 

 

# Targeted Interventions on Low Volume Rural Roads in Mozambique

## AFCAP/RRIP Project Phase 3

## DESIGN REPORT

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## Transport Research Laboratory

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# Targeted Interventions on Low Volume Rural Roads in Mozambique

## Design Report

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| **Prepared for: Project Record:** | **AFCAP/MOZ/001/C** |
| | **Design Report** |
| **Client:** | **Crown Agents** |
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# 1 Introduction

This report covers the design stage of the RRIP/AFCAP Project Phase 3. This project follows on from the execution of Phase 2 where several sites were designed by TRL in collaboration with the provincial consultants and built mostly by local contractors. Most of the works were carried out successfully and this lead to the commissioning of Phase 3.

The designs for the Phase 2 projects were based on the development of sustainable designs and construction techniques to resolve passability problems experienced on some important rural roads. The project therefore focussed not only on providing all weather access but also on research and development. A number of design solutions were trialled but, due to the limited scope of the project, some design options that were proposed were not included. Phase 3 provided the opportunity to design and trial some of these other possible options.

## 1.1 Objectives

The designs for both Phase 2 and Phase 3 focused primarily on low cost surfacings and the design of bases using locally available materials. The objectives are:

1. To minimise the costs of construction through use of appropriate designs commensurate with the low levels of traffic normally found on rural roads.
2. To minimise construction costs through use of locally available materials in their natural form or with modification.
3. To minimise the life-cycle costs through the use of sustainable design solutions which provide high durability and low maintenance.
4. To test and validate the designs by constructing trial sections of road as part of the targeted interventions under the RRIP.
5. To monitor the performance of these sections in-service through measurement and assessment of the occurrence of defects and their progression.
6. To evaluate the performance and determine specification limits where possible
7. To document such findings and mainstream the design specifications and work norms

## 1.2 TRL’s role

TRL’s role in this project included;

1. Coordinating with provincial engineers, both from ANE and the provincial consultants, defining the sites and the solution options.
2. Coordinating the sampling and testing of materials.
3. Carrying out the designs.

4. Liaising with DIMAN and DIPANE on the proposed designs and assisting in incorporating the designs in the tender documents.

### 1.3 The research and development process

The sequence of events in a typical research project on low volume roads includes the following main activities.

1 Preliminary designs are produced and agreed with ANE based on the nature of the problems to be solved, the anticipated materials that are likely to be available, the capability of the contractor and other factors that will not be known fully at this preliminary stage.

2 Draft tender documents and BoQs are produced to select a suitable contractor.

3 More detailed site and materials investigation are carried out and discussions with local engineers and the contractor take place during which modifications to the preliminary designs are inevitably made.

4 A revised design report is produced describing the revised designs that are to be implemented and describing the reasons for the changes.

5 Construction begins but, inevitably, some further changes to the designs are likely to be introduced, hopefully minor ones.

6 During construction a full record is kept of all site activities and quality control measures are recorded to produce an 'as constructed' report.

7 For research purposes more detail of what was constructed and the properties of the completed pavement layers are required. Such details are measured during the first monitoring programme thereby providing essential information for subsequent interpretation of performance and the derivation of specifications and standards.

This report is the revised design report described in item 4 above. It contains details of the preliminary designs in Appendix A. The main body of the report describes the revised designs, the reasons for the changes, preliminary work norms, preliminary standards and specifications. ….

# 2 Background

Previous research carried out by TRL in Mozambique on the performance of unpaved roads had shown that the rates of gravel loss are high, 57mm/year on average. This means that regravelling is required every two to three years and this is unsustainable. For surfaced roads, cement stabilisation is usually used in the construction of bases and this makes paved roads relatively expensive to build.

A number of factors contribute to these problems.

1. ***Poor construction materials***.

   Most of Mozambique is covered in fine coastal sands; natural gravel is hard to obtain. Thus poor quality unpaved roads are constructed usually using red sand for the wearing courses because there is no better alternative material within economic haul distances. For example, good quality surfacing materials are obtained from Maputo City for Maputo, Gaza and Inhambane Provinces. The haul distances sometimes exceed 500km which makes the cost of such materials as surfacing stone extremely expensive. Using sand for the construction of wearing courses results in short regravelling cycles, often as short as 6 months. The ensuing maintenance demand is too much for the road administration and this results in poor road networks, especially in rural areas. Construction of roadbases in most areas is only possible with stabilisation, mostly using cement. Sand requires high cement contents for stabilisation (i.e. 5-7%) and this brings with it other undesirable problems such as wide shrinkage cracking, pumping, and surface stripping, all requiring maintenance to slow down the rate of deterioration.

2. ***Climate:***

   Mozambique has both dry and wet climates. While some areas are arid, the coastal regions and some of the highlands have very wet climates with prolonged rainy seasons. This, coupled with poor soils, has lead to poor performance of unpaved roads and low durability of paved roads.

3. ***Traffic***:

   Traffic is increasing rapidly with the increase in the importation of used vehicles from Japan, Europe and other countries. This increase in traffic, while it helps economic growth, impacts negatively on the sustainability of road networks, especially the unpaved roads.

Taking all this into consideration, it is clear that more appropriate solutions are required, if they are available, to improve the sustainability of the rural road networks. This can only be possible if both construction and maintenance costs are minimised by making use of locally available materials, especially for the large network of low volume roads.

# 3 Design principles

Conventional design methods and specifications have been developed for universal use and to be applicable for a wide range of materials provided that the materials meet the relevant specifications. Thus such methods have to be conservative because they are not tailored for specific materials; they need to be sufficiently conservative to encompass many types. By developing design methods and specifications for particular types of materials separately it is possible for many types of materials that do not meet 'standard' specifications to be used successfully.

The task of developing designs and specifications for such materials is clearly more complicated than merely using existing methods. New designs can be developed by assessing the likely failure mechanisms of components of the road structure in a particular environment and then producing designs that mitigate these. To do so the most successful method is to review the most appropriate design method available and then to conduct trials in which, for a particular environment and material type, the material characteristics are allowed to differ from the accepted values. This has to be done using all the experience of the performance of such materials reported in research data from as many sources as possible. In this way the trials are not merely a hit or miss affair but build new knowledge on the back of existing research. Progress then occurs through incremental steps as knowledge is accumulated.

In Mozambique this process is complicated by the complete lack of good, or even merely reasonable, road building materials in many areas. This not only makes the research more protracted because there is often no prior knowledge of the behaviour of such materials, especially in the upper and more important layers of the pavement, and because the materials are of such poor quality that the incremental steps in developing methods and new specifications are rather large and therefore more likely to give rise to disappointing results. Such is the nature of this kind of research. However, a considerable amount of research has been done in Africa on the use in pavements of natural materials including sands for sub-bases and for bases, hence making use of such research can minimise the risks and enhance the chances of success.

An additional and important problem is that low quality materials tend to have a wide variability in engineering properties - in road engineering no two materials are exactly the same. This variability is a major issue in research because in order to produce specifications the impact of the variability of the material on performance needs to be known. However, it is also important to understand that given the right environment most materials can perform well.

A number of principles govern design processes for low volume roads, Table 3-1. They are mentioned here for two reasons. Firstly the designer needs to consider them, although they will all be addressed specifically in any design method that is used. Indeed, in many cases basic good engineering practice dictates how this should be done. Secondly, and primarily, following the monitoring period of the trials they will all need to be studied carefully in the analysis of performance to identify the main influences and their magnitude to point the way towards better designs.

**Table 3-1 Principles of design for low volume roads**

| | Design Aspects | Influence on design |
|---|---|---|
| 1 | Functionality | The function of a road should be known because this often dictates the future usage of the road. Functionality is usually closely associated with traffic. For main highways serving traffic from many different sources the volume of traffic is usually the main factor and traffic composition less so because all vehicle types and sizes will be represented in the traffic stream. However, for low volume roads the traffic may be very specific and dominated by one type, eg relatively light agricultural transport, very heavy quarry product traffic, just passenger traffic, etc. Under such circumstances the pavement materials that are suitable for one type of traffic may not be suitable for all types. |
| 2 | Materials | This is one of the most important aspects. The road is as good as the materials used in its construction provided that all other factors are taken care off in the design and construction. The influence of materials on design is such that the strength of the materials determines the size of pavement that can be designed to meet the requirements. Good materials can lead to cheaper and leaner pavements and poor materials can lead to very expensive pavements. Failure of the pavements can be a direct result of the failure of a material to resist loading or to maintain strength when, for example, moisture levels increase. Some material degenerate in service and for such materials the design has to take a different format. |
| | Traffic | This is also one of the most important aspects influencing design because it is usually the main cause of deterioration. Without traffic, roads can last for a very long time and may deteriorate only through the effects of weather. However, the effect of traffic on low volume roads differs from its effect on heavily trafficked roads in several important respects. For example, for heavily trafficked roads the specifications are so designed to eliminate material failure in the roadbase despite the chance that very heavy and overloaded wheels may impose high stresses. For roads carrying only light traffic, weaker materials can be used but there is always a risk that heavy vehicles may use the road at some time. Assessing this risk and designing for it is one of the most difficult aspects of designing low cost low volume roads. The influence of traffic on design is also dependent on other factors such as the moisture regime. Hence the impact of traffic should be considered as part of a bigger picture where the environment, the materials and the maintenance regimes become part of the equation. |
| | Environment | The influence of the environment is two-fold; direct and indirect influences. Direct influence is where the environment itself causes the deterioration eg drainage wash-outs and erosion. Indirect |

| | | |
|---|---|---|
| | | influence includes changes in moisture content in the pavement layers, thereby changing material strengths and leading to failure of the materials. When bituminous materials are used, high operating temperatures can cause rapid deterioration through accelerated loss of volatiles in the binders. Other materials are more susceptible to moisture ingress than others. Materials with high PI tend to lose strength more than materials with low plasticity. Hence climatic conditions have a greater influence on pavement strength in-service. |
| | Road foundation | Each road foundation is different and greatly influences the nature and strength of pavement required. For low volume roads the influence can be subtle but there have been cases where rapid deterioration has been caused by weak road foundations especially where high water tables in the road foundation have caused increase in fluidity of the soil matrices leading to deleterious geotechnical problems. The strengthening of the road foundation is usually simple and may involve subsurface drainage systems which can lead to the design of leaner and cheaper pavements. |
| | Consolidation | This is an important aspect of low volume road design especially where upgrading of rural roads is concerned. Consolidation can help to reduce the design strength requirements thus reducing the cost of construction and of maintenance by a significant amount. Once the road foundation is well consolidated and strong, the strength requirements of the pavement decrease significantly and, consequently, marginal materials can be used in the construction of the road base. For low-volume roads, a single base layer on top of the existing road can suffice. |
| | Drainage | Drainage can have a great impact on the design because it gives the designer the opportunity to alter the operating environment of the pavement layer(s). This is an important aspect because most materials are considered marginal due to their negative response to an adverse environment. By altering this environment, weaker materials can be usable in road construction. |

# 4 Project Scope

The scope of the project was to carry out the designs for sections selected by ANE for targeted interventions The sections had passability problems and were causing bottlenecks on the road network or particular on sections of important roads. Some of these sections are short but they provided opportunities for the trialling of new designs.

The list of projects is given in Table 4-1.

**Table 4-1 List of Phase 3 Projects**

| Province | Project Name | Scope of works |
|---|---|---|
| Maputo Project | Maragra - Machubo | The design of an approximately 1m high embankment with a blend of clay (matope) and local fine sand. There is also a section at Machubo where block paving has been constructed, the blocks being fabricated on site. The whole section is 7.8km long. |
| Gaza | Chinhacanine Nalazi | The design of a 1.7m embankment across a flood prone swamp, 6 x 900mm culverts, 300m of emulsion treated base, cement stabilisation of sand base included as an option, 1700m of blended base of sand and local plastic soil with armouring, sand seal surfacing, penetration macadam, single and double surface dressing. |
| Inhambane | Cumbana Chacane | The design of a 7.2km section, 6.2km with subbase of red sand and 4km of armoured sand base and 2km with untreated sand base. Local calcrete aggregate is used for the armouring at the surface of the sand base to a depth of 50mm. The project also involves the design of thin surfacing i.e. penetration macadam using processed calcrete aggregate, single surface dressing with sand capping, and sand seal. On a 300m section of untreated red sand a double sand seal will be constructed as an experimental section. |
| Manica | Inhacufera Machaze | Construction on this project was carried out rapidly. The project involved the design of a base of 100mm on top of the regularised existing surface. This was meant to take advantage of the existing in-situ strength. The total length to the project is 5km and the surfacing is Otta seal with a binder application rate of 1.6 and 1.8L/$m^2$. An additional 3km will be included through an addendum as a result of the savings. |
| Sofala | Caia Marromeu | This project involves the design of a 5km section of road which was an engineered earth road. This in- |

| | | |
|---|---|---|
| | | situ material used was too plastic and slippery. The project involves the construction of a subbase of blended sand and in-situ clayey soil and a base of ETB surfaced with 15mm of slurry seal |
| Zambezia | Zero Mopeia | This project was also carried out quickly. The project involved the design of 6km of 150mm base using local quartz gravel and surfaced with single Otta seal using fine quartz aggregate |

# 5 Design activities and processes

The design of these interventions and the research sections followed through from those carried out during the design stage of Phase 2 of the RRIP/AFCAP Project. However, the actual designs were different with different engineering considerations. Below is an account of the activities that were carried out on each project and the design considerations and assumptions that were considered.

## 5.1 Maragra Machubo Project – Inhambane Province

This project was selected by the ANE provincial delegation at an early stage of the AFCAP Phase 3 Project and TRL became involved at a later stage i.e. after the provincial consultant had already decided on the solutions and the construction contract had already been awarded. TRL's assistance was sought when there were problems with the blending of sand and clay in terms of proportions and processing. TRL helped in advising on the design process in order to improve the specifications that were being used on site

The traffic is likely to be fairly low but it could not be determined by TRL at that time because the road was impassable. It is anticipated that the traffic will not exceed 20 vehicles per day.

The whole project covered a section from 0+000 to 32+300. However, TRL was only concerned with the section from 0+000 to 7+800. This stretch of road included a number of trial sections as shown in Table 5-2.

A blend of sand and clay was investigated with the results shown in Table 5-1

**Table 5-1 Properties of the blended material on the Maragra Machubo Project**

| Blend Proportions Sand/clay | PI | Grading Modulus | CBR |
|---|---|---|---|
| 50:50 | 2.6 | 0.86 | 0 |
| 60:40 | SP | 0.95 | 0 |
| 70:30 | Non plastic | 0.83 | 7.5 |

**Table 5-2 Design information for the Maragra Machubo Project**

<table>
<tr><th>Chainage</th><th>Description of section</th><th colspan="4">Design aspects</th></tr>
<tr><td rowspan="4">0+000 to 2+600</td><td rowspan="4">The section traverses a swampy area which is prone to flooding during the rainy season. There was an embankment built with clay soils that was not passable during the rainy season and needed improvement.</td><td colspan="4">The designs included:<br>900mm diameter culverts<br>2600m of scarification and regularising of the existing surface and compaction to 95% Mod. AASHTO<br>800mm additional height to the embankment using a mixture of clay and coastal sand at a ratio of 30% clay (matope) and 70% sand.<br>Specified minimum CBR was 7.5%.</td></tr>
<tr><td>Layer</td><td>Material</td><td>Thickness mm</td><td>Strength CBR</td></tr>
<tr><td>Surfacing</td><td>Blend of sand and clay</td><td>150</td><td>> 7.5</td></tr>
<tr><td>Embankment</td><td>Blend of sand and clay</td><td>>800</td><td>> 7.5</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="5">2+600 to 6+300</td><td rowspan="5">This section was a track of loose coastal sand. It was not prone to flooding but posed passability difficulties in the dry season.</td><td colspan="4">The designs included:<br>Formation with local soil to a thickness of 150mm<br>A 150mm wearing course of a blend of clay (matope) and sand at a ratio of 30% clay to 70% sand.</td></tr>
<tr><td>Layer</td><td>Material</td><td>Thickness mm</td><td>Strength CBR</td></tr>
<tr><td>Surfacing /wearing course</td><td>Blend of sand and clay</td><td>150</td><td>> 7.5</td></tr>
<tr><td>Layer 2</td><td>Compacted local soil</td><td>150</td><td>>7.5</td></tr>
<tr><td>Subgrade</td><td>Local soil</td><td></td><td>>7.5</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="5">6+300 to 7+800</td><td rowspan="5">This section is at an Administrative Centre (Posto Administrative) and was not prone to flooding.</td><td colspan="4">The designs included:<br>Cement stabilised base with 5% cement content.<br>Block paving. The blocks were produced on site</td></tr>
<tr><td>Layer</td><td>Material</td><td>Thickness mm</td><td>Strength or CBR</td></tr>
<tr><td>Surfacing</td><td>Block paving</td><td>50</td><td></td></tr>
<tr><td>Road base</td><td>Cement stabilised sand</td><td>100</td><td>>100</td></tr>
<tr><td>Subgrade</td><td></td><td>-</td><td>-</td></tr>
</table>

The design process included a number of activities.

1. DCP tests were carried out on the existing embankment to determine its soundness. The tests were carried out at 50m intervals. While these data were not essential to the design itself because there was no possibility of rejecting the embankment, it gave engineers the confidence necessary to construct more layers on it.
2. Obtaining the best mix proportions for the blend of sand and clayey soils (matope) was essential because the strength of the extra layers required to elevate the embankment, and particularly the final wearing course, needed to achieve a minimum bearing capacity necessary to carry the traffic loading. The mix proportions were determined in the laboratory where different proportions of sand and clayey soils were used (Table 5-1). Normally the standard proportions for trialling are 30:70, 50:50 and 70:30. The proportion that gives the higher strength is considered unless there are other compelling reasons that might influence the decision. The minimum bearing capacity required was 15% but the CBR obtained was only 7.5% but there were no alternative materials available. The grading of the blended material is shown in Figure 5-1.
3. The section with block paving required a cement-stabilised base. The cement content for the sand soils is usually between 4% and 7% but, for these low volume roads 4% is sufficient.

**MARAGRA/MACHUBO**

**Mix 1 :70% sand +30% clay**

| sieve size | % passing |
|---|---|
| 75 | 100 |
| 50 | 100 |
| 37.5 | 100 |
| 25 | 100 |
| 19 | 100 |
| 13.2 | 100 |
| 9.5 | 100 |
| 6.7 | 100 |
| 4.75 | 100 |
| 2.36 | 100 |
| 1.18 | 99.8 |
| 0.6 | 98.2 |
| 0.425 | 93.3 |
| 0.3 | 71 |
| 0.15 | 26.1 |
| 0.075 | 24.1 |

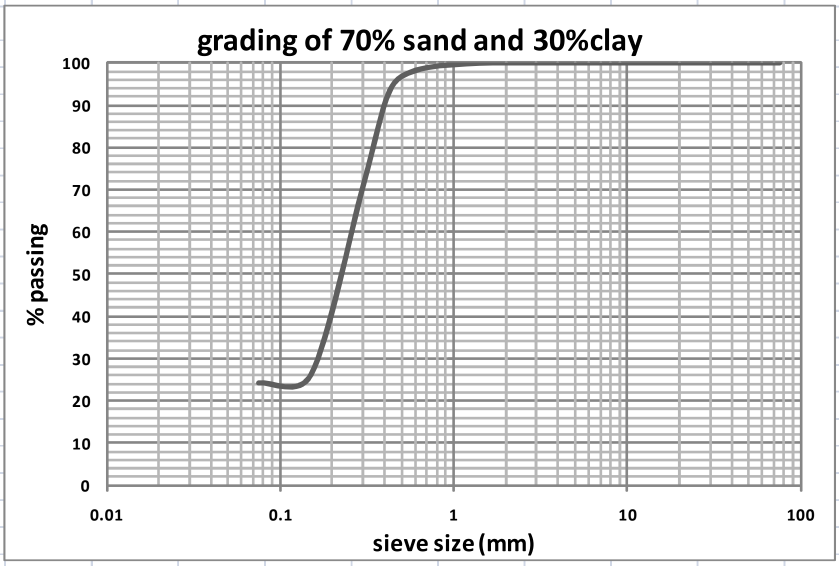


**Figure 5-1 Grading of blended material on Maragra Machubo Project**

## 5.2 Chinhacanine Nalazi Project – Gaza Province

This is an important projects being undertaken under RRIP/AFCAP Phase 3. The section is prone to sheet flooding which makes it impassability during the rainy season. The stretch that is affected is about 1800m in length. The traffic is about 20 vpd but with improvements in passability it is expected to increase to between 70 and 100vpd. No information was available on axle loads.

### *5.2.1 Drainage considerations*

Large volumes of flood water pass through this section and the strength of flood water cannot be overstated - there have been cases where whole embankments and superstructures have washed away and large investments lost. Estimating the actual discharge volumes and flow velocities was difficult. In these circumstances the principle of flood routing is the most appropriate and safest design approach. This principle is based on the damming effect when an obstruction is placed in the water channel, especially in cases where the surrounding area upstream of the crossing is flat. The embankment was designed to withstand high lateral water pressure and the following aspects were considered.

1. The embankment has a gentle side slope of 1 in 4 which enhances slope stability and provides the required resistance against the lateral pressures of the water.
2. The road is concave upstream and this enhances the lateral resistance especially in the section where the current is strongest.

The materials in the vicinity of the project were of poor quality and not suitable for road construction. Table 5-3 shows details of the available materials. The natural quartz aggregate found in Mabalane was selected for surfacing.

**Table 5-3 Materials details for Chinhacanine Nalazi Project**

| Materials source | Type of material | Engineering properties |
|---|---|---|
| Local materials | Greyish sandy clay | Sandy clay with high plasticity, PI = 17. Had small traces of calcrete in its infancy of geological formation, CBR < 15 |
| | Light greyish whitish fine coastal sand | Very fine coastal or blown sands which were non-plastic in nature (PI=0), CBR <30 |
| Imported materials | River sand found in Chokwe | Non-plastic coarse sand with little organic materials |
| | Natural quartz aggregate from Mabalane and Massingir 60km and 100km haul distances respectively | Clean aggregate obtained through sieving of natural quartzitic gravel. With a mixture of angular and rounded aggregate. ACV < 24 |
| | Crushed stone from | Stone is prepared for |

| | | |
|---|---|---|
| | Maputo brownish in colour and probably ryolite | conventional surfacing and meets conventional specification of strength and grading. |

### *5.2.2 Structural design*

***Road foundation***

The design required a high embankment hence the embankment material was the effective subgrade.

***Roadbases***

All available materials were very weak and their high plasticity was also very undesirable. In order to use them for the pavement layers the issue of high plasticity had to be resolved. The most economical way of reducing the plasticity of the material is to blend it with sand. However blending with the very fine local sand is difficult because very fine sand does not mix well with plastic material. A coarser river sand was considered for this and it was obtained from within reasonable distance from the project site. The mix proportions were carried out in the laboratory Table 5-4.

**Table 5-4 Results of blending materials for the Chinhacanine Nalazi Project**

| Mix proportions for the blend (%) | | PI levels | Remarks |
|---|---|---|---|
| Sand | Local plastic material | | |
| 100 | 0 | 0 | Non-plastic sand |
| 0 | 100 | 17 | Highly plastic sandy clay |
| 30 | 70 | 14 | PI too high |
| 50 | 50 | 9 | Good for dry areas for untreated blended bases or cement stabilised bases but not suitable for ETB |
| 70 | 30 | 4 | Good for ETB and cement stabilisation.<br>Not suitable if used untreated because of stability deficiencies |

Based on the results given above, a 50:50 blend was prescribed for the base course based on engineering factors and costs. However, the base still remained too weak and two options were considered. The first 300m was designed for stabilisation with bitumen emulsion to form an emulsion treated base (ETB). Capacity limitations on the part of the implementation of the ETB were also taken into account and an alternative stabiliser, cement, was allowed should it be necessary to change the design.

On the rest of the project a technique called *armouring* was used. In this technique a thin layer of high strength material is placed on top of the relatively weak materials. It involves placing a layer of large aggregate on the surface of a slightly compacted base. At optimum moisture content this aggregate is then hammered into the surface of the base using a heavy vibratory roller vibrating at high amplitude. The principle is the same as the piling of foundations, such as on bridge foundations, on very weak soils. Rolling is continued until the stone cannot penetrate further into the base. This forms an 'armoured' base layer were heavy vehicle wheels cannot punch through the weak base even when the base is wet. These armoured bases will be monitored to determine their performance under the AFCAP Phase 2 and RRIP Phase 3 Projects.

Sections of armoured bases have already been built and the increase in bearing strength is high. Construction vehicles were punching through the weak and wet blended base but no punching has occurred on the blended base after prolonged heavy rains on the yet unsealed armoured base.

The grading of aggregate used for armouring is given in Figure 5-2.

**Chinhacanine/Nalazi**

**Armouring aggregate**

| sieve size | % passing |
|---|---|
| 75 | 100 |
| 50 | 100 |
| 37.5 | 92.5 |
| 25 | 14.9 |
| 19 | 1.9 |
| 13.2 | 1.4 |
| 9.5 | 1 |
| 6.7 | 1 |
| 4.75 | 1 |
| 2 | 0.9 |
| 1.18 | 0.9 |
| 0.6 | 0.7 |
| 0.425 | 0.6 |
| 0.3 | 0.6 |
| 0.15 | 0.4 |
| 0.075 | 0.3 |

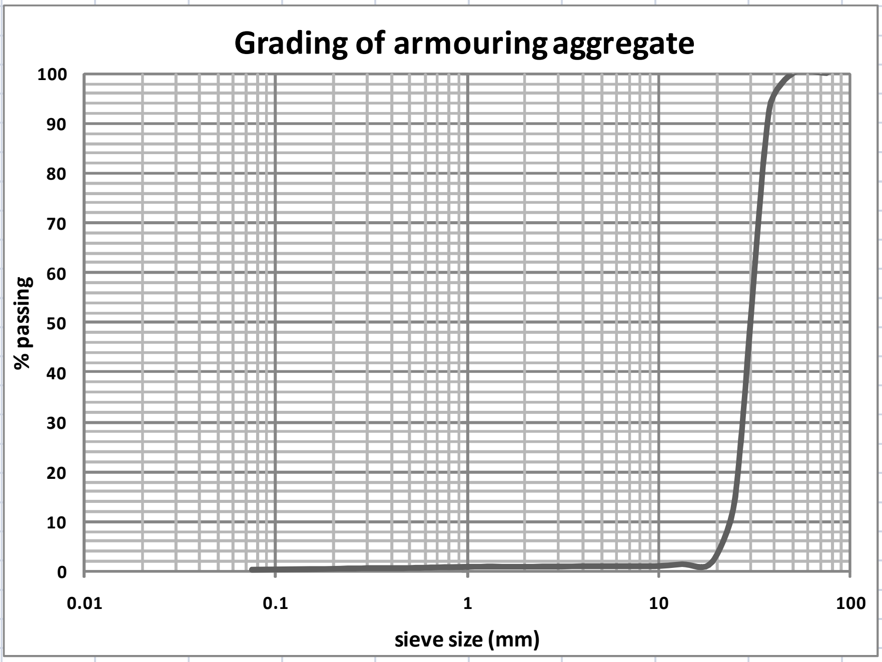


**Figure 5-2 Grading of aggregate for armouring on Chinhacanine Nalazi Project**

***Surfacing***

**Several surfacing types were designed as shown in**

Table 5-5 including a coarse sand seal on top of an armoured roadbase. Such a surface is similar in principle to other types of double surfacing where the second layer helps to 'lock' the aggregate in the lower layer by filling in the interstices. Such a design, sometimes called an 'amalgamated' surface is durable because of the interlock and the much reduced risk of the surfacing delaminating from the layer below. In this case the effect is also greatly enhanced because the armouring layer, if constructed properly, is also firmly anchored into the weaker layer below.

The performance of the surfacings, including the amalgamated surfacing, will be monitored over a period of time and findings will be documented and published in due course.

**Table 5-5 Design of the Chinhacanine Nalazi Project**

| Section | Layer | Material | Thickness mm | Design Strength soaked CBR |
|---|---|---|---|---|
| Section 1<br>0+000 to 0+300 | Surfacing | Coarse river sand seal | | |
| | Roadbase | Cement stabilised (on 50/50 mixture) | 100 | >100 |
| | Sub-base | Well compacted embankment material | 150 | 15-27 |
| | Subgrade | Embankment material | 1550 | 15-27 |
| | | | | |
| Section 2<br>0+300 to +800 | Surfacing | Coarse river sand seal | | |
| | Armouring | Course gravel armouring | 40-50 | ACV < 40 |
| | Roadbase | Gravel | 100 | 15-27 |
| | Sub-base | Well compacted embankment material | 150 | 10 - 15 |
| | Subgrade | Embankment material | 1550 | 10 - 15 |
| | | | | |
| Section 3<br>0+800 to 1+200 | Surfacing 1 | Sand seal | | |
| | Surfacing 2 | Single surface dressing (10-13mm) | | ACV < 25 |
| | Armouring | Course gravel armouring | 40-50 | ACV < 40 |
| | Roadbase | Gravel | 100 | 15-27 |
| | Sub-base | Well compacted embankment material | 150 | 10 - 15 |
| | Subgrade | Embankment material | 1550 | 10 - 15 |
| | | | | |
| Section 4<br>1+200 to 1+600 | Surfacing | Penetration Macadam | 40-50/5-13 | ACV < 25 |
| | Armouring | Course gravel armouring | 40-50 | ACV < 40 |
| | Roadbase | Gravel | 100 | 15-27 |
| | Sub-base | Well compacted embankment material | 150 | 10 - 15 |
| | Subgrade | Embankment material | 1550 | 10 - 15 |
| | | | | |
| Section 5<br>1+600 to 2+000 | Surfacing | Double surface dressing | | |
| | Armouring | Course gravel armouring | 40-50 | ACV < 40 |
| | Roadbase | Gravel | 100 | 15-27 |
| | Sub-base | Well compacted embankment material | 150 | 10 - 15 |
| | Subgrade | Embankment material | 1550 | 10 - 15 |

## 5.3 Cumbana Chacane Project – Inhambane Province

The Cumbana Chacane Project was started under AFCAP/RRIP Phase 2. It involved the construction of 2km of Otta seal and 4km of blended wearing course. The section under AFCAP/RRIP Phase 3 is an extension to the intervention and involves the design and construction of 7.2km of low cost sealing with 4km of armoured sand base.

After the construction of the Phase 2 section, the stretch of road immediately after deteriorated rapidly. This was attributed to the rapid increase in traffic because the road had become passable in all-weathers. The traffic increased from about 20vpd to about 110vpd. The road provides a shortcut for transporters of calcrete aggregate from quarries in Chacane for the construction in Maxixe and Inhambane Towns. Some of the traffic was therefore very heavily loaded. The sand on the section under Phase 3 loosened and passability was compromised. It was decided to continue with the intervention to make the road all-weather passable otherwise the potential benefits of the investments under Phase 2 would not have been realised.

The design incorporated a number of design options for the road base and surfacing, Table 5-6.

**Table 5-6 Design details for Cumbana Chacane Project**

| Pavement structure | Chainages | Design aspects |
|---|---|---|
| Roadbed | 11+800 to 20+000 | The existing track consisted of very loose sand which was causing passability problems. This sand had to be removed to a firm foundation (If the loose sand is not removed the pavement will most likely deform when the loose sand consolidates or collapses) |
| Sub-base | 11+800 to 20+000 | The removal of the loose sand to form the roadbed resulted in a trench which was backfilled with sub-base material namely with the red sand which is locally available and compacted to a minimum of 95% mdd Mod. AASHTO. The soaked CBR at 95% mdd Mod AASHTO was 23.5%. This bearing strength is adequate for the sub-base layer. The red sand was very fine with a grading modulus, GM = 1.19 and $P_{0.075}$ = 11.2 |
| Roadbase | 11+800 to 13+000<br>The roadbase on these chainages had two different surfacings as described below. | Untreated red sand base. This is a trial section. Some of the red sands have a little plasticity and/or some iron oxide (see sub-base above). This helps in creating a solid surface after compaction on which a surfacing can be constructed. If the surface is loose then the surfacing will most likely peel off. However, the behaviour of such |

| | | |
|---|---|---|
| | | untreated sand bases at low traffic volume is not fully understood and the research will look into their performance. |
| | 13+000 to 17+000 | Red sand base armoured with calcrete aggregate. The strength of the red sand (CBR = 24%) is low in relation to the standing requirements for low volume roads (CBR ≥ 40%) at 95% Mod AASHTO. Armouring is expected to enhance the strength of the weak sand. |
| | 17+000 to 18+000 | Untreated red sand base. The untreated sand base is weak. In this case the design involves the use of stronger and flexible surfacing, penetration macadam, on the weak base. This combination of a weak base under a strong *flexible* surfacing may produce some good results because large aggregate is used in the first layer (20-40mm). This may help the base layer to withstand loading at low traffic levels especially if the surfacing remains impermeable to moisture. This is possible with penetration macadam. |
| | 19+000 to 20+000 | This section already has the blended base (sand and calcrete) constructed during Phase 2 of the AFCAP/RRIP Project. |
| Surfacing | 11+800 to 12+300 | Single sand seal on untreated sand base. It is difficult to find coarse sand close to the project and two sources were identified. One within 500m from site and the other 40km from site, at Inharrime on the shoreline. The former is very fine coastal sand and the latter is a bit coarser than the coastal sand. Coarse sand with a nominal maximum size of 4.75mm or 6.7mm is more appropriate for a sand seal. The fine coastal sand has 100% passing 2mm sieve. |
| | 12+300 to 13+000 | Double sand seal untreated sand base. A double sand seal is more durable and it may be the best option in situations where the sand is very fine. |
| | 13+000 to 15+000 | Single sand seal on armoured sand base |
| | 15+000 to 17+000 | Double sand seal on armoured sand base |
| | 17+000 to 18+000 | Penetration macadam with two layers, first layer 20-40mm and second layer 5-13mm or 10-13 whichever is possible. The aggregate shall be obtained by sieving |

| | | |
|---|---|---|
| | | natural calcrete gravel. |
| | 19+000 to 20+000 | Single sand seal on an existing blended base built during Phase 2. This is meant to check if it is possible to upgrade existing gravel roads to sealed standards by regularisation of the existing surface, priming and sealing with single sand seal. |

The armouring technology has the effect of increasing strength. In this case the aggregate is obtained through sieving calcrete gravel and sometimes the aggregate has clay in it. Clay is detrimental to surfacing and for this reason the aggregate should be mixed with the sand from the sand base. The design assumes that the sand base shall be laid and compacted, then scarified to a shallow depth. The loose sand shall then be mixed with the aggregate before laying and rolling. Rolling then presses in the aggregate to produce the armouring layer which is non-plastic. Surfacing can then be placed on top of the armouring.

**CUMBANA -CHACANE**

**Grading of Red Sand**

| sieve size | % passing |
|---|---|
| 75 | 100 |
| 50 | 100 |
| 37.5 | 100 |
| 25 | 100 |
| 19 | 100 |
| 13.2 | 100 |
| 9.5 | 100 |
| 6.7 | 100 |
| 4.75 | 100 |
| 2 | 100 |
| 1.18 | 99 |
| 0.6 | 84.2 |
| 0.425 | 64.7 |
| 0.3 | 36.1 |
| 0.15 | 13.2 |
| 0.075 | 11.3 |

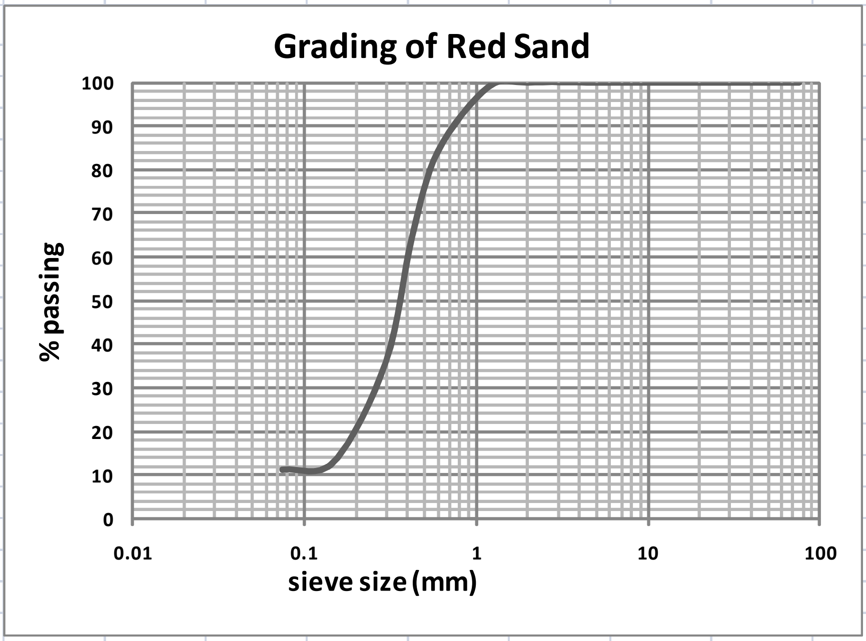


**Figure 5-3 Grading of red sand on Cumbana Chacane Project**

## 5.4 Inhacufera Machaze Project – Manica Province

The Inhacufera Machaze Project is a continuation of the work that was carried out under Phases 1 and 2 of the RRIP/AFCAP Project. The bottleneck on this road is caused by very high roughness on the road surface resulting from boulders in the gravel used to construct the wearing course. Some of the boulders exceeded

200mm in size. The traffic is approximately 70vpd but it is likely to increase beyond 100vpd because this is a national or truck road. Heavy trucks constitute approximately 20% of the traffic and there is a high proportion of medium traffic.

The project involves reducing the roughness of the existing surface and constructing a base using material from selected gravel pits located along the road. The grading is given in Figure 5-4.

The original design proposals are shown in the Appendix. However, it was subsequently noted that the Otta seal on the Phase 2 sections was performing very well and, as a result, the surfacing that was implemented on Phase 3 was single Otta seal throughout the whole section constructed using a local quartz aggregate sieved from a quartz gravel. The implemented design information is given in Table 5-7.

**Inhacufera machaze**

Base course

| sieve size | % passing |
|---|---|
| 75 | 100 |
| 50 | 100 |
| 37.5 | 94.3 |
| 25 | 86.1 |
| 19 | 82.4 |
| 13.2 | 75.7 |
| 9.5 | 68.7 |
| 6.7 | 60.2 |
| 4.75 | 52.1 |
| 2 | 40.8 |
| 1.18 | 37.9 |
| 0.6 | 32.9 |
| 0.425 | 29.8 |
| 0.3 | 26.5 |
| 0.15 | 20.5 |
| 0.075 | 18 |

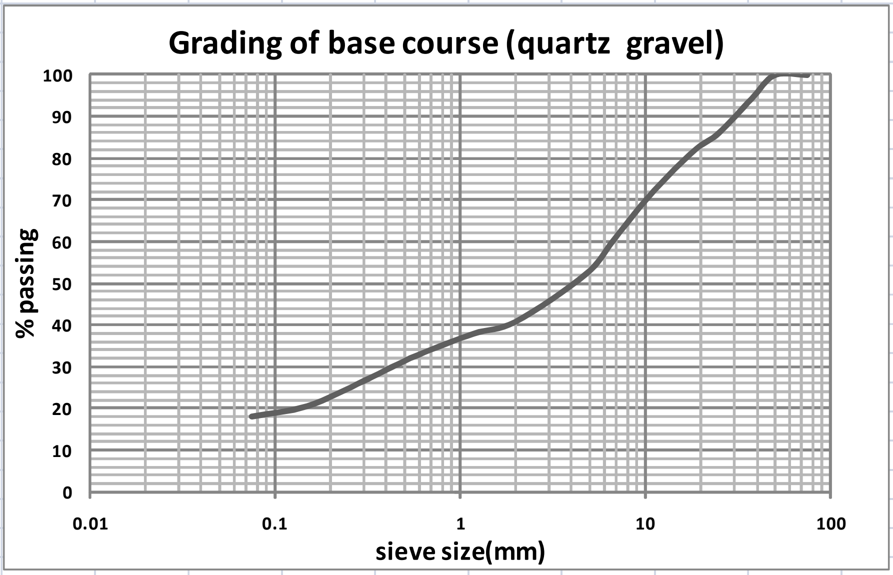


**Figure 5-4 Grading of base gravel for Inhacufera Machaze Project**

**Table 5-7 Design details for the Inhacufera Machaze Project**

| Layer | Chainages | Design aspects |
|---|---|---|
| Existing road | 10+000 to 15+000 | The existing road consisted of a well consolidated subgrade and wearing course. Minor levelling (smoothing) was necessary to reinstate the camber. The structural design took into account the inherent strength developed through consolidation over many years of trafficking. This provides the basis for designing a leaner pavement. |

| | | |
|---|---|---|
| Road base | 10+000 to 15+000 | Gravel sources were located for the roadbase. However the soaked CBR at 95% mdd Mod AASHTO was only 24-30%. The material was very coarse and some samples were plastic (PI= 5 to 9). The CBR did not meet the minimum requirements for low volume pavement design (CBR≥40%) however the design charts need to be proved for roads such as this.<br>The thickness of the roadbase was 100mm based on the assumption that the high bearing strength of the underlying layers of the old road is adequate ie the effective sub-base/subgrade strength was adequate. |
| Surfacing | 10+000 to 10+600 | Single Otta seal with binder application rate of 1.6L/m$^2$ and aggregate application rate of 16L/m$^2$. |
| | 10+600 to 15+000 | Single Otta seal with application rate of binder of 1.8L/m$^2$ and aggregate application rate of 16L/m$^2$. |

### 5.5 Caia Marromeu Project – Sofala Province

This project is located in a remote area of Mozambique. The road is about 100km long and terminates at Marromeu which is an important sugar plantation. The last 7km were in bad condition and passability was limited to 4x4s and heavy trucks because of the clay soils which become muddy and slippery when wet. Even the heavy vehicles pass with difficulty. The traffic is not expected to exceed 70vpd but it tends to be very heavy, carrying produce from the plantation.

The project was complicated by lack of suitable materials from within economic haul distances from the site. There is a quartz gravel source at kilometre 46 from Caia which is about 54km from the site and a sand borrow pit approximately 35km from the site. These issues were taken into consideration in deciding engineering solutions for this site, Table 5-8.

**Table 5-8 Design details for Caia Marromeu Project**

| Layer | Chainages | Design aspects |
|---|---|---|
| Formation | 0+000 to 5+000 | The road was flat and formation was necessary. 100m of formation using existing material was designed. The material was plastic but it was not an expansive clay. |
| Sub-base | 0+000 to 5+000 | It was necessary to raise the road above the natural ground in order to improve drainage. The surrounding area is flat and rain water tends to accumulate and rise significantly. 300mm sub-base was designed using a blend of the local plastic material and sand in order to enhance the strength and minimise the plasticity of the blended |

| | | |
|---|---|---|
| | | material. The sand was very fine with 100% passing the 2mm sieve and had a CBR of 31-47%. |
| Roadbase | 0+000 to 5+000 | 100mm of emulsion treated base (ETB) using local sand |
| Surfacing | 0+000 to 5+000 | Slurry seal with a thickness of 15mm. |

The start of this project was delayed because the tender process was protracted. When the tender process was concluded the contractor, ECMEP, also took time to mobilise and start work. Work started recently but the project has stalled because the contractor had grossly under-bid and could not proceed with the works. The contractor has written to ANE regarding his inability to continue with the project and the project has been abandoned.

## 5.6 Zero Mopeia Project – Zambezia Province

This project is an extension of the works carried out under AFCAP/RRIP Phase 2 where the construction was carried out by Ceta, one of the leading contractors in Mozambique. The Otta seal constructed under Phase 2 is in good condition and shows no defects to date. The main factors contributing to this are:

1. The base was well constructed giving a good profile to the road. The aggregate grading of the base is shown in Figure 5-5.
2. The nominal maximum size of aggregate used for the Otta seal was only 13mm. The effect was that the Otta seal cured rapidly and effectively to produce a good smooth surfacing.
3. Variable application rates of the binder MC3000 were trialled. Lower application rates with finer aggregate have produced a satisfactory Otta seal at lower cost.

TRL produced a proposed design for Phase 3 (see Appendix) but the provincial consultant reverted back to the specification in the current manual, the Normas de Execucao, especially for the application rate of the binder. A rate of 2L/m$^2$ was used and this therefore increases the number of variations on this site because, in Phase 2, this rate, which is the conventional rate of application of binder, was considered to be too high for low volume roads. However, another school of thought indicates that the conventional rate gives better value in terms of the life-cycle costs. This section will provide the opportunity to investigate this.

The traffic is approximately 50vpd.

The implemented designs are summarised in Table 5-9.

**Table 5-9 Design details for Zero Mopeia Project**

| Layer | Chainages | Design aspects |
|---|---|---|
| Existing road surface | 5+200 to 12+200 | Some earthworks were carried out during Phase 1 of the project that included formation and gravelling. While the road was still in good shape, the cross-sectional profile, particularly the camber, had been lost. The existing road needed to be levelled and smoothed by scarifying to a shallow depth of 15-20mm and reshaping the camber. |
| Roadbase | 5+200 to 12+200 | This is imported material from gravel pits from within the vicinity of the project. The gravel is fine and quartzitic. Generally the CBR at 95% mdd Mod AASHTO is approximately 45% and the grading modulus (GM) is 2.1. The gravel is well graded which has the effect of enhancing strength. The PI ranges between 0 and 7. The of the roadbase is was 150mm. |
| Surfacing | 5+200 to 12+200 | Single Otta seal using aggregate of nominal maximum size of 13mm and binder application rate of 2.0L/$m^2$. The binder application rate is the conventional rate given in the Normas de Execucao (ANE Manual) |

**Zero Mopeia(KM 10+300)**

**Base Course**

| sieve size | % passing |
|---|---|
| 75 | 100 |
| 50 | 100 |
| 37.5 | 100 |
| 25 | 100 |
| 19 | 99.1 |
| 13.2 | 95.5 |
| 9.5 | 93.1 |
| 6.7 | 88.4 |
| 4.75 | 83.3 |
| 2 | 64.8 |
| 1.18 | 55.9 |
| 0.6 | 45.6 |
| 0.425 | 38.3 |
| 0.3 | 34.8 |
| 0.15 | 26.5 |
| 0.075 | 22 |

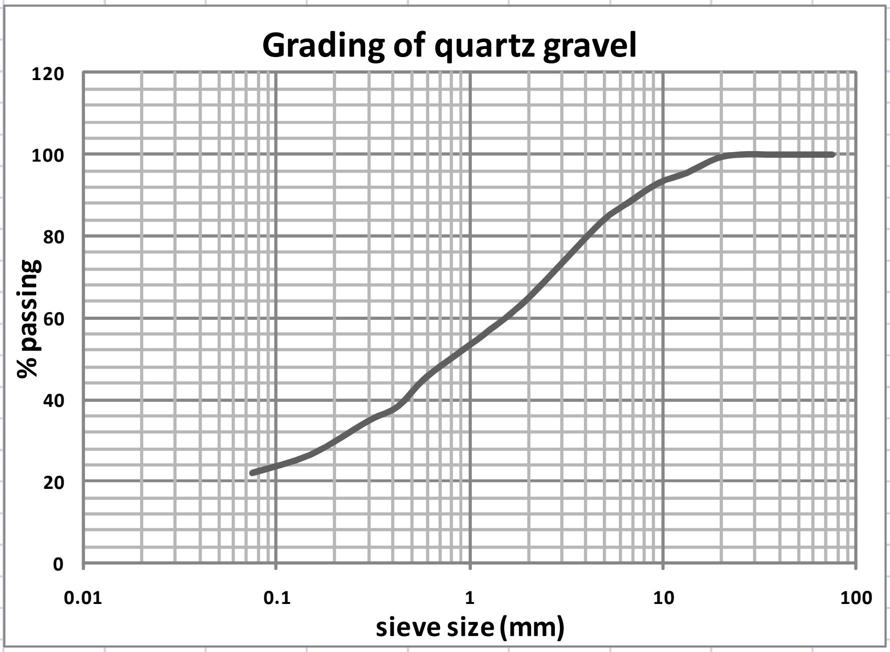


**Figure 5-5 Grading of roadbase on Zero Mopeia Project**

# 6 Summary of Design Information

The design information for all the sites is given in the Table 6-1, Table 6-2, Table 6-3, Table 6-4, Table 6-5 and Table 6-6 below.

**Table 6-1 Maragra Machubo Project Design Data**

| Section | Layer | Material | Design Thickness mm | Design Strength or soaked CBR |
|---|---|---|---|---|
| 0+000 to 2+600 | Wearing surface | Blend of sand and clay | 150 | 7.5 |
| | Subgrade | Embankment | 800 existing | |
| | | | | |
| Section 2 | Wearing surface | Blend of sand and clay | 150 | 7.5 |
| | Subgrade | | 150 | 7.5 |
| | | | | |
| | | | | |
| 6+300 to 7+800 | Surfacing | Block paving | 50 | * |
| | Roadbase | Cement stabilised | 150 | >100 |
| | Subgrade | | | |
| | | | | |
| | | | | |

*The paving blocks were constructed on site and have not been tested yet.

**Table 6-2 Chinhacanine Nalazi Project Design Data**

| Section | Layer | Material | Design Thickness mm | Design Strength soaked CBR |
|---|---|---|---|---|
| Section 1<br>0+000 to 0+300 | Surfacing | Sand seal (coarse river sand) | | |
| | Roadbase | Cement stabilised (5%) | 100 | >100 |
| | Sub-base | Well compacted local fill material | 150 | 15 - 27 |
| | Embankment | Local clayey fill material | 1550 | 15 - 27 |
| | | | | |
| Section 2<br>0+300 to +800 | Surfacing | Sand seal (coarse river sand) | | |
| | Armouring | Course armouring aggregate | 40-50 | ACV < 40 |
| | Roadbase | Local clayey soil/river sand blend (minimum 95% of mdd) | 100 | 15-27 |
| | Sub-base | Well compacted embankment material (minimum 93% of mdd) | 150 | 10 - 15 |
| | Subgrade | Fill material (minimum 91% of mdd) | 1550 | 10 - 15 |
| | | | | |
| Section 3<br>0+800 to 1+200 | Surfacing 1 | Sand seal | | |
| | Surfacing 2 | Single surface dressing (10-13mm) | | |
| | Armouring | Course gravel aggregate | 40-50 | ACV < 40 |
| | Roadbase | Local clayey soil/river sand blend (minimum 95% of mdd) | 100 | 15-27 |
| | Sub-base | Well compacted embankment material (minimum 93% of mdd) | 150 | 10 - 15 |
| | Subgrade | Fill material (minimum 91% of mdd) | 1550 | 10 - 15 |
| | | | | |
| | Surfacing | Penetration Macadam | 40-50, 5-13 | ACV < 36 |

| | | | | |
|---|---|---|---|---|
| Section 4 1+200 to 1+600 | Armouring | Course gravel aggregate | 40-50 | ACV < 40 |
| | Roadbase | Local clayey soil/river sand blend (minimum 95% of mdd) | 100 | 15-27 |
| | Sub-base | Well compacted embankment material (minimum 93% of mdd) | 150 | 10 - 15 |
| | Subgrade | Fill material (minimum 91% of mdd) | 1550 | 10 - 15 |
| | | | | |
| Section 5 1+600 to 2+000 | Surfacing | Double surface dressing | 7mm/13mm | ACV ≤ 25 |
| | Armouring | Course gravel aggregate | 40-50 | ACV < 40 |
| | Roadbase | Local clayey soil/river sand blend (minimum 95% of mdd) | 100 | 15-27 |
| | Sub-base | Well compacted embankment material (minimum 93% of mdd) | 150 | 10 - 15 |
| | Subgrade | Fill material (minimum 91% of mdd) | 1550 | 10 - 15 |
| | | | | |

**Table 6-3 Cumbana Chacane Project Design Data**

| Section | Layer | Material | Design Thickness mm | Design Strength soaked CBR |
|---|---|---|---|---|
| Section 2A 19+000 to 21+000 | Surfacing | Sand seal | | |
| | Roadbase | Well compacted red sand | 100 | 24 |
| | Sub-base | Red sand | 150 | 24 |
| | Capping | Upper subgrade with CBR >15% | 150 | ≥ 15 |
| | Subgrade | Very fine grey coastal sand | | * |
| | | | | |
| Section 2B 21+000 to 21+400 | Surfacing | Penetration Macadam plus sand seal | 5 – 13 | ACV = 26.5 |
| | Roadbase | Well compacted red sand | 150 | 15 - 27 |
| | Sub-base | Red sand | 150 | 15 - 27 |
| | Capping | Upper subgrade with CBR >15% | 150 | >15 |
| | Subgrade | | | * |
| | | | | |
| Section 2C 21+400 to 21+600 | Surfacing | Double sand seal | | |
| | Roadbase | Well compacted red sand | 150 | 15 - 27 |
| | Sub-base | Red sand | 150 | 15 - 27 |
| | Capping | Upper subgrade with CBR >15% | 150 | >15 |
| | Subgrade | | | * |
| | | | | |
| Section 2D 21+600 to 21+800 | Surfacing | Double sand seal | | |
| | Roadbase | Well compacted red sand | 150 | 15 - 27 |
| | Sub-base | Red sand | 150 | 15 - 27 |
| | Capping | Upper subgrade with CBR >15% | 150 | >15 |
| | Subgrade | | | * |

**Table 6-4 Inhacufera Machaze Project Design Data**

| Section | Layer | Material | Design Thickness mm | Strength/ soaked CBR |
|---|---|---|---|---|
| Section 1 10+000 to 11+000 | Surfacing | Otta seal | | |
| | Roadbase | Gravel | 100 | >60 |
| | Sub-base | Existing road made of very coarse gravel with boulders | Variable | Not possible to measure |
| | Subgrade | - | - | - |
| | | | | |
| Section 2 11+000 to 12+000 | Surfacing | Single surface dressing | | |
| | Roadbase | Gravel | 100 | >60 |
| | Sub-base | Existing road made of very coarse gravel with boulders | Variable | Not possible to measure |
| | Subgrade | - | - | - |
| | | | | |
| Section 3 12+000 to 14+700 | Surfacing | Sand seal | | |
| | Roadbase | Gravel | 100 | >60 |
| | Sub-base | Existing road made of very coarse gravel with boulders | Variable | Not possible to measure |
| | Subgrade | - | - | - |
| | | | | |
| Section 4 14+700 to 15+000 | Surfacing | Slurry seal | | |
| | Roadbase | Gravel | 100 | >60 |
| | Sub-base | Existing road made of very coarse gravel with boulders | Variable | Not possible to measure |
| | Subgrade | - | - | - |

**Implemented design variations**

| Section | Layer | Material | Design Thickness mm | Strength/ soaked CBR |
|---|---|---|---|---|
| Section 1 10+000 to 10+600 | Surfacing | Otta seal | | |
| | Roadbase | Gravel | 100 | >60 |
| | Sub-base | Existing road made of very coarse gravel with boulders | Variable | Not possible to measure |
| | Subgrade | - | - | - |
| | | | | |
| Section 2 10+600 to 15+000 | Surfacing | Otta seal with modified spray rates | | |
| | Roadbase | Gravel | 100 | >60 |
| | Sub-base | Existing road made of very coarse gravel with boulders | Variable | Not possible to measure |
| | Subgrade | - | - | - |
| | | | | |

**Table 6-5 Caia Marromeu Project Design Data**

| Section | Layer | Material | Design Thickness mm | Strength/ soaked CBR |
|---|---|---|---|---|
| Section 1<br>0+000 to 5+000 | Surfacing | Sand seal on single Otta seal | | ACV < 25 |
| | Roadbase | Well compacted sand | 100 | 30 |
| | Sub-base | Blended sand and clayey loam | 300 | >20 |
| | Capping | Scarified existing road blended with sand | 200 | >12 |
| | Subgrade | | | >3 |
| | | | | |
| Section 1B<br>1+000 to 3+000 | Surfacing | Sand seal on Otta seal | | ACV < 25 |
| | Roadbase | Well compacted sand | 100 | 30 |
| | Sub-base | Blended sand and clayey loam | 300 | >20 |
| | Capping | Scarified existing road blended with sand | 200 | >12 |
| | Subgrade | | | >3 |
| | | | | |
| Section 2A<br>3+000 to 3+500 | Surfacing | Sand seal | | |
| | Roadbase 1 | Coarse gravel armouring | 40 - 50 | ACV < 40 |
| | Roadbase 2 | Sand | 100 | 30 |
| | Sub-base | Blended sand and clayey loam | 300 | >20 |
| | Capping | Scarified existing road blended with sand | 200 | >12 |
| | Subgrade | | | >3 |
| | | | | |
| | Surfacing | Sand seal on single surface dressing | | ACV < 25 |

| | | | | |
|---|---|---|---|---|
| Section 2B<br>3+500 to 4+000 | Roadbase 1 | Coarse gravel armouring | 40 - 50 | ACV < 40 |
| | Roadbase 2 | Sand | 100 | 30 |
| | Sub-base | Blended sand and clayey loam | 300 | 15 - 27 |
| | Capping | Scarified existing road blended with sand | 200 | >12 |
| | Subgrade | | | >3 |
| | | | | |
| Section 3A<br>4+000 to 5+000 | Surfacing | Sand seal | | |
| | Roadbase | Emulsion treated sand base | 100 | ITS = 124KN |
| | Sub-base | Blended sand and clayey loam | 300 | >20 |
| | Capping | Scarified existing road blended with sand | 200 | >12 |
| | Subgrade | | | >3 |

The project was abandoned

| **Section** | **Layer** | **Material** | **Design Thickness mm** | **Strength/ soaked CBR** |
|---|---|---|---|---|
| Section 1<br>0+000 to 5+000 | Surfacing | Slurry seal | 15 | |
| | Roadbase | Emulsion treated sand | 100 | ITS = 124KN |
| | Sub-base | Blended sand and clayey loam | 300 | >20 |
| | Capping | Extra height for drainage using existing material | 100 | >12 |
| | Subgrade | | | >3 |

This was the final alternative design that was adopted for the project before it was abandoned

**Table 6-6 Zero Mopeia Project Design Data**

| Section | Layer | Material | Design Thickness mm | Strength/ soaked CBR |
|---|---|---|---|---|
| Section 1 | Surfacing | Otta seal | | |
| | Roadbase | Gravel | 100 | >40 |
| | Sub-base | Existing road | variable | 24 |
| | Subgrade | | - | - |
| | | | | |
| Section 2 | Surfacing | Single surface dressing | | |
| | Roadbase | Gravel | 100 | >40 |
| | Sub-base | Existing road | variable | 24 |
| | Subgrade | | - | - |
| | | | | |
| Section 3 | Surfacing | Coarse sand seal | | |
| | Roadbase | Gravel | 100 | >40 |
| | Sub-base | Existing road | variable | 24 |
| | Subgrade | | - | - |
| | | | | |
| Section 4 | Surfacing | Sand seal | | |
| | Roadbase | Gravel | 100 | >40 |
| | Sub-base | Existing road | variable | 24 |
| | Subgrade | | - | - |

# 7 Summary of Contract Prices

The proposed projects were put to tender but the response in some of the provinces was poor. For example, in Manica Province only one contractor (EREPTZ) submitted a bid. Some tender processes were quick and others were slow. The tender process of Caia Marromeu took too long to be concluded and the contractor who grossly under-bid won the contract and then subsequently stopped work. The contract prices for the projects are given in Table 7-1.

**Table 7-1 Contract prices for phase 3 projects**

| Province | Project Name | Contract Price (Mts) |
|---|---|---|
| Maputo | Maragra Machubo | 13,820,000 |
| Gaza | Chinhacanine Nalazi | 14.062,035 |
| Inhambane | Cumbana Chacane | 13,819,973 |
| Manica | Inhacufera Machaze | 18,245,842 |
| Sofala | Caia Marromeu | 13,815,648 |
| Zambezia | Zero Mopeia | 17,797,225 |

# 8 Issues

The design process was comprehensive and focussed mainly on materials, structural design and surfacings. Challenges were faced in delivering this project.

1. There is no accepted method of prospecting for materials and this remains an issue that needs to be resolved for future projects. Though limited in quantity, quality and distribution, better materials than those being used do exist in Mozambique but there is no systematic approach to prospecting and mapping the sources. For example, better materials which were more suitable for base construction were discovered close to Chinhacanine Nalazi Project when the project was already too advanced to change.
2. The tender processes can take a long time and this delayed the commencement of projects.
3. Some of the contractors are unable to comprehend the scope of works involved and, at times, their pricing is wrong or circumstances force them to under-bid. This has affected some projects – the Caia Marromeu Project is a good example.
4. Design decisions are based on the laboratory results, especially where they concern materials and pavement design, but some of the laboratory results are manifestly inaccurate.

5. It is difficult to estimate how much the traffic volume will change when the interventions are successfully implemented and much of the created traffic will bear significance to the deterioration of the road.

# 9 Recommendations

It is important to take note of the following recommendations in order to for the designs to be implemented successfully.

1. On a project of this nature where research in a significant and important component of the process it is recommended that competent contractors are engaged to carry out the works. The experience has been that the less competent contractor undercut the competent ones and then they take very long to complete the works. Quality is also compromised in the process.
2. It is important to have the laboratory personnel trained because materials testing is very important is low volume roads design. The lab tests results define the various marginal materials and inaccurate testing leads poor results which culminate in poor design decisions. Sometimes equipment is not calibrated for long periods of time and the results are sometimes difficult to trust. It is recommended that where possible parts of the same sample are sent to different laboratories for comparison purposes.
3. Construction should follow the methods stipulated in the BoQs or as directed by the supervising engineer of TA engineering staff. Marginal materials behave differently from the conventional materials and some of the methods of construction developed for the conventional materials may not apply for the non-conventional materials and thus variations are inevitable and should be given due care.
4. Lessons have been leant in the construction of Otta seals. After construction Otta seals require traffic to cure. The action of traffic will help to work the bitumen up the graded aggregate. This is the curing process. If traffic is too low the curing process is both slow and less effective. In this case more rolling of the new Otta seal surfacing is necessary and it can be referred to as 'compensatory rolling'. Guidance for the compensatory rolling is given in Table 9-1. Traffic speed should be regulated at 30-40km/h.

**Table 9-1 Guide for rolling of Otta seals**

| Grading of aggregate | Traffic | Normal compaction | Additional or Compensatory rolling |
|---|---|---|---|
| Standard: -19mm to 5mm sizes.<br>P0.075 < 10% | ADT > 100 | 4 days applying 12 passes per day of a heavy pneumatic roller (8 tonne or more). Open to traffic and direct traffic over the whole width using | None but engineer's discretion is necessary. |

| | | | |
|---|---|---|---|
| | | traffic cones | |
| | 50<ADT<100 | 3 days applying 12 passes per day of a heavy pneumatic roller (8 tonne or more). | 8 passes per day of a heavy pneumatic roller (8 tonne or more) for 4 days while section is open to traffic. |
| | ADT < 50 | 3 days applying 12 passes per day of a heavy pneumatic roller (8 tonne or more). | 8 passes per day of a heavy pneumatic roller (8 tonne or more) for 11 days while section is open to traffic. |
| Appropriate for low volume roads (nominal maximum size of 13mm and $P_{0.075}$ < 13%) | ADT > 100 | 3 days applying 12 passes per day of a heavy pneumatic roller (8 tonne or more). | None |
| | 50< ADT < 100 | 3 days applying 12 passes per day of a heavy pneumatic roller (8 tonne or more). | Engineer's discretion may be necessary |
| | ADT < 50 | 3 days applying 12 passes per day of a heavy pneumatic roller (8 tonne or more). | 8 passes per day of a heavy pneumatic roller (8 tonne or more) for 2 days while section is open to traffic. |

# 10 Conclusion

The design project was carried out successfully and some interesting innovative design ideas and methods are being developed and assessed through trialling. ANE has been forthcoming in allowing TRL and the provincial consultants to develop and trial different designs which TRL is confident will have a substantial impact on the provision of rural road networks in Mozambique.

The design process incorporated a number of aspects.

1. To utilise to abundant local resources in Mozambique which do not meet the conventional requirements and specifications.
2. To enhance the research component of the project through trialling new designs and design principles and methods.

3. To involve the recipient of this new knowledge through research so that there will be local ownership of the technologies. This is important for future mainstreaming of these specifications and work methods.
4. The designs and proposed work norms need to be clearly understood by the implementing partners i.e. the contractors and the consultants. The process included visits and meetings with staff in the Department of Maintenance (DIMAN) the provincial staff of ANE (DIPANE), the provincial consultants and the contractors (though at a later stage).
5. The process has been *'design as you go'* allowing contributions from the different partners before the finalisation of the designs. This has at times necessitated changes in the contract and BoQs so long as the overall contract value remained unchanged. This was only achieved through mutual understanding amongst the project partners. This approach of 'design as you go' has proved to be effective.

The project has provided the necessary but rare opportunity to advance engineering technologies to the benefit of designer, road authorities, ANE in particular, the Road Fund and the rural communities in general.

# 11 References


1. Guideline for Quality Assurance Procedures for Road Works (TRL 2006)
2. Mozambique Engineering Standards Project Report (TRL/ANE 2006)
3. SADC Guideline (TRL)
4. Normas de Execucao (ANE)
5. Road Note 31 (TRL)
6. Road Note 3 (TRL)
7. Part P Materials Manual (Department of Roads, Zimbabwe)

# 12 APPENDIX

## A.1 BoQs and Drawings for Chinhacanine Nalazi Project

| | Activity | Qty | Rate | Amount |
|---|---|---|---|---|
| **1** | **Preliminaries and general** | | | |
| 1.1 | Mobilisation and demobilisation | | | |
| 1.2 | Camp and site | | | |
| 1.3 | Quality control (Lab testing) | | | |
| 1.4 | Combating HIV/SIDA | | | |
| 2 | **Section 1: 0+000 to 0+300: Raise existing embankment to a total of 1.7m, 100mm cement or emulsion stabilised sand base, single sand seal surfacing. (ETB is preferred)** | | | |
| 2.1 | Regularise existing embankment: scarify surface of existing embankment to a depth of 200mm, reshape and compact to a minimum of 93% mdd Mod. AASHTO. Camber 2.5-3% | | | |
| 2.2 | Construct embankment: Excavate from borrow pit, haul, dump, water, mix and compact to a minimum of 93% mdd Mod AASHTO. Compact in layers no more than 150mm thick until a level of 1.7m (additional height of 0.5m). compact last layer to a minimum of 95% mdd Mod. AASHTO. Camber 2.5-3%, side slope 1:4. | | | |
| 2.3 | Cement/emulsion stabilised base 100mm thick, 6m width: excavate from borrow pit, haul, dump, spread, add cement to achieve 4% cement or 6% emulsion, mix, water, mix, spread and compact (maximum duration of process after adding water shall not exceed 6 hrs). Camber 2.5-3%. Apply sand cover and cure the cement or emulsion stabilised base for 7 days. | | | |
| 2.4 | Priming (6m width): Sweep the armoured base thoroughly and sprinkle water and place markings ready for priming. Apply prime at a rate 0.6 L/m$^2$ (MC30 or emulsion dilutes 50:50 with water) for 6m width (including sealed shoulders) and allow 3 to 7 days curing. | | | |
| 2.5 | Surfacing with sand seal 6m width. Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 or emulsion SS60 or 70 at 1.0 L/m$^2$. Apply the sand at 7.0 L/m$^2$. Spread and roll with a steel roller in non-vibratory mode or a pneumatic roller (pneumatic roller preferred). 14 passes on the first day and 8 passes on the hot part of the day for an extra 2 days. Open to traffic on the fourth day and limit the operating speed to 30km/h while brooming back the sand for 2 weeks. | | | |
| | | | | |

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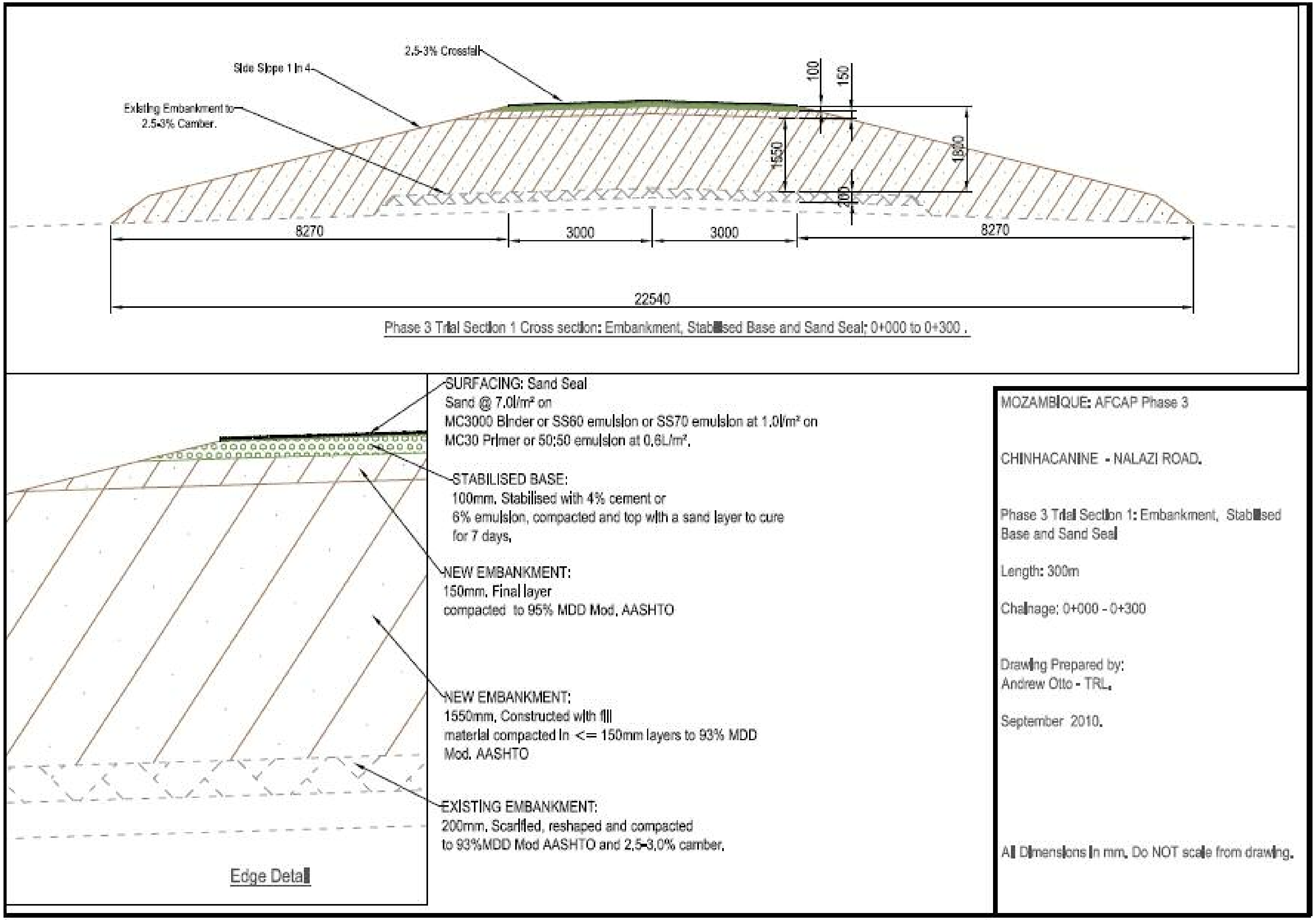
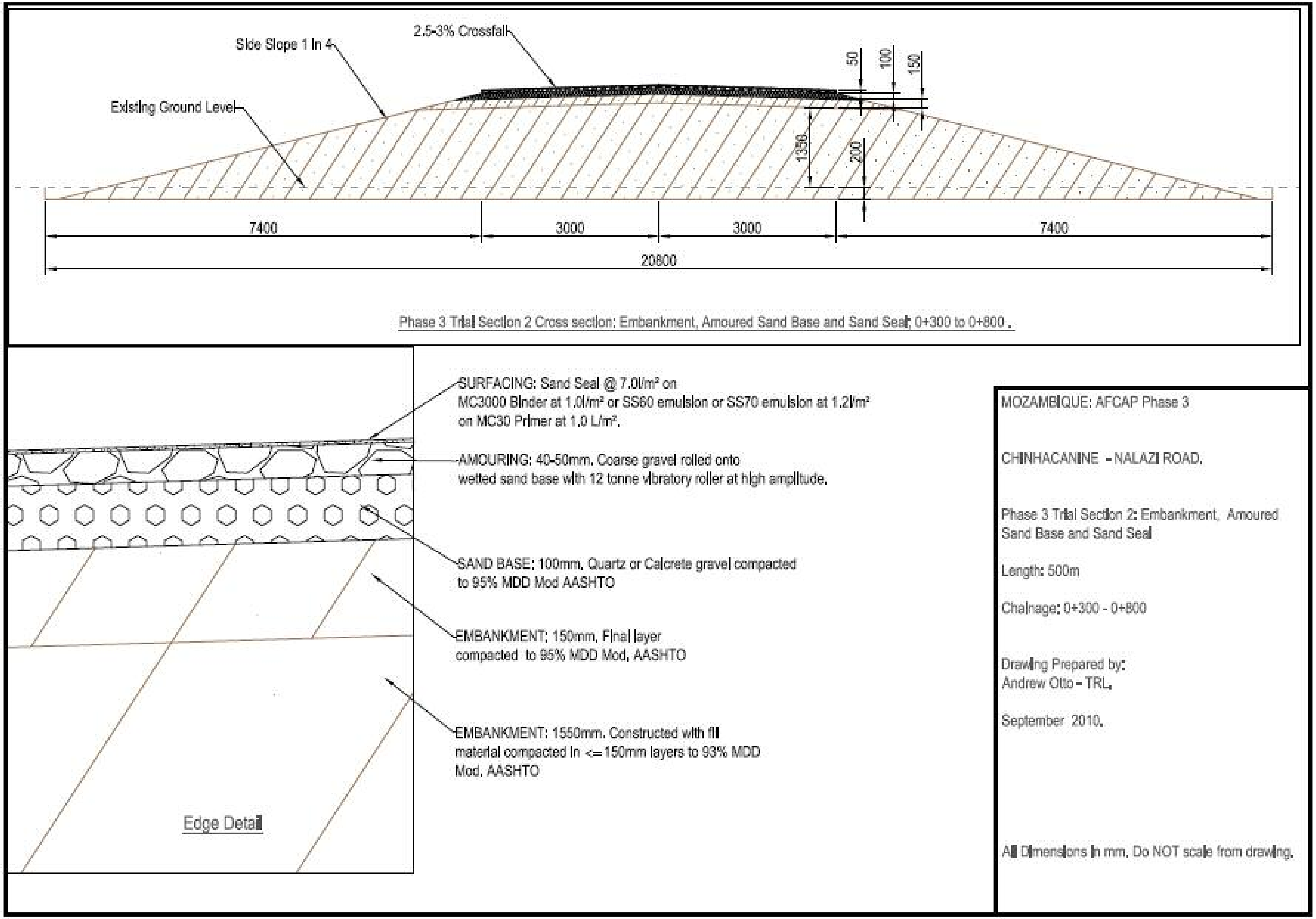
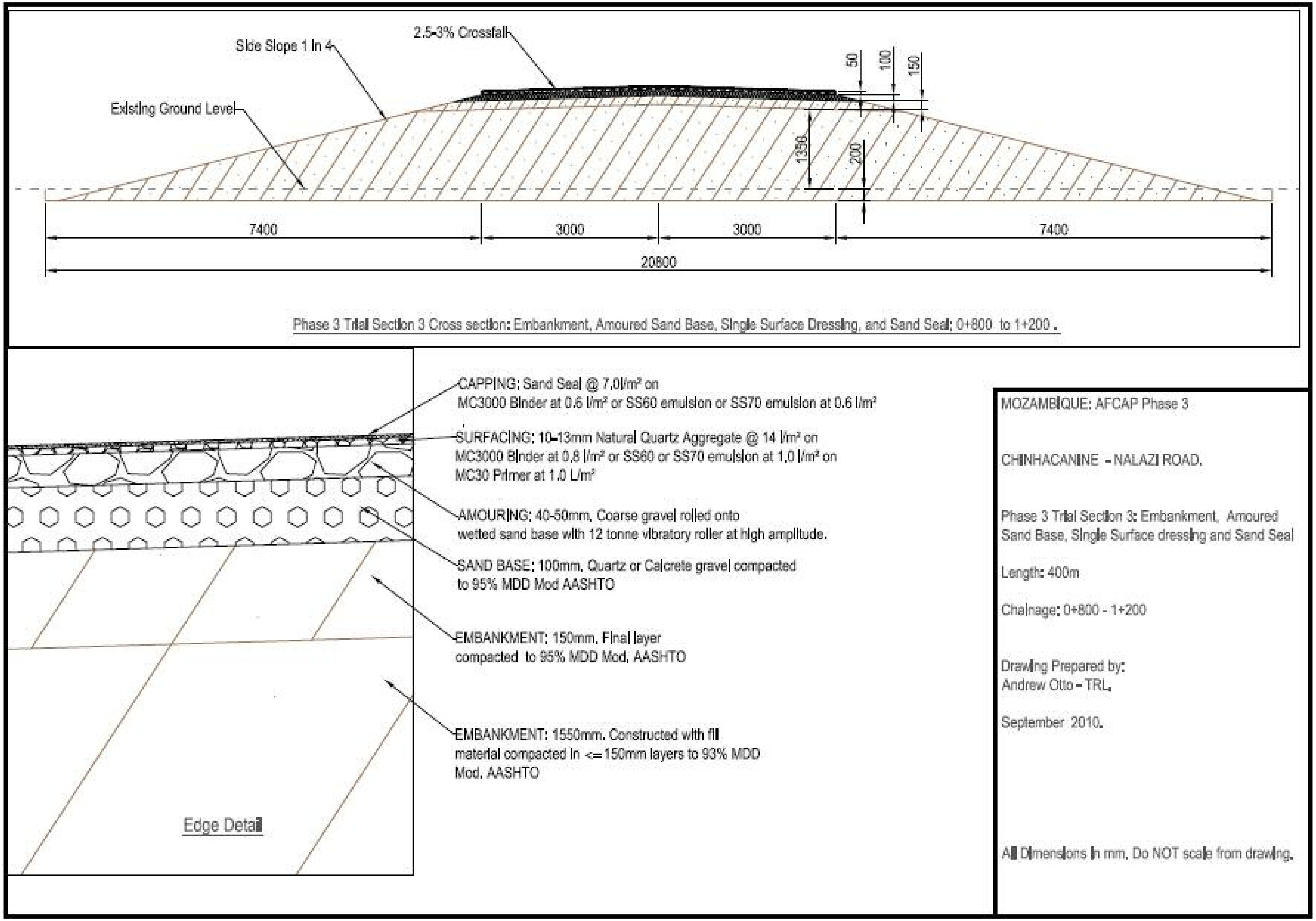
|---|---|---|---|---|
| 3 | **Section 2: 0+300 to 1+200: Raised embankment, armoured sand base with sand seal (500) and single surface dressing with sand capping (400m).** | | | |
| 3.1 | Road bed: Remove organic soils to about 200mm depth from ground level 10.4m either side of the centreline. Water and roll roadbed with pneumatic roller 8 tonne or more, minimum 8 passes. | | | |
| 3.2 | Embankment: Excavate from borrow pit, haul, dump, water, mix and compact to a minimum of 93% mdd mod. AASHTO. Compact in layers no more than 150mm thick until a level of 1.7m. Compact last layer to a minimum of 95% mdd Mod. AASHTO. Camber 2.5-3%, side slope 1:4. | | | |
| 3.3 | Armoured sand base: Excavate and stockpile coarse quartz gravel or calcrete. Excavate and stockpile, haul, dump, water, mix spread and compact to a minimum of 95% mdd Mod AASHTO, 100mm compacted thickness. Haul coarse gravel, dump, water, mix and spread 40-50mm thick (wet surface of sand base before spreading the mixed coarse gravel). Roll with heavy (12 ton or more) in vibratory mode at high amplitude. Some of the aggregate will be pressed into the sand base. This forms the armouring layer for the armoured sand base. | | | |
| 3.4 | Priming: Sweep the surface of the armoured sand base thoroughly and sprinkle water lightly and place markings ready for priming, avoid excessive wetting of the surface of the base. Apply prime at a rate 1.0 L/$m^2$ and allow 5 to 7 days curing. | | | |
| 3.5a | Surfacing with sand seal, 6m width (500m). Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 at 1.0L/$m^2$ or emulsion SS60 or 70 at 1.2 L/$m^2$. Immediately, spread sand at a rate of 7.0L/m2 and roll with pneumatic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. | | | |
| 3.5b | Surfacing with natural quartz aggregate, 6m width (10-13mm size) (400m). Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 at 0.8L/$m^2$ or emulsion SS60 or 70 at 1.0L/$m^2$. Immediately apply natural quartz aggregate at a rate of 14L/m2 and roll with pneumatic. Spray the binder MC3000 at 0.6L/m2 or emulsion SS60 or 70 at 0.6 L/m2 and apply sand. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. | | | |
| | | | | |

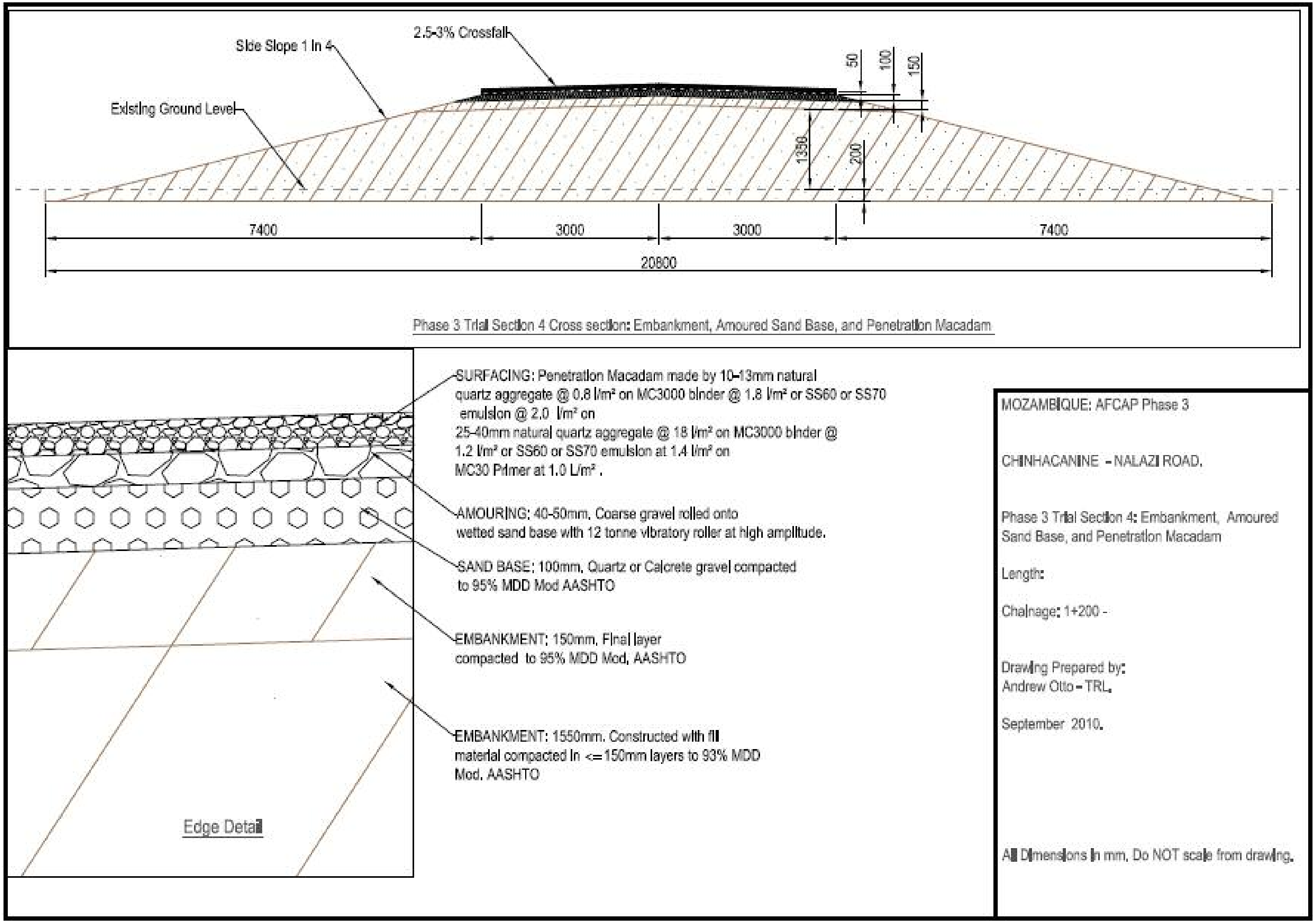
| | | | | |
|---|---|---|---|---|
| 4 | Section 3: 0+300 to 1+200: Raised embankment, untreated sand base surfaced with Penetration Macadam and double surface dressing with natural quartz aggregate. | | | |
| 4.1 | Road bed: Remove organic soils to about 200mm depth from ground level 10.4m either side of the centreline. Water and roll roadbed with pneumatic roller 8 tonne or more, minimum 8 passes. | | | |
| 4.2 | Embankment: Excavate from borrow pit, haul, dump, water, mix and compact to a minimum of 93% mdd mod AASHTO. Compact in layers no more than 150mm thick until a level of 1.7m. Compact last layer to a minimum of 95% mdd Mod. AASHTO. Camber 2.5-3%, side slope 1:4. | | | |
| 4.3 | Armoured sand base: Excavate and stockpile coarse quartz gravel or calcrete. Excavate and stockpile, haul, dump, water mix spread and compact to a minimum of 95% mdd Mod AASHTO, 100mm compacted thickness. Haul coarse gravel, dump, water, mix and spread 40-50mm thick (wet surface of sand base before spreading the mixed coarse gravel). Roll with heavy (12 ton or more) in vibratory mode at high amplitude. Some of the aggregate will be pressed into the sand base. This forms the armouring layer for the armoured sand base. | | | |
| 4.4 | Priming: Sweep the surface of the armoured sand base thoroughly and sprinkle water lightly and place markings ready for priming, avoid excessive wetting of the surface of the base. Apply prime at a rate 1.0 L/$m^2$ and allow 5 to 7 days curing. | | | |
| 4.5a | Surfacing: Penetration Macadam. Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 at 1.2L/$m^2$ or emulsion SS60 or 70 at 1.4 L/$m^2$. Immediately, spread 25-40mm natural quartz aggregate at a rate of 18L/$m^2$ and roll with pneumatic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the aggregate moved off the carriageway by traffic. Sweep off loose aggregate, dust and debris from the first layer/tack coat. Spray binder MC3000 at a rate of 1.8L/$m^2$ spread the natural quartz aggregate 10-13mm at a rate of 0.8L/$m^2$. Roll with pneumatic roller applying 12 passes on the first days and 8 passes each day for an extra 2 days. Open to traffic and broom back loose aggregate for 2 weeks. | | | |

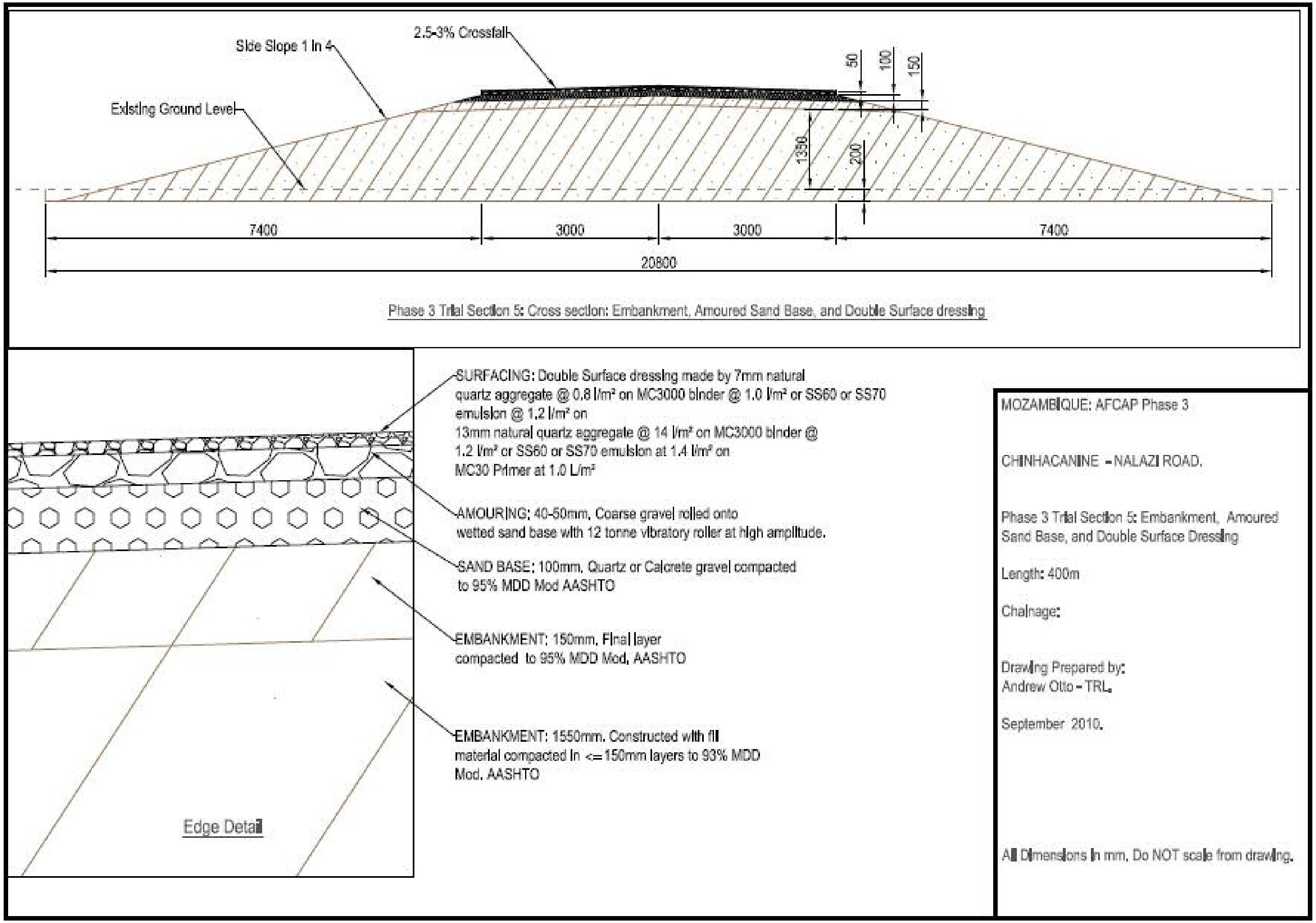
| | | | | |
|---|---|---|---|---|
| 4.5b | Surfacing: Double surface dressing 7mm/13mm (400m). Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 at 1.2L/$m^2$ or emulsion SS60 or 70 at 1.4 L/$m^2$. Immediately, spread 13mm natural quartz aggregate at a rate of 14L/$m^2$ and roll with pneumatic roller. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the aggregate moved off the carriageway by traffic. Sweep off loose aggregate, dust and debris from the first layer/tack coat. Spray binder MC3000 at a rate of 1.0L/$m^2$ and spread the natural quartz aggregate 7mm at a rate of 0.8L/$m^2$. Roll with pneumatic roller applying 12 passes on the first days and 8 passes each day for an extra 2 days. Open to traffic and broom back loose aggregate for 2 weeks. | | | |
| | | | | |


2.5-3% Crossfall
Side Slope 1 in 4
Existing Embankment to 2.5-3% Camber.
100
150
1550
1800
200
8270
3000
3000
8270
22540
Phase 3 Trial Section 1 Cross section: Embankment, Stabilised Base and Sand Seal; 0+000 to 0+300 .
SURFACING: Sand Seal
Sand @ 7.0l/m² on
MC3000 Binder or SS60 emulsion or SS70 emulsion at 1.0l/m² on
MC30 Primer or 50:50 emulsion at 0.6L/m².
STABILISED BASE:
100mm. Stabilised with 4% cement or
6% emulsion, compacted and top with a sand layer to cure
for 7 days.
NEW EMBANKMENT:
150mm. Final layer
compacted to 95% MDD Mod. AASHTO
NEW EMBANKMENT:
1550mm. Constructed with fill
material compacted in <= 150mm layers to 93% MDD
Mod. AASHTO
EXISTING EMBANKMENT:
200mm. Scarified, reshaped and compacted
to 93%MDD Mod AASHTO and 2.5-3.0% camber.
Edge Detail
MOZAMBIQUE: AFCAP Phase 3
CHINHACANINE - NALAZI ROAD.
Phase 3 Trial Section 1: Embankment, Stabilised Base and Sand Seal
Length: 300m
Chainage: 0+000 - 0+300
Drawing Prepared by:
Andrew Otto - TRL.
September 2010.
All Dimensions in mm. Do NOT scale from drawing.


2.5-3% Crossfall
Side Slope 1 In 4
Existing Ground Level
50
100
150
1350
200
7400
3000
3000
7400
20800
Phase 3 Trial Section 2 Cross section: Embankment, Amoured Sand Base and Sand Seal: 0+300 to 0+800 .
SURFACING: Sand Seal @ 7.0l/m² on MC3000 Binder at 1.0l/m² or SS60 emulsion or SS70 emulsion at 1.2l/m² on MC30 Primer at 1.0 L/m².
AMOURING: 40-50mm. Coarse gravel rolled onto wetted sand base with 12 tonne vibratory roller at high amplitude.
SAND BASE: 100mm, Quartz or Calcrete gravel compacted to 95% MDD Mod AASHTO
EMBANKMENT: 150mm, Final layer compacted to 95% MDD Mod, AASHTO
EMBANKMENT: 1550mm. Constructed with fill material compacted in <=150mm layers to 93% MDD Mod, AASHTO
Edge Detail
MOZAMBIQUE: AFCAP Phase 3
CHINHACANINE - NALAZI ROAD.
Phase 3 Trial Section 2: Embankment, Amoured Sand Base and Sand Seal
Length: 500m
Chainage: 0+300 - 0+800
Drawing Prepared by:
Andrew Otto - TRL.
September 2010.
All Dimensions in mm. Do NOT scale from drawing.


2.5-3% Crossfall
Side Slope 1 In 4
Existing Ground Level
50
100
150
1350
200
7400
3000
3000
7400
20800
Phase 3 Trial Section 3 Cross section: Embankment, Amoured Sand Base, Single Surface Dressing, and Sand Seal; 0+800 to 1+200 .
CAPPING: Sand Seal @ 7.0l/m² on
MC3000 Binder at 0.6 l/m² or SS60 emulsion or SS70 emulsion at 0.6 l/m²
SURFACING: 10-13mm Natural Quartz Aggregate @ 14 l/m² on
MC3000 Binder at 0.8 l/m² or SS60 or SS70 emulsion at 1.0 l/m² on
MC30 Primer at 1.0 L/m²
AMOURING: 40-50mm, Coarse gravel rolled onto
wetted sand base with 12 tonne vibratory roller at high amplitude.
SAND BASE: 100mm, Quartz or Calcrete gravel compacted
to 95% MDD Mod AASHTO
EMBANKMENT: 150mm, Final layer
compacted to 95% MDD Mod, AASHTO
EMBANKMENT: 1550mm, Constructed with fill
material compacted in <= 150mm layers to 93% MDD
Mod, AASHTO
Edge Detail
MOZAMBIQUE: AFCAP Phase 3
CHINHACANINE - NALAZI ROAD.
Phase 3 Trial Section 3: Embankment, Amoured Sand Base, Single Surface dressing and Sand Seal
Length: 400m
Chainage: 0+800 - 1+200
Drawing Prepared by:
Andrew Otto - TRL.
September 2010.
All Dimensions in mm, Do NOT scale from drawing.


2.5-3% Crossfall
Side Slope 1 in 4
Existing Ground Level
50
100
150
1350
200
7400
3000
3000
7400
20800
Phase 3 Trial Section 4 Cross section: Embankment, Amoured Sand Base, and Penetration Macadam
SURFACING: Penetration Macadam made by 10-13mm natural quartz aggregate @ 0.8 l/m² on MC3000 binder @ 1.8 l/m² or SS60 or SS70 emulsion @ 2.0 l/m² on
25-40mm natural quartz aggregate @ 18 l/m² on MC3000 binder @ 1.2 l/m² or SS60 or SS70 emulsion at 1.4 l/m² on
MC30 Primer at 1.0 L/m².
AMOURING: 40-50mm, Coarse gravel rolled onto wetted sand base with 12 tonne vibratory roller at high amplitude.
SAND BASE: 100mm, Quartz or Calcrete gravel compacted to 95% MDD Mod AASHTO
EMBANKMENT: 150mm, Final layer compacted to 95% MDD Mod, AASHTO
EMBANKMENT: 1550mm. Constructed with fill material compacted in <=150mm layers to 93% MDD Mod. AASHTO
Edge Detail
MOZAMBIQUE: AFCAP Phase 3
CHINHACANINE - NALAZI ROAD.
Phase 3 Trial Section 4: Embankment, Amoured Sand Base, and Penetration Macadam
Length:
Chainage: 1+200 -
Drawing Prepared by:
Andrew Otto - TRL.
September 2010.
All Dimensions in mm, Do NOT scale from drawing.


2.5-3% Crossfall
Side Slope 1 in 4
Existing Ground Level
50
100
150
1350
200
7400
3000
3000
7400
20800
Phase 3 Trial Section 5: Cross section: Embankment, Amoured Sand Base, and Double Surface dressing
SURFACING: Double Surface dressing made by 7mm natural quartz aggregate @ 0.8 l/m² on MC3000 binder @ 1.0 l/m² or SS60 or SS70 emulsion @ 1.2 l/m² on
13mm natural quartz aggregate @ 14 l/m² on MC3000 binder @ 1.2 l/m² or SS60 or SS70 emulsion at 1.4 l/m² on
MC30 Primer at 1.0 L/m²
AMOURING: 40-50mm, Coarse gravel rolled onto wetted sand base with 12 tonne vibratory roller at high amplitude.
SAND BASE: 100mm, Quartz or Calcrete gravel compacted to 95% MDD Mod AASHTO
EMBANKMENT: 150mm, Final layer compacted to 95% MDD Mod, AASHTO
EMBANKMENT: 1550mm, Constructed with fill material compacted in <=150mm layers to 93% MDD Mod, AASHTO
Edge Detail
MOZAMBIQUE: AFCAP Phase 3
CHINHACANINE - NALAZI ROAD.
Phase 3 Trial Section 5: Embankment, Amoured Sand Base, and Double Surface Dressing
Length: 400m
Chainage:
Drawing Prepared by:
Andrew Otto - TRL.
September 2010.
All Dimensions in mm, Do NOT scale from drawing.

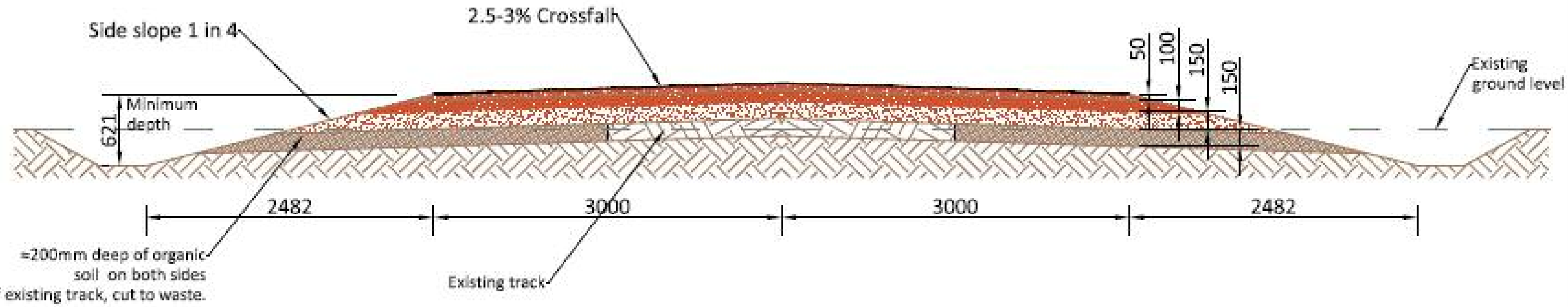
## A.2 BoQs and Drawings for Cumbana Chacane Project

The information give here was TRL's proposal. Please see updated information in Chapter 5.

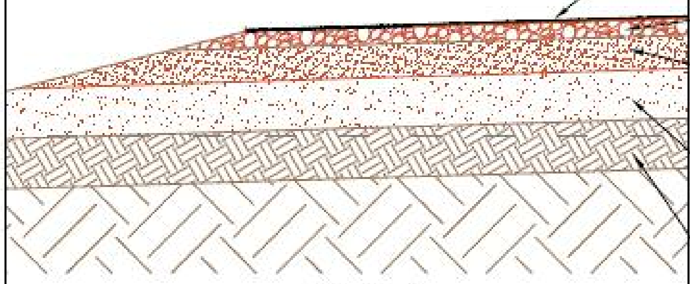
| | Activity | Qty | Rate | Amount |
|---|---|---|---|---|
| | Mobilisation and demobilisation | | | |
| | Combating HIV/SIDA | | | |
| | **Section 2A: 4000m Armoured sand base with sand seal** | | | |
| 1 | Road bed: Remove loose sand from the existing track to firm ground ( cut to waste). Remove organic soils to about 200mm depth from ground level on both sides of the existing track. Water and roll roadbed with pneumatic roller. | | | |
| 2 | Formation: Cut side drains and form the subgrade layer with in-situ material. Water mix and compact to minimum 91% mdd, Mod. AASHTO. Minimum CBR 15%. Thickness 150mm, Side slope 1:4 | | | |
| 3 | Selected Subgrade: Excavate and stockpile red sand from borrow pit. Haul dump and spread, water, mix and compact to minimum 93% mdd Mod AASHTO, thickness 150mm, minimum CBR 30%. | | | |
| 4 | Armoured red sand base course, 6m width: Dump red sand and spread. Apply two passes of pneumatic roller. Dump calcrete enough to mix at 70:30 proportions of granular calcrete and red sand. Spread and windrow the calcrete on one shoulder. Reopen the layer of red sand respectively, water and compact in 50mm layers applying 3 passes of pneumatic roller per layer for the first 100mm. Mix the sand for the final 50mm with the calcrete and windrow the mixture on the other shoulder. Open, water, mix and compact the 100mm of the red sand on the remaining width of the carriageway as described above. Water, mix and compact the final 50mm of the red sand/calcrete blend. Apply 3 passes of a pneumatic roller. Skim the surface of the base, sprinkle water and roll with a steel roller, apply a minimum of 8 passes. (The calcrete provides an armouring effect rather that a structure effect) | | | |
| 5 | Priming (6m width): Sweep the armoured base thoroughly and sprinkle water and place markings ready for priming. Apply prime at a rate 1.0 L/$m^2$ (MC30 or emulsion dilutes 50:50 with water) for 6m width (including sealed shoulders) and allow 3 to 7 days curing. | | | |
| 6 | Surfacing. Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC800 or emulsion SS60 or 70 at 1.2 L/$m^2$. Apply the sand at 7 L/$m^2$. Spread and roll with a steel roller in non-vibratory mode or a pneumatic roller. 14 passes on the first day and 8 passes on the hot part of the day for an extra 2 days. Open to traffic on the fourth day and limit the operating speed to 30km/h. | | | |
| | | | | |
| | **Section 2B Sand base with Penetration Macadam using calcrete aggregate (1000m)** | | | |

| | | | | |
|---|---|---|---|---|
| 1 | Road bed: Remove loose sand from the existing track to firm ground ( cut to waste). Remove organic soils to about 200mm depth from ground level on both sides of the existing track. Water and roll roadbed with pneumatic roller. | | | |
| 2 | Formation: Cut side drains and form the subgrade layer with in-situ material. Water mix and compact to minimum 91% mdd, Mod. AASHTO. Minimum CBR 15%. Thickness 150mm. | | | |
| 3 | Selected Subgrade: Excavate and stockpile red sand from borrow pit. Haul dump and spread, water, mix and compact to minimum 93% mdd Mod AASHTO, thickness 150mm, minimum soaked CBR 30%. | | | |
| 4 | Red sand base: Dump, spread, water, mix and compact red sand 150mm thick and minimum 95% Mod AASHTO, minimum soaked CBR 30% | | | |
| 5 | Priming: Sweep the sand base thoroughly and sprinkle water lightly and place markings ready for priming, avoid softening of the surface of the base. Apply prime at a rate 1.0 L/m$^2$ and allow 5 to 7 days curing. | | | |
| 6 | Surfacing. Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC800 or emulsion SS60 or 70 at 1.2 L/m$^2$. Apply coarse calcrete aggregate of nominal size that is less than 50mm. Apply 1 to 2 passes of a steel roller in non-vibratory mode to press the aggregate. Apply 12 passes of pneumatic roller for the first day, and 8 passes per day for 2 extra days. Sweep any loose aggregate and blow off any dust if possible. Apply a light shower of water and spray bitumen MC800 or emulsion SS70 at a rate of 1.6L/m2. Immediately, spread sand at a rate of 7.0L/m2 and roll with pneumatic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. | | | |
| | | | | |
| | **Section 2C Sand base with Double Sand Seal (700m)** | | | |
| 1 | Road bed: Remove loose sand from the existing track to firm ground ( cut to waste). Remove organic soils to about 200mm depth from ground level on both sides of the existing track. Water and roll roadbed with pneumatic roller. | | | |
| 2 | Formation: Cut side drains and form the subgrade layer with in-situ material. Water mix and compact to minimum 91% mdd, Mod. AASHTO. Minimum CBR 15%. Thickness 150mm. | | | |
| 3 | Selected Subgrade: Excavate and stockpile red sand from borrow pit. Haul dump and spread, water, mix and compact to minimum 93% mdd Mod AASHTO, thickness 150mm, minimum soaked CBR 30%. | | | |
| 4 | Red sand base: Dump, spread, water, mix and compact red sand 150mm thick and minimum 95% Mod AASHTO, minimum soaked | | | |

| | | | | |
|---|---|---|---|---|
| | CBR 30% | | | |
| 5 | Priming: Sweep the sand base thoroughly and sprinkle water lightly and place markings ready for priming, avoid softening of the surface of the base. Apply prime at a rate 1.0 L/$m^2$ and allow 5 to 7 days curing. | | | |
| 6 | Surfacing. Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC800 or emulsion SS70 at 1.2 L/$m^2$. Immediately, spread sand at a rate of 7.0L/m2 and roll with pneumatic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. Inspect the surfacing. If adequately cured prepare for the second layer and apply as described for the first layer. Curing period depends on the type of binder used and the volume of traffic. | | | |
| | | | | |
| | **Section 2D Sand base with Single Sand Seal (500m)** | | | |
| 1 | Road bed: Remove loose sand from the existing track to firm ground ( cut to waste). Remove organic soils to about 200mm depth from ground level on both sides of the existing track. Water and roll roadbed with pneumatic roller. | | | |
| 2 | Formation: Cut side drains and form the subgrade layer with in-situ material. Water mix and compact to minimum 91% mdd, Mod. AASHTO. Minimum CBR 15%. Thickness 150mm. | | | |
| 3 | Selected Subgrade: Excavate and stockpile red sand from borrow pit. Haul dump and spread, water, mix and compact to minimum 93% mdd Mod AASHTO, thickness 150mm, minimum soaked CBR 30%. | | | |
| 4 | Red sand base: Dump, spread, water, mix and compact red sand 150mm thick and minimum 95% Mod AASHTO, minimum soaked CBR 30% | | | |
| 5 | Priming: Sweep the sand base thoroughly and sprinkle water lightly and place markings ready for priming, avoid softening of the surface of the base. Apply prime at a rate 1.0 L/$m^2$ and allow 5 to 7 days curing. | | | |
| 6 | Surfacing. Sweep the primed base thoroughly, sprinkle a litte water, spray the binder MC800 or emulsion SS70 at 1.2 L/$m^2$. Immediately, spread sand at a rate of 7.0L/m2 and roll with pneumatic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. | | | |




Phase 3 Trial Section 2A: Armoured Sand Base with Sand Seal Surfacing - Cross-section Drawing



Edge Detail

SURFACING: Sand Seal
Sand @ 7ltr/m² on
MC-800 or SS60 or SS70 Emulsion @ 1.2ltr/m² on
MC-30 or 50:50 water diluted emulsion @1.0ltr/m².

ARMOURING:
50mm thick Granular Calcrete:Red Sand- 70:30.

BASE COURSE:
100mm Red Sand
Compacted to 95% MDD ModAASHTO.
Soaked CBR >30%.

SELECTED SUBGRADE:
150mmRed Sand
Compacted to 93% MDD ModAASHTO.
Soaked CBR >30%.

FORMATION.
150mm Material Cut from Side Drains
Compacted to 91% MDD ModAASHTO.
Soaked CBR >15%.

MOZAMBIQUE: AFCAP.

CUMBANA - CHACANE ROAD.

Phase 3 Trial Section 2A : Armoured Sand Base with Sand Seal Surfacing

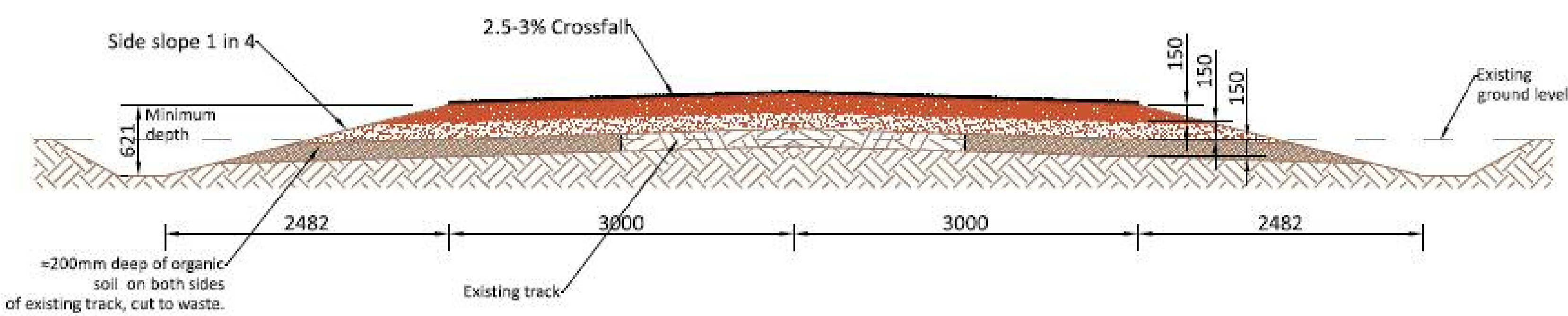
Length: 2000m

Chainage: 19+000 to 21+000

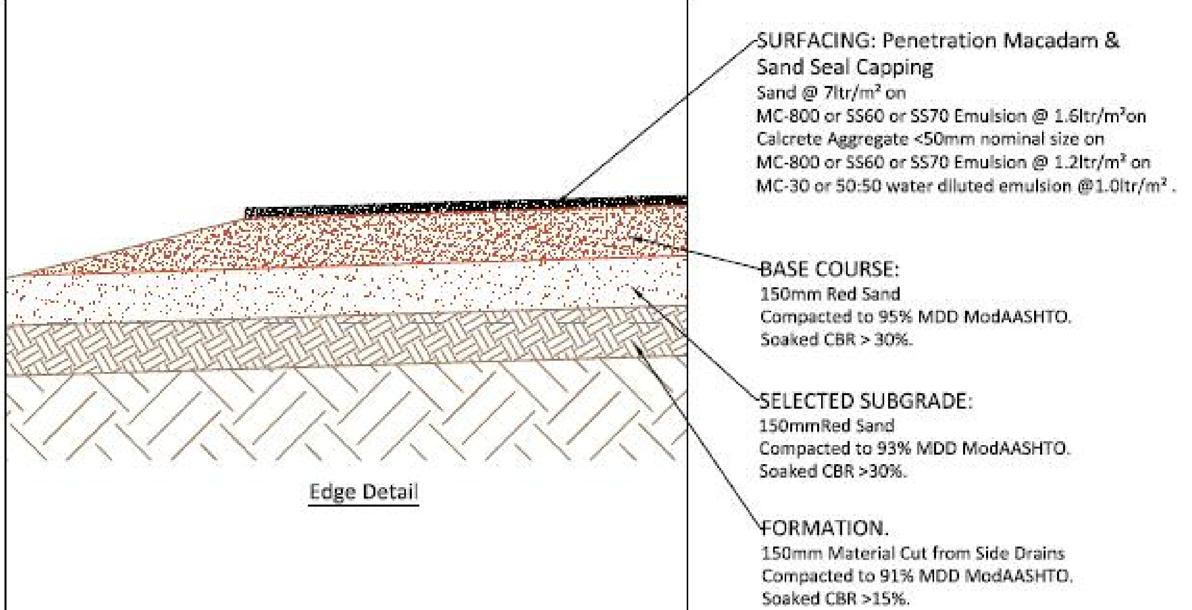
Drawing Prepared by:
Andrew Otto - TRL.

November 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 2B: Sand Base with Penetration Macadam and Sand Seal Capping - Cross-section Drawing




Edge Detail

MOZAMBIQUE: AFCAP.

CUMBANA - CHACANE ROAD.

Phase 3 Trial Section 2B : Sand Base with Penetration Macadam and Sand Seal Capping.

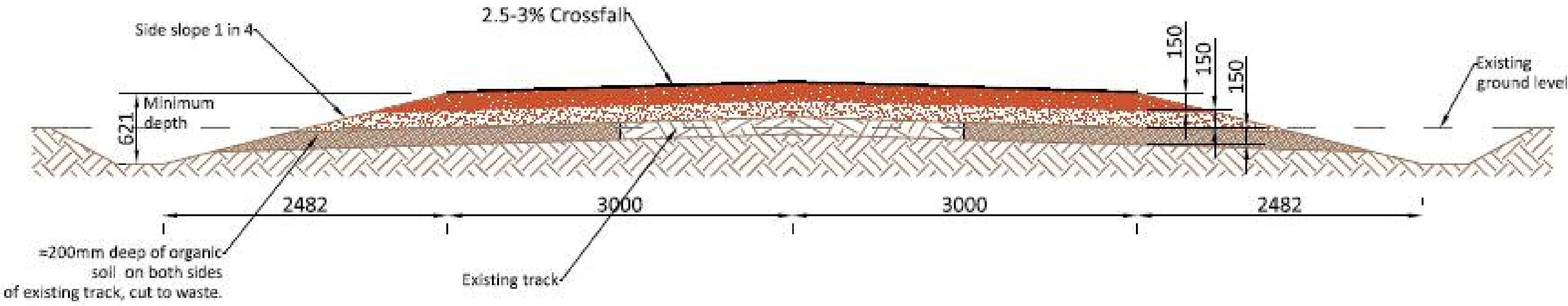
Length: 400m

Chainage: 21+000 to 21+400

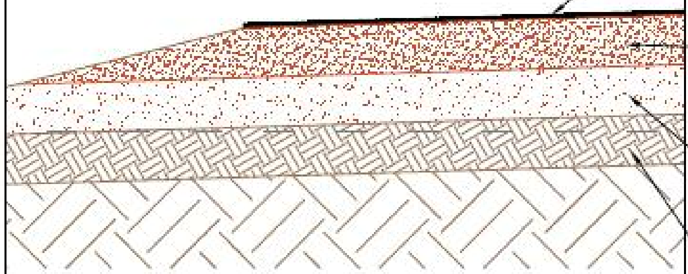
Drawing Prepared by:
Andrew Otto - TRL.

November 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 2C: Sand Base with Double Sand Seal Surfacing - Cross-section Drawing



Edge Detail

SURFACING: Double Sand Seal
Sand @ 7ltr/m² on
MC-800 or SS60 or SS70 Emulsion @ 1.2ltr/m²on
Sand @ 7ltr/m² on
MC-800 or SS60 or SS70 Emulsion @ 1.2ltr/m²on
MC-30 or 50:50 water diluted emulsion @1.0ltr/m².

BASE COURSE:
150mm Red Sand
Compacted to 95% MDD ModAASHTO.
Soaked CBR > 30%.

SELECTED SUBGRADE:
150mmRed Sand
Compacted to 93% MDD ModAASHTO.
Soaked CBR >30%.

FORMATION.
150mm Material Cut from Side Drains
Compacted to 91% MDD ModAASHTO.
Soaked CBR >15%.

MOZAMBIQUE: AFCAP.

CUMBANA - CHACANE ROAD.

Phase 3 Trial Section 2C : Sand Base with Double Sand Seal Surfacing.

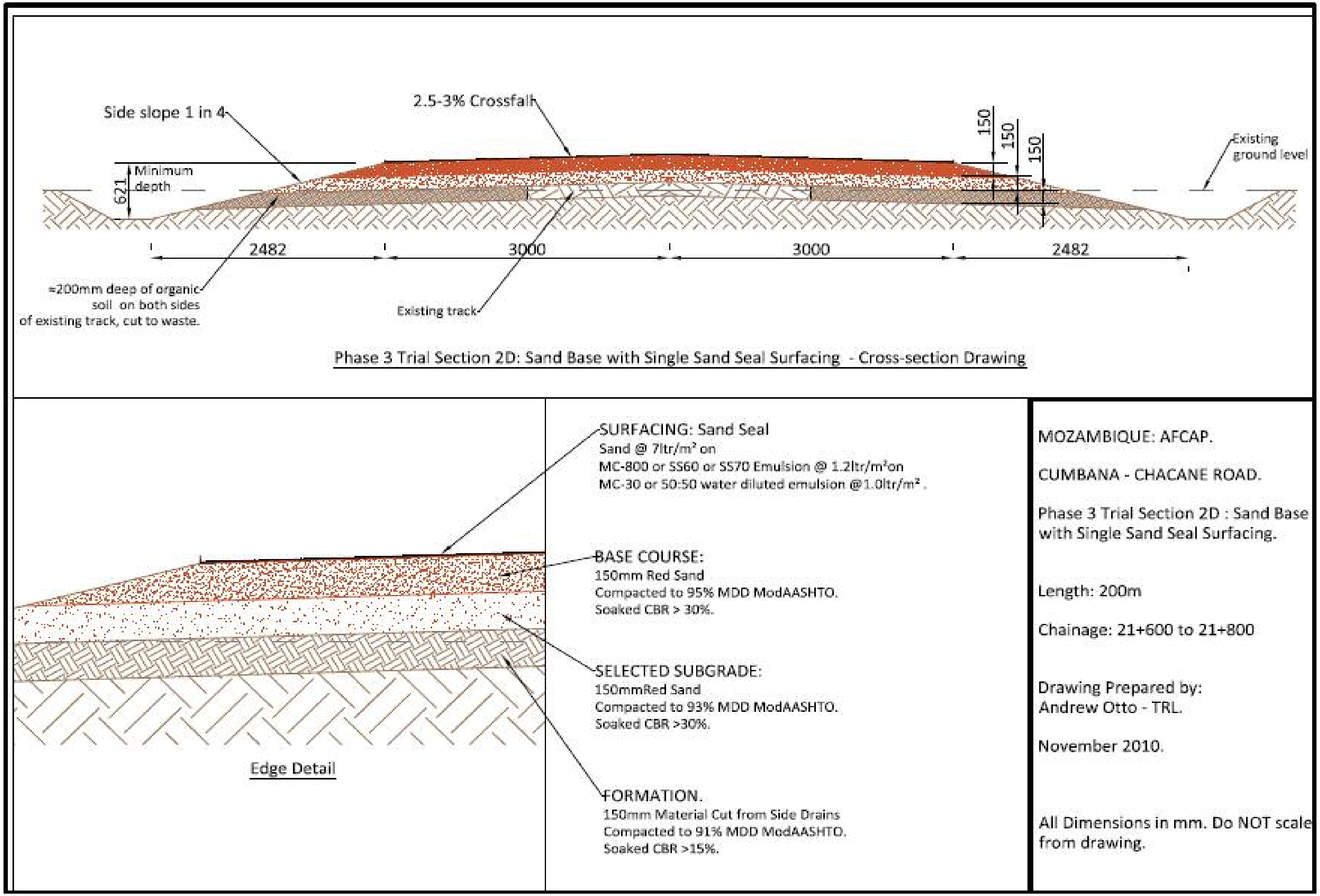
Length: 200m

Chainage: 21+400 to 21+600

Drawing Prepared by:
Andrew Otto - TRL.

November 2010.

All Dimensions in mm. Do NOT scale from drawing.



Side slope 1 in 4
2.5-3% Crossfall
Minimum depth
621
150
150
150
Existing ground level
2482
3000
3000
2482
≈200mm deep of organic soil on both sides of existing track, cut to waste.
Existing track
Phase 3 Trial Section 2D: Sand Base with Single Sand Seal Surfacing - Cross-section Drawing
Edge Detail
SURFACING: Sand Seal
Sand @ 7ltr/m² on
MC-800 or SS60 or SS70 Emulsion @ 1.2ltr/m²on
MC-30 or 50:50 water diluted emulsion @1.0ltr/m².
BASE COURSE:
150mm Red Sand
Compacted to 95% MDD ModAASHTO.
Soaked CBR > 30%.
SELECTED SUBGRADE:
150mmRed Sand
Compacted to 93% MDD ModAASHTO.
Soaked CBR >30%.
FORMATION.
150mm Material Cut from Side Drains
Compacted to 91% MDD ModAASHTO.
Soaked CBR >15%.
MOZAMBIQUE: AFCAP.
CUMBANA - CHACANE ROAD.
Phase 3 Trial Section 2D : Sand Base with Single Sand Seal Surfacing.
Length: 200m
Chainage: 21+600 to 21+800
Drawing Prepared by:
Andrew Otto - TRL.
November 2010.
All Dimensions in mm. Do NOT scale from drawing.

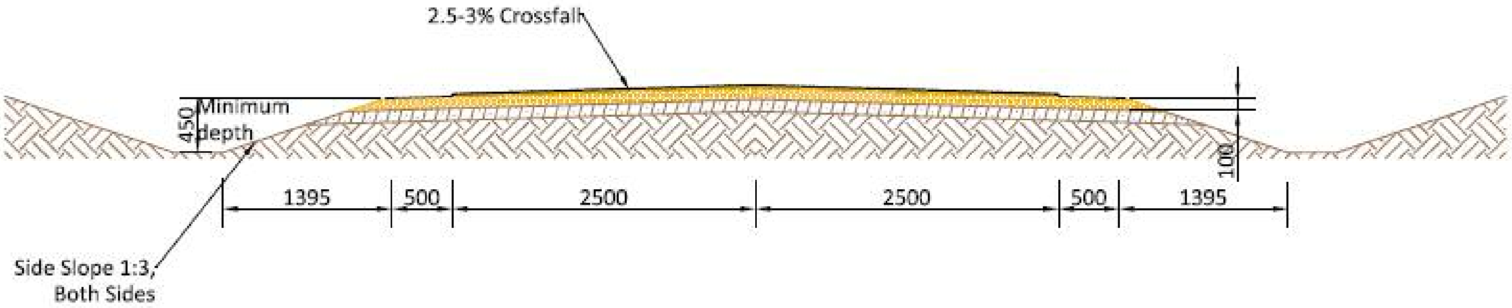
## A.3 BoQs and Drawings for Inhacufera Machaze Project

The information give here was TRL’s proposal. Please see updated information in Chapter 5.

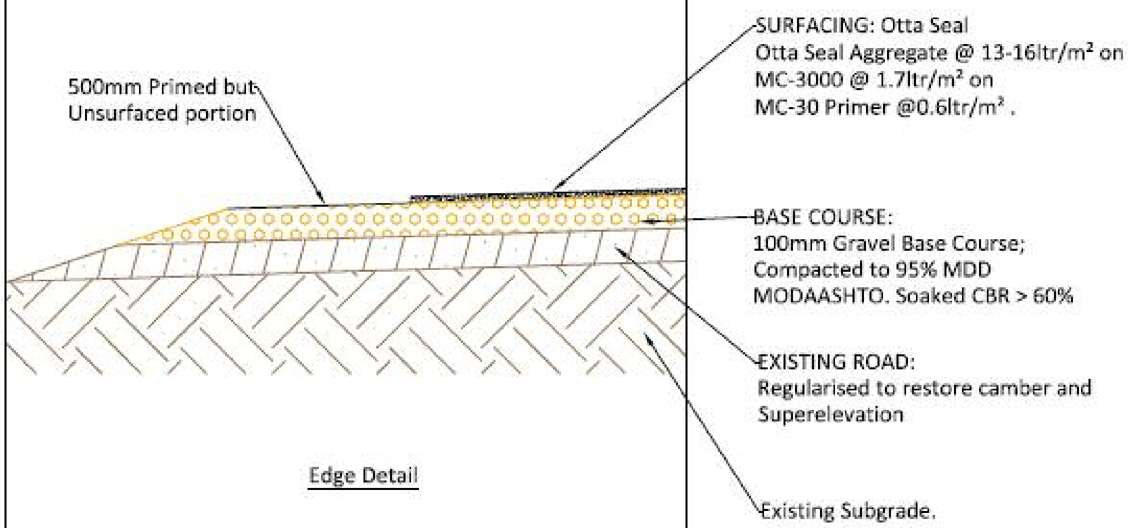
| | Activity | | | |
|---|---|---|---|---|
| **1** | **Preliminaries and General** | | | |
| **1.1** | Camp and site | | | |
| 1.2 | Mobilisation and demobilisation | | | |
| 1.3 | Quality control (Lab testing) | | | |
| 1.4 | Combating HIV/SIDA | | | |
| 2 | **Material preparation** | | | |
| 2.1 | Gravel stockpiling: Stockpile gravel for road base as directed by the Engineer and hand screen the oversize stones during stockpiling. | | | |
| 2.2 | Otta seal aggregate preparation: stockpile quartzitic gravel base and screen on a 19mm and 5mm sieve to achieve a +5mm and -19mm range of aggregate sizes. ACV shall be < 30 and percentage passing 0.075mm < 10%. | | | |
| 2.3 | Sand for sand seal: stockpile sand for sand seal and take precautions to prevent contamination. Sample for testing and approval. | | | |
| 3 | **Earthworks** | | | |
| 3.1 | Regularise existing road, 6m: Grade existing road with motorised grader to regularise the existing surface. Dump gravel where necessary to improve levels and form superelevation on curves as necessary. Water and roll with minimum 8 tonne pneumatic roller, 8 passes minimum. | | | |
| 3.2 | Construct road base, 100mm thick, 6m width: Haul, dump, spread, water, mix and compact road base to a minimum density of 95% mdd Mod. AASHTO. Soaked CBR > 60%. Camber 2.5-3%. A combination of both pneumatic and steel roller is recommended because the gravel is very coarse. | | | |
| | | | | |
| 4 | **Surfacing:** | | | |
| 4.1 | **Section 1: 1000m: Primed with MC3000 and single Otta seal surfacing** | | | |
| 4.1.1 | Priming, 6m width: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 at a rate of 0.6L/m2. Cure for 5 to 7days. | | | |
| 4.1.2 | Surfacing, 5m width: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Spray a light shower of water. Spray bitumen MC3000 at a rate of 1.7L/m2. Immediately apply Otta seal aggregate at a rate of between 13 and 16L/m2. Roll immediately while the bitumen is still hot. Apply 15 passes of a pneumatic roller (12 tonne is recommended). Apply 6-8 passes per day for 1.5 to 2 weeks (traffic is too low to effect adequate curing of the Otta seal). Open to traffic after 1 week of rolling and regulate traffic speed to 30-40km/hr. Regularly broom | | | |

| | | | | |
|---|---|---|---|---|
| | back any loose aggregate removed during trafficking. | | | |
| | | | | |
| 4.2 | **Section 2: 1000m: Primed + single surface dressing using natural quartz aggregate.** | | | |
| 4.2.1 | Priming, 6m width: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 at a rate of 1.0L/m2. Cure for 5 to 7days. | | | |
| 4.2.2 | Surfacing, 5m width: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Spray a light shower of water. Spray bitumen MC3000 at a rate of 1.4L/m2. Immediately apply quartz aggregate at a rate of 13L/m2. Roll immediately while the bitumen is still hot. Apply 15 passes of a pneumatic roller (12 tonne is recommended). Apply 6-8 passes per day for an extra 4 days. Open to traffic and regulate traffic speed to 30-40km/hr. Regularly broom back any loose aggregate removed during trafficking. | | | |
| | | | | |
| 4.3 | **Section 3: 2700m: Primed + Sand seal** | | | |
| 4.3.1 | Priming, 6m width: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 at a rate of 1.0L/m2. Cure for 5 to 7days. | | | |
| 4.3.2 | Surfacing, 5m width: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Spray a light shower of water. Spray bitumen MC3000 or emulsion SS70 at a rate of 1.0L/m2. Immediately apply sand at a rate of 7.0L/m2. Roll immediately while the bitumen is still hot. Apply 15 passes of a pneumatic roller (12 tonne is recommended). Apply 6-8 passes per day for an extra 4 days. Open to traffic and regulate traffic speed to 30-40km/hr. Regularly broom back any loose sand removed during trafficking. | | | |
| | | | | |
| 4.4 | **Section 4: 300m: Primed + Slurry seal** | | | |
| 4.4.1 | Priming, 6m: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 or emulsion diluted with water 50:50 at a rate of 1.0L/m2. Cure for 5 to 7days. | | | |
| 4.4.2 | Surfacing: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Fix rails that are 20mm thick on the centreline and the other 2.5m from the centreline. Prepare the batching of sand, emulsion, water and cement (2% of mix). Spray a light shower of water on the primed surface. Mix slurry in concrete mixer, transport with wheel barrows and place in between the rails. Level using rails as guide, | | | |

| | | | | |
|---|---|---|---|---|
| | allow time for breaking and drag a hessian cloth. Leave to set and roll with light steel roller, 1.7 tonne will suffice. Cure for 7 days before opening to traffic. | | | |
| | | | | |




Phase 3 Trial Section 1: Otta Seal Surfacing Cross-section




Edge Detail

MOZAMBIQUE: AFCAP.

INHACUFERA - MACHAZE ROAD.

Phase 3 Trial Section 1 : Otta Seal Surfacing Section.

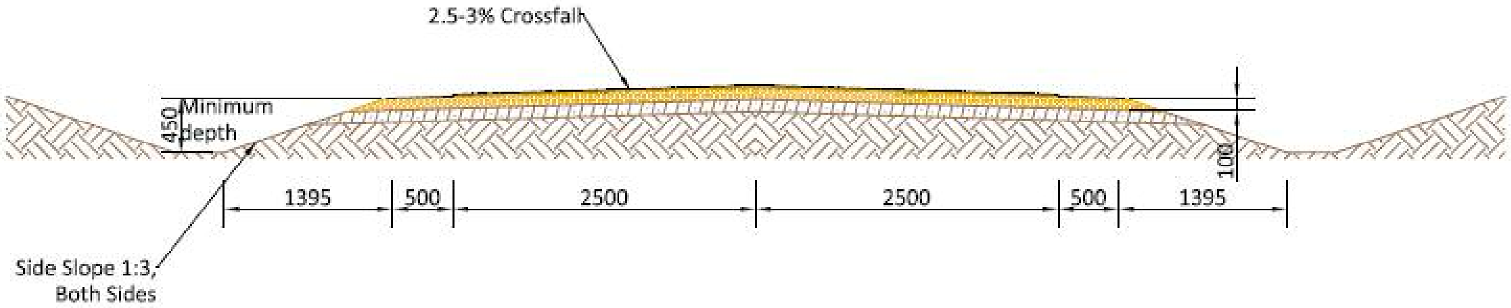
Length: 1000m

Chainage:

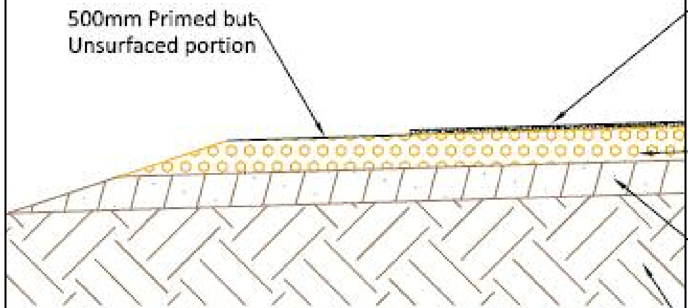
Drawing Prepared by:
Andrew Otto - TRL.

October 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 2: Single Surface Dressing Section




Edge Detail

SURFACING:Single Surface Dressing
Quartz aggregate @ 13ltr/m² on
MC-3000 @ 1.4ltr/m² on
MC-30 Primer @1.0ltr/m² .

BASE COURSE:
100mm Gravel Base Course;
Compacted to 95% MDD
MODAASHTO. Soaked CBR > 60%

EXISTING ROAD:
Regularised to restore camber and
Superelevation

Existing Subgrade.

MOZAMBIQUE: AFCAP.

INHACUFERA - MACHAZE ROAD.

Phase 3 Trial Section 2 : Single Surface Dressing Section.

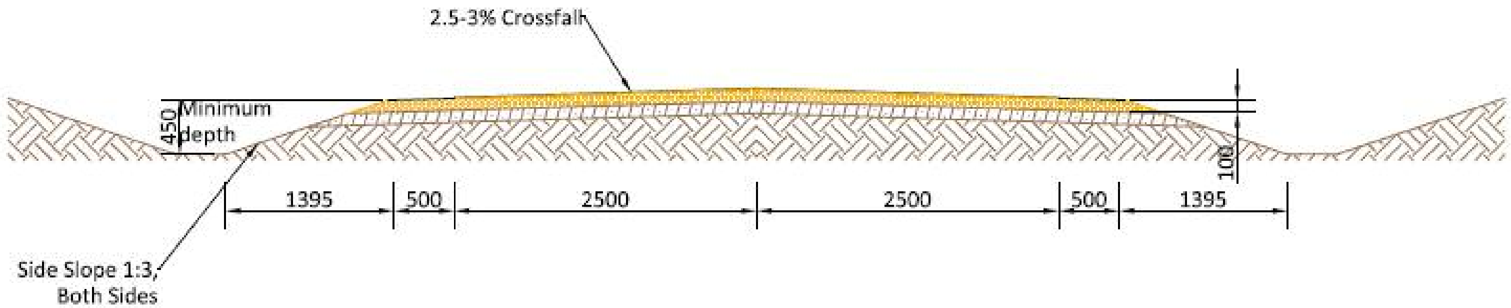
Length: 1000m

Chainage:

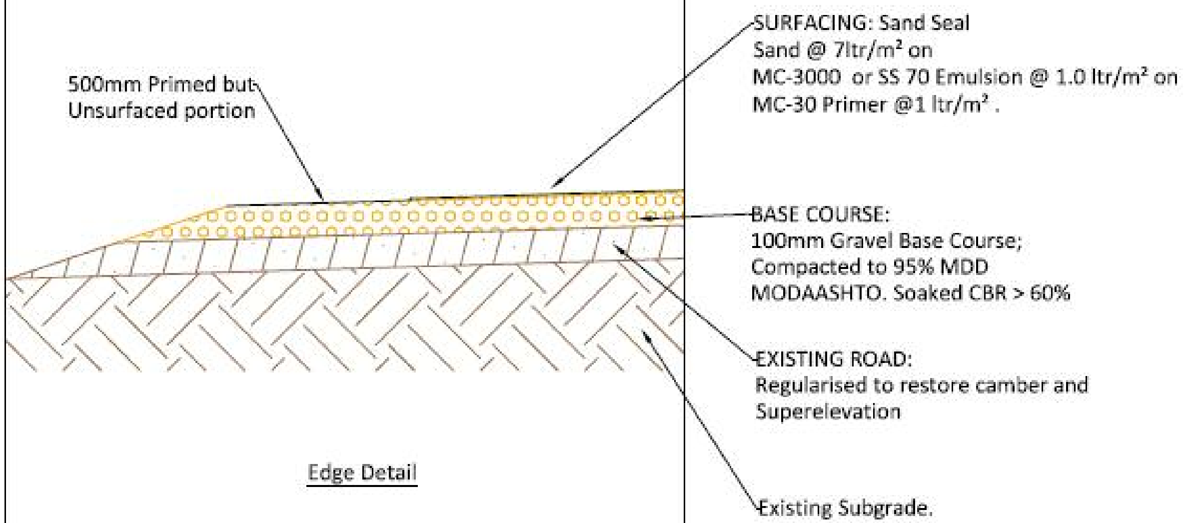
Drawing Prepared by:
Andrew Otto - TRL.

October 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 3: Sand Seal Surfacing Cross-section




Edge Detail

MOZAMBIQUE: AFCAP.

INHACUFERA-MACHAZE ROAD.

Phase 3 Trial Section 3 : Sand Seal Surfacing Section.

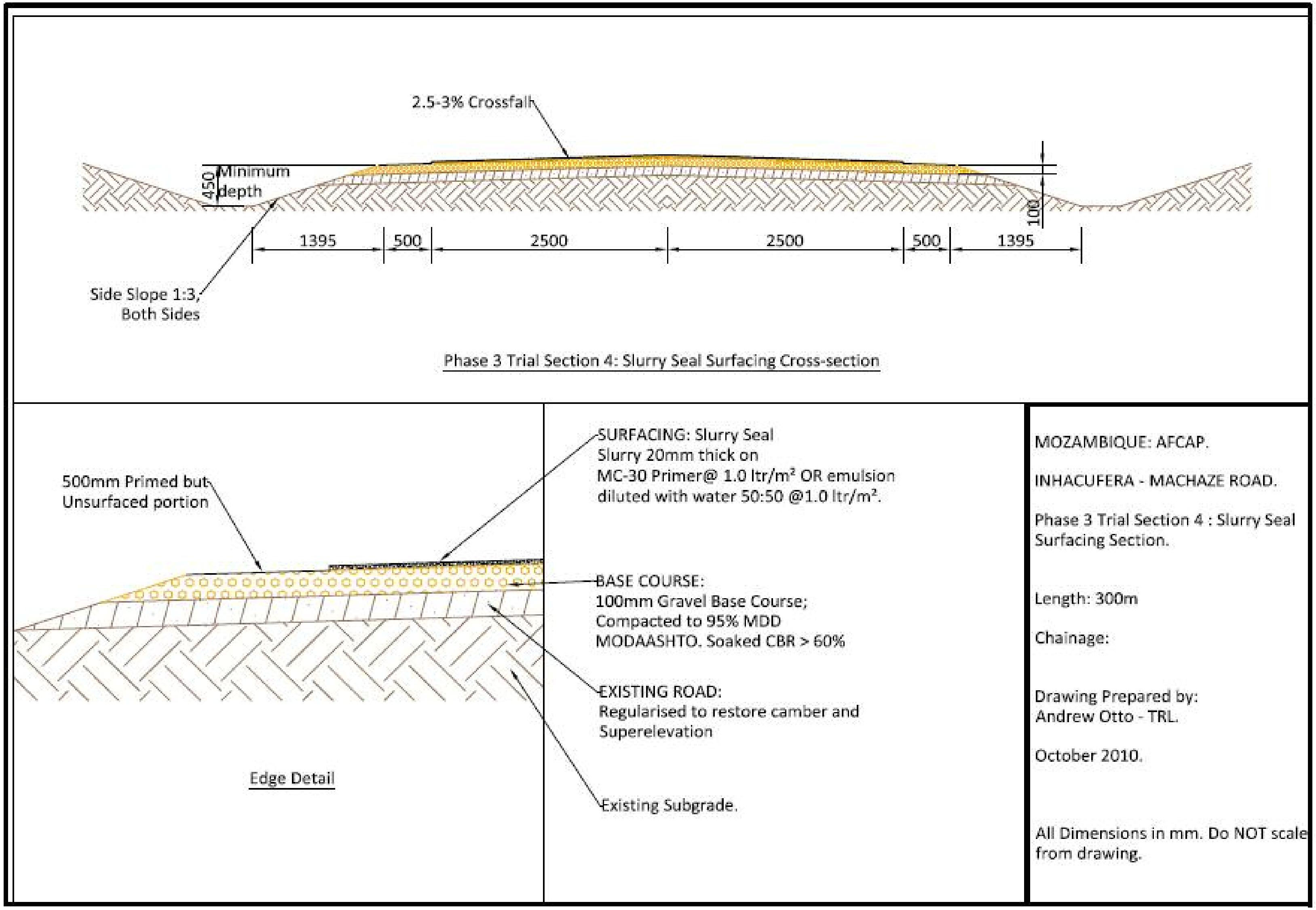
Length: 2700m

Chainage:

Drawing Prepared by:
Andrew Otto - TRL.

October 2010.

All Dimensions in mm. Do NOT scale from drawing.


2.5-3% Crossfall
Minimum depth
450
100
1395
500
2500
2500
500
1395
Side Slope 1:3, Both Sides
Phase 3 Trial Section 4: Slurry Seal Surfacing Cross-section
500mm Primed but Unsurfaced portion
SURFACING: Slurry Seal
Slurry 20mm thick on
MC-30 Primer@ 1.0 ltr/m² OR emulsion diluted with water 50:50 @1.0 ltr/m².
BASE COURSE:
100mm Gravel Base Course;
Compacted to 95% MDD
MODAASHTO. Soaked CBR > 60%
EXISTING ROAD:
Regularised to restore camber and Superelevation
Existing Subgrade.
Edge Detail
MOZAMBIQUE: AFCAP.
INHACUFERA - MACHAZE ROAD.
Phase 3 Trial Section 4 : Slurry Seal Surfacing Section.
Length: 300m
Chainage:
Drawing Prepared by:
Andrew Otto - TRL.
October 2010.
All Dimensions in mm. Do NOT scale from drawing.

## A.4 BoQs and Drawings for Caia Marromeu Project

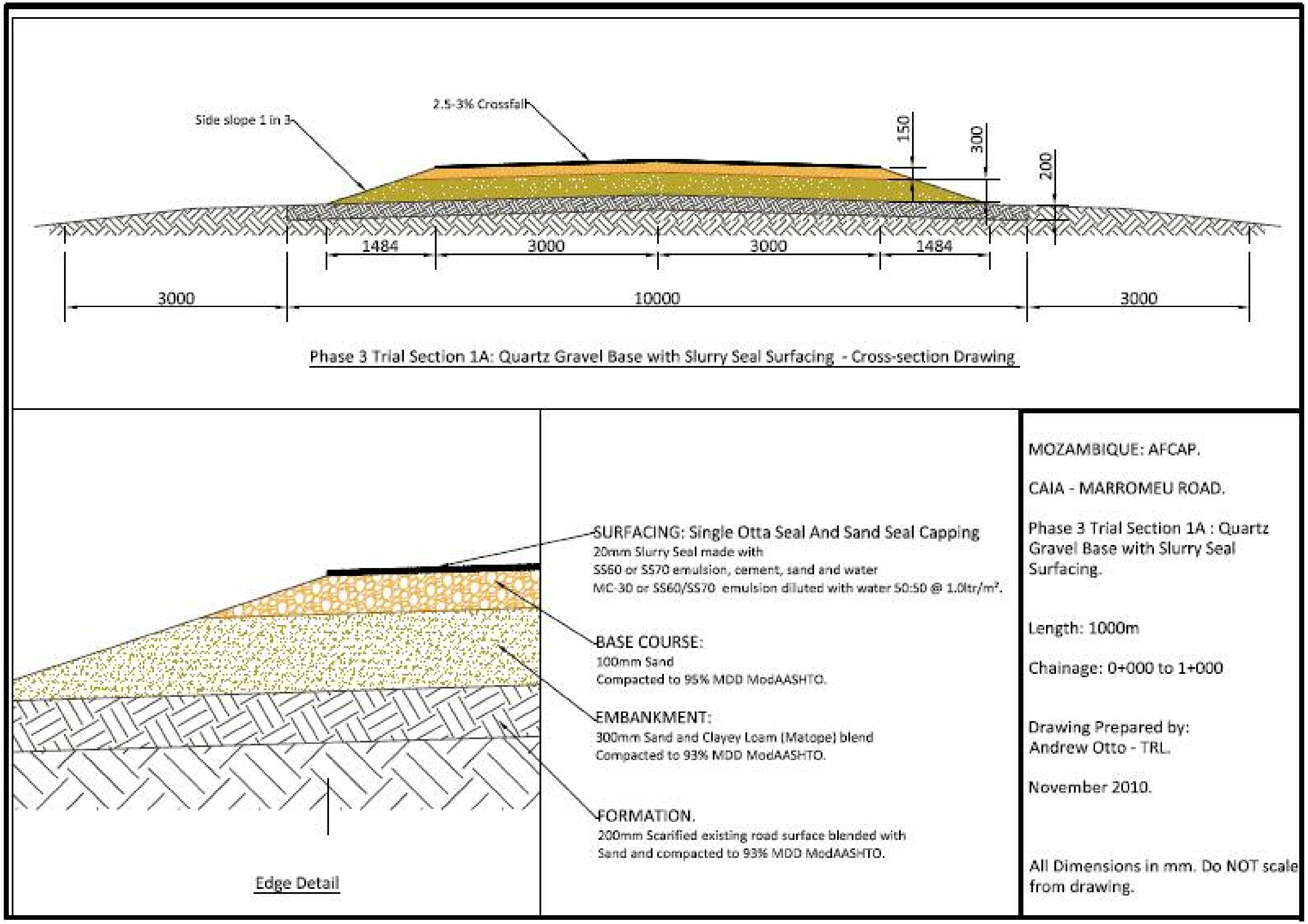
Project has been abandoned.

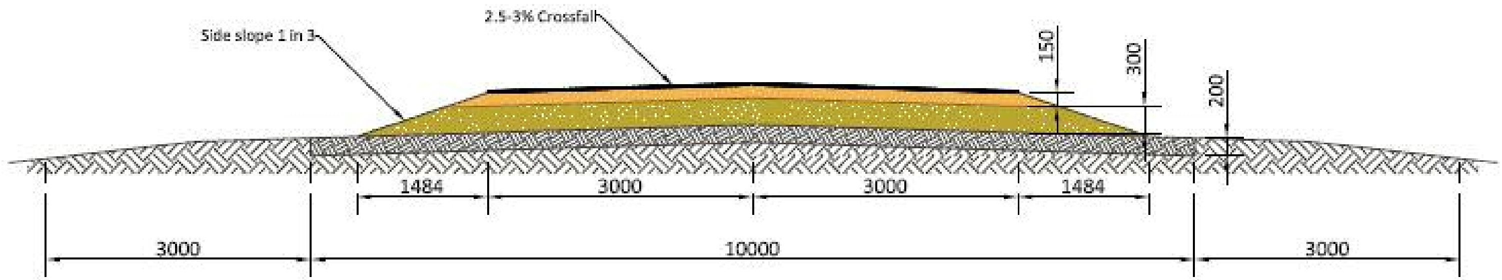
| | Activity | Qty | Rate | Amount |
|---|---|---|---|---|
| **1**<br>1.1 | **Preliminaries and general**<br>Mobilisation and demobilisation | | | |
| 1.2 | Camp and site | | | |
| 1.3 | Quality control (Lab testing) | | | |
| 1.4 | Combating HIV/SIDA | | | |
| 2 | **Section 1: 0+000 to 3+000: Raise existing embankment to a total of 300mm, 150mm quartz gravel base, surfaced with surry seal (1000) and Otta seal with sand seal capping (2000).** | | | |
| 2.1 | Clearing right of way, formation and compaction: clear the right of way to a width of 8m either side of the centreline, scarify existing road surface to a depth of 200mm and width of 10m and regularise. Stockpile selected sand, haul, dump, spread, mix with existing clayey loam soil, water, mix, compact to a minimum of 93% mdd Mod. AASHTO. Camber 2.5-3%, and side slope 1:3. Mix proportions to be provided by the lab. | | | |
| 2.2 | Construct embankment: Excavate sand and clayey loam soil (matope) from selected borrow pits. Haul, dump and spread sand then haul, dump and spread matope. The layer thicknesses of sand and matope should be in accordance with the mix proportions provided by the laboratory. Mix to produce a sand/matope blend, water and compact to a minimum of 93% mdd mod AASHTO. Compact in layers no more than 150mm thick to achieve a thickness of 300mm. Compact to a minimum of 93% mdd Mod. AASHTO. Camber 2.5-3%, side slope 1:3, width 8m. | | | |
| 2.3 | Road base 150mm thick, 7m width: excavate quartz gravel from borrow pit, haul, dump, spread, water, mix and compact to a minimum density of 95% mdd Mod AASHTO. | | | |
| 2.4 | Priming (7m width): Sweep the base thoroughly and sprinkle water and place markings ready for priming. Apply prime at a rate 1.0 L/$m^2$ (MC30 or emulsion diluted 50:50 with water) for 7m width (including sealed shoulders) and allow 3 to 7 days curing. | | | |
| | Surfacing with slurry seal 6m width (1000m). Prepare a batching site and materials including sand, emulsion SS60/70, cement and water. Sweep primed surface, clean with power broom or hand brooms. Fix rails 20mm thick on the edges and centreline. Apply a light shower of water. Mix the slurry in concrete mixers and apply the slurry in between the rails and spread with rubber squeegees. Level the surface and drag a wet hessian cloth. Allow setting then roll the surfacing, 16 passes of steel roller in non-vibratory mode. Allow 7 days curing before opening to traffic | | | |

| | | | | |
|---|---|---|---|---|
| 2.5 | Surfacing with single Otta seal with sand seal capping 6m width (2000m). Prepare surfacing aggregate by sieving quartz through a 19mm sieve and 5mm sieve and stockpile on site. Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 1.5L/$m^2$. Roll with pneumatic roller applying 14 passes on the first day and 8 passes on the hot part of the day for an extra 2 days. Open to traffic on the fourth day and limit the operating speed to 30km/h while brooming back the aggregate for 2 weeks. Spray bitumen MC3000 at a rate of 0.8L/m2. Immediately apply the sand at 7.0 L/$m^2$. Spread and roll with a steel roller in non-vibratory mode or a pneumatic roller (pneumatic roller preferred). 14 passes on the first day and 8 passes on the hot part of the day for an extra 2 days. Open to traffic on the fourth day and limit the operating speed to 30km/h while brooming back the sand for 2 weeks. | | | |
| | | | | |
| 3 | **Section 2: 3+000 to 4+000: Raised embankment, armoured sand base with sand seal (500) and single surface dressing with sand capping (500m).** | | | |
| 3.1 | Clearing right of way, formation and compaction: clear the right of way to a width of 8m either side of the centreline, scarify existing road surface to a depth of 200mm and width of 10m and regularise. Stockpile selected sand, haul, dump, spread, mix with existing clayey loam soil, water, mix, compact to a minimum of 93% mdd Mod. AASHTO. Camber 2.5-3%, and side slope 1:3. Mix proportions to be provided by the lab. | | | |
| 3.2 | Construct embankment: Excavate sand and clayey loam soil (matope) from selected borrow pits. Haul, dump and spread sand then haul, dump and spread matope. The layer thicknesses of sand and matope should be in accordance with the mix proportions provided by the laboratory. Mix to produce a sand/matope blend, water and compact to a minimum of 93% mdd mod AASHTO. Compact in layers no more than 150mm thick to achieve a thickness of 300mm. Compact to a minimum of 93% mdd Mod. AASHTO. Camber 2.5-3%, side slope 1:3, width 8m. | | | |
| 3.3 | Armoured sand base: Excavate and stockpile coarse quartz gravel. Excavate sand from selected borrow pit and stockpile, haul, dump, water, mix spread and compact to a minimum of 95% mdd Mod AASHTO, 100mm compacted thickness. Haul coarse gravel, dump, water, mix and spread 40-50mm thick (wet surface of sand base before spreading the mixed coarse gravel). Roll with heavy (12 ton or more) in vibratory mode at high amplitude. Some of the aggregate will be pressed into the sand base. This forms the armouring layer for the armoured sand base. | | | |

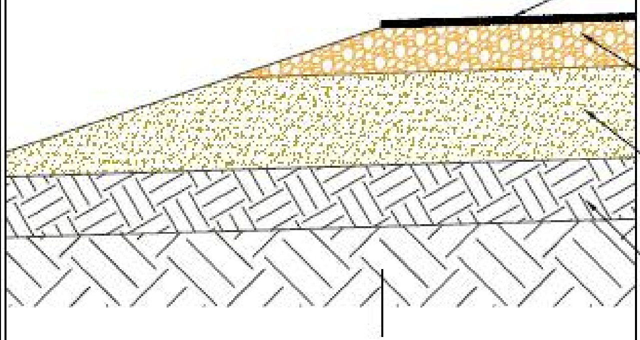
| | | | | |
|---|---|---|---|---|
| 3.4 | Priming: Sweep the surface of the armoured sand base thoroughly and sprinkle water lightly and place markings ready for priming, avoid excessive wetting of the surface of the base. Apply prime at a rate 1.0 L/$m^2$ and allow 5 to 7 days curing. | | | |
| 3.5a | Surfacing with sand seal, 6m width (500m). Sweep the primed base thoroughly, sprinkle water lightly, spray the binder MC3000 at 1.0L/$m^2$ or emulsion SS60 or 70 at 1.2 L/$m^2$. Immediately, spread sand at a rate of 7.0L/m2 and roll with pnuematic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. | | | |
| 3.5b | Surfacing with natural quartz aggregate, 6m width (10-13mm size) (500m) . Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 at 0.8L/$m^2$ or emulsion SS60 or 70 at 1.0L/$m^2$. Immediately add natural quartz aggregate at a rate of 14L/m2 and roll with pneumatic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days.. Spray the binder MC3000 at 0.6L/m2 or emulsion SS60 or 70 at 0.8 L/m2. Apply sand at 7.0 L/$m^2$. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. | | | |
| | | | | |
| 4 | **Section 3: 4+000 to 5+000: Raised embankment, 100mm ETB surfaced with sand seal.** | | | |
| 4.1 | Clearing right of way, formation and compaction: clear the right of way to a width of 8m either side of the centreline, scarify existing road surface to a depth of 200mm and width of 10m and regularise. Stockpile selected sand, haul, dump, spread, mix with existing clayey loam soil, water, mix, compact to a minimum of 93% mdd Mod. AASHTO. Camber 2.5-3%, and side slope 1:3. Mix proportions to be provided by the lab. | | | |
| 4.2 | Construct embankment: Excavate sand and clayey loam soil (matope) from selected borrow pits. Haul, dump and spread sand then haul, dump and spread matope. The layer thicknesses of sand and matope should be in accordance with the mix proportions provided by the laboratory. Mix to produce a sand/matope blend, water and compact to a minimum of 93% mdd mod AASHTO. Compact in layers no more than 150mm thick to achieve a thickness of 300mm. Compact to a minimum of 93% mdd Mod. AASHTO. Camber 2.5-3%, side slope 1:3, width 8m. | | | |

| | | | | |
|---|---|---|---|---|
| 4.3 | Emulsion treated base (ETB) 100mm thick (1000m): Excavate sand from borrow pit and stockpile. Haul and mix the sand and bitumen emulsion in concrete mixers to achieve 6% content of emulsion, mix thoroughly, transport, spread and compact with pneumatic roller. Finish with vibratory steel roller in non-vibratory mode | | | |
| 4.4 | Priming: Sweep the surface of the base thoroughly and sprinkle water lightly and place markings ready for priming, avoid excessive wetting of the surface of the base. Apply prime at a rate 0.6 L/$m^2$ and allow 5 to 7 days curing. | | | |
| 4.5 | Surfacing with sand seal 6m width (1000m). Sweep the primed base thoroughly, sprinkle a little water, spray the binder MC3000 at 1.0L/$m^2$ or emulsion SS60 or 70 at 1.2 L/$m^2$. Immediately, spread sand at a rate of 7.0L/$m^2$ and roll with pneumatic. Apply 12 passes on the first day and 8 passes per day for an extra 2 days. Open to traffic and regulate traffic speed to 30km/hour for 2 weeks while brooming back the sand moved off the carriageway by traffic. | | | |
| | | | | |


2.5-3% Crossfall
Side slope 1 in 3
150
300
200
1484
3000
3000
1484
3000
10000
3000
Phase 3 Trial Section 1A: Quartz Gravel Base with Slurry Seal Surfacing - Cross-section Drawing
SURFACING: Single Otta Seal And Sand Seal Capping
20mm Slurry Seal made with
SS60 or SS70 emulsion, cement, sand and water
MC-30 or SS60/SS70 emulsion diluted with water 50:50 @ 1.0ltr/m².
BASE COURSE:
100mm Sand
Compacted to 95% MDD ModAASHTO.
EMBANKMENT:
300mm Sand and Clayey Loam (Matope) blend
Compacted to 93% MDD ModAASHTO.
FORMATION.
200mm Scarified existing road surface blended with
Sand and compacted to 93% MDD ModAASHTO.
Edge Detail
MOZAMBIQUE: AFCAP.
CAIA - MARROMEU ROAD.
Phase 3 Trial Section 1A : Quartz Gravel Base with Slurry Seal Surfacing.
Length: 1000m
Chainage: 0+000 to 1+000
Drawing Prepared by:
Andrew Otto - TRL.
November 2010.
All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 1B: Quartz Gravel Base with Single Otta Seal and Sand Seal Capping - Cross-section Drawing



Edge Detail

SURFACING: Single Otta Seal And Sand Seal Capping
Sand @ 7ltrs/m² on
MC-3000 @ 0.8ltr/m² on
Screened Quartz Gravel @ 17ltrs/m² on
MC-3000 @ 1.5ltrs/m² on
MC-30 or SS60/SS70 emulsion diluted with water 50:50 @ 1.0ltr/m².

BASE COURSE:
100mm Sand
Compacted to 95% MDD ModAASHTO.

EMBANKMENT:
300mm Sand and Clayey Loam (Matope) blend
Compacted to 93% MDD ModAASHTO.

FORMATION.
200mm Scarified existing road surface blended with
Sand and compacted to 93% MDD ModAASHTO.

MOZAMBIQUE: AFCAP.

CAIA - MARROMEU ROAD.

Phase 3 Trial Section 1B : Quartz Gravel Base with Single Otta Seal and Sand Seal Capping.

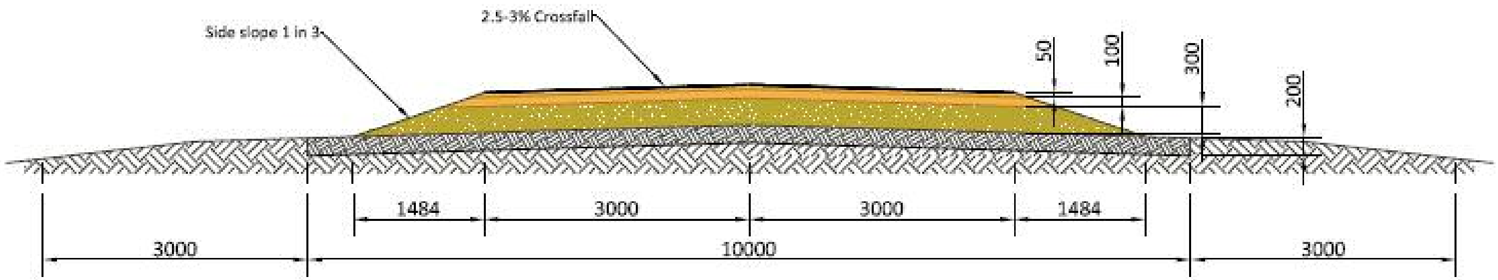
Length: 2000m

Chainage: 1+000 to 3+000

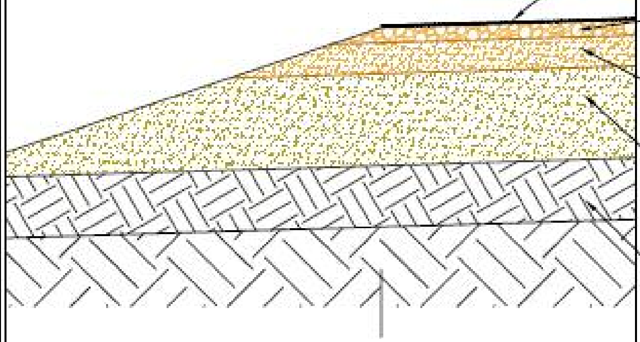
Drawing Prepared by:
Andrew Otto - TRL.

November 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 2A: Armoured Sand Base with Sand Seal Surfacing - Cross-section Drawing



Edge Detail

SURFACING: Sand Seal
Sand @ 7ltrs/m² on
MC-3000 @ 1.0ltr/m² or SS60 or SS70 Emulsion @ 1.2ltrs/m² on
MC-30 or 50:50 water diluted emulsion @1.0ltr/m².

ARMOURING:
40-50mm thick Coerse Quartz Gravel compacted onto Sand Base.

BASE COURSE:
100mm Sand
Compacted to 95% MDD ModAASHTO.

EMBANKMENT:
300mm Sand and Clayey Loam (Matope) blend
Compacted to 93% MDD ModAASHTO.

FORMATION.
200mm Scarified existing road surface blended with
Sand and compacted to 93% MDD ModAASHTO.

MOZAMBIQUE: AFCAP.

CAIA - MARROMEU ROAD.

Phase 3 Trial Section 2A : Armoured Sand Base with Sand Seal Surfacing

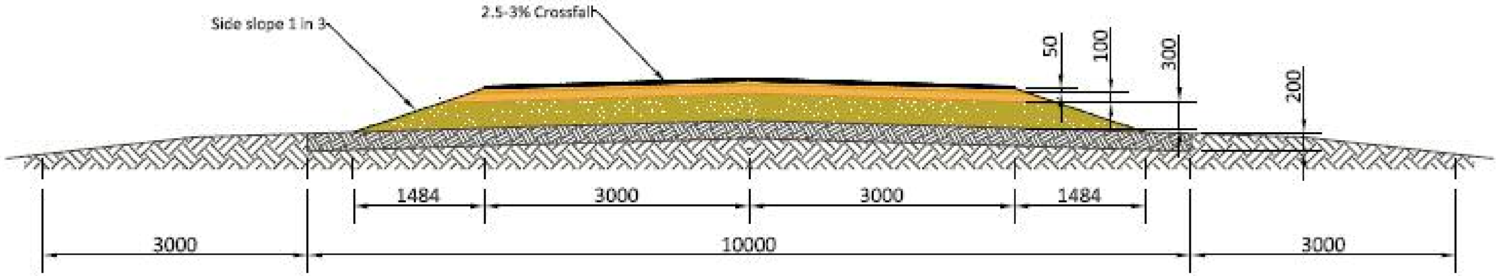
Length: 500m

Chainage: 3+000 to 3+500

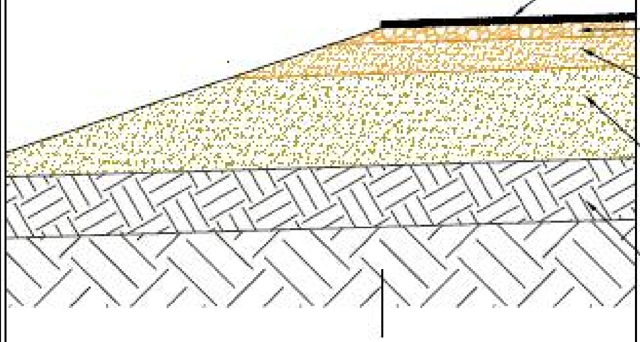
Drawing Prepared by:
Andrew Otto - TRL.

November 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 2B: Armoured Sand Base with Single Surface Dressing and Sand Capping - Cross-section Drawing



Edge Detail

SURFACING: Single Surface Dressing and Sand Capping
Sand @ 7ltrs/m² on
MC-3000 @ 0.6ltr/m²or SS60 or SS70 Emulsion @ 0.8ltr/m² on
10-13mm Quartz Aggregate @ 14ltrs/m² on
MC-3000 @ 0.8ltr/m²or SS60 or SS70 Emulsion @ 1.0ltr/m² on
MC-30 or 50:50 water diluted emulsion @1.0ltr/m².

ARMOURING:
40-50mm thick Coarse Quartz Gravel compacted onto Sand Base.

BASE COURSE:
100mm Sand
Compacted to 95% MDD ModAASHTO.

EMBANKMENT:
300mm Sand and Clayey Loam (Matope) blend
Compacted to 93% MDD ModAASHTO.

FORMATION.
200mm Scarified existing road surface blended with
Sand and compacted to 93% MDD ModAASHTO.

MOZAMBIQUE: AFCAP.

CAIA - MARROMEU ROAD.

Phase 3 Trial Section 2B : Armoured Sand Base with Single Surface Dressing and Sand Capping.

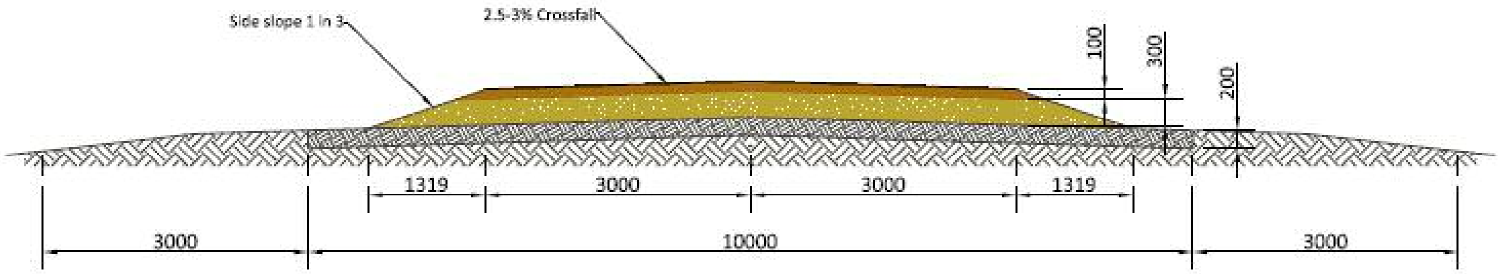
Length: 500m

Chainage: 3+500 to 4+000

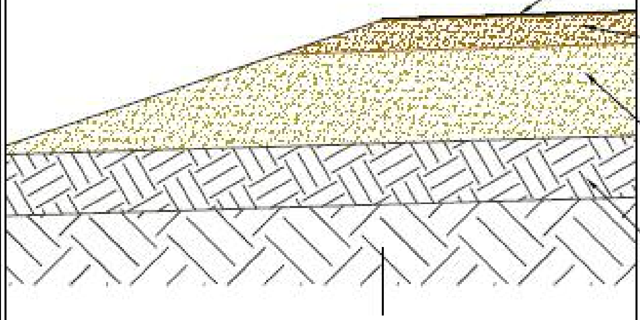
Drawing Prepared by:
Andrew Otto - TRL.

November 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 3A: Emulsion Treated Base with Sand Seal Surfacing - Cross-section Drawing



Edge Detail

SURFACING: Sand Seal
Sand @ 7ltrs/m² on
MC-3000 @ 1.0ltr/m² or SS60 or SS70 Emulsion @ 1.2ltrs/m² on
MC-30 or 50:50 water diluted emulsion @ 0.6ltr/m².

EMULSION TREATED BASE:
100mm Sand mixed with 6% Bitumen Emulsion,
Placed and compacted.

EMBANKMENT:
300mm Sand and Clayey Loam (Matope) blend
Compacted to 93% MDD ModAASHTO.

FORMATION.
200mm Scarified existing road surface blended with
Sand and compacted to 93% MDD ModAASHTO.

MOZAMBIQUE: AFCAP.

CAIA - MARROMEU ROAD.

Phase 3 Trial Section 3A : Emulsion Treated Base with Sand Seal Surfacing.

Length: 1000m

Chainage: 4+000 to 5+000

Drawing Prepared by:
Andrew Otto - TRL.

November 2010.

All Dimensions in mm. Do NOT scale from drawing.

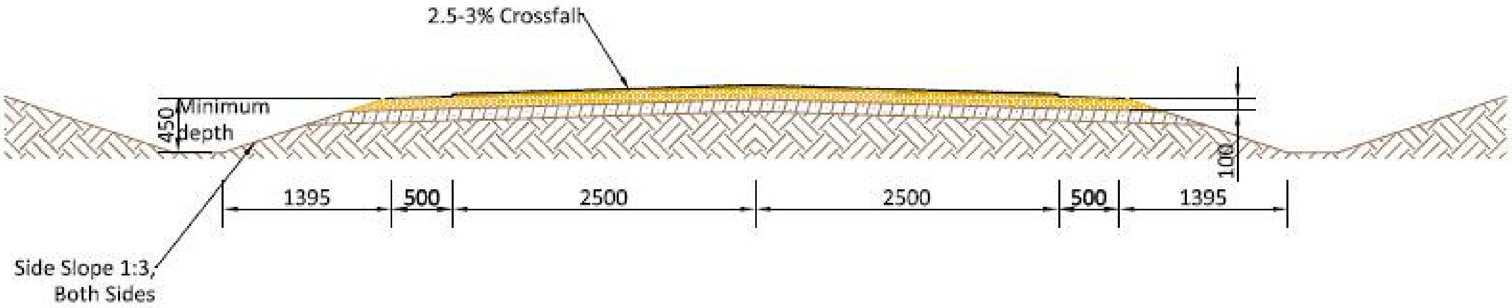
## A.5 BoQs and Drawings for Zero Mopeia Project

The information give here was TRL's proposal. Please see updated information in Chapter 5.

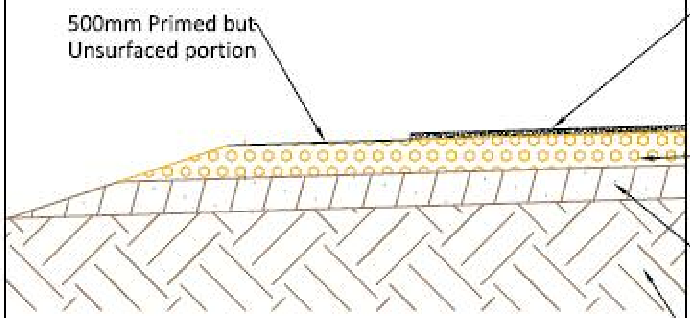
| | Activity | Qty | Rate | Amount |
|---|---|---|---|---|
| **1** | **Preliminaries and General** | | | |
| **1.1** | Camp and site | | | |
| 1.2 | Mobilisation and demobilisation | | | |
| 1.3 | Quality control (Lab testing) | | | |
| 1.4 | Combating HIV/SIDA | | | |
| 2 | **Material preparation** | | | |
| 2.1 | Gravel stockpiling: Stockpile gravel for road base as directed by the Engineer and hand screen the oversize stones during stockpiling. | | | |
| 2.2 | Otta seal aggregate preparation: stockpile quartzitic gravel base and screen on a 19mm and 5mm sieve to achieve a +5mm and -19mm range of aggregate sizes. ACV shall be < 30 and percentage passing 0.075mm < 10%. | | | |
| 2.3 | Sand for sand seal: stockpile sand for sand seal and take precautions to prevent contamination. Sample for testing and approval. | | | |
| 3 | **Earthworks** | | | |
| 3.1 | Regularise existing road, 6m: Grade existing road with motorised grader to regularise the existing surface. Dump gravel where necessary to improve levels and form superelevation on curves as necessary. Water and roll with minimum 8 tonne pneumatic roller, 8 passes minimum. | | | |
| 3.2 | Construct road base, 100mm thick, 6m width: Haul, dump, spread, water, mix and compact road base to a minimum density of 95% mdd Mod. AASHTO. Soaked CBR > 40%. Camber 2.5-3%. A combination of both pneumatic and steel roller is recommended to achieve high densities. | | | |
| | | | | |
| 4 | **Surfacing:** | | | |
| 4.1 | **Section 1: 2000m: Primed with MC3000 and single Otta seal surfacing** | | | |
| 4.1.1 | Priming, 6m width: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 at a rate of 0.6L/m2. Cure for 5 to 7days. | | | |
| 4.1.2 | Surfacing, 5m width: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Spray a light shower of water. Spray bitumen MC3000 at a rate of 1.5L/m2. Immediately apply Otta seal aggregate at a rate of between 13 and 16L/m2. Roll immediately while the bitumen is still hot. Apply 15 passes of a pneumatic roller (12 tonne is recommended). Apply 6-8 passes per day for 1 to 1.5 weeks (traffic is too low to effect adequate curing of the Otta seal). Open to traffic after 1 week of rolling and regulate traffic speed to 30-40km/hr. Regularly | | | |

| | | | | |
|---|---|---|---|---|
| | broom back any loose aggregate removed during trafficking. | | | |
| | | | | |
| 4.2 | **Section 2: 300m: Primed + single surface dressing using crushed stone aggregate from quarry 40km from site.** | | | |
| 4.2.1 | Priming, 6m width: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 at a rate of 1.0L/m2. Cure for 5 to 7days. | | | |
| 4.2.2 | Surfacing, 5m width: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Spray a light shower of water. Spray bitumen MC3000 at a rate of 1.2L/m2. Immediately apply aggregate at a rate of 13L/m2. Roll immediately while the bitumen is still hot. Apply 15 passes of a pnuematic roller (12 tonne is recommended). Apply 6-8 passes per day for an extra 4 days. Open to traffic and regulate traffic speed to 30-40km/hr. Regularly broom back any loose aggregate removed during trafficking. | | | |
| | | | | |
| 4.3 | **Section 3: 2000m: Primed + Sand seal using coarse river sand (6mm nominal size)** | | | |
| 4.3.1 | Priming, 6m width: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 at a rate of 0.6L/m2. Cure for 5 to 7 days. | | | |
| 4.3.2 | Surfacing, 5m width: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Spray a light shower of water. Spray bitumen MC3000 or emulsion SS70 at a rate of 1.2L/m2. Immediately apply sand at a rate of 7.0L/m2. Roll immediately while the bitumen is still hot. Apply 15 passes of a pneumatic roller (12 tonne is recommended). Apply 6-8 passes per day for an extra 4 days. Open to traffic and regulate traffic speed to 30-40km/hr. Regularly broom back any loose sand removed during trafficking. | | | |
| | | | | |
| 4.4 | **Section 3: 700m: Primed + Sand seal using fine coastal sand (≤2mm nominal size)** | | | |
| 4.4.1 | Priming, 6m width: Broom surface thoroughly with hard hand brooms or power broom to remove loose materials, debris and dust. Apply prime MC30 at a rate of 0.6L/m2. Cure for 5 to 7days. | | | |

| | | | | |
|---|---|---|---|---|
| 4.4.2 | Surfacing, 5m width: Broom thoroughly to remove debris and dust. Mark and make section ready for surfacing. Spray a light shower of water. Spray bitumen MC3000 or emulsion SS70 at a rate of 1.0L/m2. Immediately apply sand at a rate of 7.0L/m2. Roll immediately while the bitumen is still hot. Apply 15 passes of a pneumatic roller (12 tonne is recommended). Apply 6-8 passes per day for an extra 4 days. Open to traffic and regulate traffic speed to 30-40km/hr. Regularly broom back any loose sand removed during trafficking. | | | |
| | | | | |




Phase 3 Trial Section 1: Otta Seal Surfacing Cross-section




Edge Detail

SURFACING: Otta Seal
Otta Seal Aggregate @ 13-16ltr/m² on
MC-3000 @ 1.5ltr/m² on
MC-30 Primer @0.6ltr/m² .

BASE COURSE:
100mm Gravel Base Course;
Compacted to 95% MDD
MODAASHTO. Soaked CBR > 40%

EXISTING ROAD:
Regularised to restore camber and Superelevation

Existing Subgrade.

MOZAMBIQUE: AFCAP.

ZERO - MOPEIA ROAD.

Phase 3 Trial Section 1 : Otta Seal Surfacing Section.

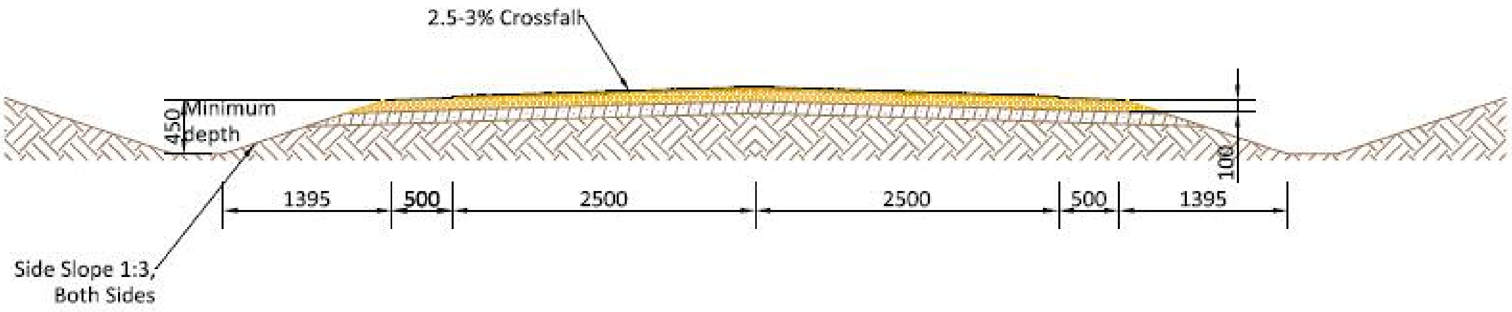
Length: 2000m

Chainage:

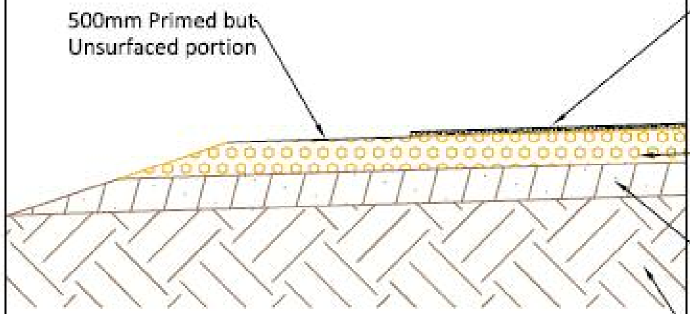
Drawing Prepared by:
Andrew Otto - TRL.

October 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 2: Single Surface Dressing Section




Edge Detail

SURFACING: Single Surface Dressing
Crushed stone aggregate @ 13ltr/m² on
MC-3000 @ 1.2ltr/m² on
MC-30 Primer @1.0ltr/m² .

BASE COURSE:
100mm Gravel Base Course;
Compacted to 95% MDD
MODAASHTO. Soaked CBR > 40%

EXISTING ROAD:
Regularised to restore camber and Superelevation

Existing Subgrade.

MOZAMBIQUE: AFCAP.

ZERO - MOPEIA ROAD.

Phase 3 Trial Section 2 : Single Surface Dressing Section.

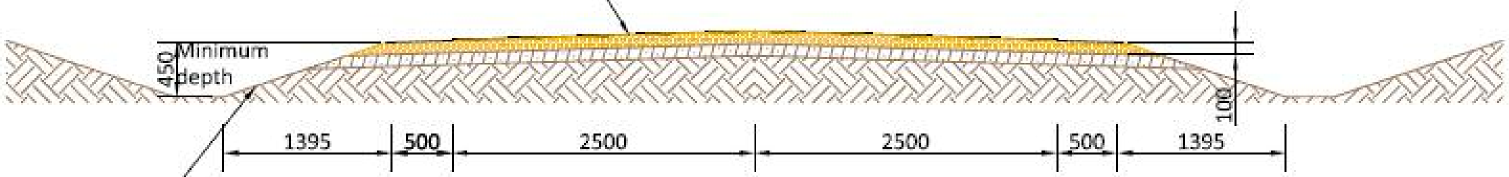
Length: 300m

Chainage:

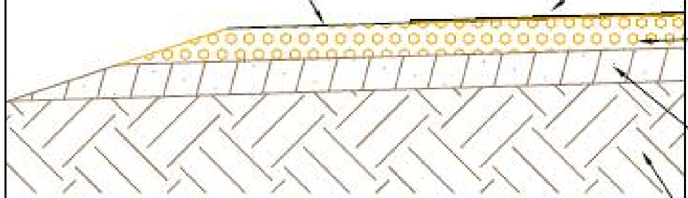
Drawing Prepared by:
Andrew Otto - TRL.

October 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 3: Coarse Sand Seal Surfacing with 6mm River Sand Cross-section




Edge Detail

SURFACING: Coarse Sand Seal
6mm River Sand @ 7ltr/m² on
MC-3000 or SS 70 Emulsion @ 1.2ltr/m² on
MC-30 Primer @0.6ltr/m² .

BASE COURSE:
100mm Gravel Base Course;
Compacted to 95% MDD
MODAASHTO. Soaked CBR > 40%

EXISTING ROAD:
Regularised to restore camber and Superelevation

Existing Subgrade.

MOZAMBIQUE: AFCAP.

ZERO - MOPEIA ROAD.

Phase 3 Trial Section 3 : Sand Seal Surfacing with 6mm River Sand Section.

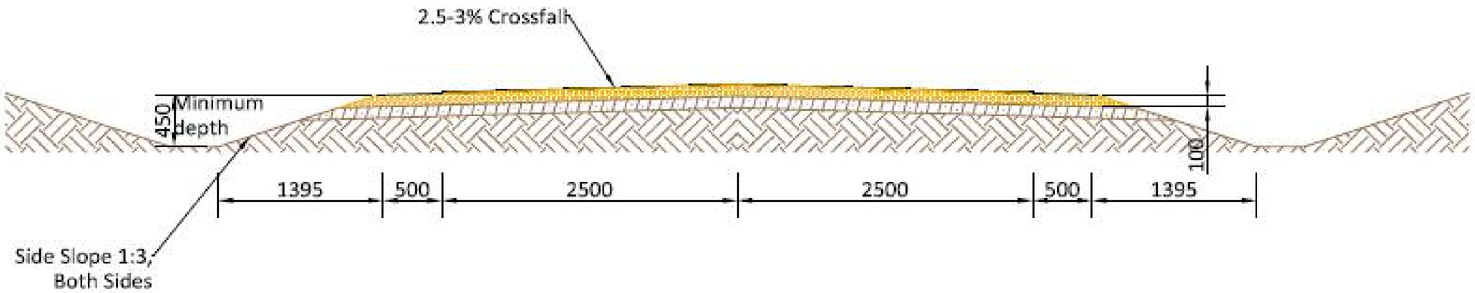
Length: 2000m

Chainage:

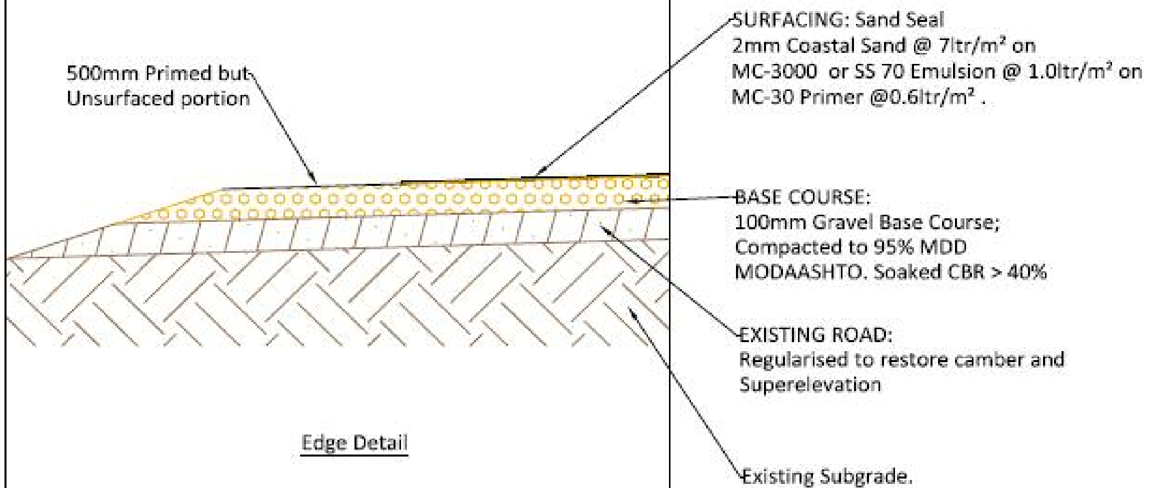
Drawing Prepared by:
Andrew Otto - TRL.

October 2010.

All Dimensions in mm. Do NOT scale from drawing.




Phase 3 Trial Section 4: Sand Seal Surfacing with 2mm Coastal Sand Cross-section




MOZAMBIQUE: AFCAP.

ZERO - MOPEIA ROAD.

Phase 3 Trial Section 4 : Sand Seal Surfacing with 2mm Coastal Sand Section.

Length: 700m

Chainage:

Drawing Prepared by:
Andrew Otto - TRL.

October 2010.

All Dimensions in mm. Do NOT scale from drawing.