DESIGN OF TRAFFICKED PAVEMENTS USING PRECAST CONCRETE FLAG PAVING

Introduction

This document provides guidance on the design of trafficked pavements surfaced with conventional (non-permeable) flag paving manufactured by Brett Landscaping and Building Products.

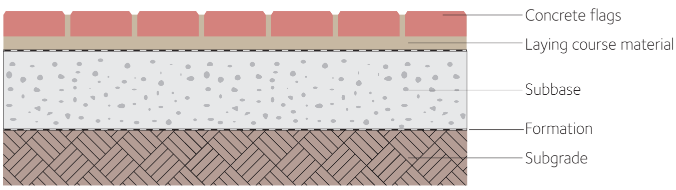
It is recommended that the designer has knowledge of the relevant British Standards and the Specification of Highway Works.

This guidance is based upon the recommendations in the British Standard BS 7533 - 8:2003, *Pavements constructed with clay, natural stone or concrete pavers, Part 8: Guide for the structural design of lightly trafficked pavements of precast concrete flags and natural stone flags.*

Design methodology

The determination of the pavement depth and structure is basically a function of the strength of the sub grade (after construction) measured as a 'California Bearing Ratio' (CBR) and the volume of traffic that is predicted to traffic the pavement over the projected life of the pavement.

The design procedure ensures that the allowable stresses in the paving flags and subgrade are not exceeded. The design of the pavement is based on the assumption that the construction conforms to requirements set out in BS 7533-4.



Step 1 - Determine the strength of the sub grade

The strength of the subgrade is quantified as the 'California Bearing Ratio' (CBR) and value(s) used for the design should take into account the condition and likely values of the subgrade CBR, at the estimated level of the sub grade, when the moisture content of the sub grade has stabilised, is sufficiently compacted i.e. values likely after the completion of the construction and for the life of the pavement. (The depth of the pavement is unknown at this stage of the design process but an experienced designer should have knowledge of typical pavement depths).

The design CBR value of the sub grade can be determined by on site testing or testing of soil samples taken from site. It is important that the soils are selected at the estimated sub grade level. Alternatively, CBR values can be estimated from observations and empirical on site testing, but this method should only be undertaken by experienced designers or geotechnical engineers.

Both BS 7533 - 1 & 2 gives advice on determining CBR values which is summarised as follows:-

The degree of subgrade drainage must also be considered when deciding the appropriate CBR value to be assumed.

On sites where the CBR varies from place to place then the lowest recorded value should be used.

Site investigation data should be analysed carefully and advice sought if in doubt. The equivalent equilibrium suction index CBR values may be estimated from the Plasticity Index (PI) from the following table (taken from BS7533-1.)

Equilibrium suction index CBR

Type of soil	PI	High water table construction conditions			Low water table construction conditions		
		Poor	Average	Good	Poor	Average	Good
Heavy clay	70	1.5 to 2	2	2	1.5 to 2	1.5 to 2	2 to 2.5
	60	1.5 to 2	2	2 to 2.5	1.5 to 2	2	2 to 2.5
	50	1.5 to 2	2 to 2.5	2 to 2.5	2	2 to 2.5	2 to 2.5
	40	2 to 2.5	2.5 to 3	2.5 to 3	2.5	3	3 to 3.5
Silty clay	30	2.5 to 3.5	3 to 4	3.5 to 4	3 to 3.5	4	4 to 6
Sandy clay	20	2.5 to 4	4 to 5	4.5 to 7	3 to 4	5 to 6	6 to 8
	10	1.5 to 3.5	3 to 6	3.5 to 7	2.5 to 4	4.5 to 7	7 to >8
Silt	-	1	1	2	1	2	2
Poorly graded sand				20			
Well graded sand				40			
Sandy gravel				60			

The construction conditions referred to in the table above relate to the general conditions on site during the construction period. This factor has a significant effect on the assessment of the CBR value to be used.

A high water table is one which is 300 mm or less below formation level and is consistent with ineffective su-soil drainage. A low water table is 1m or more below formation level.

'Good' conditions are where the subgrade is protected promptly with an improvement layer or sub-base, while 'Poor' conditions are where little or no subgrade protection is provided.

The value used for the CBR should be based on the worst results obtained on site. If it is considered to be economical, a localised design can be introduced for the poorer areas or poor materials can be replaced.

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Estimated CBR values

Type of subgrade	Plasticity index	CBR per cent
Heavy clay	70 60 50 40	2 2 2 3
Silty clay	30	4
Sandy clay	20 10	5 5
Silt		1
Poorly graded sand		20
Well graded sand		40
Well graded sandy gravel		60

The above table gives typical PI and CBR values for particular soil descriptions.

Simple Field Test to estimate Sub grade CBR

Alternatively the subgrade CBR value can be estimated using simple field tests (after initial compaction of the trimmed ground). For loose, soft and very soft materials comprising sand, silt and clay, specialist advice should be sought.

The guidance below applies where the water table is 300 mm or more below sub grade level. Specialist advice should be sought where this is less, standing water is present or there are any doubts about the ground conditions.

Rock or soil Type	Condition	Simple field test	CBR
Rock	Hard	Requires mechanical pick for excavation	Above 5%
Sand Gravel	Compact	50mm square peg hard to drive in 150mm	>5%
Clay Sandy clay	Stiff	Cannot be moulded by fingers Need pick for excavation	5%-2%
Clay Sandy clay	Firm	Can be moulded by fingers Need spade for excavation	5%-2%
Clay Silty clay Clayey sand	Loose	Dry lumps easily broken down 50mm square peg driven in easily	2%
Silt Sandy clay Silty clay Clay	Soft	Can easily be moulded by fingers	<2%
Silt Sandy clay Silty clay Clay	Very soft	Exudes between fingers when squeezed	Seek specialist advice
NOTE 1 This table is based on the principles in BS 8103-1. NOTE 2 The CBR of the rock or soil is significantly affected by moisture content			

Step 2 – Determine the size and thickness of the flag for the intended application

The type and volume of proposed traffic influence the size and thickness of the flag to be used.

Table 1 gives guidance to the plan sizes and thicknesses of flags which should be used for various applications.

Table 1 Suitability of flags for various applications

Designation	Nominal Size	Thickness	Pedestrian Only	Vehicular 1	Vehicular 2	Vehicular 3
A	600 x 450	50 or 63	✓	✓	✓63 mm	×
B	600 x 600	50 or 63	✓	✓	✓63 mm	×
C	600 x 750	50 or 63	✓	✓63 mm	×	×
D	600 x 900	50 or 63	✓	✓	×	×
E (small element)	450 x 450	50 or 70	✓	✓	✓70 mm	✓70 mm
F (small element)	400 x 400	50 or 65	✓	✓	✓65 mm	✓65 mm
G (small element)	300 x 300	50 or 60	✓	✓	✓60 mm	✓60 mm

Key

Vehicular 1 – very occasional use by cars and light mechanical sweepers, e.g. unprotected footways in no parking areas or where overrun is not a problem. These flags can be laid on either a sand or mortar laying course.

Vehicular 2 – footway where vehicles cross to access house driveways. The preferred laying course is sand.

Vehicular 3 – footways where cars and occasional commercial vehicles run over; unprotected pedestrian precincts with about 25 commercial vehicles each day; fire tender access ways. These flags to only be laid on a sand laying course.

Step 3 – Determine the volume of traffic

An evaluation is needed of the total number of commercial vehicles trafficking the pavement for the duration of the design life of the pavement. In the absence of more reliable information, an estimate may be made based on table 2 and 3.

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The number of commercial vehicles using the area must be estimated. Table 2 gives guidance on typical applications and number of commercial vehicles per day (cv/d).

Table 2 Estimate of Commercial Vehicles per Day

Location	Commercial vehicles per day
Residential areas	1
Small shopping areas	5
Large shopping areas	10
Precincts and pedestrianised areas	15

For pavements subject to normal vehicle loads, it may be assumed that each commercial vehicle per day is equivalent to one standard axle per day, but if the actual traffic mix is known, it is possible to determine the total number of standard axles per day by modifying the number of standard axles using the values in table 3.

Table 3 Standard Axles for vehicle types

Vehicle type	Number of standard axles/ commercial vehicle
2 axle rigid	0.34 sa per vehicle
3 axle rigid	1.70 sa per vehicle
4 axle rigid	2.60 sa per vehicle

The design life for flag pavements is normally a minimum of 20 years.

Step 4 Determine Base Thickness

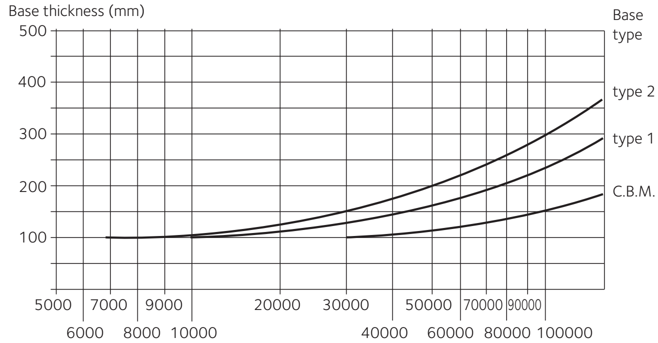
The sub-base or road base thickness are determined from graphs 1 and 2 or 3. Two thicknesses must be determined - one to prevent overstressing and cracking the flag the other to prevent overstressing the subgrade. The greater of the two thicknesses is adopted as the design thickness. The procedure is as follows:

Select the type of flag to be employed:
Type E 450 x 450 x 70 mm
Type F 400 x 400 x 65 mm
Type G 300 x 300 x 60 mm

Select which of the three types of recommended sub-base or roadbase is to be used:
Dot Type 1
Dot Type 2
CBM

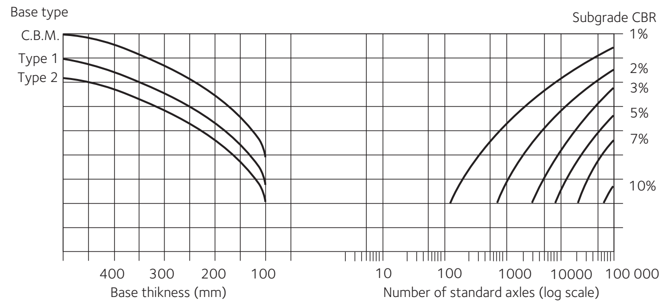
From the number of standard axles evaluated in step 3 and the sub-base or roadbase selected use Graph 1 to obtain the sub-base thickness required to prevent overstressing of the paving flag.

Graph 1 Sub base thickness required to Prevent Overstressing the Flag

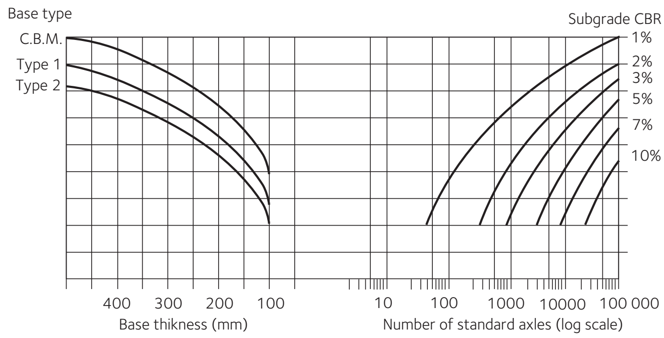


From the number of standard axles evaluated above, the CBR of the subgrade and the sub-base or roadbase selected, use either:

Graph 2 - Sub base thickness to Prevent Overstressing 450 x 450 or 400 x 400 flags, (use Graph 3 for 300 x 300 flags)



Graph 3 - Sub base thickness to Prevent Overstressing for 300 x 300 flags.



From the thicknesses derived from graph 1 and either graph 2 or 3, select the greater thickness as the design thickness.

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Design example

A pavement in a new shopping mall is to be constructed using Texitone Eco 450 mm x 450 mm x 70 mm flags on a Type 1 sub base.

A site investigation indicates the CBR of the subgrade is 3 % and the base material to be used is CBM.

It is estimated that for six days per week there will be 5no 2 axle rigid commercial vehicles, 2no 3 axle rigid commercial vehicles and 1no 4 axle rigid commercial vehicle per day servicing the shops. Servicing will take place fifty two weeks a year over a twenty year design life.

Step 1 - Determine the strength of the sub grade

A site investigation indicates the CBR of the subgrade is 3 %.

Step 2 - Determine the size and thickness for the intended application

It is proposed to use Texitone Eco 450 mm x 450 mm x 70 mm flag. From table 1 for vehicle application 3, this flag is suitable.

Designation	Nominal Size	Thickness	Pedestrian Only	Vehicular 1	Vehicular 2	Vehicular 3
A	600 x 450	50 or 63	✓	✓	✓63 mm	×
B	600 x 600	50 or 63	✓	✓	✓63 mm	×
C	600 x 750	50 or 63	✓	✓63 mm	×	×
D	600 x 900	50 or 63	✓	✓	×	×
E (small element)	450 x 450	50 or 70	✓	✓	✓70 mm	✓70 mm
F (small element)	400 x 400	50 or 65	✓	✓	✓65 mm	✓65 mm
G (small element)	300 x 300	50 or 60	✓	✓	✓60 mm	✓60 mm

Step 3 - Determine the volume of traffic

Estimated 2 axle rigid commercial vehicles per day = 5
From table 3 adjust the standard axles 5 x 0.34 = 1.7 sa

Estimated 3 axle rigid commercial vehicles per day = 2
From table 3 adjust the standard axles 2 x 1.7 = 3.4 sa

Estimated 4 axle rigid commercial vehicles per day = 1
From table 3 adjust the standard axles 1 x 2.6 = 2.6 sa

Therefore total standard axles per day = 7.7

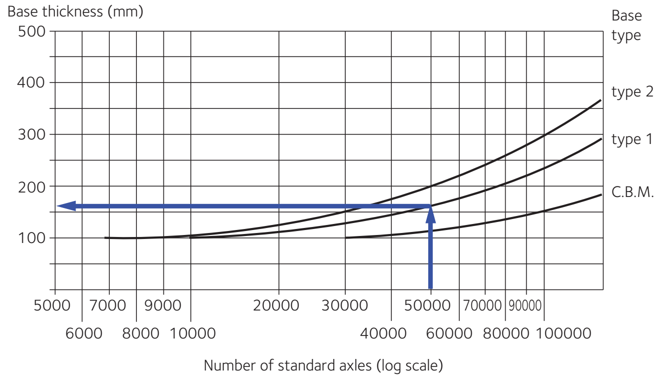
Number of days per week in operation = 6
Operational weeks per year = 52
Design life = 20 years

The total number of standard axles in the 20-year design life:

7.7 x 6 x 52 x 20 = 48,048, say 50,000

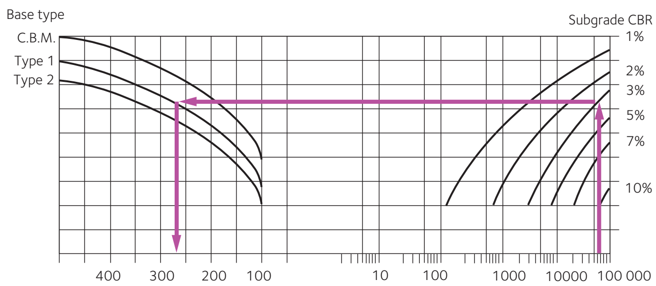
Step 4 Determine Base Thickness

Using graph 1, determine the Sub base thickness required to prevent overstressing the flag. Base is to be Type 1



Using graph 2, determine the Sub base thickness required to prevent overstressing the flag.

Standard Axles = 50,000
CBR = 3%
Subbase = Type 1
Subbase depth 160mm



Standard axles = 50 000
CBR = 3%
Sub base = Type 1
Sub base depth = 270mm

Select the greater depth as the design depth i.e. 270mm

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Brett Landscaping operate to the highest levels of independent certification:
- BS EN ISO 9001 Quality Management System
- BS EN ISO 14001 Environmental Management System
- OHSAS 18001 Health and Safety Management System

In addition, when designing projects under BREEAM we are also holders of BES 6001 Responsible Sourcing of Construction Products (Very Good)
All of these can help significantly when designing for sustainability.