GOVERNMENT OF ORISSA

WORKS DEPARTMENT

ORISSA STATE ROAD PROJECT

FINAL DETAILED ENGINEERING REPORT FOR PHASE-I ROADS

DESIGN REPORT OF CULVERTS (BHAWANIPATNA TO KHARIAR)

C O N S U L T I N G

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INTRODUCTION

INTRODUCTION

The culverts have been categorized on the basis of detailed inventory and condition survey, hydrological study, horizontal & vertical profile of highway.

The following criterion has been taken while deciding the culverts :

i. The width of culvert shall be 12.0m
ii. NP-3/NP-4 pipe culverts in good condition and hydrologically adequate shall be retained
iii. Slab culverts structurally in good condition and hydrologically adequate having width less than 10.0m shall be widened as per approved alignment.
iv. All arch type culverts shall be reconstructed.
v. All new pipe culverts shall have minimum dia. of 1.0m and box culverts of minimum span 2.0m and height 1.5m.
vi. RR stone masonry culverts shall be reconstructed.
vii. Additional culverts as per site investigation has been identified and included in this report.

On the basis of above, all culverts lies in the following category :

i. Single Pipe Culverts of 1.0m dia
ii. Double Pipe Culverts of 1.0m dia
iii. Extension of Pipe Culverts with existing pipe dia
iv. Single Cell box Culverts upto span of 6.0m
v. Widening of Slab Culverts

On the basis of above, all culverts in this stretch lies the following category

Summary of Proposed Culverts

Type of Culvert	Nos.
Culverts Retained	
Culverts Widened	
Pipe extension	4
Slab widening	Nil
Culverts Replaced	
New Single Pipe	33
New Double Pipe	13
New Single Box of 1/22/0	11
New Single Box of 1/23/0	24
New Single Box of 1/33/0	4
New Single Box of 1/34/0	11
New Single Box of 1/43/0	2
New Single Box of 1/44/0	2
New Single Box of 1/45/0	4
New Single Box of 1/63/0	2
New Single Box of 1/64/0	1
Additional Culverts proposed	

Type of Culvert	Nos.
Single Pipe	1
Double Pipe	3
Single Cell Box of 1/22/0	3
Single Cell Box of 1/23/0	2
Total	**120**

The drawings of Pipe Culverts for height of fill from 0.6 to 4.0m has been taken from SP-13.For Box Culverts with different clear heights MOST Standard Drawings has been taken.

Bed levels, Formation levels, Super-elevation/Camber has been taken from highway plan & profile drawings and data has been analysed by using Microsoft Excel Sheet.

In Box Culverts, the retaining wall is kept along the road instead of splayed Wing Wall mentioned in MOST Drawings. These Walls has been designed by using Microsoft Excel Sheet for the height varying from 2.0 to 6.0m.

Reference codes:

IRC – 6 – 2000
IRC – 21 – 2000
IRC – 78 – 2000

Proposed Culverts

S. No.	Location/ Chainage	Design Chainage	Existing Span Arrangement	Type of Existing Culvert	Proposed Span Arrangement	Type of Proposed Culvert	Remarks
1	3/450	3683	1 x 1.0	Slab	2 x 1.0	Pipe	Reconstruction due to poor condition
2	4/100	4112	1 x 0.6	Pipe	1 x 1.0	Pipe	**Replaced due to insufficient vent, to be used for Environmental purpose**
3	5/450	5494	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
4	5/650	5691	1 x 1.2	Stone Slab	1/34/0	RCC Box	Stone slab culvert, to be replaced
5	**5/800**	**5800**	**-**	**-**	**1/22/0**	**RCC Box**	**Additional structure**
6	6/550	6533	2 x 1.0	Pipe	1/34/0	RCC Box	Replaced due to poor conditon
7	6/900	6935	1 x 2.4	Slab	1/45/0	RCC Box	Replaced due to raise in road level
8	7/015	7030	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
9	7/800	7815	1 x 0.3	Stone Slab	1/22/0	RCC Box	Stone slab culvert, to be replaced
10	9/450	9474	1 x 0.9	Slab	1/34/0	RCC Box	Replaced due to poor condition
11	10/100	10109	1 x 0.6	Pipe	1/23/0	RCC Box	Replaced due to insufficient vent
12	10/150	10147	2 x 1.0	Pipe	1/23/0	RCC Box	Replaced due to poor condition

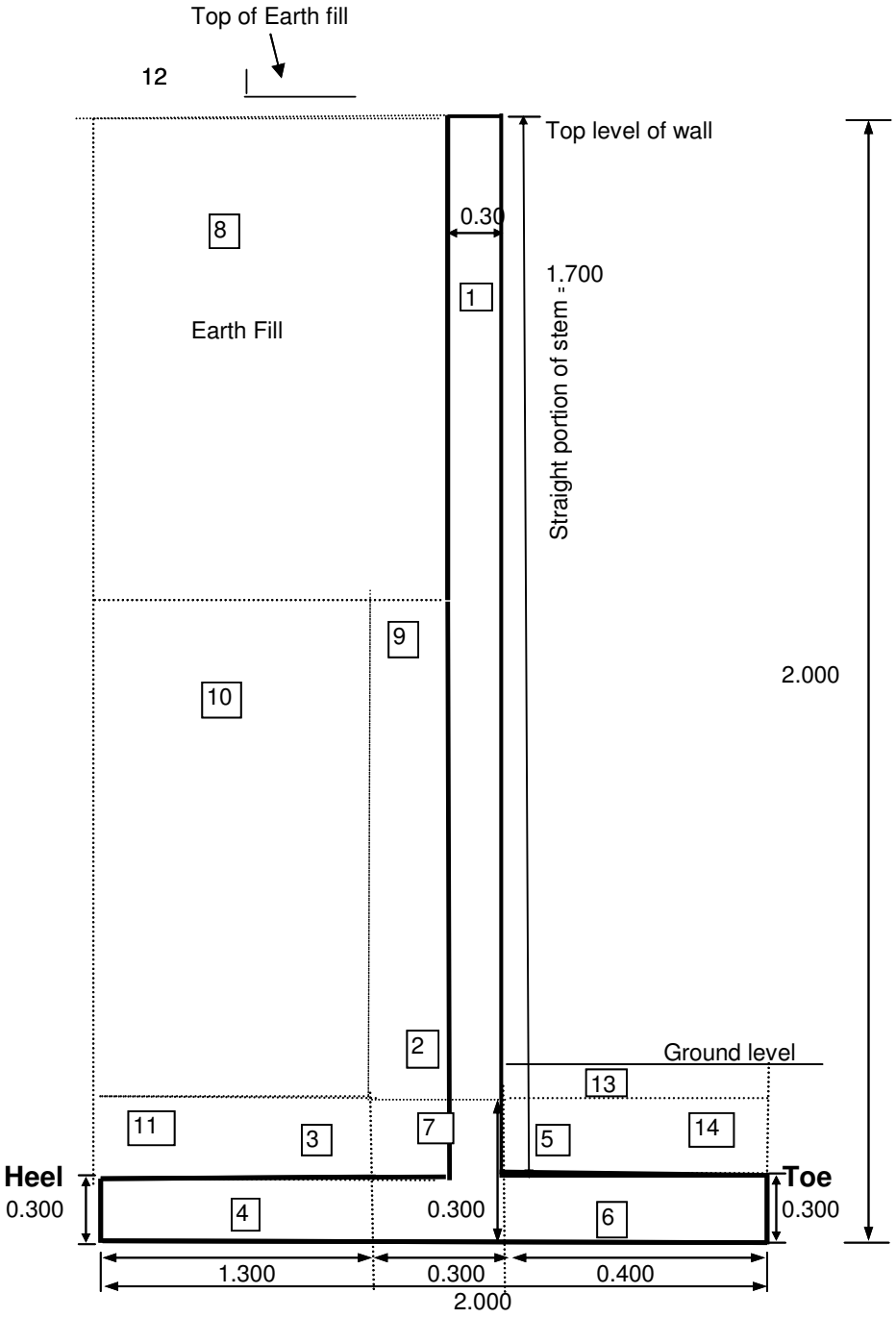
S. No.	Location/ Chainage	Design Chainage	Existing Span Arrangement	Type of Existing Culvert	Proposed Span Arrangement	Type of Proposed Culvert	Remarks
13	10/700	10698	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
14	10/750	10744	1 x 1.9	Slab	1/34/0	RCC Box	Reconstruction due to poor condition
15	**11/650**	**11700**	**-**	**-**	**1 x 1.0**	**Pipe**	**Additional structure**
16	12/600	12599	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
17	12/700	12687	1 x 1.8	Slab	1/23/0	RCC Box	Replaced due to raise in road level
18	12/750	12746	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
19	12/800	12826	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
20	13/300	13341	1 x 1.0	Pipe	-	-	To be widened
21	14/050	14055	1 x 0.9	Slab	1/22/0	RCC Box	Replaced due to raise in road level
22	14/400	14372	2 x 0.9	Vented Causeway	1/23/0	RCC Box	Vented causeway, to be replaced
23	14/800	14799	3 x 1.0	Pipe	1/22/0	RCC Box	Reconstruction due to poor condition
24	15/005	14990	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
25	15/250	15191	1 x 0.9	Vented Causeway	1 x 1.0	Pipe	Vented causeway, to be replaced
26	15/600	15574	1 x 0.6	Pipe	1/22/0	RCC Box	Replaced due to insufficient vent
27	15/850	15830	2 x 0.9	Vented Causeway	1/45/0	RCC Box	Vented causeway, to be replaced
28	16/050	16002	1 x 0.6	Pipe	2 x 1.0	Pipe	Replaced due to insufficient vent
29	17/500	17509	3 x 0.9	Vented Causeway	1/45/0	RCC Box	Vented causeway, to be replaced
30	18/100	18047	2 x 0.9	Vented Causeway	2 x 1.0	Pipe	Vented causeway to be replaced
31	18/850	18831	1 x 3.0	Arch	1/34/0	RCC Box	**Arch culvert to be replaced, to be used for Environmental purpose**
32	19/700	19661	1 x 0.75	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
33	20/150	20112	5 x 1.0	Pipe	1/43/0	RCC Box	Replaced due to insufficient vent
34	20/400	20337	5 x 1.0	Pipe	1/43/0	RCC Box	Replaced due to insufficient vent
35	21/650	21607	2 x 0.9	Vented Causeway	2 x 1.0	Pipe	Vented causeway, to be replaced
36	22/150	22135	2 x 0.9	Vented Causeway	1/23/0	RCC Box	**Vented causeway to be replaced, to be used for Environmental purpose**
37	22/350	22380	2 x 0.9	Vented Causeway	2 x 1.0	Pipe	Vented causeway to be replaced
38	23/100	23061	2 x 0.9	Vented Causeway	1/23/0	RCC Box	Vented causeway to be replaced
39	23/250	23200	1 x 1.0	Pipe	1 x 1.0	Pipe	Replaced due to raise in road level

S. No.	Location/ Chainage	Design Chainage	Existing Span Arrangement	Type of Existing Culvert	Proposed Span Arrangement	Type of Proposed Culvert	Remarks
40	23/350	23321	2 x 0.9	Vented Causeway	1/34/0	RCC Box	Vented causeway to be replaced
41	23/650	23538	2 x 0.9	Vented Causeway	2 x 1.0	Pipe	Vented causeway to be replaced
42	24/100	24062	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
43	24/450	24402	3 x 1.2	Pipe	-	-	To be widened
44	24/550	24513	3 x 0.9	Vented Causeway	2 x 1.0	Pipe	Vented causeway to be replaced
45	25/750	25723	2 x 0.9	Vented Causeway	2 x 1.0	Pipe	Vented causeway to be replaced
46	26/750	26695	2 x 0.9	Vented Causeway	2 x 1.0	Pipe	Vented causeway to be replaced
47	27/100	27045	1 x 0.6	Pipe	1 x 1.0	Pipe	Reconstruction due to poor condition
48	27/250	27175	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
49	30/850	30830	1 x 1.5	Slab	1/23/0	RCC Box	Reconstruction due to poor condition
50	31/250	31300	1 x 1.5	Slab	1/23/0	RCC Box	Reconstruction due to poor condition
51	32/050	32044	1 x 1.5	Slab	1/23/0	RCC Box	Replaced due to raise in road level
52	33/200	33238	1 x 3.0	Slab	1/23/0	RCC Box	Replaced due to raise in road level
53	**33/800**	**33800**	**-**	**-**	**1/23/0**	**RCC Box**	**Additional structure**
54	34/700	34732	1 x 1.5	Slab	2 x 1.0	Pipe	Replaced due to Submergence
55	**35/985**	**36050**	-	-	**1/22/0**	**RCC Box**	**Additional structure**
56	36/900	36961	1 x 1.5	Slab	1/33/0	RCC Box	Replaced due to Submergence
57	37/100	37214	1 x 1.5	Slab	1/34/0	RCC Box	Replaced due to Submergence
58	37/400	37563	1 x 1.5	Slab	1/23/0	RCC Box	Replaced due to Submergence
59	38/400	38383	1 x 1.5	Slab	1/23/0	RCC Box	Replaced due to Submergence
60	**39/100**	**39150**	**-**	**-**	**2 x 1.0**	**Pipe**	**Additional structure**
61	40/100	40089	1 x 1.5	Slab	1/23/0	RCC Box	Replaced due to Submergence
62	40/950	41037	1 x 1.5	Slab	1/22/0	RCC Box	Replaced due to raise in road level
63	41/300	41409	1 x 1.5	Slab	1/23/0	RCC Box	Reconstruction due to poor condition
64	41/700	41789	1 x 1.5	Slab	1/45/0	RCC Box	Replaced due to raise in road level
65	42/200	42320	1 x 1.5	Slab	1/34/0	RCC Box	Replaced due to raise in road level
66	42/550	42635	1 x 0.45	Pipe	1 x 1.0	Pipe	Reconstruction due to poor condition
67	43/100	43159	1 x 3.0	Slab	1/33/0	RCC Box	Reconstruction due to poor condition

S. No.	Location/ Chainage	Design Chainage	Existing Span Arrangement	Type of Existing Culvert	Proposed Span Arrangement	Type of Proposed Culvert	Remarks
68	44/150	44261	1 x 1.5	Slab	1/22/0	RCC Box	Replaced due to raise in road level
69	44/850	44954	1 x 3.0	Slab	1/34/0	RCC Box	Reconstruction due to poor condition
70	45/150	45296	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
71	45/600	45711	1 x 0.6	Pipe	1/23/0	RCC Box	Reconstruction due to poor condition
72	45/850	46047	1 x 4.5	Slab	1/63/0	RCC Box	Replaced due to raise in road level
73	**46/200**	**46325**	**-**	**-**	**2 x 1.0**	**Pipe**	**Additional structure**
74	46/350	46514	1 x 1.5	Slab	1/22/0	RCC Box	Replaced due to raise in road level
75	47/050	47165	1 x 1.5	Slab	1/22/0	RCC Box	Replaced due to raise in road level
76	47/200	47322	1 x 1.5	Slab	1 x 1.0	Pipe	Reconstruction due to poor condition
77	49/600	49726	1 x 1.5	Slab	1/23/0	RCC Box	Replaced due to raise in road level
78	50/150	50287	1 x 1.5	Slab	1/44/0	RCC Box	Replaced due to raise in road level
79	50/300	50499	1 x 1.5	Slab	1/23/0	RCC Box	Reconstruction due to poor condition
80	51/025	51174	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
81	51/250	51409	1 x 0.9	Pipe	2 x 1.0	Pipe	Replaced due to insufficient vent
82	51/400	51580	1 x 0.9	Pipe	2 x 1.0	Pipe	Replaced due to insufficient vent
83	51/600	51760	2 x 0.9	Pipe	1/34/0	RCC Box	Replaced due to raise in road level
84	51/900	52068	1 x 0.6	Pipe	1 x 1.0	Pipe	Reconstruction due to poor condition
85	52/100	52296	1 x 0.6	Pipe	2 x 1.0	Pipe	Reconstruction due to poor condition
86	52/250	52424	1 x 0.9	Pipe	1 x 1.0	Pipe	Reconstruction due to poor condition
87	52/700	52844	4 x 0.9	Pipe	-	-	To be widened
88	53/500	53679	1 x 0.9	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
89	53/950	54148	1 x 1.4	Slab	1/23/0	RCC Box	Replaced due to raise in road level
90	54/350	54606	1 x 1.3	Slab	1/44/0	RCC Box	**Replaced due to raise in road level, to be used for Environmental purpose**
91	55/250	55420	1 x 1.5	Slab	1 x 1.0	Pipe	Replaced due to Submergence
92	56/100	56270	1 x 5.0	Slab	1/64/0	RCC Box	Reconstruction due to poor condition
93	**56/200**	**56390**	**-**	**-**	**1/22/0**	**RCC Box**	**Additional structure**
94	56/400	56587	1 x 0.9	Pipe	-	-	To be widened

S. No.	Location/ Chainage	Design Chainage	Existing Span Arrangement	Type of Existing Culvert	Proposed Span Arrangement	Type of Proposed Culvert	Remarks
95	**56/950**	**57150**	**-**	**-**	**2 x 1.0**	**Pipe**	**Additional structure**
96	57/150	57321	1 x 0.9	Pipe	1 x 1.0	Pipe	Reconstruction due to poor condition
97	57/500	57360	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
98	57/900	57664	1 x 0.45	Skew Pipe	1 x 1.0	Pipe	Reconstruction due to poor condition
99	59/850	59625	1 x 0.45	Pipe	1 x 1.0	Pipe	Reconstruction due to poor condition
100	60/100	59915	1 x 3.0	Slab	1/33/0	RCC Box	Replaced due to raise in road level
101	60/750	60567	1 x 1.5	Slab	1/34/0	RCC Box	Replaced due to raise in road level
102	61/550	61373	1 x 1.5	Slab	1/23/0	RCC Box	Reconstruction due to poor condition
103	62/250	62100	1 x 3.0	Slab	1/33/0	RCC Box	Reconstruction due to poor condition
104	62/900	62962	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
105	63/200	63300	1 x 1.5	Slab	1/23/0	RCC Box	Replaced due to raise in road level
106	63/550	63298	1 x 6.2	Slab	1/63/0	RCC Box	Reconstruction due to poor condition
107	63/900	63700	1 x 1.5	Slab	1 x 1.0	Pipe	Replaced due to raise in road level
108	64/600	64622	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
109	64/825	64891	1 x 0.6	Pipe	1 x 1.0	Pipe	**Replaced due to insufficient vent, to be used for Environmental purpose**
110	65/100	65122	1 x 0.6	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
111	65/350	65430	1 x 1.5	Slab	1 x 1.0	Pipe	Replaced due to raise in road level
112	65/675	65624	1 x 1.5	Slab	1/23/0	RCC Box	Reconstruction due to poor condition
113	65/900	66027	1 x 1.5	Slab	1/22/0	RCC Box	Reconstruction due to poor condition
114	66/200	66161	1 x 0.9	Pipe	1/23/0	RCC Box	Replaced due to insufficient vent
115	**66/430**	**66500**	**-**	**-**	**1/23/0**	**RCC Box**	**Additional structure**
116	67/300	67100	1 x 0.6	Pipe	1/22/0	RCC Box	Replaced due to raise in road level
117	67/550	67325	1 x 0.9	Pipe	1 x 1.0	Pipe	Replaced due to insufficient vent
118	67/850	67620	1 x 0.9	Pipe	1/23/0	RCC Box	**Replaced due to raise in road level, to be used for Environmental purpose**
119	68/200	68010	1 x 0.6	Pipe	1/23/0	RCC Box	Replaced due to insufficient vent
120	68/700	68445	1 x 1.5	Slab	1/22/0	RCC Box	Replaced due to raise in road level

DESIGN OF RETURN WALL


Top of Earth fill
12
Top level of wall
0.30
1.700
Straight portion of stem =
8
1
Earth Fill
9
10
2.000
2
Ground level
13
11
3
7
5
14
Heel
0.300
Toe
0.300
4
0.300
6
1.300
0.300
0.400
2.000

DESIGN OF RETAINING WALL FOR 2.000 m HEIGHT

DESIGN DATA:

Top level of retaining wall	=	2.000	m
Ground level	=	1.000	m
Founding Level	=	0.000	m
Total Height from top of wall to founding level	=	**2.000**	m
Density of earth	=	1.8	t/m^3
Density of concrete	=	2.4	t/m^3
Clear cover to Reinforcement	=	0.05	m
Clear cover to Reinforcement for foundations	=	0.075	m
Grade of concrete	=	20	
Allowable stress in steel	=	20380	
Safe bearing capacity	=	20	t/m^2
Safety factor against overturning	=	2.0	
Safety factor against sliding	=	1.5	
Depth of L.L.Surcharge	=	1.2	m
L.L.Surcharge on wall	=	0	t/m^2
ActiveEarthPressure			
For Grade of concrete	= M	20	& HYSD reinf. with Fe 415
Lever arm factor j	=	0.916	
Moment of resistance factor Q	=	78.54	

DIMENSIONS :

Length of Base of Retaining wall	=	2.000	m
Section modulus	=	0.667	m^3
Length of Toe	=	0.400	m
Length of Heel	=	1.300	m
Thickness of Stem at base	=	0.300	m
Thickness of straight portion of stem	=	0.300	m
Ht. of straight portion of stem	=	1.700	m
Minimum thickness of Toe slab	=	0.300	m
Thickness of Toe slab at junction with stem	=	0.300	m
Minimum thickness of heel slab	=	0.300	m
Thickness of heel slab at junction with stem	=	0.300	m
Angle of inclined stem with vertical	=	0.000	
Ht.of inclined potion of stem to base of footing	=	0.300	m
Ht.of inclined potion of stem to top of footing	=	0.000	m

Calculation of Earth pressure coefficients =

Angle of internal friction of soil ϕ	=	30	deg	=	0.524	rad
Angle of wall friction δ	=	20	deg	=	0.349	rad
Angle of incli . of soil at back i	=	0	deg	=	0.000	rad
Angle of incli . of stem at back α	=	90	deg	=	1.571	rad
Coefficient of active earth pressure k_a	=	0.297				
Coefficient of horz.active earth pressure K_{ah}	=	0.279				

Calculation of Forces & moments due to Vertical Forces

S.No.	Description	Area Factor	width	Depth	Density	Weight	C.G. from Toe	Moment about toe
1	Wt of stem	1.0	0.300	1.7	2.4	1.224	0.550	0.673
2		0.5	0.000	0	2.4	0.000	0.700	0.000
3	Wt of heel slab	0.5	1.300	0	2.4	0.000	1.133	0.000
4		1.0	1.300	0.3	2.4	0.936	1.350	1.264
5	Wt of toe slab	0.5	0.400	0	2.4	0.000	0.267	0.000
6		1.0	0.400	0.3	2.4	0.288	0.200	0.058
7	Wt.of intmdt.portion	1.0	0.300	0.3	2.4	0.216	0.550	0.119
8	Wt. of soil above heel slab	1.0	1.300	1.7	1.8	3.978	1.35	5.370
9		0.5	0.000	0	1.8	0.000	0.700	0.000
10		1.0	1.300	0	1.8	0.000	1.350	0.000
11		0.5	1.300	0	1.8	0.000	1.567	0.000
12		0.0	1.300	0.65	1.8	0.000	1.567	0.000
13	Wt. of soil above toe slab	0.0	0.4	0.7	1.8	0.000	0.200	0.000
14		0.0	0.4	0	1.8	0.000	0.133	0.000
15	L.L.Surcharge	0.0	1.3	1.2	1.8	0.000	1.350	0.000
				Total forces =		**6.642**		**7.48**

Total Vertical load = **6.64** Total Restoring moment = **7.48**

Horz. components of Earth Pressure

S.No.	Horz. Press due to	Area factor	Pressure $k_{ah}\gamma h$	Height	Horz. Force	C.G. from Toe	Moment about toe
1	Active Earth Pressure	0.5	1.006	2	1.006	0.840	0.84
2	L.L.Surcharge	1	0.603	2	1.207	1.000	1.21
			Total forces =		2.213		2.05

Total overturning moment Mo = 2.05 tm Total vertical load V = 6.642 t
Total restoring moment Mr = 7.48 tm Total Horz. Force = 2.213 t

Factor of safety against overturning Mr/Mo = 3.65 **OK** > 2

Check for sliding :

Coefficient of base friction = 0.500
Total vertical force = 6.642 t
Resisting force = 3.32 t
F.O.S 1.501 **OK** > 1.5
C.G. of loads from toe = Mr/V = 1.127 m
Eccentricity of loads w.r.t. c/l raft = 0.127 m
Moment about c/l raft = 0.842 t-m
Net moment about base M = 1.210 t-m

Calculation of Base Pressure

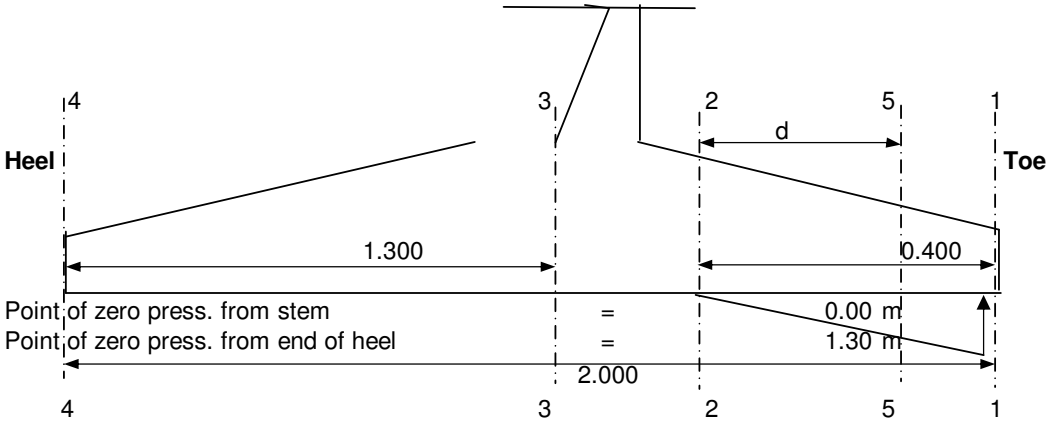
Base pressure due to vertical load V/A = 3.32 Pressure at toe = **5.14** t/m^2

Base pressure due to moment Mn/Z = 1.815 Pressure at heel= **1.51** t/m^2

CALCULATION OF DESIGN PRESSURES

Section	1-1	2-2	3-3	4-4	5-5
Upward pressure	5.136	4.410	3.866	1.506	4.742
Downward Pressure	0.720	0.720	3.780	3.780	0.720
Net pressure	4.416	3.690	0.086	-2.274	4.022

** Positive net pressure means upward pressure & negative net pressure means downward pressure



Point of zero press. from stem = 0.00 m
Point of zero press. from end of heel = 1.30 m

DESIGN OF TOE SLAB

Reinforcement calculation

Bending Moment at face of stem	=	0.33	t-m
Effective depth required	=	0.065	m
Effective depth provided at face of stem	=	0.217 > reqd	0.065
Area of Reinforcement reqd.at bottom	=	**0.82** cm^2	**HENCE SAFE**

Shear check:

Shear force at distance d from stem	=	0.77	t
Bending moment at sec 5-5 =		0.07	t-m
Net shear force at sec 5-5=S-Ms*tanβ/d_1 =		0.77	t
Depth of slab at section 5-5 =		0.300	Effective depth d_1 = 0.215 m

Nominal Shear stress = 2.57 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.038 %
Therefore Permissible shear strsss = 18.36 t/m^2 **HENCE SAFE**

DESIGN OF HEEL SLAB

Bending Moment at face of stem =		1.26	t-m
Effective depth required	=	0.127	m
Effective depth of slab at face of stem =		0.215	m
Reinforcement reqd.at top =		**3.13** cm^2	

Shear check:

Shear force at face of stem S =		1.42	t
Bending moment at face Ms =		1.26	t-m
Net shear force =S-Ms*tanβ/d_1 =		1.42	t

Nominal Shear stress = 6.62 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.146 %
Therefore Permissible shear stress = 18.36 t/m^2 **HENCE SAFE**

DESIGN OF STEM BASE

Section A

Height of Base of stem from top of earth fill = 1.7 m

Height of Base of stem below straight portion = 5.6E-17 m

S.No.	Horz. Press due to	Area factor	Pressure $k_a.g.h$	Height	Horz. Force	C.G. from base	Moment about base
1	ActiveEarthPressure	0.5	0.855	1.7	0.727	0.714	0.52
2	L.L.Surcharge	1	0.603	1.7	1.026	0.850	0.87
			Total =		1.75		1.39

Total Horizontal Force	1.75	t		
Total Moment about base	1.39	tm		
Design bending moment	1.39	t-m		
Effective depth required	0.133	m		
Thickness of stem at base	0.300	m		
Effective depth provided	0.238		> 0.133	**HENCE SAFE**
Area of steel reqd.	**3.14**	cm^2		

Shear check:

Shear force at base of stem	1.75	t		
Bending moment at base	1.39	t-m		
Net shear force	1.75	t		
Nominal Shear stress	7.38	t/m^2		

Permissible shear stress is calculated as per cl.304.7.1.3 of IRC:21-2000

100As/bd =	0.15	%		
ActiveEarthPressure			18.40 t/m^2	**HENCE SAFE**


Top of Earth fill
12
Top level of wall
0.30
2.400
Straight portion of stem =
8
1
Earth Fill
9
10
3.000
2
Ground level
13
11
3
7
5
14
Heel
0.300
0.300
Toe
0.300
4
6
1.750
0.300
0.600
2.650

DESIGN OF RETAINING WALL FOR 3.000 m HEIGHT

DESIGN DATA:

Top level of retaining wall	=	3.000	m
Ground level	=	1.000	m
Founding Level	=	0.000	m
Total Height from top of wall to founding level	=	**3.000**	m
Density of earth	=	1.8	t/m^3
Density of concrete	=	2.4	t/m^3
Clear cover to Reinforcement	=	0.05	m
Clear cover to Reinforcement for foundations	=	0.075	m
Grade of concrete	=	25	
Allowable stress in steel	=	20380	
Safe bearing capacity	=	20	t/m^2
Safety factor against overturning	=	2.0	
Safety factor against sliding	=	1.5	
Depth of L.L.Surcharge	=	1.2	m
L.L.Surcharge on wall	=	0	t/m^2

DESIGN CONSTANTS:

For Grade of concrete	= M 20		& HYSD reinf. with Fe 415
Lever arm factor j	=	0.902	
Moment of resistance factor Q	=	111.996	

DIMENSIONS :

Length of Base of Retaining wall	=	2.650	m
Section modulus	=	1.170	m^3
Length of Toe	=	0.600	m
Length of Heel	=	1.750	m
Thickness of Stem at base	=	0.300	m
Thickness of straight portion of stem	=	0.300	m
Ht. of straight portion of stem	=	2.400	m
Minimum thickness of Toe slab	=	0.300	m
Thickness of Toe slab at junction with stem	=	0.300	m
Minimum thickness of heel slab	=	0.300	m
Thickness of heel slab at junction with stem	=	0.300	m
Angle of inclined stem with vertical	=	0.000	
Ht.of inclined potion of stem to base of footing	=	0.600	m
Ht.of inclined potion of stem to top of footing	=	0.300	m

Calculation of Earth pressure coefficients =

Angle of internal friction of soil ϕ	=	30	deg	=	0.5236	rad
Angle of wall friction δ	=	20	deg	=	0.3491	rad
Angle of incli . of soil at back i	=	0	deg	=	0.0000	rad
Angle of incli . of stem at back α	=	90	deg	=	1.570796	rad
Coefficient of active earth pressure k_a	=	0.297				
Coefficient of horz.active earth pressure K_{ah}	=	0.279				

Calculation of Forces & moments due to Vertical Forces

S.No.	Description	Area Factor	width	Depth	Density	Weight	C.G. from Toe	Moment about toe
1	Wt of stem	1.0	0.300	2.7	2.4	1.944	0.750	1.458
2		0.5	0.000	0.3	2.4	0.000	0.900	0.000
3	Wt of heel slab	0.5	1.750	0	2.4	0.000	1.483	0.000
4		1.0	1.750	0.3	2.4	1.260	1.775	2.237
5	Wt of toe slab	0.5	0.600	0	2.4	0.000	0.400	0.000
6		1.0	0.600	0.3	2.4	0.432	0.300	0.130
7	Wt.of intmdt.portion	1.0	0.300	0.3	2.4	0.216	0.750	0.162
8	Wt. of soil above heel slab	1.0	1.750	2.4	1.8	7.560	1.775	13.419
9		0.5	0.000	0.3	1.8	0.000	0.900	0.000
10		1.0	1.750	0.3	1.8	0.945	1.775	1.677
11		0.5	1.750	0	1.8	0.000	2.067	0.000
12		0.0	1.750	0.875	1.8	0.000	2.067	0.000
13	Wt. of soil above toe slab	0.0	0.6	0.7	1.8	0.000	0.300	0.000
14		0.0	0.6	0	1.8	0.000	0.200	0.000
15	L.L.Surcharge	0.0	1.75	1.2	1.8	0.000	1.775	0.000
				Total forces =		**12.357**		**19.08**

Total Vertical load = **12.36** Total Restoring moment = **19.08**

Horz. components of Earth Pressure

S.No.	Horz. Press due to		Area factor	Pressure $k_{ah}\gamma h$	Height	Horz. Force	C.G. from Toe	Moment about toe
1	Active Earth Pressure		0.5	1.509	3	2.263	1.260	2.85
2	L.L.Surcharge		1	0.603	3	1.810	1.500	2.72
				Total forces =		4.073		5.57

Total overturning moment Mo = 5.57 tm Total vertical load V = 12.357 t
Total restoring moment Mr = 19.08 tm Total Horz. Force = 4.073 t

Factor of safety against overturning Mr/Mo = 3.43 **OK** > 2

Check for sliding :

Coefficient of base friction = 0.500
Total vertical force = 12.357 t
Resisting force = 6.18 t
F.O.S 1.52 **OK** > 1.5

C.G. of loads from toe = Mr/V = 1.544 m
Eccentricity of loads w.r.t. c/l raft = 0.219 m
Moment about c/l raft = 2.709 t-m
Net moment about base Mn = 2.858 t-m

Calculation of Base Pressure

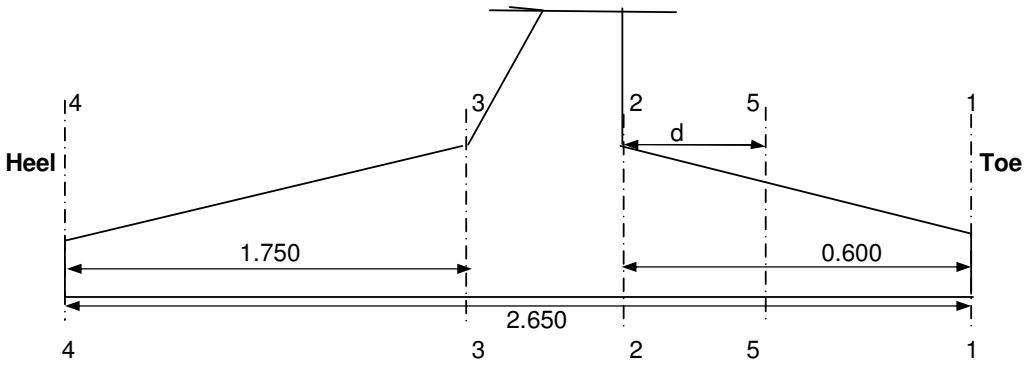
Base pressure due to vertical load V/A = 4.66 Pressure at toe = **7.10** t/m^2

Base pressure due to moment Mn/Z = 2.441 Pressure at heel= **2.22** t/m^2

CALCULATION OF DESIGN PRESSURES

Section	1-1	2-2	3-3	4-4	5-5
Upward pressure	7.104	5.999	5.446	2.222	6.705
Downward Pressure	0.720	0.720	5.580	5.580	0.720
Net pressure	6.384	5.279	-0.134	-3.358	5.985

** Positive net pressure means upward pressure & negative net pressure means downward pressure



DESIGN OF TOE SLAB

Reinforcement calculation

Bending Moment at face of stem	=	1.08	t-m	
Effective depth required	=	0.098	m	
Effective depth provided at face of stem	=	0.217	> reqd	0.098
Area of Reinforcement reqd.at bottom	=	**2.71**	cm^2	**HENCE SAFE**

Shear check:

Shear force at distance d from stem	=	2.37	t	
Bending moment at sec 5-5 =		0.46	t-m	
Net shear force at sec 5-5=S-Ms*tanβ/d_1 =		2.37	t	
Depth of slab at section 5-5 =		0.300	Effective depth d_1 =	0.215 m

Nominal Shear stress = 7.90 t/m^2

Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000

100As/bd = 0.126 %

Therefore Permissible shear strsss = 18.36 t/m^2 **HENCE SAFE**

DESIGN OF HEEL SLAB

Bending Moment at face of stem =		3.50	t-m
Effective depth required	=	0.177	m
Effective depth of slab at face of stem =		0.215	m
Reinforcement reqd.at top =		**8.85**	cm^2

Shear check:

Shear force at face of stem S =		3.06	t
Bending moment at face Ms =		3.50	t-m
Net shear force =S-Ms*tanβ/d_1 =		3.06	t

Nominal Shear stress = 14.21 t/m^2

Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000

100As/bd = 0.412 %

Therefore Permissible shear strsss = 27.71 t/m^2 **HENCE SAFE**

DESIGN OF STEM BASE

Section A

Height of Base of stem from top of earth fill = 2.7 m

Height of Base of stem below straight portion = 0.3 m

S.No.	Horz. Press due to	Area factor	Pressure $k_a.g.h$	Height	Horz. Force	C.G. from base	Moment about base
1	Active Earth Pressure	0.5	1.358	2.7	1.833	1.134	2.08
2	L.L.Surcharge	1	0.603	2.7	1.629	1.350	2.20
			Total =		3.46		4.28

Total Horizontal Force	3.46	t		
Total Moment about base	4.28	tm		
Design bending moment	4.28	t-m		
Effective depth required	0.195	m		
Thickness of stem at base	0.300	m		
Effective depth provided	0.238	>	0.195	**HENCE SAFE**
Area of steel reqd.	**9.80**	cm^2		

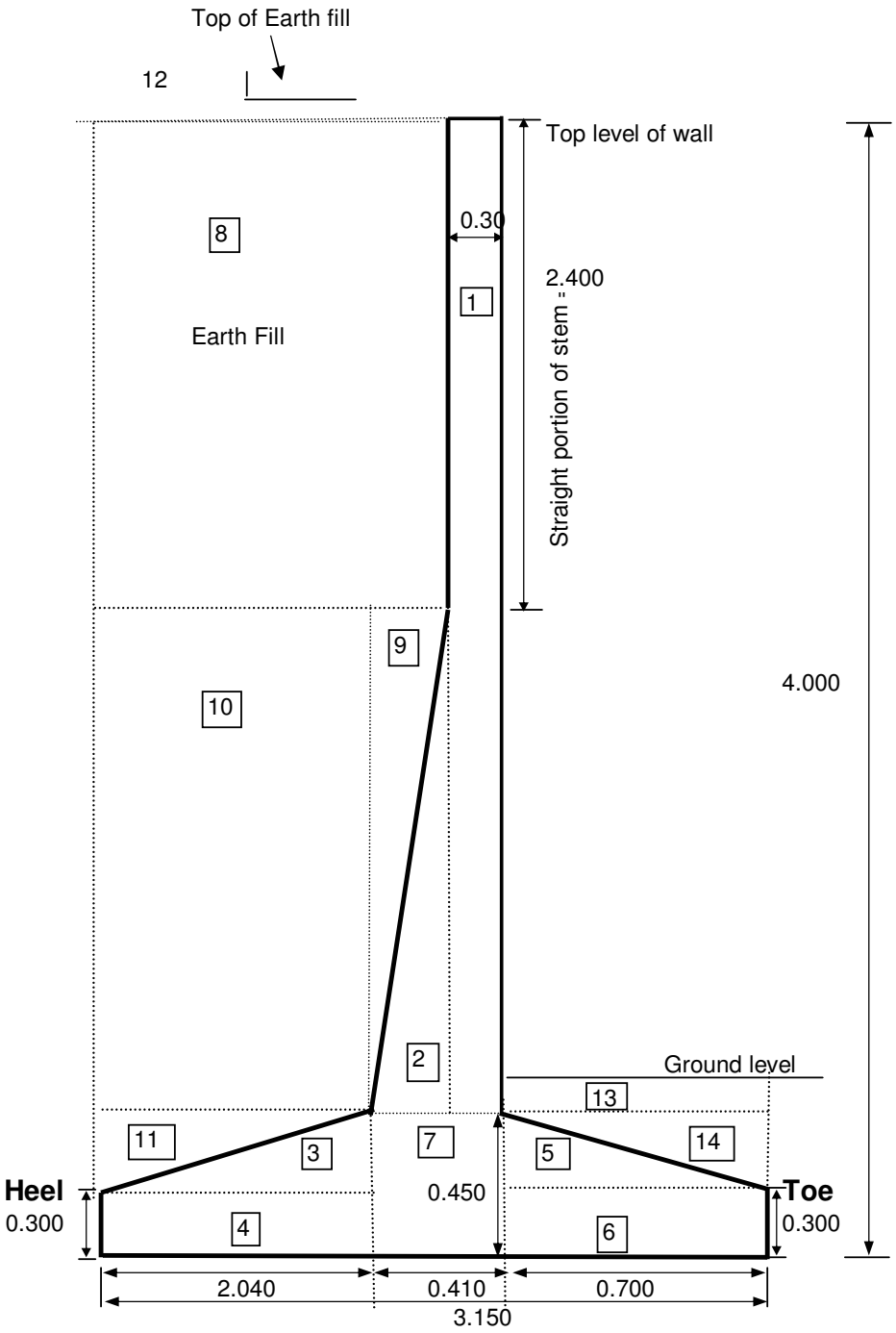
Shear check:

Shear force at base of stem	3.46	t
Bending moment at base	4.28	t-m
Net shear force	3.46	t
Nominal Shear stress	14.58	t/m^2

Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000

100As/bd = 0.41 %

Therefore Permissible shear strsss 27.75 t/m^2 **HENCE SAFE**


Top of Earth fill
12
Top level of wall
0.30
8
2.400
1
Earth Fill
Straight portion of stem =
9
4.000
10
2
Ground level
13
11
3
7
5
14
Heel
0.300
0.450
Toe
0.300
4
6
2.040
0.410
0.700
3.150

DESIGN OF RETAINING WALL FOR 4.000 m HEIGHT

DESIGN DATA:

Top level of retaining wall	=	4.000	m
Ground level	=	1.500	m
Founding Level	=	0.000	m
Total Height from top of wall to founding level	=	**4.000**	m
Density of earth	=	1.8	t/m^3
Density of concrete	=	2.4	t/m^3
Clear cover to Reinforcement	=	0.05	m
Clear cover to Reinforcement for foundations	=	0.075	m
Grade of concrete	=	20	
Allowable stress in steel	=	20380	
Safe bearing capacity	=	20	t/m^2
Safety factor against overturning	=	2.0	
Safety factor against sliding	=	1.5	
Depth of L.L.Surcharge	=	1.2	m
L.L.Surcharge on wall	=	0	t/m^2

DESIGN CONSTANTS:

For Grade of concrete	= M 20		& HYSD reinf. with Fe 415
Lever arm factor j	=	0.916	
Moment of resistance factor Q	=	78.54	

DIMENSIONS :

Length of Base of Retaining wall	=	3.150	m
Section modulus	=	1.654	m^3
Length of Toe	=	0.700	m
Length of Heel	=	2.040	m
Thickness of Stem at base	=	0.410	m
Thickness of straight portion of stem	=	0.300	m
Ht. of straight portion of stem	=	2.400	m
Minimum thickness of Toe slab	=	0.300	m
Thickness of Toe slab at junction with stem	=	0.450	m
Minimum thickness of heel slab	=	0.300	m
Thickness of heel slab at junction with stem	=	0.450	m
Angle of inclined stem with vertical	=	0.096	
Ht.of inclined potion of stem to base of footing	=	1.600	m
Ht.of inclined potion of stem to top of footing	=	1.150	m

Calculation of Earth pressure coefficients =

Angle of internal friction of soil ϕ	=	30	deg	=	0.524	rad
Angle of wall friction δ	=	20	deg	=	0.349	rad
Angle of incli . of soil at back i	=	0	deg	=	0.000	rad
Angle of incli . of stem at back α	=	90	deg	=	1.57080	rad
Coefficient of active earth pressure k_a	=	0.297				
Coefficient of horz.active earth pressure K_{ah}	=	0.279				

Calculation of Forces & moments due to Vertical Forces

S.No.	Description	Area Factor	width	Depth	Density	Weight	C.G. from Toe	Moment about toe
1	Wt of stem	1.0	0.300	3.55	2.4	2.556	0.850	2.173
2		0.5	0.110	1.15	2.4	0.152	1.037	0.157
3	Wt of heel slab	0.5	2.040	0.15	2.4	0.367	1.790	0.657
4		1.0	2.040	0.3	2.4	1.469	2.130	3.129
5	Wt of toe slab	0.5	0.700	0.15	2.4	0.126	0.467	0.059
6		1.0	0.700	0.3	2.4	0.504	0.350	0.176
7	Wt.of intmdt.portion	1.0	0.410	0.45	2.4	0.443	0.905	0.401
8	Wt. of soil above heel slab	1.0	2.150	2.4	1.8	9.288	2.075	19.273
9		0.5	0.110	1.15	1.8	0.114	1.073	0.122
10		1.0	2.040	1.15	1.8	4.223	2.130	8.995
11		0.5	2.040	0.15	1.8	0.275	2.470	0.680
12		0.0	2.150	1.075	1.8	0.000	2.434	0.000
13	Wt. of soil above toe slab	0.0	0.7	1.1	1.8	0.000	0.350	0.000
14		0.0	0.7	0.15	1.8	0.000	0.233	0.000
15	L.L.Surcharge	0.0	2.15	1.2	1.8	0.000	2.075	0.000
			Total forces =			**19.517**		**35.82**

Total Vertical load = **19.52** Total Restoring moment = **35.82**

Horz. components of Earth Pressure

S.No.	Horz. Press due to		Area factor	Pressure $k_{ah}\gamma h$	Height	Horz. Force	C.G. from Toe	Moment about toe
1	Active Earth Pressure		0.5	2.012	4	4.023	1.680	6.76
2	L.L.Surcharge		1	0.603	4	2.414	2.000	4.83
				Total forces =		6.437		11.59

Total overturning moment Mo = 11.59 tm Total vertical load V = 19.517 t
Total restoring moment Mr = 35.82 tm Total Horz. Force = 6.437 t
Factor of safety against overturning Mr/Mo = 3.09 **OK** > 2

Check for sliding :

Coefficient of base friction = 0.500
Total vertical force = 19.517 t
Resisting force = 9.76 t
F.O.S 1.52 **OK** > 1.5
C.G. of loads from toe = Mr/V = 1.835 m
Eccentricity of loads w.r.t. c/l raft = 0.260 m
Moment about c/l raft = 5.083 t-m
Net moment about base Mn = 6.504 t-m

Calculation of Base Pressure

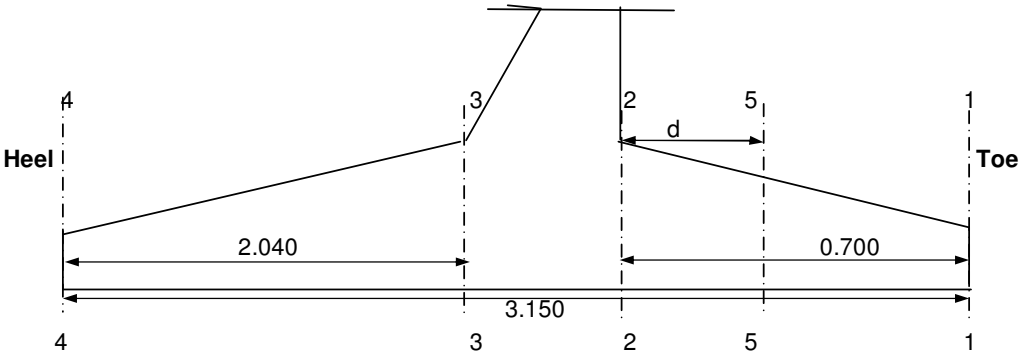
Base pressure due to vertical load V/A = 6.20 Pressure at toe = **10.13** t/m^2

Base pressure due to moment Mn/Z = 3.933 Pressure at heel= **2.26** t/m^2

CALCULATION OF DESIGN PRESSURES

Section	1-1	2-2	3-3	4-4	5-5
Upward pressure	10.129	8.381	7.357	2.263	9.212
Downward Pressure	0.720	1.080	7.470	7.380	0.891
Net pressure	9.409	7.301	-0.113	-5.117	8.321

** Positive net pressure means upward pressure & negative net pressure means downward pressure



DESIGN OF TOE SLAB

Reinforcement calculation

Bending Moment at face of stem	=	2.13	t-m	
Effective depth required	=	0.165	m	
Effective depth provided at face of stem	=	0.367	> reqd	0.165
Area of Reinforcement reqd.at bottom	=	**3.11**	cm^2	**HENCE SAFE**

Shear check:

Shear force at distance d from stem	=	2.95	t	
Bending moment at sec 5-5 =		0.50	t-m	
Net shear force at sec 5-5=S-Ms*tanβ/d_1 =		2.58	t	
Depth of slab at section 5-5 =		0.371	Effective depth d_1 =	0.286 m

Nominal Shear stress = 6.94 t/m^2

Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000

100As/bd = 0.109 %

Therefore Permissible shear strsss = 18.36 t/m^2 **HENCE SAFE**

DESIGN OF HEEL SLAB

Bending Moment at face of stem =		7.18	t-m
Effective depth required	=	0.302	m
Effective depth of slab at face of stem =		0.365	m
Reinforcement reqd.at top =		**10.53**	cm^2

Shear check:

Shear force at face of stem S =		5.33	t
Bending moment at face Ms =		7.18	t-m
Net shear force =S-Ms*tanβ/d_1 =		3.89	t

Nominal Shear stress = 10.65 t/m^2

Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000

100As/bd = 0.289 %

Therefore Permissible shear strsss = 23.70 t/m^2 **HENCE SAFE**

FOR CURTAILMENT

Shear Force at distance from stem =		123.873		
Bending Moment at distance	2.000 m from face of stem =		0.00	
Effective depth required	=	0.007	m	
Effective depth provided	=	0.220	> reqd	0.007
Curtailment Length	=	2.220		
Area of Reinforcement reqd.at bottom	=	**0.01**	cm^2	

DESIGN OF STEM BASE

Section A

Height of Base of stem from top of earth fill = 3.55 m

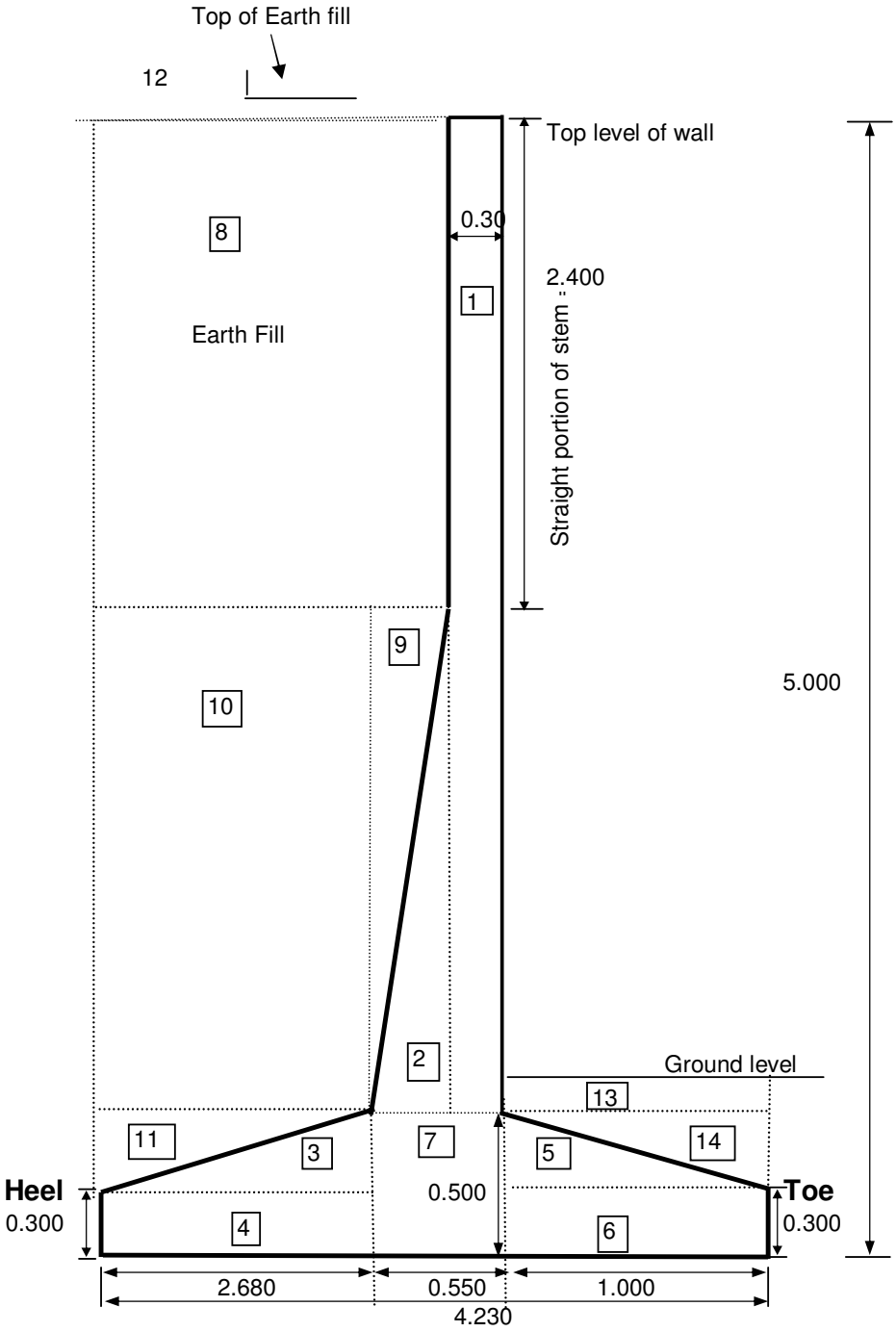
Height of Base of stem below straight portion = 1.15 m

S.No.	Horz. Press due to	Area factor	Pressure $k_a.g.h$	Height	Horz. Force	C.G. from base	Moment about base
1	ActiveEarthPressure	0.5	1.785	3.55	3.169	1.491	4.72
2	L.L.Surcharge	1	0.603	3.55	2.142	1.775	3.80
			Total =		5.31		8.53

Total Horizontal Force	5.31	t		
Total Moment about base	8.53	tm		
Design bending moment	8.53	t-m		
Effective depth required	0.330	m		
Thickness of stem at base	0.410	m		
Effective depth provided	0.348	>	0.330	**HENCE SAFE**
Area of steel reqd.	**13.14**	cm^2		

Shear check:

Shear force at base of stem	5.31	t		
Bending moment at base	8.53	t-m		
Net shear force	2.96	t		
Nominal Shear stress	8.53	t/m^2		
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000				
100As/bd =	0.38	%		
Therefore Permissible shear strsss		26.63	t/m^2	**HENCE SAFE**


Top of Earth fill
12
Top level of wall
0.30
2.400
Straight portion of stem
8
1
Earth Fill
9
10
5.000
2
Ground level
13
11
3
7
5
14
Heel
0.300
0.500
Toe
0.300
4
6
2.680
0.550
1.000
4.230

DESIGN OF RETAINING WALL FOR 5.000 m HEIGHT

DESIGN DATA:

Top level of retaining wall	=	5.000	m
Ground level	=	1.500	m
Founding Level	=	0.000	m
Total Height from top of wall to founding level	=	**5.000**	m
Density of earth	=	1.8	t/m^3
Density of concrete	=	2.4	t/m^3
Clear cover to Reinforcement	=	0.05	m
Clear cover to Reinforcement for foundations	=	0.075	m
Grade of concrete	=	20	
Allowable stress in steel	=	20380	
Safe bearing capacity	=	20	t/m^2
Safety factor against overturning	=	2.0	
Safety factor against sliding	=	1.5	
Depth of L.L.Surcharge	=	1.2	m
L.L.Surcharge on wall	=	0	t/m^2

DESIGN CONSTANTS:

For Grade of concrete	= M 20		& HYSD reinf. with Fe 415
Lever arm factor j	=	0.916	
Moment of resistance factor Q	=	78.54	

DIMENSIONS :

Length of Base of Retaining wall	=	4.230	m
Section modulus	=	2.982	m^3
Length of Toe	=	1.000	m
Length of Heel	=	2.680	m
Thickness of Stem at base	=	0.550	m
Thickness of straight portion of stem	=	0.300	m
Ht. of straight portion of stem	=	2.400	m
Minimum thickness of Toe slab	=	0.300	m
Thickness of Toe slab at junction with stem	=	0.500	m
Minimum thickness of heel slab	=	0.300	m
Thickness of heel slab at junction with stem	=	0.500	m
Angle of inclined stem with vertical	=	0.119	
Ht.of inclined potion of stem to base of footing	=	2.600	m
Ht.of inclined potion of stem to top of footing	=	2.100	m

Calculation of Earth pressure coefficients =

Angle of internal friction of soil ϕ	=	30	deg	=	0.524	rad
Angle of wall friction δ	=	20	deg	=	0.349	rad
Angle of incli . of soil at back i	=	0	deg	=	0.000	rad
Angle of incli . of stem at back α	=	90	deg	=	1.571	rad
Coefficient of active earth pressure k_a	=	0.297				
Coefficient of horz.active earth pressure K_{ah}	=	0.279				

Calculation of Forces & moments due to Vertical Forces

S.No.	Description	Area Factor	width	Depth	Density	Weight	C.G. from Toe	Moment about toe
1	Wt of stem	1.0	0.300	4.5	2.4	3.240	1.150	3.726
2		0.5	0.250	2.1	2.4	0.630	1.383	0.871
3	Wt of heel slab	0.5	2.680	0.2	2.4	0.643	2.443	1.572
4		1.0	2.680	0.3	2.4	1.930	2.890	5.577
5	Wt of toe slab	0.5	1.000	0.2	2.4	0.240	0.667	0.160
6		1.0	1.000	0.3	2.4	0.720	0.500	0.360
7	Wt.of intmdt.portion	1.0	0.550	0.5	2.4	0.660	1.275	0.842
8	Wt. of soil above heel slab	1.0	2.930	2.4	1.8	12.658	2.765	34.998
9		0.5	0.250	2.1	1.8	0.473	1.467	0.693
10		1.0	2.680	2.1	1.8	10.130	2.890	29.277
11		0.5	2.680	0.2	1.8	0.482	3.337	1.610
12		0.0	2.930	1.465	1.8	0.000	3.254	0.000
13	Wt. of soil above toe slab	0.0	1	1.0	1.8	0.000	0.500	0.000
14		0.0	1	0.2	1.8	0.000	0.333	0.000
15	L.L.Surcharge	0.0	2.93	1.2	1.8	0.000	2.765	0.000
			Total forces =			**31.806**		**79.68**

Total Vertical load = **31.81** Total Restoring moment = **79.68**

Horz. components of Earth Pressure

S.No.	Horz. Press due to		Area factor	Pressure $k_{ah}\gamma h$	Height	Horz. Force	C.G. from Toe	Moment about toe
1	Active Earth Pressure		0.5	2.514	5	6.286	2.100	13.20
2	L.L.Surcharge		1	0.603	5	3.017	2.500	7.54
				Total forces =		9.303		20.74

Total overturning moment Mo = 20.74 tm Total vertical load V = 31.806 t
Total restoring moment Mr = 79.68 tm Total Horz. Force = 9.303 t

Factor of safety against overturning Mr/Mo = 3.84 **OK** > 2

Check for sliding :

Coefficient of base friction = 0.500
Total vertical force = 31.806 t
Resisting force = 15.90 t
F.O.S 1.71 **OK** > 1.5
C.G. of loads from toe = Mr/V = 2.505 m
Eccentricity of loads w.r.t. c/l raft = 0.390 m
Moment about c/l raft = 12.416 t-m
Net moment about base Mn = 8.328 t-m

Calculation of Base Pressure

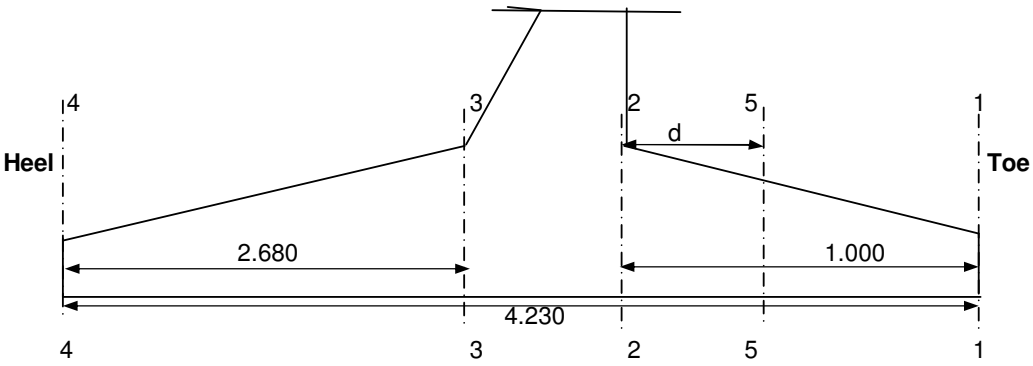
Base pressure due to vertical load V/A = 7.52 Pressure at toe = **10.31** t/m^2

Base pressure due to moment Mn/Z = 2.793 Pressure at heel= **4.73** t/m^2

CALCULATION OF DESIGN PRESSURES

Section	1-1	2-2	3-3	4-4	5-5
Upward pressure	10.312	8.991	8.265	4.726	9.761
Downward Pressure	0.720	1.200	9.300	9.180	1.000
Net pressure	9.592	7.791	-1.035	-4.454	8.761

** Positive net pressure means upward pressure & negative net pressure means downward pressure



DESIGN OF TOE SLAB

Reinforcement calculation

Bending Moment at face of stem = 4.50 t-m
Effective depth required = 0.239 m
Effective depth provided at face of stem = 0.417 > reqd 0.239
Area of Reinforcement reqd.at bottom = **5.78** cm^2 **HENCE SAFE**

Shear check:

Shear force at distance d from stem = 5.35 t
Bending moment at sec 5-5 = 1.58 t-m
Net shear force at sec 5-5=S-Ms*tanβ/d_1 = 4.40 t
Depth of slab at section 5-5 = 0.417 Effective depth d_1 = 0.332 m
Nominal Shear stress = 10.55 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.174 %
Therefore Permissible shear strsss = 19.35 t/m^2 **HENCE SAFE**

DESIGN OF HEEL SLAB

Bending Moment at face of stem = 11.90 t-m
Effective depth required = 0.389 m
Effective depth of slab at face of stem = 0.415 m
Reinforcement reqd.at top = **15.36** cm^2

Shear check:

Shear force at face of stem S = 7.35 t
Bending moment at face Ms = 11.90 t-m
Net shear force =S-Ms*tanβ/d_1 = 5.21 t
Nominal Shear stress = 12.57 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.370 %
Therefore Permissible shear strsss = 26.36 t/m^2 **HENCE SAFE**

FOR CURTAILMENT

Shear Force at distance from stem = 2.259
Bending Moment at distance 1.500 m from face of stem = 2.27
Effective depth required = 0.170 m
Effective depth provided = 0.305 > reqd 0.170
Curtailment Length = 1.805
Area of Reinforcement reqd.at bottom = **3.99** cm^2

DESIGN OF STEM BASE

Section A

Height of Base of stem from top of earth fill = 4.5 m

Height of Base of stem below straight portion = 2.1 m

S.No.	Horz. Press due to	Area factor	Pressure k_a.g.h	Height	Horz. Force	C.G. from base	Moment about base
1	ActiveEarthPressure	0.5	2.263	4.5	5.092	1.890	9.62
2	L.L.Surcharge	1	0.603	4.5	2.716	2.250	6.11
			Total =		7.81		15.73

Total Horizontal Force	7.81	t		
Total Moment about base	15.73	tm		
Design bending moment	15.73	t-m		
Effective depth required	0.448	m		
Thickness of stem at base	0.550	m		
Effective depth provided	0.488	>	0.448	**HENCE SAFE**
Area of steel reqd.	**17.29**	cm^2		

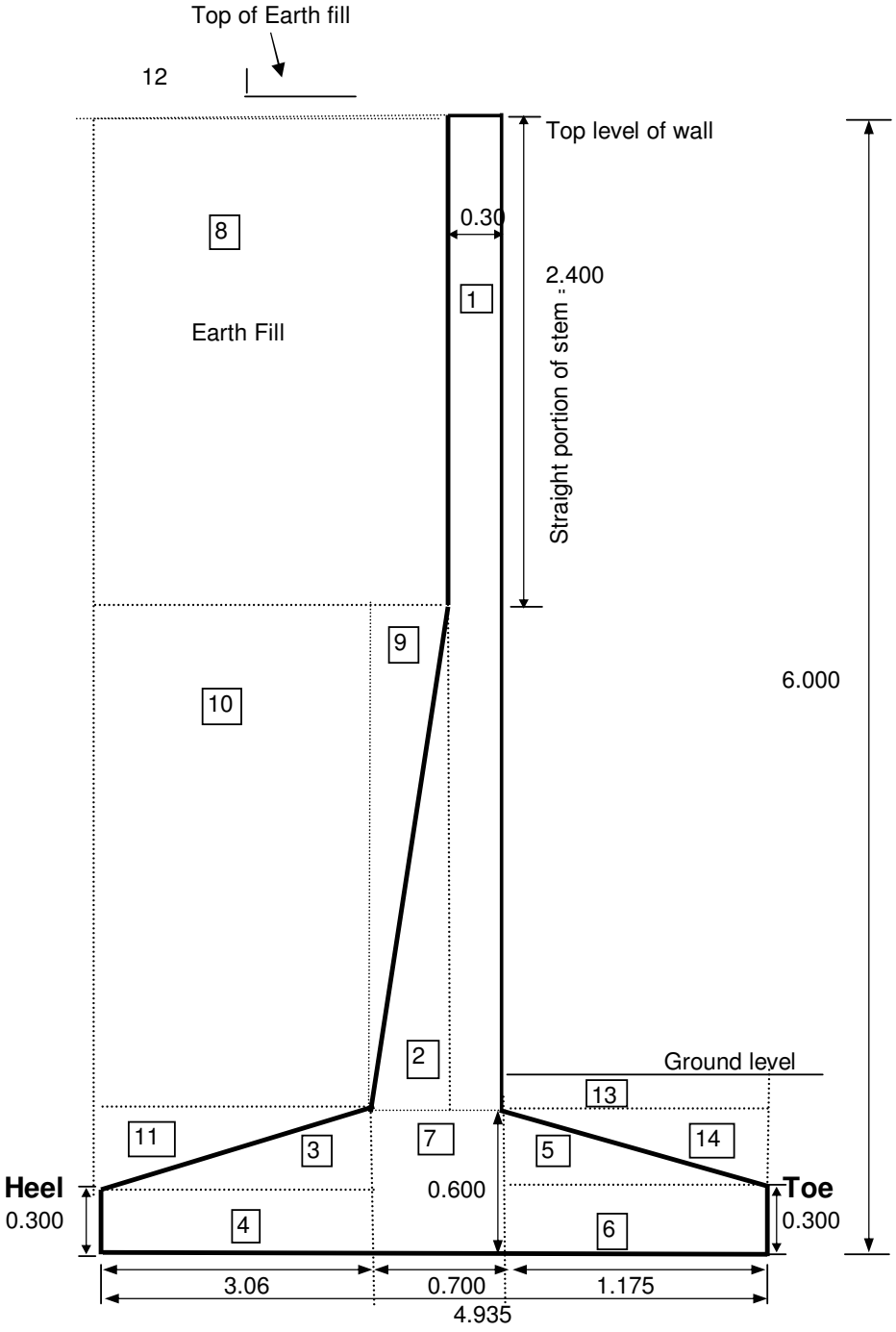
Shear check:

Shear force at base of stem	7.81	t		
Bending moment at base	15.73	t-m		
Net shear force	3.97	t		
Nominal Shear stress	8.13	t/m^2		

Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000

100As/bd = 0.35 %

Therefore Permissible shear strsss 25.86 t/m^2 **HENCE SAFE**


Top of Earth fill
12
Top level of wall
0.30
2.400
Straight portion of stem :
8
1
Earth Fill
9
10
6.000
2
Ground level
13
11
3
7
5
14
Heel
0.300
0.600
Toe
0.300
4
6
3.06
0.700
1.175
4.935

DESIGN OF RETAINING WALL FOR 6.000 m HEIGHT

DESIGN DATA:

Top level of retaining wall	=	6.000	m
Ground level	=	2.000	m
Founding Level	=	0.000	m
Total Height from top of wall to founding level	=	**6.000**	m
Density of earth	=	1.8	t/m^3
Density of concrete	=	2.4	t/m^3
Clear cover to Reinforcement	=	0.05	m
Clear cover to Reinforcement for foundations	=	0.075	m
Grade of concrete	=	20	
Allowable stress in steel	=	20380	
Safe bearing capacity	=	20	t/m^2
Safety factor against overturning	=	2.0	
Safety factor against sliding	=	1.5	
Depth of L.L.Surcharge	=	1.2	m
L.L.Surcharge on wall	=	0	t/m^2

DESIGN CONSTANTS:

For Grade of concrete	= M	20	& HYSD reinf. with Fe 415
Lever arm factor j	=	0.916	
Moment of resistance factor Q	=	78.54	

DIMENSIONS :

Length of Base of Retaining wall	=	4.935	m
Section modulus	=	4.059	m^3
Length of Toe	=	1.175	m
Length of Heel	=	3.060	m
Thickness of Stem at base	=	0.700	m
Thickness of straight portion of stem	=	0.300	m
Ht. of straight portion of stem	=	2.400	m
Minimum thickness of Toe slab	=	0.300	m
Thickness of Toe slab at junction with stem	=	0.600	m
Minimum thickness of heel slab	=	0.300	m
Thickness of heel slab at junction with stem	=	0.600	m
Angle of inclined stem with vertical	=	0.133	
Ht.of inclined potion of stem to base of footing	=	3.600	m
Ht.of inclined potion of stem to top of footing	=	3.000	m

Calculation of Earth pressure coefficients =

Angle of internal friction of soil ϕ	=	30	deg	=	0.524 rad
Angle of wall friction δ	=	20	deg	=	0.349 rad
Angle of incli . of soil at back i	=	0	deg	=	0.000 rad
Angle of incli . of stem at back α	=	90	deg	=	1.571 rad
Coefficient of active earth pressure k_a	=	0.297			
Coefficient of horz.active earth pressure K_{ah}	=	0.279			

Calculation of Forces & moments due to Vertical Forces

S.No.	Description	Area Factor	width	Depth	Density	Weight	C.G. from Toe	Moment about toe
1	Wt of stem	1.0	0.300	5.4	2.4	3.888	1.325	5.152
2		0.5	0.400	3	2.4	1.440	1.608	2.316
3	Wt of heel slab	0.5	3.060	0.3	2.4	1.102	2.895	3.189
4		1.0	3.060	0.3	2.4	2.203	3.405	7.502
5	Wt of toe slab	0.5	1.175	0.3	2.4	0.423	0.783	0.331
6		1.0	1.175	0.3	2.4	0.846	0.588	0.497
7	Wt.of intmdt.portion	1.0	0.700	0.6	2.4	1.008	1.525	1.537
8	Wt. of soil above heel slab	1.0	3.460	2.4	1.8	14.947	3.205	47.906
9		0.5	0.400	3	1.8	1.080	1.742	1.881
10		1.0	3.060	3	1.8	16.524	3.405	56.264
11		0.5	3.060	0.3	1.8	0.826	3.915	3.235
12		0.0	3.460	1.73	1.8	0.000	3.783	0.000
13	Wt. of soil above toe slab	0.0	1.175	1.4	1.8	0.000	0.588	0.000
14		0.0	1.175	0.3	1.8	0.000	0.392	0.000
15	L.L.Surcharge	0.0	3.46	1.2	1.8	0.000	3.205	0.000
			Total forces =			**44.287**		**129.81**

Total Vertical load = **44.29** Total Restoring moment = **129.81**

Horz. components of Earth Pressure

S.No.	Horz. Press due to	Area factor	Pressure $k_{ah}\gamma h$	Height	Horz. Force	C.G. from Toe	Moment about toe
1	Active Earth Pressure	0.5	3.017	6	9.052	2.520	22.81
2	L.L.Surcharge	1	0.603	6	3.621	3.000	10.86
			Total forces =		12.673		33.67

Total overturning moment Mo = 33.67 tm Total vertical load V = 44.287 t
Total restoring moment Mr = 129.81 tm Total Horz. Force = 12.673 t
Factor of safety against overturning Mr/Mo = 3.85 **OK** > 2

Check for sliding :

Coefficient of base friction = 0.500
Total vertical force = 44.287 t
Resisting force = 22.14 t
F.O.S 1.75 **OK** > 1.5
C.G. of loads from toe = Mr/V = 2.931 m
Eccentricity of loads w.r.t. c/l raft = 0.464 m
Moment about c/l raft = 20.531 t-m
Net moment about base Mn = 13.142 t-m

Calculation of Base Pressure

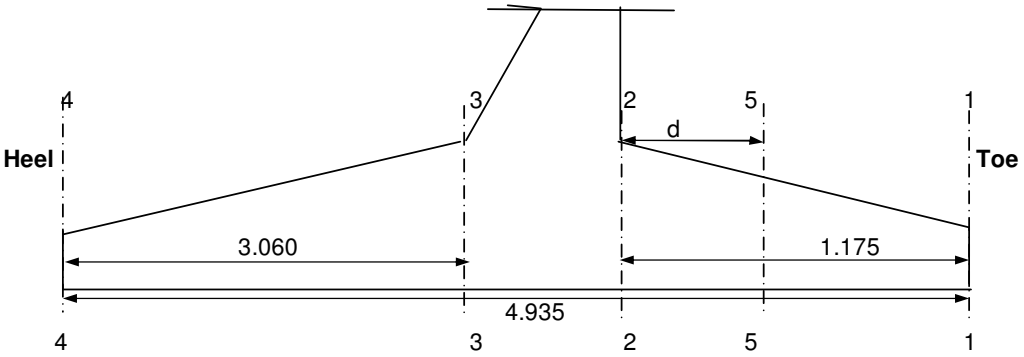
Base pressure due to vertical load V/A = 8.97 Pressure at toe = **12.21** t/m^2

Base pressure due to moment Mn/Z = 3.238 Pressure at heel= **5.74** t/m^2

CALCULATION OF DESIGN PRESSURES

Section	1-1	2-2	3-3	4-4	5-5
Upward pressure	12.212	10.670	9.752	5.736	11.531
Downward Pressure	0.720	1.440	11.160	10.980	1.122
Net pressure	11.492	9.230	-1.408	-5.244	10.409

** Positive net pressure means upward pressure & negative net pressure means downward pressure



DESIGN OF TOE SLAB

Reinforcement calculation

Bending Moment at face of stem = 7.41 t-m
Effective depth required = 0.307 m
Effective depth provided at face of stem = 0.519 > reqd 0.307
Area of Reinforcement reqd.at bottom = **7.65** cm^2 **HENCE SAFE**

Shear check:

Shear force at distance d from stem = 7.18 t
Bending moment at sec 5-5 = 2.40 t-m
Net shear force at sec 5-5=S-Ms*tanβ/d_1 = 5.58 t
Depth of slab at section 5-5 = 0.467 Effective depth d_1 = 0.382 m
Nominal Shear stress = 11.95 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.200 %
Therefore Permissible shear strsss = 20.40 t/m^2 **HENCE SAFE**

DESIGN OF HEEL SLAB

Bending Moment at face of stem = 18.56 t-m
Effective depth required = 0.486 m
Effective depth of slab at face of stem = 0.517 m
Reinforcement reqd.at top = **19.24** cm^2

Shear check:

Shear force at face of stem S = 10.18 t
Bending moment at face Ms = 18.56 t-m
Net shear force =S-Ms*tanβ/d_1 = 6.66 t
Nominal Shear stress = 12.88 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.372 %
Therefore Permissible shear strsss = 26.42 t/m^2 **HENCE SAFE**

FOR CURTAILMENT

Shear Force at distance from stem = 2.991
Bending Moment at distance 2.000 m from face of stem = 2.17
Effective depth required = 0.166 m
Effective depth provided = 0.321 > reqd 0.166
Curtailment Length = 2.321
Area of Reinforcement reqd.at bottom = **3.62** cm^2

DESIGN OF STEM BASE

Section A

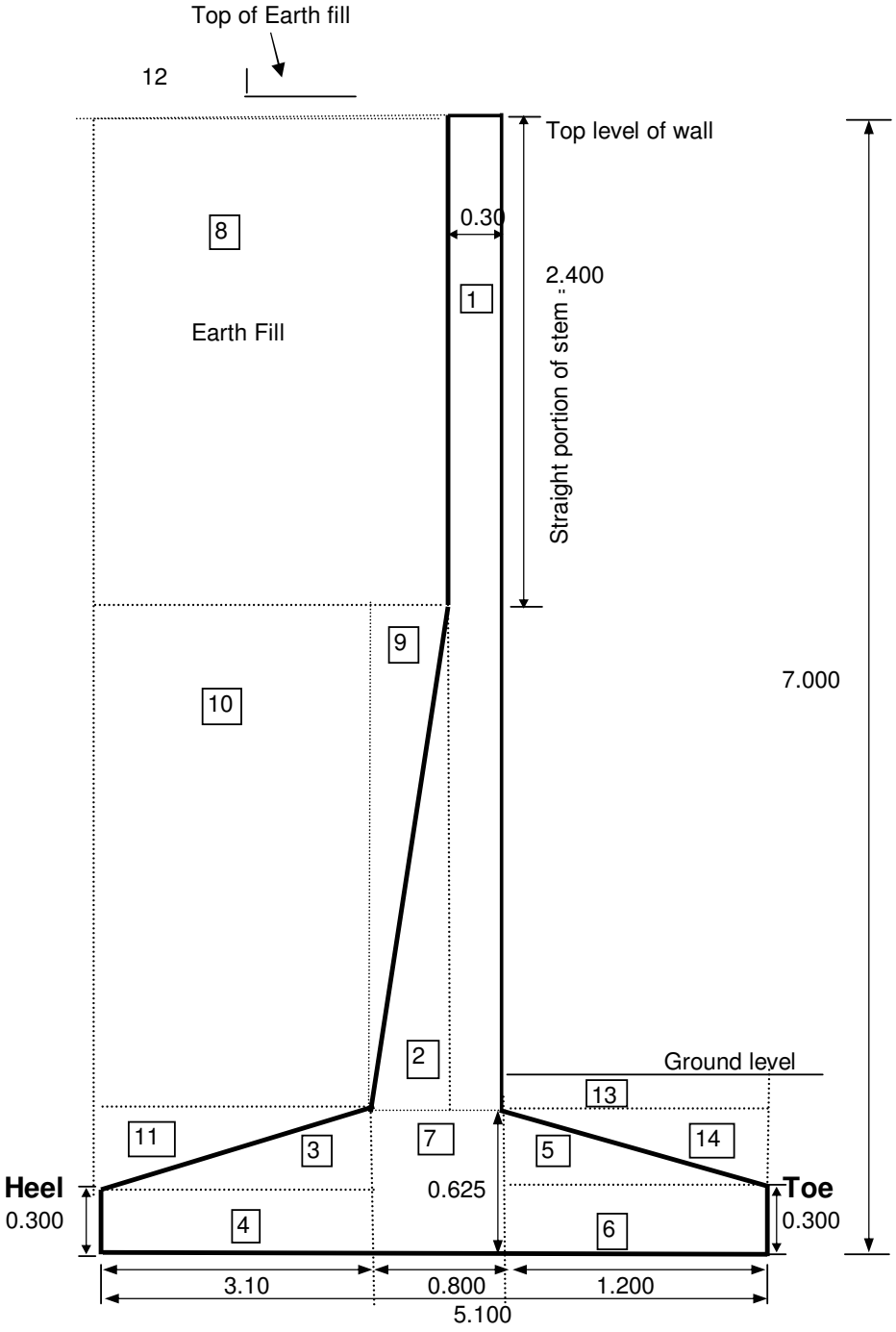
Height of Base of stem from top of earth fill = 5.4 m
Height of Base of stem below straight portion = 3 m

S.No.	Horz. Press due to	Area factor	Pressure $k_a.g.h$	Height	Horz. Force	C.G. from base	Moment about base
1	ActiveEarthPressure	0.5	2.716	5.4	7.332	2.268	16.63
2	L.L.Surcharge	1	0.603	5.4	3.259	2.700	8.80
			Total =		10.59		25.43

Total Horizontal Force 10.59 t
Total Moment about base 25.43 tm
Design bending moment 25.43 t-m
Effective depth required 0.569 m
Thickness of stem at base 0.700 m
Effective depth provided 0.640 > 0.569 **HENCE SAFE**
Area of steel reqd. **21.28** cm^2

Shear check:

Shear force at base of stem 10.59 t
Bending moment at base 25.43 t-m
Net shear force 5.29 t
Nominal Shear stress 8.27 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.33 %
Therefore Permissible shear strsss 25.13 t/m^2 **HENCE SAFE**


Top of Earth fill
12
Top level of wall
0.30
2.400
Straight portion of stem
8
1
Earth Fill
9
10
7.000
2
Ground level
13
11
3
7
5
14
Heel
0.300
0.625
Toe
0.300
4
6
3.10
0.800
1.200
5.100

DESIGN OF RETAINING WALL FOR 7.000 m HEIGHT

DESIGN DATA:

Top level of retaining wall	=	7.000	m
Ground level	=	2.000	m
Founding Level	=	0.000	m
Total Height from top of wall to founding level	=	**7.000**	m
Density of earth	=	1.8	t/m^3
Density of concrete	=	2.4	t/m^3
Clear cover to Reinforcement	=	0.05	m
Clear cover to Reinforcement for foundations	=	0.075	m
Grade of concrete	=	20	
Allowable stress in steel	=	20380	
Safe bearing capacity	=	20	t/m^2
Safety factor against overturning	=	2.0	
Safety factor against sliding	=	1.5	
Depth of L.L.Surcharge	=	1.2	m
L.L.Surcharge on wall	=	0	t/m^2

DESIGN CONSTANTS:

For Grade of concrete	= M	20	& HYSD reinf. with Fe 415
Lever arm factor j	=	0.916	
Moment of resistance factor Q	=	78.54	

DIMENSIONS :

Length of Base of Retaining wall	=	5.100	m
Section modulus	=	4.335	m^3
Length of Toe	=	1.200	m
Length of Heel	=	3.100	m
Thickness of Stem at base	=	0.800	m
Thickness of straight portion of stem	=	0.300	m
Ht. of straight portion of stem	=	2.400	m
Minimum thickness of Toe slab	=	0.300	m
Thickness of Toe slab at junction with stem	=	0.625	m
Minimum thickness of heel slab	=	0.300	m
Thickness of heel slab at junction with stem	=	0.625	m
Angle of inclined stem with vertical	=	0.126	
Ht.of inclined potion of stem to base of footing	=	4.600	m
Ht.of inclined potion of stem to top of footing	=	3.975	m

Calculation of Earth pressure coefficients =

Angle of internal friction of soil ϕ	=	30	deg	=	0.524 rad
Angle of wall friction δ	=	20	deg	=	0.349 rad
Angle of incli . of soil at back i	=	0	deg	=	0.000 rad
Angle of incli . of stem at back α	=	90	deg	=	1.571 rad
Coefficient of active earth pressure k_a	=	0.297			
Coefficient of horz.active earth pressure K_{ah}	=	0.279			

Calculation of Forces & moments due to Vertical Forces

S.No.	Description	Area Factor	width	Depth	Density	Weight	C.G. from Toe	Moment about toe
1	Wt of stem	1.0	0.300	6.375	2.4	4.590	1.350	6.197
2		0.5	0.500	3.975	2.4	2.385	1.667	3.975
3	Wt of heel slab	0.5	3.100	0.325	2.4	1.209	3.033	3.667
4		1.0	3.100	0.3	2.4	2.232	3.550	7.924
5	Wt of toe slab	0.5	1.200	0.325	2.4	0.468	0.800	0.374
6		1.0	1.200	0.3	2.4	0.864	0.600	0.518
7	Wt.of intmdt.portion	1.0	0.800	0.625	2.4	1.200	1.600	1.920
8	Wt. of soil above heel slab	1.0	3.600	2.4	1.8	15.552	3.3	51.322
9		0.5	0.500	3.975	1.8	1.789	1.833	3.279
10		1.0	3.100	3.975	1.8	22.181	3.550	78.741
11		0.5	3.100	0.325	1.8	0.907	4.067	3.688
12		0.0	3.600	1.8	1.8	0.000	3.901	0.000
13	Wt. of soil above toe slab	0.0	1.2	1.4	1.8	0.000	0.600	0.000
14		0.0	1.2	0.325	1.8	0.000	0.400	0.000
15	L.L.Surcharge	0.0	3.6	1.2	1.8	0.000	3.300	0.000
			Total forces =			**53.376**		**161.60**

Total Vertical load = **53.38** Total Restoring moment = **161.60**

Horz. components of Earth Pressure

S.No.	Horz. Press due to	Area factor	Pressure $k_{ah}\gamma h$	Height	Horz. Force	C.G. from Toe	Moment about toe
1	Active Earth Pressure	0.5	3.520	7	12.321	2.940	36.22
2	L.L.Surcharge	1	0.603	7	4.224	3.500	14.78
			Total forces =		16.545		51.01

Total overturning moment Mo = 51.01 tm Total vertical load V = 53.376 t
Total restoring moment Mr = 161.60 tm Total Horz. Force = 16.545 t
Factor of safety against overturning Mr/Mo = 3.17 **OK** > 2

Check for sliding :

Coefficient of base friction = 0.500
Total vertical force = 53.376 t
Resisting force = 26.69 t
F.O.S 1.61 **OK** > 1.5
C.G. of loads from toe = Mr/V = 3.028 m
Eccentricity of loads w.r.t. c/l raft = 0.478 m
Moment about c/l raft = 25.496 t-m
Net moment about base Mn = 25.512 t-m

Calculation of Base Pressure

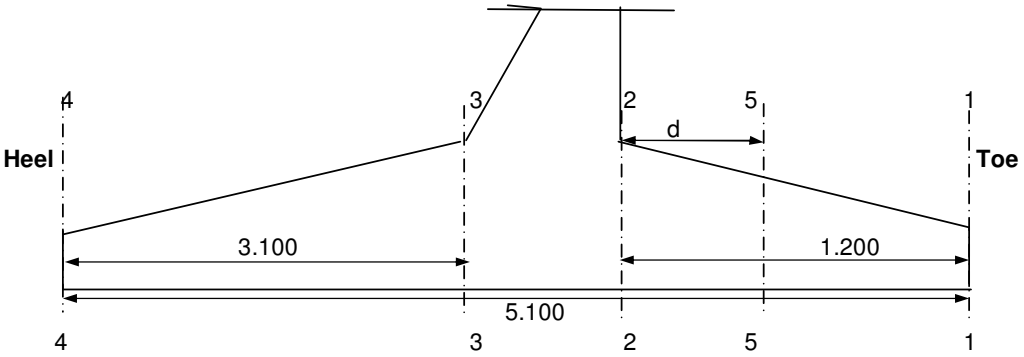
Base pressure due to vertical load V/A = 10.47 Pressure at toe = **16.35** t/m^2

Base pressure due to moment Mn/Z = 5.885 Pressure at heel= **4.58** t/m^2

CALCULATION OF DESIGN PRESSURES

Section	1-1	2-2	3-3	4-4	5-5
Upward pressure	16.351	13.582	11.735	4.581	15.096
Downward Pressure	0.720	1.500	12.975	12.780	1.146
Net pressure	15.631	12.082	-1.240	-8.199	13.949

** Positive net pressure means upward pressure & negative net pressure means downward pressure



DESIGN OF TOE SLAB

Reinforcement calculation

Bending Moment at face of stem = 10.40 t-m
Effective depth required = 0.364 m
Effective depth provided at face of stem = 0.544 > reqd 0.364
Area of Reinforcement reqd.at bottom = **10.24** cm^2 **HENCE SAFE**

Shear check:

Shear force at distance d from stem = 9.70 t
Bending moment at sec 5-5 = 3.24 t-m
Net shear force at sec 5-5=S-Ms*tanβ/d_1 = 7.47 t
Depth of slab at section 5-5 = 0.478 Effective depth d_1 = 0.393 m
Nominal Shear stress = 15.63 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.261 %
Therefore Permissible shear strsss = 22.79 t/m^2 **HENCE SAFE**

DESIGN OF HEEL SLAB

Bending Moment at face of stem = 28.25 t-m
Effective depth required = 0.600 m
Effective depth of slab at face of stem = 0.542 m
Reinforcement reqd.at top = **27.92** cm^2

Shear check:

Shear force at face of stem S = 14.63 t
Bending moment at face Ms = 28.25 t-m
Net shear force =S-Ms*tanβ/d_1 = 9.17 t
Nominal Shear stress = 16.91 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.515 %
Therefore Permissible shear strsss = 30.91 t/m^2 **HENCE SAFE**

FOR CURTAILMENT

Shear Force at distance from stem = 5.204
Bending Moment at distance 2.000 m from face of stem = 3.96
Effective depth required = 0.225 m
Effective depth provided = 0.332 > reqd 0.225
Curtailment Length = 2.332
Area of Reinforcement reqd.at bottom = **6.39** cm^2

DESIGN OF STEM BASE

Section A

Height of Base of stem from top of earth fill = 6.375 m
Height of Base of stem below straight portion = 3.975 m

S.No.	Horz. Press due to	Area factor	Pressure $k_a.g.h$	Height	Horz. Force	C.G. from base	Moment about base
1	ActiveEarthPressure	0.5	3.206	6.375	10.219	2.678	27.36
2	L.L.Surcharge	1	0.603	6.375	3.847	3.188	12.26
			Total =		14.07		39.62

Total Horizontal Force 14.07 t
Total Moment about base 39.62 tm
Design bending moment 39.62 t-m
Effective depth required 0.710 m
Thickness of stem at base 0.800 m
Effective depth provided 0.740 > 0.710 **HENCE SAFE**
Area of steel reqd. **28.68** cm^2

Shear check:

Shear force at base of stem 14.07 t
Bending moment at base 39.62 t-m
Net shear force 7.33 t
Nominal Shear stress 9.91 t/m^2
Permissible shear strsss is calculated as per cl.304.7.1.3 of IRC:21-2000
100As/bd = 0.39 %
Therefore Permissible shear strsss 26.93 t/m^2 **HENCE SAFE**