



**Government of the People's Republic of Bangladesh  
Ministry of Communications  
Roads and Highways Department**

**BENKELMAN BEAM DEFLECTION SURVEY MANUAL**



**MAY 2005**

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## 1 INTRODUCTION

A road network is a valuable Government asset and failure to maintain the roads that form the network will lead to their rapid deterioration which in turn will lead to increases in road user costs and accidents and the need for expensive re-construction works. Well-maintained roads make a valuable contribution towards the country's economy.

Maintenance of road is dependent on several factors, one of which is the bearing capacity of the pavement. To determine what treatment is necessary the bearing capacity of the pavement should to be known.

In Roads and Highways Department (RHD) the HDM Circle has the responsibility to produce the Annual Road Maintenance and Rehabilitation Needs Report using HDM-4 software. Bearing capacity of roads in terms of deflection has the greatest influence in the HDM analysis. So correct measurement of bearing capacity is a prerequisite for doing the correct HDM analysis.

Accurate information about pavement strength is a critically important input for use in RMMS.

Different types of tests such as the Benkelman Beam Test, Falling Weight Deflectometer and Dynamic Cone Penetrometer (DCP) test and the CBR test all provide useful information on pavement strength. It is obviously essential to select the right type of test. For strengthening of existing pavements, the Benkelman Beam test or the Falling Weight Deflectometer is preferred, since it gives the actual strength of the pavement directly and quickly.

The purpose of deflection testing is therefore to determine pavement strengths in order to decide what rehabilitation works need to be undertaken and how strong they need to be.

The surveys are to be carried out from the survey routes Start Node and to the survey routes End Node, e.g. always in positive direction.

The importance of having accurate deflection data for input into the RMMS cannot be overemphasized. The aim of this section is to set out, as clearly as possible, a simple description of what Benkelman Beam testing is and how it should be undertaken. The importance of accuracy of observation and attention to detail when filling out the various forms is stressed throughout.

This guide is accessible on the RHD Intranet.

## 2 TIMING OF DEFLECTION MEASUREMENT

Deflection measurement is done annually preferably from October to December.

## 3 EQUIPMENT NEEDED

Following equipment are needed for the Benkelman Beam measurement:

- Vehicles (Pickup or Jeep)
- Benkelman Beam (one or two)
- Distance Measurement Equipment (Odometer/Tripmeter)
- Truck (with a rear axle load of 8,16 tonne)

Other materials and stationers required are:

- Paint, chalk and brush
- Survey forms
- Wooden pencils
- Jute ropes

## 4 DESCRIPTION OF EQUIPMENT

### 4.1 Introduction

(Form BB1 and BB2)

The test procedure is described in full in sections 5.1. **Note** that this simplified procedure should be followed exactly to achieve the best implementation speed and provide sufficient accuracy for design.

All sound bituminous roads should be tested using the Benkelman Beam. Benkelman Beam testing can also be carried out on badly damaged bituminous roads provided that the pavement layers are not soft and/or loose (in depth). If, while testing a road, some of the evenly spread test points are soft and/or loose, this must be noted on the test form. The deflection should still be measured at the original points if at all possible. Additional test points 10 to 20 metres past the unsatisfactory original test points should also be tested.

The standard procedure for deflection testing is that the test is to be carried out in the outer wheel track. If for any reason the test has to be carried out driving against the general traffic, the test must still be taken in the outer wheel path (the wheel path closest to the edge of the pavement).

The Daily Calibration Record, Form BB1, must be completed at the beginning of each day's work and during the day whenever the truck moves to a new site. **Complete details of both beams and the truck weight are essential for future interpretation of the data.**

Form BB2, Rebound Deflection Test, contains the actual test point information. These forms must always be kept attached to the form BB1.

- The position of each test point is to be recorded on the form BB2. Position the truck as close to the test point as possible without being over accurate.
- There is no need to measure the distance from the side of pavement. Just position the truck normally in the lane.
- Record weather conditions at time of test, whether sky is clear, cloudy or rainy, and if conditions are hot or cool.
- Record if pavement surfacing is bituminous or gravel and if sound, or cracked, or disintegrated and/or soft.

## 5 BENKELMAN BEAM TEST PROCEDURE

### 5.1 Equipment Required

#### A Truck

The truck shall be a two-axle truck with a dual-tyred rear axle. The space between the tyres must be wide enough that the Benkelman Beam can be placed between the tyres without touching them. It is not necessary for the tyres to be of any standard pattern. The truck must be capable of travelling safely and reliably over the steepest and roughest roads to be encountered during the survey, whilst carrying a load of at least 8.16 tonnes on the rear axle (gross weight). The brakes, hand brake, motor and lights shall be in good condition. A working accurate Tripmeter is also very useful.

#### B Tyre Pressure Gauges and Tyre Pump

A tyre pressure gauge and one spare should be calibrated against a master gauge in the laboratory before each survey. The tyre pressure gauge shall be graduated in 0.2 kg/cm<sup>2</sup> (2.5 psi) divisions or smaller.

A tyre pump suitable for inflating the tyres to at least 5.6 kg/cm<sup>2</sup> (80 psi) shall be carried.

C Truck Scales

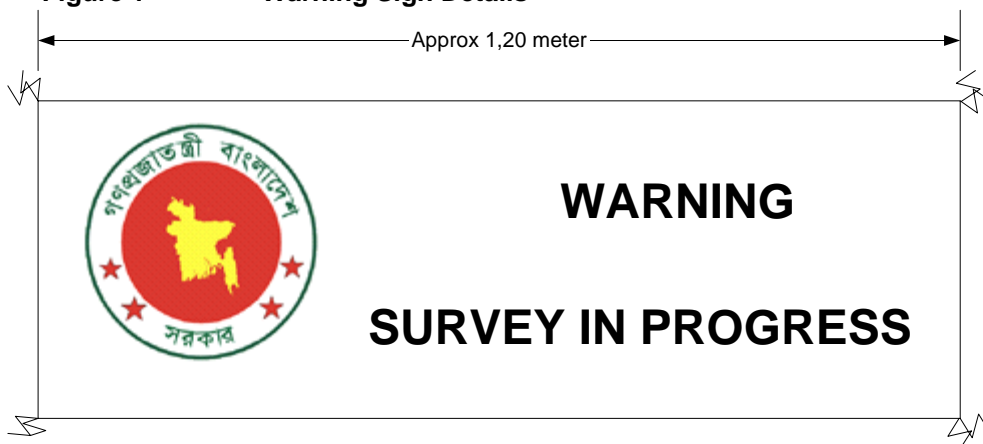
A suitable set of scales for measuring the load on the rear axle of the truck shall be carried on survey. It shall be calibrated using a concrete testing machine or other suitable means immediately before each survey (a suitable hydraulic-jack scale is shown in Figure 5b). During the calibration, the test load is plotted against the scale reading (pressure reading in the case of a hydraulic jack-scale). The value of the scale reading for a test load of exactly 4.10 tonnes can then be read off and entered on Form BB1 as calibration factor in B3.

D Safety

To safeguard the test team, especially on heavily trafficked roads, the following safety precautions should be taken:

A cloth or plywood warning sign, as shown in Figure 1, shall be attached to the truck tail-gate.

**Figure 1**                      **Warning Sign Details**



Two workers with flags, one in front and one behind the truck, for regulation of traffic and protection of the measuring team.

E Benkelman Beam

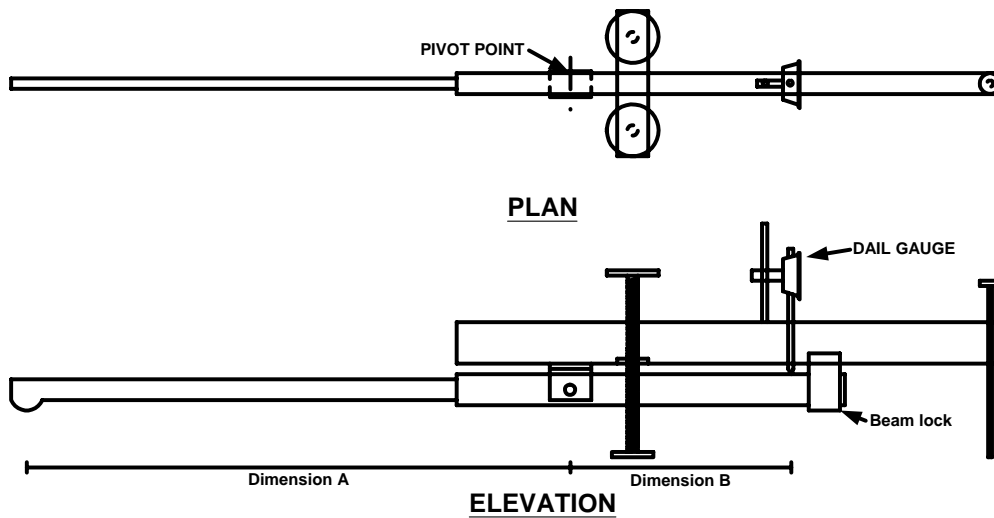
A Benkelman Beam is shown in Figure 2. Dimensions A and B must be recorded on form BB1 for each beam together with the Benkelman Beam No., before use on the survey.

The beam pivot bearing and the dial gauge must move freely without friction or slop. The entire apparatus, must be sturdy, rigid and without slop.

The dial gauge must be graduated in either 0.01mm or 0.001inch divisions. Metric gauges, with reverse (anti clockwise) scales, are preferred.

The beam shall be fitted with a lock to secure the beam during transport. A suitable vibrator mounted near the pivot point is desirable.

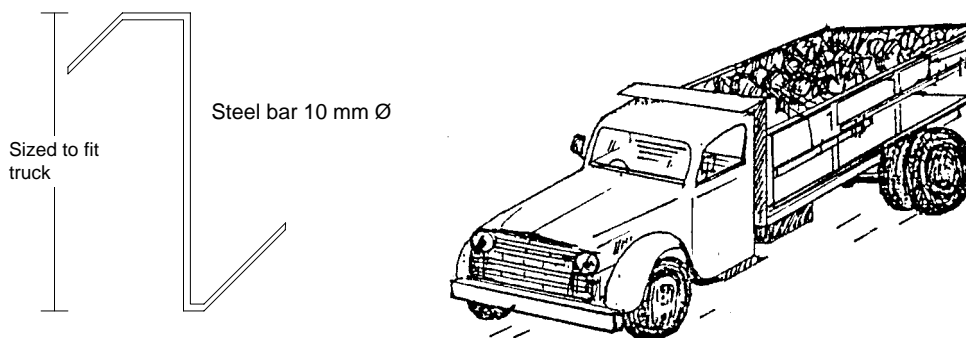
**Figure 2 Benkelman Beam**



A full set of spanners and tools for preparing and adjusting the Beam shall be carried.

The truck shall be fitted with suitable mounting brackets to carry the beam (between test points only). Figure 3 shows a suitable design of bracket. Before travelling at full road speeds, the Benkelman Beam should be disassembled and properly packed.

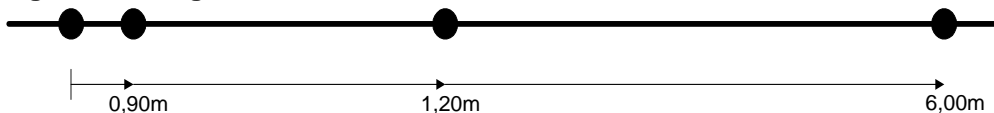
**Figure 3 Mounting Brackets for Benkelman Beam**



**F Tape Measure and Pavement Marker**

- 1 chalk, paint or some other method of marking the pavement locations.
- 2 a 50 metre measuring tape.
- 3 a string line marked at intervals of 0.90metre, 1.20metre, and 6.00metre, as shown in figure 4, may be used.

**Figure 4 String line**



G Field Data Collection Forms

Test forms should be delivered with Ref. Point Code and Offset fields filled out. If the test forms for any reason are delivered without the Ref. Point Code and Offset fields filled out adequate stocks of empty forms BB1 and BB2 for a minimum of one day's testing must be carried.

H Extra Equipment

If required, the deflections in the left and right hand wheel tracks may be measured simultaneously, using 2 teams of technicians, 2 beams and 2 sets of the equipment listed in Paragraph 3 above.

**Note:** Dimension "A" of the two beams should not differ by more than 2 cm.

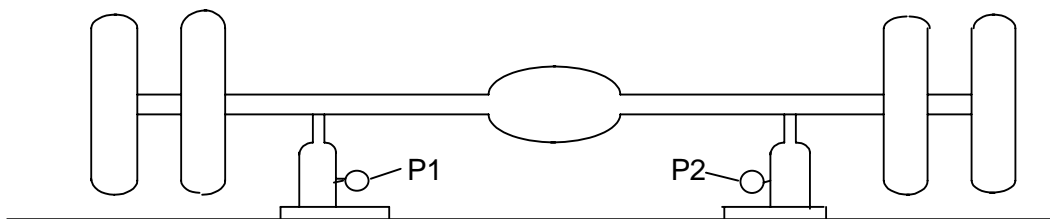
I Broom for Sweeping Pavement

## 5.2 Loading and Weighing Truck

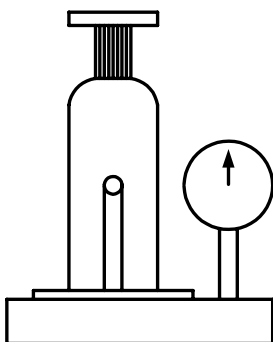
A The truck must be loaded so that the rear axle weight is approximately 8.16 tonnes  $\pm$  0,5 ton. The load must be secure so that it does not shift, and must not absorb water. Concrete blocks, well secured, asphalt or clean river stone hand levelled in the tray are suitable. Sand, bricks, soil and crusher run aggregates are unacceptable.

B Figure 5 (a) illustrates the procedure for weighing using a set of hydraulic-jack scales.

**Figure 5 Use of Hydraulic-Jack Scales to Obtain Axle Load.**



a. Weighing Procedure.



b. Hydraulic-Jack Scales

The truck must be parked on a hard surface so that it is as level as possible. The crown of the road pavement on a summit is acceptable. The jacks are positioned as shown in Figure 5. The

jacks are raised until the tyres are approximately 0.5 cm clear of the road. The pressure "P1" and "P2" is then noted.

The procedure for computing axle load and correcting deflection readings is given on form BB1.

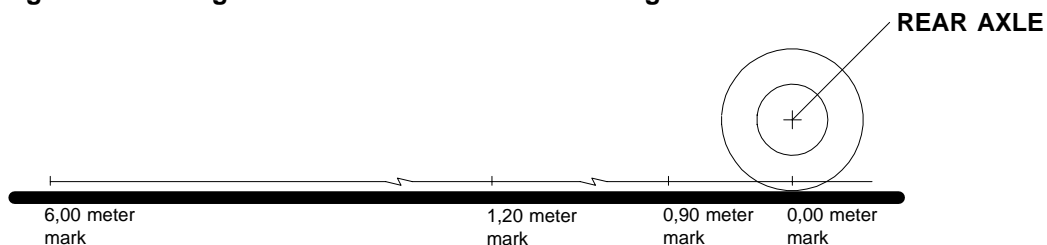
### 5.3 Checking Benkelman Beam Dimensions and Dial Gauge

- A At the beginning of the survey, the dimensions of each Benkelman Beam should be measured to the nearest 1mm, and recorded on Form BB1.
- B The dial gauge should be checked to see if it is calibrated in inches or mm.
- C Some dial gauges fitted to Benkelman Beams have been modified to read double the gauge movement. Check this, by engaging the Beam Lock and placing an object of known thickness (approx 5mm) under the gauge rod.
- D The Dial Gauge Multiplying factor (DGM) is computed, and entered on Form BB1 in field C3.
- E Finally, check the DGM factor by putting the object of known thickness under the probe tip and check that the dial gauge reading multiplied by DGM factor does give the object thickness.

### 5.4 Procedure for Deflection Measurement

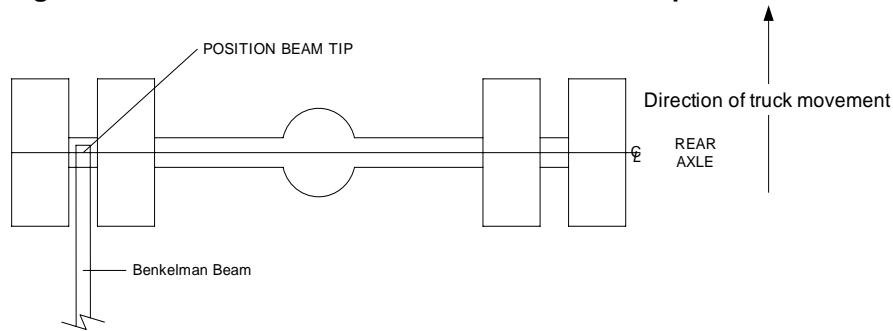
- A Each day after the truck arrives at the survey site:
  - 1 **Check axle load.** Adjust if not in range  $8,16 \pm 0,5$  tonnes, then record;
  - 2 **Adjust tyre pressure to 80 psi** ( $5,6 \text{ kg/cm}^2$ ).Fill in Form BB1 in full
- B The truck shall be driven in the traffic lane at about the same distance from the lane edge as the general truck traffic and in the same direction as the general traffic. If for any reason the test has to be carried out driving against the general traffic, the test must be taken in the outer wheel path (the wheel path closest to the edge of the pavement).
- C Stop the truck at the test location and record all required data on form BB2. If there is any loose material on the pavement it should be swept clear before finally positioning the truck.
- D Using the measuring tape or marked string-line, mark the pavement at points 0.00metre, 0.90metre, 1.20metre and 6.00metre ahead of the rear axle position.

**Figure 6 Marking Pavement For Deflection Reading Positions**



- E Prepare the Benkelman Beam equipment. Check dial gauge moves freely and smoothly.
- F Place beam in position behind truck with beam tip exactly under axle between the two tyres.

Figure 7 Plan View: Position of Benkelman Beam Tip



- G Secure Beam Lock in unlocked position.
- H Switch on vibrator if fitted, or tap beam lightly between pivot point and dial gauge for example with a pencil. Zero the dial gauge fine scale.  
**N.B.** Coarse scale readings must be taken for all readings, do not rely on counting needle rotations. If the dial gauge has a reverse (anti clockwise) scale, that scale is used.
- I Move truck very slowly forward and stop when the axle is over the 0.90 metre marking, within  $\pm 5$  cm. Tap the beam or use vibrator and record the dial gauge reading. Record axle position and dial gauge reading.
- J Move truck very slowly forward until the rear axle is over the 1.20 metre mark, within  $\pm 5$  cm. Read and record dial gauge reading as before.
- K Move truck very slowly forward until the rear axle is just over the 6.00 metre marking. Read and record the dial gauge reading as before.
- L **For each test point repeat the test two times**, reverse the truck so that the rear axle again is placed over the tip of the Benkelman Beam as shown in Figure 7. Then repeat the measuring procedure from E.
- M Re-lock the beam and lift Benkelman Beam onto the hangers.
- N Continue on to next test point.

Distance to next test point is equal to the offset value indicated on the form BB2, or if next test point is a reference point and the distance to the reference point is slightly more or less than the offset value, then "reset" at the reference point. The distance to the next testing point can be measured in one of the following ways:

- 1 Tripmeter in the truck, either on the trucks own tripmeter if the scale is in 0.010 km or by an external tripmeter fitted to the truck.
- 2 measuring tape (50m or 100m) or measuring wheel.
- 3 A piece of rope (or similar) where the distance between two knots gives the distance e.g. 50m.
- 4 By another car or motorcycle equipped with a tripmeter with a scale of at least 0.100 km or an external fitted tripmeter.

## 5.5 Reference System

The following section describes how deflection testing should be carried out using the Reference System:

It is assumed that:

Tests are to be done for each 50 m. Alternate lanes at each test point.

(Other test intervals could be 25m or 100m depending of the project type for which the deflection is to be used).

The survey is always carried out in the direction of the traffic – never against the traffic in a lane.

First test is to be taken shortly after the start of the link, here at chainage 0,010 (same as Start Node and offset 10 on the survey sheet) if the start of the link is in km 0,000.

With an offset value of 50 m., the next test is to be taken at km 0,060 (Start Node, offset 60), the next at km 0,110 (Start Node 0, offset 110) etc.

The surveyor should mark the positions to be measured in the inbound lane when marking the positions in the outbound lane. The chainage in both lanes must be measured from the start of the road/micro-link.

If the distance between km points is not exactly 1000m and the truck is not equipped with a tripmeter, then remember to "reset" the tripmeter at the reference point. If the truck is fitted with a tripmeter the distance in the first column on the data sheet gives the correct distance from the starting point and to the test point and can be used instead of the kmpost and offset reference.

The offset value gives the distance from the reference point to the test point. The offset value at a reference point is always 0.000.

**If the Link is very short (less than 150m), then a minimum of 3 point evenly spaced along the Link should be measured.**

The test procedure described here is in accordance with the data reference point system used for the URMS data base, and will make it easier for both engineers, technicians and operators to minimize the number of errors and data failures that can occur when information is passed between different groups of people.

Tests carried out on a road where the data sheet provided has not already been filled out must follow the same methodology as described above.

**APPENDIX A**  
**Benkelman Beam Test Forms**

**BENKELMAN BEAM TEST FORM**

ZONE: \_\_\_\_\_  
ROAD: \_\_\_\_\_  
LINK: \_\_\_\_\_

DATE OF TEST: \_\_\_\_\_  
SURVEYOR: \_\_\_\_\_  
TRUCK ID: \_\_\_\_\_

SKETCH OF LOCATION:

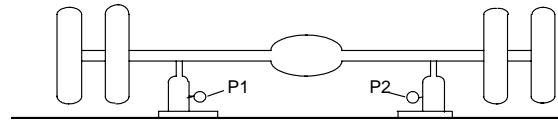
**TRUCK (C)**

- 1 REAR AXLE LOAD: \_\_\_\_\_ TONNE (MEASURED BY WEIGHBRIDGE)
- 2 ESTIMATED REAR AXLE LOAD BY USING JACK NO.: \_\_\_\_\_ AND JACK NO.: \_\_\_\_\_  
 DIAL READING (P1): \_\_\_\_\_ PSI DIAL READING (P2): \_\_\_\_\_ PSI  
 CALIBRATION (K1): \_\_\_\_\_ PSI CALIBRATION (K2): \_\_\_\_\_ PSI

AXLELOAD CALCULATION:

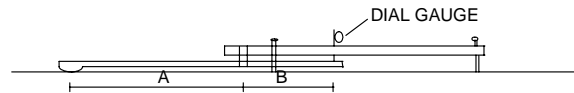
AXLELOAD =  $4.1 * ((P1/K1) + (P2/K2)) =$  \_\_\_\_\_ TON

TIRE PRESSURE: \_\_\_\_\_ PSI  
 \_\_\_\_\_ KG/CM2



**BENKELMAN BEAM (A)**

- 1 BENKELMAN BEAM NO.: \_\_\_\_\_
- 2 DIMENSION A: \_\_\_\_\_ m  
 B: \_\_\_\_\_ m



- 3 DIAL GAUGE SCALE: 0.01 mm  0.001 inch

