Kenya Rural Roads Authority

Roads 2000 Programme

Support to the Construction of a Low Volume Sealed Road in Nyanza Region in Kenya **under the**

Africa Community Access Programme (AFCAP)

Project Code: AFCAP/KEN/007/C

Inception Report

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by

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Contents

Executive Summary

The location of the research/demonstration project is good and offers excellent opportunities for research on local resource based construction methods as well as use of locally available non-standard materials in the pavement.

Laterite with similar properties to the one found in the project area has been used successfully in other countries without stabilization or modification with lime or cement. However, this requires a well designed and functional drainage system and sealing of the shoulders to ensure that the pavement is kept dry.

It is therefore proposed to include short sections with neat laterite in the base to monitor the performance over time.

Likewise screened laterite has performed well in conventional Otta Seals in other areas in Kenya. It is therefore proposed to use graded laterite aggregates for the Modified Otta Seal and Cold Mix Asphalt, both of which perform much like the conventional Otta Seal.

Use of the locally available laterite for aggregates will probably save enough funds to enable sealing of the shoulders throughout and also contribute to local employment.

In a country perspective, use of natural laterite or other naturally occurring gravel sources for base and aggregates, has a huge potential for cost savings and may thus enable KeRRA to upgrade more road to bituminous standard.

Sealing of the shoulders is paramount for the performance of these roads and will radically improve traffic safety by enhancing the segregation of non-motorized and motorized traffic.

With this objective it is proposed to include road marking and limit the carriage way to 5.50 m on the wide cross section and 3.00 m on the narrow cross section. Combined with sealing of the shoulders, this will leave 0.75 m and 1.00 m wide, user friendly shoulders respectively to be used by pedestrians and bicyclists. Without sealing, the shoulders will inevitably erode and not be used to the same extent.

The black cotton soils on the Nyenye branch should be re-tested for plasticity and swell, since the previous samples probably were contaminated with gravel. The outcome of the new tests may have a bearing on the final design of this section.

Prospecting for “hard” laterite gravel should be done and tests carried out using the 10% FACT rather than the ACV test.

Testing of the ETB should be carried out to determine the optimum mix design. It is proposed to do the initial testing with lime instead of cement. Subject to the results, further testing may be decided upon.

Some of the tools and equipment made at KTC are of good or adequate quality. In general though it is recommended that good quality hand tools be purchased locally and that fabrication be done by a well equipped commercial workshop. Good quality tools are essential and well manufactured equipment contributes to “setting the tone” for this project where good workmanship and attention to detail is paramount for a successful outcome.

The vertical alignment should be further investigated in order to avoid extensive fill at chainage 3+200.

It is proposed to replace some of the culverts in the flat terrain, particularly on the Nyenye branch, with drifts which are virtually maintenance free and will not require additional lifting of the road.

Concrete beacons should be constructed for long term monitoring and data collection on the performance of the road pavement. A detailed monitoring programme should be set up in due course.

The next visit of the AFCAP Training Adviser is tentatively planned for week 32 and 33, i.e. 9-20 August and should coincide with the visit of the Foremen from South Africa to ensure co-ordination of the training inputs.

1. Background

The Africa Community Access Programme, AFCAP is a research programme funded by the UK Government. AFCAP supports knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access the maximise the use of local resources.

AFCAP has been asked by the Kenya Rural Roads Authority, KeRRA, to assist with the design, construction and monitoring of a research/demonstration site in Bondo District in the Nyanza Region of Kenya under the GoK/SIDA Roads 2000 programme.

For the Design Phase two reports have been prepared for the project:

- Design Brief Report by Robert Petts, January 2010
- Technical Review of the above Design Brief by Mike Pinard

This report should therefore be read in conjunction with the two previous reports. Information contained in these will not be repeated here other than for ease of reading where necessary.

The research/demonstration project was split in four separate sections and tendered among prequalified local contractors. The contracts were awarded on Friday 21 May 2010. The project has thus entered the construction phase with the contractors starting to mobilize on site.

2. Objectives

The AFCAP Training Consultant was assigned to:

During the first visit (one week) to familiarise himself with the project and undertake the following tasks:

I. Review documents prepared by AFCAP during the Design Phase, including the Design Brief and the Technical Review
II. Study the final design of the road and the specifications included in the contract documents and provide advice on possible modifications to the design and technical specifications, as well as on any additional design details or specifications that might be required.
III. Visit the road site in Bondo District
IV. Visit Kisii Road Training Centre, where basic equipment for use on the site is being fabricated and stored
V. Prepare source/training materials relating to the types of construction specified for the road for use by the supervisors and the contractors during construction.

During the second visit (two weeks) to:

I. Provide training for district staff assigned the responsibility for the supervision of construction
II. Carry out site demonstration on the best practices and procedures for the proposed base construction and surfacing options. Provide training and guidance to the contractors including:
    a. Programming of the works
    b. Interpretation of the contract documents
    c. Refining their work methods to maximize the use of labour, intermediate equipment and other local resources

III. Provide recommendations to the Materials Branch for materials testing and other quality control requirements during construction

3. Orientation Meetings

During the mission the following orientation meetings were held:

- At the Director General's office at KeRRA, Nairobi with representatives from KeRRA and Materials Branch, Kenya Roads Board, AFD Roads 2000 and ILO
- At the District Road Engineer's office in Bondo with the District Engineer, Supervisors, representatives from the contractors and Roads 2000 Nyanza.

Presentations were made of the basic concepts of base construction and surfacing using labour based methods as these have been developed and evolved on similar projects *inter alia* in South Africa and Zanzibar.

Emphasis was made on the history behind the current practice, especially from the project in South Africa, to highlight potential pitfalls and the reasons why the current emulsion based techniques were chosen as the most suitable for labour based construction of low volume rural roads. The participants were shown examples of high quality roads constructed by these methods and explained the need for good site organization and high workmanship standards to ensure that the research / demonstration projects are successfully carried out.

All contractors confirmed that they would have access to the required construction plant and equipment such as motor grader, excavator, tipper trucks, water bowsers, heavy vibrating rollers for construction of the sub-grade formation, fill and sub-base where needed. It was also confirmed that they would have access to motorized sprayers for spraying of emulsion and smaller pedestrian rollers for compaction of the base layer and surfacing. The sprayer would normally be hired with a trained operator from the private market.

4. Findings and recommendations

The AFCAP Training Consultant was accompanied by the AFCAP Technical Manager Mr. Rob Geddes during the entire mission. Unless indicated otherwise, the views and suggestions raised in the following are shared by both parties.

a. Meeting with Materials Branch, Kisumu

A meeting was also held at the Materials Branch, Kisumu. The following issues were discussed:

- Further testing of the black cotton soils to determine a potential impact on the final design of the affected road sections as highlighted in the Technical Review. It appears that the samples of the black cotton soils taken for testing so far may have been contaminated with gravel and the test results therefore may not be representative. Of particular concern is the potential for volumetric change during moisture fluctuations in the sub-grade since this may give rise to cracking of the seal and subsequent moisture ingress in the pavement layers.
- Testing of ETB to determine the optimum mix design. It was tentatively decided to initially test using lime instead of cement since lime is produced locally, is cheaper and would also reduce the high PI of the lateritic gravel to be used. However, it would also be of interest to repeat the tests at a later stage

with cement to detect potential differences. See Annex 1 for permutations of mixes to be tested and test methods for ETB.

- The availability of good quality crushed stone in the correct fractions needed for the Penetration Seal (Modified Otta Seal). It was reported that several crushing plants are in operation in Kisumu, that good quality stone can be delivered when it is made clear that stockpiles will be tested both prior to delivery and after delivery to site. The crushers can deliver 10/14 + 3/6 mm fractions suitable for a Double Chip Seal and 3/10 + 0/3 mm fractions for Penetrations Seal and Cold Mix Asphalt.
- Identification of borrow pit with “hard laterite” as potential aggregate for Penetration Seal and Cold Mix Asphalt. The aggregates should be tested using the 10% FACT rather than the ACV test as recommended in the Technical Review to give a better basis for determining the suitability of the aggregates for the surfacing options.

b. Site Visit

Picture 1: Typical flat section on the Nyenye branch with damage in the black cotton sub-grade from the rainy season

During the site visit to the project roads, the following was observed:

- The location of the research/demonstration project is good for the following reasons:
  - The terrain is flat or gently undulating and does not pose big challenges construction wise for the relatively inexperienced contractors.

  - Laterite for construction is available in sufficient quantities in the vicinity of the road to minimize haul and construction costs
  - The scope for use of the screened laterite as seal aggregate appears to be great and would probably save enough money to enable sealing of the shoulders if this were to be used for the entire project. This option should be considered subject to new test results as referred to above.

- The Design Brief, Annex 2 indicates the need for fill up to 1.2m at chainage 3+200 to achieve an acceptable vertical alignment. This is a massive fill although it would be limited to about 100m. The alignment on low volume roads should first and foremost ensure proper drainage, but can otherwise be of a rolling nature following the natural terrain quite closely. The need for this fill should be investigated further.
- Some of the culverts on the flat sections would be better replaced with drifts, particularly on the branch to Nyenye Beach. The drifts should be constructed with inverts level with surrounding terrain. Culverts in flat terrain like this generally function poorly over time since the outlets would inevitably become long and silt up and should be avoided.
- Use of drifts on the Nyenye Branch would also reduce speed, which is an important factor on this narrow cross-section where the non-motorized traffic would be in majority.

Picture 2: Example of hump constructed over a culvert to avoid lowering the invert. Drifts would probably be a better solution in this type of terrain.

c. Visit to Kisii Training Centre

Picture 3: Staff at the KTC Wokshop with some of the tools and equipment produced at the centre

The visit to KTC was mainly to look at the tools and equipment which were under production. Comments on the various pieces are as follows:

Drum stand:

- Drum stand made of 1" galvanized pipe was well made, but should be equipped with wheels of, say, 6-8" diameter to make it more maneuverable in case the drum stand needs to be moved on site during operations. The stand would then function as a cart.
- One cross bar at the end where the handles are will block the operation of the ball valve for decanting the emulsion and must be removed
- Handles should be retractable, i.e. they should fit into slightly larger diameter pipes welded on the sides of the stand so that they can be pushed in and be out of the way for operation of the ball valve.
- The other model drum stand would work well, but is unnecessarily bulky and difficult to transport. No need for two different models.

Half drum, open both ends for spotting of aggregates:

- This was very well made. This will only be needed for production of Penetration Seal and DBST, so only one more is required for now.

Steel squeegees or spreaders:

- These were well made and will do the job they are intended for

Guide rails for Cold mix Asphalt:

- The lugs welded on the 20x20mm square tube have too big holes to be held steady by a small nail driven into the base.
- The better option is to remove the lugs and instead drill four no 5 mm holes though the square tube itself so that the rail can be fixed steadily to the base with small 2” nails. See Annex 3

Bulking rails:

- These were only made in short lengths and would not be suitable for use.
- The shutter system is such that the bulking rails and the base shutters are all of the same length. The bulking rails have a male and female end such that they effectively hold the shutters together as one piece when fitted on top of the base shutters. See Annex 3
- It is proposed to make all shutters and bulking rails 2 m long since this length will work well both on straights and in curves.

Spades:

- The spades were very rudimentary and low quality. Good quality hand tools (Lasher) are apparently available locally and should be procured by the contractors through contract provisions. Having good quality hand tools is half the job done! See Annex 2 for Lasher Tools product codes and descriptions.

Mixing pans:

- In our opinion KTC does not have the right equipment, nor skills for this type of production. The pans were very rudimentary and of low quality. A sketch for cutting the steel plate before welding in order to achieve the desired 45 degree angle of the sides of the pan, is provided in Annex 3.

It is recommended that all production of tools and equipment be done at a professional workshop in either Kisumu or Nairobi. Having well made, functional tools and equipment sets the tone for the project where attention to detail is paramount to achieve good results.

d. Review of Design Brief and Technical Review

Cross sections

The AFCAP Training Consultant agrees with the Design Brief on the general design of the project. As mentioned elsewhere further investigations or considerations should be made on the following:

- The chosen cross-sections (7.0 m and 5.0 m respectively including shoulders) are appropriate for this traffic level. We do however agree with the Technical Review that the shoulders should be sealed. Sealing of the shoulders would reduce or prevent moisture ingress in the pavement and consequently weakening of the pavement structure as well as facilitate segregation of non-motorized and motorized traffic.
- In addition to sealing the shoulders, it is proposed to limit the carriage way to 5.5 m and 3.0 m respectively and demarcate the carriageway with road marking. This would leave sealed shoulders of 0.75 m on the wider cross-section and 1.0 m on the narrower, basically a one lane cross section, for accommodation of non-motorized traffic. Sealing the shoulders will thus have a positive effect both on structural integrity of the pavement as well as on traffic safety. Un-sealed 0.5 m shoulders as per the Design Review are too narrow, will erode and quickly become very little user friendly for non-motorized traffic.

- On the sections with composite ETB base, the ETB should be constructed to the full width of the base including the shoulders. This will further prevent moisture ingress into the pavement.
- It is suggested to demarcate the single lane on the narrow cross section in the middle of the paved width leaving 1.0 m shoulders either side. This is not considered to constitute a traffic hazard with the anticipated traffic volume on this branch.
- The narrow cross section should have appropriate curve widening where needed for safety reasons and frequent meeting bays as per the Design Brief.

Surfacing options

The Technical Review argues that laterites similar to what is found in the project area have been used successfully for Otta Seals in Kenya before, hence there is no reason why the as-dug laterites found on site cannot be used on the demonstration project.

The conventional Otta Seal undoubtedly has its merits and would in all likelihood perform well on the project roads. In the experience of the AFCAP Training Consultant, the conventional Otta Seal is however not particularly suited for small scale, inexperienced contractors for many reasons, viz:

- The bitumen distributors would carry at least 10,000 ltrs, which ideally should be sprayed in one operation. This would mean that long sections of base would have to be ready on the days of sealing. With the inherent slower pace of base construction using labour based methods, the base would be subjected to wear and damage from traffic and inclement weather before it can be sealed, all to the detriment of the contractor who would oftentimes have to undertake cost extensive repairs or even reconstruction of damaged sections.
- Bitumen distributors are not always reliable and can cause problems when they do not come to site as agreed, break down during spraying operations, when nozzles clog up, all of which has been experienced elsewhere on similar projects.
- Working with hot bitumen and cutting back with paraffin on site constitutes a potential health hazard, particularly for inexperienced site staff and temporary labourers, as would be the case on this project.

The problems with the conventional Otta Seal on projects of this nature are thus more of a managerial and organizational than technical nature. The emulsion based surfacing techniques are much more suited for small scale contractors and labour based methods.

However, if the laterite present in the project area can function well in a conventional Otta Seal, there is no reason to believe that they could not also function well in the emulsion based surfacing options chosen for this project, i.e. the Penetration Seal (Modified Otta Seal) or the Cold Mix Asphalt, both of which use a graded gravel or crushed stone aggregate and hence perform much like the conventional Otta Seal.

Based on information received on the cost of crushed stone aggregates, the potential cost savings are huge for this project, even though the crushed stone aggregates are available from Kisumu, which is in relative proximity of the construction sites. Extrapolating this to the whole of the rural road network, most of which would be further away from sources of crushed stone aggregates, the cost implication for Kenya as a whole would be enormous.

e. Proposed pavement design

The project has been divided in sections with different pavement as shown below:

<table>
<tr><th colspan="6">Bondo Roads 2000 Trial Road (RD E1158)</th></tr>
<tr><th colspan="6">Proposed Pavement</th></tr>
<tr><td>Surfacing
20-25 mm</td><td colspan="2">Modified Otta</td><td colspan="2">Cold Premix</td><td rowspan="2">Dressed Stone Pavement</td></tr>
<tr><td rowspan="2">Base
150 mm</td><td rowspan="2">C/Li Gravel</td><td colspan="2">ETB</td><td rowspan="2">C/Li Gravel</td></tr>
<tr><td colspan="2">Neat Gravel</td><td>Neat Gravel</td></tr>
<tr><td>Subbase
150 mm</td><td colspan="5">Neat Gravel</td></tr>
<tr><td colspan="2">Ch 0+000</td><td colspan="2">Ch 2+400</td><td>Ch 4+900</td><td>Ch 5+100</td></tr>
</table>

The thickness of the Modified Otta Seal is determined by the largest fraction of the aggregate and will normally only be +/-12 mm thick. The Cold Premix when constructed with 20 mm guide rails will have a compacted thickness of +/- 14 mm. This can of course be made thicker, say +/- 20 mm when using 25 mm instead of 20 mm guide rails, but the cost would then increase proportionally.

The Base is shown as being 150 mm thick. It is assumed that this refers to uncompacted thickness which is determined by the shutters. The compacted thickness of the base with the shutters as planned for this project, will be 100 mm.

f. Proposals for design changes and contract variations

This being a research and demonstration project it is our opinion that one must try to gather as much information as possible. In our view this can be done without jeopardizing the performance of the contractors by issuing variation orders pertaining to the proposed items below:

i. Short sections with neat laterite base

There is ample evidence that laterite similar to the one found in the project area can perform well as base without stabilization or modification with lime or cement, provided the drainage system performs well and the base is kept dry.

It is therefore proposed to construct two short sections of 100 m each with neat laterite base on both the Modified Otta Seal and Cold Premix sections.

ii. Use of screened laterite for surfacing aggregates

Based on the Technical Review and the discussion of this issue above, it proposed to use screened natural laterite for surfacing aggregates for both the Modified Otta Seal and the Col Mix Asphalt subject to the results of the 10% FACT.

A Prime coat must be included in the contracts where the seals are constructed on neat or stabilized gravel. On the ETB sections, only a diluted SS60 is required.

iii. Construction of 50 m of DBST

It is recommended to construct a 50 m section of DBST as the performance and cost datum for the surfacing options. This section can be anywhere and is to be determined on site.

iv. Sealing of shoulders

Both for the performance of the pavement and for traffic safety, i.e. segregation of NMT and MT, sealing of the shoulders is paramount.

On the ETB section, it is proposed to construct the ETB composite to the full width including shoulders.

As far as we can see, the only way to find the funds for sealing of the shoulders within the available funding limits, is to use screened laterite for the surfacing aggregates. The screening will also contribute to local employment creation and be in accordance with the objective of using local resources as much as possible.

v. Adjusting the lane width and including road marking

With regard to traffic safety, particularly for the NMT, it is proposed to limit the lane width on the wider cross section to 2.75m thereby increasing the shoulder width to 0.75 m. On the narrow cross section it is proposed to have one lane 3.0m wide and 1.0 m shoulders. The total constructed width will then remain the same as proposed in the Design Brief.

It is recommended to include road marking on both the wide and narrow cross sections to further enhance the segregation of traffic. It is assumed that this can be accommodated from contingencies and/or possible from savings on use of screened laterite for surfacing aggregates.

vi. Replacing some culverts in flat terrain with drifts

The Design Brief advocates replacing or upgrading existing culverts and installing some new ones.

In flat sections, particularly on the Nyenye branch, it is rather suggested to replace some of the culverts with drifts as shown below. When well constructed, such drifts are virtually maintenance free, are comfortable to drive through and will contribute to reduced speed on the affected sections. This is important on the narrow cross section with more non-motorized than motorized traffic.

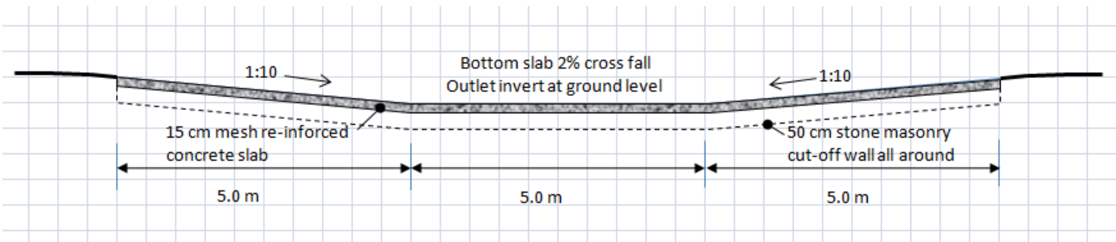

Figure 1: Basic design of a well functioning drift

If culverts are to be installed on these sections, the road must be lifted to avoid lowering the culvert inverts and thereby making them susceptible to silting. Drifts such as shown above will not require additional lifting of the road.

5. Monitoring and data collection

To facilitate long term monitoring and data collection on the performance of the pavement and seals, concrete beacons should be constructed at each data collection point, i.e. one beacon for each permutation of sub-grade, base and seal options.

The monitoring will include:

- Visual inspection of seal defect, i.e. cracking, aggregate loss and bleeding
- Rutting
- Volumetric change on sections with black cotton soils in the sub-grade
- DCP measurements for field CBR values

The design of the beacons have to ensure that they will not move up or down with moisture variations in the sub-grade

A detailed monitoring programme should be set up in due course.

6. Next visit

The next visit by the AFCAP Training Consultant is tentatively planned for week 32 and 33, i.e. 9-20 August 2010. The exact timing may have to be reviewed in accordance with the progress on site. The sub-grade formation and drainage works should be well advanced and at least some 4-500 m of sub-base should be ready by the time of the visit on separate sites for construction of Modified Otta Seal and Cold Mix Asphalt.

The training will encompass the following:

- General construction of base using the shutter system
- Construction of composite ETB
- Construction of Modified Otta Seal (Penetration Seal)
- Construction of Cold Mix Asphalt

This should coincide with the visit of the two Foremen from South Africa to ensure best possible co-ordination and effectiveness of the training inputs.

Annex 1: ETB Testing

Tests to be carried out for Emulsion Treated Base

ETB Test results summary

Mix proportions		OMC	Air dried		Oven dried		Neat		
			MDD	CBR @98% of MDD	MDD	CBR @98% of MDD	PI	MDD	CBR @98% of MDD
Lime	0,0 %								
Emulsion	1,5 %								
Lime	0,0 %								
Emulsion	2,0 %								
Lime	0,0 %								
Emulsion	2,5 %								
Lime	0,5 %								
Emulsion	1,5 %								
Lime	0,5 %								
Emulsion	2,0 %								
Lime	0,5 %								
Emulsion	2,5 %								
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Emulsion	2,0 %								
Lime	1,0 %								
Emulsion	2,5 %								
Lime	1,5 %								
Emulsion	1,5 %								
Lime	1,5 %								
Emulsion	2,0 %								
Lime	1,5 %								
Emulsion	2,5 %								

The tests at 2.5% emulsion should only be carried out if the tests at the lower emulsion contents are deemed not to give adequate strength of the ETB

In the following are given guidelines for preparation of samples for CBR testing of ETB. The standard procedures for CBR testing used for granular materials cannot be used for ETB since they will not reflect the true strength of the ETB.

Testing by both methods should be done since the Oven drying method gives a good indication of the early strength of the ETB. The Air drying method normally takes three to four days longer and gives a better indication of the final strength of the ETB although the ETB will continue to increase in strength for some time still.

The Oven Drying method for preparation of sample for CBR test for Emulsion Treated Base

The "standard methods" of curing the ETB samples for CBR testing is not appropriate as the true strengths of the sample can only be determined once the emulsion has broken. Soaking of samples before the emulsion has broken precludes the emulsion from breaking.

To overcome this it is recommended that, prior to soaking for 3 – 4 days, the samples (which have been prepared at the required liquid content see example below) are placed in an oven at 60^{o} – 70^{o} C and the loss of moisture controlled until the residual moisture is less than 30% of the original moisture in the sample.

The amount of moisture absorbed after soaking must also be noted.

Even this method does not fully reflect the true strength generated when the emulsion breaks completely but does give a more representative indication of the CBR value of the material.

Note that the OMC to be used for compacting the material must be 1.2% over OMC for the 2% emulsion and 1.5% over OMC for the 2.5% emulsion for a 60% stable grade emulsion (60% of the emulsion is bitumen which is regarded as part of the solids)

Example

If OMC of the material is 6% the amount of liquid to be used is as in the table below:

2% emulsion	***2.5 % emulsion***
6% (OMC) – 2% (emulsion)= 4.0% water Plus 2.0% emulsion Plus 1.2% water 7.2% liquid Total water is therefore 4 + 1.2 = 5.2%*	*6% (OMC) – 2.5% (emulsion)= 3.5% water Plus 2.5% emulsion Plus 1.5% water* 7.5% liquid Total water is therefore 3.5 + 1.5 = 5%*

**to balance the 60% bitumen in the emulsion which is regarded as part of the solids*

ETB Design Mix and Testing Procedure (The air drying method)

The design procedure

The material design process for gravels treated with small percentages of emulsion (less than 3%) is based on the following procedure:

- characterisation of materials to be used in ETBs;
- determination of the optimum fluid content;
- preparation of samples, in which the amount of residual bitumen varies from 0%-2% in increments of 0,5%, but where the optimum fluid content (hydroscopic water, emulsion and compaction water) remains unchanged;
- compaction in accordance with the standard modified AASHTO method at room temperature;
- curing of samples;
- determination of CBR and UCS after 4 days and 6 hours soaking, respectively;
- determination of optimum residual bitumen content.

Key definitions
The following definitions are given for fluid content, maximum density and optimum fluid content:

- Fluid content is the total quantity of fluid in the mix, including
    - hygroscopic moisture,
    - the bitumen and water within the emulsion, and
    - moisture added for compaction.
- The maximum density of a material at a specific compactive effort is the highest density obtainable when compaction is carried out on the material at various fluid contents.
- The optimum fluid content for a specific compactive effort is the fluid content at which the maximum density is obtained.

STEP 1: Sieve analysis and determination of Atterberg limits.

PI < 6, ok
PI > 6, add lime
Shrinkage product (linear shrinkage x % passing 0,425 mm sieve) < 50, ok

STEP 2: Determination of the optimum fluid content

The maximum dry density and optimum fluid content are determined by establishing the fluid/density relationship of the material when prepared and compacted at the Modified AASHTO compaction effort at different fluid contents.

Determine the amount of compaction water as follows:

Optimum moisture content:	10,0%	
- Emulsion	2,0%	(Test for 1.5, 2.0, 2.5 and 3.0%)
= Water	8,0%	
+ Residual bitumen (e.g. 60% of 2%)	1,2%	(As % of actual emulsion in mix)
= Required fluid content	9,2%	
- Moisture incl. hygroscopic water	5,0%	(To be determined beforehand)
= Compaction water	4,2%	

Mixing

- The sample in each basin should be weighed accurately to the nearest five grams
- and transferred to the mixing basin.
- The volume of water required should then be determined and measured into a suitable container.
- The required mass of emulsion should also be determined and measured into another suitable container.
- 1% cement should be thoroughly mixed with the dry material at this stage.

- A portion of the compaction water (equivalent to the moisture absorption) should then be added to the dry sample until the material is damp. While the water is being added, the material should be mixed continuously with a trowel. This should normally continue until dust is no longer generated by the mixing.

- The remaining compaction water should then be thoroughly mixed with the emulsion and added to the damp material. Under no circumstances should diluted emulsion be added to dry porous material.

- The mixing of the moist material should be continued for another few minutes. The moist material should now be covered with a damp sack to prevent evaporation and should be allowed to stand for half an hour so that the fluid may become evenly distributed throughout.

Fluid (moisture) / density relationship
Fluid (moisture) / density relationship is determined in the normal way. The fluid contents should be plotted graphically against the respective dry densities. The peak of the curve indicates the optimum fluid content and the maximum density of the material when compacted under this particular effort.

Reporting of results
The maximum density should be reported to the nearest whole number as a reference for field densities or CBR determinations.

Note

- The material should be compacted within one hour of mixing, since the emulsion must not have broken at the time of compaction.
- Once material has been compacted, it cannot be used for another compaction.

STEP 3: Manufacturing and curing of specimens

Sample manufacturing
The sample manufacturing procedure is described in the procedure for the determination of optimum fluid content (Step 2).

It is recommended that samples be prepared over a range of emulsion contents, where the amount of residual bitumen varies from 0% to 2% in increments of 0,5%, but where the optimum fluid content (hygroscopic water, emulsion and compaction water) remains unchanged. Samples prepared at various residual binder contents should be compacted at room temperature according to the standard methods.

Any material larger than 19 mm should be crushed prior to treatment and compacted until it passes this size.

It is recommended that samples prepared for UCS testing be manufactured at a moisture content of 0,5 to 1,0% above optimum moisture content. If samples are compacted at optimum moisture content, the UCS results often underestimate the strength of the material because of their dryness.

Curing and soaking of specimens

After compaction specimens shall be be cured for seven days at ambient temperature.

Before CBR and UCS testing, the cured specimens should be cooled, weighed and submerged in water at ambient temperature for four days and six hours respectively. After removal from the soaking baths, it is recommended that the samples be surface-dried with a towel and weighed again to establish the amount of water, if any, which has been absorbed.

STEP 4: Testing of specimens

California Bearing Ratio (CBR)
After curing and four days' soaking, the CBR values of the various specimens, each prepared at a given residual bitumen content, are determined to a penetration depth of 2,54 mm. The optimum residual bitumen content is defined as the residual bitumen content at which the CBR of 100% at 100% Mod. AASHTO compaction are met.

Unconfined compressive strength
After curing and six hours' soaking, the UCS values of the various specimens, each prepared at a given residual bitumen content, are determined in order to establish whether or not the material complies with base standards. The optimum residual bitumen content is defined as the residual bitumen content at which the minimum UCS requirement of 700 kPa is met.

The form below can be used for monitoring the residual moisture content in the samples with either of the two methods above:

Preparation of ETB samples for testing

	Example	Mould 1	Mould 2	Mould 3	Mould 4	Mould 5	Mould 6
1. Weight of mould and sample	10,800						
2. Weight of mould	5,200						
3. Weight of sample (1 - 2)	5,600						
OMC %	13 %						
4. Weight of water in sample (3 X OMC%)	0,728						
5. Weight of 30% of water in sample (4 X 0.3)	0,218						
6. Weight of dry sample (3 - 4)	4,872						
7. Weight of sample with 30% of original moisture (6 + 7)	5,090						
8. Target weight of mould and sample before soaking (2 + 7)	10,290						

When the sample has reached the target weight, the moulds are soaked for 4 days before the CBR testing is done

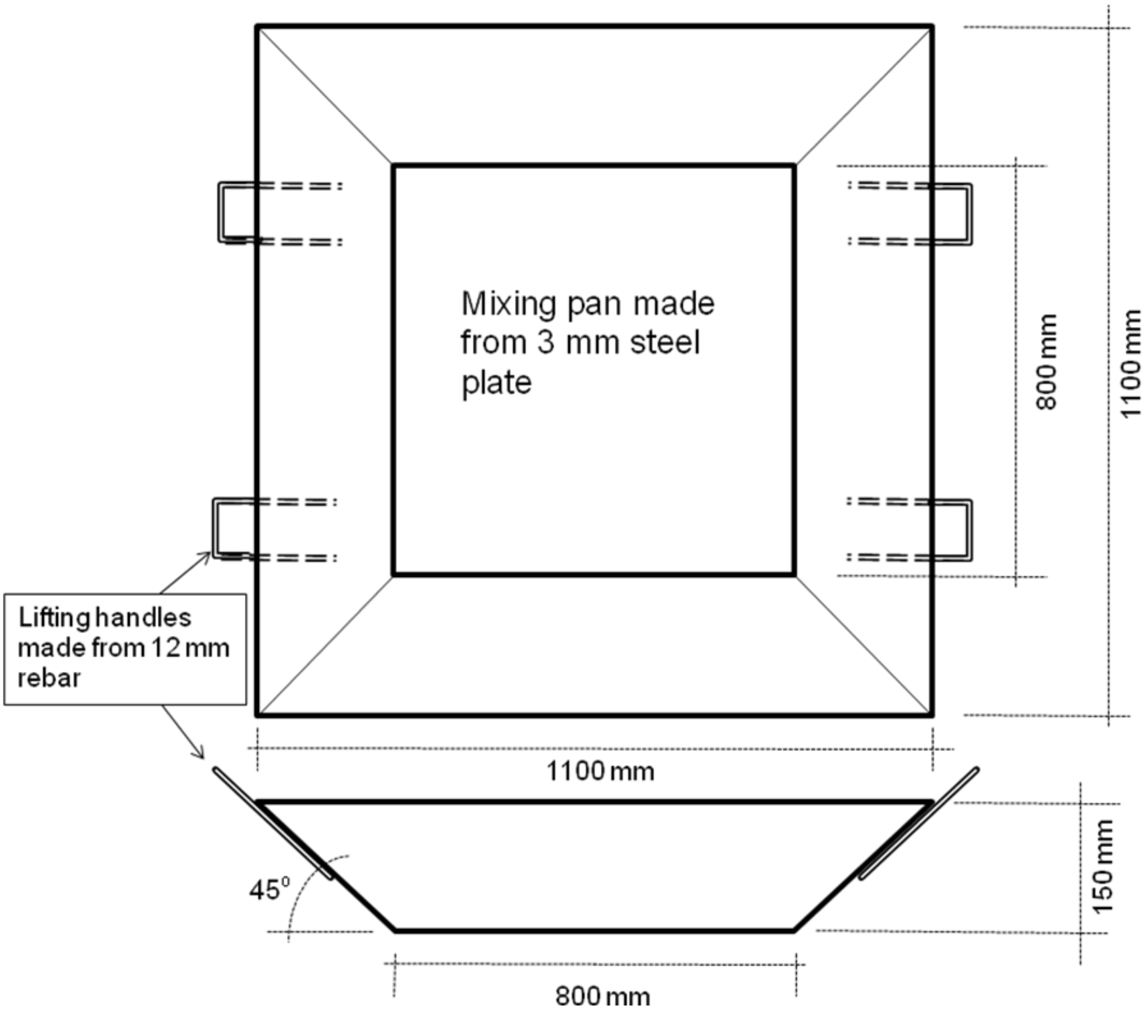
For UCS testing the samples should be soaked for 6 days before testing.

Annex 2: Product codes and description of good quality Lasher Tools

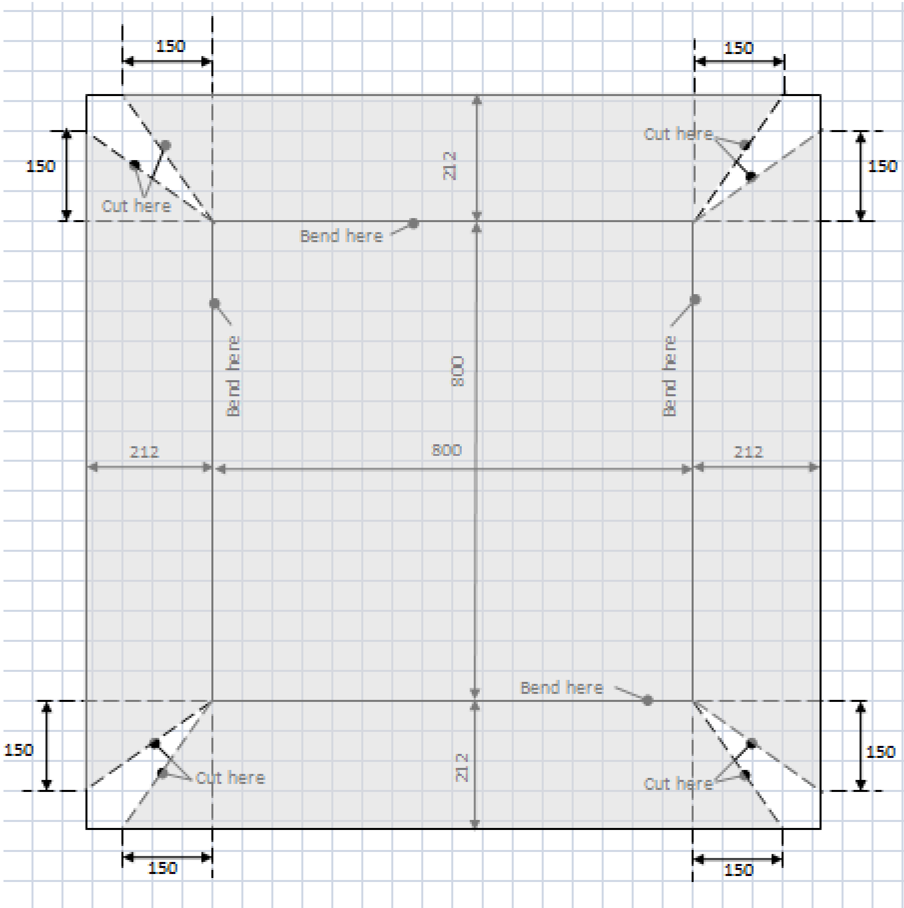
Prod no	Prod. Code	Qty per pack	Description
95	FG00065	5	Road rake, heavy duty, 16 tooth, head only
	FG00055	5	Road rake, heavy duty, 16 tooth, wood shaft
150	FG00505	10	Digging Spade No 2 - All steel
143	FG00430	10	Round Nose - Open Socket - All Steel ASB4
76	FG00250	10	Picks - American Eye - Diamond and Chisel, head only
	FG00340	10	Pick Handle
82	FG00305	10	Mattocks - Cutter, head only
83	FG00315	10	Mattocks - Pick, head only
60	FG05920	20	Agricultural Hoes Head, 900g - Sunken eye, blade width 135 mm
157	FG02305	10	Slashers - Grass, wood handle
166	1CB FG81003		SABS Flat, 14x3 tyre, sealed bearing
167	3CB FG81045		SABS Concrete, 14x3 tyre, sealed bearing
1	FG02795	5	Crowbar, 25 X 1200 mm

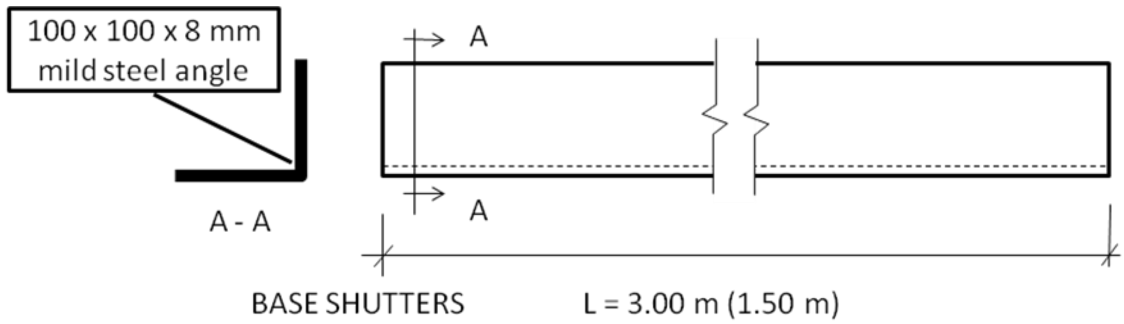
Further information can be found on www.lasher.co.za

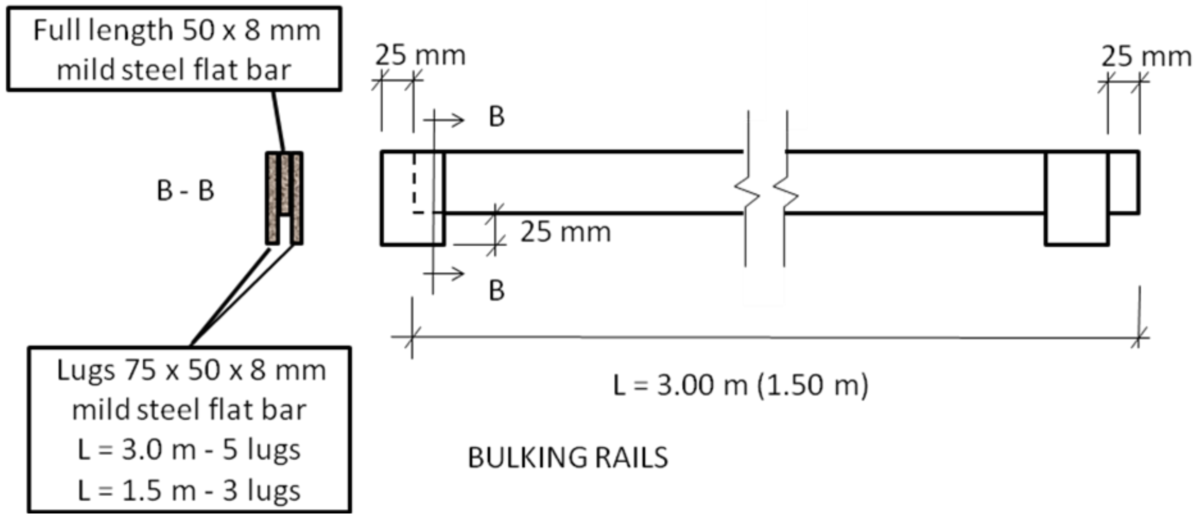
Annex 3: Tools and Equipment to be manufactured locally



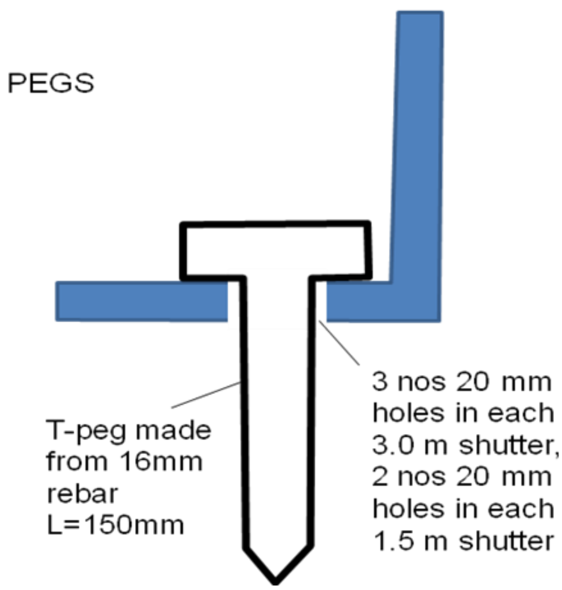
Measurements for cutting the steel plate for the mixing pan



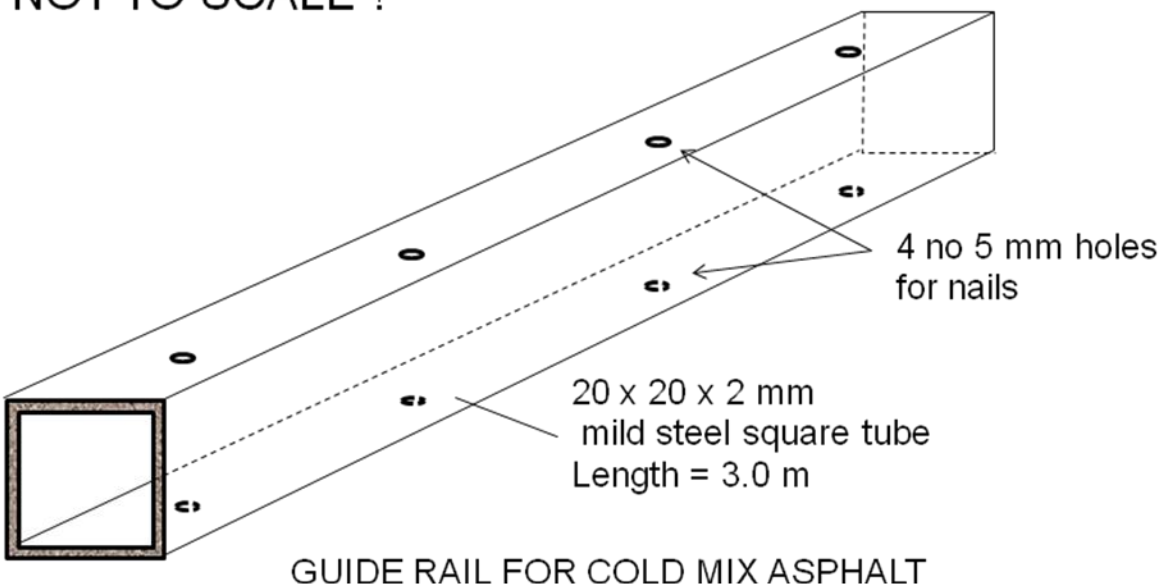




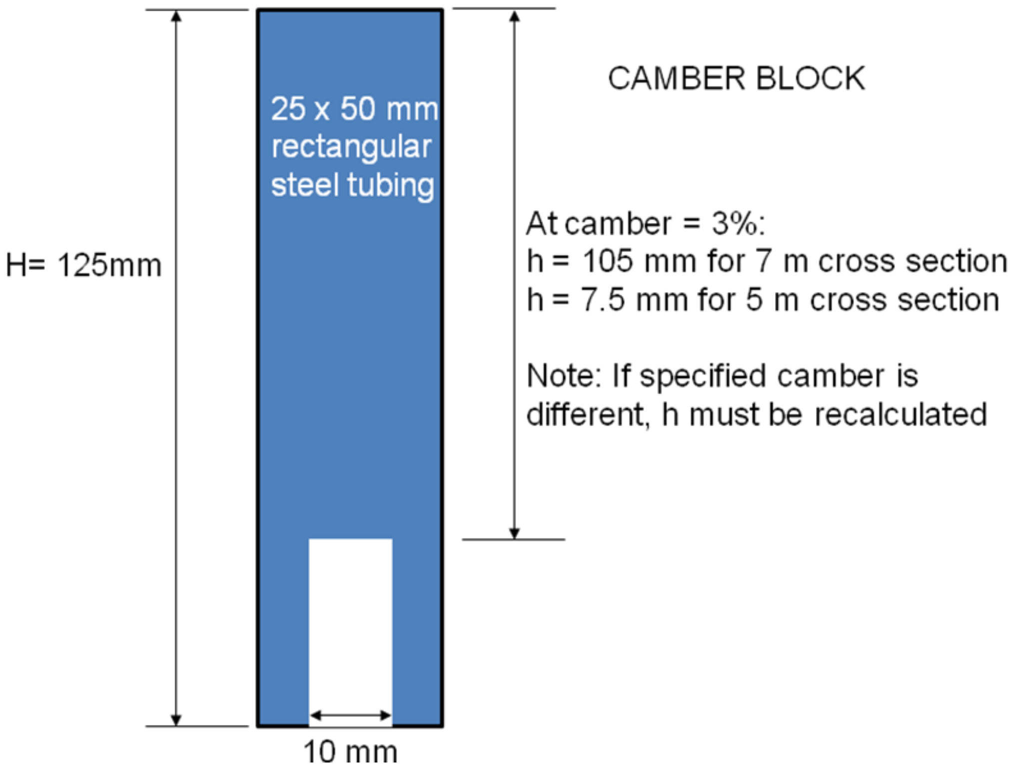
Note: The 1.5 m lengths will be needed for curves. Alternatively all sections can be made 2 m long and be used both on straights and in curves

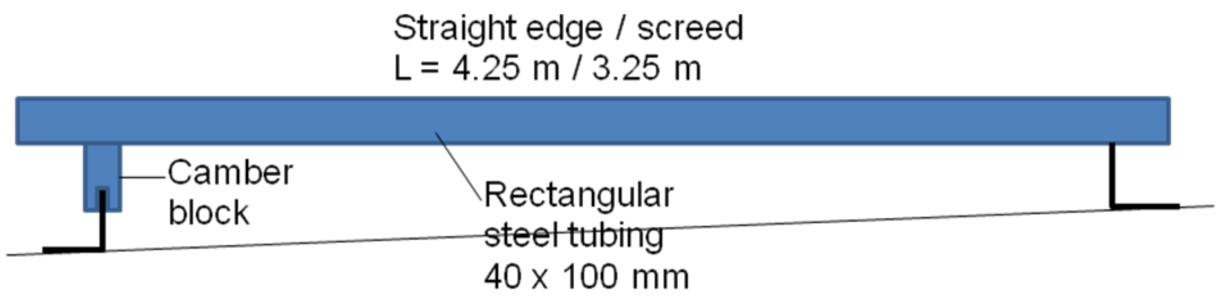


NOT TO SCALE !

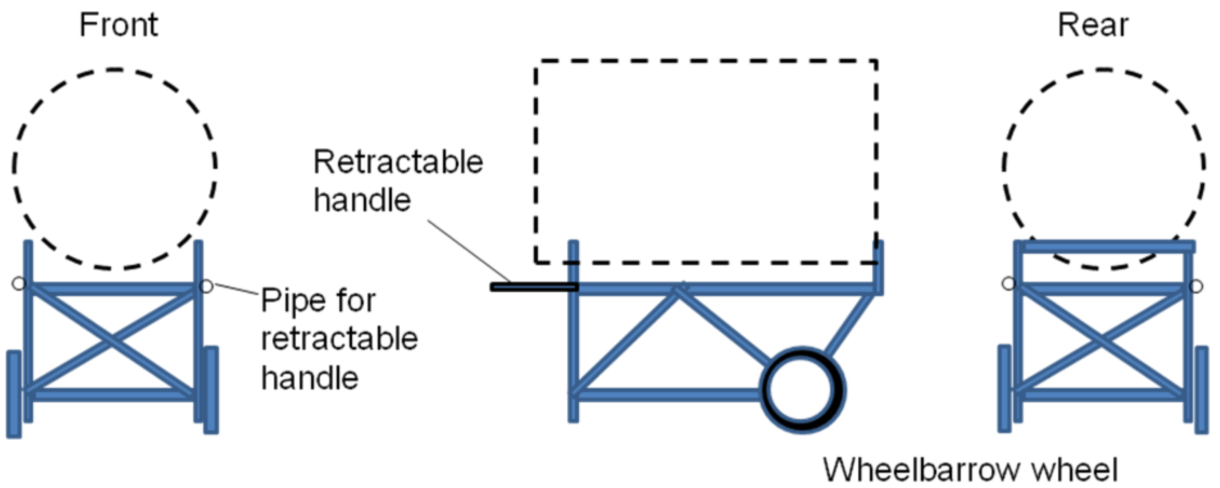


GUIDE RAIL FOR COLD MIX ASPHALT



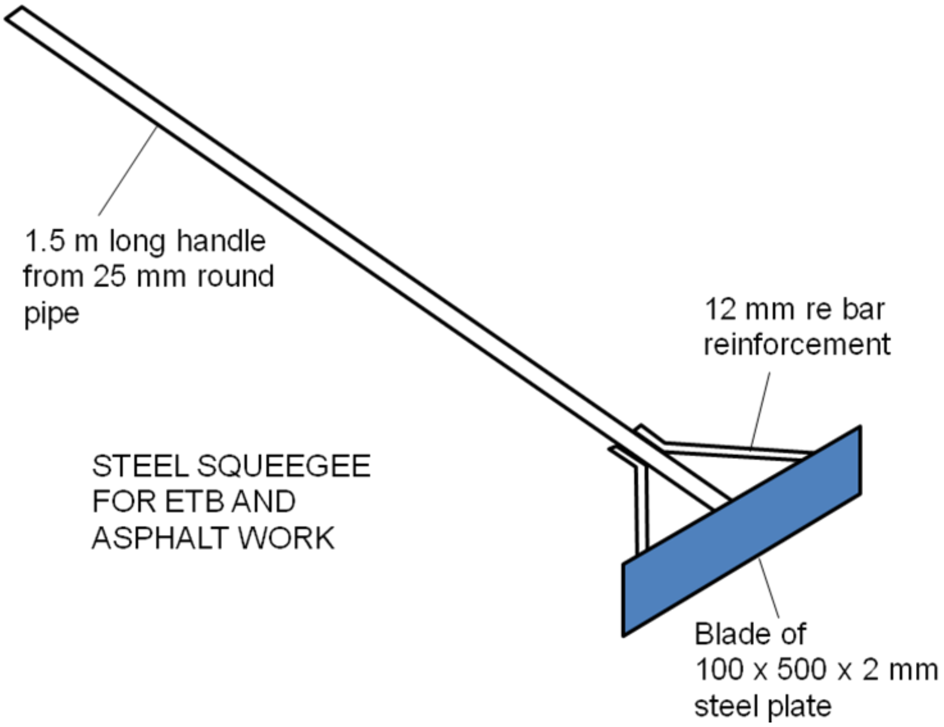


STRAIGHT EDGE / SCREED FOR ETB



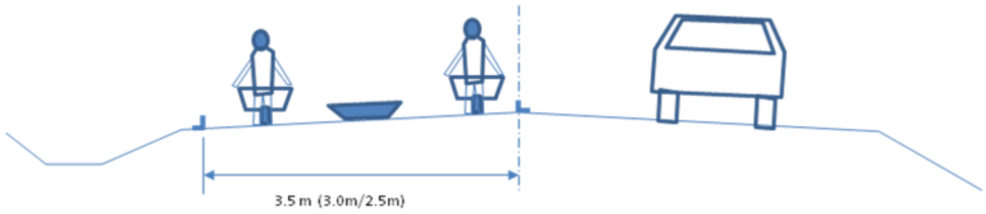
EMULSION DECANTING STAND

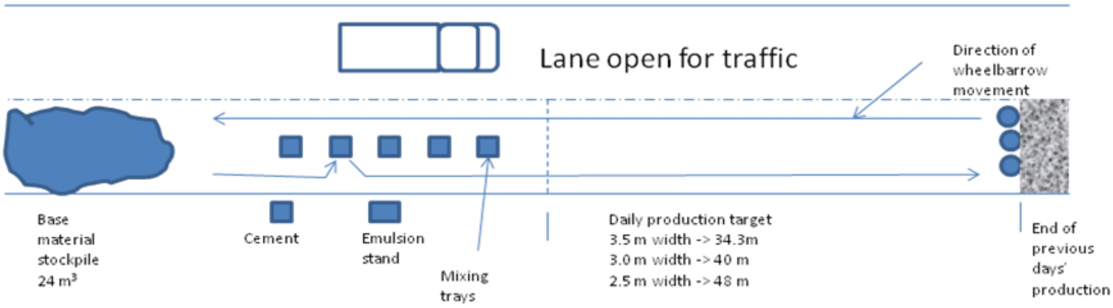
The design should be such that one can strap the drum in standing position and tilt in using the stand to a lying position on the stand. The stand can then also be used as a cart to change the position of the drum. When not in use the handles can be pushed into the pipes on the side of the stand.


1.5 m long handle
from 25 mm round
pipe
12 mm re bar
reinforcement
STEEL SQUEEGEE
FOR ETB AND
ASPHALT WORK
Blade of
100 x 500 x 2 mm
steel plate

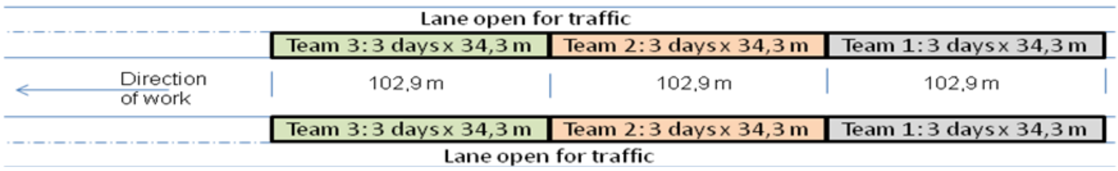
Annex 4: Examples of ETB and Asphalt Site organization

Example of Site Organization for ETB Production



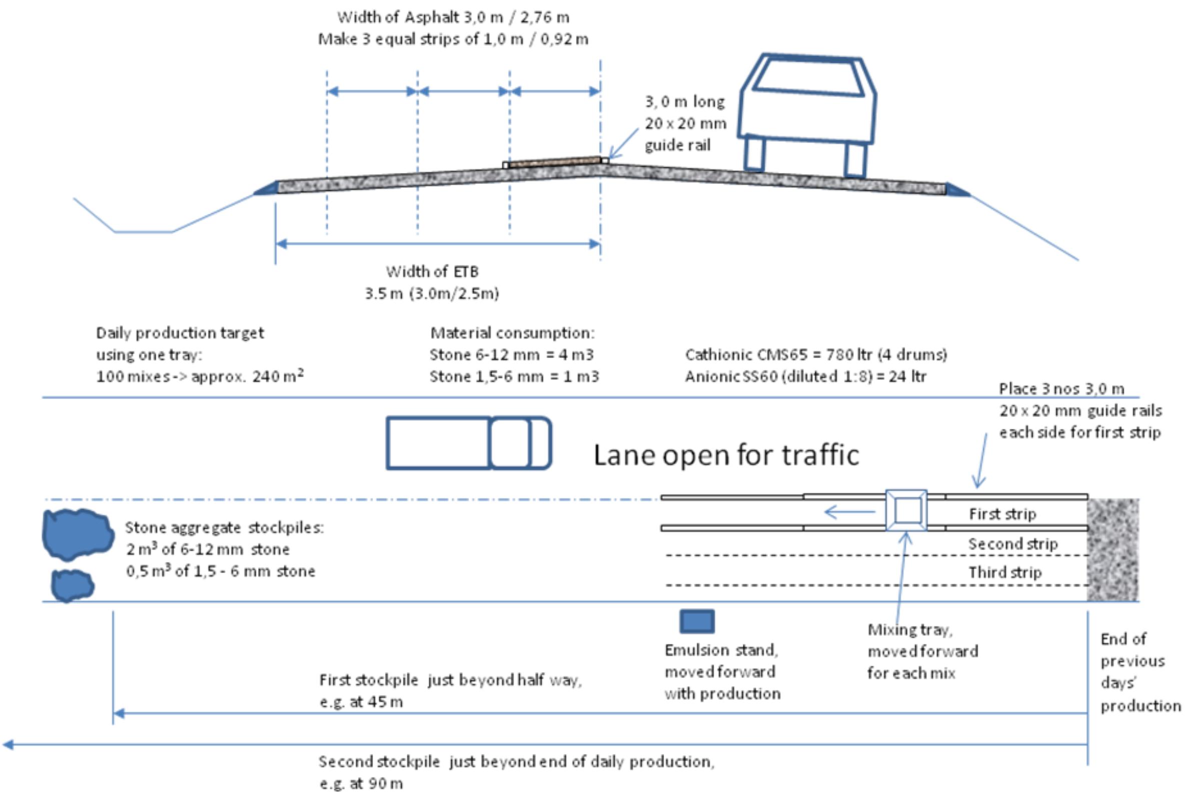


Sequencing with three teams working on half the road width



ETB Site setup	Duties	No of workers	Tools requirements
3 x ETB Teams	See description for ETB Team	25	See description for ETB Team
Setting out, correcting sub-base if required	Setting out shutters for next days production, correcting sub-base to within tolerances where required, applying 1:8 diluted emulsion on sub-base, demarkating start and end of each team production target	1 x Foreman 3 x Asst. Foreman / Team leader 3 x general duty workers Screeding team	2 x small sledge hammer 100 x 30 cm steel pegs 4 x 100 m string line Shutters and bulking rails: 3.5m width -> 58 x 3m 3.0 m width -> 68 x 3m 2.5 m width -> 80 x 3m T-pegs for shutters 1 x camber block 1 x 500 mm spirit level Straight edge / screed 5 m tape measure 30 m tape measure 3 x Watering cans 3 x brooms 1 x Bomag 100 vibr. roller 1 x Plate compactor 3 x 3 m steel straight edge for base correction Hino Tipper truck Pick-up Water bowser 2 x Stop/go signs Warning signs Diversion signs Traffic cones
Compaction	Compact base to refusal, correct base un-evenness to within tolerances, compact shoulders	1 x Bomag operator 1 x Plate compactor operator 2 x workers	
Stockpiling base material	Hauling and dumping base material as directed by tipper truck		
Emulsion supply	Certify amount of emulsion used, moving drum to correct position for the next day, supply new drums as required by end of the day		
Cement supply	Certify amount of cement used by end of the day, transporting left over cement to store, delivering cement to site in the morning		
Water supply	Refilling water bowser as required		
Handling of tools, shutters and construction equipment, maintain site tidyness	Inspecting condition of tools, supply new tools as required, collect and stack shutters and other equipment not in use in secure place		
Direction of traffic	Direct traffic		
Total ETB Site setup		1 x Foreman 3 x Asst. Foreman / Team Leaders 2 x compactor operators 30 x Workers	

Example of Site Organization for Cold Mix Asphalt production



Asphalt Team composistion	Duties	No of workers	Tools requirements
Aggregate supply	Provide stockpiles in correct positions for the days production. Load into gauging boxes , load wheelbarrows and cart to mixing tray	2	2 x shovels 2 x 20 litre gauging boxes (6-12 mm stone) 1 x 10 litre gauging box (1,5-6 mm stone) 2 x Wheelbarrows
Emulsion and water supply	Measure out required quantities of emulsion and water, supply mixing teams as required	1	1 x drum stand 1 x ball valve 1 x measuring container for emulsion 1 x water bucket 1 x measuring container for water
Mixing and placing asphalt	Mix coarse and fine stone aggregates, add water and mix so that all aggregates are moist, add emulsion and mix thoroughly and quickly just until all aggregates are coated, place in between guide rails as directed	3	3 x spades for mixing 3 x shovels for scooping asphalt out of pan 1 x mixing pan
Screeding	Set out guide rails, spread and level asphalt between guide rails, recover asphalt falling outside guide rails, tidy up, backfill joints where required	2	1 x spade 1 x steel squeegee / spreader 1 x tarpaulin for covering asphalt in case of rain 6 x 3 m long 20 x 20 mm guide rails 2 x 3 m long 50 x 6 mm flat bar
Total Asphalt team		8	

Asphalt Site setup	Duties	No of workers	Tools requirements
1 x Asphalt Team	See description for Asphalt Team	8	See description for Asphalt Team
Setting out, correcting base if required, priming with 1:8 diluted anionic emulsion SS60	Correcting base to within tolerances where required, applying 1:8 diluted emulsion on base, demarkating start and end of daily production target	1 x Foreman (shared with closest ETB Team) 1 x Asst. Foreman / Team leader 2 x Workers (screeding team)	1 x carpentry hammer Box of 1 ½ inch nails Guide rails and flat bars: 6 x 3 m long guide rails 2 x 3 m long flat bar 5 m tape measure 30 m tape measure 1 x Watering can w/rose head 3 x brooms 1 x Bomag vibr. Roller 1 x 3 m steel straight edge for base correction 1 x Empty drum for water Hino Tipper truck Traffic cones
Compaction	Compact asphalt as directed	1 x Bomag operator	
Stockpiling aggregates	Hauling aggregates by tipper truck to asphalt production site, dumping on ETB base as directed		
Emulsion supply	Certify amount of emulsion used, moving drum to correct position for the next day, supply new drums as required by end of the day		
Water supply	Placing empty drum in correct position, filling with water		
Handling of tools, guide rails and construction equipment, maintain site tidyness	Inspecting condition of tools, supply new tools as required, collect and clean guide rails, squeegees etc, bring back to store at end of day		
Direction of traffic	Direct traffic		
Total AsphaltB Site setup		1 x Foreman (shared) 1 x Asst. Foreman / Team Leader 1 x Bomag operator (shared) 8 x Workers	