

Use of the DCP-DN Design Method in LVRR Design and Construction

Memo for Circulation to Practitioners – December 2019

Introduction

The objective of this note is to summarise the ReCAP Research Report¹ and associated discussions on the use of the DCP-DN method for Low Volume Rural Road (LVRR) design and construction.

The Dynamic Cone Penetrometer (DCP)

The DCP has been in use in Asia, Africa and USA for many years and is an accepted tool for rapidly assessing natural or man-made ground conditions at shallow depth. Its main application has been in the assessment sub-grade strength as an input into pavement design; other well-established uses include foundation conditions for small structures and quality control of placed fill or compacted road pavement layers. It has principally been applied in terms of a correlation with California Bearing Ratio (CBR), although correlations (e.g. with shear strength) have also been derived. Descriptions of the DCP and its uses are contained in the following documents, amongst others:

ASTM D6951-03, Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications, ASTM International, West Conshohocken, PA, 2003.

TRL, 2006, UKDCP 3.1, Manual. Measuring Road Pavement Strength and Designing Low Volume Sealed Roads using the Dynamic Cone Penetrometer. <https://www.gov.uk/dfid-research-outputs/uk-dynamic-cone-penetrometer-dcp-software-version-3-1>.

AfCAP 2013. Design Manual for Low Volume Sealed Roads Using the DCP Design Method. Ministry of Transport and Public Works, Malawi.
<http://research4cap.org/SitePages/Rural%20access%20library.aspx>

The DCP-DN Approach

DFID had previously supported the continued development of the DCP-DN method of LVRR pavement design through the AfCAP initiative (AfCAP, 2013). In this approach penetration rate (DN) is used directly as a design parameter in coordination with a DCP-DN design catalogue without resorting to correlation with CBR. ReCAP included DCP-DN development and training within its current 2014-2020 programme².

The recent research and discussion have not been about the DCP itself, but rather about the use of the more recently developed DCP-DN procedures and the associated catalogues as an alternative to the more traditional methods based correlation with the CBR. The DCP-DN approach has been largely applied in some countries in Southern Africa in the context of upgrading gravel roads to sealed standard. Concerns had been expressed as to the risks involved in extrapolating the approach outside its current climatic, physical and geotechnical environment without further research.

¹ Pinard, M., Van Zyl, G. and Hongve, J. (2019). Evaluation of Cost-Effectiveness and Value-for-Money of DCP-DN Pavement Design Method for Low-Volume Roads in Comparison with Conventional Designs, Final Report. London: ReCAP for DFID.

² CSIR (2016). Improvements to the WinDCP software for Pavement Design of Low Volume Roads - Final Development report. London: ReCAP for DFID.

The ReCAP DCP-DN Research Report

The main purpose of the DCP-DN research project was to evaluate, in terms of cost-effectiveness and value-for-money the DCP-DN approach using a number of unpaved road sections located in selected African countries that were upgraded to a paved standard using the DCP-DN method. This entailed the collection and analysis of road data for these road sections in order to compare designs and costs standard with a selection of CBR-based pavement design methods for low volume roads (TRH4, DCP-CBR and ORN31). These actual designs were supplemented by a large number of “hypothetical” designs based on a wide range of road environmental conditions likely to be encountered in practice.

In view of the fact that the selected roads are all relatively new and without a performance history that would allow true whole-life costs to be evaluated, the cost comparison came down to only pavement construction costs as opposed to the intended whole-life-cost analysis.

The conclusion that was drawn from the very wide range of design evaluations was that, in general, the DCP-DN method is the most cost-effective design option at relatively low traffic classes, up to about 0.7 MESA and across all subgrade strengths. However, at traffic classes above 0.7 MESA the method gradually becomes less cost effective than the other methods, particularly ORN31, which becomes more cost-effective in many situations. It remains to be tested as whether this conclusion might apply to other similar catalogues contained in the various LVRR design manuals or guidelines in Africa and Asia.

In terms of Value for Money, the outcome of the various cost evaluations undertaken illustrate the general cost-effectiveness of the DCP-DN method in the lower traffic ranges up to about 0.7 MESA against the other design methods. The difference in pavement construction costs per km for the various design methods, and the pavement construction cost efficiency of the DCP-DN design method, relative to the other design methods, decreases with higher quality subgrades and higher traffic classes. Also, for the specific set of environmental conditions considered, there is no major difference in the trends between Wet and Dry-Moderate environments.

Workshop and Follow-on Discussions

A workshop on the DCP-DN Research Report was held in Durban, South Africa, at the end of the SARF/IRF/PIARC Conference on Friday 12th October 2018³. The workshop was attended by 23 persons representing roads agencies in three ReCAP partner countries, academia, the ReCAP Technical Panel, the ReCAP Programme Management Unit, independent consultants and the project consultants (report authors). The aim was to discuss whether the DCP-DN method was founded on sound scientific principles and the extent of its use with confidence albeit within defined limits. In addition, the workshop was expected to provide guidance on further research work necessary to improve the efficacy and applicability of the DCP-DN design method for LVRs.

Key comments to come out from the Workshop were:

1. The science behind the development of the DCP-DN method is well documented and credible but could be refined through additional research.
2. The limits of the application of the DCP-DN method need to be recognised.

³ Pinard, M. et al (2018). Evaluation of Cost-Effectiveness and Value-for-Money of DCP-DN Pavement Design Method for Low-Volume Roads in Comparison with Conventional Designs, Final Workshop Report. London: ReCAP for DFID.

3. Caution should be exercised about extrapolating or extending the method across different environmental conditions and geographical regions without further verification and performance monitoring.
4. The DCP does not measure any fundamental properties of pavement materials. It cannot assess mineralogy or soil type or the likely durability properties of pavement materials.

Discussion following the workshop led to further clarifications:

1. **Material selection.** There must be a continued requirement for traditional materials testing in the laboratory, DCP-DN testing cannot be used as a sole materials selection tool.
2. **Longer Term Potential.** DCP-DN and other DCP approaches are just one of a range of factors in a causal package delivering more effective and sustainable rural access.
3. **Cuts and Fills.** As with other DCP design approaches the DCP is not a relevant tool for design in areas of significant cut and/or fill (>2m) or in new alignments.

ReCAP Recommendations and Further Research

Following the discussions, ReCAP recommends further supported research and training in the use of the DCP-DN pavement design method be subject to key checks and safeguards. The following are suggestions on possible additional research, subject to budget and time:

1. A review of the variability of DCP results (Repeatability, “r” and Reproducibility, “R”) of the DCP in laboratory and the field is recommended. The poor variability of the laboratory CBR in terms of r and R has been cited as a major issue, but no evidence is yet available on the DCP.
2. Continued monitoring on the roads designed using the DCP-DN process is strongly recommended. The DCP-DN study included, through necessity, sections which had received just a fraction of the design traffic and this constitutes a risk that needs ongoing evaluation.
3. A wider evaluation for practitioners of the DCP as a design tool that includes the full UKDCP and ASTM procedures.
4. A Rural Road Note (RRN) 01: A Guide on the Application of Pavement Design Methods for Low Volume Rural Roads is currently being developed, whose aim is to provide guidance to a designer so they are able to compare design options using a systematic approach before final selection of the preferred option. The design options considered will include the DCP-DN approach.