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Contents

1. Preamble 4/3
2. Introduction 4/3
3. Background 4/4
4. Test Principles 4/4
5. Test Considerations 4/5
5.1 Pavement Construction 4/5
5.1.1 Long Life Pavements 4/5
5.2 Traffic 4/6
5.3 Deflection History 4/6
5.4 Survey Categories 4/6
5.5 Early Life Surveys 4/7
5.6 Temperature 4/7
5.7 The role of Deflectograph post the introduction of SCANNER 4/7
5.8 UKPMS Rule Set 4/8
6. Processing of Test Results 4/8
7. Deflectograph HMDIF 4/9

1. Preamble

This chapter is intended to provide a brief overview of the Deflectograph and is aimed at those who require an appreciation of the principles behind the test method and the factors involved in the analysis and processing of results for utilisation within UKPMS. It also directs the reader, where appropriate, to other references for more detailed information.

2. Introduction

The Deflectograph is an established and widely used tool for the structural assessment of road pavements. The underlying principle of the test method is that the deflection measured under a rolling wheel load provides an indication of the strength of a pavement structure. The survey technique and subsequent analysis procedures have been used for many years for the evaluation of structural condition and to inform the design of strengthening treatments.

The Deflectograph parameter most commonly imported into UKPMS is *'Residual Life'* which, as its name suggests, is intended to give an indication of the remaining life of the pavement before strengthening is required. Pavements deteriorate through exposure to a number of factors including traffic loading and environmental effects. As such, the '*Residual Life*' of a pavement decreases over time until a '*Zero Life*' condition is reached. Beyond this point negative '*Residual Life*' values are reported and the pavement is considered to be in a '*Critical Life*' condition. '*Zero Life*' or '*Critical Life*' pavements may remain in a serviceable state for some time although the degree of strengthening works required to remediate them becomes more onerous.

The design of strengthening overlays via the Deflectograph method is beyond the scope of UKPMS and is not covered within this Manual. The reader is instead directed to alternative references.

Recently, SCANNER (**S**urface **C**ondition **A**ssessment of the **N**ational **NE**twork of **R**oads) has become the mandatory survey technique for statutory reporting of road pavement condition in England. However, a subsequent CSS Guidance Note identified that there is a continuing role for Deflectograph for designing pavement strengthening treatments. Further guidance is included in Section 5.7 below.

Care must always be taken in the interpretation and use of Deflectograph data since experience has shown that apparently high recorded deflections may not always be indicative of structural weakness in the pavement construction. The recorded deflection will, in general, be significantly influenced by the condition of the subgrade. A weak subgrade, due to defective drainage or seasonal variations in moisture content, may give rise to high deflections from which a pessimistic prediction of residual life could be inferred. Conversely, strong subgrades, such as chalk, can produce low deflection values that could be misinterpreted to produce an over optimistic estimation of residual life. See also Section 5.5 with regard to early life surveys.

For these reasons, established good maintenance practice in the use of Deflectograph dictates that maintenance treatments should not be based on Deflectograph information alone but supporting data should always be used to assist in diagnosing pavement distress and designing appropriate remedial measures.

Further advice is provided within HD 29/94 and HD 30/99 of the Design Manual for Road and Bridges (Volume 7. Section 3).

3. Background

The analysis method associated with the use of Deflectograph in the UK is based on correlations of measured deflection and pavement performance from a large number of full-scale road experiments. The method was developed at the Transport Research Laboratory (TRL) and is described in their report LR 833 "*Prediction of pavement performance and the design of overlays"* (1978).

4. Test Principles

This Section is intended to provide a brief overview of the principles behind the Deflectograph. The reader is directed to the following references for more in-depth consideration:

- HD 29/94 *"Structural Assessment Methods"*, Design Manual for Road and Bridges, Volume 7, Section 3, Part 2.
- TRL Report LR 834 *"Pavement deflection: Equipment for measurement in the United Kingdom"* (1978).
- TRL Report LR *835 "Pavement deflection: Operating procedures for use in the United Kingdom"* (1978).

The Deflectograph is a road-going vehicle with loaded rear wheels and a measuring beam assembly. In test mode it travels at a nominal speed of 2.5km/hour. The rear wheels carry a recommended loading of 3175kg and cause a transient deflection of the road surface as they travel. The measuring beam assembly rests independently on the road surface between the two rigid axles of the vehicle and is attached to a reference frame. As the loaded rear wheels travel towards the measuring beam the resulting peak deflections of the road surface are recorded in both wheel paths to an accuracy of one hundredth of a millimetre. Typical deflections are of the order of 0.5mm, however maximum values of 1.0mm are not uncommon.

After the rear wheels have passed the measuring beam a mechanism pulls the assembly forward to a position 3.8m ahead of the previous measurement location. The vehicle's motion is continuous and as the rear wheels approach the new measurement location, deflections are again recorded. This cycle continues throughout the length of the survey section.

When the survey is completed the measuring beam assembly is raised clear of the road surface and the Deflectograph is able to travel at normal traffic speed between sites.

The underlying principle of this method is that the magnitude of the measured deflections is related to the strength of the pavement layers and the sub-grade. The analysis of the Deflectograph results is empirical and relies upon standardised test conditions and accurate data for pavement construction and traffic to generate values of *'Residual Life'* and indications of required overlay thickness.

5. Test Considerations

5.1 Pavement Construction

The analysis of Deflectograph data is limited to flexible and flexible composite pavements. The analysis of the data is not valid for rigid construction and so the routine survey is not appropriate for concrete pavements, but modified versions of the equipment have been produced to permit measurement at the joints in jointed rigid construction.

Analysis of Deflectograph results (via PANDEF – see Section 6) requires the following information regarding the pavement construction:

- The type, thickness and condition of the component pavement layers. This can be determined by ground radar, bore holes, trial pits or coring, as appropriate.
- The date of construction of the road (or its most recent strengthening).
- The sub-grade strength, as measured by the California Bearing Ratio test.

5.1.1 Long Life Pavements

Conventional theory suggests that flexible and flexible composite pavements sustain structural damage due to repeated traffic loading which, over time, will lead to greater measured deflections and that the structure has a determinate life. The Deflectograph analysis method is founded upon these principles.

Recent research[1] has suggested that this conventional theory may not apply to thick, well constructed, fully flexible pavements constructed on strong

[1] TRL Report TRL250"*Design of long-life flexible pavements for heavy traffic*" (1997)

foundations. Often, the only distress found in such pavements is confined to the surfacing layers. Timely intervention to arrest surface defects can result in pavements that have a long but indeterminate life without the need for structural strengthening. These are termed "long life" pavements.

The CSS Code of Practice for Highway Maintenance Management interprets a "long life" fully flexible pavement to comprise over 300mm of bituminous material and to exhibit low deflection (as measured using the Deflectograph).

Measured deflections on "long-life" pavements do not increase over time but remain constant (or may even decrease). As such, they require careful interpretation. Further reference should be made to the following reports:

- Nunn M E and Ferne B W (1997). *"Design and assessment of long-life flexible pavements"* Transportation Research Circular. 2001-12 503. Transportation Research Board. Washington DC.
- TRL Report TRL639 *"Guidance on the development, assessment and maintenance of long-life flexible pavements"* (2005).

5.2 Traffic

The analysis of Deflectograph results in PANDEF (see Section 6) requires details of traffic loading. Traffic is expressed in terms of equivalent standard axles and is derived using the method in HD 24/96 of the Design Manual for Roads and Bridges (Volume 7. Section 2. Part 1).

Traffic figures are required for:

- The cumulative loading from the year of construction (or last major strengthening) to the date of the Deflectograph survey.
- Future annual traffic loading for each year from the date of the Deflectograph survey to at least twenty years into the future.

5.3 Deflection History

Deflection measurements are inherently variable. Conclusions based upon a single, potentially unrepresentative, survey present a significant risk. HD 30/99 (DMRB, Volume 7. Section 3. Part 3) and HD 29/94 (DMRB, Volume 7. Section 3. Part 2) both advocate the establishment of a database of historical deflection readings. This will enable trends to be established and abnormal deflection readings to be identified. Areas exhibiting abnormally high readings can then be targeted for further investigation.

5.4 Survey Categories

The analysis of Deflectograph results is empirically based. Surveys must be carried out under prescribed conditions to ensure that the founding empirical relationships are valid. Survey Categories are defined by the time of year and temperature limits. Classifications are provided in HD 29/94 (DMRB, Volume 7. Section 3. Part 2)

5.5 Early Life Surveys

Deflectograph surveys on newly constructed (or strengthened) pavements are likely to produce variable results. It is estimated that the pavement and sub-grade can take up to two years to stabilise after construction. Reliable indications of strength and '*Residual Life*' cannot be achieved until this process is complete. As such Deflectograph surveys should not be undertaken during this period.

5.6 Temperature

Deflection readings are influenced by temperature. The temperature of the pavement is measured at a depth of 40mm below the road surface in the line of the nearside wheel path. Obtained deflection results are corrected for a standard temperature of 20°C.

5.7 The role of Deflectograph post the introduction of SCANNER

SCANNER road condition surveys became mandatory for statutory reporting in England in 2004/5. These network–level automated surveys are conducted at traffic speeds and collect data on transverse and longitudinal profiles, texture and cracking of pavements.

In the case of long-life pavements (see Section 5.1.1), initial deterioration will be confined to the road surface and should be identified by SCANNER. Timely intervention to surface defects will prevent structural deterioration. The need for Deflectograph surveys on such pavements is potentially diminished.

In the case of determinate-life (i.e. non long-life) pavements, SCANNER will only be able to identify structural deterioration when it has manifested itself at the road surface by rutting and/or cracking. By this stage the requirement for structural remediation works are likely to be more extensive. Deflectograph surveys can identify deterioration in the lower pavement layers (before the onset of surface deterioration) and so their use on determinate-life pavements remains valid.

For further details, reference should be made to the *"Guidance Note for Local Authorities on the Future Use of the Deflectograph"* published by the CSS Highway Condition Assessment Group in October 2004.

5.8 UKPMS Rule Set

The Deflectograph parameter most commonly imported into UKPMS is '*Residual Life*'. The calculation of '*Residual Life*' is empirically based and is influenced by the accuracy of the input data and (possible) experimental errors within the empirical relationships used. The UKPMS Rules and Parameters were developed in consultation with practicing maintenance engineers and so the treatment of Deflectograph data within UKPMS reflects good maintenance practice, as discussed in Section 2, in that '*Residual Life*' alone is constrained from generating a structural treatment within UKPMS. A low value of '*Residual Life*' requires coincident wheel track cracking and/or rutting from visual surveys to trigger a treatment using the national default rule set. Local rule sets may be developed and configured to use the data differently.

6. Processing of Test Results

The analysis of Deflectograph results is empirical and is typically carried out by a software program called PANDEF (**P**rocessing and **AN**alysis of **DEF**lections). Reference should be made to the *"PANDEF User Manual"*, (DfT, 1993) for further details. (It should be noted that, although widely used by Local Authorities, PANDEF is no longer maintained or supported by the DfT. Equivalent commercial packages are also available).

TRL have carried out long-term studies of pavement performance and have developed a method for predicting the '*Residual Life*' of pavements. Reference should be made to TRL Report LR 833 "*Prediction of pavement performance and the design of overlays"* (1978) for details of this research – upon which PANDEF is based.

Input parameters to the program are:

- Raw deflections (from Deflectograph)
- Pavement construction details.
- Traffic figures.

PANDEF separates pavements into long-life and determinate-life categories and estimates the '*Residual Life*' of the latter. The accuracy of the '*Residual Life*' values produced by PANDEF has been found to be within a range of ± 2 years when the pavement is approaching an investigatory condition.

7. Deflectograph HMDIF

UKPMS does not incorporate any functionality for processing raw Deflectograph data to produce *'Residual Life'* values. Therefore imported data must be pre-processed using PANDEF (see Section 6).

Table 1 provides an example of the file structure and content of a Deflectograph HMDIF file that would be produced by a Contractor.

```
HMSTART ukPMS 001 " " ; , \
TSTART;
SURVEY\OWNER,TYPE,VERSION,NUMBER,SUBSECT,MACHINE,PREPROC,REQLIFE,WTRACK,XSPUS
ED;
SECTION\NETWORK,LABEL,SNODE,LENGTH,SDATE,EDATE,STIME,ETIME;
OBSERV\DEFECT,VERSION,XSECT,SCHAIN,ECHAIN;
OBVAL\PARM,OPTION,VALUE,PERCENT;
TEND\6;
DSTART;
SURVEY\LA,DEF,1,10,10M,CBCD1,PAN,20,C,F;
SECTION\UKPMS,UKPMSA244/4916,050579L,35,191093,191093,,;
OBSERV\LIFE,1,CR1,0,10;
OBVAL\13,,7,V;
OBSERV\LIFE,1,CR1,10,20;
OBVAL\13,,9,V;
OBSERV\LIFE,1,CR1,20,30;
OBVAL\13,,26,V;
DEND\10;
HMEND\18;
```

Table 1 Example Deflectograph HMDIF