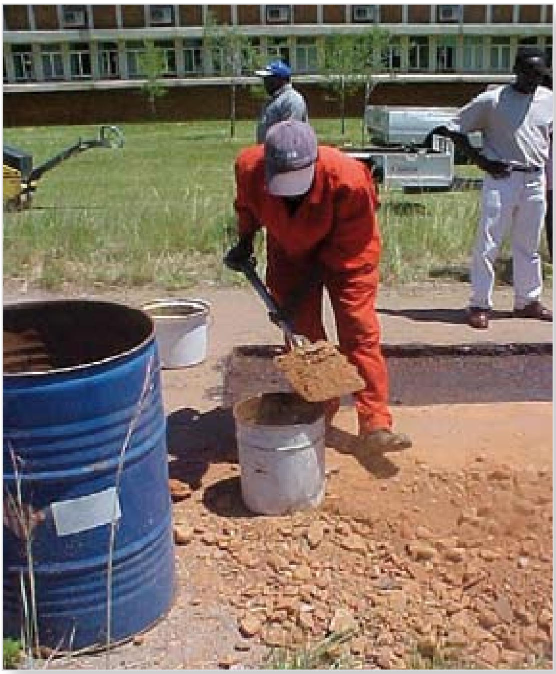

Photo 3.2:
Measure aggregate

Measure aggregate in 25 litre measuring cans.

Photo 3.3:
Add aggregate and cement

Add aggregate and cement to mixer while the drum is turning and mix well.

Photo 3.4:
Add water

Add ⅔ of the water to the mix.

Photo 3.5:
Add emulsion

Add ⅓ of water to the emulsion and add the diluted emulsion to the contents of the mixer.

Photo 3.6: Mix ingredients

Mix ingredients to a uniform consistency.

Photo 3.7: Discharge into wheelbarrows

Placing of the ETB

Before placing the ETB, the sub-base should be lightly watered.

Placing of the ETB should be done as uniformly as possible, by placing the barrow loads at a uniform spacing, between the side forms to achieve the minimum amount of movement for levelling the loose material for a 150 mm loose layer. (Figure 3.56 a)

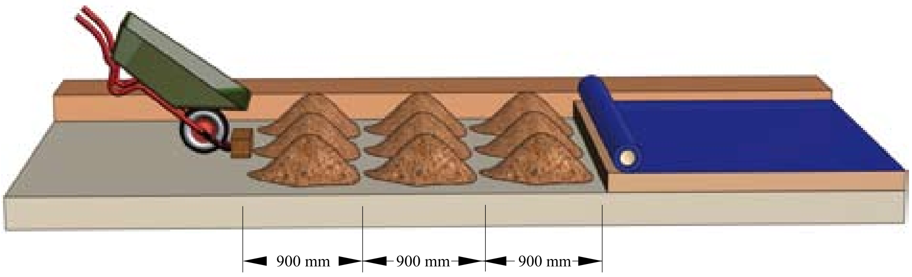

Figure 3.56 a: Placing of ETB

Calculation of spacing for 150 mm loose layer for half width of 3,5 m

A width of 3,5 metres will allow 7 wheelbarrow loads to be tipped at a spacing of 0,5 metres.

Assuming the capacity of a wheelbarrow is 0,067 m^3 the spacing between rows of wheelbarrows to obtain a loose depth of 150 mm (0,15 m) is then:

$$\frac{7 \times 0{,}067\ (m^3)}{3{,}5\ (m) \times 0{,}15\ (m)}$$

= 0,89 m

or 0,9 m = 900 mm (Figure 3.56 b)

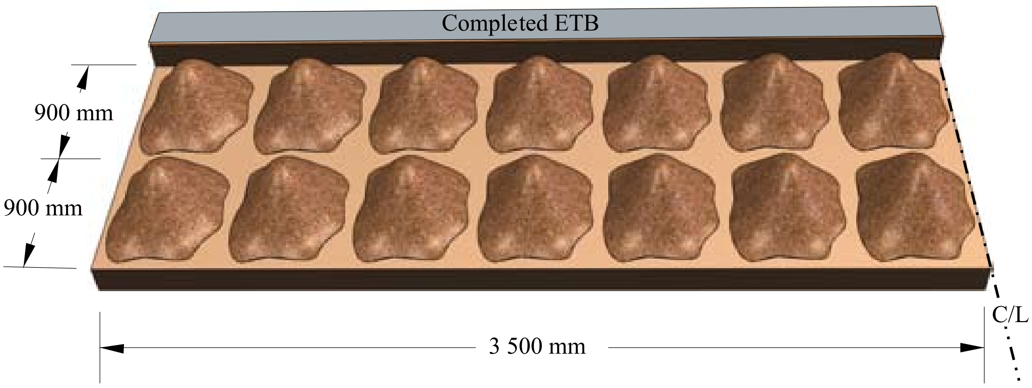

Figure 3.56 b: Spacing of barrow loads

Place the 50 mm × 6 mm thick steel spacer plate, as detailed in Figure 3.57, on top of the 100 mm leg of the side forms and, using the steel squeegees and steel screed bar, spread the ETB to obtain a 150 mm loose layer. (Less segregation of the material is attained by using steel squeegees in place of rakes.)

Spacer plate (bulking rail)

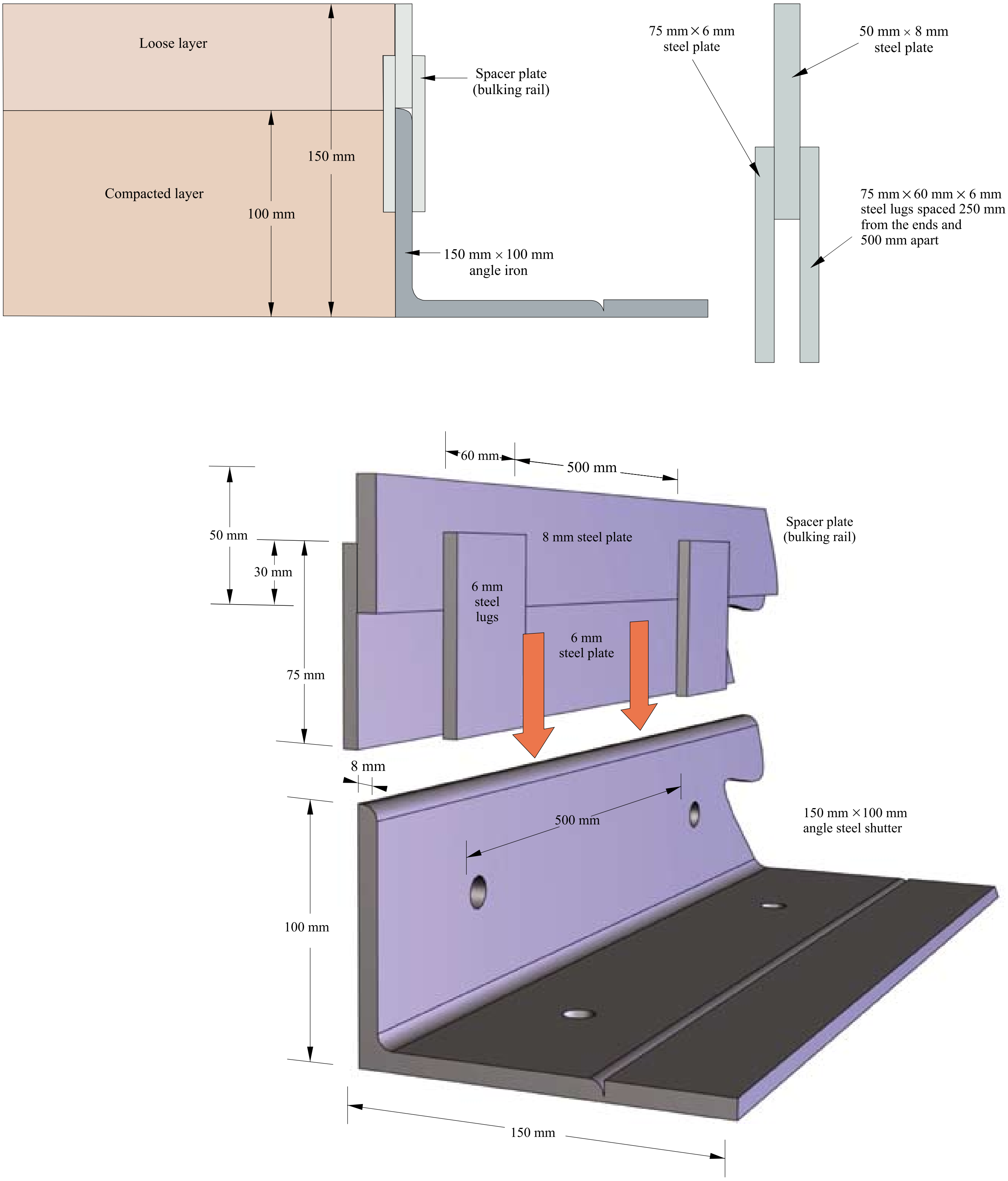

Figure 3.57: Sketch of spacer plate (bulking rail) to place 150 mm loose ETB.
(Refer to Workshop drawings LIC 002 and 0031 for details)

Construction adjacent to compacted work, kerb or channel

Where the layer is being constructed adjacent to previously constructed work (e.g. half width construction), or a kerb or channel; a 50 mm × 50 mm spacer must be placed on top of the existing work to obtain the correct loose thickness for the new work. (Figures 3.57 a, b and c)

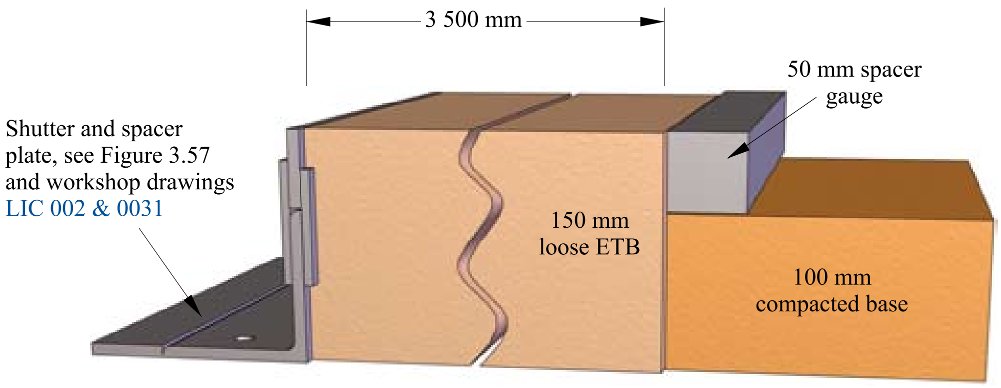

Figure 3.58 a: Construction adjacent to compacted layer

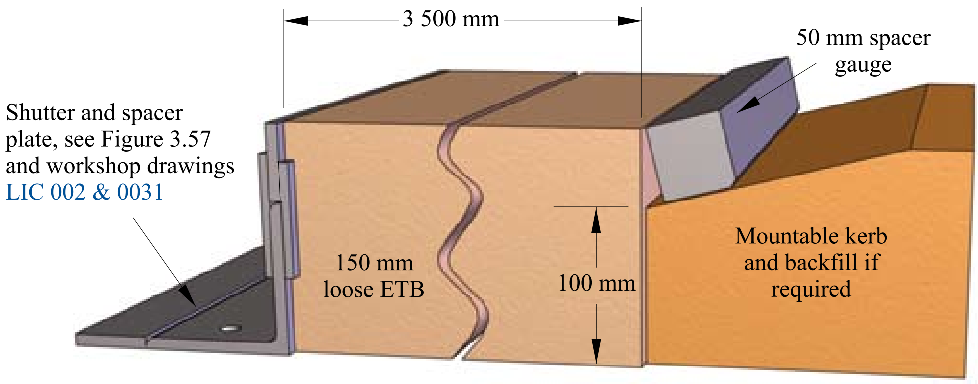

Figure 3.58 b: Construction adjacent to mountable kerb

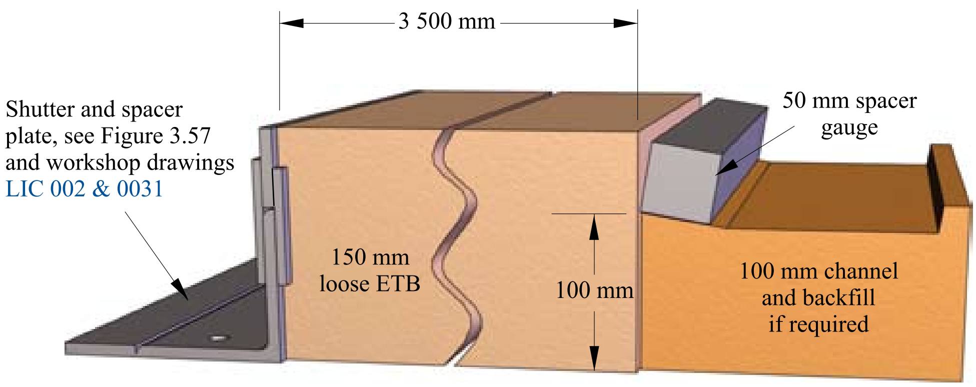

Figure 3.58 c: Construction adjacent to channel

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When using a coarse material, the judicious removal of the large fractions from the surface, and their replacement with finer material will result in a smoother finish. The large fractions can be placed on the floor of advancing work.

As the work progresses, a black plastic sheet should be rolled out over the work to inhibit the emulsion breaking prematurely. Once some 8 – 10 metres of ETB has been placed, the cover can be rolled up, the spacer plates removed and rolling commenced.

Compaction of ETB

Rolling, with the roller in vibratory mode, is continued until the 150 mm loose layer has been compacted to the top edge of the 100 mm leg of the side form. Incorrect rolling can result in the building of undulations in the surface.

In order to eliminate undulations, rolling should commence at 45° to the edge line of the shutters. Thereafter rolling should be undertaken in such a manner that the roller is always supported over approximately a half of its width, as indicated in Figures 3.59 a and 3.59 b, initially either on an existing surface or the steel side forms.

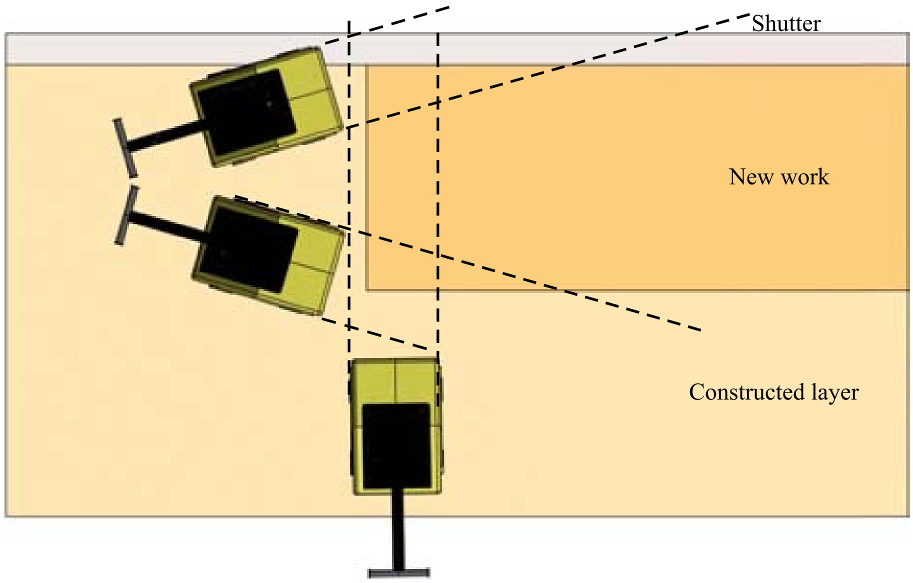


Figure 3.59 a: Initial rolling at 45° and across joint

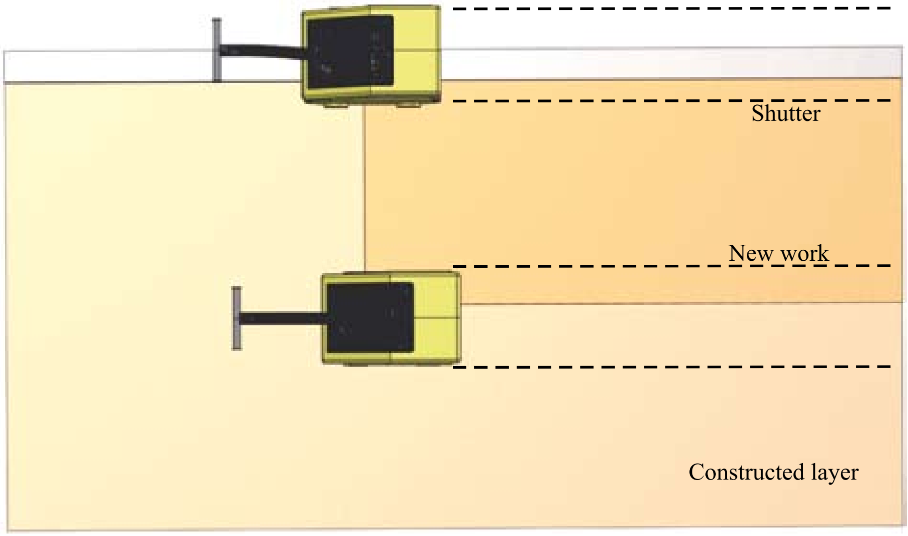


Figure 3.59 b: Rolling parallel with shutters from outside inwards

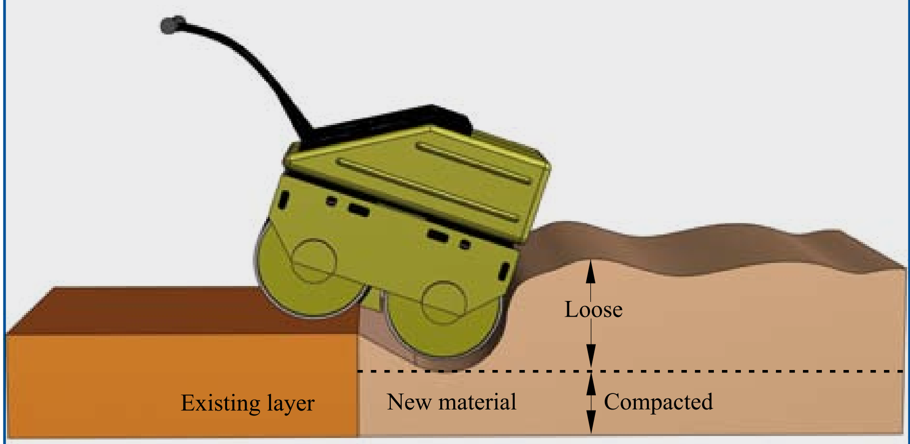
Always roll, in vibratory mode, parallel with the shutter lines. Move from both sides towards the middle of the layer, in a little less than ½ the width of the roller after each pass of the roller.

Continue to roll the section until the layer is level with the shutters.

1. **Reason for operating roller in vibratory mode**

   The reason for operating the roller in vibratory mode from the outset is to overcome the problem of sealing air in the voids of uncompacted material. This makes it difficult to attain the required density, which is the case if the uncompacted material is initially rolled in non-vibratory mode.

2. **Reason for commencing rolling at 45°**



   Where construction starts when approaching the new work, parallel with the centre line of the road, approach the uncompacted material from the existing compacted material, initially at 45° with the roller. This overcomes the problem of creating/constructing a bump in the road, between the existing and new work.

Sufficient time should be allowed for the emulsion to fully break, before construction of the surfacing is commenced.

Before commencing with the surfacing, all loose material must be removed from the surface, and a diluted emulsion (1:8) applied neatly and uniformly to the surface. A coarse broom can be used to evenly distribute the diluted emulsion.

5 Notes to consultants/designers

Introduction

Emulsion-treated bases are particularly suitable for labour-intensive construction projects, not only because the technique lends itself to the construction of a quality base using labour and light plant, but it can also be opened to traffic for an extended period, without untoward damage to the surface.

This is an advantage as construction by labour-intensive methods normally proceeds more slowly than is the case with conventional methods. It is therefore more difficult to keep traffic off the partially finished base.

This does not apply to bases constructed with unstabilised material or cement or lime stabilised material.

Materials survey

General

Before any work is commenced on the design of the road layers to support the ETB base, it is advisable to determine:

- The quality of gravel available in the area.
- The quality of gravel on the road:
  - Establish the average depth of the gravel.
  - Establish the average width of the gravel.
  - What the CBR, Grading Modulus (GM) and PI of the material is.
- The quality of the sub-base/sub grade materials.
- The drainage conditions of the system.

Centre-line survey

The quickest and most economical means of establishing the bearing capacity of the in-situ material is by means of the DCP test.

DCP tests should be done in the middle of the wet season, or just at the end of the wet season. This will factor in safety into the design.

It is recommended that DCP tests are done every 50 metres along the route and, in the case of short lengths of road/street, at least 3 tests on every 80 – 100 metres.

It is recommended that physical tests, i.e. PI and grading be done at selected points of similar material. Road material can be classified/similarities established visually or the DCP tests could be used for testing the test points.

From the DCP tests the CBRs can be established for the in-situ materials. However, it is advisable to do CBR tests on selected samples after completion of the indicator tests.

From the cover curves in Figure 3.60, design can be checked to see if a 100 mm ETB will be adequate (Note: The CBR of the ETB will normally exceed 100 in the field.)

The in-situ field CBR of the sub-base must not be less than 30.

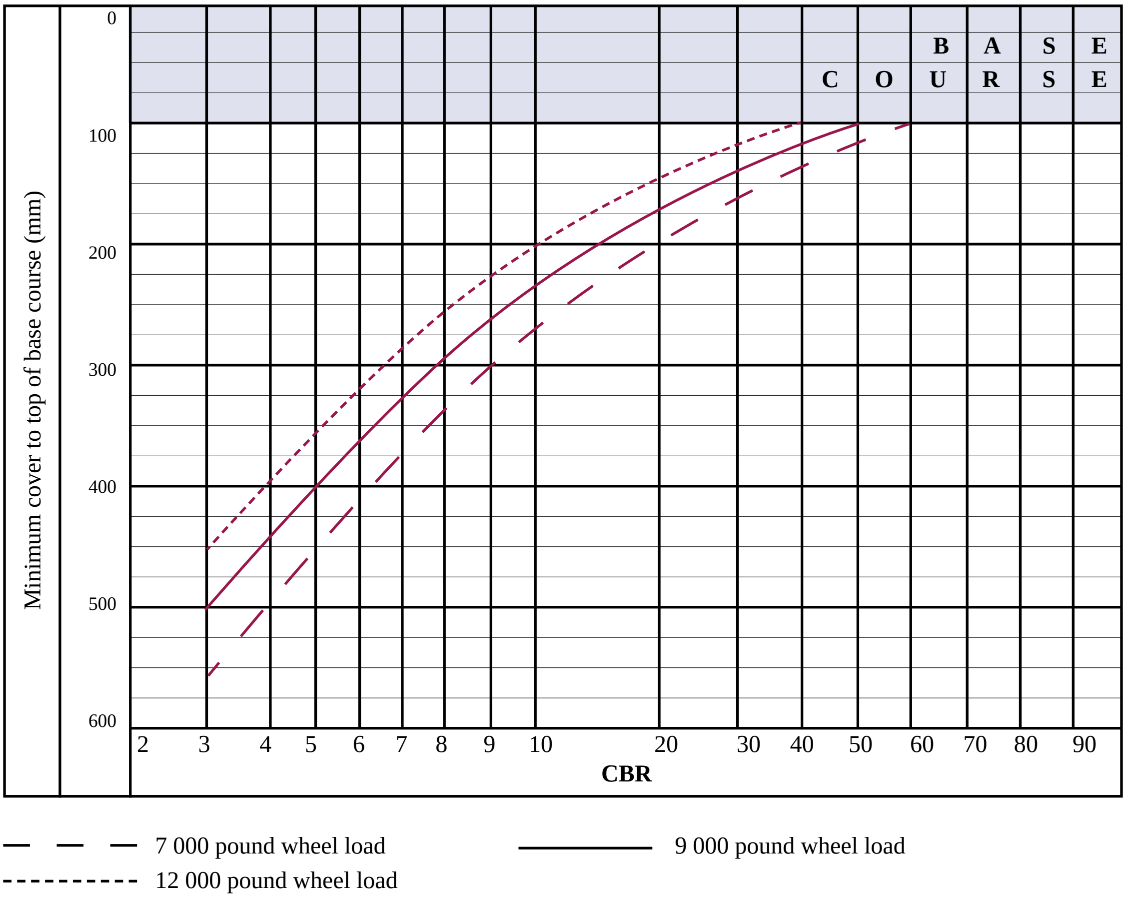


Figure 3.60: CBR curves

Quarry (borrow pit survey)

It is advisable/recommended that before funds are expended on opening/preparing a quarry site for winning gravel, a proper investigation is undertaken, comprising:

- The establishment of possible sites from geological knowledge of the area, and/or study of the local vegetation, cutting faces and discussions with locals.
- Trial pits to establish the extent of the deposit/existence of possible suitable material.
- The preparation of a plan of the area showing the location and systematic establishment of further trial pits and showing these on the plan with test results.
- Testing. The minimum tests required for gravel roads are the indicator tests i.e. grading and Atterberg limits. For surfaced roads, all the required tests must be shown on the materials survey plans.

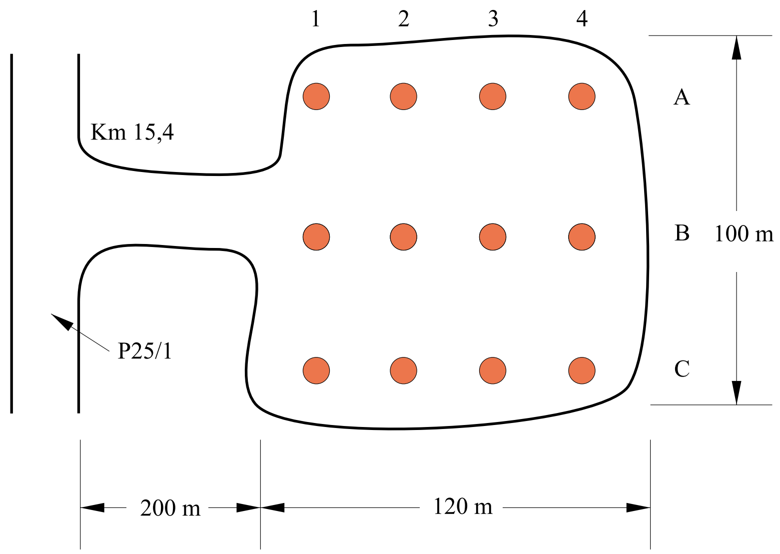


Figure 3.61: Quarry plan

Normally where large trees occur, the topsoil is deep and the material is finely graded soil. Stunted vegetation often indicates relatively shallow deposits and coarsely graded material.

The grass growing over gravel deposits is less intense/concentrated/lush. This is not always true as the overburden may be thick enough to encourage grass growth.

It is important to establish the depth of suitable material. Often ouklip/laterite/ferricrete deposits overly clay deposits which are unsuitable.

Each area has its own vegetation characteristics e.g. Protea bushes usually occur on granite deposits and Bobbejaanstert over quartzitic gravels.

Note

- As the work is about to be contracted out, it is essential that this information of the quarry site is readily available, including estimated material quantity.
- Before any site is tested, the owner must be consulted and permission to enter obtained – power of compensation/expropriation is normally covered in the relevant Road Ordinance.

Materials suitable for ETB

As a guideline, the following materials can be considered for use in emulsion-treated bases:

- Weathered granites (may require lime).
- Weathered dolerites (may require lime).
- Quartzitic gravels.
- Laterites/ferricrete/ouklip preferably containing quartz.
- Chert gravels.
- Calcrete (some).

- Crusher run.
- Sandstone gravel.

Sometimes only fine grained sands are available. By adding 15% to 20% of 6,7 or 9,5 crushed aggregate to this fine material, substantial improvement of bearing qualities can be obtained.

> **Note**
>
> Before any of these materials are used, it is recommended that a reputable materials laboratory carries out emulsion (ETB) tests, based on the latest SABITA manual for testing ETB.

Winning gravel in approved gravel pit (quarry)

Management of quarry sites

Once the preliminary investigations have been expanded, the detailed investigations completed and the quarry plans and test results, including the estimated material quantities are available at each site, the planning/management of the site is possible.

It is generally uneconomical to win gravel at the quarry face using hand labour. It is therefore recommended that the material is won and stockpiled by machine, as a separate contract, for loading using only hand labour.

Overburden

It is necessary to strip the soil and vegetation (overburden) before working the quarry for the following reasons:

- The topsoil is not always suitable for the layer for which it is required. This can be assessed from the test results.
- The grass and roots in the overburden are not suitable for layer work.
- Reinstatement of the quarry is most important – top soil, seeds and grass roots must be stockpiled for this exercise.

> **Cost effective practice**
>
> As a dozer is required for this work – delivered to site by low-loader, it may be policy/ effective to use it for stockpiling gravel, depending on the depth of the suitable material.

Stockpiling of gravel

In many areas of the country, suitable material occurs in shallow lenses of alluvial or secreted deposits less than ± 1½ metres deep.

Why rip and stockpile gravel?

- It speeds up the process for loading by hand later.
- Better control of the quality of the material won in the quarry – the dozer operator can avoid any suspect/clay deposits. (The foreman/superintendent must supervise this work – using the quarry plan and test results to guide the operator.)
- The uniformity of material will be more easily obtained, if the quarry survey has been carried out efficiently.
- If the gravel consists of coarse and over-size material e.g. weathered dolerite or quartzitic boulder material, it is advisable to allow for crushing the material using mobile primary crushing plant.

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- The winning and stockpiling of material can be carried out under a separate contract. The dozer can complete its work at a specific quarry and move on to the next quarry for loading of the material by hand later, for use as required in the road layers. (This saves the cost of keeping the dozer on-site for extended periods.)

Method of stockpiling gravel

1. Move the vegetation and specified amount of topsoil neatly into a stockpile/windrow, on either edge of the demarcated area indicated on the quarry plan. Rip the cleared area to the depths approved on the quarry plan.

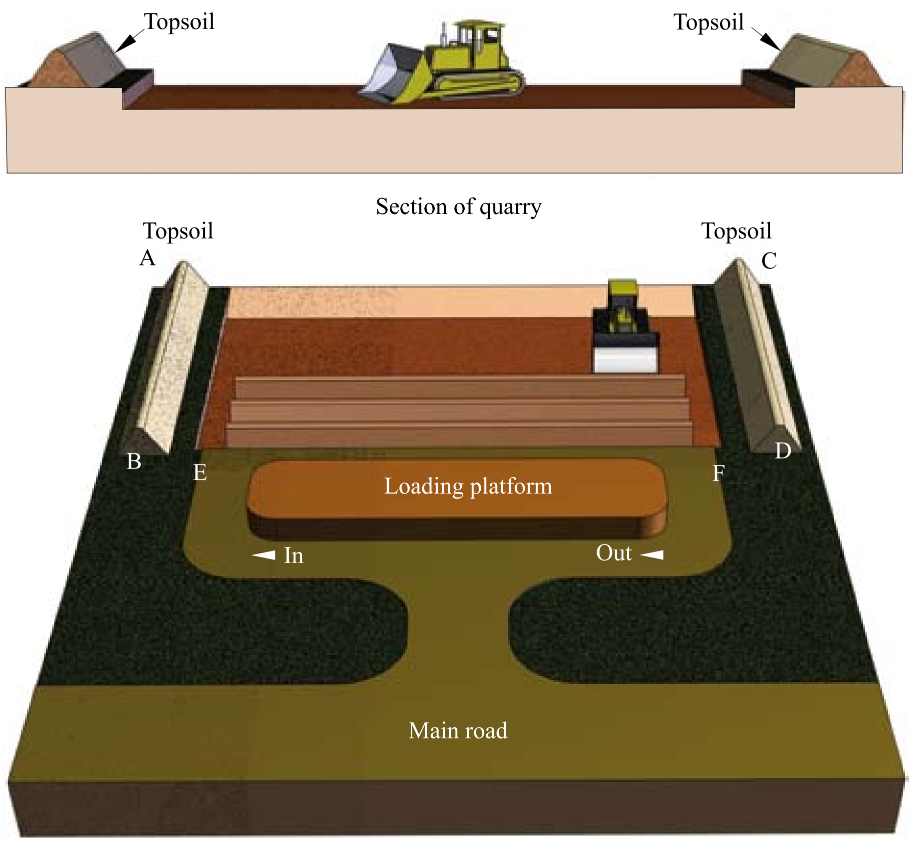

Figure 3.62: Management of quarry site

N.B. Road signs and flagmen must be used for controlling traffic, at junction of access to quarry, from main road.

2. At right angles to the line of topsoil stockpiles AB & CD, stockpile the gravel to a height of 1½ - 2 m in approximately parallel lines.

3. Shape, water and compact the access road, from the main road to the quarry. This road must be wide enough for passing of trucks (6 – 8 m), or preferably two access roads 4 m wide – one IN and one OUT.

   Prepare the loading platform in front of the gravel stockpile, as described below for loading by hand, before commencing with the loading.

   When loading the trucks or trailers by hand, the management of the quarry stockpiling is essential for efficient loading. Slots with a depth approximately equal to the diameter of the wheels of the truck or trailer must be provided in the stockpile area. (Figure 3.63)

- Gravel must be stockpiled on either side of the slot to allow for loading the truck or trailer from both sides.
- More than one slot can be provided to expedite the work.
- Gravel should be stockpiled in heaps of ± 20 cubic metres.

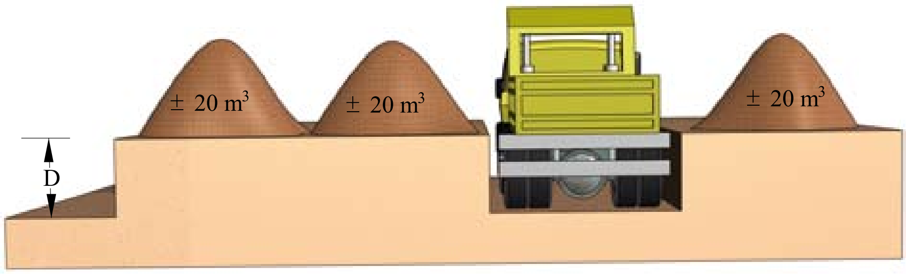

Figure 3.63: Stockpiling of gravel for loading by hand

4. The quarries must be reinstated at the end of the regravelling operation, by returning the vegetation and topsoil from AB and CD to neatly cover the area.
   - This can be undertaken by hand labour.
   - If possible, the reinstated area should be watered to encourage the growth of vegetation.
   - N.B. The quarry must be properly drained for health reasons – especially in malaria areas.

The above approach is particularly applicable to flattish areas or low rolling hills. In hilly or mountainous country, the process will have to be modified but the principles remain the same e.g. winning and stockpiling by suitable machines and loading platform, properly prepared prior to loading by hand.

The plant used may be changed e.g. a face shovel instead of a front-end loader for working a hard face.

The use of explosives is very effective in certain types of material.

Road alignment

In view of the nature of the roads (low volume rural roads which mostly follow existing alignments) and method of construction (labour based), roads should be set out to a rolling grade to minimise earthworks and therefore costs, and to promote the use of labour.

Vertical curves should, however, be checked for safety sight distances.

Horizontal curves should also be checked e.g. do not introduce isolated sharp bends in a 120 km terrain.

MODULE 5.2: Composite emulsion-treated base

1 Specification

The specification will call for the construction of a 100 mm thick composite base of 67 mm thick gravel and 33 mm emulsion-treated gravel, constructed in accordance with the relevant specifications referred to in the scope of work in the contract documents.

2 Materials

Materials required for the construction of the composite base are:

- Gravel – approved from in-situ source or gravel pit (quarry)
- 60% Anionic stable-grade emulsion (vinzyl resin emulsifier) decanted from 210 litre drums (Emulsion made using vinzyl resin as emulsifier, has less tendency to settle than other emulsifiers)
- Cement – pockets
- Lime – pockets (if required to adjust PI)

3 Construction plant, equipment and tools

The following specialised plant and equipment is recommended to promote the construction of the base by labour intensive methods:

- Steel-framed stand with steel or timber ramps for emulsion drums (Photo 3.8)
- Ball valve (75 mm diameter)
- Measuring containers – 25, 20 and 5 litre (for dry and wet materials)
- Drum handles for 20 and 25 litre drums (Workshop drawing LIC 009)
- Dipstick (Workshop drawing LIC 001)
- Suitably sized concrete mixer (14/10 or 400/300)
- Builders' wheelbarrows (capacity ± 65 – 67 litres)
- Suitably sized (approximately 1 ton) tandem vibratory pedestrian roller, having two equally sized drums – both drums driven, each drum to have a separate eccentric shaft (e.g. Bomag 75 or equivalent)
- 150 × 100 mm × 8 mm thick steel angle formwork (steel shutter) (3 m, 2 m and 1 m lengths) (Figures 3.64 and 3.69 and Workshop drawing LIC 002)
- 50 × 8 mm steel spacer plates (bulking rails) (Figure 3.69 and Workshop drawing LIC 0031) (3 m, 2 m and 1 m lengths)
- Steel pegs (Y 10) for securing the formwork
- Steel squeegees (Workshop drawing LIC 005)
- Screeding boards (Workshop drawing LIC 004)
- Plastic sheeting
- 1 000 litre water tank on LDV or mounted on trailer – with pump
- 210 litre drums for storing water
- 25 litre container with clip-on lid to store balance of cement from cement pocket

4 Construction

General

Emulsion

The emulsion to be used must be anionic stable grade 60% emulsion (vinzyl resin emulsifier), decanted from 210 litre drums.

Before using the drums of emulsion, they should be rolled backwards and forwards to ensure that the emulsion is properly mixed. When stockpiled for any length of time, the bitumen in the emulsion tends to settle. (Full drums should be stored flat and empty drums upright.)

For neat and accurate workmanship, it is essential that the drums are placed on a steel frame and that a ball valve is fitted to the drum. (Photo 3.8). The ball valve should be soaked and cleaned in paraffin at the end of each shift. Measuring containers with calibrated dipsticks should be available for accurately measuring the required amount of emulsion for each mix.

Photo 3.8: Emulsion drum stand
(Note ramps for easy handling and ball valve for decanting emulsion)

Steel side forms (steel shutters)

Steel formwork (shutters) for the placing of the composite ETB should be 150 × 100 mm × 10 mm thick angle and be available in 3, 2, and 1 metre lengths. The shorter lengths should be used for small curves.

It is recommended that the steel formwork (shutters) should conform to the dimensions and thickness shown in Figure 3.64 and Workshop drawing LIC 002.

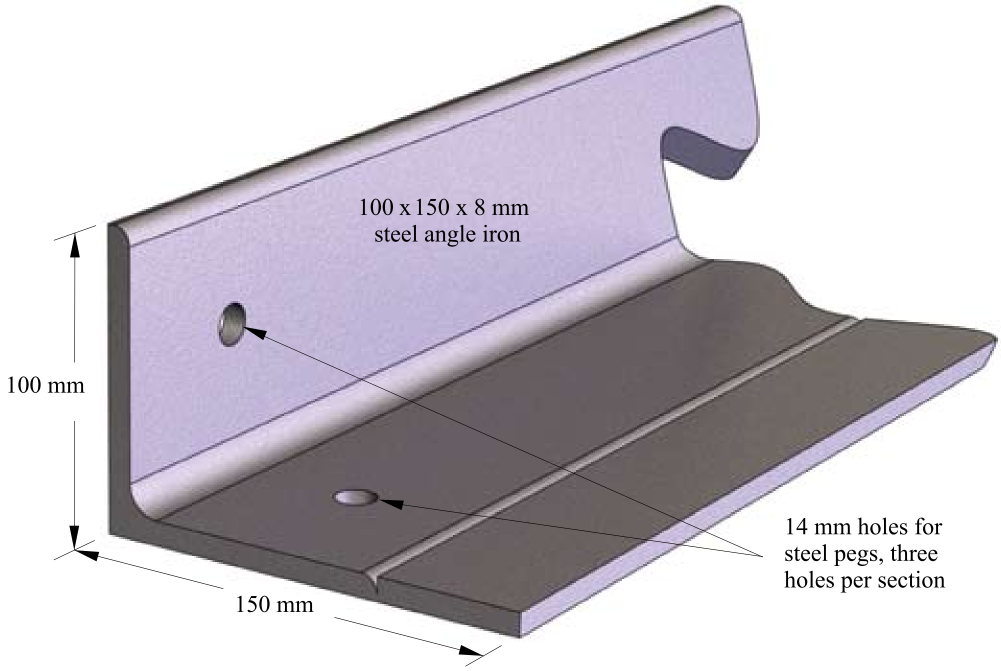

Figure 3.64: Side forms for composite ETB

Sufficient quantities of formwork (shutters) should be available for a day's work.

4.1 Construction process

Tolerances

In view of the relatively thin surfacing being placed, the composite ETB base should be constructed to levels to accommodate the surface within 6 mm of designed level.

Placing of steel side forms (shutters)

In placing and fixing the formwork (shutters), care must be taken to ensure that no bumps are built into the surface, and that a smooth vertical and horizontal alignment and the correct cross-fall (camber) is obtained.

Care must be taken to check the vertical and horizontal alignment of the formwork, as well as the camber (cross-fall), and to ensure that the side forms are firmly and correctly placed before placing the material.

Once the shutters are in place, the camber can be checked by placing a camber spacer of the correct height for the specific camber, on top of the vertical leg of the lower shutter (edge of road). A spirit level can then be placed on top of a screed board spanning from the centre-line shutter to the lower shutter, to ensure that there is no fall between the top of the camber spacer and the centre-line shutter. (Figure 3.65)

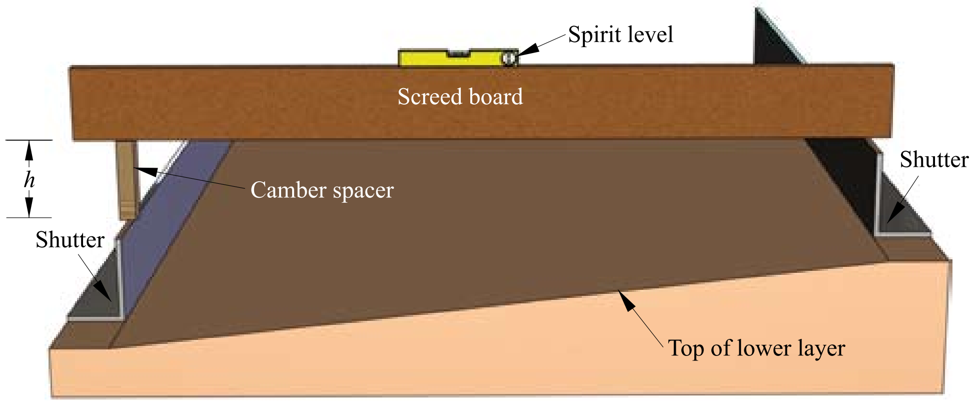

Figure 3.65: Use of camber spacer

Half width of road – ½*w* in (m)	Height of camber spacer – *h* in (mm)		
	2% cross-fall	3% cross-fall	3,5% cross-fall
2,0	40	60	70,0
2,5	50	75	87,5
3,0	60	90	105,0
3,5	70	105	122,5
4,0	80	120	140,0
4,5	90	135	157,5

Table 3.8: Height of camber spacer for 2%, 3% and 3,5% cross-falls

Once the side forms (shutters) have been placed, the levels must again be checked (by string lining across the tops of the side forms), and the surface trimmed to ensure that the correct thickness of base (100 mm) is laid. Slacks or depressions in the sub-base will not only result in an increase in the amount of ETB required in the top layer of the base, but also differential settlement.

Work site planning

It is essential that the planning of the delivery and stockpiling of gravel from the quarry sources is carefully planned and controlled.

Example

Assume:

Material is delivered in 8 ton trucks.
Road is being constructed in half width (3,5 metres).
Layer thickness 100 mm compacted (150 mm loose/uncompacted).

Then:

1. Spacing of stockpiles is:

$$\text{Volume} = \text{length} \times \text{width} \times \text{thickness (uncompacted/loose)}$$

$$8\ m^3 = \text{length} \times 3{,}5\ m \times \frac{150}{1\ 000}\ m$$

$$\text{Length (spacing of stockpiles)} = \frac{8\ m^3}{3{,}5\ m \times 0{,}15\ m} = 15{,}24\ m \text{ (say 15 metres)}$$

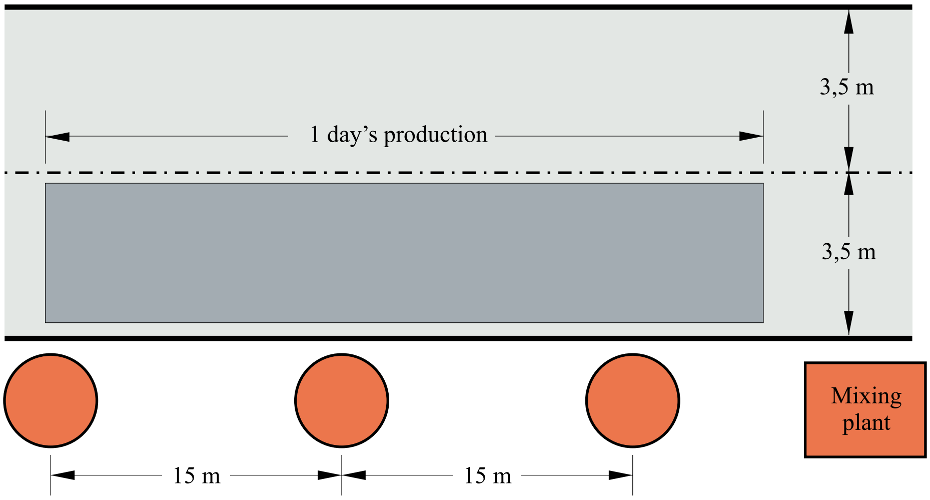

Figure 3.66: Placing of mixer (work site)

2. Placing of mixing plant

The mixing plant is placed one day's production ahead of the gravel stockpiles (Figure 3.66), so that it only needs to be moved every second day.

3. Quantities of emulsion and cement

Emulsion:
Assuming 42 litres of emulsion is required for each m³ of compacted material, then the amount required for an 8 m³ stockpile is:

$$\frac{8}{1,5} \times 42 = 224 \text{ litres}$$

For 3 loads the amount is thus 3 × 224 = 672 litres = 3,2 drums (1 drum = 210 litres).

Therefore, approximately 3 drums of emulsion per day are required to be placed at the mixing plant.

Cement:
Assuming 1% by mass of cement is required for each kg of gravel, and the density of the gravel is 2 000 kg/m³ compacted.

The compacted mass of one stockpile is therefore:

$$\frac{8}{1,5} \times 2\,000 = 10\,666 \text{ kg}$$

For 3 stockpiles the mass is 3 × 10 666 = 31 998

1% cement = 319,98 kg say 320 kg

One pocket of cement is 50 kg, therefore approximately 6 pockets of cement are required at the mixer per day.

If the rate of production is too slow, the number of units producing ETB must be increased accordingly.

Note

The amount of emulsion and cement (lime) to be used must be determined by an approved materials laboratory.

Mixing of materials for the composite ETB base

1. Gravel for lower layer 67 mm thick (100 mm loose)

Mixing of the gravel should be done in appropriately sized concrete mixers.

The material to be used should be stockpiled as closely as possible to the work area. The mixing of materials should take place in the following order (Photos 3.9 - 3.14):

- The dry materials, aggregate, cement and lime (if required) should be added first and mixed well.
- This is followed by adding the water, to OMC, as determined in the laboratory, and mixing well.

2. ETB for top layer 33 mm thick (50 mm loose)

Mixing of the ETB should be done in appropriately sized (400/300) concrete mixers.

Material to be used in the ETB should be stockpiled as closely as possible to the work area.

The mixing of materials should take place in the following order (Photos 3.9 - 3.14):

- The dry materials, aggregate, cement and lime (if required) should be added first and mixed well.
- This is followed by adding one third of the water and mixing well.
- Lastly the emulsion, diluted with the remaining two thirds of the water, is added to the contents of the mixer and mixed to a uniform consistency.

Note

The photos depict the gravel (aggregate) being added to the mixer in a container. For larger mixers (400/300), struck-off wheelbarrow loads (± 67 litres) of aggregate are added to the mixer – 4 wheelbarrows per mix.

The amount of liquid to be added must be approximately 1 – 1½% over the optimum moisture content required for the Mod. AASHTO density.

Typical mix proportions

Aggregate – 1 wheelbarrow (loose)

Cement – 1 kg (⅔ litres)

Emulsion – 2 litres

Water (approximate) – 5½ litres

Process of mixing of ETB in concrete mixer

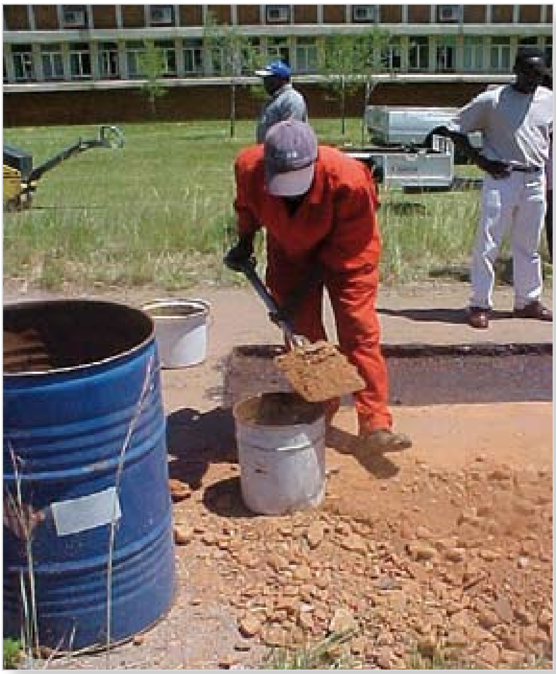

Photo 3.9: Measure aggregate

Measure aggregate in 25 litre measuring cans.

Photo 3.10: Add aggregate and cement

Add aggregate and cement to mixer while the drum is turning and mix well.

Photo 3.11:
Add water

Add ⅔ of the water to the mix.

Photo 3.12:
Add emulsion

Add ⅓ of water to the emulsion and add the diluted emulsion to the contents of the mixer.

Photo 3.13: Mix ingredients

Mix ingredients to a uniform consistency.

Photo 3.14: Discharge into wheelbarrows

Placing of the material

1. Gravel for lower layer 67 mm thick (100 mm loose)

Before placing the gravel layer, the sub-base should be lightly watered.

Placing of the gravel should be done as uniformly as possible, by placing the barrow loads at a uniform spacing, between the side forms, to achieve the minimum amount of movement for levelling the loose material for a 100 mm loose layer. (Figure 3.67)

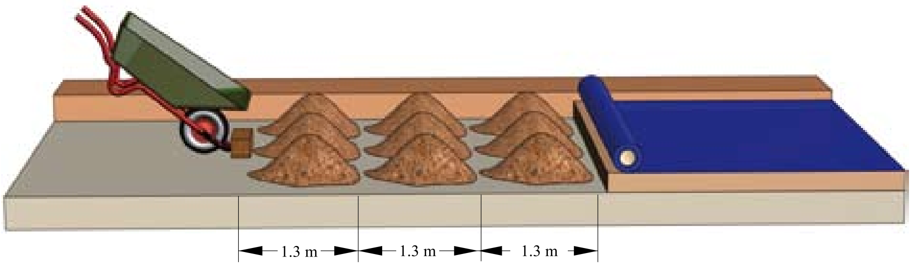

Figure 3.67 a: Placing of ETB

Calculation of spacing for 100 mm loose layer for half width of 3,5 m

A width of 3,5 metres will allow 7 wheelbarrow loads to be tipped at a spacing of 0,5 metres.

Assuming the capacity of a wheelbarrow is 0,067 m^3 the spacing between rows of wheelbarrows to obtain a loose depth of 100 mm (0,10 m) is then:

$$\frac{7 \times 0{,}067\ (m^3)}{3{,}5\ (m) \times 0{,}10\ (m)}$$

= 1,34 m

or 1,3 m (Figure 3.67 b)

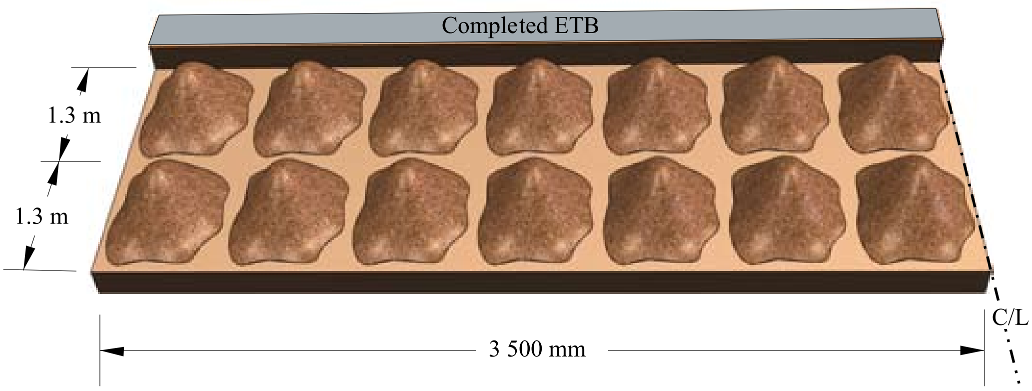

Figure 3.67 b: Spacing of barrow loads

Place the 100 mm × 150 mm side forms (shutters) as shown in Figure 3.64, in position with the 100 mm leg of the side forms in the vertical position and, using the steel squeegees and steel screed bar spread the gravel to obtain a 100 mm loose layer. (Less segregation of the material is attained by using steel squeegees in place of rakes.)

When using a coarse material, the judicious removal of the large fractions from the surface, and their replacement with finer material and/or placing coarse material on the bottom of the layer, ahead of the work will result in a more uniform smoother finish.

As the work progresses, a black plastic sheet should be rolled out over the work to inhibit the gravel drying out. Once some 8 – 10 metres of ETB has been placed, the cover can be rolled up, the spacer plates removed and rolling commenced.

2. ETB for upper layer 33 mm thick (50 mm loose)

Once some 8 – 10 metres of the 100 mm loose gravel layer has been placed the cover can be rolled up the spacer plates (bulking rails) as detailed in Figure 3.68 a can be placed on top of the 100 mm leg of the side form and the placing of the ETB commenced.

Placing of the ETB should be done as uniformly as possible by placing the barrow loads at a uniform spacing, between the side forms, to achieve the minimum amount of movement for levelling the loose material for a 50 mm loose layer. (Figure 3.65)

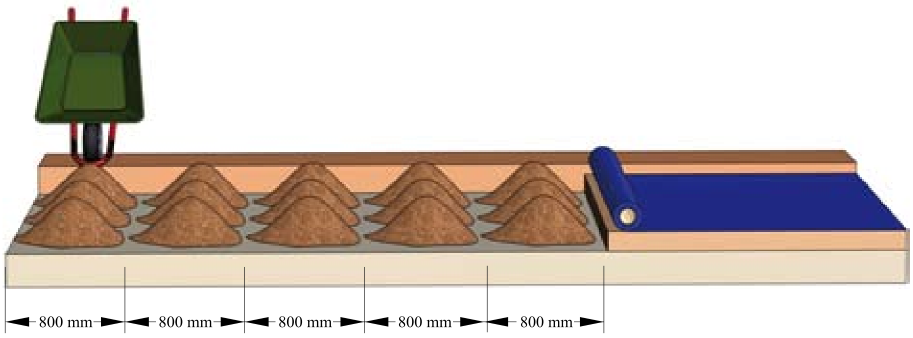

Figure 3.68 a: Placing of ETB

Calculation of spacing for 50 mm loose layer for half width of 3,5 m

A width of 3,5 metres will allow 7 wheelbarrow loads to be tipped at a spacing of 0,5 metres.

Assuming the capacity of a wheelbarrow is 0,067 m^3 the spacing between rows of wheelbarrows to obtain a loose depth of 50 mm (0,05 m) is then:

$$\frac{7 \times 0{,}067\ (m^3)}{3{,}5\ (m) \times 0{,}05\ (m)}$$

$$= 2{,}20\ m$$

or 2,3 m (Figure 3.68 b)

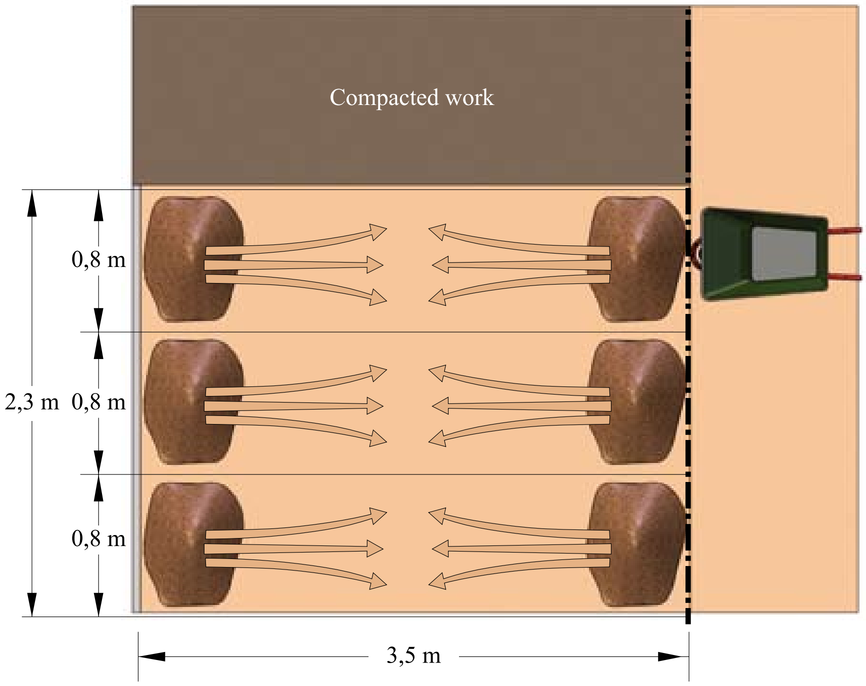

Figure 3.68 b: Spacing of barrow loads

Note

The passage of the barrows must be outside the traffic lane, and no walking must occur on the spread but uncompacted gravel by labour, as this will result in differential compaction and an uneven final surface.

With the 50 mm × 6 mm thick steel spacer plate, as detailed in Figure 3.69, on top of the 100 mm leg of the side forms, and using the steel squeegees and steel screed bar, spread the ETB to obtain a 50 mm loose layer. (Less segregation of the material is attained by using steel squeegees in place of rakes.)

Where the layer is being constructed adjacent to previously constructed work (e.g. half width construction), a 50 mm × 50 mm spacer must be placed on top of the existing work, to obtain the correct loose thickness for the new work.

Spacer plate (bulking rail)

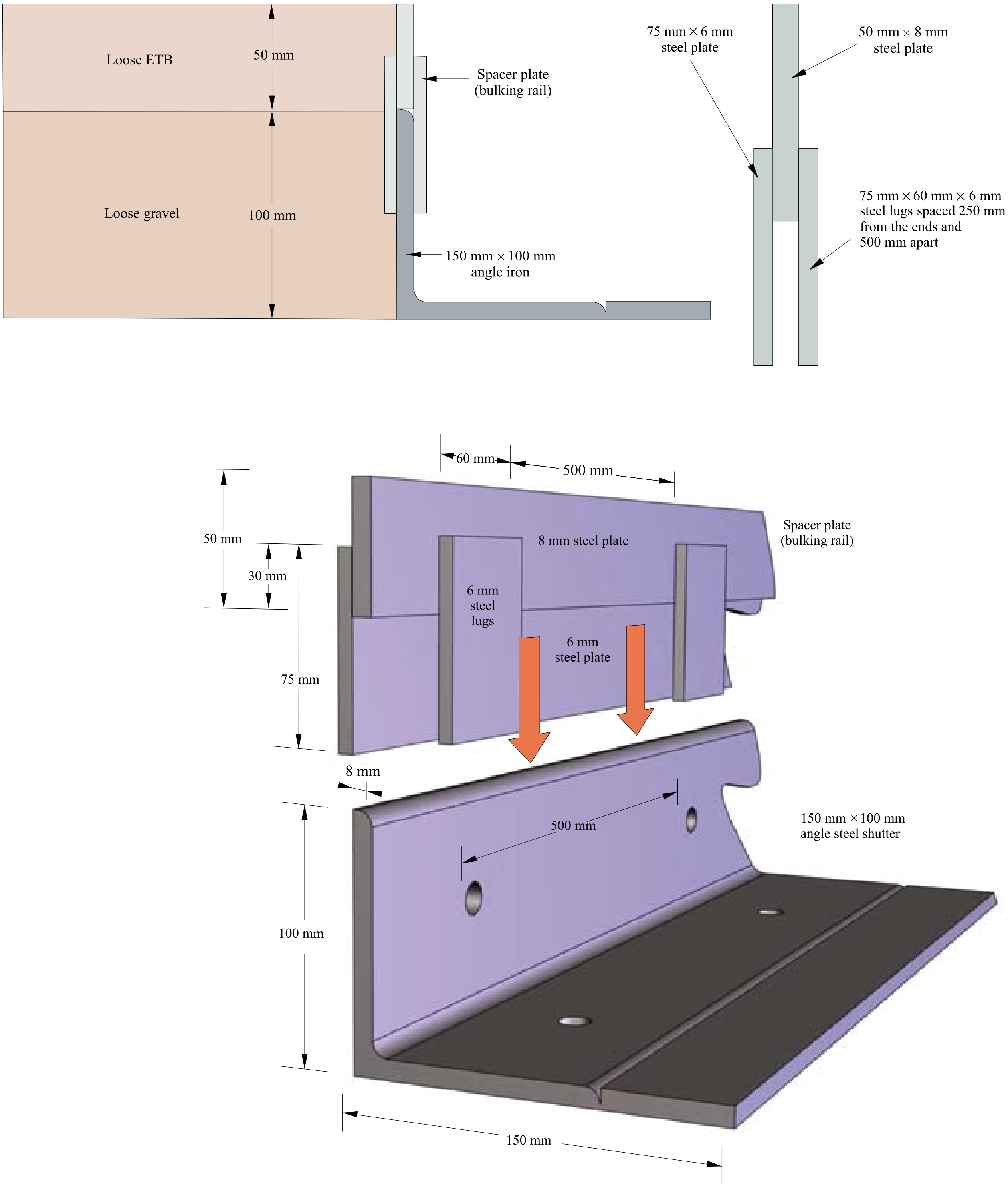

Figure 3.69: Sketch of spacer plate (bulking rail) to place 150 mm loose composite ETB (Refer to Workshop drawings LIC 002 and 0031 for details)

When using a coarse material, the judicious removal of the large fractions from the surface, and their replacement with finer material will result in a smoother finish.

As the work progresses, a black plastic sheet should be rolled out over the work to inhibit the emulsion breaking prematurely. Once some 8 – 10 metres of ETB has been placed, the cover can be rolled up, the spacer plates removed and rolling commenced.

Compaction of composite ETB layer

Rolling, with the roller in vibratory mode, is continued until the 150 mm loose layer has been compacted to the top edge of the 100 mm leg of the side form. Incorrect rolling can result in the building of undulations in the surface.

In order to eliminate undulations, rolling should commence at 45° to the edge line of the shutters. Thereafter rolling should be undertaken in such a manner that the roller is always supported over approximately a half of its width, as indicated in Figures 3.70 a and 3.70 b, initially either on an existing surface or the steel side forms.

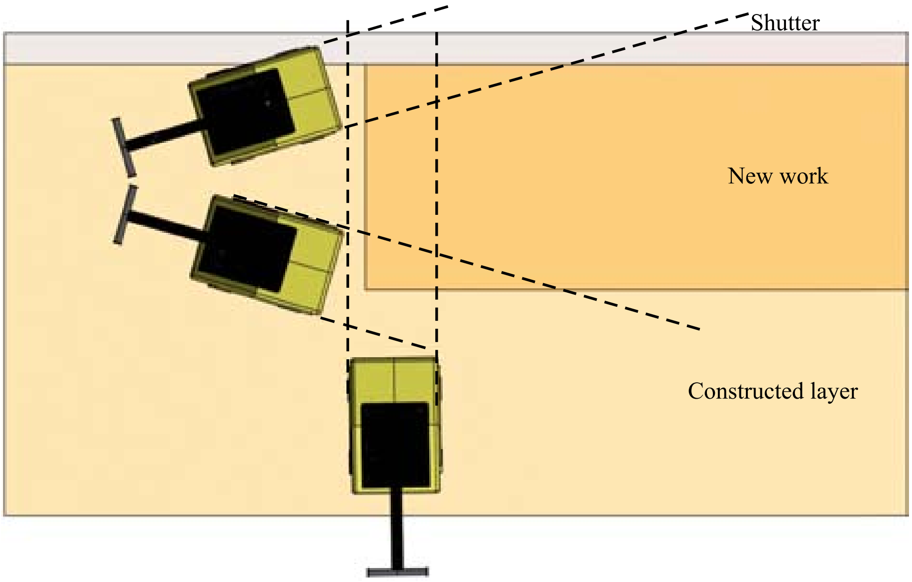

Figure 3.70 a: Initial rolling at 45° and across joint

MODULE
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5.1
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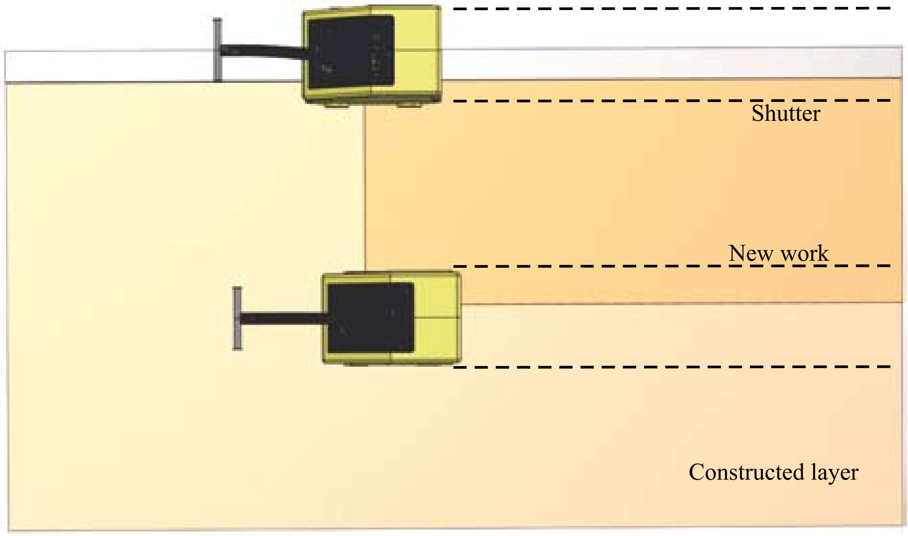


Figure 3.70 b: Rolling parallel with shutters from outside inwards

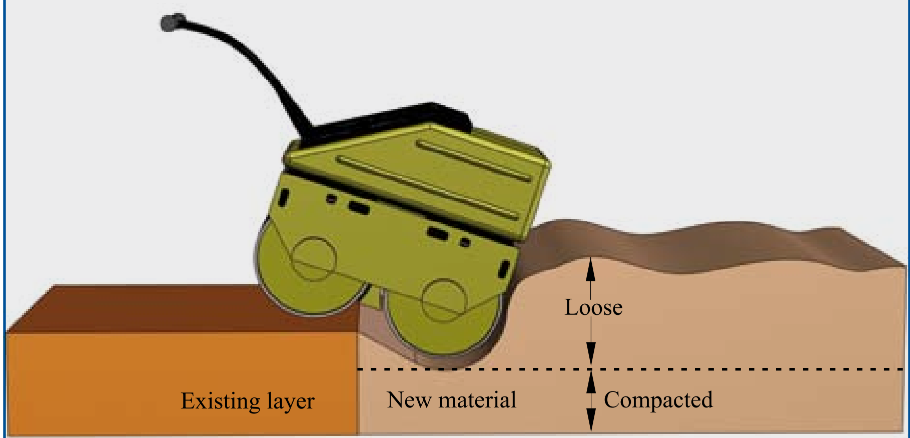
Always roll, in vibratory mode, parallel with the shutter lines. Move from both sides towards the middle of the layer, in a little less than ½ the width of the roller after each pass of the roller.

Continue to roll the section until the layer is level with the shutters.

1. Reason for operating roller in vibratory mode

The reason for operating the roller in vibratory mode from the outset is to overcome the problem of sealing air in the voids of uncompacted material. This makes it difficult to attain the required density, which is the case if the uncompacted material is initially rolled in non-vibratory mode.

2. Reason for commencing rolling at 45°



Where construction starts when approaching the new work, parallel with the centre line of the road, approach the uncompacted material from the existing compacted material, initially at 45° with the roller. This overcomes the problem of creating/ constructing a bump in the road, between the existing and new work.

Sufficient time shall be allowed for the emulsion to fully break, before construction of the surfacing is commenced.

Before commencing with the surfacing, all loose material must be removed from the surface, and a diluted emulsion (1:8) applied neatly and uniformly to the surface. A coarse broom can be used to evenly distribute the diluted emulsion.

Construction adjacent to compacted work, kerb or channel

Where the layer is being constructed adjacent to previously constructed work (e.g. half width construction), or a kerb or channel a 50 mm x 50 mm spacer must be placed on top of the existing work, to obtain the correct loose thickness for the new work. (Figures 3.71 a, b, c)

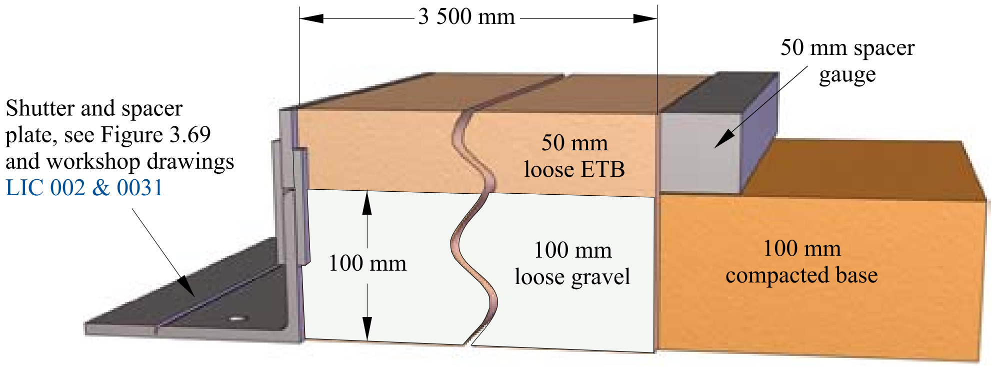


Figure 3.71 a: Construction adjacent to compacted layer

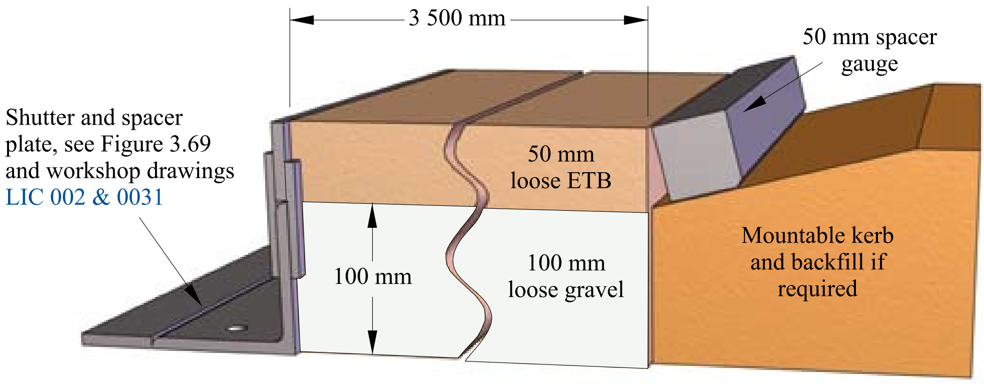


Figure 3.71 b: Construction adjacent to mountable kerb

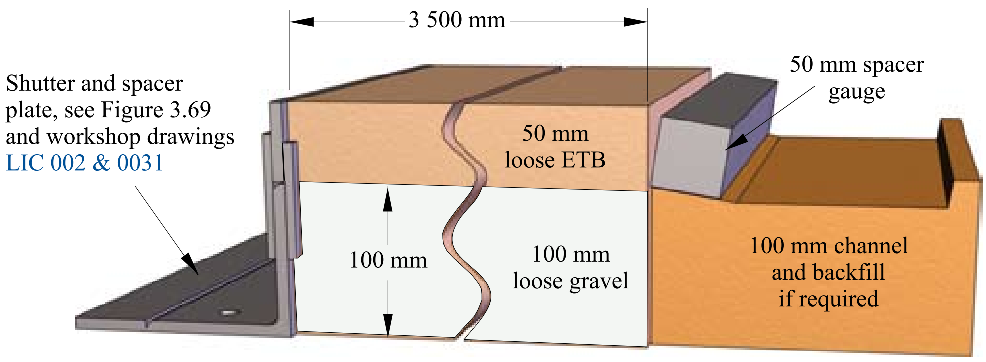


Figure 3.71 c: Construction adjacent to channel

5 Notes to consultant

Introduction

Emulsion-treated bases are particularly suitable for labour-intensive construction projects, not only because of the technique lends itself to the construction of a quality base using labour and light plant, but because it can also be opened to traffic for an extended period, without untoward damage to the surface.

This is an advantage as construction by labour-intensive methods normally proceeds more slowly than is the case with conventional methods. It is therefore more difficult to keep traffic off the partially finished base.

This does not apply to bases constructed with unstabilised material or cement or lime stabilised material.

Materials survey

General

Before any work is commenced on the design of the road layers to support the ETB base, it is advisable to determine:

- The quality of gravel available in the area.
- The quality of gravel on the road:
  - Establish the average depth of the gravel.
  - Establish the average width of the gravel.
  - What the CBR, Grading modulus (GM) and PI of the material is.
- The quality of the sub-base/sub grade materials.
- The drainage conditions of the system.

Centre-line survey

The quickest and most economical means of establishing the bearing capacity of the in-situ material is by means of the DCP test.

DCP tests should be done in the middle of the wet season, or just at the end of the wet season. This will factor in safety into the design.

It is recommended that DCP tests are done every 50 metres along the route and, in the case of short lengths of road/street, at least 3 tests on every 80 – 100 metres.

It is recommended that physical tests, i.e. PI and grading be done at selected points of similar material. Road material can be classified/similarities established visually or the DCP tests could be used for testing the test points.

From the DCP tests the CBRs can be established for the in-situ materials. However, it is advisable to do CBR tests on selected samples after completion of the indicator tests.

From the cover curves in Figure 3.72, design can be checked to see if a 100 mm ETB will be adequate (Note: The CBR of the ETB will normally exceed 100 in the field.)

The in-situ field CBR of the sub-base must not be less than 30.

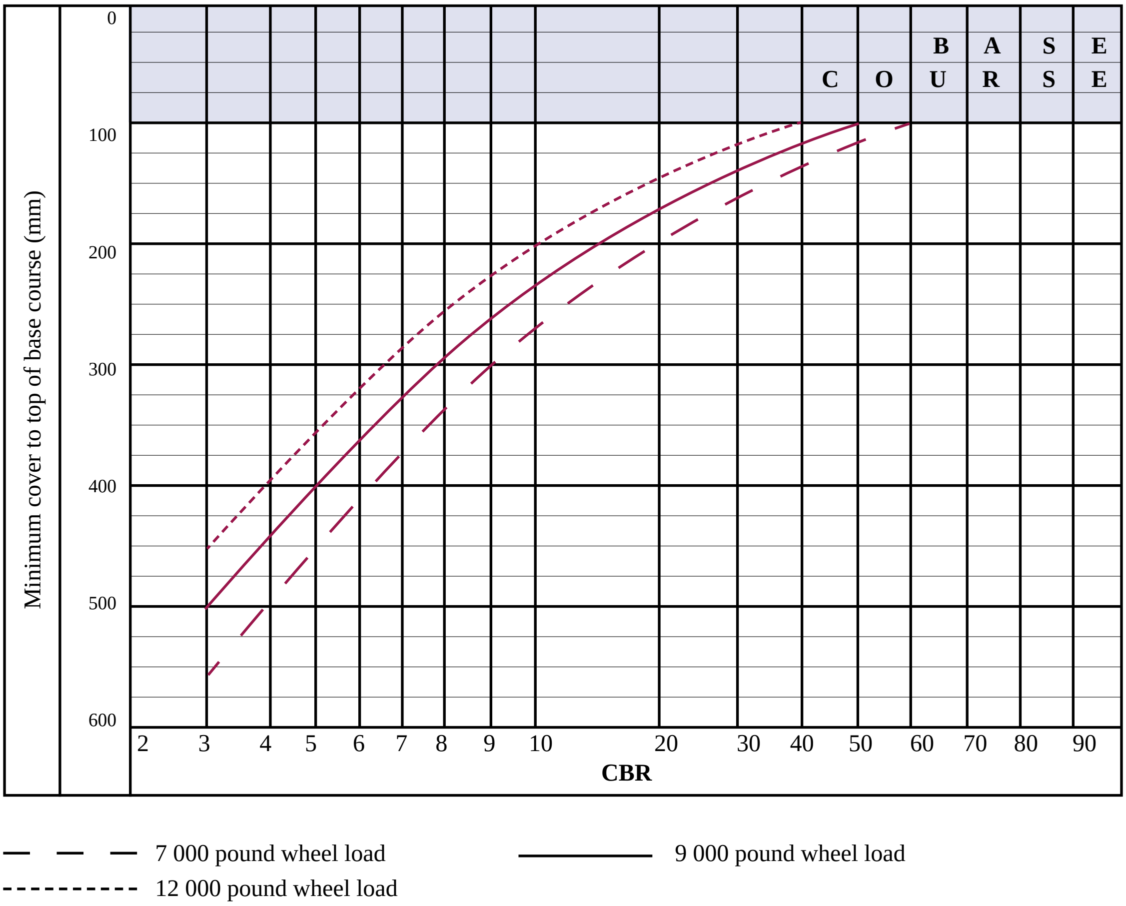


Figure 3.72

5.1 Quarry (borrow pit survey)

It is advisable/recommended that before funds are expended on opening/preparing a quarry site for winning gravel, a proper investigation is undertaken, comprising:

- The establishment of possible sites from geological knowledge of the area, and/or study of the local vegetation, cutting faces and discussions with locals.
- Trial pits to establish the extent of the deposit/existence of possible suitable material.
- The preparation of a plan of the area showing the location and systematic establishment of further trial pits and showing these on the plan with test results.
- Testing. The minimum tests required for gravel roads are the indicator tests i.e. grading and Atterberg limits. For surfaced roads, all the required tests must be shown on the materials survey plans.

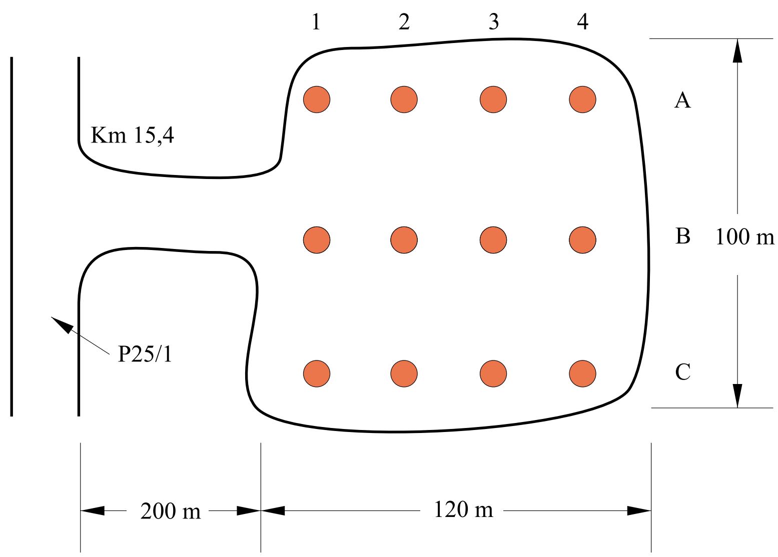


Figure 3.73: Quarry plan

Normally where large trees occur, the topsoil is deep and the material is finely graded soil. Stunted vegetation often indicates relatively shallow deposits and coarsely graded material.

The grass growing over gravel deposits is less intense/concentrated/lush. This is not always true as the overburden may be thick enough to encourage grass growth.

It is important to establish the depth of suitable material – often ouklip/laterite/ferricrete deposits overly clay deposits which are unsuitable.

Each area has its own vegetation characteristics e.g. Protea bushes usually occur on granite deposits and Bobbejaanstert over quartzitic gravels.

Note

- As the work is about to be contracted out, it is essential that this information of the quarry site is readily available including estimated material quantities.
- Before any site is tested, the owner must be consulted and permission to enter obtained – power of compensation/expropriation is normally covered in the relevant Road Ordinance.

Materials suitable for ETB

As a guideline, the following materials can be considered for use in emulsion treated bases:

- Weathered granites (may require lime).
- Weathered dolerites (may require lime).
- Quartzitic gravels.
- Laterites/ferricrete/ouklip preferably containing quartz.
- Chert gravels.

- Calcrete (some).
- Crusher run.
- Sandstone gravel.

Sometimes only fine grained sands are available. By adding 15% to 20% of 6,7 or 9,5 crushed aggregate to this fine material, substantial improvement of bearing qualities can be obtained.

> **Note**
>
> Before any of these materials are used, it is recommended that a reputable materials laboratory carries out emulsion (ETB) tests, based on the latest SABITA manual for testing ETB.

Winning gravel in approved gravel pit (quarry)

Management of quarry sites

Once the preliminary investigations have been expanded, the detailed investigations completed and the quarry plans and test results, including the estimated material quantities are available at each site, the planning/management of the site is possible.

It is generally uneconomical to win gravel at the quarry face using hand labour. It is therefore recommended that the material is won and stockpiled by machine, as a separate contract, for loading using only hand labour.

Overburden

It is necessary to strip the soil and vegetation (overburden) before working the quarry for the following reasons:

- The topsoil is not always suitable for the layer for which it is required. This can be assessed from the test results.
- The grass and roots in the overburden are not suitable for layer work.
- Reinstatement of the quarry is most important – top soil, seeds and grass roots must be stockpiled for this exercise.

> **Cost effective practice**
>
> As a dozer is required for this work – delivered to site by low-loader – it may be policy/effective to use it for stockpiling gravel, depending on the depth of the suitable material.

Stockpiling of gravel

In many areas of the country, suitable material occurs in shallow lenses of alluvial or secreted deposits less than ± 1½ metres deep.

Why rip and stockpile gravel?

- It speeds up the process for loading by hand later.
- Better control of the quality of the material won in the quarry – the dozer operator can avoid any suspect/clay deposits. (The foreman/superintendent must supervise this work – using the quarry plan and test results to guide the operator.)
- The uniformity of material will be more easily obtained, if the quarry survey has been carried out efficiently.
- If the gravel consists of coarse and over-size material e.g. weathered dolerite or quartzitic boulder material, it is advisable to allow for crushing the material using mobile primary crushing plant.
- The winning and stockpiling of material can be carried out under a separate contract. The dozer can complete its work at a specific quarry and move on to the next quarry for loading of the material by hand later, for use as required in the road layers. (This saves the cost of keeping the dozer on-site for extended periods.)

Method of stockpiling gravel

1. Move the vegetation and specified amount of topsoil neatly into a stockpile/windrow, on either edge of the demarcated area indicated on the quarry plan. Rip the cleared area to the depths approved on the quarry plan.

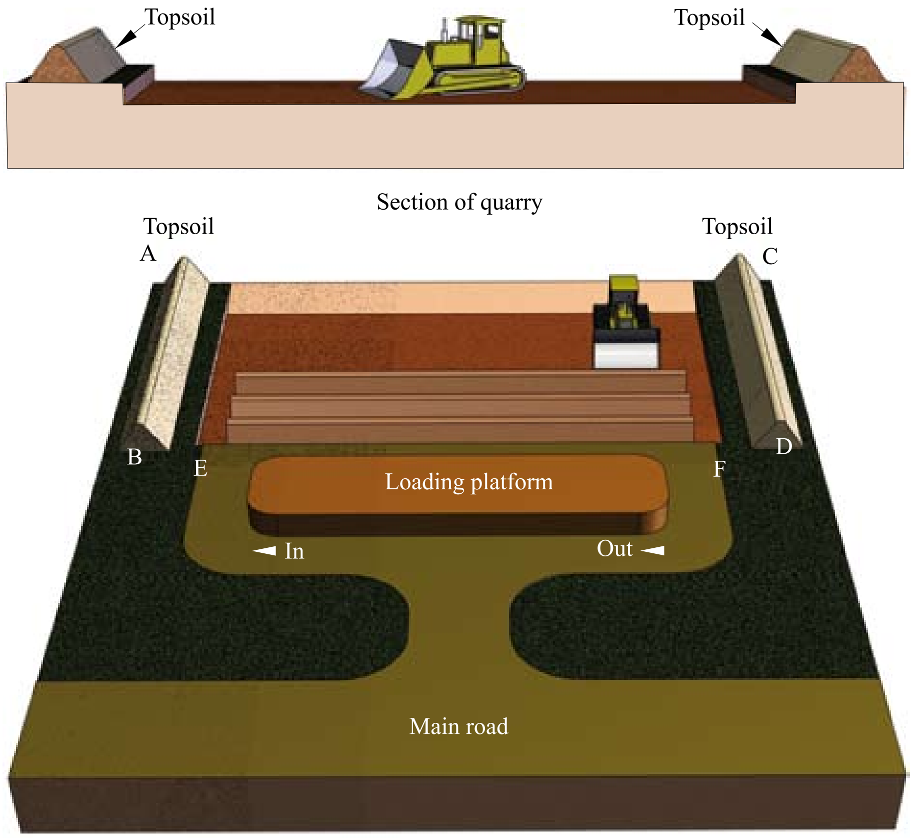


Figure 3.74: Management of quarry site

N.B. Road signs and flagmen must be used for controlling traffic, at junction of access to quarry, from main road.

2. At right angles to the line of topsoil stockpiles AB & CD, stockpile the gravel to a height of 1½ – 2 m in approximately parallel lines.

3. Shape, water and compact the access road, from the main road to the quarry. This road must be wide enough for passing of trucks (6 – 8 m), or preferably two access roads 4 m wide – one IN and one OUT.

   Prepare the loading platform in front of the gravel stockpile, as described below for loading by hand, before commencing with the loading.

   When loading the trucks or trailers by hand, the management of the quarry stockpiling is essential for efficient loading. Slots with a depth approximately equal to the diameter of the wheels of the truck or trailer must be provided in the stockpile area. (Figure 3.75)

- Gravel must be stockpiled on either side of the slot to allow for loading the truck or trailer from both sides.
- More than one slot can be provided to expedite the work.
- Gravel should be stockpiled in heaps of ± 20 cubic metres.

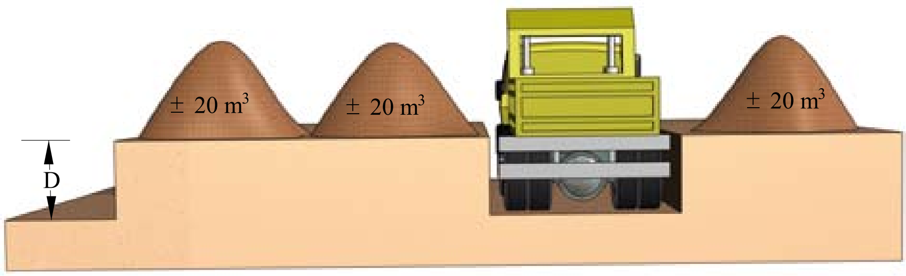


Figure 3.75: Stockpiling of gravel for loading by hand

4. The quarries must be reinstated at the end of the regravelling operation, by returning the vegetation and topsoil from AB and CD to neatly cover the area.

   - This can be undertaken by hand labour.
   - If possible, the reinstated area should be watered to encourage the growth of vegetation.
   - N.B. The quarry must be properly drained for health reasons – especially in malaria areas.

   The above approach is particularly applicable to flattish areas or low rolling hills. In hilly or mountainous country, the process will have to be modified but the principles remain the same e.g. winning and stockpiling by suitable machines and loading platform, properly prepared prior to loading by hand.

   The plant used may be changed e.g. a face shovel instead of a front end loader for working a hard face.

   The use of explosives is very effective in certain types of material.

Road alignment

In view of the nature of the roads (low volume rural roads which mostly follow existing alignments) and method of construction (labour based), roads should be set out to a rolling grade to minimise earthworks and therefore costs, and to promote the use of labour.

Vertical curves should, however, be checked for safety sight distances.

Horizontal curves should also be checked e.g. do not introduce isolated sharp bends in a 120 km terrain.

MODULE 1 2 3 4 5 5.1 5.2 6

MODULE 6: Indicative production and task rates

Indicative production rates and team sizes for selected activities based on a 7-hour production day

Activity	Description	Unit	Production rate	Team size
Clear and grub	Clearing	m^2	150 – 300	1
	Clearing and grubbing		80 – 150	1
Excavation (Earthworks) (In wider excavations double handling may have to be arranged for)	Soft class 1 (soil)	m^3	2,5 – 5,0	1
	Intermediate (soil)		2,0 – 3,0	1
	Hard (soil)		1,0 – 2,0	1
Borrow pits	Select and load rock	m^3	2,0	1
	Feed crusher		3,5	1
	Load gravel		6,0	1
Hauling (wheelbarrow)	0 – 20 m	m^3	10,0 – 13,0	1
	40 – 60 m		8,0 – 10,0	1
	60 – 80 m		6,0 – 8,0	1
	80 – 100 m		5,0 – 6,0	1
Backfilling	Trenches	m^3	4,0 – 8,0	1
	Excavation		2,0 – 5,0	1
Sub grade preparation (new alignment) excluding clearing and grubbing	Excavate to wheelbarrows	m^3	1 – 4	1
	Wheelbarrow haul 0 – 20	m^3	10 – 13	1
	Construction of 2 × 150 mm thick sub grade layers from in-situ material	m^3 (2 × 150 mm compacted thickness)	24 – 32	12 Note1
Unstabilised gravel sub-base	Add water to stockpile, wheelbarrow haul, spread and compact	m^3	24 – 32 (loose) 16 – 22 (compacted)	12 Note 1
		m^2 (150 mm compacted thickness)	100 –150	
Gravel wearing course	Add water to stockpile, wheelbarrow haul, spread and compact	m^3	24 – 32 (loose) 16 – 22 (compacted)	12 Note 1
		m^2 (150 mm compacted thickness)	100 – 150	

Activity	Description	Unit	Production rate	Team size
ETB (Emulsion treated base) and composite gravel/ETB	Mix (in 400/300 mixer), spread and compact (100 mm compacted thickness)	m^3	12 – 21 (loose) 8 – 14 (compacted)	13 [Note 2]
		m^2	80 – 140	
	Mix (in 400/300 mixer), spread and compact (100 mm compacted thickness – 66 mm gravel and 34 mm ETB)	m^3	12 – 21 (loose) 12 – 21 (loose)	13 [Note 2]
		m^2	80 – 140	

Notes:

Note 1: Team composition sub grade and unstabilised gravel layers.

Labour units	
Activity	**Number**
Prepare dams in stockpiles and cover with plastic sheet (assist with adding water)	2
Loading and carting wheelbarrows	2
Squeegees	2
Screeding	2
Roller operator	1
Steel shuttering and plastic covers	2
Supervisor	1

Note 2: Team composition for emulsion-treated base (ETB).

Labour units	
Activity	**Number**
Loading and carting wheelbarrows	2
Concrete mixer operator	1
Materials measurements (emulsion/cement/water)	2
Squeegees	2
Screeding	2
Roller operator	1
Steel shuttering and plastic covers	2
Supervisor	1

References

The framework agreement for public works projects using labour intensive construction systems. Johannesburg: COSATU.

De Veen, J.J. 1980 and 1983: *The Rural Access Road Programme: Appropriate Technology in Kenya*. Geneva: ILO.

The Productivity of Labour Based Infrastructure Works. 1996. Zimbabwe: ILO.

Little, R. 1993. *Earth Roads: Team task calculation aids*. Durban: University of Natal.

Scott, W. 1983. *Labour Construction Unit: Technical Manual.* Paper included in Labour Based Construction of Civil Engineering Projects: Information ex. Lesotho Nov 1998.

Simpson, J. 1980. The Design, Construction and Maintenance of Low Cost Roads. *Proceeding of 4th IRF Conference*. Nairobi, Kenya, 20 – 25 January 1980.

World Bank study on substitution of labour for equipment. 1995. Washington DC: World Bank.

Notes

Notes

"We have made the firm commitment to confront the challenges of poverty and joblessness. We have made the solemn pledge that we will do everything possible to achieve the goal of a better life for all our people."

President Thabo Mbeki