THE HIGHWAYS AGENCY HD 25/95

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF
THE ENVIRONMENT FOR NORTHERN IRELAND

Foundations

Summary:

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REGISTRATION OF AMENDMENTS

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VOLUME 7 PAVEMENT DESIGN AND MAINTENANCE

SECTION 2 PAVEMENT DESIGN AND CONSTRUCTION

PART 2

HD 25/94

FOUNDATIONS

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January 1994

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1. INTRODUCTION

General

1.1 The main purpose of the foundation is to distribute the applied vehicle loads to the underlying subgrade, without causing distress in the foundation layers or in the overlying layers. This is required both during construction and during the service life of the pavement.

1.2 The stresses in the foundation are relatively high during construction, although the number of stress repetitions from construction traffic is relatively low and is not so channelised as normal traffic during the service life of the pavement.

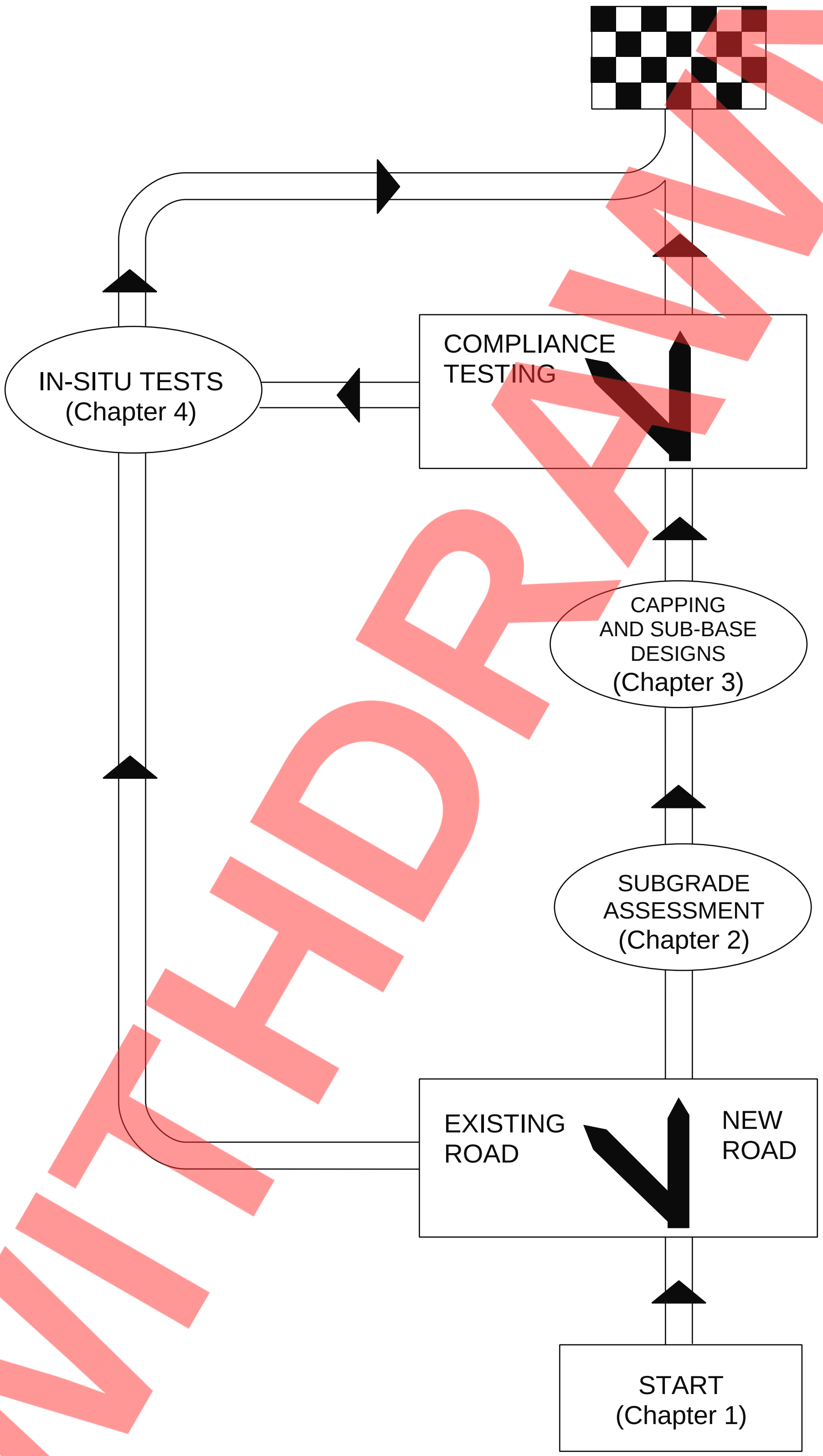
1.3 The standard practice, which is described in this part, is to design the foundation for construction traffic loading. This approach provides a "standard foundation" for the design of the pavement.

Implementation

1.4 This Part shall be used forthwith on all schemes for the construction, improvement and maintenance of trunk roads including motorways, currently being prepared provided that, in the opinion of the Overseeing Department, this would not result in significant additional expense or delay. Design organisations should confirm its application to particular schemes with the Overseeing Department.

Mutual Recognition

1.5 The construction and maintenance of highway pavements will normally be carried out under contracts incorporating the Overseeing Department's Specification for Highway Works (MCHW 1). In such cases products conforming to equivalent standards and specifications of other member states of the European Community and tests undertaken in other member states will be acceptable in accordance with the terms of the 104 and 105 Series of Clauses of that Specification. Any contract not containing these Clauses must contain suitable clauses of mutual recognition having the same effect regarding which advice should be sought.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2. SUBGRADE ASSESSMENT

2.1 The subgrade is normally not strong enough to carry the construction traffic without distress, unless it is rock which is not subject to degradation by weathering. Therefore, unbound or bound foundation layers of adequate stiffness modulus (see glossary) are required to reduce the stresses on the subgrade.

MATERIAL PROPERTIES

2.2 Unbound aggregates and soils can suffer from permanent internal deformation when subjected to high stresses. They tend to have relatively poorer permanent deformation characteristics and lower shear strength than bound materials. There is no established test to predict susceptibility of these materials to permanent deformation. It is common for the designer to infer from experience and index tests that materials have an acceptable level of stiffness modulus and shear strength. Both stiffness modulus and shear strength are usually reduced by increases in moisture content.

2.3 Ideally, a knowledge of the stiffness modulus and shear strength of the subgrade would be required to determine the thickness of the overlying pavement layers in order to avoid under- or over- design. However, these two parameters are dependent on soil type (particularly plasticity), degree of remoulding, density and effective stress. Effective stress is dependent on the stress due to the overlying layers, the stress history and the pore water pressure or suction. In turn, suction is dependent on the moisture content history, the soil type and the depth of the water table. The number of factors involved makes it necessary to adopt simplifications and to use index tests.

Index Tests

2.4 Since direct determination of stiffness modulus and shear strength is not always practical, the California Bearing Ratio (see CBR - paragraphs 4.6, 4.7) is frequently used as an index test: CBR is quoted in percent to two significant figures. The CBR is not a direct measure of stiffness modulus or of shear strength but it is widely used and considerable experience with it has been developed. It thus provides a common means of comparison.

2.5 The following equation has been derived empirically for typical UK soils:-

$$E = 17.6\ (CBR)^{0.64},\ MN/m^2$$

It provides a means of assessing the stiffness modulus, ***E***, which is approximately valid for values of CBR between 2 and 12 %. This may be used with care in analytical design HD 26 (DRMB 7.2.3.6). For more detailed information refer to CR72 (1987).

DETERMINATION OF SUBGRADE CBR

2.6 If it is not possible to determine a CBR value using the tests described in Chapter 4 then Table 2.1 provides a simple means of assessing the equilibrium in- service (ie. long term) CBR of the subgrade. The table shall be used to derive a design in-service CBR unless site or laboratory test data clearly indicate otherwise. Considerable care is required in assessing the lower values of CBR. Note that Table 2.1 is based on calculations rather than measurement. Even though CBRs are quoted to the nearest ½%, this degree of accuracy should not be implied as achievable. As subgrades get softer so the CBR values become less consistent. Values should be rounded down unless positive and consistent CBR determinations have been carried out.

2.7 In Table 2.1, a `high' water table is one within 300mm of formation (or sub-formation if a capping is present). A `low' water table is 1 metre down. `Thick' construction represents a 1200mm pavement (including capping); a `thin' pavement is 300mm of construction. The construction condition referred to relates to whether the subgrade is allowed to become wet, ie. protection from rain, and the quality of drainage provided. More detailed advice is given in LR1132 (1984).

2.8 If full information is not available for Table 2.1 to be used, then certain assumptions can be made. The worst condition of a high water table can be taken together with construction being carried out to the Specification (MCHW1) and thus at least `average' construction conditions pertain. The pavements discussed in this Section vary between "thick" and "thin" constructions; by interpolating between the values in Table 2.1, a table of acceptable Equilibrium Values can be derived. This is shown in Table 2.2. Background information on this table is available in HA 44/91 (DMRB 4.1.1). Table 2.2 should be used where full information is not available. The following methods may be used as a check for the CBR value, but shall only supersede the use of Tables 2.1 and 2.2 with the prior approval of the Overseeing Department.

Laboratory Testing

2.9 CBR values can be measured in the laboratory on recompacted specimens, in accordance with BS1377 (1990), during the site investigation stage and when the equipment and experience are available. Tests should be carried out over a range of conditions to reproduce, as far as possible, the conditions of moisture content and density which are likely to be experienced during construction and in the completed pavement. Cohesive soils should be compacted to not less than 5% air voids, to reproduce the likely conditions on site. Equilibrium moisture content can be deduced from measurements on a suction plate (LR889, 1979).

Site Testing

2.10 For design, the CBR must be estimated before construction commences. For fine grained soils in-situ CBR values can however be measured for checking purposes (not to allow design changes) in pits or on trial strips during construction. Equilibrium CBR values require the testing of existing pavements and HA 44/91 (DMRB 4.1.1) suggests a suitable procedure. Plate bearing tests are necessary for coarse materials (BS5930, 1981).

TYPE OF SOIL	PI	HIGH WATER TABLE						LOW WATER TABLE					
		CONSTRUCTION CONDITIONS: POOR		AVERAGE		GOOD		CONSTRUCTION CONDITIONS: POOR		AVERAGE		GOOD	
		Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
HEAVY CLAY	70	1½	2	2	2	2	2	1½	2	2	2	2	2½
	60	1½	2	2	2	2	2½	1½	2	2	2	2	2½
	50	1½	2	2	2½	2	2½	2	2	2	2½	2	2½
	40	2	2½	2½	3	2½	3	2½	2½	3	3	3	3½
SILTY CLAY	30	2½	3½	3	4	3½	5	3	3½	4	4	4	6
SANDY CLAY	20	2½	4	4	5	4½	7	3	4	5	6	6	8
	10	1½	3½	3	6	3½	7	2½	4	4½	7	6	>8
SILT*		1	1	1	1	2	2	1	1	2	2	2	2
SAND (POORLY GRADED)		20											
SAND (WELL GRADED)		40											
SANDY GRAVEL (WELL GRADED)		60											

* estimated assuming some probability of material saturating

TABLE 2.1 Equilibrium Subgrade CBR Estimation

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Suction Method

2.11 For remoulded cohesive specimens the suction method of Blood and Lord (1987) may be used. However, this method effectively considers a worst case construction condition with very high water table, poor drainage and full wetting. Its application is also limited to soils of plasticity index 13% to 35%.

Type of Soil	PI	Predicted CBR %
Heavy Clay	70	2
	60	2
	50	2
	40	2 to 3
Silty Clay	30	3 to 4
	20	4 to 5
Sandy Clay	10	4 to 5
Sand (Poorly graded)		20
Sand (Well graded)		40
Sandy gravel (Well graded)		60

Table 2.2 Equilibrium Subgrade CBR Estimation

3. CAPPING AND SUB-BASE

3.1 Capping is used to improve and protect weak subgrades by using a relatively cheap material between the subgrade and the sub-base. The aim is to increase the stiffness modulus and strength of the formation, on which the sub-base will be placed. Capping with a laboratory CBR value of at least 15% should provide an adequate platform for construction of the sub-base when compacted to the appropriate thickness.

3.2 Granular and cemented sub-bases are permitted for flexible and flexible composite pavements but only cemented sub-bases are permitted for rigid and rigid composite pavements.

3.3 The grading for unbound granular sub-base is intended to provide a dense layer of relatively high stiffness modulus, which is reasonably impermeable and will thus shed rain water during construction, given adequate fall. It is not necessarily free draining and may exhibit suction, and thus increase in moisture content. Granular sub-base with a laboratory CBR of at least 30% should provide an adequate platform for construction of the pavement when compacted to the appropriate thickness.

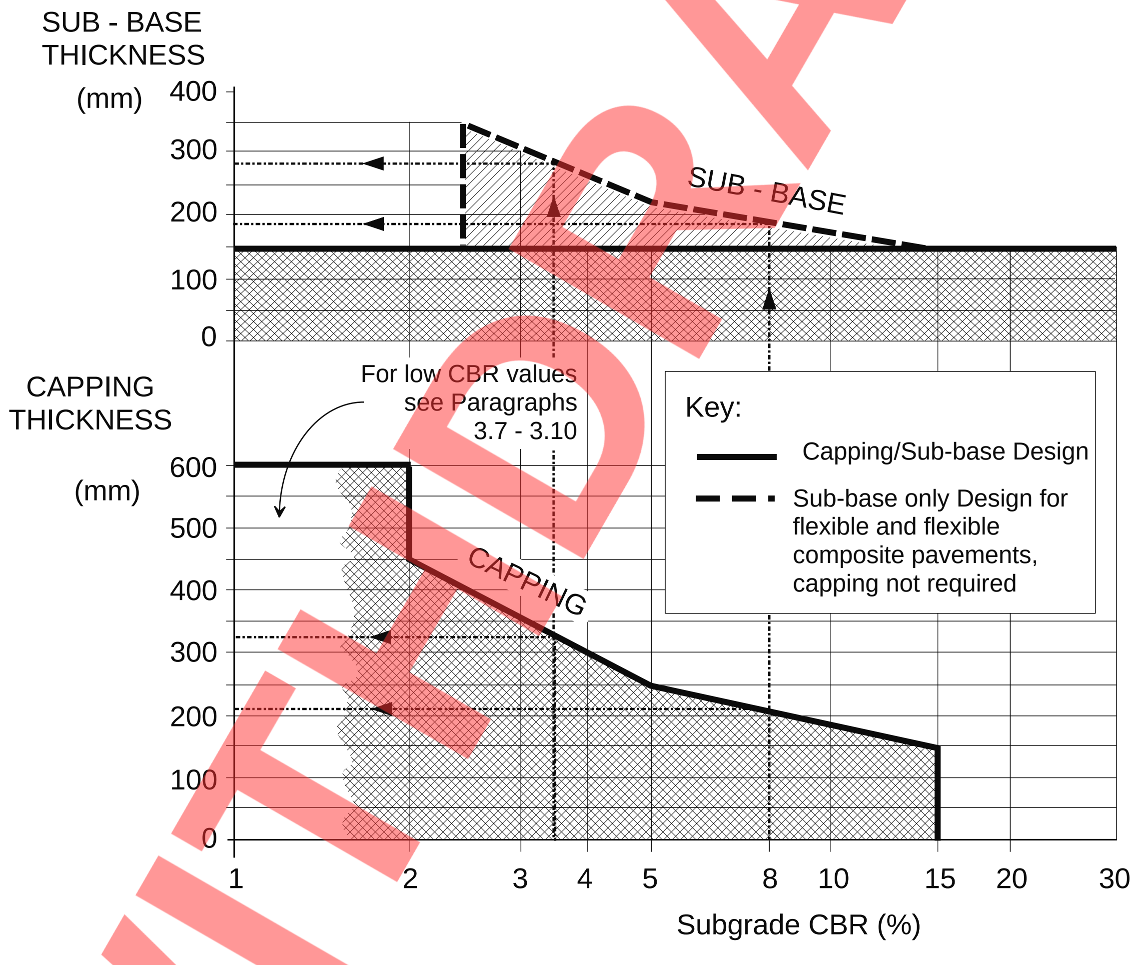


FIGURE 3.1 Capping and Sub-base Thickness Design

Example 1 : CBR 3.5%
Alternative Designs
a. Sub-base 150mm
on Capping 330mm
b. Sub-base 280mm
No Capping

Example 2 : CBR 8%
Alternative Designs
a. Sub-base 150mm
on Capping 210mm
b. Sub-base 190mm
No Capping

THICKNESS DESIGN

3.4 The thickness of capping and sub-base shall be obtained from Figure 3.1. The sub-base may be omitted on hard rock subgrades that are intact or, if granular would have a laboratory CBR of at least 30%, and which do not have a high water table. For a subgrade having a CBR greater than 15 %, the thickness of sub- base is 150 mm, this being controlled by the minimum practicable thickness for spreading and compaction. When the subgrade CBR is between 2.5 and 15% for flexible and flexible composite construction, there are two options available:

1. **150mm of sub-base can be used on a varying thickness of capping depending on the CBR value or,**
2. **An increasing thickness of sub-base can be used with the decreasing CBR, with no requirement for capping.**

For all pavements on subgrades with CBR values below 2.5%, and for rigid and rigid composite construction on CBRs below 15%, 150mm of sub-base on the varying thickness of capping _must_ be used. See Figure 3.1. When the subgrade CBR is sufficiently below 2% such that capping with sub-base is insufficient to support the pavement, then refer to Paragraphs 3.7 to 3.10.

3.5 It is not intended that the foundation design should vary frequently along the road but that an appropriate value shall be selected for each significant change in the subgrade properties. For this reason changes in foundation design should not be made for lengths less than 100 m and rarely less than 500 m.

3.6 The final design thickness shall be specified to the nearest 10 mm greater than the value obtained from Figure 3.1. On subgrades with a CBR of less than 15 %, the minimum thickness of a layer of aggregate (either capping or sub-base) placed directly on the subgrade shall be 150 mm. At and below 3 % CBR, the first layer of aggregate shall be at least 200 mm thick. The thickness of all foundation layers shall be constant over the full width of the pavement.

Soft Subgrades

3.7 When a subgrade has a CBR suficiently below 2% such that it becomes unsuitable as a pavement foundation, (a subgrade would tend to deform and `wave' under construction traffic), then a number of options are available.

3.8 The material can be removed and replaced by more suitable material; if the depth is small, all can be replaced but it may only be necessary to replace the top layer. The thickness removed will typically be between 0.5 and 1.0 m. Although the new material may be of good quality, the subgrade should be assumed to be equivalent to one of a CBR value just under 2% (ie. 600mm capping), in order to allow for movements in the soft underlying material. A total construction thickness about 1.5 m thick will often result. A geosynthetic may also be useful.

3.9 If the soil is cohesive, a lime treatment may be an economic option, subject to soil suitability being shown. Details of various soil treatments are given in HA44/91 (DMRB 4.1.1). The overlying capping is again designed on the basis of a subgrade with a CBR just under 2% (ie. 600mm capping).

3.10 If the soil is reasonably permeable, a deeper than normal drainage system may be considered, together with a system of monitoring the improvement expected. Design of the main foundation may then be based on whatever conditions are achievable in the time available.

CAPPING MATERIALS

3.11 The Specification (MCHW1)(Series 600) allows a fine graded material (6F1) and a coarser graded (6F2). The latter can be considered as relatively free draining and is thus most suitable for sites with a shallow water table. It should, however, be noted that capping is not required to be a drainage layer as long as contained water does not prevent it from satisfying its primary function of load spreading. The specified gradings also do not guarantee adequate shear strength and a demonstration area should normally be placed and tested to check on the material's characteristics by trafficking with normal site vehicles and construction plant.

3.12 Alternative permitted materials are cement and lime treated soil and, particularly when the removal and replacement of unacceptable soil is the alternative, lime/cement or lime/PFA. Further details are given in HA 44/91 (DMRB 4.1.1).

3.13 Reuse of crushed excavated road pavement materials as capping may also be carried out provided the compacted material complies with the Specification (MCHW1)(Series 600).

3.14 The design should allow as wide a range of capping materials as possible and particular materials should only be excluded if there are over-riding engineering reasons for so doing. In pavements with capping over subgrades with CBRs greater than 5%, it may be necessary to lay a greater thickness than that given in Figure 3.1 if large stone sizes are involved.

3.15 Some contamination from weak cohesive soils into granular capping, particularly with 6F2, can be expected and the design thicknesses allow for this. In some cases, a geosynthetic separator may also be beneficial.

SUB-BASE MATERIALS

Granular Sub-bases

3.16 Granular sub-base, Type 1 (see Specification (MCHW1), Series 800) is the standard unbound material for use with flexible and flexible composite pavements. Granular sub- base, Type 2, may be used in pavements which have a design traffic loading of less than 5 msa at opening, provided that, when tested, a laboratory CBR of 30 % or more is obtained (see Specification (MCHW1), Series 800); particular care is required to ensure that drying out does not occur before covering.

Cemented Sub-bases

3.17 For rigid and rigid composite construction a cemented sub-base is required to minimise the risk of water penetrating slab joints and cracks, causing erosion and weakening the sub-base. Cement-bound sub-bases also aid compaction of the overlying pavement concrete. An impermeable membrane is required over the sub-base to prevent suction of water from the pavement concrete. This also acts as a slip layer for jointed concrete and should be plastic sheeting. For CRCP and CRCR, the membrane should be sprayed bituminous. Strong cement bound material, CBM3, or wet lean concrete, C15, shall be used except when the initial design life of the pavement is less than 12 msa, in which case CBM2 or C10 are permitted (see Specification (MCHW1) Series 1000, for materials).

3.18 For flexible and flexible composite construction cemented sub-bases may also be used. Weak cement bound material, CBM1 or CBM2, or a weak wet lean mix, C7.5 are advised (see Specification (MCHW1) Series 1000).

Non-Standard Sub-base Materials

3.19 With reducing availability of suitable sub-base materials, there is pressure to use non-standard materials, such as crushed masonry, by-product aggregates and industrial residues. Because of greater variability and the possibility of contamination of such materials, it may be necessary to increase the frequency of control testing. In any event, the Overseeing Department must be consulted before non-standard materials are used.

3.20 Variants of Type 1, such as material having a coarser grading and thus increased permeability, may also be used subject to test and approval by the Overseeing Department. Aggregates with gradings that have a pronounced gap or an excess of material passing a 0.075 mm sieve are probably unsuitable.

3.21 A `correct' Ten per cent Fines Value (TFV), according to BS812 Part 111, 1990, can only be obtained on samples from materials having 15 % or more of their particles in the 10-14 mm size range. A compaction trial may be carried out to check actual particle damage under the type of roller to be used. Low TFV does not necessarily preclude use as grading, particle size and self-cementation, which occurs with some materials, may counteract the weakness.

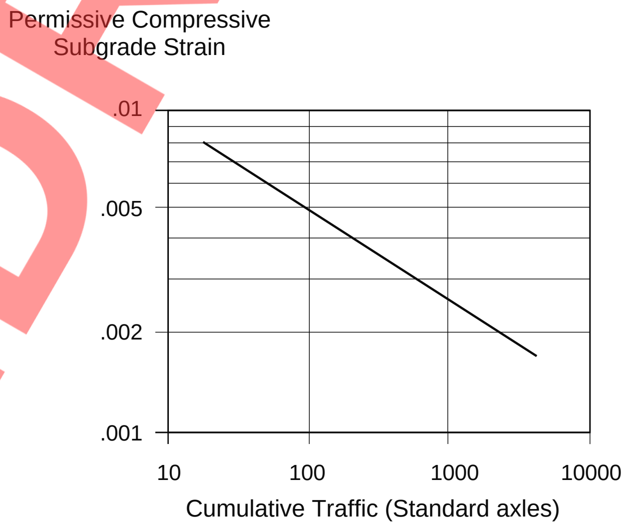
3.22 Some aggregates have self- cementing properties. To detect self-cementing properties, trial areas could be tested in-situ at intervals of time. Alternatively, triaxial tests in the laboratory may be used to assess any improvement in stiffness modulus and/or shear strength. Care is required to distinguish between self cementing and suction effects.

Bituminous Replacement

3.23 It is permitted to replace some or all of the sub-base by bituminous material. A substitution rate of 30mm of bituminous roadbase to 100mm of Type 1 sub-base shall be used. This technique must not be applied to capping, or to the lowest 150mm layer of sub-base where sub-base lies directly on soil of less thanCBR (at the time of construction). Construction practices on thin foundations may have to be modified compared with normal procedures due to the reduced ability of the foundation to carry construction traffic.

ANALYTICAL FOUNDATION DESIGN

3.24 An analytical foundation design requires the stiffness modulus of the subgrade, capping and sub-base to be determined, assumptions made regarding Poisson's ratio and a linear elastic calculation made using a layered system analysis. From such a computation, the maximum compressive strain in the subgrade under a standard axle load may be calculated and related to rut development. If this method is followed, a considerable number of sensitivity analyses must be carried out to assess the effects of material variability. The aim should be to provide a design with an 85 % probability of achieving the required design life.



3.25 The allowable subgrade strain may be taken from Figure 3.2. Unless information to the contrary is available, a construction traffic loading of 1000 standard axles should be used; this is suitable for a site with access points at 1 km spacing. For very short

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lengths this loading may be too high or for very long sections too low. Guidance for such situations may be found in LR1132 (1984). Since such a design is for construction traffic only, it will have to be followed by proposals for the pavement as a whole.

3.26 If an analytical pavement design is to be considered, approval is required from the Overseeing Departments at the preliminary design stage. Submissions seeking approval shall include a justification for the choice of non-standard materials and/or thicknesses, supporting calculations and an indication of any additional specification requirements or testing regime which may be necessary for their validation.

DRAINAGE

3.27 It is of vital importance to keep water out of the sub-base, capping and subgrade, both during construction and during the service life of the pavement. This is achieved by excluding incoming water and providing an escape route for water already in the foundation (Figure 3.3). During construction, every effort should be made to protect the subgrade by placing aggregate before rain can soften it. Wherever possible the foundation drainage should be kept separate from pavement run-off drainage in all new construction and in reconstruction work. There should always be a downslope route from the sub-base to the drain. Further details are in HA 44/91 (1991) (DMRB 4.1.1). In reconstruction and widening projects it is necessary to maintain the continuity of drainage from existing capping and sub-base materials to adjacent new materials, using appropriate thicknesses and crossfalls.

3.28 When the water table is high and the subgrade is moisture sensitive (Plasticity Index < 25) a subgrade drain is beneficial. A granular aggregate drainage blanket (see Specification (MCHW1), Series 600) of thickness at least 150mm and not more than 220mm thick may be used. In order to stop pore clogging by fines from other adjacent layers, geosynthetic separators may be used when those layers are constructed of fine soil or fine capping. The drainage layers so formed may be treated as capping for structural design purposes.

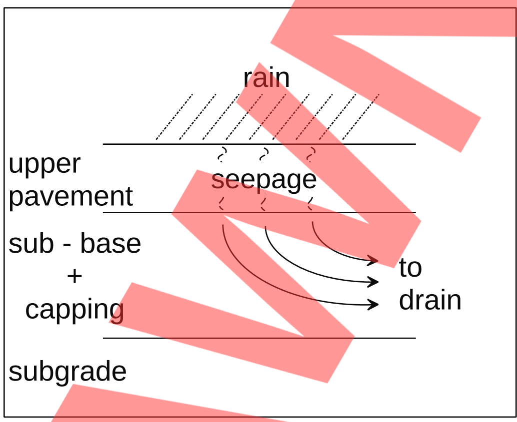

FIGURE 3.3 Foundation Drainage

3.29 Where a drainage blanket is not used, drains as detailed in Highway Construction Details (MCHW3) shall be used. The drain is placed below the bottom of capping, not because sub-base and capping need to be permeable, but so that they will be drained if they are permeable.

3.30 It is useful to check the speed at which water can drain out of a granular sub-base, as a result of ingress due, perhaps, to a faulty pavement or a surcharging drain. A procedure for calculating this is given in Jones & Jones (1989a) along with a means of estimating ingress through cracks in the bound layers. On this basis it may be possible to specify a permeability value. Care should be taken to ensure that the value required does not conflict with any limitations imposed by a specified grading, see Jones & Jones (1989 b).

3.31 If it is necessary to determine the permeability of the sub-base or capping material, this must be done on the full grading, at the correct density under a low hydraulic head. A suitable permeameter and procedure is described in HA 41/90 (1990) (DMRB 4.1.1).

3.32 Drainage of the sub-base may be omitted only if the underlying materials (capping and subgrade) are more permeable than the sub-base, and the water table never approaches the formation closer than 300mm.

FROST PROTECTION

3.33 For routine cases all material within 450mm of the road surface shall be non frost-susceptible as required by the Specification (MCHW1)(Series 700) and tested according to BS812 : Part 124 : (1989).

3.34 This requirement can be over- severe in some places (e.g. coastal areas) and may be reduced to 350mm if the mean annual frost index of the site is less than 50. Advice on the frost index for any particular area may be obtained from the Meteorological Office Advisory Services, Building Construction Section, and further information from RR45 (1986).

3.35 The frost index, I, is defined as the product of the number of days of continuous freezing and the average amount of frost (in degrees Celsius) on those days. It is related to the depth of frost penetration, H.

$$H = 4\sqrt{I} \quad , \text{ cm}$$

Example.

Number of days freezing 12
Amount of frost 3ºC

$$\text{Penetration} \quad H = 4\sqrt{36} = 24 \text{ cm} = 240 \text{ mm}$$

3.36 From meteorological data the maximum depth of frost penetration over a given historical period can be readily assessed. The method should show areas where frost is clearly no problem at all, or conversely, a serious problem. A return period analysis would establish the probability of a winter of a certain intensity occurring within the nominal life of the pavement. However, highly precise assessment of frost penetration is not advised due to unquantifiable microclimate effects.

4. IN-SITU TESTING

4.1 The two reasons for testing pavement foundation layers are to check compliance with the design during construction and in pavement assessment see HD30 (DMRB 7.3.3). The Specification (MCHW1)(Series 800) gives a method of construction to be followed. An inadequate test result may indicate either that the method was not followed, that the material was sub-standard, that abnormal conditions requiring a variation in procedure were encountered, or that damage has occurred. The following paragraphs introduce some of the tests which are available, most of which are specified in BS1377 (1990). They are for general information and advice only and do not comprise part of the Overseeing Departments' requirements.

Moisture Condition Value (MCV)

4.2 The test takes about half an hour and involves compaction of soil or fine aggregate using a hand operated device. The amount of compactive effort is plotted against the density so that the test gives the amount of effort needed to obtain the specified density. The effort can be compared to that needed at Optimum Moisture Content and a rapid indirect assessment made of whether the material is at the desired moisture content. The size of the apparatus limits its use to fill finer than 20mm maximum particle size.

Density Testing (Figure 4.1)

4.3 The sand replacement test involves excavating and weighing material removed from a small hole and refilling the hole with a uniform sand. The hole volume is calculated from the mass of sand used. The water replacement test is similar except that a plastic liner filled with water is used to determine the volume. The equipment for either is transported by vehicle. The tests are time consuming (up to 1 hour) and thus expensive, and operator sensitive. However they do give a direct means of measuring density, which can then be compared with values obtained in the laboratory or in trials.

4.4 An alternative is nuclear density testing. A radiating source is applied to the material. The amount of radiation detected decreases in proportion to the bulk density of the material between source and receiver. To determine the moisture content another source sends out radiation intercepted by hydrogen atoms. The dry density is

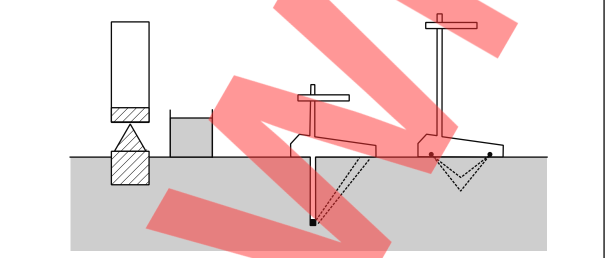

FIGURE 4.1 Density Testing Apparatus

calculated from the bulk density and moisture content. If the material being tested is carbonaceous, care is required in interpreting the moisture content and dry density obtained. Testing is extremely rapid (less than 5 minutes) and a reading may be repeated readily. The machine is portable. Calibration is required for each soil or aggregate tested.

4.5 It should be noted that two modes of nuclear density test are possible. The quickest and easiest is 'backscatter' mode which is influenced only by the density of the top 100 - 150 mm of material and is most heavily influenced by material very near the surface. `Transmission' mode provides a more representative density result.

California Bearing Ratio (Figure 4.2)

4.6 The California Bearing Ratio (CBR) test involves the insertion of a small plunger into the ground surface at a rate of 1 mm per minute, whilst the load is recorded. Surcharge rings can be placed around the plunger to simulate an overburden. A laboratory version of the same test is available in which the sample tested is constrained within a small mould. The stress at penetrations of 2.5 and 5 mm is compared with the result for a standard aggregate and the ratio given as a percentage. The test is not suitable for coarse aggregates because the plunger and aggregate particles will be of similar size. The test measures neither stiffness modulus nor shear strength directly - giving a somewhat combined measure of both. It takes around half an hour on site and between 1 and 2 hours in the laboratory and there is a large body of experience of its use.

4.7 There are several variants on the CBR test; laboratory, field, with surcharge, saturated, etc. In the context of this document the laboratory CBR with a surcharge to simulate the appropriate vertical stress of the case being considered should be taken as the standard method used. The appropriate moisture content and wetting or drying condition is also important. Laboratory CBR results for granular soils are often higher than those in the field due to mould confinement effects. The test is penetration controlled and so does not model the stress level imposed by traffic. The time of loading is also much longer than that due to traffic. CBR is an empirical test and is best measured as initially intended although other test devices such as the Clegg Impact Hammer, various static and dynamic cone penetrometers and the plate bearing test can be used to determine approximate estimates of CBR.

Clegg Hammer (Figure 4.2-Clegg, 1976)

4.8 In some respects this is a dynamic CBR and suffers from similar scale problems. The hammer/plunger is lifted and dropped, and the deceleration on impact is recorded. The equipment is portable and the test extremely rapid (20 seconds). Except on stiff aggregates and subgrade soils, the test causes some local shear failure and thus is not a direct measure of stiffness modulus. The stress applied is high and the time of loading short so that the stress pulse due to traffic is not modelled accurately. For soils generally dry of optimum moisture content the `Clegg Impact Value' has been related approximately to CBR. It is useful as a guide tool and is able to detect soft spots on a subgrade or fine capping and can differentiate between material types.

Cone Penetrometers (Figure 4.2)

4.9 Various sizes of field cone penetrometer exist for the rapid approximate assessment of CBR. In general they can only give values of up to about 5 or 6%, and are therefore applicable for soft and medium fine grained subgrades.

4.10 The dynamic cone penetrometer is similar to other field cone penetrometers except that it is driven into the ground under the action of a weight dropped onto an anvil. It is therefore suited to stronger and coarser materials than other penetrometers. The rate of penetration into the ground can then be related approximately to CBR.

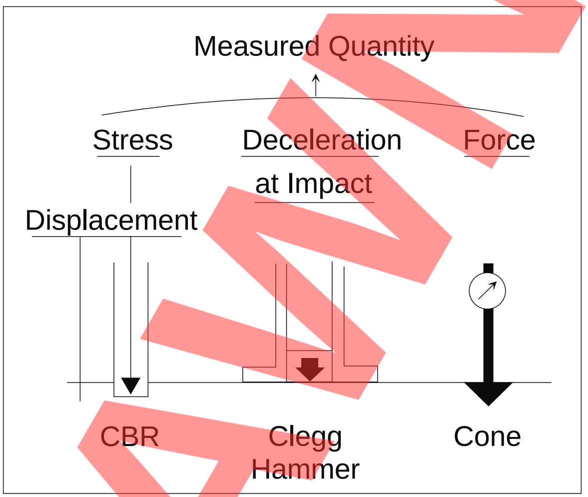

FIGURE 4.2 Strength Tests

Plate Bearing Test (Figure 4.3)

4.11 This test is described in detail in BS1377 (1990) and its use for testing is described in The Specification (MCHW1)(Series 600). For pavement materials no removal of surface material or non-vibratory compaction is needed.

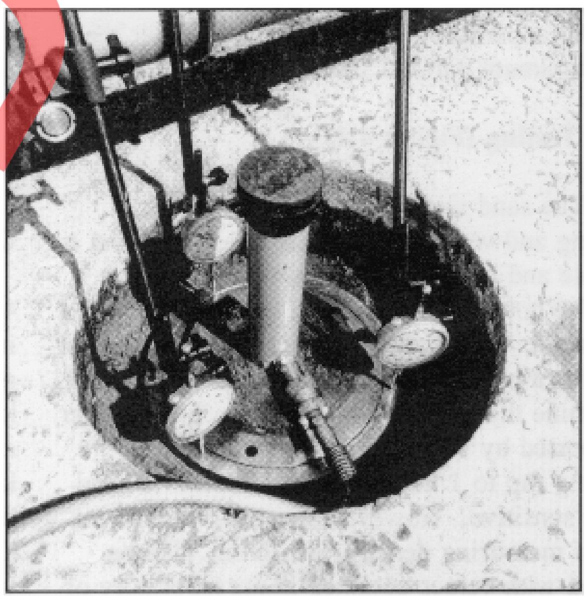

FIGURE 4.3 Plate Bearing Apparatus

4.12 As a variation to the standard method the plate may be unloaded and reloaded until a relatively constant elastic modulus is observed (eg. 3 times). The results are interpreted using the equation

$$E = \frac{\pi \ pr \ (1-v^2)}{2y}$$

where ***E*** is the elastic modulus, ***p*** is the stress applied, ***y*** is the plate deflection and ***r*** its radius. Assuming Poisson's ratio (***v***) typical of granular material (.3) this approximates to

$$E = 1.45 \left[\frac{pr}{y}\right]$$

4.13 The effectiveness of compaction can also be assessed by comparing the elastic modulus on first and last loading. If the ratio (last/first) is greater than 2.0, compaction is probably inadequate.

4.14 An approximate empirical correlation with CBR can be made, as follows:-

$CBR = 6.1 \times 10^{-8} \times (k_{762})^{1.733}\%$

where k_{762} is the modulus of subgrade reaction (equal to ***p***/***y*** in units kN/m^2/m at normally a plate penetration y of 1.25mm) from a plate of 762 mm (30 inch) diameter. Figure 4.4 allows conversion for other plate sizes.

Example

At y = 1.25 mm, ***p*** = 70 kN/m^2
Plate diameter = 300 mm

$k_{762} = 0.43 \times \frac{70}{1.25} \times 10^3$
$= 2.41 \times 10^4$
CBR = 24%

4.15 The test is laborious to set up and carry out, and requires a lorry or excavator to provide reaction. The speed of loading is slow giving poor simulation of traffic loading.

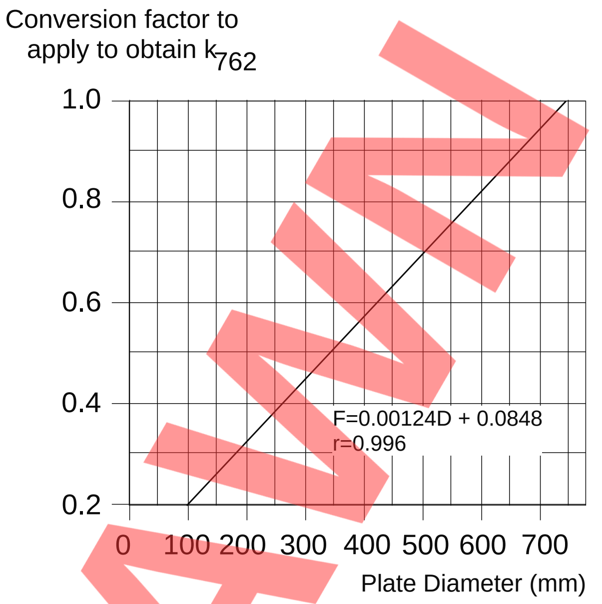

FIGURE 4.4 Correction for Smaller Plates

Dynamic Plate Tests

4.16 These tests involve dropping a weight onto a platen. Usually a damping mechanism is incorporated to control the loading time. Thus the area of loading, stress and speed of loading may be controlled. The Dynaplaque measures the rebound of its sprung weights. The Falling Weight Deflectometer (FWD) measures the stress applied and the deflection at several radial positions. Interpretation is generally in terms of the stiffness modulus of each layer but is not straightforward and should be carried out by an experienced pavement engineer. If only the central deflection is used to determine a composite stiffness modulus for the foundation (as for the plate bearing test), then interpretation is simple and can be carried out as described above.

5. REFERENCES AND BIBLIOGRAPHY

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6. ENQUIRIES

All technical enquiries or comments on this Part should be sent in writing as appropriate to:-

Chief Highway Engineer The Department of Transport St Christopher House Southwark Street LONDON SE1 OTE	T A ROCHESTER Chief Highway Engineer

The Deputy Chief Engineer The Scottish Office Industry Department Roads Directorate New St Andrews House EDINBURGH EH1 3TG	J INNES Deputy Chief Engineer

The Director of Highways Welsh Office Y Swyddfa Gymreig Government Buildings Ty Glas Road Llanishen CARDIFF CF4 5PL	K J THOMAS Director of Highways

Chief Engineer - Roads Service Department of the Environment for Northern Ireland Roads Service Headquarters Clarence Court 10-18 Adelaide Street BELFAST BT2 8GB	W J MCCOUBREY Chief Engineer - Roads Service