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Dynamic Cone Penetrometer tests and analysis

Technical Information Note

By Colin Jones

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1. Introduction

The Dynamic Cone Penetrometer (DCP) is an instrument which can be used for the rapid measurement of the in situ strength of existing flexible pavements constructed with unbound materials. Measurements can be made down to a depth of 800 mm or to a maximum depth of 1500mm by adding an extension rod. Where the pavement layers have different strengths, the boundaries between them can be identified and the thickness of each layer determined using the software program called UK DCP 2.2. This software program is available free from the web site www.transport-links.org/ukdcp. The installation process will install the program along with the User Manual in the user's computer.

This Technical Information Note describes the DCP test procedure, provides guidance on details to be collected from each test and highlights the use of various outputs produced by UK DCP 2.2. The User Manual of UK DCP explains the installation of the program and gives a detailed description of the use of the analysis software. UK DCP 2.2 and the User Manual replaces the TRL DCP analysis program 1.06a previously distributed and Overseas Road Note 8. The program is intended for use by engineers responsible for roads or road networks who need to measure the properties of existing pavement. For example, it will be used by district engineers managing maintenance program, consultant engineers and road evaluators for rehabilitation and strengthening program, by engineers carrying out research studies, and so on.

2. The DCP

The TRL DCP uses an 8 Kg hammer dropping through a height of 575mm and a 60° cone having a maximum diameter of 20mm. The instrument is assembled as shown in Figure 1. It is important that the three screwed joints connecting handle and upper shaft, coupling (referred to as the 'anvil') and upper shaft, lower shaft and cone are kept tight at all times with "Loctite" or similar non-hardening thread locking compound prior to use⁽¹⁾. Operating the DCP with any loose joints will significantly reduce the life of the instrument.

3. Health and Safety issues

In order to avoid any potential damage to the underground utilities, **it is essential** to ensure that there are no utilities beneath the test location before the test starts. Adequate warning signs should always be used to caution the road users that work is in progress.

During testing the operators should **NOT** put their hands near the Anvil to ensure that their fingers are not trapped underneath the Hammer when it is dropped.

Key:-

- 1 Handle
- 2 Hammer (8kg)
- 3 Hammer shaft
- 4 Coupling
- 5 Handguard
- 6 Clamp ring
- 7 Standard shaft
- 8 1 metre rule
- 9 60° cone

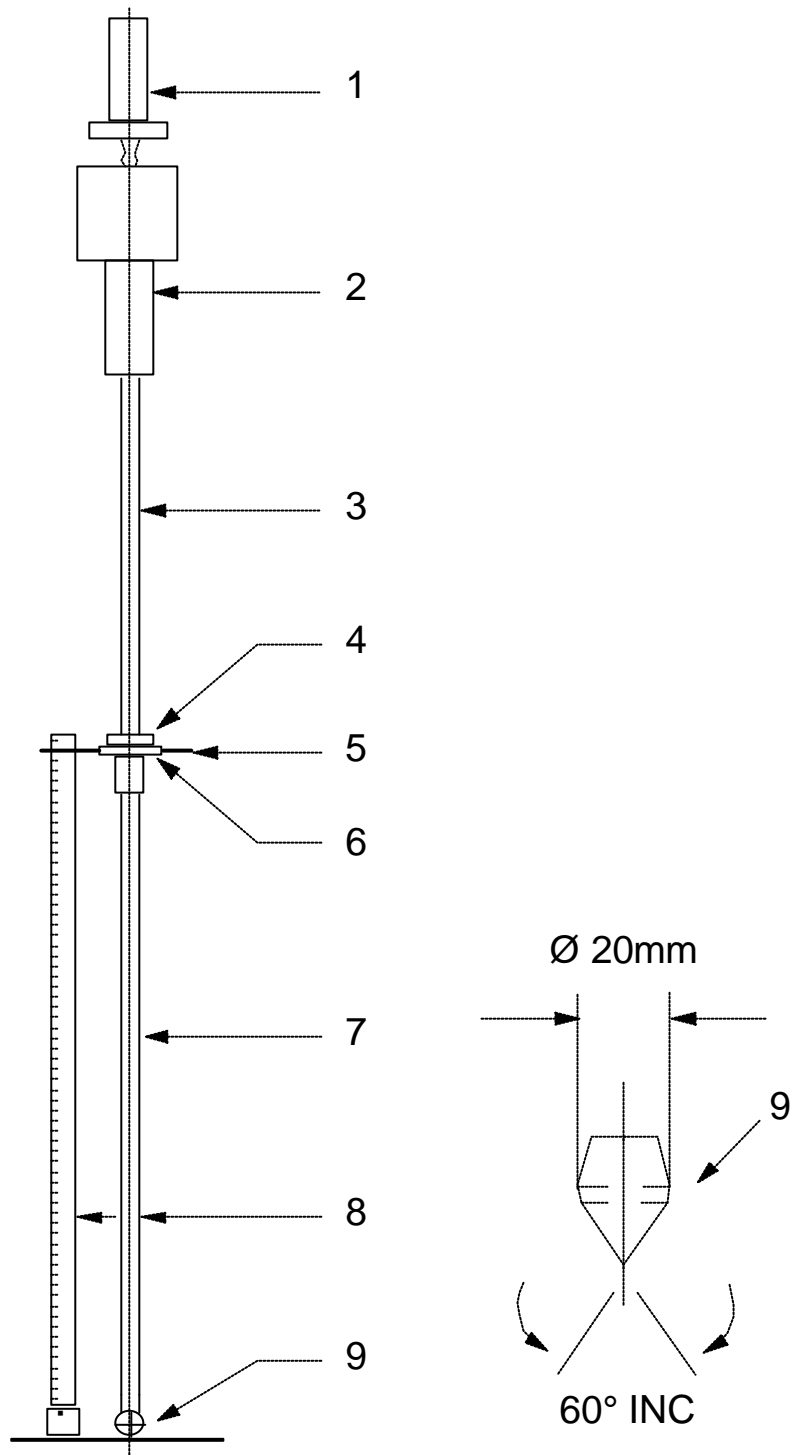


Figure 1 TRL Dynamic Cone Penetrometer

4. Operation and recording of data

After assembly, the first task is to record the zero error of the instrument. This is done by holding the DCP on a hard flat surface such as concrete, checking that it is vertical, and then entering the zero reading in the appropriate place on the DCP Test Data Form shown in Figure 3.

Prior to testing, site details should also be recorded on the Test Data Form. These include:

- Chainage (km)
- Location - either Carriageway, Shoulder, Verge or other
- Lane number – 1/2/3/4 if the location is carriageway
- Offset (m) As defined by user
- Direction
- Cone angle – either 30° / 60° cone
- Zero error (mm)
- Test date
- Remarks, if any to a maximum of 60 spaces
- Layers removed – None, One or Two
- Surface type – either Thin Bituminous Seal, Hot Mixed Asphalt, Unpaved, Concrete or Other
- Thickness of surfacing, if removed (mm)
- Surface condition – where the road has a bituminous surfacing
- Strength coefficient of surface, if surface condition unknown
- Base type – either Bituminous, Cement treated or Coarse granular (Water Bound Macadam)
- Thickness of base, if removed (mm)
- Strength coefficient of base, if removed

The DCP needs three operators, one to hold the instrument, one to raise and drop the weight and a technician to record the readings as shown in Figure 2. The instrument is held vertical and the hammer lifted to the handle. Care should be taken to ensure that when the hammer is raised, it does not 'lift' the instrument and just before the hammer is allowed to drop it is just touching the handle. The operator must let it fall freely and not partially lower it with his hands.



Fig. 2 Dynamic Cone Penetrometer in operation

Readings should be taken at increments of penetration of about 10mm. However, it is usually easier to take a reading after a set number of blows. It is therefore necessary to change the number of blows between readings according to the strength of the layer being penetrated. For

good quality granular bases, readings every 5 or 10 blows are usually satisfactory but for weaker sub-base layers and subgrades readings every 1 or 2 blows may be appropriate. There is no disadvantage in taking too many readings but if readings are taken too infrequently, weak spots may be missed and it will be more difficult to identify layer boundaries accurately.

After completing the test the DCP is removed by tapping the hammer upwards against the handle. Care should be taken when doing this; if it is done too vigorously the life of the instrument will be reduced.

The DCP can be driven through thin bituminous seals but thick hot mixed asphalt surfacings should be cored prior to testing the lower layers. Little difficulty is normally experienced with the penetration of most types of granular or lightly stabilised materials; however it is more difficult to penetrate strongly stabilised layers, granular materials with large particles, and very dense, high quality crushed stone. Penetration rates as low as 0.5mm/blow are acceptable but if there is no measurable penetration after 20 consecutive blows it can be assumed that the DCP will not penetrate the material. Under these circumstances a hole can be drilled through the layer using an electric or pneumatic drill. The lower pavement layers can then be tested in the normal way. If only occasional difficulties are experienced in penetrating granular materials, it is worthwhile repeating any failed tests a short distance away from the original test point.

If, during the test, the DCP leans away from the vertical no attempt should be made to correct it because contact between the shaft and the sides of the hole can give rise to erroneous results. If the lean becomes too severe and the hammer slides down the hammer shaft, rather than dropping freely, the test should be abandoned and the test repeated approximately one metre away.

If the DCP is used extensively for hard materials, wear on the cone itself will be accelerated. The cone is a replaceable part and it is recommended that it should be replaced when its diameter is reduced by 10 per cent. However, other causes of wear can also occur hence the cone should be inspected before every test.

5. Test spacing

Sampling frequency will depend on the objective of the testing. Table 1 below gives recommended minimum distances between DCP tests.

Objective	Minimum test spacing
Routine testing for the rehabilitation of paved roads	500m or less
Areas of distress in paved roads	100m or less
Upgrading of gravel roads to sealed roads	500m or less
Design of spot improvements	50m or less

Table 1 Recommended test spacing

6. Interpretation of results

DCP results can be analysed in a standard spreadsheet or using the UK DCP 2.2 software. The operation of the software is fully described in the User Manual. The facilities of the software are summarised below.

- a. The software allows for a maximum 999 DCP tests to be entered for any one project.
- b. Data entry allows for the use of an extension rod which can penetrate up to a depth of 1200 mm or for harder layers to be drilled out using an electric or pneumatic drill
- c. Two methods of analysis are provided. A 'System' procedure, which identifies changes in layer strength up to a maximum of 10 layers. A 'User' procedure, which allows the user to identify layers of uniform strength. Figure 4 shows a system analysis which has identified 4 layers in a test.

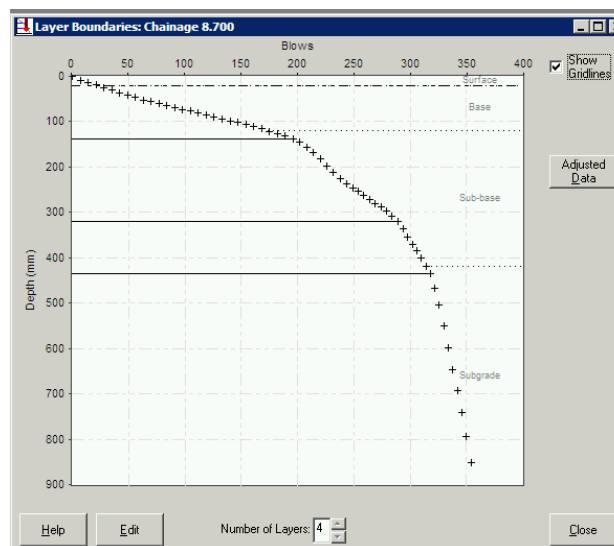


Fig. 4 Layers Identification by System analysis

- d. During analysis the software calculates the thickness and strength of each pavement layer identified, determines the Structural Number ⁽²⁾, the Modified Structural Number ⁽³⁾ and the Adjusted Structural Number (used in HDM4) ⁽⁴⁾.
- e. After analysis the software graphically displays the results of the individual tests and allows the user to identify any test that needs to be re-analysed.
- f. Once the DCP analysis is finalised, the software allows the user to identify homogeneous sections of road for design purposes using the CUSUM method of analysis. The parameters which can be considered in this analysis are:
 - CBR of the Base, Sub-base or Subgrade
 - Structural Number and Adjusted Structural Number
 - Thickness of Surface, Base, Sub-base and thickness of the complete Pavement.

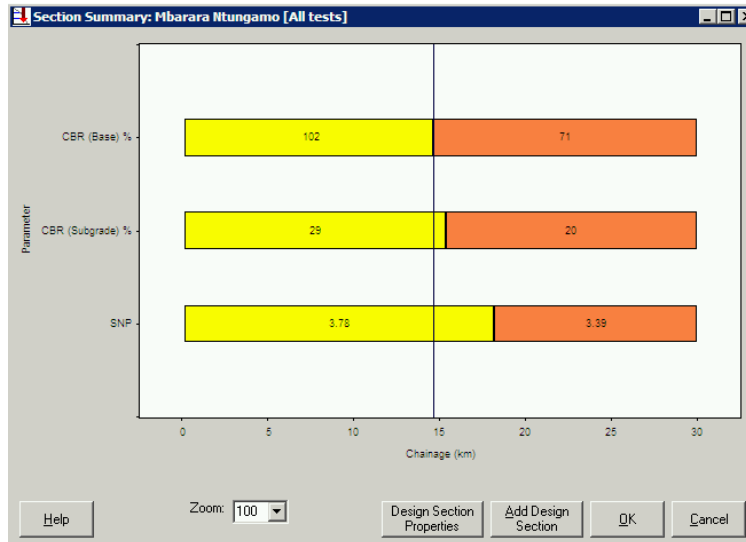


Fig. 5 Homogeneous Design Sections
(using CBR of Base, Subgrade and Adjusted Structural Number)

- g. After the sectioning process is completed the software reports the results of the following parameters in each design section of road.
- Base CBR
 - Sub-base CBR
 - Subgrade CBR
 - Structural Number
 - Adjusted Structural Number
 - Base thickness
 - Sub-base thickness
 - Pavement thickness

7. Summary

UK DCP provides essential information on the thickness and strength of the pavement layers using data collected during DCP tests. Its capability for dividing the road into smaller section of uniform characteristics greatly simplifies the task of interpreting DCP test data.

8. References

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