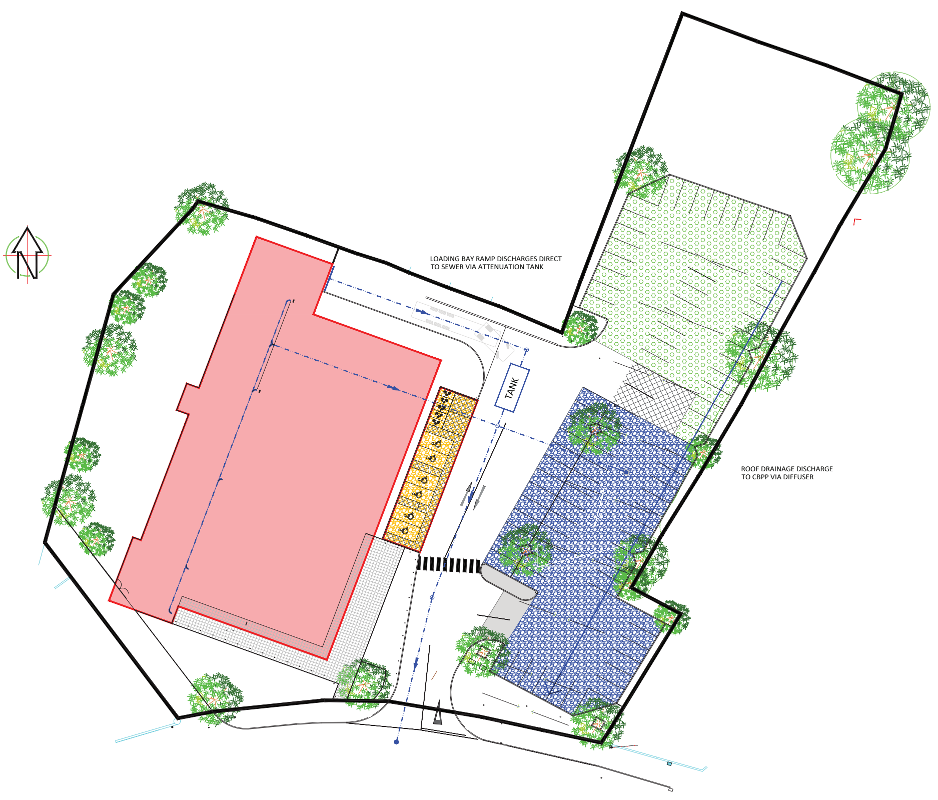
March 2019

Uniclass L534:L217

A DESIGN EXAMPLE FOR
CONCRETE BLOCK PERMEABLE PAVEMENTS



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ENGINEERING DESIGN EXAMPLE

This document provides a comprehensive example illustrating the engineering design process for concrete block permeable pavements (CBPP) set out in Sections 6 – 10 of the Interpave document 'Design & Construction of Concrete Block Permeable Pavements', Edition 7: 2018 (CBPP DACI).

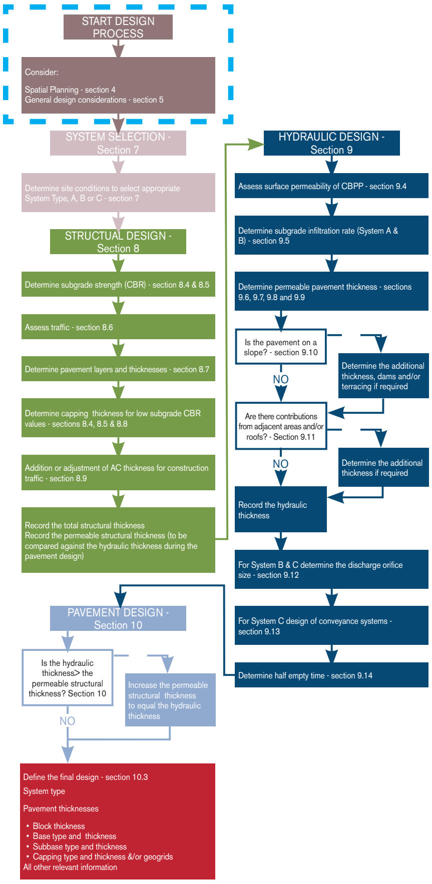
In this example references to the relevant part of the CBPP DACI are highlighted in *Bold Italics*. The engineering design procedure flow chart shown on the following pages is taken from Figure 16 on page 26 of the CBPP DACI.

The site under consideration is located in Leicester and the site layout plan is shown in Figure 1. The design requirements for the SuDS on this site, as agreed with the LLFA, are:

- Infiltration is to be used wherever possible.
- Where infiltration is not possible surface water discharge is to be limited to a greenfield runoff rate = 7l/s/ha for events up to 1 in 100 years with a 20% allowance for climate change.

Figure 1: Site Layout

Zone	Area (m²)	Length (m)	Width (m)	Slope	Contributing Area
CBPP Area 1	151			--	No
CBPP Area 2	939	48	21	1:100	Roof
CBPP Area 3	819	30	28	1:100	No
Roof Area	1791			--	No



STEP 1 - START DESIGN PROCESS

Spatial planning – *Section 4*

The maximum surface slope of the CBPP will be 1 in 100 which is less than 1 in 20 (*Section 4.2*). The impact of the slope on the available storage will need to be taken into account in the design.

The roof water from the supermarket building is to be drained into the sub-base of Area 2 (*Section 4.3*).

All the main statutory services into the site will be located under the main access road which is constructed in asphalt. They have been located so that they do not pass under any areas of CBPP. (*Section 4.4*).

General Design Considerations – *Section 5*

Roof drainage will be discharged into the CBPP sub-base via filter chambers (*Section 5.3*).

Infiltration close to a building is not proposed (*Section 5.4*).

Water quality design (*Section 5.6*).

The site is considered to have a medium Pollution Hazard Level.

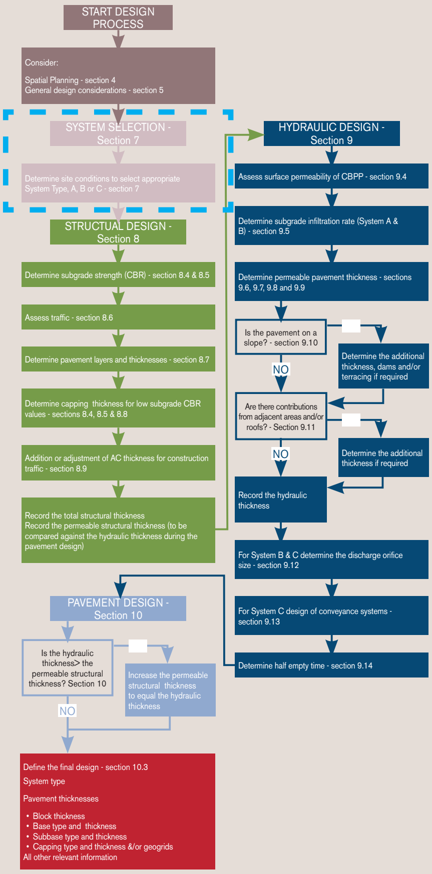
The pollution hazard indices and the mitigation indices for the CBPP are therefore as follows (*Table 1*):

	TSS	Metals	Hydrocarbons
Hazard Index	0.7	0.6	0.7
Pollution Mitigation Index for CBPP	0.7	0.6	0.7

In all cases the Pollution Mitigation Index for the CBPP is greater than, or equal to, the Hazard Index and additional SuDS features for treatment are not required.

Construction traffic (*Section 5.7*)

Construction traffic will not be required to use the CBPP permeable sub-base or the completed surface (*Section 5.7*). The construction will be phased with the capping layer below Areas 1 and 2 used for construction traffic prior to placing the impermeable geomembrane and CBPP construction (Option 2 in *Section 5.7*). Area 3 will be constructed last and will not be subject to construction traffic as it is at the rear of the site (Option 1 in *Section 5.7*).



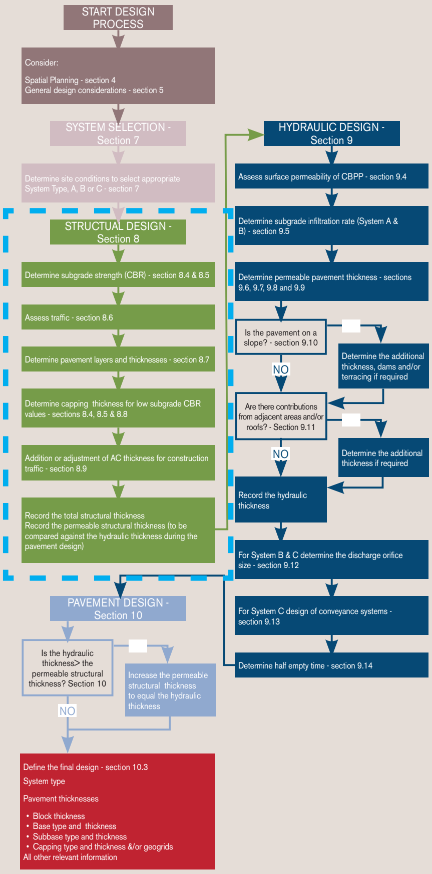
STEP 2 - SYSTEM SELECTION - *SECTION 7*

The site is a former backfilled sand and gravel quarry. The ground conditions are as follows:

- Building and CBPP Areas 1 and 2 CBPP – infilled quarry – Made Ground comprising silty clay with occasional bricks, concrete and timber. Some evidence of hydrocarbon contamination of the soils. Groundwater at 2.5m depth with no evidence of groundwater contamination. Permeability is 8 x 10^{-9}m/s.
- CBPP Area 3 – Outside infilled quarry and underlain by natural ground – River Terrace Gravels comprising well graded sand and gravel that is medium dense. No evidence of contamination and groundwater is at 2.5m depth. Permeability is 3.2 x 10^{-5}m/s.

Using *Figure 17* the following System Types are appropriate:

- CBPP Areas 1 and 2 – System C – the ground permeability is below the limit for System A or B and the ground is contaminated. Therefore, a lined system is required.
- CBPP Area 3 – System A – the ground permeability is greater than the minimum required for System A and there is no other reason to prevent infiltration (contamination or proximity to buildings).



STEP 3 - STRUCTURAL DESIGN - *SECTION 8*

Subgrade assessment (*Section 8.4*)

Based on the ground conditions described in the site investigation report the following guideline CBR values are obtained from *Table 3*. These should be confirmed on site prior to construction.

- Areas 1 and 2 – Made Ground comprising silty clay with Plasticity Index (PI) of 29%. Use the next highest value of PI in *Table 3* (30%). *Table 3* gives CBR for design = 3%. However, Made Ground may settle over time and will be variable in composition. Therefore, adopt CBR of 2%. This will require subgrade improvement works to bring the design CBR up to 3.0%.

  CBR for design = 3.0% with capping layer required.

- Area 3 – River Terrace Gravels comprising well graded sand and gravel.

  CBR for design = 15%.

Traffic assessment (*Section 8.6*)

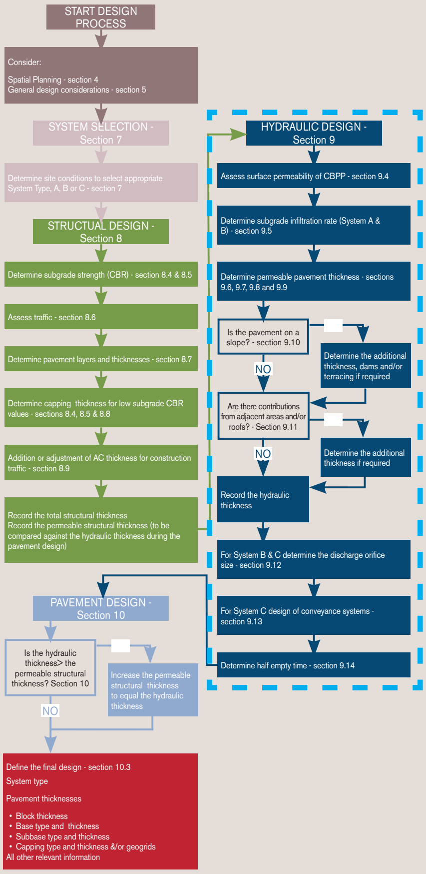
CBPP Areas 1 and 2 are adjacent to main access road to the loading bay for the supermarket. They may therefore be occasionally trafficked by HGVs. Assume Traffic Category 5 from *Table 4.*

CBPP Area 3 is located away from the main HGV access route and is likely to be only trafficked by cars or light commercial vehicles. This would indicate Traffic Category 3 which applies to small car parks. However, to allow for some very occasional over run by HGVs increase to Traffic Category 4 (which is for pedestrian areas with very occasional HGVs such as maintenance vehicles). Assume Traffic Category 4 from *Table 4.*

Pavement layers and thickness (*Section 8.7*), adjustment for low CBR (*Section 8.8*) and allowance for construction traffic on AC layer (*Section 8.9*)

From *Table 5* the following construction is required and recorded:

Zone	Concrete block thickness	Laying course	Base	Sub-base	Capping layer
Areas 1 & 2	80mm in herringbone pattern	50mm	Choose 70mm AC32 to allow contractor flexibility in construction programme (It can be used for construction traffic and cored later – see *Note 5 to Table 5*). (Note increase to 80mm if AC layer used for construction traffic – *Section 8.9*).	Choose 150mm coarse graded aggregate (CGA).	The subgrade improvement comprising 6F2 material will be incorporated into the capping layer to give a total layer thickness of 350mm.
Area 3	80mm in herringbone pattern	50mm	Not required	Choose 300mm coarse graded aggregate (CGA).	This design is suitable for CBR of 5% or greater and therefore no capping layer is required.



STEP 4 - HYDRAULIC DESIGN - *SECTION 9*

Assess surface permeability (*Section 9.4*)

The ACME blocks and jointing material have been tested and have a surface permeability of greater than 2500mm/h. This is sufficient.

Determine subgrade infiltration rate (*Section 9.5*)

Not applicable to Areas 1 and 2 as the system is a Type C attenuation and infiltration will not occur.

For Area 3 the soakaway tests from a site investigation gave infiltration results in the River Terrace Gravels of 3.2×10^{-5}m/s.

Determine hydraulic thickness (Simple method using tables in *Section 9.9*)

Hydraulic design for Area 1

Catchment area = 151m^2

Type C – required Greenfield Runoff Rate for design is 7l/s/ha.

Figure 22 – Leicester M5-60 = 20mm and r = 0.4

Table 10 for 7l/s/ha for events up to 1 in 100 year with a 20% allowance for climate change – sub-base thickness = 210mm

Is the pavement on a slope (Section 10) – No – No further action

Are there contributing areas and or roofs? – No – No further action

Record hydraulic thickness = 210mm

Discharge orifice size (*Section 9.12*)

Q = Orifice discharge rate for the area of pavement being drained

Q = Area of pavement x allowable discharge rate

Q = 151m^2 x (7l/s/ha)/10,000 = 0.11l/s [Note dividing by 10,000 converts ha to m^2]

0.11l/s = 0.11/1000 = 1.1×10^{-4}m^3/s

$C_d = 0.6$

h = Hydraulic head = Storage depth in sub-base = 210mm or 0.21m above centreline of orifice
[Note: the full depth is used here which means the maximum flow will only occur when the sub-base is full. In theory this could lead to under design of the storage. However, experience has shown that this is not a problem in practice because the design approach is conservative and does not for example take account of the interception provided by permeable pavements. As a precaution the orifice will be provided with an overflow, which should be standard practice for any flow control.]

g = 9.81m/s^2

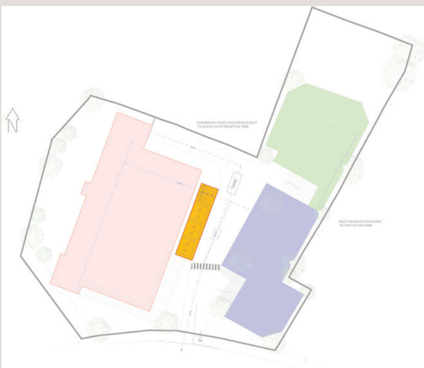
Using the equation from *Section 9.12*

$Q = C_d A_o \sqrt{(2gh)}$

$1.1 \times 10^{-4} = 0.6 A_o \sqrt{(2 \times 9.81 \times 0.21)}$

Rearranging and solving the equation gives area of orifice required, Ao = 9.0×10^{-5} m^2

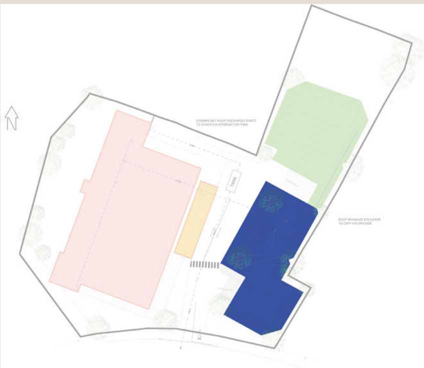
Diameter of orifice required = 0.011m or 11mm.



This is obviously far too small to be practicable and therefore a minimum size protected orifice of 20mm should be provided with an overflow route within the chamber, for excess flows.

The Area 1 CBPP is to discharge into the surface sewer across the site. The area is less than 300m² and this can be achieved by installing a length of geocomposite drainage material along the edge of the sub-base and connecting it to a 100mm diameter pipe at a gradient of 1 in 100 that discharges to the sewer (*Section 12.5* and *Figure 35*).

Determine half empty time – this is already dealt with in the table and half empty time is less than 24 hours.



Hydraulic design for Area 2

Catchment area = 939m² pavement area plus 1791m² roof area

Type C – required Greenfield Runoff Rate for design is 7l/s/ha.

Figure 22 – Leicester M5-60 = 20mm and r = 0.4

Table 10 for 7l/s/ha for events up to 1 in 100 year with a 20% allowance for climate change – sub-base thickness = 210mm

Is the pavement on a slope? – Yes – At 1 in 100. Need to allow for this (see below – make this allowance after considering any extra additional contributing areas).

Are there contributing areas and or roofs? – Yes – Roof area of 1791m².

Allow for impermeable area (*Section 9.11*)

Total thickness $T = t(A_I + A_p)/A_p$

t = Thickness from hydraulic design above = 210mm

A_I = Area of impermeable surfacing = 1791m²

A_P = Area of CBPP = 939m²

Therefore T = 610mm <u>if CBPP is flat</u>

Allow for slope of site/CBPP (*Section 9.10*)

Vs = 0.5 x l x W x T

l = Length of permeable construction where water can be stored at low end of slope = T/tanβ

T = Thickness of sub-base = 610mm and β for a 1 in 100 slope = 0.57°

l = 610mm / tan 0.57° = 61.3m, i.e., check dams would be required every 60m and storage in between check dams is 50% of that provided by the total thickness of sub-base. However, the length of the pavement is less than 60m (it is 48m). Therefore, assess the storage provided on the slope over 48m or reduce the sub-base thickness to suit the length of the CBPP and maximise the volume of sub-base used for storage in one compartment without check dams.

Assess storage on slope for the length of the CBPP

Reduce sub-base thickness to 450mm with 48m length of pavement. Width of pavement W= 21m

Check dams required at l = 450mm/tan 0.57° = 45.2m – as the pavement length only slightly exceeds this, treat it as one compartment.

Volume of sub-base available for storage = 0.5 x 48 x 21 x 0.45 = 227m³

Volume of sub-base required for storage for CBPP and roof = 0.61 x 21 x 48 = 615m³

Therefore, additional storage will have to be provided. Some possible options are:

1. Increase the sub-base thickness
2. Redesign site levels so the CBPP is flat
3. Provide a geocellular tank in a trench at the bottom of the slope
4. Complete a more detailed analysis of water flow within the pavement to see if the sub-base will retard flow to the bottom of the slope and thus allow more storage to be mobilised.

For this example, option 3 has been chosen.

The shortfall in the volume of sub-base is 615m^3 - 227m^3 = 388m^3

The design charts assume the sub-base has a porosity of 30% and therefore the volume of water to be stored is 388 x 0.3 = 116m^3

Use a geocellular attenuation tank with a porosity = 95% so required tank volume = 116/0.95 = 122m^3

Provide a tank at the bottom of the slope. Length of tank = 15m and width = 10m. Therefore height = 122/(15 x 10) = 0.8m

The tank should be constructed at the lowest point of the CBPP across the width of the CBPP (perpendicular to the slope). The CBPP sub-base should be constructed on top of the tank. The top is covered by a permeable geotextile and it acts as a collector for water from the sub-base. The side and base should be lined with an impermeable geomembrane and an outlet provided via the flow control (see below for sizing) to the surface water sewer. Structural and geotechnical design of the tank is beyond the scope of this document.

Record hydraulic thickness = 450mm + attenuation tank of 122m^3

Discharge orifice size (*Section 9.12*)

Q = Orifice discharge rate for the area of pavement being drained.

Q = Area of pavement (and additional area) x allowable discharge rate

Q = (1791 + 939)m^2 x (7l/s/ha)/10,000 = 1.9l/s
[Note: dividing by 10,000 converts ha to m^2]

1.9l/s = 1.9/1000 = 1.9 x 10^{-3}m^3/s

C_d = 0.6

h = Hydraulic head = Storage depth in attenuation tank at base of system in this case = 800mm + 450mm in sub-base = 1250mm or 1.25m from above.

g = 9.81m/s^2

Using the equation from Section 9.12

$Q = C_d A_o \sqrt{(2gh)}$

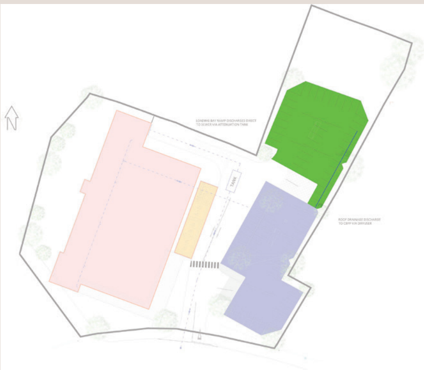
$1.9 \times 10^{-3} = 0.6A_o \sqrt{(2 \times 9.81 \times 1.25)}$

Rearranging and solving the equation gives Area of Orifice required, $A_o = 6.4 \times 10^{-4}$ m^2

Diameter of orifice required = 0.029m - assume 30mm. Provide an overflow route within the chamber.

The Area 2 CBPP is to discharge into the surface sewer across the site. This area requires an attenuation tank below the sub-base at the lowest part of the permeable pavement. The discharge can be via a pipe connected to the attenuation tank that discharges to the sewer.

Determine half empty time - this is already dealt with in the table and half empty time is less than 24 hours.



Hydraulic design for Area 3

Catchment area = 819m^2

Type A – infiltration rate = 3.2 x 10^{-5}m/s The nearest infiltration rate in *Table 10* is 1 x 10^{-5}m/s, i.e., three times lower

Figure 22 – Leicester M5-60 = 20mm and r = 0.4

Table 10 for infiltration rate of 1 x 10^{-5}m/s for events up to 1 in 100 year with a 20% allowance for climate change – sub-base thickness = 90mm

Is the pavement on a slope – Yes – Further action required (see below)

Are there contributing areas and or roofs? – No – No further action

Allow for slope

Vs = 0.5 x l x W x T

l = length of permeable construction where water can be stored at low end of slope = T/tanβ

W = Width of permeable construction

T = Thickness of sub-base = 300mm (from traffic design as that is greater than the hydraulic design thickness) and β for a 1 in 100 slope = 0.57°

l = 300mm / tan 0.57° = 30m, i.e., check dams would be required every 30m to maximise storage in sub-base. Length of pavement is 30m so treat as a single compartment.

Volume of sub-base available for storage = 0.5 x 30 x 28 x 0.3 = 126m^3

Volume of sub-base required for storage = 819 x 0.09 = 74m^3

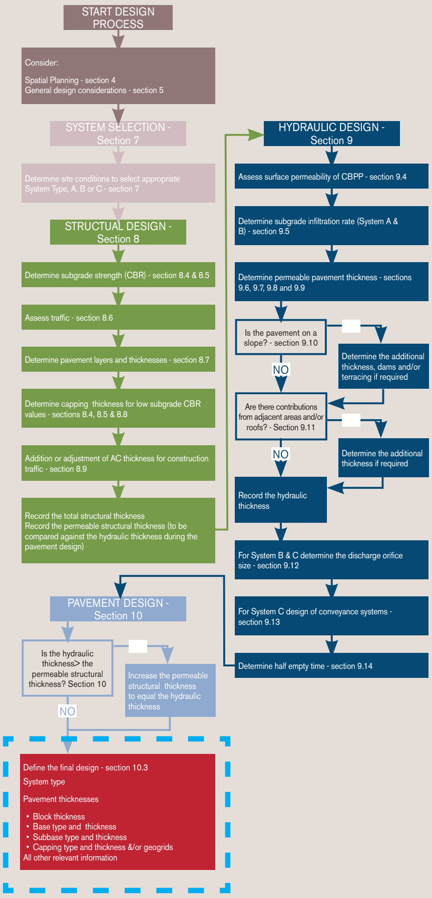
Therefore, the storage provided is greater than that required and so, in this case, there is no need to increase the sub-base thickness further.

Record hydraulic thickness = 300mm

Discharge Orifice Size (*Section 9.12*)

Type A system – infiltration does not require a discharge control

Determine half empty time – this is already dealt with in the table and half empty time is less than 24 hours.



STEP 5 - PAVEMENT DESIGN - *SECTION 10*

Area 1

Sub-base thickness:

Hydraulic = 210mm

Structural = 150mm

<u>Therefore, design thickness = 210mm</u>

Define final design – Area 1

Type C pavement
80mm block
50mm laying course 2/6.3 material
70mm AC32 Base (80mm if to be used for construction traffic)
210mm CGA sub-base
1mm flexible geomembrane with welded joints
350mm 6F2 capping layer

Area 2

Sub-base thickness:

Hydraulic = 450mm

Structural = 150mm

<u>Therefore, design thickness = 450mm (plus attenuation tank)</u>

Define final design – Area 2

Type C pavement over soil
80mm block
50mm laying course 2/6.3 material
70mm AC32 Base (80mm if to be used for construction traffic)
450mm CGA sub-base
1mm flexible geomembrane with welded joints
350mm 6F2 capping layer (may not be required in area of attenuation tank – subject to structural design)

Type C pavement over attenuation tank (tank structural calculations to be completed by others – see SuDS Manual)
80mm block
50mm laying course 2/6.3 material
70mm AC32 Base (80mm if to be used for construction traffic)
450mm CGA sub-base
Permeable geotextile – 300g/m2
Attenuation tank – 800mm
1mm flexible geomembrane with welded joints

Area 3

Sub-base thickness:

Hydraulic = 300mm

Structural = 300mm

<u>Therefore, design thickness = 300mm</u>

Define final design – Area 3

Type A pavement
80mm block
50mm laying course 2/6.3 material
300mm CGA sub-base
Geotextile separation layer

HARD LANDSCAPE AND INTERPAVE

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Precast Concrete Paving

- Visually attractive and able to deliver distinctive local character
- Helping to deliver 'Manual for Streets' and other guidance
- Capability for clear differentiation between distinct areas
- Accessible to all with consistent slip and skid resistance
- Durable and maintainable with reliable product supply
- Sustainable – in every sense.

a diversity of shapes, styles, finishes and colours for contemporary design.

Concrete Block Permeable Paving

- Reducing, attenuating & treating rainwater near the surface
- Direct infiltration to the ground or conveyance to SuDS or sewers
- Multi-functional SuDS meeting current requirements
- Low cost storage using flow controls without additional land-take
- Established technology with decades of proven performance
- Safe, level, puddle-free, shared surfaces for all.

a gradual supply of clean water for landscape, biodiversity and harvesting.

Improving Paving Quality

Interpave supports the National Highways Sector Scheme for the Installation, Maintenance and Repair of Modular Paving (NHSS 30). This scheme assures the installed quality of all forms of modular paving by providing an industry benchmark and a foundation for ongoing improvement, while highlighting the importance of a suitably trained workforce.

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