ANNEXURE 3

ENGINEERING UNIT
ROADS PROVISION DEPARTMENT
EXECUTIVE BRANCH

OFFICE MEMORANDUM

TO : 1. D/H:Development Engineering

FROM : E.P. Lathleiff
(Sen. Man. : P&GE)

OUR REF. : -

EXT. NO. : 17326

DATE : 2014-07-30

INTERIM SERVICE PROVISION FOR HOUSING
MINIMUM INTERIM DESIGN STANDARDS FOR ROAD LAYER-WORKS

(Revision #0 : 2014-07-30)

Overview

This document defines the minimum design standards for the provision of road layer-works under the Interim Service Provision initiative for Housing. The design standards are therefore viewed as a short term measure to provide surfaced access in areas identified under the Interim Service Provision programme. The risk of failure is consequentially higher than is the norm for standard pavement design applications.

Category of Road (PMS)				
A	B	C	D	Interim Services
Approximate Associated Risk[1,2] (% Failed length at end of design life)				
5%	10%	20%	20%	50%

Table 1. Typical Risk Profiles

Network Management Issues

Roads constructed under Interim Service Provision will be captured on the Roads Provision Department's Pavement Management System (eRoads) as "surfaced" roads and will be flagged as "Interim Service" roads (Category "F"). It is noted however that dedicated funding for rehabilitation of these roads will **not** be available in the event that final road alignment and re-construction does not take place. Rehabilitation of Interim Service roads will therefore be funded through the standard budget process for road rehabilitation as dictated by the strategic network needs generated by the eRoads system. Rehabilitation of these Interim Service roads will however be designed on the same basis as the original upgrade as defined in this document.

Design Methodology

The primary objective of the design approach is to reduce costs through the judicious use of in-situ materials. It is thus envisioned that the existing "gravel" surfacing will be used wherever appropriate as the base or sub-base of the surfaced road. To this end, a "field" type design approach has been adopted using the 8kg DCP as the primary design tool. This is a significant departure from the standard "prescriptive" material catalogue approach (TRH 4[1]) and therefore permits the judicious use of materials that would otherwise be considered "unsuitable".

Drainage

Effective control of both surface and sub-soil drainage is **essential** to the performance of road pavement structures utilising relatively moisture sensitive and/or marginal in-situ materials. This document does not provide detailed guidance on the matter, but recognises and emphases the crucial importance that drainage design plays in the performance of the road structure. Guidance on the evaluation of existing drainage infrastructure and the need for new infrastructure can be found in the Malawian Design Manual for Low Volume Sealed Roads[3]. Guidance on detailed hydraulic design can be found in SANRAL's Drainage Manual[5].

Design Parameters

Road Category

The Road Category for Interim Service roads will be defined uniquely as **Category "F"** roads, the characterisation of which is as outlined in this document. These roads will therefore NOT be defined according to the standard categorisation for the surfaced network (i.e. categories "A" through "E").

Design Life

The Structural Design Life for roads constructed under the Interim Services initiative shall be **10 years**.

Traffic loading

Traffic loading shall be categorised in accordance with Table 2. The minimum Traffic Class used for Interim Service roads shall be LE 0.01. Evaluation of the Traffic Class should be detailed in the Pavement Design Report.

Traffic Class	Cumulative E80's ($x10^6$)
LE 0.01	0.003 - 0.01
LE 0.03	0.01 - 0.03
LE 0.1	0.03 - 0.1
LE 0.3	0.1 - 0.3
LE 0.7	0.3 - 0.7
LE 1.0	0.7 - 1.0

Table 2. Design Traffic Classes

A simple evaluation of the Traffic Class may be conducted as follows :-

1. Estimate the daily number of heavy vehicles using the road in **each** direction (A,B).
   This should reflect the daily traffic at the time of opening to traffic after construction.

2. Estimate the heavy vehicle growth rate (*i*).

   Unless otherwise proven, this should be taken as 3%.
3. Estimate the number of equivalent E80 axle loads per heavy vehicle (C).

   Unless otherwise proven, this should be taken as 1.0 E80's/heavy vehicle.
4. Calculate the cumulative growth factor (f) using the following formula :-

   $f = 365.(1+0.01i)\{[(1+0.01i)^y - 1]/0.01i\}$

   where f = cumulative growth factor

   i = heavy vehicle growth rate

   y = structural design period (years)
5. Determine the lane width adjustment factor from the Table 3.
6. Calculate the cumulative E80 traffic (CESA) using the following formula :-

   CESA = (A+B).C.f.L

   where A, B, C, f, L and *i* are as defined above.

   Note that the evaluation of the Traffic Class is based on traffic carried in **both** directions. This is a function of the narrow width of these roads.

Surfaced Road Width (m)	Lane Width Adjustment Factor (L)
< 3.5	2
3.5 to 4.5	1
4.5 to 6.0	0.8
> 6.0	N/A

Table 3. Lane Width Traffic Loading Adjustment Factor

7. Determine the Traffic Class from Table 2.

A more detailed analysis of the traffic loading can be undertaken when warranted using the method outlined in the Malawian Design Manual for Low Volume Sealed Roads[3].

Pavement Structural Design

The pavement layer-work design shall be based on a DCP assessment of the existing pavement strength using a standard 8kg DCP[4]. The required pavement layer-strength profile for any particular Traffic Class is derived from the DCP Design Catalogue in Table 4. Alternatively, this can be visualised in the Layer Strength Diagram of Figure 1.

Where strengthening of the existing structure is required through the importation of additional base or sub-base material, or modification of existing materials, the bearing capacity of the imported / modified material is assessed through a laboratory evaluated weighted average DCP DN test process. The process is described in the section on Material Selection. The laboratory evaluated weighted average DN value for imported material **tested at the Optimum Moisture Content (OMC)** should be lower that the DN design values in Table 4.

Depth (mm)	Basic Compaction Requirement	Traffic Class					
		LE 0.01	LE 0.03	LE 0.1	LE 0.3	LE 0.7	LE 1.0
		Maximum DN Values - 8kg DCP (mm/blow)					
0 - 150	≥ 98% Max. Dry Density	8.0	5.9	4.0	3.2	2.6	2.5
150 - 300	≥ 95% Max. Dry Density	19.0	14.0	9.0	6.0	4.6	4.0
300 - 450	≥ 95% Max. Dry Density	33.0	25.0	19.0	12.0	8.0	6.0
450 - 600	In-situ material	40.0	33.0	25.0	19.0	14.0	13.0
600 - 800	In-situ material	50.0	40.0	39.0	25.0	24.0	23.0
DN 800 (min.)		39	52	73	100	128	143

Table 4. DCP Design Catalogue

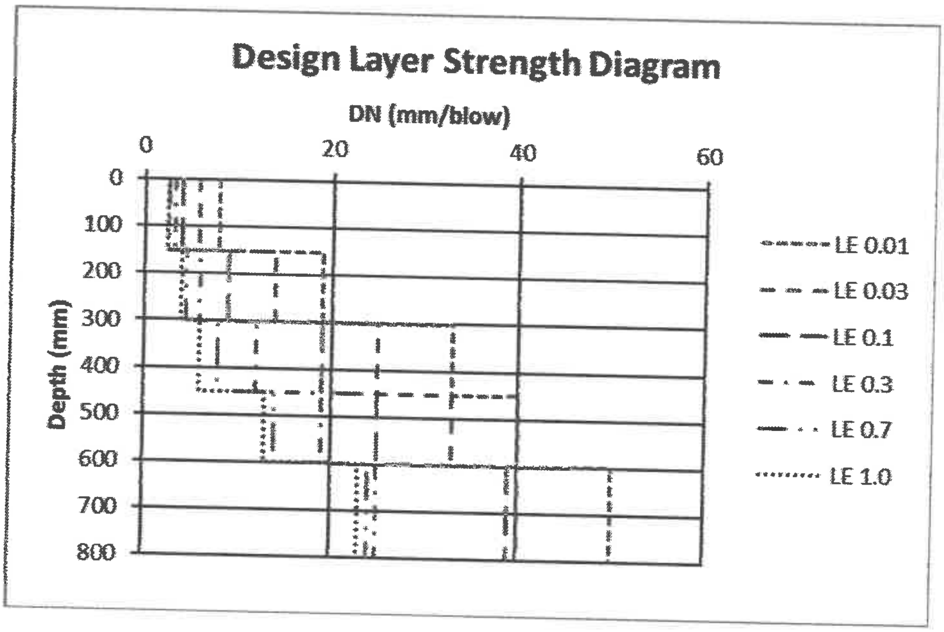

Figure 1. DCP Design Layer Strength Diagram

Site Investigation

Every road shall be assessed through a DCP survey. The minimum frequency of testing shall be 1 DCP test for every 100m length of road with a minimum of 10 DCP tests in total per road. A higher frequency should be implemented in areas exhibiting poor drainage conditions in order to define the extent of such areas better. Each DCP test shall be carried down to a depth of at least 800mm unless refusal is reached before this. Longer roads should be broken up into uniform sections using the CUSUM analysis method for each 150mm horizon and the DSN_{800} value.

It is essential that the moisture conditions experienced at the time of DCP testing are recorded. Essentially this is a simple record of how the moisture regime at the time of testing is likely to compare to the long term in-service moisture regime for the road. This enables the moisture regime to be taken account of in the structural design of the pavement through appropriate use of DN percentile values obtained through the DCP assessment of the road (Table 5).

DCP Assessment Percentiles		
Site Moisture Condition During DCP Survey	Moisture Susceptibility of Material	
	Low Moisture Susceptibility	High Moisture Susceptibility
	$DN_{omc}/DN_s \leq 25\%$	$DN_{omc}/DN_s > 25\%$
Wetter than expected in service	20	35
Same as in service moisture	50	65
Drier than in service moisture	80	85

Table 5. DCP Assessment Percentiles for Moisture

The moisture sensitivity of **imported base and sub-base materials** should also be taken into consideration when determining the DN percentile value to be used in the DCP analysis. Imported material used within the **base layer** should however exhibit a **low** moisture susceptibility. The moisture sensitivity of a material is assessed through determining the ratio of the weighted average DN at OMC (DN_{omc}) to the weighted average DN after saturation (DN_s).

Material Selection

Selection of imported layer-work materials is based on a Lab weighted average DCP DN evaluation rather than a conventional material characterisation catalogue (e.g. TRH14).

Laboratory Process for evaluating the Lab DN profile.

1. Conduct a Maximum Dry Density (MDD)/Optimum Moisture Content (OMC) test in accordance with SANS 3001-GR30.
2. Prepare 2 sets of 3 mould samples as follows :-
    a. Compact a set of 3 moulds at OMC to produce a range of densities between 93% and 100% MDD in each set in the manner described in SANS 3001-GR40. Measure the density attained for each mould sample (Set 1).
    b. Repeat the process to produce a second set of 3 moulds (Set 2).
3. Soak Set 1 in a water bath for 4 days as described in SANS 3001-GR40. The surcharge weight should be applied to each mould although it is **NOT** necessary to measure the swell.
4. Seal the remaining set (Set 2) in airtight plastic bags/containers for 4 days.
5. At the end of the "curing" period, remove the 6 moulds in preparation for testing with a DCP. The standard CBR annular surcharge weight should be placed on the mould to be tested. The DCP should then be positioned within the opening in the annular weight at the centre of the mould sample and set up as for a standard DCP test. The penetration in mm should be read after every "n" blows. Note that "n" may vary within a test on a mould and should be gauged by the tester but should be approximately the number of blows to achieve 20mm penetration. "n" is likely to be 5 or more for the moulds compacted at OMC. However, "n" may be as low as 1 or 2 for the saturated moulds. Either way, care should be taken that the DCP does not penetrate through to the base plate (<127mm) to prevent damage to the DCP penetration cone.
6. A weighted average DN value is then calculated as follows :-
   For each mould;
    a. Record the initial DCP depth reading. Record the DCP depth reading at the end of each set of blows. Record the number of blows within each set of blows.
    b. Calculate the depth of penetration (DN) for each set of blows.

c. Calculate the average DN/blow for each set of blows.

d. Calculate the weighted average DN value from the following formula :-

$$DN = \frac{\sum(\text{Avg.DN per blow x DN per "n" blows})}{\sum \text{DN per "n" blows}}$$

7. Plot the weighted average DN value against the % compaction for each of the "Soaked"(Set 1), "OMC" (Set 2) sets. The characteristic weighted average DN value for imported material should be evaluated at the following compactive efforts for either the base or sub-base layer :-
   - Base layer (0mm – 150mm) 98% MDD
   - Sub-base layer (150mm – 300mm) 95% MDD
8. Calculate the moisture sensitivity of the material at each compactive effort as follows :-

$$\text{Moisture Sensitivity (\%)} = \frac{DN_{omc}}{DN_s} \times 100$$

The calculation of the weighted average DN value and the material moisture sensitivity is illustrated in Table 6.

Soaked				
No. of Blows Per Set of Blows (n)	DCP Reading (mm)	DN per "n" Blows (A)	Avg. DN/blow (B)	A x B
0	130			
1	150	20	20.0	400.0
1	167	17	17.0	289.0
1	180	13	13.0	169.0
1	190	10	10.0	100.0
1	215	25	25.0	625.0
	Sum	85	Sum	1583.0
			Weighted Average DN	18.6

OMC				
No. of Blows Per Set of Blows (n)	DCP Reading (mm)	DN per "n" Blows (A)	Avg. DN/blow (B)	A x B
0	129			
5	137	8	1.6	12.8
8	158	21	2.6	55.1
8	176	18	2.3	40.5
8	192	16	2.0	32.0
5	204	12	2.4	28.8
4	213	9	2.3	20.3
4	221	8	2.0	16.0
	Sum	92	Sum	205.5
			Weighted Average DN	2.2

$$\text{Moisture Sensitivity (\%)} = \frac{2.2 \times 100}{18.6} = 12.0$$

Table 6. Typical Calculation of Weighted Average DN and Moisture Sensitivity

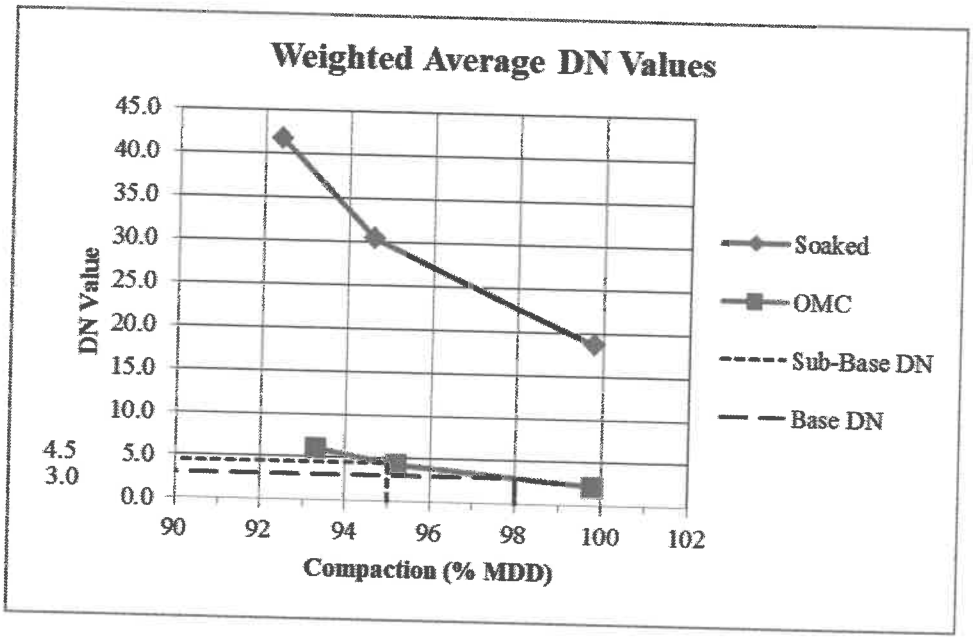

Figure 2. Typical Evaluation of Weighted Average DN Values for Base or Sub-Base Materials

Construction Quality Assessment

The optimal compaction to give the best possible performance of the existing surface layer-works and any imported layer-works is to "Refusal" density. The compaction should typically exceed the minimum basic compaction values found in the DCP DN Design Catalogue (Table 4). However, rather than monitoring the strength of the layer-works indirectly through density measurement methods, control of the layer-work strength should be monitored using the DCP in a direct comparison with the design layer strength profile.

The following criteria should be applied.

- DCP testing should be conducted within 24hours of completion of a particular layer.
- A minimum of 10 DCP tests should be conducted in any section under review.
- The 80th percentile of the DCP DN values for the layer under review should be less than the required Weighted Average DN value obtained in the laboratory for that material.
- The 90th percentile of the DCP DN values for the layer under review should be less than the design DN value for the associated Design Traffic Class (Table 4).
- After compaction of the final layer prior to surfacing, the DCP test should be conducted to the full 800mm depth and the full depth layer strengths obtained for compared with the design layer strength diagram as per the initial site investigation DCP survey.

DCP holes should be filled with a fine, cohesionless sand before covering with a subsequent layer or surfacing.

Surfacings

The prime technical function of a surfacing is to prevent the ingress of water into the base layer. This function takes on greater significance if the quality of material used for the base is "marginal" and more sensitive to the ingress of moisture than standard TRH 4 type base materials (e.g. G2, G4). The surfacing thus plays an integral role together with the drainage design in minimising the moisture ingress into the pavement layer-works. Ideally, the moisture content under the outer wheel path in the road should not rise above the Optimum Moisture Content of the base material.

The appropriate choice of surfacing type is left to the discretion of the designer. However, constraints based on the capacity of the Municipality to undertake planned treatments must be taken into consideration. The requirement for re-sealing of a bituminous surfaced road within a 5 year period after new construction is **NOT** acceptable. Single seal type applications are therefore **NOT** acceptable. Similarly, a phased approach to a double seal type application is therefore **NOT** acceptable.

The construction of surfacings on steep gradients (>8%) can be problematic. Guidance in this regard can be found in TRH 3[13]. In the event that steep gradients limit the use of surfacing types to those such as concrete or block paving, a conventional approach to the design of these portions of the road should be adopted using appropriate design codes.

The designer is referred to SABITA Manual 10[8] and TRH 3[13] for a more detailed description of the appropriate surfacing options available.

Road Widening

In instances where it is evident that widening of the road is necessary, the same design approach should be adopted. However, there should be a specific focus on identifying and establishing the extent of the widening. Specific DCP testing should be conducted in this area (minimum of 4 tests) to determine the extent of additional layer-works required in the widening. These additional layer-works should be constructed to bring the widening up to the same strength standard as the adjacent road so that final sub-base and/or base layer-works (as required) and surfacings can be constructed across the full width of the widened road.

Design Process Summary

The design process can be summarised as follows :-

1. Assess storm-water run-off and sub-grade moisture conditions and upgrade as appropriate.
2. The structural design period is 10 years.
3. Determine the design traffic loading.
4. Determine the LE traffic class (Table 2) (Min. LE0.01).
5. Determine required layer strength profile (Table 4).
6. Conduct DCP survey (including prior location of services).
7. Determine uniform sections.
8. Adjust DCP DN values for design moisture conditions.
9. Determine in situ layer-strength profile (for each uniform section) (Figure 1).
10. Compare in-situ and required layer strength profiles.
11. Identify sections requiring imported layer-works.
12. Identify place suitable imported materials.
13. Shape and surface the road.
14. Compile Materials "As-Built".
15. Hand-over road.

Cost Analysis

A cost analysis of alternative pavement design options is not required. However, a life cycle analysis of material and surfacing alternatives is required to highlight the most cost effective options. Details of these options should be included in the Pavement Design Report.

Safety

In any construction activity, safety is of primary importance. There are three areas in this design approach that require emphasis.

1. The end safety of the road user is of primary importance. This document however does not address issues of safety related to geometric design and road safety furniture although these will need to be taken into consideration for every project undertaken.
2. The DCP is a mechanical test apparatus that can (and has) caused serious injury to hands and fingers. The DCP should be checked on a daily basis to ensure the proper functioning of the device. Staff undertaking DCP testing should also be trained in the safe use of the device.
3. The presence of numerous under-ground infrastructure services within the urban environment can be extremely hazardous to users of a DCP (e.g. electrical cables) and also to the continued proper functioning of those services if hit by a DCP probe (e.g. water, fibre optic cables, etc.). The location of such services should be verified prior to undertaking a DCP survey along any length of road.

Documentation

Pavement Design Report

A pavement design report is required for every road considered under the Interim Service Provision programme. The following detail should be included in the report.

- Road category
- Design life
- Design traffic class (LE)
- Design layer strength profile
- Life cycle cost analysis
- Maximum road gradients

Materials As Built

A Materials "As Built" Report will be required for every road constructed and will consist of a simple summary of the work conducted inclusive of :-

- The Pavement Design Report
- The DCP site investigation survey and percentile values utilised
- A summary of the Weighted Average DCP DN values for materials tested in the laboratory
- The layer-work DCP DN values in comparison with the required Weighted Average DN value obtained in the laboratory, and the design DN value for the associated Design Traffic Class (80^{th} and 90^{th} percentile values respectively) for the existing surfacing and every imported layer
- The final layer strength evaluation from the DCP testing conducted on the completed layer-works
- Standard eThekwini "As Built" requirements for surfacings and ancillary works

Road Hand-Over

Roads will be handed over in accordance with the latest hand-over policy of the eThekwini Municipality, Roads Provision Department[12].

References

1. Structural Design of Flexible Pavements for Interurban and Rural Roads, TRH 4:1996
2. Flexible Pavement Rehabilitation Investigation and Design, Draft TRH 12:1997
3. Design Manual for Low Volume Sealed Roads, January 2013, Ministry of Transport and Public Works, Republic of Malawi
4. Measurement of the In Situ Strength of Soils by the Dynamic Cone Penetrometer (DCP), Draft TMH 6:1984 Method ST6
5. Drainage Manual, 6th Edition, September 2013, SANRAL
6. Determination of the maximum dry density and optimum moisture content, SANS 3001-GR30
7. Determination of the California Bearing Ratio, SANS 3001-GR40
8. Appropriate Standards for Bituminous Surfacings, SABITA Manual 10, 1992
9. Optimum Design of Sustainable Sealed Low Volume Roads Using the Dynamic Cone Penetrometer (DCP), P. Paige-Green, M.I. Pinard, 25th ARRB Conference, Perth, Australia, 2012
10. Applying the Dynamic Cone Penetrometer (DCP) Design Method to Low Volume Roads, P. Paige-Green, Proceedings of the 15th African Regional Conference on Soil Mechanics and Geotechnical Engineering, 2011
11. The Use and Interpretation of the Dynamic Cone Penetrometer (DCP) Test, P. Paige-Green, L. Du Plessis, CSIR, 2009
12. Policy for the Handover of Surfaced Road and Related Structural Infrastructure, Roads Provision Department, eThekwini Municipality, Rev.#7 2013
13. Design and Construction of Surfacing Seals, TRH 3:2007.

30/7/14

Dave Thomas
Deputy Head : Roads Provision

If density testing is to be conducted, then we should test against 93% MTRD (rather than Marshall). However, the asphalt layer will be very thin and it will be difficult to measure the compaction with a nuclear gauge – and I am not happy with coring all over these roads. I would suggest a visual approach to acceptance of the surfacing rather than trying to conduct density tests. More emphasis should be placed on construction practice and ensuring that the asphalt is still hot (> 100°C) before compacting and an adequate roller is being used. It may be possible to check this with a camera and a thermometer by taking photographs of the thermometer within the spread mix immediately before rolling. If this is achieved then the asphalt should behave in a satisfactory manner. Another possibility may be the use of a Warm Mix additive to extend the compaction window – but this adds an extra cost.

Regards,

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083 488 5552

Following our discussion, I have revised the approach to the design of the interim services roads as follows :-

1. The design traffic loading shall be LE0.01. However, should it be apparent that the heavy vehicle loading is greater than 1 heavy per day, this should be brought to the attention of the Development Engineering Department.
2. Undercutting and removal of poor quality material shall only be undertaken if the overall DCP design indicates as such, or if wet conditions at the time of construction make compaction of the layer impossible. The maximum depth of undercut of the insitu material shall be 300mm unless specifically motivated otherwise.
3. All imported material shall be of G5 quality (TRH14:1985). Compaction of the imported G5 material (at any depth within the pavement structure) shall be to 95% Mod.AASHTO.
4. The asphalt used shall be the eThekwini 10.0mm Continuously Graded Asphalt Mix (Mix "A") but designed using the Marshall method using 75 + 15 hammer blows. The target design air voids shall be 3.0%.
5. It is recognised that the responsibility for the design rests with the eThekwini Municipality. It is however incumbent upon the Consultant to ensure that both the proposed and constructed (as built) layerworks meet the DCP layer strength diagram for LE0.01 traffic as reflected in the "Pavement Design Report" and the "Materials As Built Report". As long as these two requirements are met, the Consultant cannot be held responsible for the performance of the pavement.

Regards,

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