INDUSTRIAL DEFINED PROJECT

DESIGN OF REINFORCED EARTH RETAINING WALL

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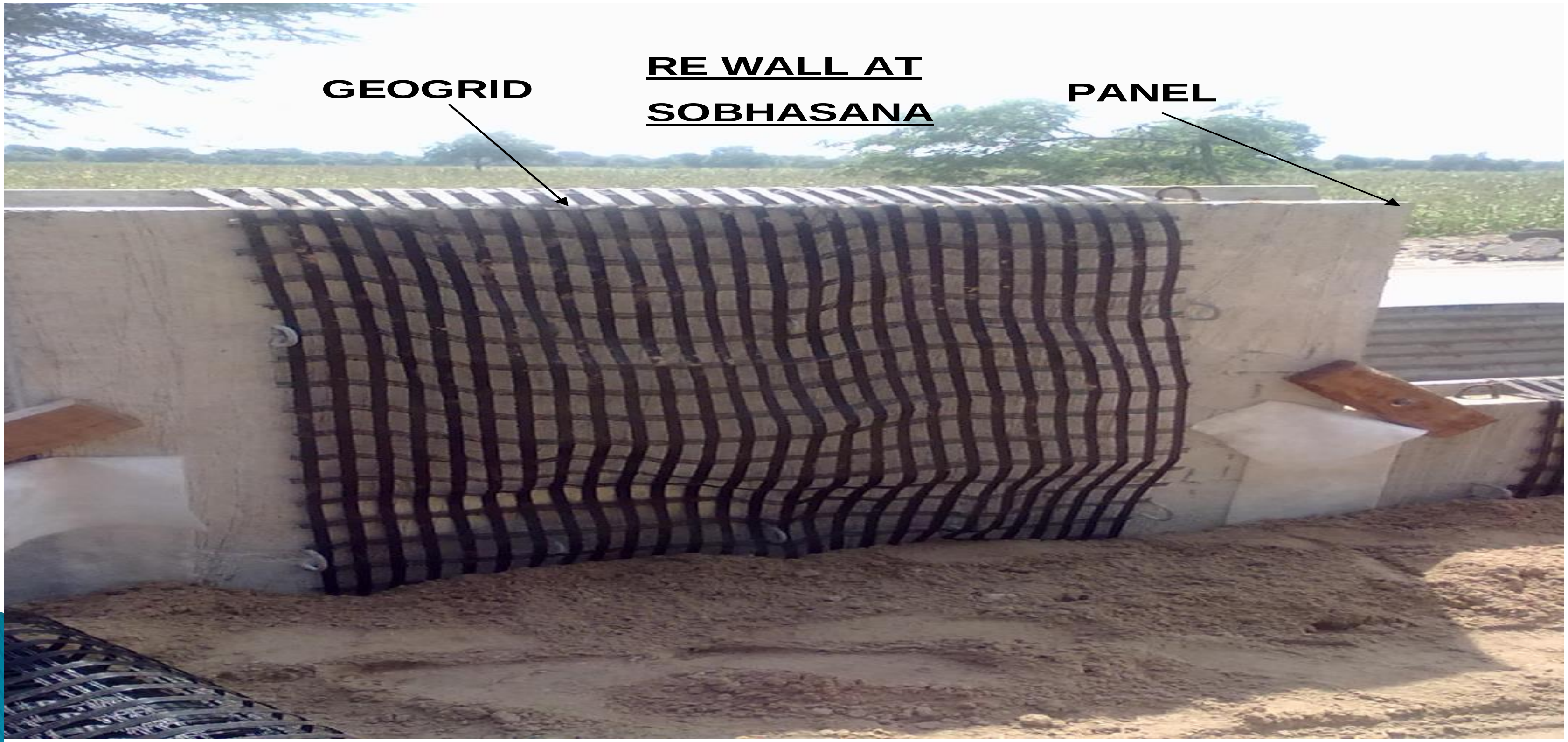
Introduction

- Reinforced Earth retaining walls are gravity structures consisting of alternating layers of granular back fill and reinforcing strips with a modular precast concrete facing.
- They are used extensively in transportation and other civil engineering applications. Because of its high load-carrying capacity
- Reinforced Earth retaining wall is ideal for very high or heavy-loaded retaining

- They are used extensively in highway projects for retaining walls and bridge abutments, in seawalls, dams, bulk storage facilities, and in supporting various types of railway transit.

COMPONENTS OF R.E WALL

i. GEOGRID
ii. PRECAST DISCRITE CONCRETE PANEL



GEOGRID

- These are made up of High Density Polyethylene (HDPE) and interconnected longitudinal and transverse Member. These are made from sheets of polymer by punching holes and stretching the sheets in one or two direction.

PRECAST DISCRETE CONCRETE PANNELS

- Discrete panels can be of different shapes – square, hexagonal, T, diamond, cruciform etc. and sizes – width and heights varying from 600 mm to 2000 mm and thickness varying from 140 mm to 220 mm.
- One of the simplest types of panels is the square panels. Standard size panels will have nominal dimensions of 1500mm x 1500mm (actual dimension of the panel will be 1480 x1480 mm; a 20 mm gap is maintained at vertical and horizontal joints; the nominal dimension of panel is taken as from the c/c distance between joints).

PRECAST DISCRETE CONCRETE PANNELS

FIELD INVESTIGATION:

- **Boring:**

The exploratory boreholes of 150mm diameter were drilled by Rotary Drilling by mud circulation. The depth of the test bore at the proposed location is as under:

Bore hole no.	Chainage (km)	RL of Ground (m)	Depth investigation (m)
BH- 1	15.500	49.700	30
BH- 2	(-)15.500	49.800	30
BH- 3	160.000	48.997	10
BH- 4	(-)125.000	51.384	10

Geotextile

- Geo textiles are made from polypropylene, polyester, polyethylene, polyamide (nylon), polyvinylidene chloride, and fiberglass. Polypropylene and polyester are the most used. Sewing thread for geotextiles is made from Kevlar1 or any of the above polymers.

SOIL BEARING CAPACITY

GEOTECHNICAL INVESTIGATION

- NO. OF BORE HOLE- 4 AT SOBHASAN CROSSING
- DEPTH OF BOREHOLES-10M IN APPROACHES AND 30M IN CENTRAL SPAN AREA
- COLLECTION OF UNDISTURBED AND DISTURBED SAMPLES AT DIFFERENT INTERVAL

FIELD INVESTIGATION

- DRILLING OF BORE HOLE
- COLLECTION OF SOIL SAMPLES
- CONDUCTING STANDARD PENETRATION TEST

BORING

- THE EXPLORATORY BOREHOLES OF 150MM DIAMETER WERE DRILLED BY ROTARY DRILLING

- DRILLING BY MUD CIRCULATION

DEPTH OF BORE TEST

BORE HALL NO.	CHAINAGE (KM)	RL OF GROUND (M)	DEPTH INVESTIGATION (M)
BH-1	15.500	49.700	30
BH-2	(-)15.500	49.800	30
BH-3	150.000	48.997	10
BH-4	(-)125.00	51.384	10

DESIGN OF PANEL

PROJECT IDENTIFICATION

- Title: 12.0 m High Reinforced Soil Wall
- Project Number: GWRL/12/N/RSW/9
- Client: M/S R&B Department Gov. of Gujarat.
- Designer: CS
- Station Number:
- **Description:**
- **Company's information**:
- Name: Garware-Wall Ropes Ltd.
- Street: Plot No. 11, Bock D1, MIDC
  Chinchwad
  Pune, MR 411019
- E-Mail: geo@garwareropes.com
- **Original file path and name**: E:\RS wall\Vijaypur\RS wall Designs for ROB at Vijapur 12.0.BEN

- **PROGRAM MODE**: ANALYSIS of a SIMPLE STRUCTURE using GEOGRID as reinforcingmaterial

Design Procedure

In general design involves the following steps:

Define wall geometry, loading, soil and geogrid properties

- Wall geometry: height, facing batter, slope of ground surface in front of wall, back slope at top of wall etc.
- External loads: Dead load surcharge, live load surcharge, strip loads etc.

- Soil properties: Effective cohesion, angle of shearing resistance and unit weight for reinforced fill, retained fill and foundation soil; pore pressure parameter; depth of ground water table; undrained shear strength of foundation soil (where short term undrained bearing capacity analysis is to be performed); consolidation parameters of foundation soil for settlement analysis.

- Geogrid characteristics: long-term design strength, coefficient of interaction

- Seismic parameters: peak ground acceleration

DESIGN OF FACING PANEL

- All facing panels are precast concrete panel having thickness of 150mm and dimensions as specified.
- Grade of concrete for precast panel shall be M35.
- Dimensional & textural details of ‘F’ and ‘F-spl’ panels are same
- Corner panel shall be casted at site as per required dimensions

SOIL PROPERTIES

	Unit Weight Ƴ, (kN/m³)	Cohesion, c (kN/m³)	Angle of friction, ϕ (Degrees)
Reinforced fill	20.0	0	30
Retained fill	20.0	0	30
Foundation fill	20.0	0	28

STRUCTURAL DESIGN OF SEGMENTAL PANELS

- Let depth from the top of wall to the center of panel is 9.10 m.
- Angle of shearing resistance = 32°
- Unit weight = 20 kN/m3
- Coefficient of active earth pressure = 0.307
- Dead load surcharge = 0.625 x 22 = 13.75 kPa
- Live load surcharge = 24.00 kPa
- Total surcharge = 13.75 + 24.00 = 37.75 kPa
- Earth pressure due to fill = 0.307 × 20 ×9.10
  = 55.874 kN/m
- Earth pressure due to surcharge = 0.307 × 37.75
  = 11.59 kN/m

- Total earth pressure per LM of panel = 67.46 kN/m
- Consider a panel of length 1250 mm and height of 600mm and geogrid spacing of 600 mm.
- It is considered as a simply supported beam with width of 1250 mm and effective span of 600 mm.
- Total earth pressure is converted into a uniformly distributed load (w)
- UDL acting on the beam = 67.46 1.25 = 84.33 kN/m
- Maximum bending moment (at center)

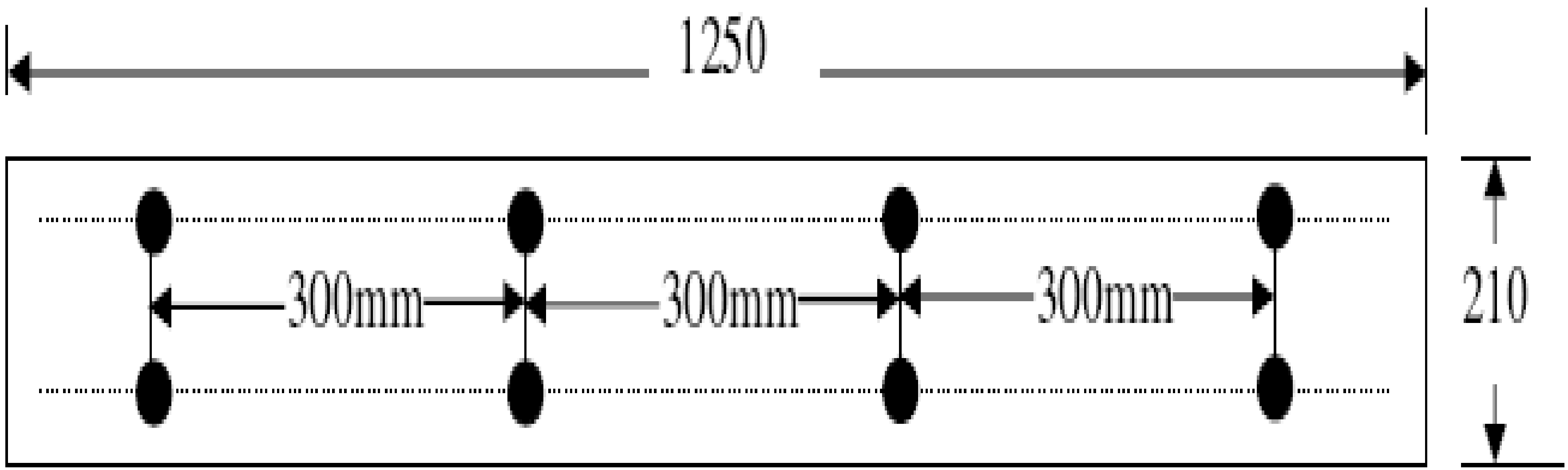
  $= 83.404 \times 0.62 / 8$

  = 3.795 kN-m

  = 3794807.81

PROPERTIES OF SECTION

- The panel thickness is 210 mm. There are 4 nos. of 8 mm dia. HYSD bars on each face (see
- figure below).



Here,

- grade of concrete = M35
- modular ratio = 8.11
- modulus of rupture (fcr) = 0.7 (35)0.5 = 4.14 MPa
- area of tension steel (Ast) = 4 × (p/4) 82 =201.06 mm2
- area of compression steel (Asc) = 4 × (p/4) × 82 = 201.06 mm2
- net thickness of section = 195 mm
- total area of section (Ag) = 1250 X 195 =243,750 mm2

CHECK FOR BENDING

- Cracking moment $=4.14 \times 7.826 \times 108/98.3$
  $= 32959959$ N-mm

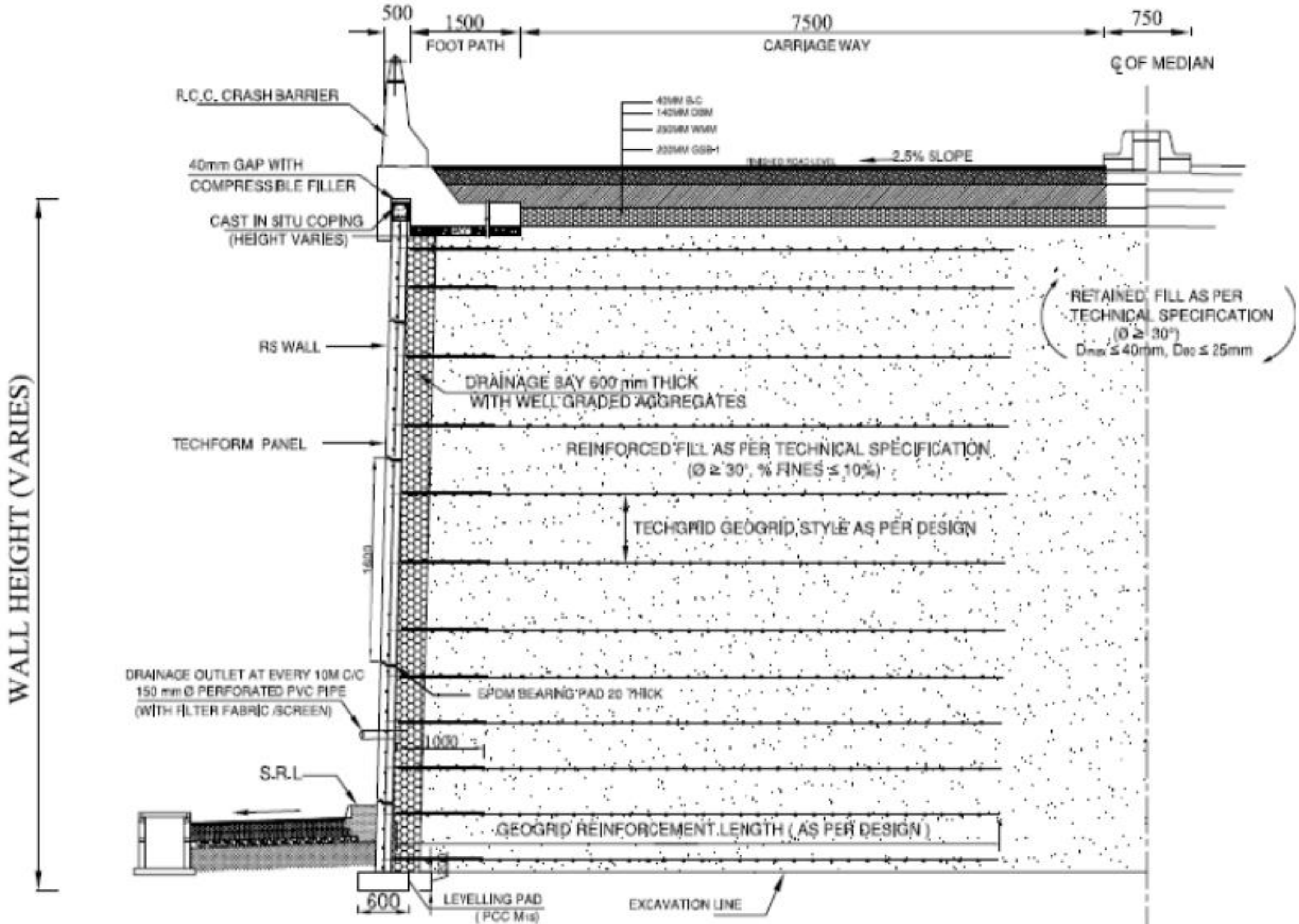
Here maximum bending moment (M)
$=3794807.81$ N-mm

- Cracking moment (Mcr) $= 32959959$ N-mm
  $M < Mcr$

CHECK FOR SHEAR

- Maximum shear force develops at the joints.
- Maximum shear force $= 84.33 \times 0.6/2$
  $= 25.3$ kN
- Nominal shear stress $= 25.3 \times 1000/1250 \times 195$
  $= 0.103$ MPa.
- Permissible shear stress in concrete = 0.2MPa (for M35 grade concrete)

An idealized cross-section of a reinforced soil wall is shown in figure



DATA FOR DESIGN OF WALL(federal highway administration

- Wall facing height (Hf) =12m
- Depth of top of wall below top of pavement =0.630 m
- Design height of wall(Hd)=12-0.355= 11.646 m ≈ 11.65m
- Min Length of reinforcement L =0.70 × Hf
  Where Hf = 12m
- Minimum Length of Reinforcement Required = 0.7 × 12 = 8.4m
- Trail Length of Reinforcement Provided = 8.5m

Surcharge load

- **Permanent surcharge(wsd)**
- The weight of pavement above the friction slab crash barrier (630mm, as per drawing
provided) is applied as a surcharge. Unit weight isassumed to be 22 KN/m3
- Permanent surcharge load (w_{sd})$=0.630 \times 22$
$= 13.86$ KPa.
- **Live load surcharge due to traffic load (wsl)**
- As per IRC guidelines, live load due to traffic is considered equivalent to 24 KPa.
- Surcharge load due to traffic (wsl) = 24 KPa

REINFORCED SOIL & RETAINED SOIL

- Unit weight, γ= 20.0 kN/m^3
- Design value of internal angle of friction,ϕ = 30.0 °
- **FOUNDATION SOIL** (Considered as an equivalent uniform soil)
- Equivalent unit weight, γ equiv. = 19.0 KN/m ^{3}
- Equivalent internal angle of friction, ϕ equiv.

  = 28.0 °
- Equivalent cohesion, c equiv. = 0.0 KPa
- Water table does not affect bearing capacity

Seismic Design Parameters

- Seismic zone = III As per IS 1893 (Part 1) : 2002., Pg-35&36
- Zone factor (Z) = 0.16 As per IS 1893 (Part 1) : 2002. Pg-35&36
- Importance factor (I) = 1.5
- Response reduction factor (R)= 2.5
- Average response acceleration coefficient (Sa/g) =2.5
- Therefore peak ground acceleration= 0.12

INITIAL DIMENSIONS OF THE STRUCTURE

- **Reinforcement Length**
- $0.7 \times HF$ (where HF is the Facing height,)

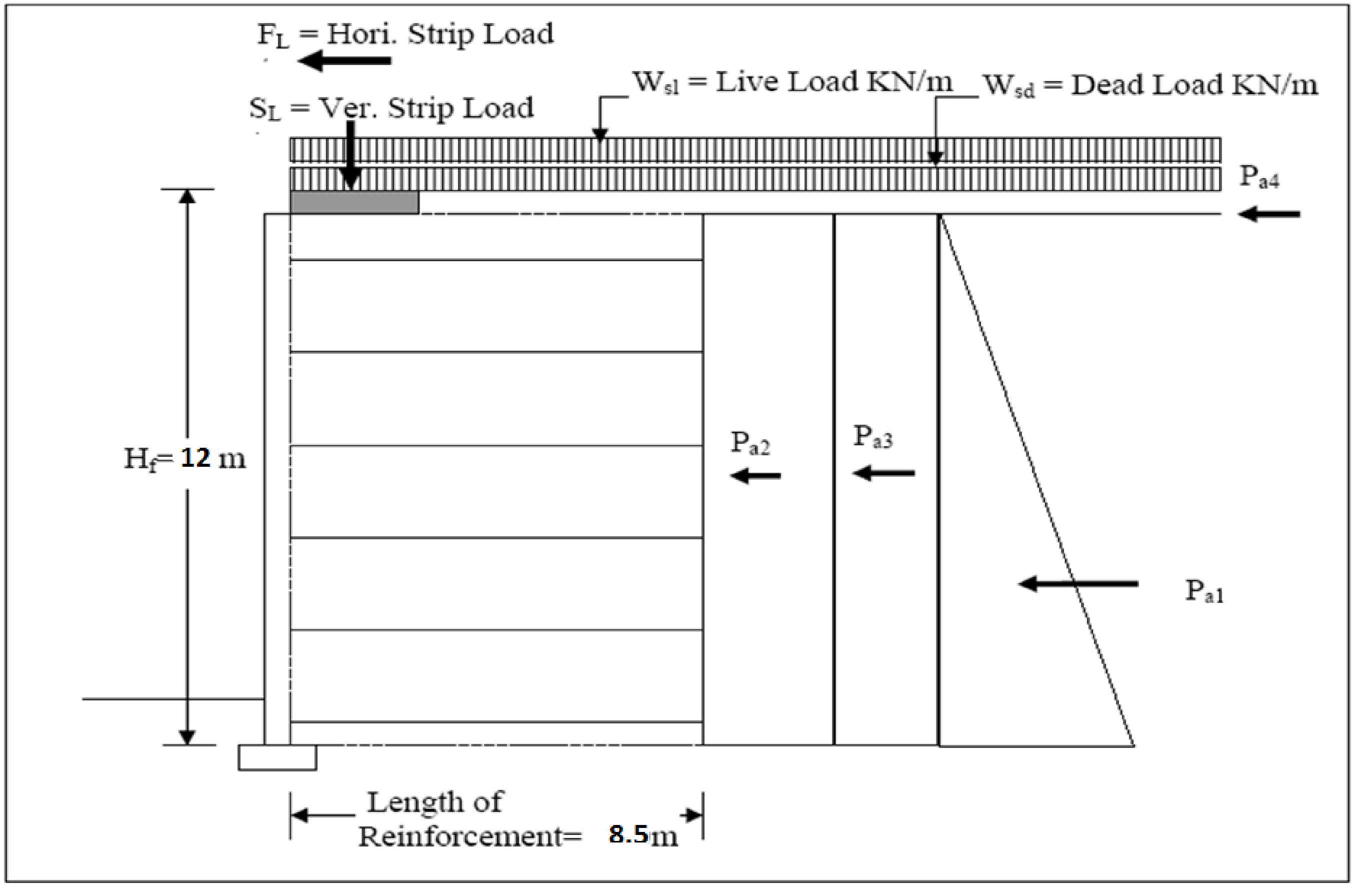
  2.50m (except for low height walls, i.e. $HF < 1.5m$)
- Minimum length of reinforcement

  $= 0.7 \times 12 = 8.4m$
- Trail Length of Reinforcement Provided= 8.5m

Minimum depth of embedment (Dm)

- As per FHWA, depth of embedment is from GL to bottom of facing and should be greater of the following
- 0.45 m
- HF /20 = 12 / 20 = 0.6 m
- As per MORTH specifications depth to bottom of leveling pad ≥ 1.0m,

CHECK FOR STABILITY – STATIC LOADING(EXTERNAL STABILITY)



Coefficient of Active Earth Pressure for External Stability (Ka2)

- For external stability, FHWA recommends angle of wall friction $\delta = 0$. Hence Rankine's theory is used
- $Ka2 = (1 - \sin\phi) / (1 + \sin\phi)$
  $= 0.333$

- Pa1 = Horizontal force due to active earth pressure exerted by the retained fill on the reinforced soil block

- $Pa1 = 0.5\ Ka2\ (\gamma 2) \times Hd^2$
- Where $\gamma 2$ is unit weight of earth fill, Hd is design height of the wall,
  $= 0.5 \times 0.333 \times 20 \times (11.65)2 = 451.95$ Kpa

- Pa2 = Horizontal force due to active earth pressure exerted by dead load surcharge on the reinforced soil block
- Pa2= Ka2 (wsd) Hd
- Where is wsd is Dead load surcharge, Hd is design height of the wall, Ka2 is coefficient of active earth pressure due to fill

  = 0.333 x 13.86 x 11.65

  = 53.76 KPa

- Pa3 = Horizontal force due to active earth pressure exerted by live load surcharge on the reinforced soil block
- Pa3 = Ka2 (wsl) Hd
- Wsl= Live load surcharge, Hd is design height of the wall; Ka2 is coefficient of active earth pressure due to fill.

= 0.333 x 24 x 11.65

= 93.10 KPa

- Pa4 = 10 KPa
- Total horizontal force (Rh)

= Pa1 + Pa2 + Pa3+ Pa4

= 451.95+53.76+93.10+10.0

= 608.81 KPa

Check for Sliding along the Base

- Vertical force due to weight of fill

  $V1 = L \times Hd \times \gamma = 8.5 \times 11.65 \times 20 = 1980.5$ KN/m
- Vertical force due to surcharge

  $V2 = L \times (wsd) = 8.5 \times 13.86 = 117.81$ KN/m
- Vertical force due to strip load

  $V3 = SL = 15$ KN/m
- Rv = Vertical force due to weight fill+ vertical force due to surcharge + vertical force due to strip load

  $= 1980.5 + 117.81 + 15 = 2113.31$ KN/m
- Partial Factor of Safety against Sliding at Base

  $= (\tan\phi') \times Rv) / Rh$
- Φ' = (angle of shearing resistance of reinforced fill)

  $= (\tan 30 \times 2113.31)/608.81$

  $= 2.0$ (≥ 1.5, OK),

Check for Bearing & Tilt
Calculation of Bearing Pressure

- $(Md) = (Pa1 \times Hd/3) + (Pa2 \times Hd/2) + (Pa3 \times Hd/2) + (Pa4 \times Hd)$
- $Md = 451.95x\ (11.65/3) + 53.76\ x\ (11.65/2) + 93.10\ x\ (11.65/2) + 10x\ (11.65)$

  $= 2727.02$ KN-m/m
- Eccentricity $(e) = Md\ /Rv$

  $= 27272.02\ /2113.31 = 1.29$
- Effective width of foundation $(B) = L\text{-}2e = 8.5 - 2x1.29 = 5.91m$
- Factored bearing pressure $(qr) = Rv/\ B = 2113.31/5.91 = 357.02$ KPa

Check for Overturning

- Eccentricity (e) must be ≤ L/6,
- Here L/6 = 8.5/6 = 1.41 m
- **Load Combination 1**
- Eccentricity (e) = Md /Rv

  = 2727.02 /2113.31

  = 1.29
- **(Hence OK)**

Calculation of Partial factor of safety

- Partial factor of safety available (fms) = qult / (qr – γ Dm)
- Where (fms) is partial material factor applied to soil parameter, qult is ultimate bearing
- capacity of foundation soil, qr = Factored bearing pressure, γ = unit weight of foundation
- soil, Dm = depth of foundation
- fms = 1522.12 /(357.02–19 x 0.8) = 4.45 (>2.50, OK)

EXTERNAL STABILITY

- Ah= Z I Sa/2RG

Here,

- Seismic zone = III
- Zone factor (Z) = 0.16
- Importance factor (I) = 1.5
- Response reduction factor (R) = 2.5 (Assumed considering ductile Behaviors of reinforced soil structure)
- Average response accleration coefficient (Sa/g) = 2.5
- $Ah = 0.16 \times 1.5 \times 2.5 / (2 \times 2.50) = 0.12$

Check for Sliding Along Base

- Total horizontal resultant force = 515.71 KN
- Force resisting sliding = 2113.31 × tan 30

  = 1220.12 KN
- Available factor of safety against sliding

 = 1220.12 / 764.26

= 1.59

- Minimum required factor of safety against sliding = 1.125

Hence **SAFE**

- Total vertical force = 2113.31 KN
- Eccentricity = 3738.64 / 2113.31=1.76 m
- Allowable eccentricity (for seismic loading case) = L/3 = 8.5 / 3 = 2.83
- Since, e < L/3

Hence SAFE

Conclusion

- The global stability analysis is carried out by using Reinforced slope Stability Analysis for a height of 12m.
- The stability analysis is carried out by using rotational (Circular arc; Bishop) Stability analysis and the minimum factor of safety of all the critical slip failures analyzed is 1.31.
- The RS Wall structure is located in seismic zone –III so the Horizontal peak ground acceleration coefficient is considered in the analysis as per IRC 6-2000. The final factor of safety achieved is with in the required safety factor and the system is safe against global stability.
- Partial factor available

  =1568.87 / 84.71

  = 18.52 **(>1.125, Hence OK)**

Reference

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- FHWA NHI-00-043

PHOTO GALLERY


HB-26-7-12

THANK YOU