Design Comparison of an RC Retaining Wall with BS8110 and EC 2

BY

Aloysius Tan Sze Howe

Being a Project Report submitted to INTI INTERNATIONAL UNIVERSITY as a requirement for DIPLOMA IN CIVIL ENGINEERING. (Semester: JANUARY 2015)

Faculty of Science, Technology, Engineering and Mathematics

INTI INTERNATIONAL UNIVERSITY

Supervisor: Ir. Siow Yun Tong

Acknowledgement

I have been on this project for 3 months now in INTI International University and it has been a long way from scratch to my final product. Along the way I had a lot of help from lecturers and friends which I would like to express my gratitude here.

First of all, I would like to thank my supervisor Ir. Siow Yun Tong for helping me to finish my project. He gave me a lot of suggestions and useful tips to help me on designing the retaining wall, because I'm not familiar with it. He also checked on my progress so I won't lose track.

Secondly I would like to thank my friends for giving me support and some help on this. Although they also have their own reports to do, they still helped me out whenever I needed.

I would also want to thank my parents for giving me financial support at my diploma and my project budget so I can finished it smoothly.

Lastly I would like to thank FOSTEM and INTI International University for giving me an opportunity to do a Final Year Project to simulate a real life project when working in the future.

I declare that this project is entirely my own work except where due references are made.

Aloysius Tan Sze Howe

9 April 2015

Abstract

The purpose of this project is to design a cantilever retaining wall using BS8110 and EC2 and do a comparison between them. Retaining wall is the more efficient, safe and space-saving structure than the traditional method.

There are a lot of different designs of retaining walls but in this project, cantilever retaining wall is chosen because of its advantages than other designs.

There are a lot of differences between British Standards and Eurocode, and some of it will be applied in this project. The calculation differences will be tabulated out at the end of the project.

Calculation will be on firstly, the stability of the wall, and second the reinforcement. The different codes have different formulae and will produce various results.

Content:

List of illustrations

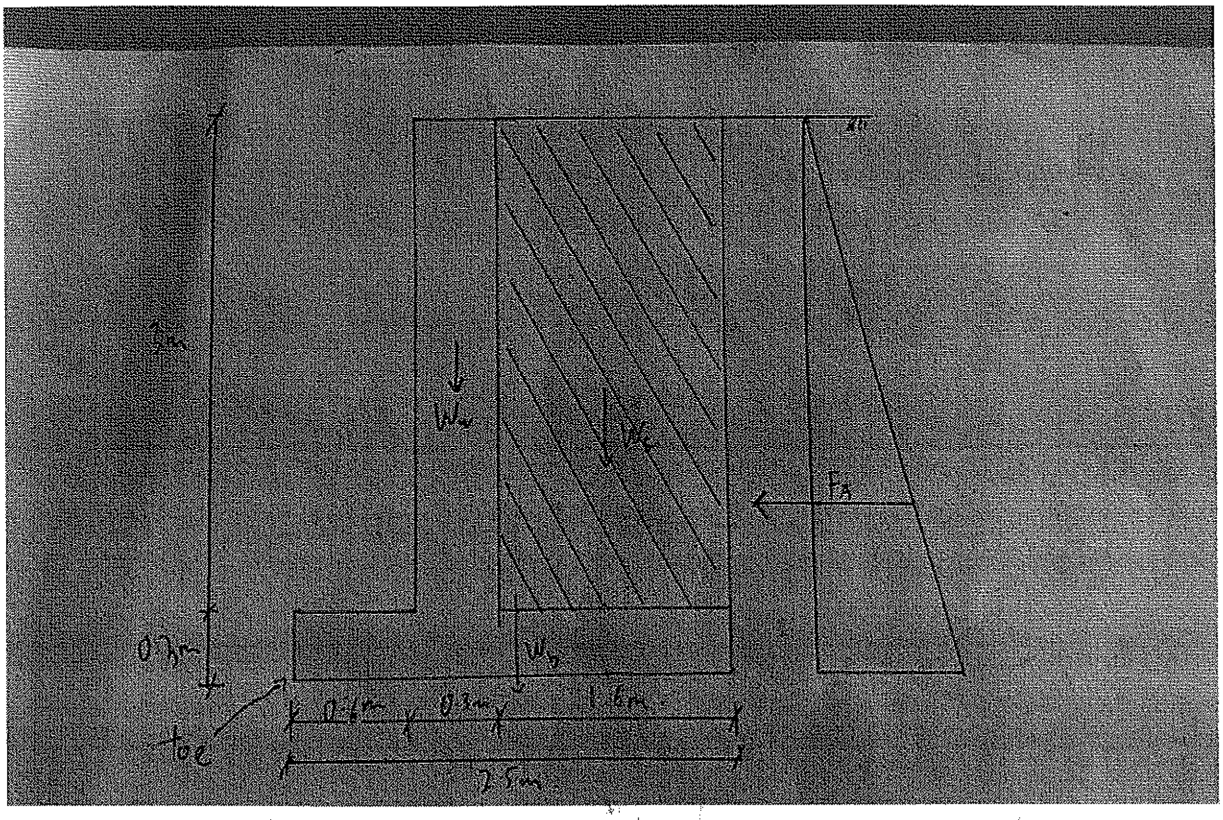


Figure A

Table 3.22 Cross-sectional area per metre width for various bar spacing (mm²)

Bar size (mm)	Spacing of bars								
	50	75	100	125	150	175	200	250	300
6	566	377	283	226	189	162	142	113	94.3
8	1010	671	503	402	335	287	252	201	168
10	1570	1050	785	628	523	449	393	314	262
12	2260	1510	1130	905	754	646	566	452	377
16	4020	2680	2010	1610	1340	1150	1010	804	670
20	6280	4190	3140	2510	2090	1800	1570	1260	1050
25	9820	6550	4910	3930	3270	2810	2450	1960	1640
32	16100	10700	8040	6430	5360	4600	4020	3220	2680
40	25100	16800	12600	10100	8380	7180	6280	5030	4190

Figure B

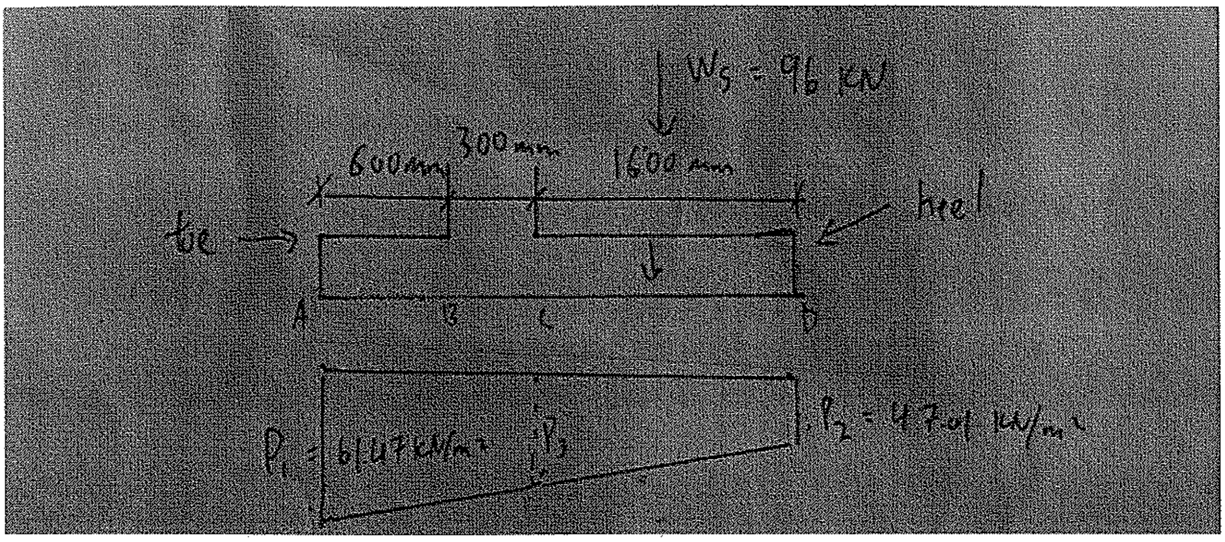


Figure C

these three combinations are given in table 10.1.

Table 10.1 Partial safety factors at the ultimate limit state

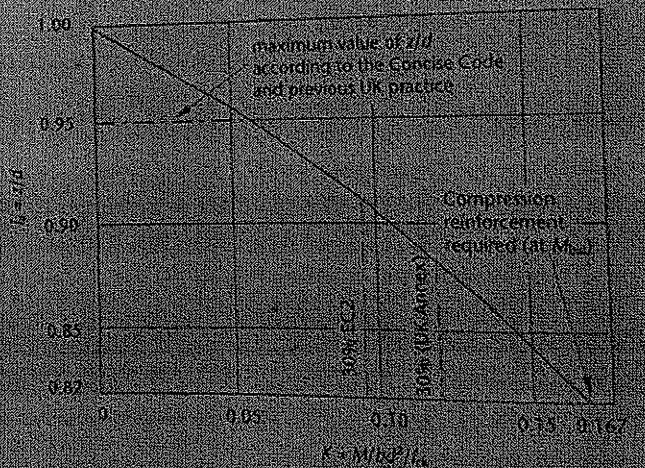
Persistent or transient design situation	*Permanent actions* (G_k)		*Leading variable action* ($Q_{k,1}$)		*Accompanying variable action* ($Q_{k,i}$)	
	Unfavourable	*Favourable*	*Unfavourable*	*Favourable*	*Unfavourable*	*Favourable*
(a) for consideration of structural or geotechnical failure: combination 1 (STR) & (GEO)	1.35	1.00*	1.50	0	1.50	0
(b) for consideration of structural or geotechnical failure: combination 2 (STR) & (GEO)	1.00	1.00*	1.30	0	1.30	0
(c) for checking static equilibrium (EQU)	1.1	0.9	1.50	0	1.50	0

* To be applied to bearing, sliding and earth resistance forces.

Figure D

$K = M/bd^2 f_{ck}$	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.167
$l_a = z/d$	0.954	0.945	0.934	0.924	0.913	0.902	0.891	0.880	0.868	0.856	0.843	0.830	0.820

Figure 4.5
Lever-arm curve



The percentage values on the K axis mark the limits for singly reinforced sections with moment redistribution applied (see Section 4.7 and Table 4.2)

Figure E

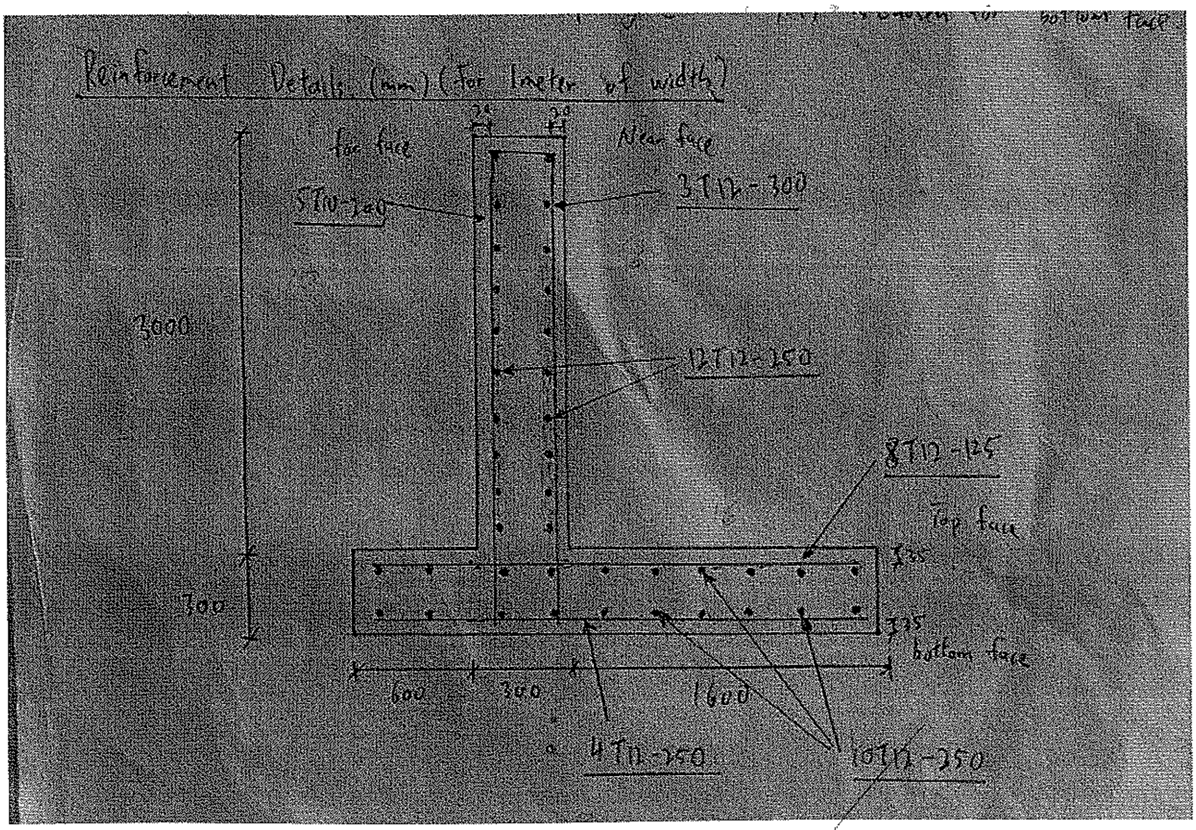


Figure F

1.0 Introduction

Retaining Wall is a vertical wall which is able to resist pressure or weight of the material that it is retaining. It can be made out of either concrete, timber, bricks or just stones, is to be placed between two different elevations of unstable soil or slopes, or landscape needed to be shaped for better purposes like highway. Actually there is another solution to this problem is to build a natural slope between the two levels, but it is space consuming. So a rigid vertical wall is the best solution.

There are a few types of retaining wall which are gravity retaining wall, semi-gravity retaining wall, counterfort retaining wall and cantilever retaining wall. Cantilever retaining wall is chosen for this project.

1.1 Advantages

The advantages of cantilever retaining wall than other walls is:

1. Use lesser materials than others.
2. Can have a height between 1.2m to 6m.
3. Use reinforced concrete to design.
4. Economical and easier to construct.

1.2 Objective

Objective of this project is to be able to design a reinforced concrete cantilever retaining wall using BS 8110 and EC 2.

And at the end to produce a comparison between the two calculation.

A scaled model of the retaining wall will also be done.

1.3 Scope

The limitation in this project is

1. There is no drainage system calculation.
2. There is no water/ice, surcharge pressure calculation.
3. Active earth pressure assumed to be 0.
4. Soil conditions are assumed, due to this project is focused on designing.

2.0 Methodology

2.1 Initial sizing of the wall

First of all the height of the wall was assumed to be 3m, and according to a BS8110 reference book, the base should be approximate 0.75-0.8 times the height, so the base assumed to be 2.5m length. The minimum thickness for retaining wall is 300mm (0.3m), so the thickness chosen is 0.3m. The breadth of the base toe is almost a quarter of the total length of the base, so 0.6m was chosen. The breadth of the heel is 1.6m. (Figure A)

2.2 Soil and other properties

The soil properties for this project are assumed as this project is mainly on designing.

Density, γ	: 20 KN/m^3
Internal angle of friction, Φ	: 30^o
Coefficient of friction, μ	: 0.5
Allowable bearing pressure	: 150 KN/m^2

2.3 Concrete properties

Density, γ	: 24 KN/m^3
Concrete strength, f_{cu}	: 30 KN/m^2
Yield strength, f_y	: 500 KN/m^2
Cover for wall	: 20 mm
Cover for base	: 35 mm

3.0 Results and Discussions

3.1 British Standards Calculations

3.1.1 Checks for Stability (Figure A)

a) Sliding: (consider 1m length of the wall)

Horizontal force = 0.5 x active pressure x height of wall

$F_A = 0.5p_ah$

Active pressure = coefficient of active pressure x density of soil x height of retained fill

$p_a = k_a\rho h$

Coefficient of active pressure

$$K_a = \frac{1-\sin\Phi}{1+\sin\Phi}$$

$$= \frac{1-\sin 30}{1+\sin 30}$$

$$= \frac{1-0.5}{1+0.5}$$

$$= 1/3$$

So active pressure

$$p_a = 1/3 \times 20 \times 3.3$$

$$= 22\ KN/m^2$$

And horizontal force

$$F_A = 0.5 \times 22 \times 3.3$$

$$= 36.3\ KN$$

Weight of wall (W_w) = 0.3 x 3 x 24 = 21.6 KN

Weight of base (W_b) = 0.3 x 2.5 x 24 = 18 KN

Weight of soil (W_s) = 1.6 x 3 x 20 = 96 KN

Total vertical force (W_t) = 135.6 KN

So the frictional force F_f = μW_t

= 0.5 x 135.6

= 67.8 KN

Since the passive earth pressure = 0, hence factor of safety against sliding

$$\frac{67.8}{36.3} = 1.87 > 1.5\ (O.K.)$$

b) Overturning

Total moment from toe

(overturning moment) = $F_A \times \frac{3.3}{3}$ = 36.3 x 1.1 = 39.93 KNm

Sum of restoring moment, M_{res} = $W_w \times 0.75 + W_b \times 1.25 + W_s \times 1.7$

= 21.6 x 0.75 + 18 x 1.25 + 96 x 1.7

= 16.2 + 22.5 + 163.2

= 201.9 KNm

Factor of safety against overturning

$$\frac{201.9}{39.93} = 5.06 > 2\ (O.K.)$$

c) **Ground bearing pressure**

Moment at center line of base (anti-clockwise as positive)

$$M = F_A \times \frac{3.3}{3} + W_w \times 0.5 - W_s \times 0.45$$

$$= 36.3 \times 1.1 + 21.6 \times 0.5 - 96 \times 0.45$$

$$= 39.93 + 10.8 - 43.2$$

$$= 7.53 \text{ KNm}$$

Total vertical load, $N = W_t$ $= 135.6KN$

$$\frac{M}{N} = \frac{7.53}{135.6} = 0.056m < \frac{D}{6} = \frac{2.5}{6} = 0.417m$$

So, the maximum ground pressure is at toe,

$$P_{toe} = \frac{N}{D} + \frac{6M}{D^2}$$

$$= \frac{135.6}{2.5} + \frac{6 x 7.53}{2.5^2}$$

$$= 54.24 + 7.23$$

$$= 61.47 \text{ KN/m}^2 < \text{allowable } 150 \text{ KN/m}^2$$

The maximum ground pressure at heel,

$$P_{heel} = \frac{N}{D} - \frac{6M}{D^2}$$

$$= \frac{135.6}{2.5} + \frac{6 x 7.53}{2.5^2}$$

$$= 54.42 - 7.23$$

$$= 47.01 \text{ KN/m}^2$$

3.1.2 Reinforcement

a) Wall

Height of wall = 3m, horizontal force

$$F_s = 0.5k_a ph^2$$

$$= 0.5 \times 1/3 \times 20 \times 3^2$$

$$= 30 \text{ KN/m}$$

Design moment at base of wall,

$$M = \frac{\gamma f\,Fsh}{3}$$

$$= \frac{1.4 \times 30 \times 3}{3}$$

$$= 42 \text{ KNm}$$

Effective Depth

Assume diameter of the steel bar = 12mm

$$\text{Effective depth, D} = 300 - \text{cover} - \frac{12}{2}$$

$$= 300 - 20 - 6$$

$$= 274 \text{ mm}$$

Ultimate moment of resistance

$$M_u = 0.156\, f_{cu}\, bd^2$$

$$= 0.156 \times 30 \times 10^3 \times 274^2 \times 10^{-6}$$

$$= 351.36 \text{ KNm}$$

Since $M_u > M$, so no.compression reinforcement required.