Assessing the integrity of subsurface drainage system using Deflectograph residual life data

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ABSTRACT
Drainage is one of the key factors that consider as a risk for the integrity of the pavement. In most cases, impact from longitudinal sub-surface drains or adjacent filter drain failure results in the damage mostly to the nears-side wheeltrack (NSWT), with less impact on the offside wheeltrack (OSWT). This paper aims to investigate if there is a relationship between the condition of the longitudinal drains and the residual life differences between the two wheeltracks of a given road, as obtained from Deflectograph surveys.
This investigation has used historic Deflectograph survey results from some 20 road renewal schemes to test the hypothesis. The review focused on case studies in the SW of England where there were known drainage issues under the road. It was found that where there were no subsurface drains or failed carrier drains under the NSWT, the deflections were more than twice on the NSWT in comparison to the OSWT. This hypothesis was also tested on a wide range of road renewal schemes where GPR surveys had been undertaken and data was on the presence of moisture beneath the NSWT of a road. The historic Deflectograph data was as much as several years older than the GPR data in some cases. However, the review showed that in 40% of the total 60km length considered, there was a direct correlation between the presence of moisture under the road and the high deflections in the nearside edge of the road as compared to the lane centre.

RÉSUMÉ
Le drainage est un des facteurs clé qui réfléchissent comme un risque pour l'intégrité du pavement. La plupart du temps, l'impact de la sous-surface longitudinale égoutte ou les résultats d'échec de canalisation de filtre adjacents dans le dommage surtout à l'approcher-côté wheeltrack (NSWT), avec moins d'impact sur hors jeu wheeltrack (OSWT). Ce papier a l'intention d'enquêter s'il y a un rapport entre la condition des canalisations longitudinales et des différences de vie restantes entre deux wheeltracks d'une route donnée, comme obtenu des enquêtes de Deflectograph.
Cette enquête a utilisé des résultats d'enquête de Deflectograph historiques d'environ 20 projets de recommencement routiers pour évaluer l'hypothèse. La révision s'est concentrée sur les études de cas dans l'À ONDES COURTES de l'Angleterre où il y avait des éditions de drainage connues sous la route. Il a été constaté qu'où il n'y avait aucune canalisation sousde surface ou a raté des canalisations de camionneur sous le NSWT, les déviations étaient plus que deux fois sur le NSWT en comparaison de l'OSWT. Cette hypothèse a été aussi évaluée sur une large gamme de projets de recommencement routiers où les enquêtes de GPR avaient été entreprises et les données était sur la présence d'humidité au-dessous du NSWT d'une route. Les données Deflectograph historiques étaient jusqu'à plusieurs années plus vieilles que les données GPR dans certains cas. Pourtant, la révision a montré qu'à 40 % de la longueur de 60 kms totale considérée, il y avait une corrélation directe entre la présence d'humidité sous la route et les hautes déviations dans le bord de quasi côté de la route en comparaison du centre de petite route.

1 INTRODUCTION

This paper discusses the feasibility of a potential process for assessing the drainage systems in the South West of England.

The assessment of the subsurface drainage network is generally undertaken by routine CCTV survey of a proportion of the network each year. There is, however, no set mechanism for reviewing the integrity of the roadside filter drains apart from the detailed visual inspections (DVI) carried out from the surface on 20 per cent of the network each year. Hence, on an annual level, the state of the full drainage network can not be determined from these surveys. Therefore, the symptoms of any drainage defects are picked up by defects shown on the pavement surface. However, this may be too late in dealing with drainage effectively as by then it would have affected the adjacent pavement integrity resulting in substantial repair to not only the drainage system but also to pavement and surrounding areas.

The hypothesis investigated in this paper is to study the Deflectograph survey results as deflections on the nearside and offside wheeltracks with a view to assessing any changes between the two wheeltracks in relation to any drainage defect. As in most situations where the drain carrier pipes are located in the proximity of the nearside wheeltrack, any weakening of the foundation can be picked up by higher deflections in the nearside wheeltrack.

This hypothesis is investigated here for three separate road renewal schemes on fully flexible pavements where drainage defects have been confirmed alongside other pavement issues. The merits of other possible effects on the Deflectograph responses are also discussed.

2 CASE STUDIES

2.1 Case Study 1: A30 Honiton to Haynes Farm

Figure 1. Wheeltrack cracking through a section of the scheme

This single carriageway contains drainage that is mostly piped (carrier drains) and is functioning though there are sections through the site containing no positive drainage that occasionally flood. Two streams flood the carriageway in periods of heavy rain.

CCTV survey showed that a total of 29 short locations (ranging from 5 to 20m in length each) required replacement of the carrier drains

The Deflectograph profiles show that in a number of locations the NSWT deflections are higher than the OSWT deflections.

Chainage 600 to 800 and 1400 to 1800 EB: There is a marked increase in the NSWT deflections compared to OSWT ones. Drainage investigation shows that no drains are present in the same precise locations. This can mean that water is somehow flowing over the carriageway which has gradually reached the foundation, thus weakening the pavement along the haunches, possibly by soaking into the edge, where it is un-kerbed and possibly damaged.

On the other hand, the WB carriageway shows strong NS foundation, meaning that drains are not leaking.

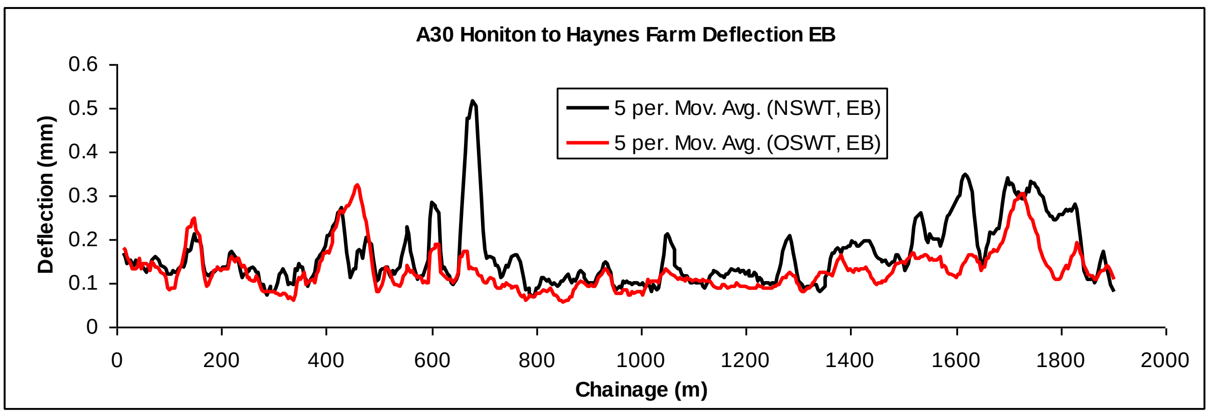

Figure 2. Deflection profiles for NSWT and OSWT in the EB direction

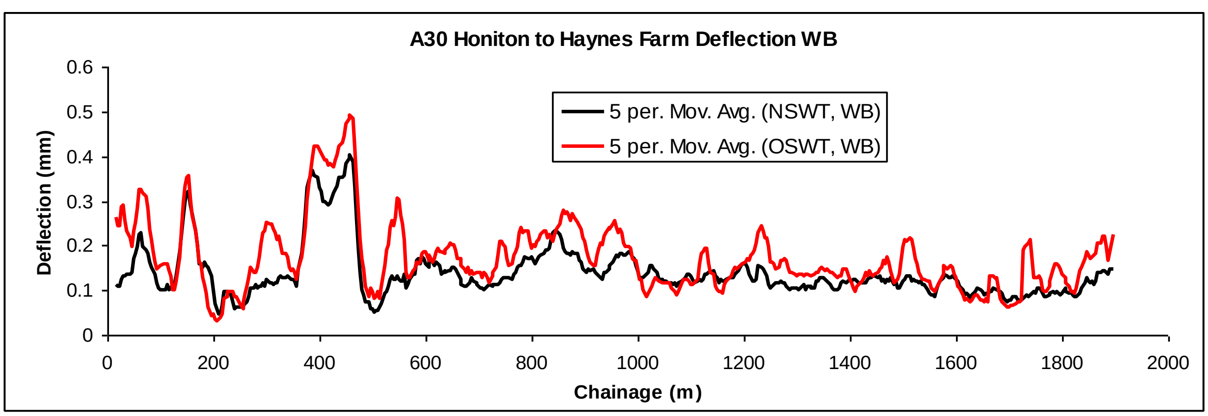

Figure 3. Deflection profiles for NSWT and OSWT in the WB direction

This can be due to a number of possible reasons:

1. The NSWT foundation is weaker in construction than the OSWT foundation. This sometimes happens on evolved roads (versus designed roads) whereby the road may have been historically a single track or a very narrow road which then widened naturally to a 2-way road (by current standards). It is worth noting that current standard for a lane width is 3.65m as opposed to the 3.1m noticed in some parts of this piece of road.

2. The testing is not consistent on very narrow roads where the Deflectograph testing relies on the nearside wheels sitting near the edge (i.e. considering a 2.75m for the width of the machine, the measurements on the NSWT are located some 150mm away from the asphalt edge). This can skew the results thus making this hypothesis not consistent along a piece of road that does not have uniform lane width.

3. The NSWT foundation has been weakened as a result of the effect of seepage water from failed drains that are located near the road edge. This is the main element of the proposed hypothesis that is being checked in this analysis.

4. The assumed weakening of the foundation beneath the NSWT is perhaps due to localised strengthening of the OSWT foundation (i.e. due to deep localised patching or a stronger trench reinstatement), thus making the deflections on the OSWT lower than those along the NSWT. This can be ruled out by studying the general deflection trend along the route. Also, with seed moduli for the bound layers, it is possible to use layer-linear elastic modelling (i.e. BISAR) to predict the strength of the foundation - this can be used to verify the Deflectograph indications. For the purpose of illustration in this paper, the 5 moving average values of the deflection profiles have been shown to illustrate the general trend of defects at every 20m intervals. Although it is possible to analyse individual deflection values (taken every 4m), reporting will be beyond the scope of this paper.

5. There appears to be a direct relationship between the lack of drainage and weakening of the NSWT foundation when the surface water flows towards the nearside verge. This is expected as water would gradually seep through the verge into foundation. Any signs of wheeltrack cracking on the surface would be an indication of water seepage as well.

Other possible scenarios are being investigated in order to show where there is a direct linkage between the weakening of the foundation due to water ingress from subsurface drains and higher deflection values from the Deflectograph.

2.2 Case Study 2: A30 Rawridge Hill to Devonshire House

This 1.6km pavement scheme is situated along the same road as the case study 1, which is a rural single carriageway with a 50mph limit. The road width is standard (7.3m). The main driver for this scheme is the extensive longitudinal (alligator) cracking along the nearside wheeltrack, as illustrated in the following visual plans. The secondary driver for this scheme includes poor drainage with water ponding on the carriageway during prolonged periods of rain.

Figure 4. Wheeltrack cracking through a section of the scheme

Of the full length of the scheme, only 550m has subsurface drainage (chainage 950 to 1500m along both the EB and WB carriageways). Of this length of drain pipes, 400m have failed and need replacement (as identified by CCTV survey).

The site is located along a cutting to the south (adjacent to the WB carriageway edge) and a deep embankment to the north (on the EB carriageway edge). Hence, any surface water running down the cutting is not able to be absorbed by the verge, hence crossing the WB carriageway and flowing down the embankment of the EB carriageway. The flooding has resulted in extensive surface cracking and ravelling / disintegration.

The deflection profile on the NSWT shows a similar response in the pavement foundation between areas where there is no drainage system but there is surface cracking and areas where there is drainage but the drain pipes have collapsed/broken. Both cases allow water to enter the foundation, resulting in higher deflections on the NSWT in comparison to OSWT. This appears to be the case in both EB and WB directions.

It is worth noting that where the wheeltrack cracking has occurred in both the NSWT and OSWT of the EB (i.e. chainage 1100 to 1350m of the EB carriageway), the deflection profiles converge to a value similar to that in the rest of the NSWT where there foundation has softened.

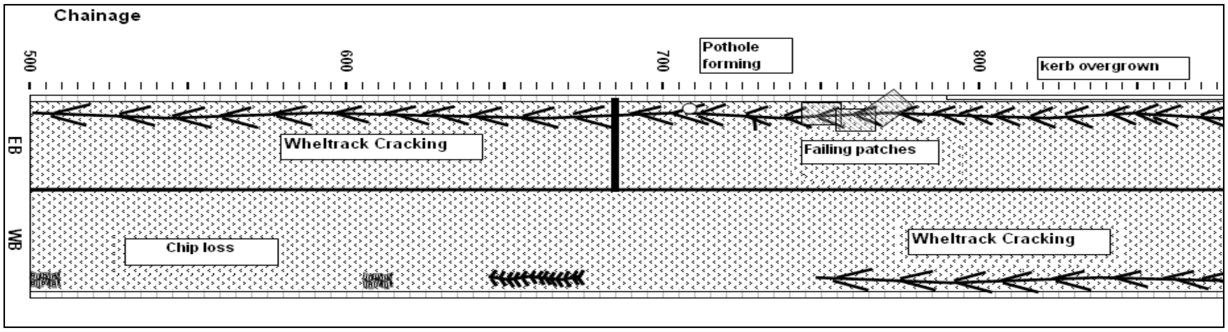

Figure 5. Schematics of the surface defects on A30 Rawridge Hill to Devonshire House (ch. 500 – 850m)

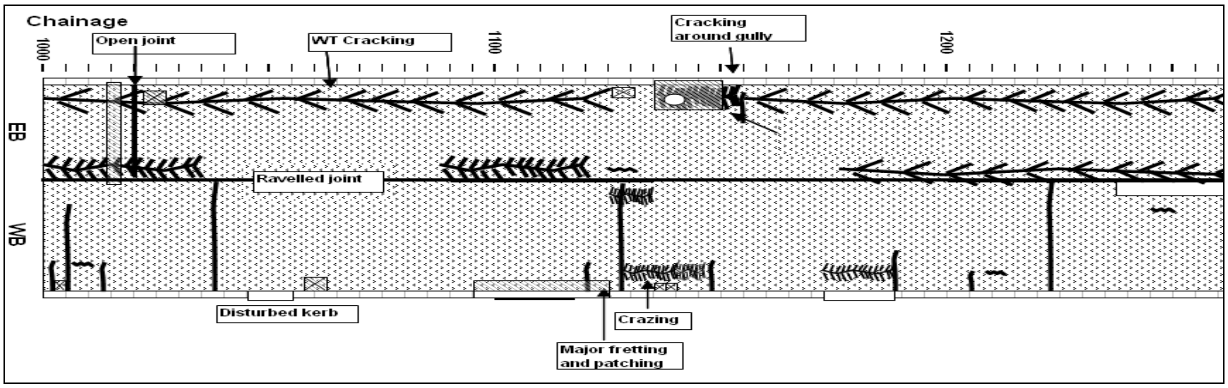

Figure 6. Schematics of the surface defects on A30 Rawridge Hill to Devonshire House (ch. 1000 – 1250M)

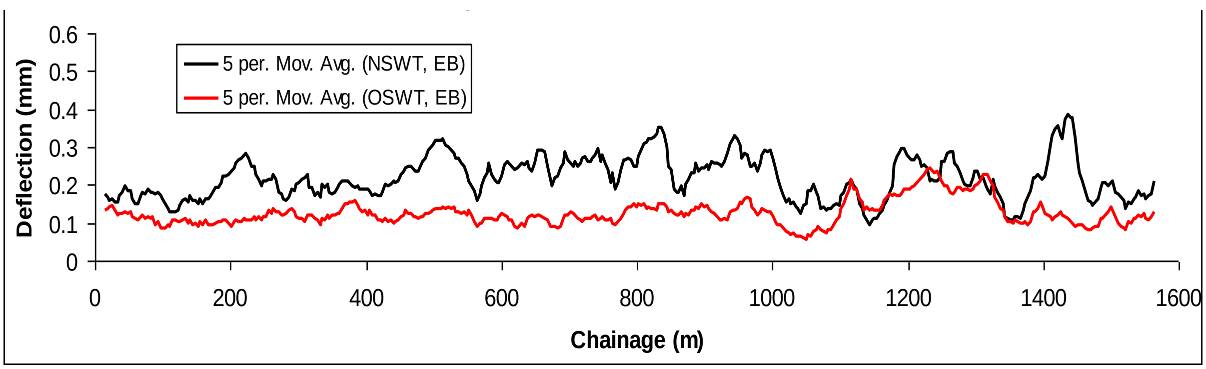

Figure 7. Deflection profiles for NSWT and OSWT on A30 Rawridge Hill to Devonshire House in the EB direction

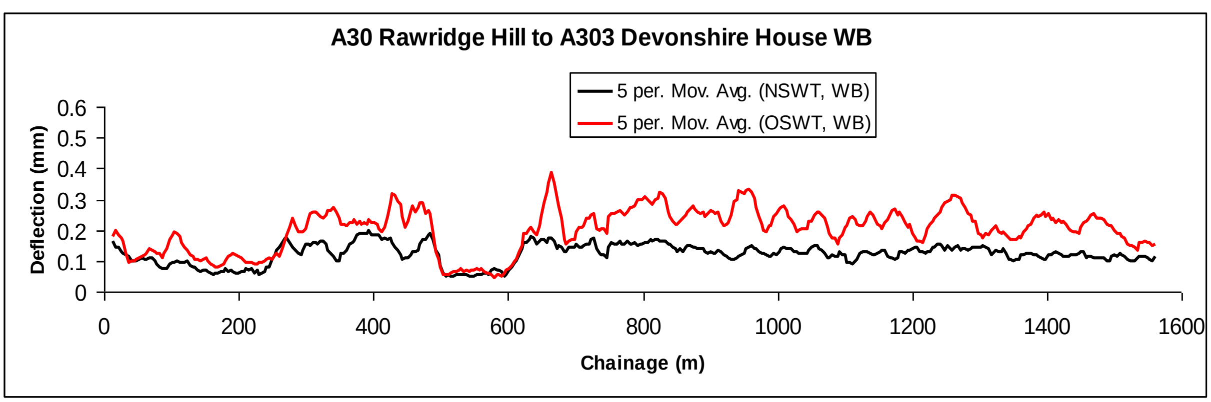

Figure 8. Deflection profiles for NSWT and OSWT on A30 Rawridge Hill to Devonshire House in the WB direction

In comparison, the WB carriageway shows higher deflection on the OSWT in comparison to the NSWT. This can be seen by the joint cracking on the centreline of the road (see the visual survey illustration given previously for chainage 1000 to 1200m). This trend is similar to that found in the first case study where water entering through the centreline cracks has weakened the foundation of the OSWT in the WB carriageway.

This case study also illustrates a direct link between foundation weakness as a result of water seepage and deflection response obtained by Deflectograph testing.

2.2 Case Study 3: A40 Huntley to Lea

The A40 from Huntley to Lea is an evolved single carriageway trunk road of varying construction. The main driver for this 6km pavement treatment scheme is the extensive surface disintegration and localised wheeltrack cracking.

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Figure 9. Localised failure and cracking through a section of the scheme

Figure 10. Flooding of the road through the defective area within the scheme

Visual survey has shown that during heavy rain, water tends to flow on the nswt for a great deal of the scheme length. However, wheeltrack cracking defects are only localised to certain locations.

The CCTV surveys showed substantial number of drainage defects or lack of provision of drainage along the scheme length. In specific places, this is causing accelerated failure of the pavement surface. Flooding and collapsed gullies have been the cause of emergency call outs in the last twelve months.

Profiles of the deflection values indicate a very weak foundation for the NSWT for the majority of the scheme length in both directions. This can be expected given the amount of ponding on the pavement, wheeltrack cracking and softened verges as a result of water runoff. There was a known drainage scheme at Boxbush (located between chainage 1712 and 1900m) which caused major flooding of the carriageway. The carrier drain had reduced capacity due to excessive silting, causing the water to flow over the carriageway. Hence, the NSWT deflection is at its peak value at chainage 1900m on the WB direction. The same trend is also evident on the EB direction.

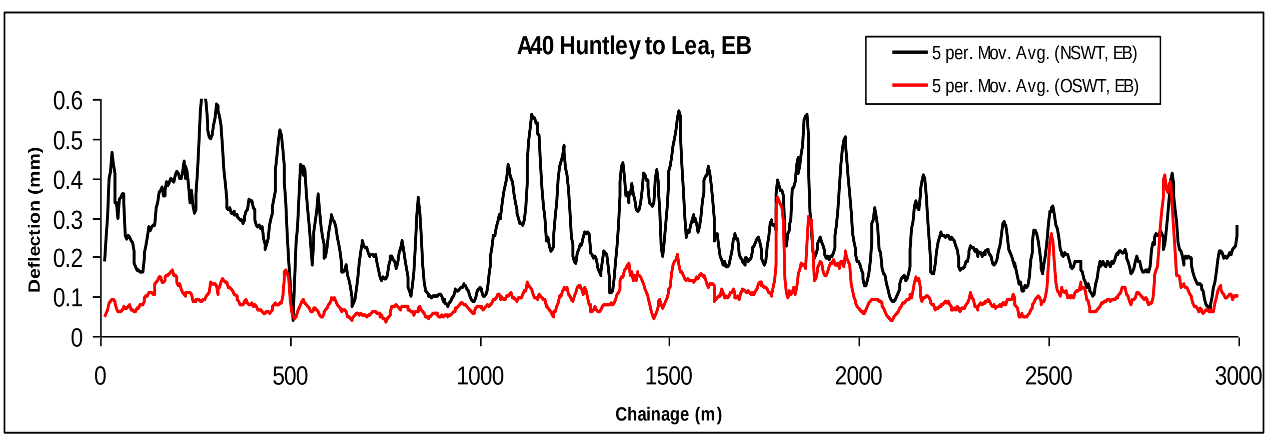

Figure 11. Deflection profiles for NSWT and OSWT on A40 Huntley to Lea in the EB direction

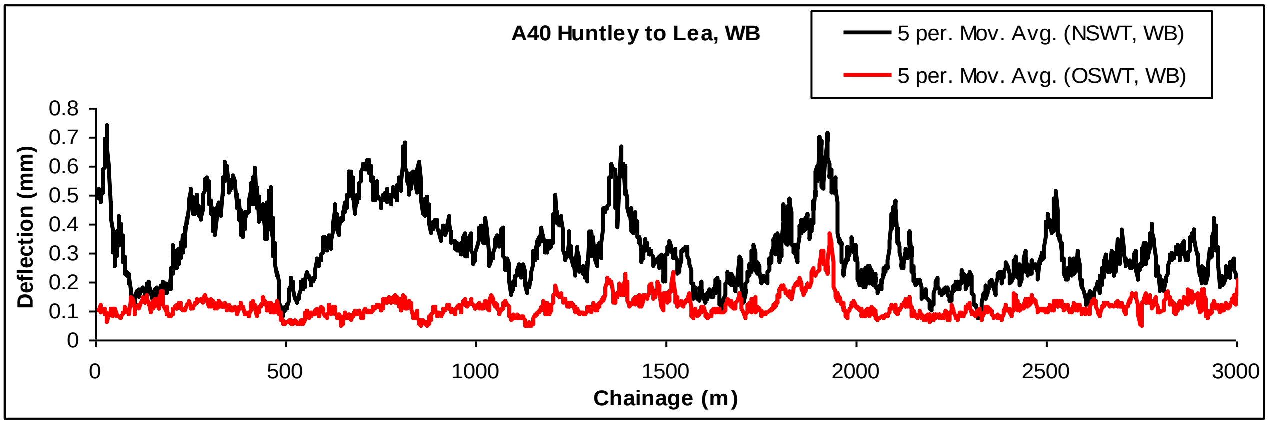

Figure 12. Deflection profiles for NSWT and OSWT on A40 Huntley to Lea in the WB direction

This case study clearly indicates a distinct correlation between failures in the carrier drain or the presence of wheeltrack or other carriageway cracking and the deflection response from the Deflectograph surveys.

3. CORRELATION BETWEEN GPR MOISTURE PROFILES AND DEFLECTOGRAPH RESULTS

In an attempt to widen the database, GPR moisture profile data from some 20 road renewal schemes studied in the last 5 years were compared with the historic Deflectograph deflections available from earlier and recent investigations. The overall length of the review was some 60km in each direction. As a basic criterion, all those 100m sections that contained at least 50% more NSWT deflections than the OSWT deflections were then compared with the presence of moisture beneath the NSWT obtained from GPR surveys. The sum of all the 100m sections showing compliance were then added up and compared against the total length of the review. The results indicated compliance ranging from 20% on A36 to 54% on A40, with A303 showing some 37% compliance. The A36 runs through an urban environment that contains positive drainage system that is mostly functioning but however contains substandard road width that could hamper the deflection results (i.e. the nearside deflections would be picking up response from the adjacent verge as well as the weakened edge). As shown in the last Case study, the A40 is known for localised nearside wheeltrack cracking that allows the ingress of water to pavement foundation. Hence, there was a better compliance.

4. DRAINAGE NETWORK REVIEW PROCESS

The case studies reviewed in the last sections provide the opportunity to use the deflection profiles from Deflectograph surveys to identify potential drainage problems.

Considering that there are historic Deflectograph results for a great portion of the road network in the UK, it becomes possible to review them using a consistent process. Deflection values from two wheeltracks (say averaged every 20m) together with location referencing and some geometry information are put into a simple spreadsheet. This can highlight where the NSWT deflections are higher than the OSWT ones. Another data column can show the ratio of OSWT to NSWT deflections which will also have the same highlighting criterion. For example, as a first approximation, it is assumed that where the deflection values on one wheeltrack are twice or more than those on the adjacent wheeltrack, the site is highlighted for further investigation (see Table 1).

The above table is based on actual values from a particular site that has definite drainage problems. In general, when the overall network is reviewed, there may be odd 20m spots that can be highlighted. In such cases, it may be convenient to look into individual 20m highlighted sections to study the trend within each 3-4m deflection points.

Using this process will allow a list of potential drainage investigation sites to be produced for further review.

4.1 Sifting for Possible Rogue Data

4.1.1 Physical Features

Since the Deflectograph testing may be susceptible to any physical features on the road such as gullies, the averaging of deflections over 20m may be one option to remove the localised volatility from the review.

Table 1. Tabulated deflection data for NSWT and OSWT

Chainage (m)	Lane width (m)	NSWT Deflection (mm)	OSWT Deflection (mm)	Ratio of NSWT/ OSWT deflections
160	3.5	0.460	0.090	5.1
180	3.2	0.172	0.067	2.6
200	3.6	0.570	0.110	5.2
220	3.3	0.088	0.058	1.5
240	3.1	0.600	0.090	6.7
260	3.2	0.193	0.067	2.9
280	3.3	0.680	0.070	9.7
300	3.4	0.129	0.096	1.3
320	3.5	0.410	0.050	8.2
340	3.6	0.212	0.117	1.8
360	3.5	0.380	0.090	4.2
380	3.6	0.203	0.107	1.9
400	3.5	0.212	0.086	2.5
420	3.5	0.270	0.140	1.9
440	3.6	0.241	0.077	3.1
460	3.4	0.200	0.140	1.4
480	3.5	0.172	0.067	2.6
500	3.5	0.280	0.070	4.0

6.1.2 Road Geometry

It is also possible that road geometry affects the output data. For example, where roads are very narrow (say 3m lane width), the nearside wheels of the 2.4m wide Deflectograph will be positioned close to the verge (see Kennedy et al. 1978) for equipment layout and details of testing). Hence, this data should be excluded from the review.

6.1.3 Geotechnical Issues

All know sites containing geotechnical issues along a route need to be excluded from this review as they could cause the NSWT to show increased deflections during Deflectograph surveys. It is possible to link this to GIS or the HADDMS (Highways Agency Drainage Data Management System) to graphically represent the potential problem areas.

6.2 Confirmation of Potential Investigation Sites

In the network review process for pavement scheme investigation sites (Zohrabi, 2008), a drive through process has been adopted that allows the potentials sites to be scored against a number of defects. The drainage review sites will, however, need to be investigated in some more detail. One possible but crude method may be to plan a drive through during heavy rain to confirm the general condition of a long section of the road. In other cases, detailed investigations will be needed.

6.3 Potential Use of the Process in the Future

The process discussed in this paper relies on regular Deflectograph surveys being undertaken on the network. However, for comparison purposes, the historic data can be used since the comparison is always made on the data from same testing run that covers both wheeltracks simultaneously. Allowance will have to be made for sites that have already been treated. Testing such sites will however show what the correlation is between NSWT and OSWT in comparison to historic data on the same sites. This can be used for baseline measurements between treated and untreated sites or tolerance in collected data.

Highways Agency in the UK are currently in the process of introducing Traffic Speed Deflectometer (TSD) to measure continuous pavement deflection profiles at traffic speed (Krarup, et al. 2006). This allows annual deflection surveys to be undertaken on the motorway and trunk road network.

The UK version of the TSD currently allows the deflections to be measured along the NSWT only (left side wheel location). The Danish version, however, collects the measurement on the OSWT (since the direction of travel in Denmark is on the right-hand side with lasers located along the offside wheelpath). Once this survey is rolled out in the UK, there is a possibility of using additional lasers to cover the OSWT with a view to reviewing the variation between the two wheeltracks to assess drainage conditions. Another alternative approach may be to use the historic data to identify potential hotspots where there may be drainage issues. When the TSD surveys are undertaken in future, the change in the deflection values in the NSWT compared to what they are now could be used to trend the worsening of pavements, which may be attributed to drainage issues. Nevertheless, it will be a way forward to identify potential areas where pavement foundation may show signs of weakening.

DISCLAIMER

The views expressed in this paper are those of the authors and not necessarily those of the Highways Agency.

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