METHOD A8

THE DETERMINATION OF THE CALIFORNIA BEARING RATIO OF UNTREATED SOILS AND GRAVELS

1. SCOPE

The California Bearing Ratio (CBR) of a material as defined below, is determined by measuring the load required to allow a standard piston to penetrate the surface of a material compacted according to Method A7. The determination of the CBR-density relationship and swell of the material is also covered.

Definition

The California Bearing Ratio of a material is the load in Newtons, expressed as a percentage of California standard values, required to allow a circular piston of 1 935mm^2 to penetrate the surface of a compacted material at a rate of 1,27 mm per minute to depths of 2,54, 5,08 and 7,62 mm. The California standard values for these depths are 13,344, 20,016 and 25,354 kN respectively.

2 APPARATUS

2.1 Moulds, 152,4 ± 0,5 mm in diameter and 152,4 ± 1 mm high, detachable collar, a base plate, 25,4 ±1 mm spacer plate and perforated soaking base plates (see Method A7, Section 2.1)(Figure A7/l).

2.2 A 4,536 kg ± 20 gram tamper with a 50,8 ±1,0 mm diameter face and with a sheath to give a 467,2 ± 2 mm drop.

2.3 A 2,495 kg ± 10 gram tamper with a 50,8 ± 1,0 mm diameter face and with a sheath to give a 304,8 ± 2 mm drop.

2.4 Annular 4,536 kg ± 50 9 surcharge weights for use during soaking or alternatively a combined unit for items 2.4 and 2.6, i.e. a surcharge weight of 5,56 kg with adjustable stem (Figure A8/ll).

2.5 An annular 5,56 kg ± 50 gram surcharge weight for use during penetration.

2.6 1,024 kg ± 10 gram perforated plates with adjustable stems.

2.7 A steel straight-edge, approximately 300 mm in length and having one bevelled edge.

2.8 A tripod (Figure A8/ll).

2.9.1 Two dial gauges reading 0,01 mm with a range of 25 mm, one to be fitted on tripod for measuring swell and one for measuring depth of penetration (see 5.1).

2.9.2 A dial gauge with 0,127mm divisions, range 25 mm and 1,27 mm per revolution for measuring depth of penetration (see 5.1).

2.10 A compression testing machine with a capacity of at least 55 kN total load, recordable to the nearest 50 N and capable of applying load at a rate of strain of 1,27 mm per minute.

2.11 A metal circular piston with a diameter of 49.6 ± 0,5 mm and weighing 4,536 kg ± 50 gram, i.e. if not attached to the compression machine.

2.12 A stopwatch with 60 second dial.

2.13 A balance to weigh up to 15 kg, accurate to 5 gram.

2.14 A balance to weigh up to 2 kg, accurate to 0,1 gram.

2.15 Suitable containers to hold about 1000 gram material for determination of moisture contents .

2.16 A drying oven, thermostatically controlled and capable of maintaining a temperature of 105 to 110 EC.

2.17 Sieves - A 19,0 mm and 4,75 mm according to SABS 197.

2.18 A steel tamper or a small laboratory crusher.

2.19 A riffler.

2.20 An iron mortar and pestle and a rubber-tipped pestle.

2.21 A sample extruder, i.e. a jack, lever, frame, or other device adapted for the purpose of extruding compacted specimens from the mould (optional).

2.22 Measuring cylinders,1000 ml and 500ml capacity.

2.23 A water-spray or sprinkler.

2.24 Filter paper, 150 mm rounds.

2.25 Copper or brass gauze discs, about 30mesh and 170 mm diameter.

2.26 A galvanized iron mixing bath, about 450 mm x 650 mm x 200 mm deep.

2.27 A garden trowel.

2.28 A spatula.

2.29 An air-tight container, about 18 litre capacity.

2.30 A soaking bath, about 300 mm deep. *(for calibrating the moulds)*

2.31 A 180 mm x 180 mm glass plate, ± 7 mm thick.

2.32 Lubricating grease.

2.33 A 5 ml pipette.

2.34 A thermometer, measuring 0 - 50 EC.

3 METHOD

3.1 Preparation

The material is prepared as set out in Method A7, i.e. all aggregate retained on the 19,0mm sieve is crushed lightly to pass that sieve, and if the sample contains soil aggregations, these should be disintegrated. Approximately 25 kg of the thoroughly mixed material is now divided out. I n order to ensure that the material used for this test is exactly similar to that used for the determination of the moisture-density relationship, the preparation and division for the two tests are carried out at the same time as one operation (see 5.2).

3.2 Determination of hygroscopic moisture content

Two representative samples are taken and placed in suitable containers to determine the moisture content. The samples should be between 500 and 1 000 9. The more coarsely graded the material, the larger the samples. The samples are weighed immediately and dried to constant mass in an oven at 105 to 110EC. The average moisture content is determined to the nearest 0,1 per cent (see 5.3). Immediately after the moisture content samples have been taken, the material is transferred to an air-tight container

3.3 Admixture of water

The moulding moisture content should be the optimum moisture content (± 0,3 per cent) as determined in accordance with Method A7. Therefore, the additional water to be admixed is the difference between the optimum and the hygroscopic moisture content. After the latter has been determined the material in the airtight tin is weighed and transferred to the mixing bath. The required amount of water is calculated, measured out and added slowly by means of the spray can or sprinklers (see 5.4). While adding the water, the material should be mixed continuously with a trowel. The moist material is now covered with a damp sack to prevent evaporation and allowed to stand for at least half an hour so that the moisture may become evenly distributed throughout. After a quick rem ix, a representative sample is taken for the determination of the moisture content and the moist material is then again transferred to the airtight tin, where it remains until the result of the moisture determination is available, usually overnight. If the moisture content is more than 0,3 per cent above the optimum moisture content, the whole sample is remixed in the bath, allowing the moist material to dry slightly by evaporation. The operator will have to use his discretion as to how long the material should be mixed. If the moisture content is more than 0,3 per cent below the optimum moisture content, the calculated additional water is admixed. After either of these adjustments has been made, another moisture content is determined, the moist material in the air-tight tin again being stored until

the result is available. No further adjustment ought to be necessary if the operator is reasonably experienced.

N.B. - The mixing of the wet material in order to ensure that it is homogenous and at the right moisture content is most important. When mixing, the moist material should be kept loose and on no account should the clayey soil fines be allowed to form clods. Care should also be exercised to ensu re that representative samples are taken for moisture content determinations.

3.4 Preparation of moulds

The volumes of three moulds are determined as set out in Method A7, Section 5.3. The clean dry moulds are then weighed and one is assembled ready for tamping. Two 150 mm rounds of filter paper are placed on the spacer plate and the collar is fitted to the mould.

3.5 Compaction

The moist material (at the specified moisture content) is transferred from the tin to the mixing bath. It is thoroughly but rapidly mixed and then covered with a damp sack, which should be kept over the material until the compaction is completed so as to keep the moisture content as constant as possible.
The first mould is now tamped full of material, the excess material removed and only the mould with the material weighed, as described in Method A7. A representative sample for moisture content is now taken from the mixing bath.
The second mould is then assembled immediately and tamped full of material in a similar manner, except that only 25 blows of the 4,536 kg tamper are applied to each layer. It is probable that for each layer to be compacted, less material will have to be weighed off than in the case of the higher compactive effort. The moulded material is finished off and weighed and another representative sample for moisture content is taken from the mixing bath.
The third mould is then prepared and tamped full of material, but in th is case only three layers of material are compacted and on each layer 55 blows of the 2,495 kg tamper are applied. As with the other compactive efforts, between 5 mm to 15 mm of material should project above the top of the mould, and hence, each layer should be approximately 46 mm in thickness. The moulded material is again finished off and weighed.
The compactive efforts used for the three moulds are summarized as follows:

(a) 4,536 kg tamper, 457,2 mm drop, five layers and 55 blows per layer.
(b) 4,536 kg tamper, 457,2 mm drop, five layers and 25 blows per layer.
(c) 2,495 kg tamper, 304,8 mm drop, three layers and 55 blows per layer.

The average of the two moisture content determinations, taken after the compaction of the first and second moulds, is taken as the moulding moisture content for all three moulds.

3.6 Soaking

Three perforated soaking base plates are placed ready with a wire gauze disc over the perforations and a 150 mm round of filter paper on top of the gauze. Each mould is then placed on the filter paper with the finished off surface facing downwards and screwed down tightly onto the soaking plate. The surface of the moulded material which was against the spacer plate, and on which there is a round of filter paper, should be facing upwards.
A perforated plate with adjustable stern is then placed on top of the filter paper on the surface of the material and a 4,536 kg surcharge weight is placed carefully on top of the plate. The whole assembly is then transferred to an empty soaking bath. The tripod with the dial gauge is then placed on the mould with the rear leg on a mark on the rim of the mould so that the same position is used for subsequent readings of the swell. The stem of the perforated plate is adjusted so that the dial gauge reads 1 mm. After removal of the tripod and dial gauge, the bath is filled with water to a depth of about 12 mm above the top of the mould. To ensure that the water has free access to the bottom of the material in the mould, suitable strips are fitted to the bottom of the bath, or, alternatively, a layer of small stone chippings is placed in the bath. The mould with material is allowed to soak for four days, and readings with the dial gauge should, if possible, be taken each day.

3.7 Draining after soaking

After four days' soaking, the mould, with perforated plate, etc., is removed from the water. The water is poured out by holding the mould in a slanting downward position and holding the perforated plate and soaking weight in position. It is held like this for about one minute and then returned to its normal position and allowed to drain for 15 minutes on a grid or on a layer of chippings. The perforated plate with stem and the soaking weight are removed carefully.

N.B. - In all handling of the moulded material care should be exercised not to jar the material.

3.8 Penetration

The mould with material, still screwed down on the soaking plate, is placed in the press and the 5,56 kg surcharge weight is placed carefully on top of the material as centrally as possible. The penetration piston is seated on the surface of the material through the centre of the annular weight (see 5.5). The depth gauge is fitted in such a manner that the depth of penetration of the piston into the material can be measured. The speed of penetration is determined by means of the stop-watch and it is, therefore, desirable to have it mounted adjacent to the dial gauge, with the two zeros at the top of the dials. After setting the depth gauge to zero, the load is applied at a uniform rate of penetration of 1,27 mm per minute. Load readings are taken every 0,635 mm penetration as recorded on the depth gauge. The piston is allowed to penetrate 9,0 mm or slightly more (see 5.6). Having a depth gauge registering 1,27 mm per revolution, and a stop-watch with a 60-second dial, means that the hands of the gauge and the stop-watch should move round together (see 5.1).

4 CALCULATIONS

4.1 Moisture Content (per cent)

4.1.1 The hygroscopic moisture content, the check moisture contents after admixing of water and the moulding moisture content are calculated as set out in Method A7.

4.2 Amount of water to be admixed

$$W = \frac{z(y - x)}{100 + x}$$

where

W = amount of water to be admixed
x = hygroscopic moisture content.
y = required (optimum) moisture content.
z = mass of air-dried test sample.

4.3 Dry density of moulded material (kg/m3)

Using the moulding moisture content, the dry density of the moulded material is calculated as set out in Method A7.

4.4 Swell (per cent)

$$S = \frac{(k - L)}{127} \; x \; 100$$

where

S = swell expressed as a percentage of the height of the moulded material before soaking, i.e. 127mm
k = dial gauge reading after four days' soaking
L = dial gauge reading before soaking

The swell is reported to the nearest first decimal point on the A8/1 or similar form

4.5 California Bearing Ratio

For each specimen the stress-strain curve is drawn on a natural scale, i.e. the load readings are plotted against the depth of penetration (see appended example, Figure A8/l). In some cases the curve will have a concave downward shape, varying from an almost straight line relationship to a curve in which the rate of increase in the load readings decreases with the depth of penetration. However, many curves in the initial stages have a concave upwards shape, and in order to obtain true stress-strain relationships, such curves should be corrected by extending the straight line portion of the curve downwards until it intersects the abscissa. The point of intersection is then taken as the zero depth of penetration.

Using this new zero, the load is read off at 2,54 mm, 5,08 mm and 7,62 mm penetration. The readings for the above depths of penetration are then expressed as a percentage of the California standard for that penetration, viz.

Penetration	**California Standard**
Millimetres	kNewtons
2.54	13.344
5.08	20.016
7.62	25.354

This percentage is called the California Bearing Ratio (CBR) at the particular depth of penetration. The CBR at 2,54 mm penetration is generally used for assessing the quality of materials.
All calculations should be carried out to the first decimal figure except for the quantity of water to be added which is calculated to the nearest gram or ml.

4.6 CBR-Density Relationship

In order to obtain the relationship between CBR and dry density, the CBR at 2,54 mm penetration is plotted on a logarithmic scale against the dry density on a natural scale for the three compactive efforts used, on Form A8/4. The best fit line of the three points is an isoline of moulding moisture content, i.e. the moisture content is the same for the three points. The design CBR can thus be obtained at the desired percentage of the maximum dry density--normally the specified minimum percentage compaction. The results are recorded on the A8/2 or similar Form.

5 NOTES

5.1 The 0,01 mm gauge may be used to measure the depth of penetration and the 0,127 mm gauge to control the rate of penetration, as described in 3.8. As an alternative, the 0,127 mm gauge may also be used to measure the depth of penetration and load readings may be taken every 0,635 mm penetration, i.e. at the 'bottom' and 'top' position of the gauge.

5.2 In view of the fact that the optimum moisture content has to be determined (Method A7) before the CBR test can be carried out, the first part of the procedure (3.1 to 3.5) can be adapted as follows:

5.2.1 *Preparation* - After a sufficiently large sample for the moisture-density and CBR test has been prepared to pass the 19,0 mm sieve, the material is moistened to about three per cent below optimum moisture content and mixed thoroughly. The whole sample is then transferred to air-tight tins and stored at least overnight. This will allow the moisture to become evenly distributed which is a desirable condition.
The material is then quartered so as to obtain eight portions of equal mass (6 - 7 kg is required per portion). Five portions are used for the moisture-density test and are kept under damp sacks to avoid loss of moisture. The other three portions may be returned

to air-tight tins.

5.2.2 *Hygroscopic moisture* - The determination of this is no longer necessary.

5.2.3 *Admixture of water*- The optimum moisture content for the dry density can be obtained by plotting the wet density against an assumed moisture content (which is the estimated moisture content plus the nominal percentage water added) on the Form A8/3. It can also be obtained by plotting the computed dry density as described in Method A7. As the moisture content of the material used for the moisture density test and for the CBR test is the same (because of the moistening beforehand), the same percentage water required to achieve optimum moisture content on the preliminary moisture-density curve is added to the material. It is not necessary to carry out a check moisture content with the view to adjusting the moisture content. After the mixing in of the water, the material is kept under a damp sack, ready for compaction.

5.2.4 *Compaction* - Immediately prior to compaction a sample of ± 1 000 gram is taken to determine the moisture content, and the material is compacted as described above.

5.3 If the duplicates of the moisture content determinations differ by more than 0,5 per cent, another determination ought to be carried out and the average of the two with the best agreement taken.

5.4 In calculating the required amount of water to be admixed, it is advisable to allow for evaporation during mixing by adding slightly more water, say 0,1 to 0,3 per cent, depending on weather conditions.

5.5 If the penetration piston is attached to the penetration machine, a load of 45 N should be applied to the piston before the dial gauge is set at zero. This load is the same as the weight of a loose piston and ensures that the piston is truly seated.

5.6 The penetration is continued beyond 7,62 mm to allow for an extension in the stress-strain curve if a correction is required which results in a considerable shift of the zero depth of penetration .

5.7 The material may also be compacted with a mechanical tamping machine, provided:

(a) that it complies with the requirement regarding density as set out in Method A7, Section 5.4;

(b) that the tamper face is of the same shape and diameter as the hand tamper; and

(c) that the spacing of the blows is the same as with the hand tamper.
A tamping machine with a triangular tamper face is. therefore, not acceptable.

5.8 Particular care should be taken with materials which do not adhere to the side of the mould and are liable to drop out of the mould if the mould is handled without the base plate. In this instance, after the surface of the moulded material has been finished off, a weighed soaking plate and wire gauze are inverted over the top of the moulded material on which a round of filter paper has already been placed. The soaking plate is

screwed into position and the whole assembly, including the base plate, is inverted. The base plate with the spacer plate, is removed carefully and the mould, material and soaking plate are weighed.

5.9 When granular materials are compacted, it will be found that the filter paper on the spacer plate side of the moulded material becomes fractured and should be covered with a fresh round of filter paper before placing the perforated plate with stem in position.

5.10 Although it is not necessary to determine the volume and mass of the moulds for each test, these should, nevertheless, be checked regularly.

REFERENCES

AASHTO Designation T193-63
ASTM Designation D1883-67

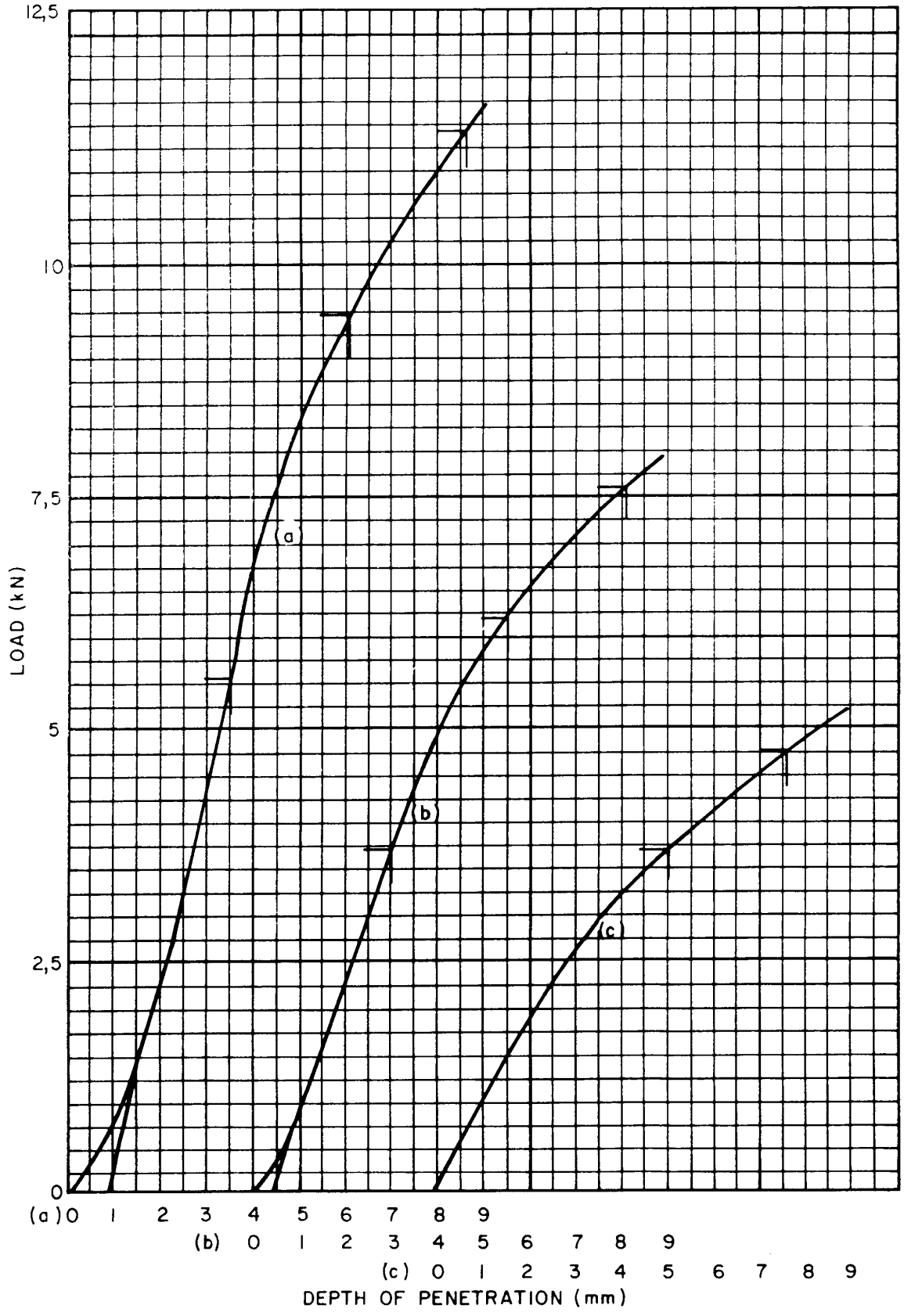


FIGURE A8/I

Example of a CBR curve

SAMPLE NO _____
MONSTER NR _____

DATE _____
DATUM _____

MAX DRY DENSITY _____/O M C _____
MAK. DROË DIGTHEID _____/O V I _____

MASS OF AIR DRY MATERIAL _____
MASSA VAN LUGDROË MATERIAAL _____

MOISTURE CONTENT DATA
VOGINHOUDDATA

	HYGROSCOPIC M C HIGROSKOPIESE V I		WATER REQUIRED (%) WATER NODIG	CHECK M C. AFTER MIXING KONTROLEER V I NA MENGPROSES		MOULDING M C VORMINGS-V I	
CONTAINER NO HOUER NR							
MASS OF CONTAINER & WET MATERIAL MASSA VAN HOUER & NAT MATERIAAL							
MASS OF CONTAINER & DRY MATERIAL MASSA VAN HOUER & DROË MATERIAAL							
MASS OF CONTAINER MASSA VAN HOUER							
MASS OF WATER MASSA VAN WATER							
MASS OF DRY MATERIAL MASSA VAN DROË MATERIAAL			ml				
% WATER % WATER							
				AVERAGE MOULDING M C GEMIDDELDE VORMINGS-V I			%

COMPACTION DATA
VERDIGTINGSDATA

	(a)	(b)	(c)
COMPACTIVE EFFORT VERDIGTINGSKRAG			
MOULD NO VORM NR			
FACTOR FAKTOR			
MASS OF MOULD & WET MATERIAL MASSA VAN VORM & NAT MATERIAAL			
MASS OF MOULD MASSA VAN VORM			
MASS OF WET MATERIAL MASSA VAN NAT MATERIAAL			
MASS OF DRY MATERIAL MASSA VAN DROË MATERIAAL			
DRY DENSITY DROË DIGTHEID			
% COMPACTION % VERDIGTING			

EXPANSION DATA
UITSETTINGSDATA

DAYS DAE	1	2	3	4	1	2	3	4	1	2	3	4
% SWELL % UITSWELLING												

PENETRATION DATA
PENETRASIEDATA

DEPTH / DIEPTE (mm)		READING LESING	CORRECTED READING AANGEPASTE LESING	CBR KDV	READING LESING	CORRECTED READING AANGEPASTE LESING	CBR KDV	READING LESING	CORRECTED READING AANGEPASTE LESING	CBR KDV
0,01 mm GAUGE 0,01-mm-METER	0,127 mm GAUGE 0,127-mm-METER									
0,0	0,000									
0,5	0,635									
1,0	1,270									
1,5	1,905									
2,0	2,540									
2,5	3,175									
3,0	3,810									
3,5	4,445									
4,0	5,080									
4,5	5,715									
5,0	6,350									
5,5	6,985									
6,0	7,620									
6,5	8,255									
7,0	8,890									
7,5	9,525									
8,0										
8,5										
9,0										

FORM A8/1

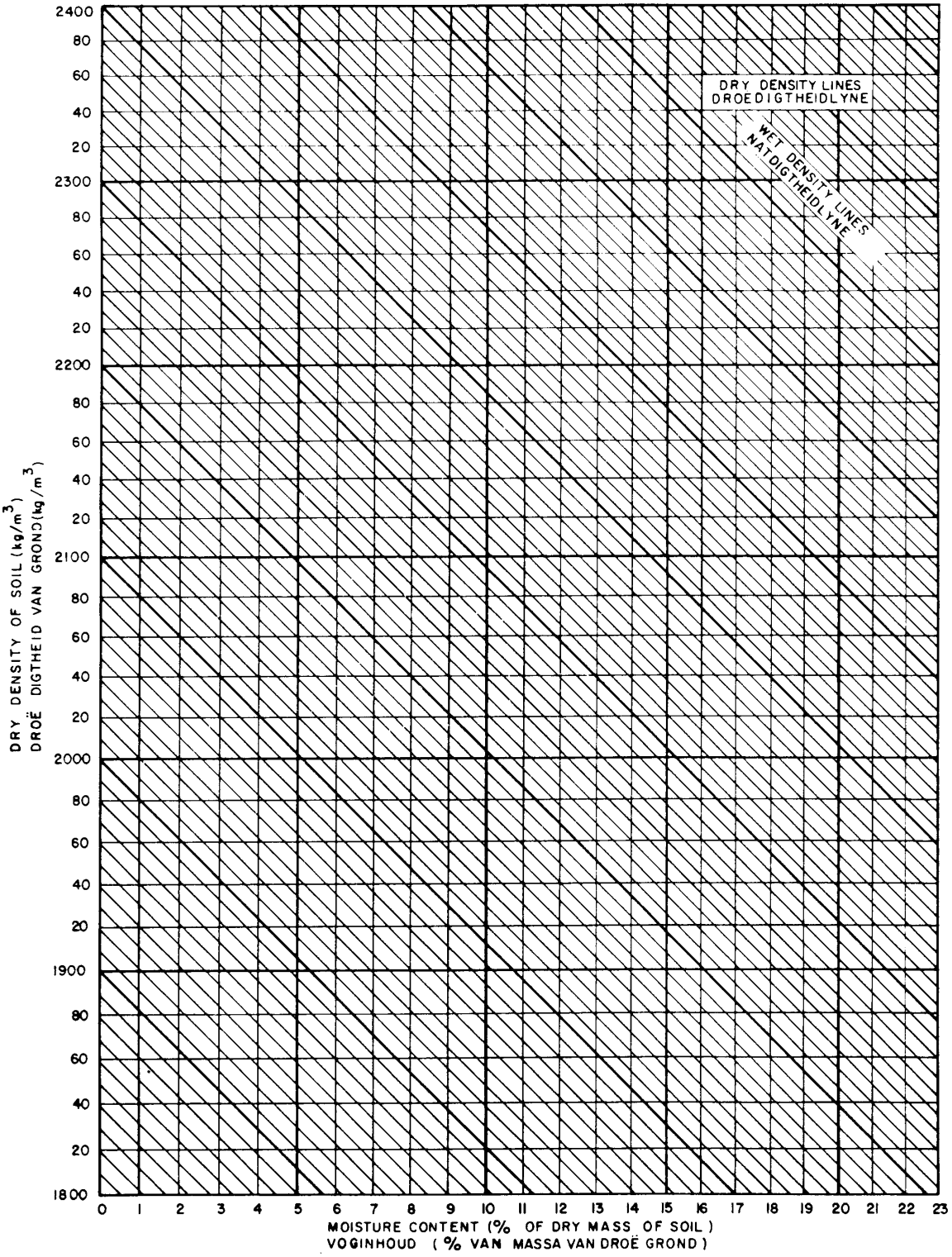
Recording sheet for the determination of the CBR of untreated soils and gravel

CBR / KDV

SAMPLE NO. MONSTER NR.		BEARING RATIO AT DRAKRAGVERHOUDING BY			SWELL (%) UITSWELLING	MOD AASHTO DATA GEWYS AASHTO-DATA		COMPACTION DATA VERDIGTINGSDATA		
		2,54 mm	5,08 mm	7,62 mm		MDD	OPTIMUM MOISTURE OPTIMUM VOG	DRY DENSITY DROE DIGTHEID	COMPACTION (%) VERDIGTING	MOISTURE (%) VOG
	a									
	b									
	c									
	a									
	b									
	c									
	a									
	b									
	c									
	c									
	b									
	c									
	a									
	b									
	c									
	a									
	b									
	c									
	a									
	b									
	c									
	a									
	b									
	c									
	a									
	b									
	c									

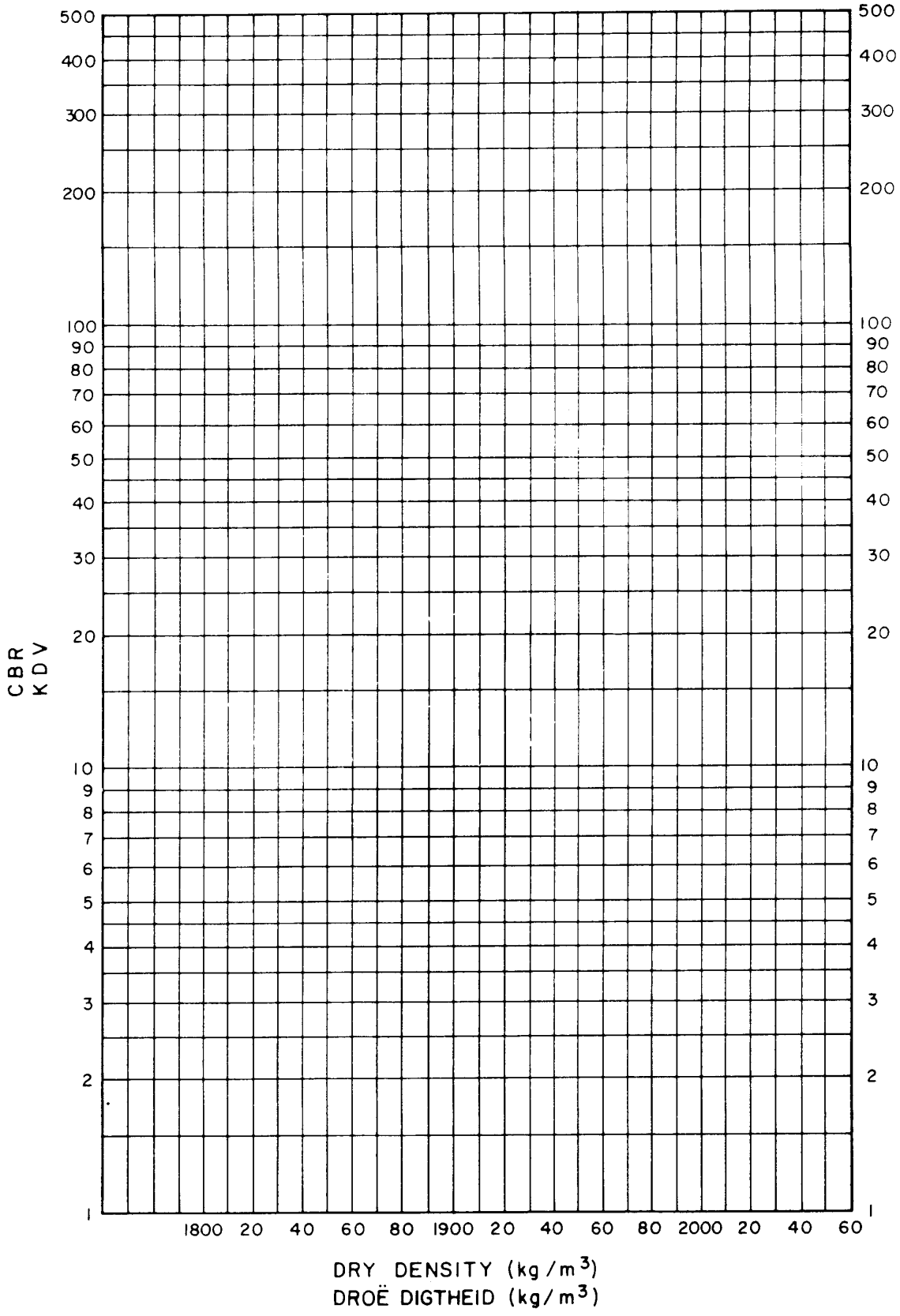
FORM A8/2

Data sheet for the CBR-density relationship



FORM A8/3

Moisture-density relationship



FORM A8/4

Form for the CBR-density relationship curve