

SDS Structural Design Calculations

New Barn Lane

E/549/20

01/10/20

Version 1

1 Introduction

This is a report showing the structural analysis of a geocellular modular drainage tank for the new proposed New Barn Lane. Four tanks is to be installed. Tank loading is calculated using DIN 1072 loading classification 30/30.

Assumptions:

- Pressure from point load of tyre disperses at an angle of 26°.
- Shear angle of resistance taken as 38°.
- Soil/ fill density of 19kNm³.
- Maximum and minimum cover depths as below report
- Groundwater level as per end of fieldwork. GL assumed as finished cover

2 Design information

Calculations are based on the following design information:

Site Levels and tank dimensions	<i>1643-WSP-XXX-NBL-DR-C-0501</i>
	<i>1643-WSP-XXX-NBL-DR-C-0502</i>
	<i>Groundwater monitoring Results – 15/04/20</i>
Loading	<i>CIRIA C680 – Table 4.2 Characteristic loads for different land use 2008</i>
Factors	<i>CIRIA C680 – Table 4.5 Partial load factors (based on EN 1997-1:2004) 2008</i>

3 Design equations

3.1 Vertical pressure equations:

Vertical loading takes account of permanent loading from cover backfill c according to (3.1), variable load from vehicles etc (surcharge) q and accidental loading from HGVs (point) w . Pressure from HGV assumes a 26° distribution, from point of application. Load due to depth of cover over tank is given by equation (3.1)

$$c = \gamma \cdot z \quad (3.1)$$

where γ is soil density and z the cover depth. Therefore design vertical pressure given by:

$$\sigma_{v,d} = c \cdot \lambda + q \cdot \lambda + w \cdot \lambda \quad (3.2)$$

where λ are appropriate the load factors.

3.2 Lateral pressure equations:

Lateral pressures calculated using the coefficient of lateral earth pressure and vertical pressure resulting from permanent backfill and variable surcharge. Maximum pressure taken at 200mm above the base of tank.

$$\sigma_{h,d} = \{K_a(q + \gamma h)\} \times \lambda \quad (3.3)$$

where K_a is the coefficient of lateral earth pressure given by equation (3.4), h is the reference depth at which the lateral pressure is ascertained. Again λ is the factor of safety.

$$K_a = \frac{1 - \sin \phi}{1 + \sin \phi} \quad (3.4)$$

where ϕ is the angle of shear resistance.

3.3 Uplift pressure equations:

If the tank is located below the water table, uplift can occur, whereby the uplift pressure equals to the weight of water displaced.

Case1: Water table level between top and bottom of tank, i.e. depth of ground water table greater than depth of cover. Thus uplift U given by equation (3.5)

$$U = D_{dw} \times \gamma_w \quad (3.5)$$

where D_{dw} is depth of water displaced and γ_w the unit weight of water.

Case2: Water table level above tank, i.e. depth of ground water table less than or equal to the depth of cover. In this case design uplift U_d is given by equation (3.6)

$$U_d = H \times \gamma_w \times \lambda \quad (3.6)$$

where H is the height of the tank

The uplift force is resisted by the weight of soil overlying the tank, neglecting the weight of tank. Thus vertical resisting pressure calculated from equation (3.7)

$$\sigma_{v,r} = \gamma \times z \quad (3.7)$$

Note that when case 2 is in effect, the unit weight of backfill must be considered separately as normal and saturated soils. For the saturated soil, and effective unit weight must be used and derived from equation (3.8)

$$\gamma' = \gamma - \gamma_w \quad (3.8)$$

4 Design calculation spreadsheets

Tank 1

Borehole No: WS01 Groundwater depth at the end of field work:- 1.50m bgl

Proposal number:	E/549/20
Date:	01/10/2020

Job Name:	New Barn Lane
Author:	BW

Site Elevations (m)		
Ground Level AOD	Max	4.637
	Min	4.637
Tank Level	Top	3.920
	Bottom	2.670
Cover Depth, z	Max, z_{max}	0.717
	Min, z_{min}	0.717
Ground water table depth AOD	z_w	3.137

Soil/Fill Characteristics	
γ (kNm^{-3})	19.00
ϕ (°)	38.00

WS01

VERTICAL

Area Due To Spread Of Point Load, A (m^2)		
Spread angle (degrees)		26.00
A (z_{max})		0.99
A (z_{min})		0.99

Load Area (m.m)	
0.20	0.40

Loading Case (Din 1072)	30/30.
Surcharge, q	10.00 kNm^{-2}
Cover Fill, c Max/Min [$\gamma \cdot z$]	13.62 kNm^{-2}
	13.62 kNm^{-2}
Point, w	50.00 kN

Factors, λ	
Surcharge	1.50
Cover	1.35
Point	1.50

Factored Vertical Loading, (kNm^{-2})	
Surcharge [$q_d = q \cdot \lambda$]	15.00
Cover [$c_d = c \cdot \lambda$]	18.39
	18.39
Point [$w_d = (w/A) \cdot \lambda$]	75.85
	75.85

Design Vertical Loading, $\sigma_{v,d}$		
$\sigma_{v,d}(z_{max})$	109.2	kNm^{-2}
$\sigma_{v,d}(z_{min})$	109.2	

LATERAL (no ground water included)

Reference Depth	
h (m)	1.77

ϕ (rad)	0.66
$k_a [1 - \sin\phi / 1 + \sin\phi]$	0.24

Loading Case (Din 1072)	30/30.
Surcharge, q	10.00 kNm^{-2}
Cover, c [$\gamma \cdot h$]	33.57 kNm^{-2}

Factors, λ	
Permanent	1.35
Variable	1.50

Factored Lateral Loading, (kNm^{-2})	
Surcharge [$q_d = k_a \cdot q \cdot \lambda$]	3.57
Cover Fill [$c_d = k_a \cdot c \cdot \lambda$]	10.78

Design Lateral Loading, $\sigma_{l,d}$		
$\sigma_{l,d}(z_{max})$	14.3	kNm^{-2}

LATERAL (ground water included as above base of tank)

Reference Depth		ϕ (rad)	0.66
h (m)	1.77	$k_a [1 - \sin\phi / 1 + \sin\phi]$	0.24

Loading Case (Din 1072)		30/30.	Factors, λ	
Surcharge, q	10.00	kNm ⁻²	Lateral	1.35

Factored Lateral Loading, (kNm ⁻²)		Design Lateral Loading, $\sigma_{r,d}$	
Surcharge [$q_d = k_a \cdot q \cdot \lambda$]	3.21	$\sigma_{r,d}(z_{max})$	16.7 kNm ⁻²
Backfill above ground water [$k_a \cdot \gamma \cdot z_w \cdot \lambda$]	9.15		
Backfill below ground water [$k_a \cdot (\gamma - \gamma_w) \cdot (z - z_w) \cdot \lambda$]	0.77		
Water pressure [$\gamma_w \cdot (z - z_w) \cdot \lambda$]	3.60		

UPLIFT

Water table elevation (m)	3.14	Depth of tank D_T (m)	1.25
Water displaced D_{dw} (m)	0.47	Factors λ	
		Permanent Uplift	1.0
		Permanent Resist press.	0.9

Case 1 $D_{dw} < D_T$	TRUE	
Design Uplift kNm ⁻²		Satisfactory: TRUE
$U_d [D_{dw} \cdot \gamma_w \cdot \lambda]$	4.67	
Design Resisting Pressure $\sigma_{r,d}$		
Cover Fill $c_d [\gamma \cdot z \cdot \lambda]$	12.26	

Case 2 $D_{dw} > D_T$	FALSE	
Submerged Cover z_s (m)	-0.78	Satisfactory: TRUE
Unsubmerged cover z_u (m)	1.50	
Design Uplift (kNm ⁻²)		
$U_d [D_T \cdot \gamma_w \cdot \lambda]$	12.50	
Design Resisting Pressure (kNm ⁻²)		
Submerge cover $c_{d,s} [\gamma' \cdot z_s]$	-6.34	
Cover $c_{d,u} [\gamma \cdot z_u \cdot \lambda]$	25.65	
TOTAL	19.31	

Tank 2

Borehole No: WS04 Groundwater depth at the end of field work:- 1.56m bgl

Proposal number:	E/549/20
Date:	01/10/2020

Job Name:	New Barn Lane
Author:	BW

Site Elevations (m)		
Ground Level AOD	Max	5.040
	Min	5.040
Tank Level	Top	4.415
	Bottom	3.665
Cover Depth, z	Max, z_{max}	0.625
	Min, z_{min}	0.625
Ground water table depth AOD	z_w	3.480

Soil/Fill Characteristics	
γ (kNm^{-3})	19.00
ϕ ($^\circ$)	38.00

WS04

VERTICAL

Area Due To Spread Of Point Load, A (m^2)		
Spread angle (degrees)		26.00
A (z_{max})		0.82
A (z_{min})		0.82

Load Area (m.m)	
0.20	0.40

Loading Case (Din 1072)		30/30.
Surcharge, q	10.00	kNm^{-2}
Cover Fill, c Max/Min [Y.z]	11.88	kNm^{-2}
	11.88	kNm^{-2}
Point, w	50.00	kN

Factors, λ	
Surcharge	1.50
Cover	1.35
Point	1.50

Factored Vertical Loading, (kNm^{-2})	
Surcharge [$q_d = q \cdot \lambda$]	15.00
Cover [$c_d = c \cdot \lambda$]	16.03
	16.03
Point [$w_d = (w/A) \cdot \lambda$]	91.74
	91.74

Design Vertical Loading, $\sigma_{v,d}$		
$\sigma_{v,d}(z_{max})$	122.8	kNm^{-2}
$\sigma_{v,d}(z_{min})$	122.8	

LATERAL (no ground water included)

Reference Depth	
h (m)	1.18

ϕ (rad)	0.66
$k_a [1 - \sin\phi / 1 + \sin\phi]$	0.24

Loading Case (Din 1072)		30/30.
Surcharge, q	10.00	kNm^{-2}
Cover, c [Y.h]	22.33	kNm^{-2}

Factors, λ	
Permanent	1.35
Variable	1.50

Factored Lateral Loading, (kNm^{-2})	
Surcharge [$q_d = k_a \cdot q \cdot \lambda$]	3.57
Cover Fill [$c_d = k_a \cdot c \cdot \lambda$]	7.17

Design Lateral Loading, $\sigma_{l,d}$		
$\sigma_{l,d}(z_{max})$	10.7	kNm^{-2}

Tank 3

Borehole No: WS05 Groundwater depth at the end of field work:- 1.65m bgl

Proposal number:	E/549/20
Date:	01/10/2020

Job Name:	New Barn Lane
Author:	BW

Site Elevations (m)		
Ground Level AOD	Max	4.579
	Min	4.579
Tank Level	Top	3.860
	Bottom	3.110
Cover Depth, z	Max, z_{max}	0.719
	Min, z_{min}	0.719
Ground water table depth AOD	z_w	2.929

Soil/Fill Characteristics	
γ (kNm^{-3})	19.00
ϕ ($^{\circ}$)	38.00

WS05

VERTICAL

Area Due To Spread Of Point Load, A (m^2)		
Spread angle (degrees)		26.00
A (z_{max})		0.99
A (z_{min})		0.99

Load Area (m.m)	
0.20	0.40

Loading Case (Din 1072)	30/30.
Surcharge, q	10.00 kNm^{-2}
Cover Fill, c Max/Min [$\gamma \cdot z$]	13.66 kNm^{-2}
	13.66 kNm^{-2}
Point, w	50.00 kN

Factors, λ	
Surcharge	1.50
Cover	1.35
Point	1.50

Factored Vertical Loading, (kNm^{-2})	
Surcharge [$q_d = q \cdot \lambda$]	15.00
Cover [$c_d = c \cdot \lambda$]	18.44
	18.44
Point [$w_d = (w/A) \cdot \lambda$]	75.55
	75.55

Design Vertical Loading, $\sigma_{v,d}$		
$\sigma_{v,d}(z_{max})$	109.0	kNm^{-2}
$\sigma_{v,d}(z_{min})$	109.0	

LATERAL (no ground water included)

Reference Depth	
h (m)	1.27

ϕ (rad)	0.66
$k_a [1 - \sin\phi / 1 + \sin\phi]$	0.24

Loading Case (Din 1072)	30/30.
Surcharge, q	10.00 kNm^{-2}
Cover, c [$\gamma \cdot h$]	24.11 kNm^{-2}

Factors, λ	
Permanent	1.35
Variable	1.50

Factored Lateral Loading, (kNm^{-2})	
Surcharge [$q_d = k_a \cdot q \cdot \lambda$]	3.57
Cover Fill [$c_d = k_a \cdot c \cdot \lambda$]	7.74

Design Lateral Loading, $\sigma_{l,d}$		
$\sigma_{l,d}(z_{max})$	11.3	kNm^{-2}

Tank 4

Borehole No: WS03 Groundwater depth at the end of field work:- 1.52m bgl

Proposal number:	E/549/20
Date:	01/10/2020

Job Name:	New Barn Lane
Author:	BW

Site Elevations (m)		
Ground Level AOD	Max	4.870
	Min	4.870
Tank Level	Top	4.050
	Bottom	2.800
Cover Depth, z	Max, z_{max}	0.820
	Min, z_{min}	0.820
Ground water table depth AOD	z_w	3.350

Soil/Fill Characteristics	
γ (kNm^{-3})	19.00
ϕ ($^\circ$)	38.00

WS03

VERTICAL

Area Due To Spread Of Point Load, A (m^2)		
Spread angle (degrees)		26.00
A (z_{max})		1.20
A (z_{min})		1.20

Load Area (m.m)	
0.20	0.40

Loading Case (Din 1072)		30/30.
Surcharge, q	10.00	kNm^{-2}
Cover Fill, c	15.58	kNm^{-2}
Max/Min [$\gamma \cdot z$]	15.58	kNm^{-2}
Point, w	50.00	kN

Factors, λ	
Surcharge	1.50
Cover	1.35
Point	1.50

Factored Vertical Loading, (kNm^{-2})	
Surcharge [$q_d = q \cdot \lambda$]	15.00
Cover [$c_d = c \cdot \lambda$]	21.03
	21.03
Point [$w_d = (w/A) \cdot \lambda$]	62.51
	62.51

Design Vertical Loading, $\sigma_{v,d}$		
$\sigma_{v,d}(z_{max})$	98.5	kNm^{-2}
$\sigma_{v,d}(z_{min})$	98.5	

LATERAL (no ground water included)

Reference Depth	
h (m)	1.87

ϕ (rad)	0.66
$k_a [1 - \sin\phi / 1 + \sin\phi]$	0.24

Loading Case (Din 1072)		30/30.
Surcharge, q	10.00	kNm^{-2}
Cover, c [$\gamma \cdot h$]	35.53	kNm^{-2}

Factors, λ	
Permanent	1.35
Variable	1.50

Factored Lateral Loading, (kNm^{-2})	
Surcharge [$q_d = k_a \cdot q \cdot \lambda$]	3.57
Cover Fill [$c_d = k_a \cdot c \cdot \lambda$]	11.41

Design Lateral Loading, $\sigma_{l,d}$		
$\sigma_{l,d}(z_{max})$	15.0	kNm^{-2}

LATERAL (ground water included as above base of tank)

Reference Depth		ϕ (rad)	0.66
h (m)	1.87	$k_a [1 - \sin\phi / 1 + \sin\phi]$	0.24

Loading Case (Din 1072)		30/30.
Surcharge, q	10.00	kNm ⁻²

Factors, λ	
Lateral	1.35

Factored Lateral Loading, (kNm ⁻²)	
Surcharge [$q_d = k_a \cdot q \cdot \lambda$]	3.21
Backfill above ground water [$k_a \cdot \gamma \cdot z_w \cdot \lambda$]	9.27
Backfill below ground water [$k_a \cdot (\gamma - \gamma_w) \cdot (z - z_w) \cdot \lambda$]	1.01
Water pressure [$\gamma_w \cdot (z - z_w) \cdot \lambda$]	4.73

Design Lateral Loading, $\sigma_{r,d}$	
$\sigma_{r,d}(z_{max})$	18.2 kNm ⁻²

UPLIFT

Water table elevation (m)	3.35	Depth of tank D_T (m)	1.25
Water displaced D_{dw} (m)	0.55	Factors λ	
		Permanent Uplift	1.0
		Permanent Resist press.	0.9

Case 1 $D_{dw} < D_T$	TRUE
Design Uplift kNm ⁻²	
$U_d [D_{dw} \cdot \gamma_w \cdot \lambda]$	5.50
Design Resisting Pressure $\sigma_{r,d}$	
Cover Fill $c_d [\gamma \cdot z \cdot \lambda]$	14.02
Satisfactory: TRUE	

Case 2 $D_{dw} > D_T$	FALSE
Submerged Cover z_s (m)	-0.70
Unsubmerged cover z_u (m)	1.52
Design Uplift (kNm ⁻²)	
$U_d [D_T \cdot \gamma_w \cdot \lambda]$	12.50
Design Resisting Pressure (kNm ⁻²)	
Submerge cover $c_{d,s} [\gamma' \cdot z_s]$	-5.67
Cover $c_{d,u} [\gamma \cdot z_u \cdot \lambda]$	25.99
TOTAL	20.32
Satisfactory: TRUE	