Snettisham Caravan Park Access Road Pavement Investigation

FWD and GPR Report

For Norfolk County Council

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1 Introduction

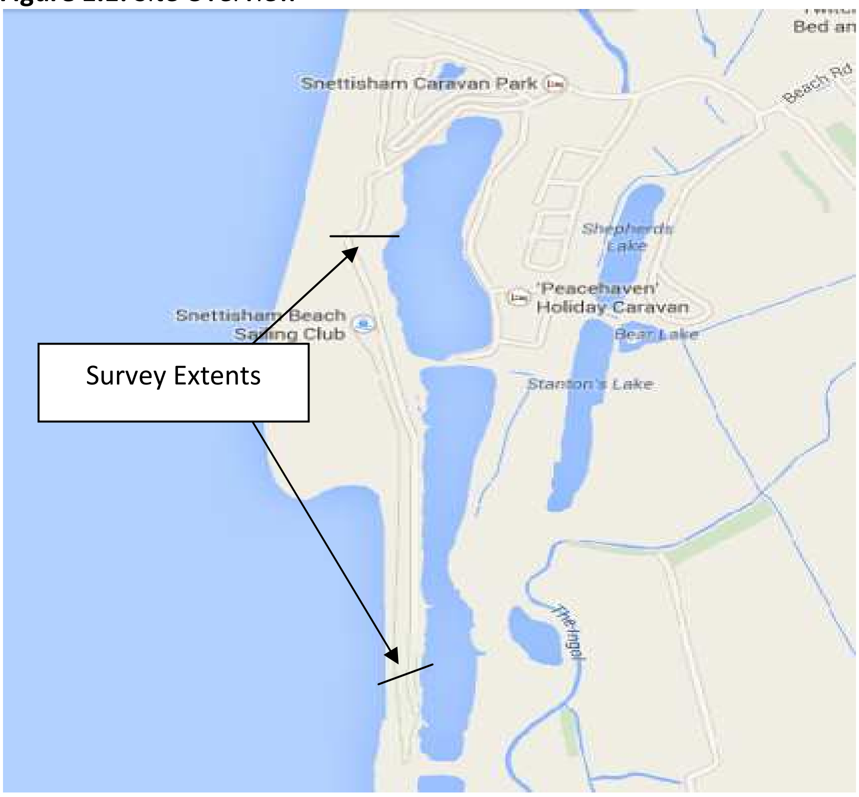
Pulse Surveying Limited (PSL) were commissioned by Norfolk County Council to carry out a pavement assessment onto a private access road at Snettisham caravan site in Norfolk which was undertaken during a single shift on the 23rd of September 2014.

During the survey a combination of different survey techniques were employed by PSL to investigate the construction of the pavement and to give an indication of its structural capacity. These included a Ground Penetrating Radar (GPR) survey to investigate the depth and composition of the pavement and a Falling Weight Deflectometer (FWD) survey to measure the performance of the pavement under load and to gain information on any possible voiding (air spaces) affecting it.

2 Site Description

The site is located near the village of Snettisham in Norfolk on a section of road which is closed to the general public and operated as an access road to the properties along its length. The section surveyed is approximately 900m in length, and runs from the corner of property No 50 past the Beach Sailing Club to the gate at the end of road adjacent to property No 138. An overview of the position of the site can be seen below :

Figure 1.1: Site Overview



The road itself was found to comprise of a single trafficked lane constructed from cement bound material over a granular sub-base with no supporting kerbline or drainage system in place. Visually the surface of the carriageway was found to be in poor condition with heavy cracking in evidence throughout and several areas with no bound material at the surface. Numerous repairs had been carried out along its length, but these are inconsistent in construction and have also failed in many locations.

Figure 1.2 – View of carriageway in SB direction - Site Chainage 90

Figure 1.3 – View of carriageway in NB direction - Site Chainage 620

3 Pavement Survey and Testing

Due to the limited access available on site and the width of the carriageway it was decided to carry out GPR survey runs in each wheel track along the length of the road to allow a comparison to take place across the width of the pavement. FWD data was collected from the oil track (the middle of carriageway) as this was the only position in which the trailer could be safely positioned. In many areas testing with the FWD was not possible as the gravel on the surface would not allow for a reasonable contact area for the test to take place, and because of this the total test area for the FWD was shorter than that of the GPR. In areas where the surface was predominantly gravel the GPR survey was conducted over its surface in order to gain an understanding of the makeup of the ground below but no stiffness values are given for these locations so no accurate conclusion can be made for the structural condition of these areas.

A table showing the areas tested with the FWD & GPR can be found below.

Table 3.1: FWD & GPR Survey Extents

Carriageway	Position	Survey Type	Direction	Site Chainage		Length (m)
				From	To	
Snettisham Access Road	Left hand wheel track	GPR	SB	0	933	933
Snettisham Access Road	Right hand wheel track	GPR	SB	0	933	933
Snettisham Access Road	Oil Track	FWD	SB	0	845	845

3.1 FWD System Details and Configuration

The FWD used for the collection of data was Dynatest Model 8002-271. The machine passed its annual correlation trial for the Transport Research laboratory (TRL) at MIRA in October 2013, and has a current calibration certificate in accordance with the requirements of HD29/08 of the Design Manual for Roads and Bridges (DMRB) and the TRL's monthly QA procedure.

The survey was carried out in accordance with the basic recommendations of HD 29/08 and were adjusted to suit the conditions found on site. Tests were carried out in the centre of the carriageway at a maximum of 10m intervals in one direction and referenced by cumulative chainage.

At each FWD test location the load applied to the pavement surface and the surface deflection was measured to an accuracy of 1kPa and 1µm (0.001mm) respectively. Surface deflections were measured at the centre of the 300mm diameter loading plate and at the radial distances shown in Table 2.1 below.

Table 3.2: FWD deflector configuration

DMRB Deflector Ref.	Distance from Centre of Load Application (mm)	FWD Geophone No
d1	0	5281
d2	200	5282
d3	300	5283
d4	600	5290
d5	900	5285
d6	1200	5286
d7	1500	5287

3.2 GPR System Details

The GPR survey conducted by PSL was to establish layer thicknesses and to identify homogenous lengths in the pavement construction and any anomalous areas.

A Geophysical Survey Systems Inc. (GSSI) SIR-20 GPR system utilising two surface coupled GPR antennas of 900MHz and 1.5GHz was used for collecting the GPR data. The use of 2 antennas, each with different transmission frequencies, allowed a data collection methodology providing the optimum approach for providing pavement structure information of sufficient detail and depth.

The survey was undertaken based on the procedure outlined in HD 29/08 of the DMRB.

The GPR survey was conducted at slow speed (approximately 10km/h) on the same day as the FWD survey. A calibrated survey wheel attached to the antenna box recorded the distance travelled along each survey line, and also controlled the GPR sample rate so that a radar scan (pulse) was recorded at 4cm intervals along the road up to a depth of 1.5m.

4 Pavement Analysis Methodology

4.1 Ground Penetrating Radar Analysis

GPR raw data files were processed and analysed by PSL using the REFLEXW v5.0 program, for determination of layer depths, and identification of homogenous and anomalous lengths of pavement construction. Data was subjected to processing and filtering stages including static correction, background noise removal and conversion of signal travel times to depths within the pavement structure.

Analysis of the reflected signals, amplitude, phase, velocity and travel time within the pavement materials structure allowed determination of layer thicknesses, and an indication of material type and integrity to be made. However as no physical samples of the pavement were taken to calibrate the GPR data against the velocity of the radar signal remains uncalibrated and should therefore be treated with a +/- 10 % margin for its calculated depths.

Layer depth information from the processed GPR data is exported as ASCII data from REFLEX and graphical representations of layer depths are produced as charts. These layer depth charts indicate material type and material thickness along the GPR survey lines taken, with site chainages, points of interest and core locations included for location determination.

GPR charts for each design element can be found in Appendix C.

4.2 Falling Weight Deflectomter Pavement Deflections

In order to compare test results, FWD Deflection bowl data was normalised to an applied load of 50kN and deflection parameters d0, d0 - d900 and d1500 were determined.

The principal deflection parameters used in this evaluation indicate the performance of the individual layers of the pavement as follows:

- d0 Indicator of overall pavement response
- d0 – d900 Indicator of response from bound layers
- d1500 Indicator of response from subgrade/upper foundation

A CUSUM analysis of the deflection parameters was undertaken in order to identify homogeneous lengths of pavement.

4.2.1 Back-calculation Based on FWD Deflections (Layer Stiffness)

Data from the FWD testing was analysed in accordance with the procedure given within Chapter 5 of HD 29/08 of the DMRB to determine layer stiffness.

The back-analysis was performed using the Linear Elastic Theory (LET), then related to typical strength ranges found for similar types of material. Table 4.1 shows the typical values used for the assessment as described in HD 30/08.

Table 4.1: Condition Thresholds Related to Bound Layer Stiffness

Material	Condition	Layer Stiffness at 20°C (MPa)	Source Reference
Bituminous	Poor integrity	< 3000	HD 30/08
	Some deterioration	3000 – 7000	HD 30/08
	Good integrity	> 7000	HD 30/08
Cement Bound	Poor integrity	< 20,000	HD 30/08
	Some deterioration	20,000 – 30,000	HD 30/08
	Good integrity	> 30,000	HD 30/08
Foundation	Poor integrity	<100	HD 30/08
	Good integrity	>100	HD 30/08

Tables of the back analysed FWD results can be found in Appendix A which are compliant to the criteria shown in table 4.1.

4.2.2 Pavement Foundation Assessment

For the purposes of this evaluation the foundation is considered to be the underlying subgrade soil (cut or fill), capping (if used) and sub-base. The stiffness of this layer can be assessed during back-calculation and is modelled using either a single layer (equivalent foundation modulus) or two layers, granular layer overlying subgrade. Equivalent foundation modulus provides an indication of the foundation support conditions and does not differentiate between the individual foundation layers. This type of analysis is often undertaken where the granular layer is either too thin to be modelled, where the granular layer has similar properties to the subgrade or when the thickness of the layer is unknown.

4.3 Voiding Assessment

In order to gain an understanding of any voiding issues affecting the pavement the FWD was setup to measure the deflection in the road at three different loads. Theoretically for a zero load the corresponding pavement deflection should also be zero. However, for voided foundations where deflections may not increase proportionally with load then a linear regression analysis may not intercept the origin of a load versus deflection plot. The point at which the linear regression line intercepts the y axis is known as the void intercept (see Figure 4.1).

To determine void intercept values at least three tests should carried out at different load levels. Voids underneath the pavement will be closed as the pavement is loaded. Increasing the applied load will further increase the closure of the void resulting in deflections that will not increase proportionally with the load level. By extrapolating from the three tests the deflection corresponding to zero loading may be calculated by linear regression.

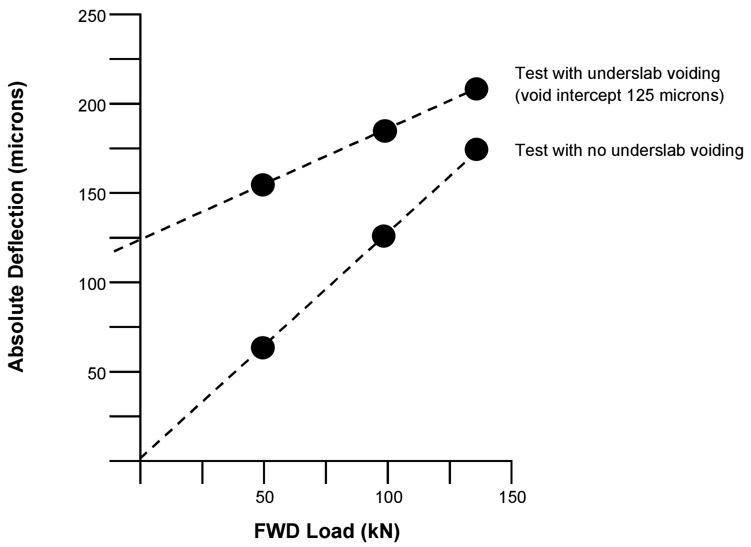


Figure 4.1 Void Intercept

Detailed guidance for void intercept analysis is published by the American Association of State Highway and Transportation Officials (AASHTO) in their guide for the design of pavement structures.

5 Pavement Analysis Results

To enable the results from the survey runs to be viewed in their entirety a summary table has been compiled and presented below.

Construction Thicknesses from GPR survey					
Bituminous Material (mm)			Cementitious Material (mm)		
Min	Max	Avg	Min	Max	Avg
n/a	n/a	n/a	78	347	206

Design Stiffness Results from FWD Survey			
Bituminous Condition	% < 3000	% 3000 – 7000	% > 7000
	n/a	n/a	n/a
PQC/CBM Condition	% < 20,000	% 20,000-30,000	%>30,000
	60	20	20
Foundation Condition	% < 100	% 100 – 150	% > 200
	9	21	70

Void Intercept Results from FWD Survey			
Void Intercept in Microns	% < 25	% 0 - 25	% > 0
	43	51	6

6 Conclusions

The findings of the pavement investigation can be summarised as follows:

- A total of 905m of GPR data has been collected from each wheel path.
- A total of 100 FWD tests have been carried out from the centre of the pavement.
- The carriageway is built from a cement bound material with an average depth of 206mm.
- The underlying sub-grade material is granular material.
- The results for the first 360m of the road (up to the area where the bins are kept) are similar to the results for the rest of the road, with no noticeable decline in the pavements condition from the corner of house No 83 to 138
- Overall the majority of the cement bound material is performing poorly, although there are isolated areas where the stiffness values are good. This is particularly in evidence between chainage 207 – 260 adjacent to houses 65 to 72 and outside houses 95 to 97 where remedial work has taken place to replace the existing construction.
- The supporting material beneath the cement bound layer is performing adequately with results from the FWD survey showing signs of good integrity within the foundation. This is likely to result in the continual decline of the surface material and ride quality of the road but should not result in a failure of the pavement to withstand loading at its present level.
- Voiding has been found to be an issue within the pavement structure, however these values are inconsistent and in many places not high enough to cause concern. In pavements of this type high void intercepts can often be a result of a stiff concrete material above the supporting material but as most of the concrete here is in poor condition it is likely settlement has occurred and that the voiding is a result of compression between the granular sub-base and the bottom of the cement bound material.
- Large air voids were not found to be in evidence from the GPR survey .
- Although there is a strong reflection between the interfaces in the GPR data between the CBM and the subgrade indicating possible moisture ingress or a higher than usual air content without further intrusive investigation this cannot be substantiated.

Appendix A : Layer Stiffness Results

Appendix B: Deflection Profiles

Appendix C: Ground Penetrating Radar Charts