The Design, Construction and Maintenance of Otta Seals

Guideline no 1

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The Design, Construction and Maintenance of Otta Seals
Ministry of Works, Transport & Communications,
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ROADS DEPARTMENT

Under the policy direction of the Ministry of Works, Transport & Communications, Roads Department is responsible for providing an adequate, safe, cost-effective and efficient road infrastructure within the borders of Botswana as well as for facilitating cross-border road communications with neighbouring countries. Implied in these far-ranging responsibilities is the obligation to:

1. ensure that existing roads are adequately maintained in order to provide appropriate level of service for road users;
2. improve existing roads to required standards to enable them to carry prevailing levels of traffic with the required degree of safety;
3. provide new roads to the required geometric, pavement design and safety standards.

The Department has been vested with the strategic responsibility for overall management of the Public Highway Network (PHN) of some 18,300 km of roads. This confers authority for setting of national specifications and standards and sheared responsibility with the District Councils and Department of Wildlife and National Parks for the co-ordinated planning of the PHN.

Roads Department is also responsible for administering the relevant sections of the Public Roads Act, assisting local road authorities on technical matters and providing assistance in the national effort to promote citizen contractors in the road construction industry by giving technical advice wherever possible. This task is facilitated by the publication of a series of Technical Guidelines dealing with standards, general procedures and best practice on a variety of aspects of the planning, design, construction and maintenance of roads in Botswana that take full account of local conditions.

In its endeavour to provide uniformity of practice in the provision of efficient and effective road infrastructure, Roads Department has embarked on the preparation and publication of a number of Technical Guidelines. The main objective of these Guidelines is to document best practice and to preserve local knowledge on a variety of aspects of road planning, design, construction and maintenance that have evolved over many years in Botswana.

Guideline No. 1 The Design, Construction and Maintenance of Otta Seals (1999)
FOREWORD

An Otta Seal surfacing was first constructed in Botswana in 1978 on the Oodi - Modipane road. Since then, this type of bituminous surfacing has been used successfully on more than 1000 km of roads comprising more than 20 per cent of the primary and secondary road network of the country.

Experience has shown that, in appropriate circumstances, Otta Seal surfacings can be very cost-effective when compared with more traditional bituminous surfacings such as single or double surface dressings (Chip Seals). Moreover, Otta Seals are particularly well suited for use with local materials which may be non-standard or of marginal quality and have proved to be very durable and cost-effective in the harsh, semi-arid climate that prevails in Botswana.

The main objective of the Otta Seal Guideline is to provide a ready, practical reference for engineers and technicians at Roads Department and District Councils as well as for consultants, contractors and other organisations that are involved in the specification, design, construction and maintenance of bituminous surfacings. The Guideline provides detailed guidance on the materials constituents and selection criteria for the Otta Seal as well as a general approach to its design, construction and maintenance. Consideration is also given to various contractual issues associated with the use of Otta Seals and, for completeness, a model specification is also provided.

It is my hope that the Otta Seal Guideline will provide useful guidance to practitioners and promote the continued wide-spread use of this innovative type of bituminous surfacing in situations favouring its adoption.

Gaborone 1999 - 06 - 20

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Director of Roads
Roads Department
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The production of the Guideline has been a joint effort between the Roads Department and the NPRA; its preparation was co-ordinated by Mr. Charles Overby of the NPRA, who has been responsible for introducing Otta Seals to Botswana as well as to a number of countries in East and Southern Africa and Bangladesh.

A number of people were involved in commenting on various drafts of the Guideline including, in particular, Mr. Rolf Johansen, Norconsult International for his critical comments and advice, and Messrs. Michael Pinard and Bernard Obika of Roads Department for their significant contributions to the document.

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1 INTRODUCTION

1.1 The Guideline

Background
Dwindling resources for the provision of low volume roads in many developing and industrialised countries have prompted road engineers to search for and develop innovative methods of road design and construction in order to reduce costs and at the same time not impair the quality of the end product. Very often, consideration has to be given to the use of local materials, which may be non-standard or of marginal quality, in situations where the use of conventional materials could be prohibitively expensive.

One area where cost savings can be made in road construction is with the judicious choice of bituminous surfacing. Normally, the selection of the most cost-effective surfacing would be based on a life cycle analysis of appropriate surfacing types in which the influence of a range of factors is investigated. One type of surfacing which has proven to be eminently cost-effective in appropriate situations is the Otta Seal using graded aggregate.

Purpose and scope
The main purpose of this Guideline is to provide practical guidance on the design, construction and maintenance of Otta Seals. In so doing, the intention is to improve the understanding of this type of road surfacing and to promote its use, not only in Botswana, but also elsewhere in Southern Africa and other countries where optimum use has to be made of the limited funds available for road construction and maintenance. The Guideline is based on the experience gained from more than 20 years of the use of Otta Seals in Botswana and elsewhere.

It is emphasised that this Guideline should be used for the purpose intended, i.e. as a guideline and not as a prescriptive approach or standardised way of designing, constructing or maintaining Otta Seals. Some judgement will always have to be exercised in arriving at decisions regarding the parameters that are incorporated in particular designs.

The Guideline is intended for use by the various organisations associated with the design, construction and maintenance of Otta Seals. These organisations include employers, consultants, contractors and materials suppliers.

Structure
The guideline contains nine main chapters and three Appendices. Following the general introduction and provision of an overview of the role and function of bituminous surfacings which are given in this Chapter, Chapter 2 provides details of the Otta Seal, including its origin, description and performance characteristics. This is followed by the Chapters 3 and 4 which describe the materials constituents of the Otta Seal. Chapter 5 then outlines the various selection criteria affecting the choice of surfacing followed by the Chapters 6, 7 and 8 which deal with the design, construction and maintenance of Otta Seals respectively. Finally, Chapter 9 deals with various contractual issues associated with the use of Otta Seals.

A model specification for a single Otta Seal is also provided in Appendix A. Appendix B and C gives Mass/Volume Conversion Tables and Abbreviations, respectively.
1.2 Bituminous Surfacings

Role and function
Bituminous surfacings are an integral component of paved roads and perform a number of functions that offer many advantages over unsealed roads. These include:

- Provision of a durable, impervious surfacing which seals and protects the pavement layers from moisture ingress and consequent loss of pavement strength and degradation;
- Provision of a skid-resistant surface which can resist the abrasive and disruptive forces of traffic and the environment;
- Prevention of the formation of corrugations, dust and mud which generally permits relatively safe travel at higher speeds and lower vehicle operating and maintenance costs.

As for all bituminised roads, the pavement strength must be adequate to carry the anticipated traffic loading.

Types
Various types of bituminous surfacing have been used on the Public Highway Network in this country. These have included:

- Sand Seals
- Surface Dressings (Chip Seal)
- Cape Seals
- Otta Seals
- Asphaltic Concrete (varying thickness)

The above seal types are illustrated in Figure 1.1.

![Figure 1.1 Schematic illustration of various types of bituminous surfacings.](image)
Factors affecting choice
The choice of bituminous surfacing in any given situation will depend on a number of factors which include the following:

- Type of pavement (strength, flexural properties, etc);
- Economic and financial factors (funds available, life cycle costs, etc.);
- Riding quality required;
- Operational factors (traffic, surface stresses, geometry, etc.);
- Safety (surface texture, interference with traffic, etc.);
- Environmental considerations (climate, noise, etc.);
- Construction and maintenance strategies;
- Characteristics of available materials (aggregate, binder, etc).

Subject to the surfacing meeting various technical and environmental requirements, a life cycle cost comparison of alternative surfacing types should be carried out as a basis for determining the most cost-effective solution. Such a comparison would normally consider not only initial construction costs, but also maintenance and vehicle operating costs.
2 HISTORY AND PERFORMANCE CHARACTERISTICS OF OTTA SEALS

2.1 Origin

An Otta Seal is a particular type of bituminous surfacing that was originally developed in the early 1960’s by the Norwegian Road Research Laboratory. It derives its name from the location in Norway where it was first used - the Otta Valley.

Although originally intended to serve as a temporary surfacing for newly constructed gravel roads, its good performance has led to its adoption as a permanent single or double seal surfacing for both new and existing roads in a number of countries. These include Scandinavia, Iceland, East and Southern Africa and, to a limited extent, Bangladesh.

2.2 Description and types

Otta Seals consist essentially of a 16 - 32 mm thick bituminous surfacing constituted of an admixture of graded aggregates ranging from natural gravel to crushed rock in combination with relatively soft (low viscosity) binders, with or without a sand seal cover. This type of surfacing contrasts with the single sized crushed aggregate and relatively hard (high viscosity) binders used in conventional surface dressings e.g. Chip Seals.

There are various types of Otta Seals in terms of number of layers, type of aggregate grading and whether or not a cover sand seal is used. These various types may, in general, be summarised as follows:

1. **Single Otta Seal**
   - aggregate grading “open”, “medium” or “dense”
   - with sand cover seal
   - without sand cover seal

2. **Double Otta Seal**
   - aggregate grading “open”, “medium” or “dense”
   - with sand cover seal
   - without sand cover seal

The choice of type of Otta Seal is dependent on a number of factors which are described in Chapter 6.

2.3 History of Otta Seals in Botswana

**The first project**

The use of Otta Seals in Botswana dates back to 1978 when this type of surfacing was first used on the Oodi - Modipane road under the Rural Roads Project. Single and double layers were constructed, both on primed and unprimed base courses. The aggregate used was a natural gravel derived from decomposed granite with the following key properties:

- maximum particle size ≥ 19 mm
- % passing 0.075 mm sieve: up to 14%
plasticity Index: between Slightly Plastic and 8%
aggregate Crushing Value: approximately 40%

Both MC 800 and MC 3000 cutback bitumen were applied using a bitumen distributor. The aggregate was hand-screened and spread on the road by hand. The various types of Otta Seals used on the Oodi - Modipane road all performed well for more than eight years, carrying up to 300 vehicles per day.

The period 1978 to 1998
By mid-1998 more than 1000 km of both primary and secondary roads had been constructed using mostly a single Otta Seal with a Kalahari sand cover seal. Mainly crushed aggregates were used from a variety of material sources. Many of these roads have performed very well after more than 12 years in service and have exhibited no significant surfacing defects.

2.4 Mechanism of performance
The mechanism of performance of Otta Seals is quite different to that of the more conventional Chip Seals. These differences may be summarised as follows:

Otta Seal: Graded aggregate is placed on a relatively thick film of comparatively soft binder which, on rolling and trafficking, can work its way upwards through the aggregate interstices. In this manner, the graded aggregate relies both on mechanical interlocking and bitumen binding for its strength - a bit like a bituminous premix.

Traffic of the seal immediately after rolling is desirable and its final appearance is formed after 4-8 weeks giving a “premix” like appearance in the wheel paths. Priming of the base is normally not required.

Chip Seal: In the case of the conventional Chip Seal surfacing, aggregate is placed on a film of comparatively hard binder with the objective of “gluing” the former to the latter. Thus, the Chip Seal relies very much on the bond between the binder and the aggregate for its strength. If this bond is insufficient (e.g. due to the use of a too thin binder film or the occurrence of in-service embrittlement due to binder oxidation) then ravelling will occur. Moreover, the selection of the respective aggregate sizes is critical to ensure interlocking between the first and second layers. Traffic on the surfacing needs to be carefully controlled until the binder is finally set. Priming of the base is normally required.

The concept of bleeding should also be viewed quite differently between Otta Seals and the more conventional Chip Seals. In the former, if excess bitumen works its way to the surface during rolling or trafficking, it can simply be blinded with fine aggregate or coarse to fine sand. The fine aggregate (or sand) tends to be fairly readily coated by the comparatively soft binder and work its way into the interstices of the graded aggregate to produce a tight, closely knit surface which looks very much like a conventional premix. In contrast, bleeding of Chip Seals can be more problematic due to the difficulty of coating the fine blinding aggregate (or sand) with a relatively harder binder.

Due to the differences in the mechanism of performance between Otta Seals and Chip Seals, it is important to recognise that their respective methods of design and construction should not be assumed to be similar.
Figure 2.1 illustrates the difference in make-up and mechanism of performance of a Single Otta Seal in comparison to a Single Chip Seal.

**Single Otta Seal (0-16 mm). Thickness: minimum 16 mm**

**Single Chip Seal (13.2 mm). Thickness = ALD (8 to 10 mm)**

**Figure 2.1  Mechanism of performance, a single Otta Seal compared to a single Chip Seal.**

### 2.5 Performance characteristics

**General**
The performance of Otta Seals depends (as for all other types of surfacing) on a number of factors such as:
- type of Otta Seal, (texture, durability etc.)
- bearing capacity of the pavement
- traffic using the road

**Durability - texture**
The dense, closed texture of an Otta Seal, which is further enhanced with the use of a cover sand seal, is particularly advantageous in the hot temperature conditions that occur in the country. In such conditions, high solar radiation significantly increases the rate of oxidation of the surfacing binder which occurs less quickly with Otta Seals as compared with the more conventional Chip Seals.

**Flexibility**
Long service lives experienced in Kenya with Otta Seals placed on pavements with relatively high Benkelman Beam deflections (in excess of 1.25 mm) indicate that this type of seal exhibits excellent flexibility.

**Traffic**
The Otta Seal concept is not considered to have any limitations regarding traffic volumes than would not also apply to any other type of sprayed bituminous surfacing.
2.6 Relative advantages and disadvantages

Otta Seals differ in many respects from conventional sprayed bituminous surfacings such as Chip Seals.

One of the major advantages offered by Otta Seals is their ability to perform well with aggregates of relatively low quality in terms of strength, shape, texture and dust content, giving rise to cost savings which can be considerable depending on project location, availability of aggregates and bitumen price. However, as with other types of bituminous surfacings, Otta Seals possess both advantages and disadvantages that are described below.

Advantages
Some of the factors favouring the use of Otta Seals include situations were:

- Road construction is taking place in remote areas where, for example, only natural gravels occur, such as in the western Kalahari areas of the country, and where it may be prohibitively expensive to set up crushing facilities;
- Workmanship may be of indifferent quality;
- Flexibility and durability of the surfacing are required to tolerate, for example, comparatively low quality, low bearing capacity pavements with high deflections;
- There is a low maintenance capability;
- High solar radiation levels prevail.

Disadvantages
One of the main disadvantages of Otta Seals is their initial, inconsistent and somewhat patchy appearance during the first 4 - 6 months of their service life. During this stage, the surface may appear rich in bitumen or may even “bleed”, necessitating the spreading of sand or crusher dust over the affected area to absorb the excess of bitumen. This tends to give the erroneous impression to the lay person that something is wrong with the surfacing or that it is of inferior quality to the more traditional Chip Seal. However, this is certainly NOT the case. After some 8 - 12 weeks of trafficking the surfacing will start to “bed down” and will provide a more uniform and consistent appearance which looks somewhat like the more expensive Asphaltic Concrete that is generally used on very heavily trafficked roads.

Another disadvantage with the use of Otta Seals is with regard to the need to consider a number of additional contractual issues that need to be specially dealt with in the Contract Documents. These issues are discussed in Chapter 9. Table 2.1 describes the relative differences between Otta Seals and conventional Chip Seals and indicates the qualitative differences between the two types of surfacing.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Otta Seal</th>
<th>Conventional Chip Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate quality</td>
<td>Relaxed requirements for: strength, grading, particle shape, binder adhesion, dust content. Maximises use of locally available natural gravel or of the crushed product.</td>
<td>Stringent requirements for: strength, grading, particle shape, binder adhesion, dust content. Maximised use of the crushed product is difficult, use of natural gravel is in practice inappropriate.</td>
</tr>
<tr>
<td>Binder type</td>
<td>Relatively soft binders (low viscosity) are required: 150/200 penetration grade or MC3000 or MC800 cutback bitumen.</td>
<td>Relatively hard binders are required for necessary stone retention: (80/100 pen. grade under Botswana conditions).</td>
</tr>
<tr>
<td>Design</td>
<td>Empirical approach to design. Relied earlier to a large extent on experience and site trials.</td>
<td>Empirically based rational design methods.</td>
</tr>
<tr>
<td>Construction technique</td>
<td>Relatively little sensitivity to standards of workmanship. Labour intensive methods easy to apply if desired.</td>
<td>Sensitive to standards of workmanship. Labour intensive methods difficult to apply.</td>
</tr>
<tr>
<td>Construction costs</td>
<td>In most instances costs are lower than Chip Seals, up to 40% depending on the availability of aggregate.</td>
<td>Cost competitive only where good quarries are located nearby; the bitumen price is high and the traffic volumes are high (&gt; 500 vpd).</td>
</tr>
<tr>
<td>Contractual matters</td>
<td>Additional contractual issues need to be resolved.</td>
<td>Contractual issues well-known</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>An appealing, uniform appearance can be difficult to achieve. However, such an achievement is not necessarily an indicator of a good result for Otta Seals.</td>
<td>Ranges between a very appealing and a poor appearance depending on quality of construction workmanship.</td>
</tr>
<tr>
<td>Skid resistance in wet weather</td>
<td>Poorer than a Chip Seal that is well designed and constructed using large chipping. However better than Slurry Seals and Asphalt Concrete.</td>
<td>Ranges between the extremes of excellent and very poor depending on quality of construction workmanship.</td>
</tr>
<tr>
<td>Use on fresh bituminous base layers</td>
<td>Not suitable due to the need for high bitumen contents required for quick rise of the binder through the aggregate interstices.</td>
<td>Suitable, but requires careful design and construction if excessive bleeding is to be avoided.</td>
</tr>
<tr>
<td>Periodic maintenance between reseals</td>
<td>Generally little need for periodic maintenance between reseals.</td>
<td>Rejuvenation with emulsion fog spray between reseals is normally required for maintaining stone retention.</td>
</tr>
<tr>
<td>Durability of the seal</td>
<td>The use of relatively soft binders and a dense matrix enhances durability of seal.</td>
<td>The use of relatively hard binders reduces the durability of the seal.</td>
</tr>
<tr>
<td>Typical service life</td>
<td>Typical service life: Double Otta Seal: 12 – 15 years, Single Otta Seal with a sand cover seal: 9 – 11 years.</td>
<td>Typical service life: Double Chip Seal: 8 - 10 years, Single Chip Seal: 5 - 6 years. Adequately workmanship is essential.</td>
</tr>
</tbody>
</table>

Table 2.1 Relative differences between Otta Seals and conventional Chip Seals.
3 AGGREGATES

3.1 Key properties

A large variety of material sources can be used for the production of graded aggregate for use in Otta Seals. The following materials are among those that have been used successfully in the country:

- screened natural gravel from weathered granitic rocks;
- crushed and screened gravel from sandstone and lake deposits (Lake Ngami quartzite deposits);
- screened river/lake gravel and sand;
- crushed, screened rock from a variety of rock types such as igneous rocks and pedogenic deposits of calcrete and silcrete.

Aggregate strength

Aggregates of relatively lower strength may be used for Otta Seals, compared to those typically specified for conventional Chip Seals (See Table 3.1).

Grading

The aggregate grading for Otta Seals is relatively relaxed and allows for a rather wide grading envelope. However, the grading curve of the aggregate should fall within the designated area and should be as “smooth” and parallel to the envelopes as possible. Table 3.1 gives the general grading requirements for Otta Seals.

3.2 Screened natural gravel

‘As-dug’ gravel should be screened to remove oversize particles and excessive fines. A low moisture content in the material is desirable to avoid clogging of the finer mesh of the sieve. If moist material cannot be avoided, it may be necessary to increase the mesh size of the sieve. The presence of fines in the screened material is acceptable provided appropriate compensation is made for the binder viscosity, binder application rate and construction methodology.

3.3 Crushed aggregate

Crushed gravel

The wide grading envelope requirement of Otta Seals allows a relatively higher proportion of the crushed product to be used compared to Chip Seals. Crushing allows a better utilisation of the gravel sources and generally improves the quality of the aggregate. The bulk of the crushed gravel product is normally utilised in Otta Seals resulting in little or no wastage. However, high establishment costs may prohibit crushing of gravel on smaller projects.

Crushed rock

Crushed rock is usually the most widely used type of aggregate for any surfacing in the country, including Otta Seals. A general rule of thumb is that any crushed material acceptable in the base course layer can be used to produce aggregate for an Otta Seal surfacing.

The general approach is to select the appropriate binder viscosity type and binder application rates to suit the available aggregate.

Although the aggregate strength requirements are relaxed, it is always good practice to select the best quality of materials that are economically available in the project area.

The wide grading envelope allowed for the Otta Seal maximises the use of natural gravel (as-dug material), which in many cases requires only screening of oversize materials by use of a power screen (Mahalapye – Machaneng road).

Screening may be carried out by the use of labour based methods or by a power screen. Labour based methods were used extensively in the late 1970’s and early 1980’s by the Direct Labour Division of Roads Department in the construction of sealed rural roads throughout the country.

Crushed gravel has been the most commonly used type of aggregate for Otta Seals in Botswana dating back to the mid 1980’s. Relatively large deposits of material are necessary from an economic point of view and the number of sources suitable for this process are limited to a few isolated locations known to date. These deposits are found between Khakea and Werda (sand stone), near Lake Ngami (ancient lake deposit of quartzitic gravel) and near Gweta (silcrete in an ancient river bed).

Experience has shown that the best performance of an Otta Seal may be obtained when 30% of the aggregate is crushed. However, this should not be considered as “a rule of thumb”.

The Design, Construction and Maintenance of Otta Seals
3.4 Aggregate for sand cover seals

A sand cover seal is normally applied over a single Otta Seal instead of using a double Otta Seal for low volume roads (< 500 AADT). The aggregate for the sand cover seal will normally consist of crusher dust or screened river sand. Alternatively, Kalahari sand can be used if no better material is available within an economical haulage distance.

3.5 Aggregate requirements

**General**

The preferred aggregate grading will, to some extent, depend on the traffic volume at the time of construction, as well as during the two months immediately following the sealing operation, as this contributes significantly in forming the Otta Seal.

**Maximum particle size**

The preferred maximum particle size is 16 mm, but ±19 mm can be accepted in the first seal where a double seal is to be constructed.

**Fines content**

The amount of fines (<0,075 mm) should preferably not exceed 10%. A higher fines content may result in construction problems, as the binder tends to coat the finer particles before the larger ones, and may lead to a less durable surfacing with inferior surfacing characteristics. However, aggregate with fines contents up to 15% have performed well on one project in Botswana, and no surfacing defects have yet been recorded due to excessive fines contents on any project in the country.

**General grading envelopes and aggregate strength**

Table 3.1 shows the aggregate requirements for an Otta Seal and Figure 3.1 the general grading envelope. The aggregate strength requirements are shown in Table 3.2.

<table>
<thead>
<tr>
<th>Material properties</th>
<th>Requirements</th>
<th>TMH test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasticity Index</td>
<td>max 10</td>
<td>A 3</td>
</tr>
<tr>
<td>Flakiness Index</td>
<td>max 30 (applies only for crushed material)</td>
<td>B 3T</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Sieve sizes [mm]</th>
<th>Overall grading requirements [% passing]</th>
</tr>
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<tbody>
<tr>
<td>19</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>80 - 100</td>
</tr>
<tr>
<td>13.2</td>
<td>52 - 100</td>
</tr>
<tr>
<td>9.5</td>
<td>36 - 98</td>
</tr>
<tr>
<td>6.7</td>
<td>20 - 80</td>
</tr>
<tr>
<td>4.75</td>
<td>10 - 70</td>
</tr>
<tr>
<td>2.00</td>
<td>0 - 48</td>
</tr>
<tr>
<td>1.18</td>
<td>0 - 38</td>
</tr>
<tr>
<td>0.425</td>
<td>0 - 25</td>
</tr>
<tr>
<td>0.075</td>
<td>0 - 10</td>
</tr>
</tbody>
</table>

Table 3.1 Material requirements for Otta Seals.
Figure 3.1 General grading envelope for Otta Seal aggregates.

<table>
<thead>
<tr>
<th>Aggregate strength requirements</th>
<th>Vehicles per day at the time of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 100</td>
</tr>
<tr>
<td>Min. Dry 10% FACT</td>
<td>90 kN</td>
</tr>
<tr>
<td>Min. Wet/Dry strength ratio</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Table 3.2 Aggregate strength requirements for Otta Seals.

**Flakiness**

No requirement for flakiness is specified for natural gravel or a mixture of crushed and natural gravel in Otta Seals. For crushed rock, it is preferable that the weighted Flakiness Index does not exceed 30. The weighted Flakiness Index is determined on the following fractions:

9.5 - 13.2 mm, 6.7 - 9.5 mm and 4.75 - 6.7 mm

**Sand cover seals**

Material for a sand cover seal used in Otta Seals can be crusher dust, river sand or Kalahari sand or a combination of these materials. The material should be free from organic matter and lumps of clay and should be non-plastic. All material should preferably pass the 6.7 mm sieve.

The required aggregate strength for Otta Seals is lower than that of a Chip Seal. Lower strengths can be tolerated because the graded particle matrix results in less internal pressure caused by stone to stone contact. The soft binders used in Otta Seals are, in addition, able to surround, coat and hold in place any particle that may break during rolling.
4 BINDERS

4.1 Desirable characteristics

The correct choice of binder for Otta Seals is critical for its performance and a good result requires that both the binder type and application rate are tailored to the aggregate properties. Binders used for Otta Seals should:

1. be soft enough to initially coat the fines in the aggregate;
2. be soft enough to rapidly move up through the matrix of aggregate voids by the action of rolling and traffic;
3. remain soft long enough to continue moving up through the matrix of aggregate voids over a period of 4 to 8 weeks;
4. be able to be applied in a large enough quantity in one spray operation.

In addition to the above, the following binder properties are desirable in any bituminous seal. The binder must:

- be viscous enough to provide sufficient stability after the initial curing of the seal;
- be durable enough to give the expected service life;
- be able to be used with available equipment and skills;
- be environmentally friendly to the greater possible extent;
- be economical in use.

4.2 Types

General

A general description of selected binder types and their potential use in Otta Seals is given below.

Penetration grade bitumen

80/100 penetration grade bitumen, which is normally used with conventional Chip Seals in the country, does not meet the requirements for Otta Seals and should NEVER be used for such surfacings. The hardest type of bitumen that can be used for Otta Seals is the 150/200 penetration grade which has been successfully used in the country, particularly during hot periods.

Local experience suggests that that 150/200 has generally performed well for crushed rock aggregate provided it is cut back with 5% power paraffin when used during the cold months of the year.

Cutback bitumen

Cutback bitumen in the MC 3000 and MC 800 viscosity range has also been used extensively in the country.

Bitumen emulsion

Emulsions have never been used for Otta Seals in this country, although it has been used in the Scandinavian countries with limited success. Emulsions are generally difficult to apply in a large enough quantity without run-off along the road’s cross fall or gradient, and do not remain soft for long enough
unless produced especially for this purpose. Specially made emulsions from suppliers are, however, unlikely to be economical for use in Botswana. Moreover, production of any type of emulsion on site is a specialised operation that entails quality control problems, hence this process is not recommended.

**Tar**
Tar has not been used in Otta Seals because it tends to harden much more rapidly than bitumen, thus compromising the service life of the seal. Furthermore, tars have serious environmental disadvantages and their use in road surfacings is not recommended.

**Modified bitumen**
Binders modified with rubber, SBS, SBR, PVA or other constituents have not been tried in Otta Seals. Any modified binders that are known on the market have too high a viscosity for use in Otta Seals and are therefore generally not suitable. In theory, however, there is no reason why a modified binder cannot be specially tailored to provide the properties that Otta Seals require, but such applications can only be recommended for trials.

### 4.3 Properties

**Applicable binders for Otta Seals**
Under Botswana conditions, the range of acceptable binder viscosities for Otta Seals is provided by the following standard types:

- MC 800 cut back bitumen (softest)
- MC 3000 cut back bitumen (medium)
- 150/200 penetration grade bitumen (hardest)

These binders are available locally and supplied directly from the refineries. The process of manufacture at the refineries varies. The 150/200 is often a softened (fluxed) 80/100 straight run bitumen. The cutbacks are frequently produced from a blown stock harder than 80/100 which has been cut back with a type of kerosene known locally as power paraffin to give the required viscosity.

**Durability of cutback bitumen**
The long-term durability of manufactured cut back bitumen (MC 3000 and MC 800) that is available locally is not acceptable. This is due to the production process which entails blending from a hard base bitumen. Improved durability is achieved by producing cut back bitumen on site from a softer base bitumen such as 150/200 or 80/100 penetration grades, rather than using cutbacks supplied directly from the manufacturers.

### 4.4 Blending on site

**General**
Blending of bitumen on site may be desirable for one or more of the following reasons:
- The viscosity of the medium curing (MC) cutback bitumen (e.g. MC 3000, MC 800, MC 70, MC 30) is determined by the amount of cutter used, not the type of cutter.
- The type of cutter used determines the length of time (Rapid, Medium or Slow) required for evaporation of the volatiles to take place, producing RC, MC or SC grades.

Under normal circumstances MC cutters will evaporate from the seal within 8 - 12 weeks.

Diesel as a cutter will produce a slow curing (SC) cutback bitumen that remains soft over a long period. Evaporation may take in excess of six months to occur and will cause unnecessarily prolonged bleeding and, at worst, instability of the seal.

- to obtain the required viscosity of cutback bitumen (by cutting back with an appropriate cutter);
- to enable use of a preferred type of base bitumen;
- to ‘permanently’ soften a penetration grade bitumen that is too hard (by fluxing);
- to improve the durability of a bitumen (by fluxing);
- to simplify handling and storage where a number of binder types are required on the same site (by cutting back or fluxing).

**Cutters**

Cutting back is the addition of volatile oils to produce a temporary reduction of the binder’s viscosity. The volatility of the cutter used will influence the type of cut back bitumen that will be produced in terms of whether it is rapid, medium or slow curing.

Table 4.1 shows the cutters that produce the respective types of cutback bitumen.

<table>
<thead>
<tr>
<th>Grade of the produced cutback</th>
<th>Cutter</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC (Rapid Curing)</td>
<td>Petrol</td>
<td>Hazardous, should not be used</td>
</tr>
<tr>
<td>MC (Medium Curing)</td>
<td>Kerosene (Power paraffin, JetA1 aviation turbine fuel)</td>
<td>Suitable for Otta Seals</td>
</tr>
<tr>
<td>SC (Slow Curing)</td>
<td>Diesel or heavy fuel oils</td>
<td>Curing process too slow for Otta Seals</td>
</tr>
</tbody>
</table>

*Table 4.1 Cutters.*

An Otta Seal will in most cases require a cutter that produces a medium curing (MC) cutback bitumen. Power paraffin is normally preferred among the cutting oils producing a MC cutback bitumen. Illuminating paraffin and JET A1 may also be used depending on the prevailing price.

**Flux oil**

Fluxing is the addition of heavy oil that affects the long-term viscosity and durability of the binder. Fluxing slows down the hardening process of the bitumen and, within certain limits will produce a more durable seal. Engine oil, unused or used, is suitable for this purpose. Fluxing should be carried out in moderation, as there is a risk of disintegration of the seal if the binder is excessively fluxed.

**Blending proportions**

The cutter proportions presented in Table 4.2 are indicative for blending with the penetration grades 80/100 or 150/200 respectively.
### Table 4.2 Typical blending proportions to produce medium curing cutback bitumen.

<table>
<thead>
<tr>
<th>Required product</th>
<th>Cutter (power paraffin) in percent of total mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80/100 base bitumen</td>
</tr>
<tr>
<td>150/200</td>
<td>3-5% (flux oil is used instead of cutter)</td>
</tr>
<tr>
<td>MC 3000</td>
<td>8 - 10 % *)</td>
</tr>
<tr>
<td>MC 800</td>
<td>18 - 20 % *)</td>
</tr>
</tbody>
</table>

*) The durability of the binder can be improved by replacing 3% of points of the cutter with flux oil where the 80/100 penetration grade is used as base bitumen.

### Safety precautions

Blending of cutback bitumen on site may be hazardous. Correct procedures should be followed during blending and appropriate safety precautions against fire and hot bituminous spray should be taken to safeguard personnel involved in the operations. Precautions are also necessary to ensure that the public is kept at a safe distance from the blending site.

The following safety precautions should be adhered to:

- The blending site shall be located at a minimum distance of 100 metres from installations, homes or places that people occupy;
- No open fire or smoking shall be allowed during the blending operation within a radius of 100 metres. This includes heaters in bitumen tanks;
- The blending site should be at least 100 metres away from cutter and fuel storage tanks.

It is emphasised that the blending process shall be kept fully under the responsibility of qualified personnel.

### Blending operations

Cutter or flux oil should not be mixed with bitumen having a higher temperature than 140°C. This is due to the hazards of flammable gas emission from the tank. The correct procedure is to pre-heat the bitumen to 140°C and either pump the cold cutter or flux oil into the bottom of the tank through the designed hose and valve, or to pump the hot bitumen over in a new, cold tank already containing the cutter or flux oil. The following precautions should be strictly adhered to as the blending operation is a hazardous one and causes considerable risk of explosion and fire.

- The manhole should NEVER be used for adding cutter or flux oil to hot bitumen;
- Cutter or flux oil should NEVER be pumped into an empty tank that is still hot after having contained bitumen;
- The bitumen level in the tank should NEVER be allowed to fall below that specified by the manufacturer while the heaters are in operation. This is normally a minimum of 150 mm above the highest point of the heater pipes.

After combining bitumen with cutter or flux oil the mixture shall immediately be circulated for 1 hour in order to ensure a homogenous product.
4.5 Temperatures for storage and spraying

Recommended temperatures for storage and spraying of binders are shown in Table 4.3.

<table>
<thead>
<tr>
<th>Bitumen product</th>
<th>Storage temp. °C</th>
<th>Spraying temp. °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 24 hours</td>
<td>&gt; 24 hours</td>
</tr>
<tr>
<td>150/200</td>
<td>165</td>
<td>115</td>
</tr>
<tr>
<td>MC 3000</td>
<td>155</td>
<td>100</td>
</tr>
<tr>
<td>MC 800</td>
<td>120</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 4.3 Recommended storage and spraying temperatures.

4.6 Anti-stripping agent

**General**

The adhesion between bitumen and aggregate depends on close contact between the two materials. Stripping is the breaking of the adhesive bond between the aggregate surface and the bitumen, normally by water displacing the bitumen because water has greater surface tension than bitumen. By adding a comparatively small quantity of anti-stripping agent to the bitumen, the surface tension of the water is reduced and the bitumen is able to wet aggregate surfaces. In general, adhesion agents are intended to:

- promote adhesion of binder to wet aggregate;
- prevent loss of adhesion under influence of immediate rain after construction;
- provide satisfactory adhesion during construction.

The use of anti-stripping agent is always recommended when using natural gravel with a high fines content. However, good performance has been reported without the use of additives. When crushed material is used, appropriate laboratory testing should be carried out to identify the need for anti-stripping agent.

**Handling and dosage of anti-stripping agents**

Anti-stripping agents are usually corrosive and require the use of protective gloves and eye goggles during handling. Liquid agents can easily cause splashing and require special care. Some ‘solid’ agents may appear in a liquid form, depending on ambient temperature, and should be treated with equal caution.

Normal dosage of anti-stripping agent is 0.5% to 0.8% by weight of bitumen. Appendix B gives the Mass/Volume conversion tables.

The most common method of achieving the admixture is to pour the calculated amount of additive into the bitumen distributor immediately before the spraying operation is to start and to allow 30 minutes of circulation to ensure a homogenous mix.

Anti-stripping agents that have been kept hot in the bitumen distributor for more than five hours should be considered stale. An additional dosage would then be required, amounting to half of the originally specified percentage.
4.7 Prime

General
Priming of base courses made of non-calcareous material is normally not required when using Otta Seals. However, when using calcrete of any type in the base course, priming is warranted due to the high amount of bitumen absorption.

Types of prime
Cutback bitumen with a viscosity in the range 30 - 140 cSt (MC 30 or MC 70) is normally used for priming. Tar primes have serious environmental disadvantages and are not recommended for use as primes.

Application rate
A prime is normally applied at an application rate of between 0.8 and 1.2 l/m². Calcrete base courses require application rates in the high range and a lower viscosity of the prime than other types of base course material. High soluble salts content in the base course require high application rates or the use of an emulsion tack coat (see Roads Department Guideline for the prevention of salt damage).

Priming can, in some instances, provide practical benefits for reasons such as wet weather conditions, problems with traffic control or as a preferred construction procedure for operational reasons. However, Otta Seals do not require priming of the base course to function well.

There are negligible cost savings arising from the use of tars in Botswana because the cost of transporting binders generally outweighs the cost of the product itself.
5 SURFACING SELECTION CRITERIA

5.1 Factors influencing choice of surfacing

There are a number of factors that need to be taken into account when selecting the most appropriate type of bituminous seal. This will always be the case whether it is new construction, rehabilitation or reseal work. The initial construction cost for various types of bituminous surfacings depends on a variety of factors including the cost of prospecting for aggregate and the construction methodology adopted. In addition to initial construction costs, maintenance and vehicle operating costs should be considered as well (e.g. life-cycle cost) as a basis for selecting the most cost-effective surfacing type.

5.2 Life expectancy

Different types of surfacings will provide different service lives for given site conditions. Table 5.1 shows the life expectancy for the various types of Otta Seal and a Double Chip Seal. These have been derived from experience gained in the country and in Kenya.

<table>
<thead>
<tr>
<th>Type of Otta Seals</th>
<th>Expected service life [years]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Otta Seal</td>
<td>No cover seal</td>
</tr>
<tr>
<td></td>
<td>Fine sand in the sand cover seal</td>
</tr>
<tr>
<td></td>
<td>Crusher dust or river sand in the sand cover seal</td>
</tr>
<tr>
<td>Double Otta Seal</td>
<td></td>
</tr>
<tr>
<td>Double Chip Seal</td>
<td></td>
</tr>
<tr>
<td>Frequency of rejuvenation (fog spray)</td>
<td>2 - 3</td>
</tr>
</tbody>
</table>

Table 5.1 Life Expectancy for various types of Otta Seals and a Double Chip Seal.

5.3 Economic assessment of Otta Seals versus Chip Seals

An economic assessment of the alternative surfacing seals should always be carried out in order to select the most cost-effective solution.

As different seals vary in construction cost, and give varying maintenance-free lives, an economical comparison between a Double Chip Seal and the various type of Otta Seals should not only consider the initial construction costs, but also include the cost of required future maintenance such as rejuvenation (fog spray) reseals and road markings over an appropriate analysis period.
In order to obtain life-cycle costs for alternative surfacing types the following are required for the calculations:

- Initial construction cost;
- Fog sprays (number required and cost);
- Reseals (number required and cost);
- New road markings after each intervention (number required and cost);
- Discount and inflation rates.

The relative construction cost of a Double Otta Seal with a cover sand seal compared with a Double Chip Seal (cost factor 1.0) from experienced gained in the country is indicated in Table 5.2.

<table>
<thead>
<tr>
<th>Project Features</th>
<th>High traffic AADT &gt; 500</th>
<th>Low traffic AADT &lt; 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long haulage of acceptable chipping (&gt; 100 km)</td>
<td>0,8</td>
<td>0,7</td>
</tr>
<tr>
<td>Quarry sites for chipping are close to project (&lt; 25 km)</td>
<td>1,1</td>
<td>1,0</td>
</tr>
</tbody>
</table>

Note: The cost of a Chip Seal = 1.0

Table 5.2 Relative construction costs of a Double Otta Seal and a Double Chip Seal.

All types of surfacing seals will normally lend themselves to simple, although different maintenance techniques such as fog spraying, rescaling or slurry sealing. Fog sprays with diluted emulsion have been found to be cost-effective for Chip Seals where the seal is beginning to ravel. If this is done before the seal starts to disintegrate, the service life of the seal can be prolonged.

The life-cycle maintenance strategy for Otta Seals and Chip Seals in this country have been compared and the results are presented in Table 5.3.

<table>
<thead>
<tr>
<th>Life expectancy, activities and construction costs</th>
<th>Single Otta Seal + sand cover</th>
<th>Double Otta Seal</th>
<th>Double Chip Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life expectancy (years)</td>
<td>11</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Maintenance activities (years)</td>
<td>None</td>
<td>None</td>
<td>Fog sprays after 3 and 10 years. Reseal after 8 years. Road marking after each intervention (3 times).</td>
</tr>
<tr>
<td>Initial relative cost of construction</td>
<td>1.0</td>
<td>1.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Chipping size used for 11 and 15 years analysis period 13.2 mm + 6.7 mm and 19.0 mm + 13.2 mm, respectively.

To simplify the life-cycle cost analysis it has been assumed that no other type of maintenance will take place during the analysis period and that vehicle operation costs are the same for both Otta Seals and Double Chip Seal.

Table 5.3 Maintenance intervention for lifetime cost comparison of different type of seals.
6 DESIGN

6.1 Factors influencing the design
The design of Otta Seals is based on empirical methods, rather than the more rational methods used for Chip Seals.

The principles governing the design of Otta Seals are based closely on the inter-relationship between the aggregate used and the binder viscosity and spray rates adopted, which means that the binders used will always be tailored to the type of aggregate produced.

Otta Seals may be constructed as a single or double layer, with or without a sand cover seal, and the choice of a particular type of Otta Seal is normally based on the following considerations:

- properties of available aggregate
- traffic volume
- construction cost
- required service life

In the design of Otta Seals, the type of bitumen and the bitumen spray rates are initially established based on typical values of the main parameters determining the design. Variations in the site conditions or aggregate grading at the time of construction may require adjustments of spray rates on site. Changes in binder viscosity may also be necessary where the variations in site conditions or materials are significant.

The procedures to be followed in the design of Otta Seals are shown as a flow chart in Figure 6.1.

6.2 Selection of Otta Seal type

**Double Otta Seal**
The Double Otta Seal is the most durable, but also the most expensive and is recommended for main roads carrying high volumes of traffic. Double Otta Seals with a cover sand seal are seldom specified due to their high costs and marginal benefits.

**Single Otta Seal with sand cover seal**
The combination of a Single Otta Seal followed by a sand cover seal is a cheaper option than a Double Otta Seal. The service-life will however, be shorter, but the former provides a very cost-effective solution for roads with AADT generally less than 500. The benefits of using a sand cover seal are the following:

- improved stone retention in the underlying seal;
- enhanced durability due to increased binder thickness and the forming of a dense surface texture;
- protection of the aggregate in the underlying seal in the case of marginal quality of materials;
- reduced risk of damage in the case of imperfections in the underlying seal.
Figure 6.1 Flow chart for the design procedures of Otta Seal.

**Single Otta Seals**

Single Otta Seals are not commonly used in this country, as they require high standards of workmanship to perform well, as is the case for all types of single seals.

Table 6.1 shows recommended Otta Seal types in relation to traffic level and the type of sealing work to be carried out. However, the given recommendations are flexible and will be project dependent.

<table>
<thead>
<tr>
<th>Traffic levels and type of work</th>
<th>Type Otta Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary seal (diversions, haul roads, temporary accesses, etc.)</td>
<td>Single Otta Seal</td>
</tr>
<tr>
<td>Maintenance resealing (all traffic classes to which sprayed surfacings are)</td>
<td>Single Otta Seal</td>
</tr>
<tr>
<td>AADT less than 500</td>
<td>Single Otta Seal + sand cover seal</td>
</tr>
<tr>
<td>AADT more than 500</td>
<td>Double Otta Seal</td>
</tr>
</tbody>
</table>

*Table 6.1 Recommended type of Otta Seal in relation to traffic levels.*
6.3 Preferred aggregate grading

The design of Otta Seals allows for a variety of aggregate gradings to be used as long as the grading curve falls within the designated area of the general grading envelope (ref. Figure 3.1) and runs as “smoothly” and parallel to the envelope as possible.

As guidance for the designer of Otta Seals, three grading envelopes, depending on traffic, have been produced to allow for a more rational design. However, the designer should always bear in mind that generally all types of aggregate which fall within the general specified envelope can be used, provided the binder viscosity and spray rates are tailored accordingly.

The only limitation regarding the aggregate grading used in an Otta Seal is with regard to the “Open” grading which should not be used for traffic volumes above AADT 1000.

Table 6.2 indicates the preferred aggregate grading for design purposes according to traffic volume.

<table>
<thead>
<tr>
<th>AADT</th>
<th>Best suited grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 100</td>
<td>“Open”</td>
</tr>
<tr>
<td>100 - 1000</td>
<td>“Medium”</td>
</tr>
<tr>
<td>More than 1000</td>
<td>“Dense”</td>
</tr>
</tbody>
</table>

Table 6.2 Preferred aggregate grading for Otta Seals.

The grading envelopes for “Open”, “Medium” and “Dense” grading are given Table 6.3, the design procedure for Otta Seals.

6.4 Type of binder

Table 6.3 shows the recommended type of binder for Otta Seals made with the three respective aggregate gradings under typical site conditions as described in the table.

Where “weak” natural gravel containing a fairly high proportion of fines is used the correct binder type will be MC 3000 or even MC 800 viscosity range, depending on weather conditions.

It should be noted that in Table 6.3 MC 3000 viscosity grade bitumen is recommended for use with “Medium” grading aggregates in cold weather. However, project experience in the country has shown that for crushed stone aggregate 150/200 pen. bitumen, cutback slightly with power paraffin during the cold months has also worked well.

6.5 Binder spray rates

The required binder spray rates for Otta Seals varies according to the following parameters:

- traffic (AADT)
- aggregate grading (open / medium / dense)
- the absorbency of the aggregate particles
- whether the base course is primed or not
Hot spray rates lower than 1,4 l/m² should not be allowed.

For aggregates with a water absorbency of more than 2%, the hot spray rate should be increased by 0,3 l/m².

In the case where the base has been primed the hot spray rate should be decreased by 0,2 l/m² for the first layer.

### 1. ALTERNATIVE GRADING ENVELOPES

<table>
<thead>
<tr>
<th>Sieve sizes (mm)</th>
<th>Open grading (% passing)</th>
<th>Medium grading (% passing)</th>
<th>Dense grading (% passing)</th>
<th>TMH test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>A 1</td>
</tr>
<tr>
<td>16</td>
<td>80 – 100</td>
<td>84 – 100</td>
<td>93 – 100</td>
<td></td>
</tr>
<tr>
<td>13,2</td>
<td>52 – 82</td>
<td>68 – 94</td>
<td>84 – 100</td>
<td></td>
</tr>
<tr>
<td>9,5</td>
<td>36 – 58</td>
<td>44 – 73</td>
<td>70 – 98</td>
<td></td>
</tr>
<tr>
<td>6,7</td>
<td>20 – 40</td>
<td>29 – 54</td>
<td>54 – 80</td>
<td></td>
</tr>
<tr>
<td>4,75</td>
<td>10 – 30</td>
<td>19 – 42</td>
<td>44 – 70</td>
<td></td>
</tr>
<tr>
<td>2,00</td>
<td>0 – 8</td>
<td>3 – 18</td>
<td>20 – 48</td>
<td></td>
</tr>
<tr>
<td>1,18</td>
<td>0 – 5</td>
<td>1 – 14</td>
<td>15 – 38</td>
<td></td>
</tr>
<tr>
<td>0,425</td>
<td>0 – 2</td>
<td>0 – 6</td>
<td>7 – 25</td>
<td></td>
</tr>
<tr>
<td>0,075</td>
<td>0 – 1</td>
<td>0 – 2</td>
<td>3 – 10</td>
<td></td>
</tr>
</tbody>
</table>

Any material falling within the Open, Medium and Dense grading envelopes may be used as aggregate in an Otta Seal. However, for a traffic level AADT > 1000 vpd. at the time of construction. Material within the Open grading envelope shall NOT be used.

### 2. CHOICE OF BITUMEN IN RELATION TO TRAFFIC AND GRADING

<table>
<thead>
<tr>
<th>AADT at the time of construction</th>
<th>Type of bitumen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open grading</td>
</tr>
<tr>
<td>More than 1000</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>100 - 1000</td>
<td>150/200 pen. grade</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 100</td>
<td>150/200 pen. grade</td>
</tr>
</tbody>
</table>

80/100 pen. grade bitumen shall NEVER be used in Otta Seals unless softened or cut back to meet the above viscosity requirements.

The cut back bitumen grades can be made by blending 80/100 pen. grade on site using the following proportions:
To make 150/200 pen. grade: 3 - 5% softener mixed with 95 - 97 % 80/100 pen. grade.
Softener can be a purpose-made petroleum distillate, alternatively engine oil, old or new. In addition 3% points of power paraffin shall be used.

The cut back bitumen grades can be made by blending 150/200 pen. grade on site using the following proportions:
To make MC 3000: 5 - 8% power paraffin mixed with 92 - 95% 150/200 pen. grade.
To make MC 800: 15 - 18 power paraffin mixed with 82 - 85% 150/200 pen. grade.

Circulation in the tank shall be carried out for at least 1 hour after mixing.
Diesel shall not be used for cutting back to MC grades.

Table 6.3 a Design procedures for Otta Seals.
3. BITUMEN SPRAY RATES

Hot bitumen spray rates for un-primed base course (l/m²)

<table>
<thead>
<tr>
<th>Type of Otta Seal</th>
<th>Grading</th>
<th>Open</th>
<th>Medium</th>
<th>Dense AADT &lt;100</th>
<th>Dense AADT &gt;100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double</td>
<td>1st layer</td>
<td>1.6</td>
<td>1.7</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>2nd layer (*)</td>
<td>1.5</td>
<td>1.6</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Single, with a sand cover seal</td>
<td>Fine sand</td>
<td>0.7</td>
<td>0.7</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Crusher dust or coarse river sand</td>
<td>0.9</td>
<td>0.8</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>1st layer (*)</td>
<td>1.6</td>
<td>1.7</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Single (*)</td>
<td></td>
<td>1.7</td>
<td>1.8</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Maintenance reseal (single)</td>
<td></td>
<td>1.5</td>
<td>1.6</td>
<td>1.8</td>
<td>1.7</td>
</tr>
</tbody>
</table>

(*) On a primed base course the spray rate shall be reduced by 2.0 l/m² in the first layer.

Notes:
- Where the aggregate has a water absorbency of more than 2%, the bitumen spray rate shall be increased by 0.3 l/m².
- Binder for sand cover seal shall be MC 3000 for crusher dust or coarse river sand, MC 800 for fine sand.

4. AGGREGATE APPLICATION RATES

<table>
<thead>
<tr>
<th>Type of seal</th>
<th>Aggregate spread rates (m³/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open grading</td>
</tr>
<tr>
<td>Otto Seals</td>
<td>0.013 – 0.016</td>
</tr>
<tr>
<td>Sand cover seals</td>
<td>0.010 – 0.012</td>
</tr>
</tbody>
</table>

In practice, the aggregate application rates will very often be increased in order to reduce the risk of bleeding.

Table 6.3b Design procedures for Otta Seals.

6.6 Aggregate application rates

It is important to apply sufficient amounts of aggregate to ensure that there is some surplus material during rolling and through the initial curing period of the seal. This aggregate embedment will normally take about 2 weeks to be achieved where crushed aggregate is used, after which any excess aggregate can be swept off. Where natural gravel is used the initial curing period will be considerably longer.

The aggregate application rates should fall within the ranges given in table 6.3

Table 6.3 gives the criteria for selection of bitumen type and spray rates for the design of Otta Seals. No correction of bitumen spray rates should be made in the design to compensate for the solvent used in the cutback bitumen.

In contrast to the procedures adopted for the design of Chip Seals on shoulders, no special design procedure is required for Otta Seals on shoulders.
7 CONSTRUCTION

7.1 General
The construction of Otta Seals is generally similar to the conventional Chip Seal. The binder is sprayed onto the surface followed by the spreading and rolling of the aggregate. However, the use of prime is not essential for Otta Seals.

7.2 Preparation of base course

General
A good bond between the base course and the surfacing is as important for Otta Seals as for any bituminous seal.

Un-primed base course
The base course should be broomed free of all dust or any other foreign matter before commencing the surfacing operations. In order to suppress any dust, and to promote some penetration into the base course, it is necessary to carry out light watering prior to spraying the binder. After watering, the base course should be allowed to dry to a dampened state before the binder is sprayed.

Primed base course
The preparation of a primed surface for construction of Otta Seals is similar to good practice procedures adopted for placing any bituminous seal.

7.3 Sealing operations

General
In the construction of Otta Seals the following factors should be given particular attention:

On the day of construction
A rule of a thumb is to assume that a good result would have been achieved when one can see bitumen being pressed up in-between the aggregate particles, sparsely distributed in the wheel tracks of the chip spreader or truck wheels.

Sufficient rolling of the Otta Seal cannot be over-emphasised. A minimum of two pneumatic tyred rollers at a minimum weight of 12 tonnes or more are essential at the day of construction, as they have a superior ability to knead the binder upwards into the aggregate particles, and to apply pressure over the entire area. A minimum of 15 passes with a pneumatic tyred roller is required over the entire surface area, shoulders included, on the day of construction.

After the initial rolling is completed (on the day of construction) it may be an advantage to apply one pass with a 10-12 tonnes static tandem steel roller to improve the embedment of the larger aggregate. During this process any weak aggregate will be broken down and will contribute to the production of a dense matrix texture.

Table 7.1 gives the minimum rolling requirements.
The use of loaded trucks to assist in the rolling, following a pre-determined rolling pattern has proved to give significant improvement of the Otto Seal per-formance.

Any bridging caused by the one pass of the steel roller will be taken out by the pneumatic rollers.

In the absence of pneumatic rollers, compaction can be successfully carried out by the use of loaded trucks following a pre-determined rolling pattern covering the entire surfaced area.

Surplus cover material is always needed in the construction of an Otto Seal, and it is important to ensure that the aggregate application rate is sufficient to accommodate this requirement (ref. Chapter 6.6).

The inspections can subsequently take place at less frequent intervals until the seal has finally "bedded down".

**Table 7.1 Minimum rolling requirements.**

<table>
<thead>
<tr>
<th>Rolling after treatment</th>
<th>Minimum requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the day of construction</td>
<td>15 passes with pneumatic roller (weight &gt; 12 tonnes) + 1 pass with a static steel roller</td>
</tr>
<tr>
<td>For each of the next two days after construction</td>
<td>15 passes with pneumatic roller (weight &gt; 12 tonnes)</td>
</tr>
<tr>
<td>2-3 weeks after construction</td>
<td>Sweep off any excess aggregate</td>
</tr>
</tbody>
</table>

Note: During construction a minimum of two pneumatic tyred rollers are required. One pneumatic tyred roller will either delay the surfacing operations or worse, not be able to roll the newly laid surfacing sufficient.

Commercial traffic should be allowed on the surfaced area immediately following completion of the initial rolling with the pneumatic roller(s). This will assist further in the kneading of the binder/aggregate admixture.

A maximum speed limit of 40 - 50 km/hour should be enforced immediately after construction and sustained for 2 - 3 weeks when any excess aggregate should be swept off.

### 7.4 Follow-up inspections

It is essential that follow-up inspections of the Otto Seal surfacing are carried out to ensure that any defects that may have occurred during the sealing operation are corrected.

An inspection must be made during the first 6 - 7 days following sealing, particularly if there is a major change in the weather conditions e.g. rainfall or an extreme change of temperature. A sudden change in traffic loading may also affect the newly constructed surfacing.

### 7.5 Immediate post-construction care

To successfully construct an Otto Seal, immediate post-construction care is important and should not be neglected. This includes additional rolling and brooming back of the aggregate that has been dislodged by traffic.

**The initial two days after construction**

During the first two days after sealing, extensive rolling by pneumatic rollers shall take place in order to ensure that all particles embedded in the binder are properly coated. A minimum of 15 passes with the pneumatic tyred roller shall be applied daily, covering the entire surfaced area.

**Subsequent 2 - 3 weeks after construction**

Aggregate that has been dislodged by traffic during the immediate post-construction period should be broomed back into the wheel tracks as required during the first 2 - 3 weeks. This ensures that maximum amounts of aggregate particles are embedded into the soft binder. A newly constructed Otto Seal may be dusty and could produce “flying stones” for the first few weeks after construction.

2 - 3 weeks after construction, any excess aggregate can be swept off and the traffic speed limitations can be lifted. If natural gravel with a fairly high content of fines is used the period should be prolonged.
A minimum period of 8 - 12 weeks should elapse between the construction of the first and the second layers. This is to allow as much traffic as possible to traverse the surfacing as well as to allow evaporation of the solvent. During this period, the surfacing becomes more settled and in the wheel paths, where the aggregate has become embedded by traffic, a “premix” like appearance should start to appear.

The initial occurrence of bleeding and isolated fatty spots should not be any cause of concern, and can be blinded off with aggregate and preferably rolled into the surfacing. Signs of slight bleeding confirm that the aggregate/binder ratio has been optimal.

If natural gravel having a fairly high fines content is used, the period before sweeping off the excess gravel should be prolonged as long as possible, and not less than 6 - 8 weeks.

**Bleeding**
Some bleeding in localised areas and in the wheel paths is a normal part of the curing process for Otta Seals. Any available fine aggregate can be used for blinding off, such as crusher dust, river sand or Kalahari sand. Where bleeding is extensive, a coarse aggregate may be used. It is advisable to apply rolling when blinding off the surface and to choose the hot time of the day for this work.

**7.6 Traffic management**
Traffic control is an important aspect that should not be overlooked as the early trafficking is a valuable contribution to the curing of the seal, leading to its enhanced performance.

The traffic management should be carried out in such a manner that the entire surfaced area, including shoulders, is equally exposed to traffic. This can be achieved by forcing the traffic into designated artificial lanes marked by traffic cones or similar.

**7.7 Additional considerations for Double Otta Seal and combination seals**

**General**
Special attention to certain details is required during construction of Double Otta Seal and combination seals using a sand cover seal.

**Curing**
It is important that the curing of the 1st seal is allowed to continue for a minimum of 8 - 12 weeks, depending on curing conditions and binder type, before applying the following seal. This is required to minimise prolonged fatting up due to cutter oil from the binder.

**Sand cover seal**
The most important factors to be observed in constructing a sand cover seal are to ensure that enough cover aggregate is applied, and that aggregate
dislodged by traffic is broomed back into the exposed areas as required. The back brooming should be repeated regularly until the sand is fully embedded in the first layer of the surfacing. This normally takes place after 4 weeks.

7.8 Important construction details

General

In addition to normal good construction practice certain construction details require particular attention when constructing sprayed bituminous surfacings, including Otta Seals.

Joints

Extra care is needed at all joints, both horizontal and longitudinal, to ensure that sufficient bitumen is sprayed and sufficient rolling and trafficking is applied. It is necessary to ensure that a minimum longitudinal joint overlap of 150 mm is attained and that additional heavy rolling is applied to even out the joints and the built up ridge caused by bitumen over-spray.

To avoid longitudinal joints it is preferable to spray the full width of the road in one pass if at all possible with the available equipment.

If longitudinal joints are necessary, they should be positioned outside the wheel tracks, i.e. along lane boundaries or the centre line.

Transverse joints should be constructed by normal good sealing techniques whereby start and finishing sheets are used, and the end of the previous section is blinded off to make an accurate starting line for the new section.

Any over or under application will cause either a bump, or aggregate stripping respectively. Transverse joints should never be placed on top of each other. These joints should be staggered by approximately 50 metres.

Intersections with yield sign or roundabouts

Due to the relatively soft binder and high binder application rate, heavy trucks may push the seal across the carriageway during the early life of the seal. This can cause ridges of bitumen to be formed, exposing the base in the bottom of the “ruts”.

In areas where this may be a problem, one should reduce the binder content by 0.3 l/m² and utilise a coarse aggregate grading. In cases where this is regarded to be a major problem, the binder should be 150/200 penetration grade, or if possible a penetration grade slightly harder than 150/200. This can be achieved by adding 2-3 % kerosene (power paraffin or illuminating paraffin) to 80/100 penetration grade bitumen.
8 MAINTENANCE

8.1 General

as a result of the enhanced durability characteristics of Otta Seals, maintenance intervention are not required to the extent necessary with conventional seals. Thus, such interventions as fog spraying, which is required every 3 - 4 years with Chip Seals, are unnecessary with the Otta Seals. Further, the resealing frequency for the Otta Seal varies between 9 - 15 years, depending on type of seal, whereof for Chip Seals the frequency is in the order of 7 years.

The repair and resealing of any localised surface defects are similar for the Otta Seal as for any other sprayed type of surfacing.

8.2 Use of Otta Seals as reseals

The use of Otta Seals as reseals do not differ from other sprayed types of bituminous reseals that are commonly used. The preparatory work necessary for a reseal using a conventional Chip Seal is also required for Otta Seals. However, in contrast to conventional Chip Seals where aggregate size requirements are an important factor depending on the existing seal aggregate, this meshing aggregate requirement does not apply for Otta Seals. Any aggregate size within the general grading envelope can be used.

The recommended spray rates for Otta reseals are given in Table 6.3.
9 CONTRACTUAL ISSUES

9.1 General
This Chapter deals with some of the important contractual issues which should be considered when specifying Otta Seals, particularly where it contrasts with a conventional Chip Seal. The approach to certain contractual issues differs from normal Chip Seal contracts and the following are considered to be important:

- The need to specify a minimum number of passes with the rolling equipment.
- The requirement for the Otta Seal to be trafficked for a minimum period of 8 - 12 weeks before the second or cover sand seal is applied.
- The back-brooming of dislodged crusher dust/sand to the exposed areas.
- The requirement that road marking cannot be applied until the second seal has settled down, usually several months after the first seal has been applied. There will be a need for temporary road markings in such situations.
- “Bleeding” and blinding of localised areas which may required that a small team must be available to undertake such operations, which may take place during the first hot season after the contract is completed.
- An allowance should be made in the Bill of Quantities for an additional item to clean off blinding sand, in case of extreme bleeding for the first seal, prior to the laying of second or sand cover seal.

The items listed above may present contractual problems unless they are unambiguously dealt with in the Contract Documents. The following section deals with measures that will cater for these items, which differ from contracts where a conventional Chip Seal is used.

9.1 Contractual issues
Rolling using pneumatic equipment
The “Special Technical Provisions” which form a part of the Contract Documents should include the following text:

- Any part of the surfaced area, shoulders included, shall receive not less than 15 passes with a pneumatic tyred roller with a gross weight of not less than 12 tonnes on the day of the sealing operations, and one pass with a static steel roller after the initial roller with the pneumatic roller is completed. In the following two days, further 15 passes with a pneumatic roller will be required on each day.

The Contractor must have sufficient roller capacity on site to achieve the above requirements. In practice, at least 2 pneumatic tyred rollers will be required in addition to the steel roller.

Any other additional rolling will be in accordance with the “payment item for additional passes”.

The Otta Seal requires to be trafficked for a minimum period of 8 – 12 weeks before the second seal or sand cover seal is applied.

This item can cause problems contractually, and may be dealt with as follows:

- “Substantial Completion” could be given when the Otta Seal is opened to traffic, provided there are no surface defects or other outstanding works which violate the “Road Traffic Act” (stop signs, speed limit signs, etc.). It may be necessary to employ temporary road markings for road safety purposes (project dependant).

After a further one month (i.e. approximately 4 months after “Substantial Completion” for the whole contract) the permanent road markings will be painted onto the road surface by the Contractor and the payment for permanent road marking made only at this stage.

The back-brooming of dislodged aggregates

A separate pay item for back-brooming of dislodged aggregate should be included in the Contract Documents, possibly as a rate per km.

Road marking

The road marking could be undertaken as a separate contract, since a good result is difficult to achieve until a great time after construction (this also applies to a lesser extent for ordinary Chip Seals). Such practice could be extended to capital as well as maintenance resealing projects.

If it is decided to include road marking in the main contract, then the contractor should be informed of this delay requirement in the contract documents. For safety reasons, some pre-marking or temporary lines may be painted on the road during the interim period.

Bleeding and blinding off

Experience within the country has shown that in some cases, especially where the binder application rate is on the high side, some blinding of fatty surface spots may be required during the first hot season after the contract has been completed and the contractor has moved off site. Allowance should be made in the contract for establishment of a team for blinding of the seal, if and when required, for a duration of 4 to 8 weeks.

This item must be included in the Bill of Quantities as a separate item, otherwise, payment may be under Day Works, which will be much more costly. The payment should be specified per km (not per sq. metre).

Cleaning off blinding sand on the first and second seal

This should be catered for as an additional pay item in the Contract Documents.

The payment should preferably also be per km.

Model Specifications

In order to assist in the preparation of the tender documents Appendix A contains a model specification for a Single Otta Seal with a cover seal using crusher dust or sand. The Model Specification should be amended to suit individual projects taking into account local conditions, project specifications and the foregoing discussions.
REFERENCES


11. **LGED 1994. Monitoring report, Environmental Road Trial, Faridpur, Bangladesh October.**


APPENDIX A

Model Specification for Single Otta Seal (crushed material) with cover sand seal

SECTION 4900C : OTTA SEAL

4901C SCOPE
This section covers the supply and application of Otta Seal surface treatment using a crushed material, and a sand or crusher dust cover sand seal. Reference shall be made to Section 4300: "Surface Treatment: Materials and general requirements", as provisions contained therein will not necessarily be repeated or specifically referred to in this section.

4902C MATERIALS
(a) Binders
150/200 penetration grade bitumen or MC 3000 cutback grade bitumen shall be used in warm weather. In cold weather, when night temperatures are likely to fall below 10°C, MC 800 cutback grade bitumen may be used or alternatively 150/200 penetration grade bitumen may be cutback with power paraffin to the appropriate viscosity range as directed by the Engineer. Table (to be inserted in the contract documents) shows the recommended type of binder for Otta Seals.

(b) Power paraffin for cutting back bitume
Power paraffin shall be used as the cutter and allowance shall be made for quantities between 0 – 18% by volume of the total quantity hot sprayed bitumen, depending on site conditions.

(c) Anti-stripping agent
When anti-stripping agent is required it shall be added to the bitumen immediately before the start of spraying operations and shall be circulated for a minimum period of 30 minutes prior to spraying. Anti-stripping agent that has been kept hot in the bitumen distributor for more than 5 hours shall be considered stale, and a further dosage amounting to half of the originally specified shall be added.

(d) Aggregate for Otta Seals
Crushed fresh rock material shall be used. The grading curve for the Otta Seal shall fall smoothly within the envelopes detailed in Figure (to be inserted in the contract documents). The upper nominal size shall not be larger than 16,0mm, if not otherwise directed by the Engineer to be 19,0mm nominal size.

The aggregate strength requirements shall be according to Table (to be inserted in the contract documents).

If crushed material is used the weighted Flakiness Index should be determined on the following fractions 9.5 – 13.2 mm, 6.7 - 9.5 mm and 4.75 - 6.7 mm sieves, and should not exceed 30.

(e) Sand for cover seal
The materials used can be crusher dust, river sand or Kalahari sand and shall be non-plastic, free from organic matter and lumps of clay. All the material shall pass the 6.7 mm sieve, unless otherwise approved by the Engineer.
4903C CONSTRUCTION

(a) General

(i) Granular bases of non-calcareous materials do not normally require a prime, unless otherwise directed by the Engineer. Calcrete bases shall always be primed.

(ii) The sealed surface shall receive not less than 15 passes of a pneumatic tyred roller on the day of sealing. On the same day, the Engineer may direct one pass with a 10 - 12 tonnes heavy tandem steel roller. During the following 2 days, the entire sealed area, including the shoulders, shall receive a further minimum of 15 passes daily, unless otherwise approved by the Engineer. A minimum of two pneumatic tyred rollers with a minimum weight of 12 tonnes shall be used for the rolling operations.

(iii) The Engineer may direct even trafficking of the surfaced area and channelling of the traffic may be required for certain periods and traffic cones or similar may be required.

(iv) The road should be opened to traffic immediately after the sealing operations are completed, but a maximum speed limit of 50km/h should be enforced during the initial 2 - 3 weeks after construction.

(v) Aggregate that has been dislodged by traffic during the immediate post construction period shall be broomed back into the exposed areas during the first 2 - 3 weeks, as directed by the Engineer.

(vi) After 2 - 3 weeks of trafficking the excess aggregate shall be swept off the road surface and the speed limitations can be lifted, unless otherwise directed by the Engineer. If natural gravel is used with a fairly high content of fines, the period may be extended to 6 weeks or as directed by the Engineer.

(vii) A team shall be retained on site to deal with areas of bleeding if required. The team will be required during the normal construction period as well as during the first hot season following the completion of sealing operations.

(viii) A minimum period of 8 - 12 weeks should normally elapse between construction of the subsequent layers of the surfacing, and during that period the road should receive as much heavy trafficking as possible, unless otherwise directed by the Engineer.

(ix) Prior to applying the sand cover seal, the surfaced area shall be broomed free of dust and loose stones or other foreign matter

(x) The sand cover seal shall receive on the day of surfacing not less than 15 passes of a pneumatic tyred roller with a minimum weight of 12 tonnes.

(xi) Sand that has been dislodged by traffic during the immediate post construction period shall be broomed back into the exposed areas during the first 2 - 3 weeks as directed by the Engineer.

(b) Equipment

Plant and equipment required for the construction of Otta Seals, as specified in Clause 4303 and Sub-Clause 4904A (a), shall be readily available on site.

(c) Preparation of Surface

The requirements of Clauses 4306 and 4307 and Section 4100 shall apply.

(d) Application of Surfacing

The binders, of the type and grade required, and the aggregates, of the size specified in the Bill of Quantities or ordered by the Engineer, shall be applied in accordance with the provisions of Sub-Clause 4308 (a).
(e) **Rates of Application of Material**

(i) **Binder**

All spray rates refer to hot spray rates of binder and shall fall within the ranges given in Table *(to be inserted in the contract documents)*. Penetration bitumen 150/200, MC 3000 or softer may be used. Power paraffin may be used as a cutter to obtain the required viscosity range as directed by the Engineer. Penetration bitumen 80/100 or stiffer shall not be allowed used unless cut back by the use of both a softener and power paraffin.

The binder for the Otta Seal shall be according to Table *(to be inserted in the contract documents)*. No hot spray rates lower than 1.4 l/sq.m shall be allowed. For tender purposes a rate of 1.7 l/sq.m shall be used. Absorbent aggregates with a water absorption of more than 2% shall require an additional 0.3 to 0.5 l/sq.m (in total) for both layers, as directed by the Engineer.

The binder for the sand or crusher dust seal shall be according to Table *(to be inserted in the contract documents)*. Penetration bitumen 150/200 shall not be used unless cut back by power paraffin to MC 3000 or MC 800 viscosity ranges.

Suitable hot spray rates shall range from 0.6 to 0.9 l/sq.m depending on the texture of the underlying seal and the type of sand/crusher dust used in the seal. For tender purposes a rate of 0.8 l/sq.m shall be used.

(ii) **Anti-stripping agent**

When required, the anti-stripping agent shall be mixed with the hot bitumen bitumen by 0.8% by weight of cold bitumen, or as directed by the Engineer.

(iii) **Aggregate**

The aggregate application rates for Otta Seal aggregate and crusher dust/sand for cover seal shall be in accordance with Table *(to be inserted in the contract documents)*.

For tender purposes a rate of 0.015 m³/m² shall be used for Otta Seal aggregate “Open-Medium” grading, and 0.018 m³/m² for “Dense” grading. For sand cover seal a rate of 0.011 m³/m² shall be used.

### MEASUREMENT AND PAYMENT

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4904C</strong></td>
<td></td>
</tr>
<tr>
<td><strong>49.01C</strong> Single Otta Seal (crushed material) with cover sand seal using crusher dust or sand using:</td>
<td></td>
</tr>
<tr>
<td>(a) 150/200 penetration grade bitumen</td>
<td>sq. m</td>
</tr>
<tr>
<td>(b) MC 3000 cutback bitumen viscosity grade</td>
<td>sq. m</td>
</tr>
<tr>
<td>(c) MC 800 cutback bitumen viscosity grade</td>
<td>sq. m</td>
</tr>
<tr>
<td><strong>49.02C</strong> Variations in bituminous binder</td>
<td></td>
</tr>
<tr>
<td>(a) 150/200 penetration grade bitumen</td>
<td>litre</td>
</tr>
<tr>
<td>(b) MC 3000 cutback bitumen viscosity grade</td>
<td>litre</td>
</tr>
<tr>
<td>(c) MC 800 cutback bitumen viscosity grade</td>
<td>litre</td>
</tr>
</tbody>
</table>
(d) Power paraffin .............................................................. litre

Item

49.03C Variations in anti-stripping agent

(a) Approved anti-stripping agent ........................................................... kg

Item

49.04C Variations in aggregate

(a) Otta Seal: crushed material ........................................... cubic metre
(b) crusher dust ................................................................ cubic metre
(c) sand ................................................................. cubic metre

The tendered rate shall include full compensation for furnishing all materials, for an unlimited free haul distance whether the crushed materials are obtained from a commercial source or an approved borrow-pit or quarry, marking the centreline, spraying of binders, spreading of aggregates, rolling, removing deleterious material, supplying of water and spraying of haul roads and construction roads, trimming the edges of the completed surf-face and all other incidentals necessary for completing the work as specified.

Item

49.07C Sweeping back dislodged aggregate into the wheel tracks, as directed by the Engineer ................................................................. km

Item

49.08C Attending to areas of fattiness and bleeding by applying fine aggregates or sand ................................................................. km

Item

49.09C Sweeping back dislodged sand into the wheel tracks, as directed by the Engineer ................................................................. km

Item

49.10C Supply and mixing of power paraffin for cutting back bitumen ................................................................. litre

Item

49.11C Supply and mixing of anti-stripping agent ................................................................. kg

Item

49.12C Providing cones for channelling traffic to ensure even trafficking ................................................................. .. no
# APPENDIX B

## Mass/Volume conversion Tables

**MEXPHALTE 80/100**

<table>
<thead>
<tr>
<th>MASS (kg)</th>
<th>20</th>
<th>100</th>
<th>105</th>
<th>110</th>
<th>115</th>
<th>120</th>
<th>125</th>
<th>130</th>
<th>135</th>
<th>140</th>
<th>145</th>
<th>150</th>
<th>155</th>
<th>160</th>
<th>165</th>
<th>170</th>
<th>175</th>
<th>180</th>
<th>185</th>
<th>190</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLUME (litres) at TEMPERATURE (°C)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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### MASS (kg)


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Roads Department

45
### SPRAMEX 150/200

#### Mass (kg)

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**ROADS DEPARTMENT**

*A Guide to the Design, Construction and Maintenance of Otta Seals*
### SHELMAC MC-800

**MASS (kg)** | **20** | **55** | **60** | **65** | **70** | **75** | **80** | **85** | **90** | **95** | **100** | **110** | **120** | **125** | **130** | **135**
---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---
**VOLUME (litres) at TEMPERATURE (°C)** | | | | | | | | | | | | | | | | | |

### SHELMAC MC-800

**MASS (kg)** | **6 000** | **7 000** | **8 000** | **9 000** | **10 000** | **11 000** | **12 000** | **13 000** | **14 000** | **15 000** | **16 000** | **17 000** | **18 000** | **19 000** | **20 000** | **21 000** | **22 000** | **23 000**
**VOLUME (litres) at TEMPERATURE (°C)** | | | | | | | | | | | | | | | | | | | | | |
APPENDIX C

ABBREVIATIONS

cST centi Stokes
ISBN International Standard Book Number
MC Medium curing
NORAD Norwegian Agency for Development Cooperation
NPRU Norwegian Public Roads Administration
PHN Public Highway Network
PVA Polyvinyleacelate
RC Rapid Curing

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ABBREVIATIONS

cST centi Stokes
ISBN International Standard Book Number
MC Medium curing
NORAD Norwegian Agency for Development Cooperation
NPRU Norwegian Public Roads Administration
PHN Public Highway Network
PVA Polyvinyleacelate
RC Rapid Curing

SBR Styrenebutadiene rubber
SBS Styrenebutadiene styrene
SC Slow Curing
SPMB Semi-Priming Modified Binder
TMH Technical Methods for Highways (South African Standards)

AADT Average Annual Daily Traffic