DESIGN FOR COUNTER FORT RETAINING WALL

1.5 Design For Counter Fort Retaining Wall For Toe Design

Example:5

Design a counter fort retaining wall based on the following data

Height of wall above ground level =6m

SBC of soil = 160 KN/m^2

Angle of internal friction ϕ =33°

Density of soil = 16KN/m^3

Spacing of counter forts = 3m c/c

Adopt M20 grade concrete and Fe415 HYSD bars

Solution:

Step:1 Dimension of retaining wall

(a) Depth of foundation =P/W(1-sinϕ/1+sinϕ)^2

= 160/16(1/3)^2

=1.11m

Provide depth of foundation =1.2m

(b) Overall height of wall ,H = 6+1.2

H =7.2m

(c) Thickness of base slab = 2LH cm

=2x3x7.2

=43.2cm

Provide 450mm thick base slab

Base width = 0.6H to 0.7H

(0.6x7.2) = 4.32m

(0.7x7.2) = 5.04m

Adopt base width = 4.5m

Toe projection = (1/4)x4.5

=1.1m

Step:2 Stability calculations

(a) Find load

W1 = b x d x γc

=0.22x6.75x24

=35.64 KN

W2 =b x dx γc

= 0.45x4.5x24

=48.60KN

W3 =b x dx γs

=3.28x6.75x16

=354.24 KN

Total = W1+W2+W3

=35.64+48.60+354.24

=438.49KN

(b) Find moment

M1 = W1 X length

=35.64 x 3.39

=120.80KNm

M2 = W2 X length

=48.60 x 2.25

=109.35KNm

M3 = W3 X length

=354.24x1.64

=580.95KNm

M4 = Moment of earth pressure

ka =Wh^3/6

1/3 =(16x7.2^3)/6

M4 = 331.77KNm (moment at base)

Total moment,

M = M1+M2+M3+M4

= 120.80+109.35+580.95+331.77

M =1142.87KNm

Distance of the point of application of the resultant from point ‘a’ is,

Z =∑M/∑W

= 1142.87/438.49

=2.66m

Eccentricity, e = Z- b/2

= 2.66 – 4.5/2

= 0.41m

but, (b/6) = 4.5/6

=0.75m

e < (b/6)

Maximum and minimum pressure at the base are given by,

σ = ∑W/b [1± 6e/b]

σ_{max} = 438.49/4.5 [1+ (6x0.41)/4.5]

= 150KN/m^2

σ_{min} = 438.49/4.5 [1- (6x0.41)/4.5]

= 45KN /m^2

The maximum intensity of pressure does not exceed the permissible value of 160KN/m^2

Step:3 Design of toe slab

W1 = B X DX unit weight of concrete

= 126.6x1

=126.6KN

W2 = B X DX unit weight of soil

= 0.5x1x23.4

=11.7KN

Find moment,

M1 =W1 X Length

= 126.6x0.5

=36.30KNm

M2 =W2 X length

=11.7x0.67

=7.84KNm

Total moment, M = M1+M2

= 63.30+7.84

=71.14KNm

Deduct for self weight of toe slab,

W3 =1X0.45X24

=10.8KN

Deduct for weight of soil above toe slab,

W4 = 0.75X1X16

=12KN

Moment deduction, Wd1 = W3 X length

= 10.8 x 0.5

=5.40KNm

Wd2 = W4 x length

= 12 x 0.5

= 6KNm

Total deduction, Md = Md1 + Md2

= 5.40+6.00

= 11.4 KNm

Maximum working moment in toe slab,

M = M-Md

= 71.14-11.4

= 59.74 KNm

Forced moment, Mu = 1.5 x M

= 1.5 X 59.74

=89.61 KNm

Effective depth of toe slab = 400mm

Reinforcement in toe slab,

Mu = (0.87 fy Ast d)[(1-Ast fy)/bd fck]

89.61x10^6 =(0.87x415Astx400)[(1-415Ast)/(1000x400x20)]

Ast = 644mm^2

Provide 12mm dia bars at 150mm c/c

Ast = 754mm^2

Distribution bars = 0.0012x1000x450

= 540mm^2

Provide 10mm dia bars at 280mm c/c on both the faces

Ast = 561mm^2

Step:4 Design of counter forts

Thickness provide at top = 220+220 = 440mm

Thickness of counterfort = 440mm

Max working moment in counter forts is

M = ka x Wh^3/6 x L

= 1/3 x (16x6.75^3)/6 x 3

=820.12KNm

Factored moment = Mu x 1.5

= 820.12x1.5

=1230KNm

Reinforcement at bottom of counterforts is computed using the relation,

(1230x10^6)=(0.87x 415Astx440)[(1-415Ast)/(440x4400x20)

Ast = 800mm^2

But, minimum reinforcement as per IS code, 456:2000,

Ast = 0.85 bd/fy

= (0.85x440x4400)/415

= 3965mm^2

Provide 5 bars of 32mm dia

Ast = 4020mm^2

Step:5 Curtailment of bars

h1 = depth at which 1 bar can be curtailed, then

(5-1)/5 = h1/6.75^2

h1 = 6m from top

h2 = depth at which 2 bars are curtailed,

(5-2)/5 = h2/6.75^2

h2 = 5.2m from top

h3 = depth at which 3 bars are curtailed,

(5-3)/5 = h3/6.75^2

h3 = 4.2m from top

Remaining two bars are taken right upto the top.

Step:6 Connection between counterforts and upright slab

Considering bottom 1m height of up right slab, pressure on this strip = $36 KN/m^2$

Total working load pressure transferred to the counterfort for

1m height = 36(3-0.44)

= 91.8 KN

Factored force = 1.5 x 91.8

=138 KN

Reinforcement required per metre height

= $138x10^3/(0.87x415)$

=$382mm^2$

Minimum reinforcement = $0.0012x10^3x440$

=$528mm^2$

Spacing of 10mm dia bars = (78.5x1000)/52.8

= 148.6mm

This amount of reinforcement is provide as two legged horizontal lines of 10mm dia at 280mm c/c.

Step:7 Connection between counterforts and heal slab

Working tension transferred in 1m width of the counterforts near heal end

a = 73.80(3-0.44)

= 189KN

Factored tension = 1.5x189

= 283.5KN

Reinforcement required in 1m width

= $(283.5x10^3)/(0.87x415)$

$= 785 mm^2/m$

Spacing of 10mm dia two legged links

$= (2 \times 78.5 \times 10^3)/785$

$= 200 mm$

Provide 10mm dia two legged links at 200mm c/c.