Concrete Beton, Volume 105, pp 8-13, December 2003

Low-volume Concrete Roads

Author: B D Perrie

Cement and Concrete Institute, Midrand, Gauteng, South Africa

INTRODUCTION: Low-volume concrete roads have a number of advantages. These include:

- Very low maintenance costs
- Labour friendly and therefore suitable for labour-based construction
- Skills acquired are not limited to road construction but are transferable to the wider building and construction industry
- Existing subgrade and alignment can be used
- Ideal for upgrading existing deteriorated roads by overlaying
- Can reduce storm water reticulation needed
- Only simple, inexpensive equipment needed
- Uses local materials
- Requires less lighting energy where streetlights are provided
- Built-in skid resistance.

Journal Contact Details:
PO Box 75364
Lynnwood Ridge
Pretoria, 0040
South Africa
+27 12 348 5305

CONCRETE SOCIETY
OF SOUTHERN AFRICA

admin@concretesociety.co.za
www.concretesociety.co.za

TECHNICAL PAPER

LOW-VOLUME CONCRETE ROADS

By: Bryan David Perrie - Cement and Concrete Institute

BRYAN DAVID PERRIE

He started his career contracting throughout Southern Africa and has been with the Cement and Concrete Institute, previously the Portland Cement Institute for the last 18 years. He currently heads the Concrete Roads Project which is aimed at increasing the use of concrete pavements in South Africa.

Qualifications
Bsc Eng (Civ) (Wits) 1977
Registered Professional Engineer, Number 870141.
MSc Eng (Wits) 1995 by dissertation "Testing of curing compounds for concrete".

Publications
Joint Author of a book "Concrete Industrial Floors on the Ground".
Author of a book "Low-Volume Concrete Roads".
Author of sections of "Fulton's Concrete Technology".
Has authored a number of papers for publication and presentation at local and overseas seminars, conferences and symposia.

Committees:
Council Member of the Southern Africa Road Federation.
Member of the advisory board of Transportek, CSIR
Represents South Africa on the World Road Association's Technical Committee on Road Pavements

INTRODUCTION

Low-volume concrete roads have a number of advantages. These include:

- Very low maintenance costs
- Labour friendly and therefore suitable for labour-based construction
- Skills acquired are not limited to road construction but are transferable to the wider building and construction industry
- Existing subgrade and alignment can be used
- Ideal for upgrading existing deteriorated roads by overlaying
- Can reduce stormwater reticulation needed
- Only simple inexpensive equipment needed
- Uses local materials
- Requires less lighting energy where streetlights are provided
- Built-in skid resistance

DESIGN

Drainage

Experience has shown that inadequate drainage is probably responsible for more pavement distress in Southern Africa than inadequate structural or material design.

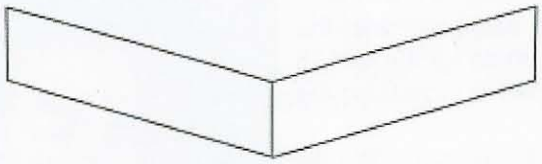
Surface run-off can be controlled in the rural environment by constructing sufficiently wide side drains. In the urban environment it can be controlled with the use of kerb and channel systems discharging into inlets into a stormwater pipe system. In order to reduce costs for low-volume roads, consideration should be given to dishing the road surface and carrying the stormwater on the road surface to suitable discharge points. The road can be dished in a number of ways, some of which are shown in Fig 1.
Subsurface drainage is equally important and while it should be considered during the design stage, it is expensive and should only be provided where absolutely necessary in low-volume roads.

Supporting layers

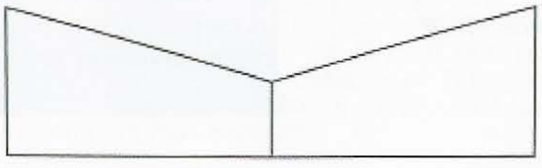
Concrete for paving typically has a high degree of rigidity enabling concrete pavements to distribute loads over large areas of the subgrade, resulting in small deflections and low subgrade pressures. Concrete pavements consequently do not require strong subgrades, and it is much more important that subgrade

TECHNICAL PAPER(cont.)

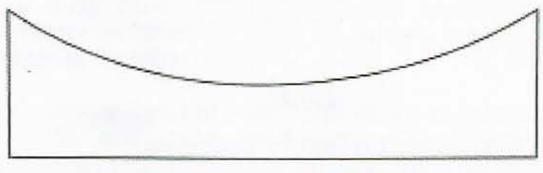
support be uniform with no abrupt changes in the degree of support. Where uniform support cannot be achieved with granular material and or where increased support is necessary, consideration should be given to the use of a cement-stabilized subbase.



Shaped earthworks, uniform concrete



Flat earthworks, dished concrete



Flat earthworks, dished concrete

Figure 1: Alternative sections of dished roads.

Pavement type

Economy, ease of construction and maintenance considerations usually suggest that jointed unreinforced pavement (JCP) should be specified for low-volume roads and streets. However, continuously reinforced concrete pavement (CRCP) may have certain advantages in the case of rural roads in isolated areas or where periodic maintenance does not occur. The steel provided is usually of the order of 0,6% of the concrete cross-sectional area.

When close joint spacings are used, reinforcing steel is not needed in concrete pavements. However, selective use of wire fabric or reinforcing bars can be most effective in: bridge approaches; over sections of unsatisfactory subgrade; in irregularly shaped slabs and slabs with length:width ratios greater than 1:25..

Thickness design

It is recommended that the computer program cncPave be used for determining the thickness of concrete pavements. The program requires a number of input variables and constants and contains an extensive help screen to guide users. The program can be obtained free of charge by registering on the website at www.cncipave.org.za and it will be e-mailed to those registering.

Joint design

Joints are provided in concrete pavements to:

- Limit stresses and control cracking resulting from restrained contraction and the effects of restrained warping and traffic loads.
- To facilitate construction and level control.
- To accommodate movements

Joints must provide adequate load transfer to ensure adequate performance of the pavement.

Three joint types are used in concrete pavement. They are:

- Longitudinal joints
- Transverse joints
- Isolation joints

Longitudinal joints

Longitudinal joints are installed to control cracking in the longitudinal direction. They can be either construction or contraction joints. On two-lane and multi-lane pavements, a spacing of 3,0 to 4,0 m serves the dual purpose of crack control and lane delineation. On arterial streets they should be spaced to provide traffic and parking lane delineation. Joint spacing should not be greater than 4,0 m. These joints depend on a tiebar to maintain load transfer, structural capacity and serviceability. (See Figure 3) In streets where the pavement is adequately laterally restrained by the backfill behind kerbs there may not be a need for the installation of tiebars. However on roads not restrained from lateral movement, tiebars must be placed at mid depth of the slab at spacings of 600 or 750 mm. For pavement widths in excess of 15 m, untied joints should be used to ensure that no more than 15 m is tied together.

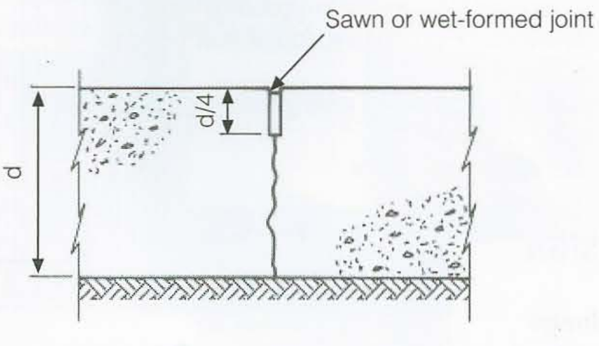


Figure 2: Transverse contraction joint.

TECHNICAL PAPER (cont.)

Transverse joints
These joints are used to control cracking across the width of the pavement, relieve tensile stresses that occur when the slab contracts, and curling stresses caused by temperature and moisture gradients in the slab. They can be either construction or contraction joints

Contraction joints (See Figure 2) may be constructed by sawing after the concrete has set, or by installing a plastic strip to be left in place, or by inserting a preformed material into the plastic concrete. The selection of the method to be used is based on several factors, including weather during construction, the characteristics of the aggregate, the economics of the operation and results achieved. In any case, the depth of the joints should be equal to one quarter of the pavement thickness or one third for pavements on cement-stabilized subbases.

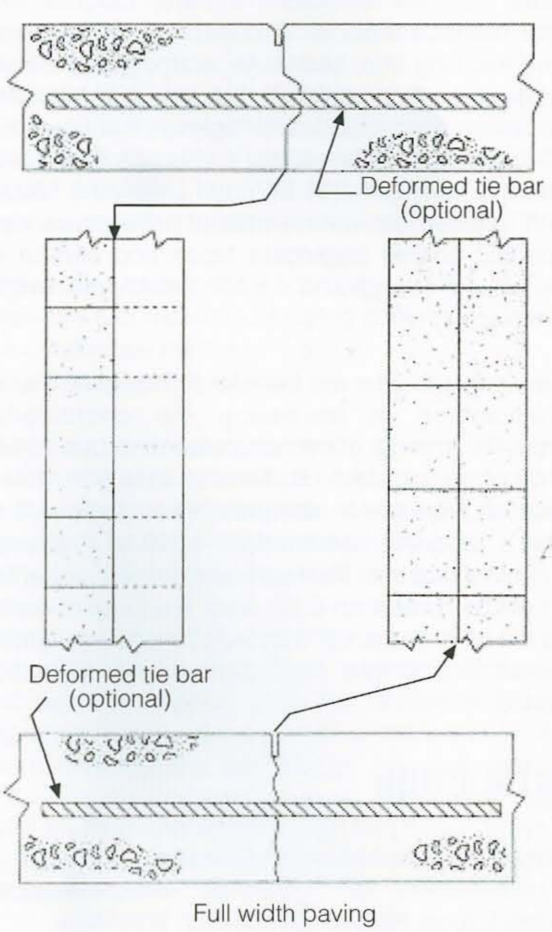


Figure 3: Longitudinal joints.

Construction joints are used at planned interruptions in paving operations, such as occur at the end of each day's paving and where unplanned or emergency interruptions exceeding 30 minutes occur, due to rain, equipment breakdown, or other reasons. Thirdly, they are used in "alternate panel" paving, in which alternate panels are cast between planned transverse and longitudinal construction joints. Transverse construction joints are usually keyed and untied.

Depending on the requirements of the particular thickness-design procedure used, load-transfer devices, such as round mild steel dowels, may be needed in transverse contraction joints to supplement load transfer by aggregate interlock (See Figure 4). They require careful installation. Because dowels complicate construction, aggregate-interlock joints are used where permitted by the specific thickness-design procedure used.

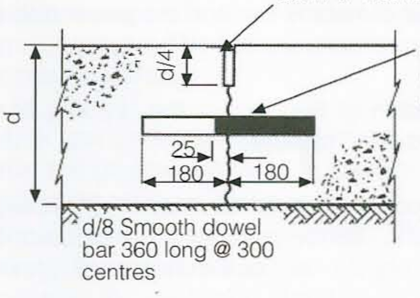


Figure 4: Dowelled transverse contraction joint

Isolation joints
Isolation joints isolate the pavement from a structure, another paved area or an immovable object. Isolation joints include full-depth, full-width joints at bridge approaches, T- and unsymmetrical intersections, ramps, or between old and new pavements. The term isolation joint also refers to joints around in-pavement structures, such as drainage inlets, manholes, lighting structures and footings.

Joint layout
When designing the joint layout in concrete pavement, the following guidelines and criteria should be applied:
1. Avoid odd-shaped panels.
2. Maximum spacing of longitudinal joints: 3,8 m.
3. Maximum spacing of transverse joints: 25 times pavement thickness, subject to a maximum of 4,5 m.
4. Keep panels as square as possible.
5. Joints should meet at a point to obviate any risk of reflection cracking into adjacent lanes. Stepping of

TECHNICAL PAPER (cont.)

joints is therefore not recommended.

6. Angles of less than 60 degrees should be avoided.
7. All structures, such as manholes, should be isolated from the pavement.
8. Adjacent pavement in these locations should be thickened by 20%.
9. Non-rectangular panels and panels surrounding manholes should be reinforced with 0,15 % mesh in each of two mutually perpendicular directions, 50 mm from the top surface. Reinforcement should be terminated 75 mm on either side of joints and should not be continued through joints.

Joint sealing

The role of joint sealant is to minimize infiltration of surface water and incompressibles into the pavement joint. Incompressibles cause point-bearing pressures which may lead to spalling and/or blow-ups. There seems to be no disadvantages in leaving narrow (2 to 3,5 mm wide) transverse contraction joints unsealed when:

- Traffic is light;
- Traffic is heavy, but the climate is dry; or
- Traffic is heavy, the climate is wet and the pavement is doweled.

An annual precipitation of 800 mm is the dividing line between a "wet" and "dry" climate.

Construction and contraction joints requiring sealing may be sealed with either preformed elastomeric compression joint seals or one-component, low-modulus silicone.

MATERIALS AND PROPERTIES

Aggregates

Satisfactory aggregates are those that comply generally with SABS Specification 1083 Aggregates from natural sources - Aggregates for concrete.

Cement

Cement should be CEM I or CEM II A complying with the requirements of SABS ENV 197. Where extenders (ground granulated blastfurnace slag or fly ash) are used, they should comply with the requirements of SABS 1491. When extenders are used, allowances should be made in the concrete mix design, particularly with regard to early strength under field conditions to ensure timeous cutting of joints. Curing methods and regimes may also have to be improved, especially in inclement weather.

Chemical admixtures

Under certain circumstances the properties of paving concrete may be improved by the proper use of chemical admixtures, such as water-reducing and air-entraining admixtures. Their use should be based on an evaluation of their effects on specific materials and combinations of materials, including strength development, particularly within the first 24h after concrete placing. This is because certain admixtures may retard the setting and strength development of the concrete, thus delaying joint sawing and increasing the risk of random cracking.

Consistence of fresh concrete

Establishment of the optimum consistence of the concrete is usually left to the contractor, dependent on his method of construction, and approved by the engineer. Consistence may be measured by means of a slump test or by means of a Vebe test. With hand paving, concrete consistence is usually measured by means of a slump test. Typically, a slump of 70 to 120 mm is used for hand-compacted concrete, and 30 to 70 mm for vibrated concrete.

Properties of hardened concrete

Concrete for use in concrete pavement should possess adequate strength to ensure a hard, durable, skid-resistant surface and to accommodate the tensile stresses resulting from shrinkage, warping and loading. This requirement is satisfied by specifying a target flexural strength or modulus of rupture of not less than 3,8 MPa at 28 days. Generally, a characteristic 28-day compressive strength of 30 MPa will satisfy the flexural-strength requirement, unless alluvial pebbles are used. With certain coarse aggregate types and careful mix design, flexural strengths of 4,5 MPa and higher may be achieved.

High flexural strengths are beneficial. However, there is little advantage in increasing the characteristic compressive strength of the concrete mix above 30 MPa to achieve an increase in flexural strength. This is because an increase in compressive strength will not produce a proportionate increase in flexural strength. For durability reasons, the maximum water:cement ratio should not be more than 0,52. Also, the cement content should not be less than 310 kg/m3. These requirements may result in strengths significantly higher than those mentioned above.

CONSTRUCTION

Roadbeds, subgrades and subbases

The construction of roadbeds, subgrades, and subbases follows normal construction practices.

Forms for concrete

While either steel or wood forms could be used, only steel forms should generally be permitted. The exceptions are where the project is small and relatively

TECHNICAL PAPER (cont.)

unimportant or steel forms are unsuitable (e.g. short-radius curves).

Only forms capable of supporting the loads imposed by the paving equipment should be used. Forms should be provided with adequate devices for secure setting so that when in place they will withstand, without visible spring or settlement, the impact and vibration of the compacting and finishing equipment. When checked for straightness, forms should not vary by more than 3 mm in 3 m from the true plane surface on the top, and 6 mm in 3 m along the face of the form. When set, the forms should be uniformly supported for their entire length and be at the proper elevation. Forms should be set sufficiently in advance of concrete placing so as to permit progress and inspection of the work.

Forms should remain in place at least 8 h after concrete placing. When the air temperature falls below 10(C at any time during 8 h from the time of concrete placing, the forms should be left in place for such longer period as is necessary to ensure that pavement edges will not be damaged. Curing of exposed concrete pavement edges should begin immediately upon removal of forms.

Concrete
Good practice is recommended for the production and transport of concrete. Ready-mixed concrete should be mixed, handled, and transported to the site in accordance with the requirements of SABS 878.

Methods of laying
There are two methods of laying concrete pavement:
The continuous method.
The alternate-panel method.

With the continuous method, a strip of concrete pavement is laid continuously and transverse joints are made either in the plastic concrete as work proceeds, or later sawn in the semi-hardened concrete. This latter method is the normal method of construction.

With the alternate-panel method, a panel of concrete is laid, compacted and finished between stop-ends; the next panel is missed; then the next is laid, between stop-ends, and so on, alternately. After 4 to 7 days the intermediate panels are filled in. A keyed construction joint is provided between each panel. The alternate panel method should generally be used only on minor works. With hand laying, lane-at-a-time paving is advisable.

There are two basic methods of mechanized concrete paving: sideform and slipform. Where mechanized paving is not feasible, manual laying has to be adopted.

For manual laying of concrete paving, the concrete will generally be supplied from a ready-mix truck, or dump truck. The use of pumps, conveyors or other equipment may be necessary in congested areas. The concrete should be deposited evenly and in a manner that requires a minimum amount of rehandling or redistribution. It should be placed at a sufficient depth to provide a proper surcharge for subsequent finishing operations. If the slab is to be reinforced, the steel should be supported on stools at the proper location, and the concrete compacted from the surface.

All concrete should be fully compacted during and/or immediately after placing, special measures being taken to compact concrete adjacent to sideforms.

Two methods are available for compacting pavement to be laid by manual methods, hand tamping or hand-operated vibrating beam
Immersion (poker) vibrators are, however, used to supplement compacting by hand tamper or vibrating beam.

To remove minor irregularities and promote good surface regularity a bull float or a scraping straightedge may be used. The latter is particularly advantageous for close tolerances.

After the concrete has been compacted and finished, the still-plastic concrete is textured to provide a skid-resistant surface. The coarse texture may be achieved by means of several methods. These include burlap dragging, wire brushing, and tining. Burlap dragging is suitable for roads and streets with traffic speeds below 60 km/h and consists of dragging a burlap longitudinally over the surface of the pavement to produce a uniform texture with corrugations about 1,5 mm in depth.

Brooming/brushing is suitable for both low-speed and high-speed roads in noise-sensitive areas. Brushing may be done either by hand or by mechanical brushes of a type that will produce surface corrugations reasonably uniform in appearance and to a depth of about 1,5 mm. Brushing is normally executed in a transverse direction. Brushes should have stiff bristles, spaced to produce an acceptable texture. Brushing should be completed before the concrete is in such condition of set that the surface would be torn or unduly roughened by the operation.

Deep transverse grooving is suitable for high-speed roads in areas which are not noise sensitive. This texture consists of the application of a burlap drag finish, followed by grooving of the concrete surface using a tining device. Directly after completing the burlap finish, the surface of the pavement is grooved with a metal tining device. The tines on the device consist of flat spring steel, approximately 0,6 mm x 3,0 mm in section

TECHNICAL PAPER (cont.)

and 125 mm in length, and spaced between 12 mm and 25 mm in an approved random pattern. Space transverse tines randomly as follows: minimum spacing 10 mm, maximum spacing 40 mm, with no more than 50% of the tines more than 25 mm apart. Space longitudinal tines uniformly at 20 mm. Form the tines to a depth of 3 - 6 mm. Where tining is done manually, the tining device may be operated against a straightedge to ensure straight grooves.

From the time concrete has been placed and compacted, and until it is a few days old, it must be protected against damage that can be caused by environmental factors.

Curing is the process of ensuring that the moisture content of the concrete is sufficient for cementing reactions to proceed. Immediately after the finishing operations have been completed the entire surface of the newly placed concrete should be cured. This is best accomplished by uniformly applying, by means of a suitable atomizing spray, an approved white-pigmented, resin-based or chlorinated-rubber-based, membrane-forming compound. The compound should be applied at a rate of 5,0 m2/l for standard applications, 3,75 m2/l for fast track applications and 2,5 m2/l for slabs thinner than 125 mm.

When the road is laid by the continuous-strip method, joints must be either wet-formed in the plastic concrete as work proceeds, or sawn prior to the development of cracking. The sawing technique is the best available at present, and should be considered for important routes. For less important routes, a suitable wet-forming technique (See Figure 5) may be more economical than sawing, particularly if joints do not require sealing.

Sawn joints are created by sawing grooves in the surface of the pavement with an approved concrete saw. Sawing of transverse contraction joints should begin as soon as the concrete has hardened sufficiently to permit sawing without excessive ravelling, usually 4 to 24 h. All contraction joints should be sawn before uncontrolled cracking occurs. The use of ultra-light saws or dry cut saws may allow significantly earlier cutting of joints, thereby reducing the risk of random cracking

One method of forming a transverse contraction joint, and recommended for low-volume concrete roads, consists of depressing into the plastic concrete, by means of a T-bar, a strip of polyethylene sheeting laid across the concrete (see Fig 5). Some hand finishing will inevitably be required, but over-finishing should be avoided, because it tends to weaken the concrete surface in the joint area. It is important that the strips be installed normal to the surface and not below it.

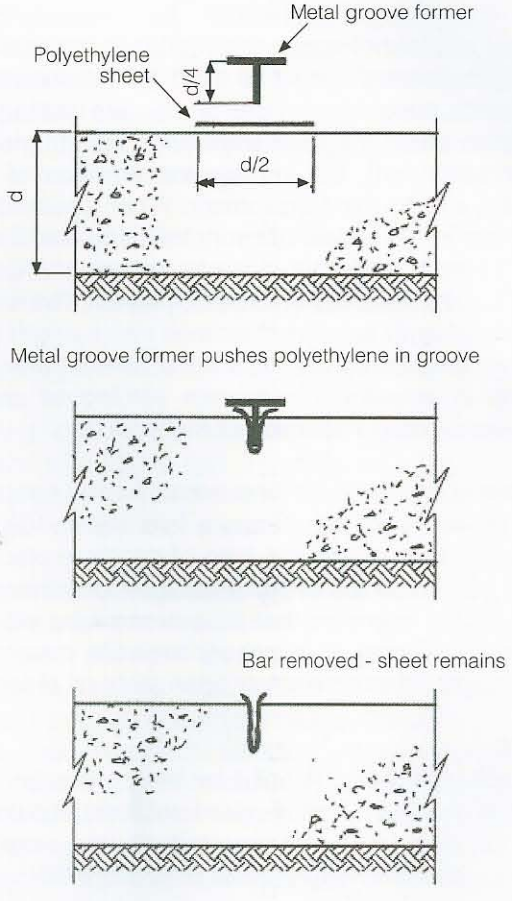


Figure 5: Steps in wet-forming a contraction joint

REFERENCE

Perrie, B. Low-volume concrete roads, Midrand: Cement and Concrete Institute, 2000.