PROTOTYPE DESIGN FOR A PHARMACEUTICAL INTERMEDIATE WAREHOUSE

ROADS PROJECT DESCRIPTION

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LIST OF ABBREVIATIONS

TRH	*Technical Recommendations for Highways*
SADC	*Southern African Development Community*
CBR	*California Bearing Ratio*
AASHTO	*American Association of State Highway and Transportation Officials*

PROTOTYPE DESIGN FOR A PHARMACEUTICAL INTERMEDIATE WAREHOUSE

ROADS PROJECT DESCRIPTION

1 INTRODUCTION

The present report is part of the technical documentation drafted for the Project design of the access and parking areas of the Construction of a Prototype Design of a Pharmaceutical Intermediate Warehouse*.*

The project includes the paving and signaling a joint area of about 2863m^2.

The paving area includes parking areas, and roadways with paving block finish. The pavement will be contained by concrete beams and in prefabricated kerbs and the adjacent sidewalks will have a concrete finish.

For drainage purposes, there are concrete gutters with a triangular section running along the edge of the roadway.

2 GEOMETRICAL DESIGN

2.1 Introduction

The comfort and safety of the operation of a road vehicle are determined by the consistency of the layout among other components. This consistency is achieved in part by relating the magnitude of horizontal and vertical alignment elements to a given traffic speed. Although these elements are subject to the laws of mechanics, it turns out that in practice the distribution of speeds between vehicles and their varied characteristics sometimes it becomes necessary to ignore the theoretically calculated values. It was analyzed the coordination between the layout in longitudinal profile and the layout in plant, because it is important to notice the development of the layout without doubts due to perspective errors, breaks or discontinuities.

The main concern from a geometric point of view is to minimize the volume of embankments and excavations, trying to reconcile the longitudinal inclinations with the slope of the terrain by adjusting the layout to the existing contour lines, ensuring a good relation between the cost and the environment.

2.2 Longitudinal and transversal profiles

The vertical alignment is the result of a combination of vertical gradients agreement and a given slope. The choice of slope gradient and extension of vertical concordances is based on assumptions about the characteristics of the driver, vehicle and the roadway lane. Slopes facilitate longitudinal drainage while introducing forces that affect vehicle speed, driver comfort, and the ability to accelerate and decelerate.

In this project the longitudinal profile was designed to guarantee a better connection with the adjacent buildings, avoiding great differences that could create difficulties in the circulation of vehicles. This being the case, the pavement has a longitudinal slope equal to 0%, safeguarding transversal drainage.

3 EARTHWORKS

Topography is assumed to be known due to the fact that the external pavement project is a model to be executed in multiple locations. The results of this ñinvestigationò are used in the design works. e.g. to conceive the surface drainage and ground levels.

A topographic survey of the project area with the objective of perceiving the behavior of the terrain as well as the location of physical obstacles should be done in order to minimize the impacts in relation to the topography of the terrain.

Before any activity the removal of the topsoil layer and tree clearing before the excavation and backfilling work is needed.

3.1 Earthworks Quality Control

The Contractor shall base his initial program of the scope of works which conforms in quality and accuracy of detail to all the requirements of the specifications and drawings, and shall at his own expense, institute a quality control system and provide experienced engineers, foremen, surveyors, materials technicians and other technical stuff, together with all instruments and equipmentôs to conduct tests or have them conducted continually on a regular basis to check the properties of natural material encountered to ensure compliance with the specified requirements.

The intensity of control and tests to be conducted by the Contractor in terms of these obligations is not specified but shall be adequate to ensure that proper control is being exercised.

4 PAVEMENT DESIGN

4.1 Type of pavement

With respect to the pavement structure, it is important to mention the need to minimize construction costs. For this, it is essential to evaluate the possibility of using local soil as an alternative to the structural solution of road pavements.

In the preliminary analysis, several road pavement types have been evaluated.

Several types of pavement were considered:

Å Concrete Pavement;

Å Paving Block;

Å Asphalt.

From this comparison it was concluded that a concrete block pavement is preferred, for the following reasons:

1. Uncertainty about existing subgrade and fill materials (Possibility of differential settlements that require intervention at the level of the pavement layers);

2. Uncertainty of the future request of the pavement before the expansion of the project (frequency and type of loads) development of the area in the several locations that the project will be implemented;
3. Materials availability;
4. Experience of construction and maintenance compared to other solutions

The structural behavior of a road pavement during its useful life is dependent on the interaction between stiffness of several layers that compose it and the repetitive request of the traffic on its structure. Once known traffic, the rigidity of the pavement layers is dependent on the properties of materials used in its construction. To ensure that certain rigidity is satisfied, it is necessary to define the properties of the materials to be used.

For this purpose, samples must always be taken within the project implementation area, and they must be submitted to the Laboratory for characterization laboratory tests, for subsequent classification of local soils according to TRH 14, in conjunction with the manual "The structural Design of heavy duty pavements for ports and other industries, Edition 4 ".

i. **TRH14**

The TRH14 specifications classify the materials according to the table below: The TRH (TECHNICAL RECOMMENDATIONS FOR HIGHWAYS) specifications were made to mirror engineering practices, recommending selected aspects of road engineering. They are based on South African experience and research findings, with full support from the Committee of State Highway Authorities (CSRA).

The TRH14 specifications - Guidelines for Road Construction Materials, recommend standards for materials that can be considered during pavement design. Materials used in the structure of a pavement should be selected according to material availability criteria, economic factors and past experiences.

The TRH14 specifications classify materials according to the table below:

Code	Material		Section
AG	Asphalt surfacing - gap-graded	Surfacings and overlays	2.2
AC	Asphalt surfacing - continuously graded		2.2
AS	Asphalt surfacing - semi-gap-graded		2.2
AO	Asphalt surfacing - open-graded		2.2
S1	Surface treatment - single seal		2.1
S2	Surface treatment - multiple seal		2.1
S3	Sand seal		2.1
S4	Cape seal		2.1
S5	Slurry - fine grading		2.1.3
S6	Slurry - coarse grading		2.1.3
G1	Graded crushed stone	Layered material (untreated)	3.1
G2	Graded crushed stone		3.1
G3	Graded crushed stone		3.1
G4	Natural gravel		3.1
G5	Natural gravel		3.1
G6	Natural gravel		3.1
G7	Gravel-soil		3.1
G8	Gravel-soil		3.1
G9	Gravel-soil		3.1
G10	Gravel-soil		3.1
WM	Waterbound macadam		3.1
DR	Dumprock		3.1
C1	Cemented crushed stone or gravel	Layered material (treated)	3.2
C2	Cemented crushed stone or gravel		3.2
C3	Cemented natural gravel		3.2
C4	Cemented natural gravel		3.2
BC	Bitumen hot-mix, continuously graded		3.2
BS	Bitumen hot-mix, semi-gap-graded		3.2
TC	Tar hot-mix, continuously graded		3.2
TS	Tar hot-mix, semi-gap-graded		3.2
BT1	Bituminous treated crushed stone		3.2
BT2	Bituminous treated natural gravel		3.2
BT3	Bituminous treated cohesionless sand		3.2
PM	Penetration macadam		3.3
PCC	Portland cement concrete	Concrete paving layer	4
GWC	Gravel wearing course	Gravel wearing course	5

Table 1 - Material Classifications (TRH14)

ii. THE STRUCTURAL DESIGN OF HEAVY DUTY PAVEMENTS FOR PORTS AND OTHER INDUSTRIES, EDITION 4

This Manual was commissioned and published by Interpave. The aim of the port pavement design process is to safeguard the pavement from failure over a predetermined period of time or number of cargo movements. There are four categories of failure associated with port pavements:

- Environmental failure
- Structural failure
- Surface failure
- Operational failure.

Each of these categories may influence failure in one of the other three, so a complete pavement design must address all of the issues which might lead on a particular project to one or more of these categories of failure.

This Manual is concerned specifically with the structural design of pavements serving ports and other industries.

Ignoring one or more component of the whole design process can lead to progressive reduction in pavement serviceability and performance so that ultimately one or more of the four categories of failure will occur.

4.2 Structural Design

The pavement design is based on the design manual îHeavy Duty Pavements ï the structural design of heavy duty pavements for ports and other industriesò edition 4 issued by Interpave.

All structures are designed such that all safety requirements imposed by the relevant codes and standards are met at the end of the design life, taking into account normal maintenance and only minor repair work (no replacements).

The design procedure set out in the Fourth Edition is based upon the principle that pavements are designed to remain serviceable throughout the design life of the pavement. A pavement design procedure includes pavement foundation which relates sub-base and capping specification to subgrade strength such that the subgrade is always stressed to a level commensurate with its strength. The thickness of the capping layer increases as to deal with the heavier loads applied on heavy duty pavements. Usually when the foundation layer of road / pavement does not present soils with good quality it is chosen to replace them with better soils as road bed layer.

For pavement design, the CBR (California Bearing Ratio) is important. For the design of the pavement foundation, it is assumed that the existing pavement will be completely removed and that the sub-grade at pavement formation level will have a minimum CBR of 5%.

4.2.1 Design lifetime

The structure is designed such that all safety requirements imposed by the relevant codes and standards are met at the end of the design life, taking into account normal maintenance and only minor repair work (no replacements).

Taking into account the road / pavement category, it was considered a structural design period of **25 years**.

4.2.2 Truck

a) Truck axle loads

The maximum permitted weight of a road truck- chassis combination is 500kN (50 Tons). The spread of this load of the truck and chassis axles and wheels is shown in the **Error! Reference source not found.**:

	Truck (axle distance >1,3 m)		Chassis (axle distance>1,3 - <1,8m)		
Axle	1st	2nd	3rd	4th	5th
500 kN Truck					
Total axle load [kN]	70	110	110	110	110
Wheel load [kN]	35	27.5	27.5	27.5	27.5

Table 2 - Loads – 50 Tons road truck

According to the Client, ñsometimes trucks are heavily overloaded so the maximum occurring loads are higher, up to 1 x 40ò container at nearly 30 Tons + truck weight. Therefore the maximum truck load is set at 80 Tons to be ´safe´ò

To consider this situation and taking into account the load distribution of a standard 50 Tons truck, the maximum load of an 80 Tons truck is given in the following table:

	Truck (axle distance >1,3 m)		Chassis (axle distance>1,3 - <1,8m)		
Axle	1st	2nd	3rd	4th	5th
800 kN Truck					
Total axle load [kN]	110	173	173	173	173
Wheel load [kN]	55	43.25	43.25	43.25	43.25

Table 3 - Loads – 80 Tons road truck

As it is difficult to maintain prohibited areas for trucks, it is assumed they will operate anywhere within the project area.

b) Wheel proximity factor

The wheel proximity factor depends on the effective depth, which varies with CBR value.

$$\text{Effective Depth} = 300 \cdot \sqrt[3]{\frac{35,000}{CBR \cdot 10}}$$

Where: **CBR**=California Bearing Ratio of the subgrade

Effective Depth = 300 * 3 ã(35000 / 5 * 10) = **2664 mm**

Wheel spacing = 300mm

Wheel Spacing (mm)	Proximity factor for effective depth to base of:		
	1000mm	2000mm	3000mm
300	1.82	1.95	1.98
600	1.47	1.82	1.91
900	1.19	1.65	1.82
1200	1.02	1.47	1.71
1800	1.00	1.19	1.47
2400	1.00	1.02	1.27
3600	1.00	1.00	1.02
4800	1.00	1.00	1.00

Table 4 – Proximity factor (Interpave Design Guideline)

Through a linear interpolation based on the values in table 4., we have a Total Proximity factor = 1+0.97=**1,97**

Trucks wheel loads

Each front wheel: 55 kN

Each rear wheel: 43,25 kN

Trailer Wheel : 43,25 kN

The rear loads are governing due the wheel proximity, so:

Static effective wheel load = 1.97 x 43,25 = 85,20 KN

c) Dynamic loading factor

The effects of dynamic loading induced by cornering, accelerating, braking and surface unevenness are taken into account by the factor **fd**.

An uneven surface can result in the wheel load always increasing at a particular point, so an increase should be applied to all wheel loads. Cornering will result in all the wheel loads on the outside of the corner increasing, so again an increase should be applied to all wheel loads.

The overall dynamic factors taken into account in the design consequently vary between road type (corner or straight) and type of equipment. (See Table 5 below).

Condition	Fd max	Fd design
Braking	30%	10%
Cornering	40%	30%
Acceleration	10%	10%
Uneven surface	20%	20%

Table 5 - Dynamic factors factor (Interpave Design Guideline)

The pavement design is based on the combination of dynamic factors.

A dynamic factor of 50% has been taken for cornering (30%) + uneven surface (20%) for Tractor+Trailers passing over a particular area of pavement.

For both braking and accelerating, the effect is +/-, i.e. the total load does not change.

The Single Equivalent Wheel Load (SEWL) = 1,5 x 85,20 = 127,80 kN ~**130 kN**

d) Number of truck passages

The roads will mainly be used by trucks. The truck intensity is unknown, but roads will be ĩheavilyò used. It is difficult to make an accurate assumption regarding the number of passages over this life time. The following is assumed regarding the number of truck passes:

For the area:

- 1 loaded truck a day at most heavily loaded.
- The area will have very limited movements.
- At this location the area is projected as heavy duty pavement.
- There is an expansion plan for the area and considering the uncertain in the development, it seems wise to be on the safe side.
- Design number of the loaded trucks at one day is approximately 1.

Total number of passages:

- 1 per day in the 25 years: = 1 * 365 * 25 = **9,125 passages**

4.2.3 Pavement layers

a) Base thickness

The Design Chart shows that 200 mm thickness of C8/10 CBGM is required for the pavement base, based on dynamic loading.

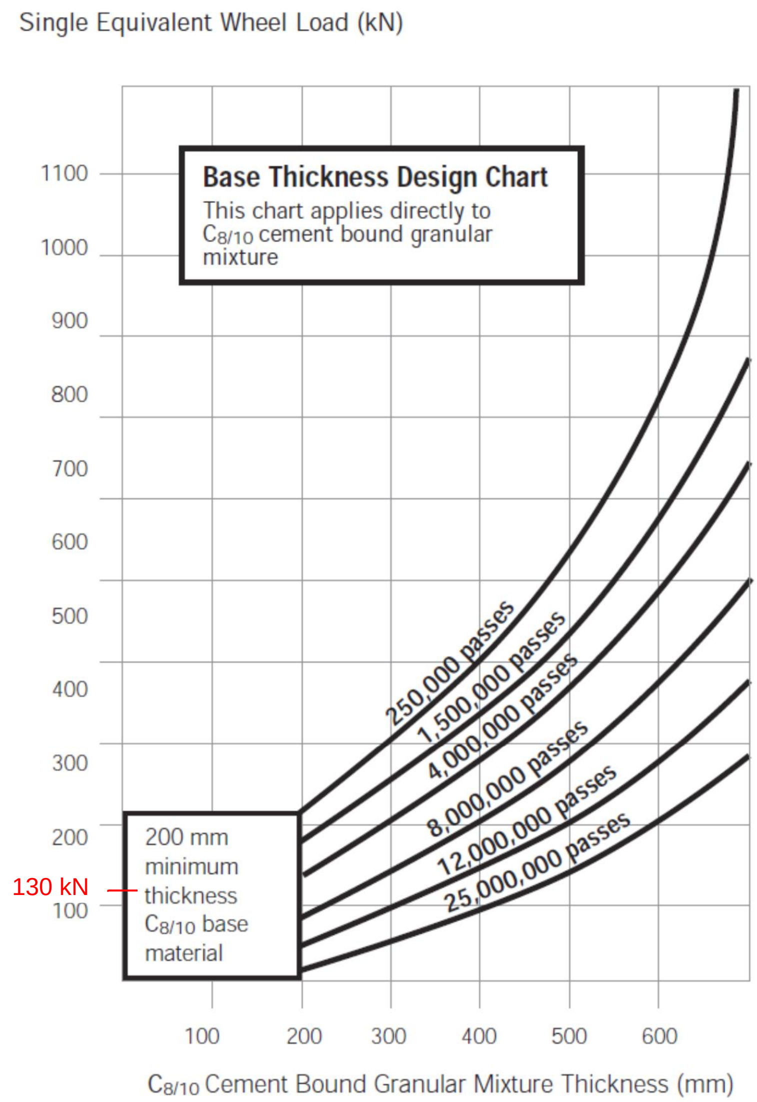

Figure 1- Base The Design Chart (Interpave Design Guideline)

The use of Material Equivalence Factor (MEFs) by heavy duty pavement designs indicates that within a limited range, they can prove to be and efficient means of expanding one design solution into many alternatives, each of similar structural capability. The proposed material is suitable for the purpose, taking into account its proposed function and position within the project.

The thicknesses derived from the Design Charts have been multiplied by the factors in the table below to obtain thicknesses for materials other than C8/10.

Material Grouping	Preferred Pavement Base Construction Material	Material Equivalence Factor (MEF)
Traditional Cement Bound Materials	*CBM1 (4.5N/mm² minimum 7-days compressive cube strength)*	*1.60*
	CBM2 (7.0N/mm² minimum 7-days compressive cube strength)	*1.20*
	CBM3 (10.0N/mm² minimum 7-days compressive cube strength)	**1.00**
	CBM4 (15.0N/mm² minimum 7-days compressive cube strength)	0.80
	CBM5 (20.0N/mm² minimum 7-days compressive cube strength)	0.70
	No-fines Lean Concrete for Permeable Paving	1.00
Bitumen Bound Materials	HDM as defined by SHW DBM as defined by SHW *HRA as defined by SHW*	0.82 1.00 *1.25*
Unbound Materials	Crushed rock sub-base material of CBR ≥ 80%	3.00
Concrete Block Paving	Concrete Block Paving as a surfacing (80mm blocks and 30mm laying course)	1.00

Table 6 - Material Equivalence Factor (Interpave Design Guideline)

Pavement Base - Option 1

C1 (TRH14) = CBM2 = C8/10 x 1.2 = 200x1.2 = 240mm

Pavement Base – Option 2

G4 (TRH14) = Unbound material (CBR>=80%) = C8/10 x 3.0 = 200x3.0 = 600mm

b) Sub-Base and Capping layer thickness

Weak ground is the most common cause of heavy duty pavement distress and a rigorous site investigation should always be undertaken under the supervision of a geotechnical engineer familiar with the specific site investigation requirements for a heavy duty pavement. Sufficient intrusive investigation must be undertaken to establish variations of soil properties with depth and location. A site investigation undertaken near to the development site should be used only as a guide to the design of a thorough site investigation of the site to be developed. Special care should be taken in the case of weak soils underlying competent ones.

The table below for unbound sub-base and capping thicknesses for various subgrade CBR values must be followed rigorously:

CBR of Subgrade	Capping Thickness (mm)	Sub-base Thickness (mm)
1%	900	150
2%	600	150
3%	400	150
4%	250	150
5% and greater	Not required	150

Table 7 - . Unbound sub-base and capping thickness for various subgrade CBR values (Interpave Design Guideline)

Sub-base thickness = **150mm ; CBR≥ 10% → G8 (TRH14)**

4.2.4 Pavement structure

A typical cross section of the Concrete Block Pavement design is determined (see Table 8) but a second option has been given in table 9.

Minimum Layer Thickness	Construction
80mm	Concrete block paving
30mm	Layer course sand (Bedding sand)
240mm	Cemented Stabilization - C1
150mm	Unbound Sub-base (CBR>=10%) ï G8
N/A (See table 7)	Sub-grade CBR not less than 5%

Table 8 - Option 1 Pavement Design

Minimum Layer Thickness	Construction
80mm	Concrete block paving
30mm	Layer course sand (Bedding sand)
600mm	Unbound Material ï G4
150mm	Unbound Sub-base (CBR>=10%) ï G8
N/A (See table 7)	Sub-grade CBR not less than 5%

Table 9 - Option 2 Pavement Design

a) Subgrade (Selected soil)

The roadbed/subgrade material shall comply with the specified in the Table 7. Unbound sub-base and capping thickness for various subgrade CBR values specified in the manual ñHeavy Duty Pavements ï the structural design of heavy duty pavements for ports and other industriesò edition 4 issued by Interpaveą for CBR > 5% for the level of service require. This material should be used for the platform of the project with variable thickness depending on the CBR of the material found and compacted at 93% -95% density Mod. AASHTO.

b) Sub–Base (Selected soil)

150mm thickness of Selected Soil - G8 according to the specifications "TRH14 - Guidelines for Road Construction Materials", with a minimum CBR >= 10% @ 93% CBR AASHTO; IP <12; compacted to 95% - 98% Mod AASHTO density.

c) Base C1 (Stabilization)

240mm G6 or G7 Class selected soil according to the "TRH14 - Guidelines for Road Construction Materials" specifications, stabilized with Portland cement and compacted at 98% density Mod. AASHTO, to achieve unconfined compressive strength at 7 days between 6 and 11 MPa @ 100% Mod AASHTO density, to obtain a Class C1 material in accordance with the "TRH14 - Guidelines for Road Construction Materials" specifications.

d) Surface

The road surface layer shall be made of pavement blocks of class S-A, type ZIG-ZAG, with a thickness of 80 mm with a tensile strength exceeding 25 Mpa along the lanes and parking areas according to Annex **I**.

The paving block will be accommodated in a layer of course sand (bedding sand) of about 30mm thickness and the joints filled with fine sand and its horizontal locking will be done with concrete beams and prefabricated kerbs of type Fig. 7 According to Annex **II**.

5 ROAD SIGNALING

Taking into account the safety and comfort of traffic, road signs have been designed in order to be uniform, homogeneous, simple and consistent.

It is planned in the horizontal and vertical signaling project to be in accordance with the Southern African Development Community (SADC) standards of which Mozambique is a subscriber and the Road and Traffic Code regulation approved by Decree Law No. 1/2011 of 23 Of March and Decree 51/2009 of 29 September.

5.1 Horizontal Signaling

The road markings have been designed with the main function of ensuring the correct channeling of the traffic, guiding the driver on the boundaries of the lanes, the following directions, speed variations to be performed as well as the need for stoppages or crossover.

The technical parameters such as dimensions, colors, implantation, nomenclature, etc., have been designed according to the standards in force in Mozambique, SADC-Road Traffic Signs Manual. Horizontal signaling shall be applied with materials specified in SADC standards to ensure their visibility quality especially in adverse conditions in both night and wet conditions.

5.2 Vertical Signaling

The vertical signaling is designed in harmony with the horizontal signaling and will be placed along the perimeter in a clear, simple and objective way to guide the driver on the approach of an intersection, direction indication and indication of stop obligation and assignment of priorities. Technical parameters such as dimensions, colors, deployment, nomenclature, etc. Were designed in accordance with the regulations in force in Mozambique, SADC-Road Traffic Signs Manual. The vertical signs must be on anti-corrosive plates and must be produced with retro-reflective screens in order to optimize their visibility in night-time environments, promoting their perception in low light conditions. This project contemplates the vertical signaling according to the table below.

Maputo, November 24th de 2017

(Bruno Aleluia, Eng.º)

6 ANNEX

6.1 Annex 1 – Catalogs

6.2 Annex 2 – Technical Specifications