Design of Reinforced Soil Retaining Wall with RCC Facia Panels in Pursuance with IRC and BS Code

Girish Sawai[1], Sanket Raju Dhote[2]

[1]*Head of Dept. of Civil engineering, VM Institute of Engineering and Technology, Nagpur, Maharashtra, India*

[2]*Research Scholar, Dept. of Civil engineering, VM Institute of Engineering and Technology, Nagpur, Maharashtra, India*

Abstract - Reinforced earth may be a material shaped by combining earth and reinforcement material. The reinforced soil is obtained by putting extensile or non-extensile materials like gold strips or compound reinforcement at intervals the soil to get the requisite properties. The reinforcement allows the soil mass to resist tension during a manner that the planet alone couldn't. The supply of this resistance to tension is that the internal friction of soil, as a result of the stresses that created at intervals the mass transferred from soil to the reinforcement strips by friction. Reinforcement of soil is practiced to enhance the mechanical properties of the soil being reinforced by the inclusion of structural components. The reinforcement improves the earth by increasing the bearing capability of the soil. It additionally reduces the physical change behavior of the soil. reinforced earth isn't complicated to realize. The parts of reinforced earth are soil, skin and reinforcing material. The reinforcing material could embrace steel, concrete, glass, planks etc. reinforced earth has such a large amount of applications in construction work. a number of the applications embrace its use in stabilization of soil, construction of retentive walls, bridge abutments for highways, industrial and mining structures.

***Key Words*: RE –Reinforced Earth, RS – Reinforced Soil.**

1.INTRODUCTION

There are tremendous increase in the construction of highway and bridges where the height of the approaches are up to certain limits where use of the retaining walls or other rigid retaining structures are uneconomical and most importantly not safe as in view of stability and safety consideration of the structures. So, nowadays the reinforced soil retaining walls are being used by the engineers. These retaining structures are used for maintaining the ground surface at different elevations on either side of it. Reinforced soil retaining wall have gained substantial acceptance as an alternative to conventional masonry and reinforced concrete cantilever retaining wall structures. These walls can be construct for a long height where conventional retaining walls are not suitable in terms of stability, safety, cost and time required for construction. Seismic loading, differential have and settlement requirements make rigid masonry and concrete cantilever walls very difficult to achieve the desired safety factor. Whereas, reinforced soil retaining walls when subjected to seismic loads and differential earth movement has shown exceptional performance due to its flexibility and inherent energy absorption capacity. Even reinforced soil retaining wall is being used widely in India mostly for highways and bridges construction for last more than 20 years.

Soil is a natural material and its properties are varies with types of soil. Which is mainly depends on its soil parameters i.e. cohesion c and angle of internal friction. During free flow of dry soil, it always makes a slope. It is not in straight vertical face. But in many cases, it is necessary to retain the soil in straight vertical face, like both side of highway, for bridge abutment, sea walls, submerge walls, wing walls and also for slope stabilization. To retain the soil in vertical face, it is necessary to give a vertical support to the soil and that support isgiven by Earth Retaining Structure. There are a significant number of geosynthetics types and geosynthetic applications in geotechnical and environmental engineering. Common types of geosynthetic used for soil reinforcement include geotextile (particular oven geotextiles), geogrids and geocells. The mix of improved materials and design methods has made possible engineers to face challenges and to build structures under conditions that would be unthinkable in the past.

The development in the theory, design methods and experience of the behavior of these walls gained in laboratories, full scale tests and field applications in India and abroad have brought knowledge from development stage to widespread applications in hands of practicing engineers.

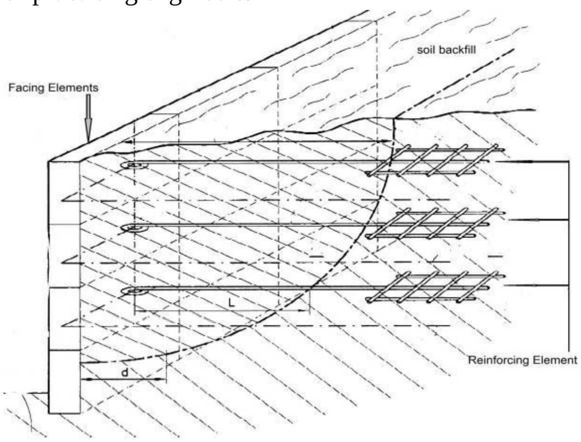

Fig. 1.1: Basic arrangement of reinforced soil wall with reinforcing element

Fig. 1.2: Reinforced soil retaining wall constructed for highway structures

2. Elements of Structure

Reinforced soil retaining wall of height 8.00m, 10.00m and 12.00m are considered for the design subjected to earthquake loading of zone II has been considered. MS excel programs for the analysis and designs are used. RCC precast panels of size 1600mm x 1600mm are used of thickness 180mm to retain the backfill soil. Extensible soil reinforcement is assumed for design of wall. Hence in this chapter we will discuss the elements of wall, basic assumption of geometry and forces to be applied on wall and design principles.

Fig. 3.1 shows the elements of a reinforced soil retaining wall. In addition following section describes the elements.

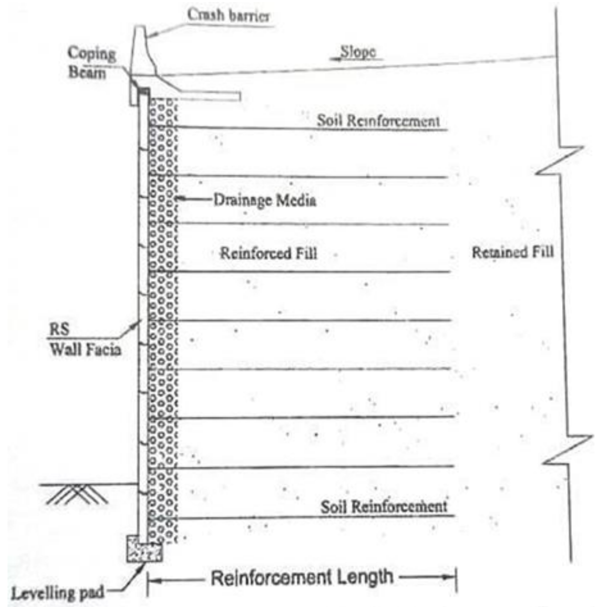

Fig. 3.1: Typical cross section of reinforced soil wall

Retained soil is the layers of earth at a certain height. The main purpose of reinforced soil retraining wall is to hold / retain this soil layer in its position. The retained soil exerts the lateral forces on the wall. The retained soil have angle of internal friction and should be permeable.

Reinforced fill is layers of soil filling which is placed between retained soil and facia of the wall. The reinforced fill of high angle of internal friction must be used. Generally flyash confirming to IRC:SP-58 is used for design and construction of the walls.

The spacing is provided to prevent the spilling/falling over of fill and also to provide firm anchorage to the reinforcements. Facing should be tough and robust. Facing also provided architectural finishes to the structure.

Facing system shall be one of the following (Refer MORT&H specification – 2013)

- Precast reinforced concrete panels
- Precast concrete blocks and precast concrete hollow blocks
- Gabion facing
- Wrap around facing using geosynthetics
- Metallic facing

Other proprietary and proven system Traffic barriers are constructed over the front faces of reinforced soil wall. Commonly a friction slab is used to transfer the lateral loads sue to the impact of vehicles on barriers. Typically a friction slab varies from 1500 to 2500 mm width and 250 mm thick depending on the types of the crash barrier used. Fig. 3.2 shows a typical section of traffic barrier over a reinforced soil wall.

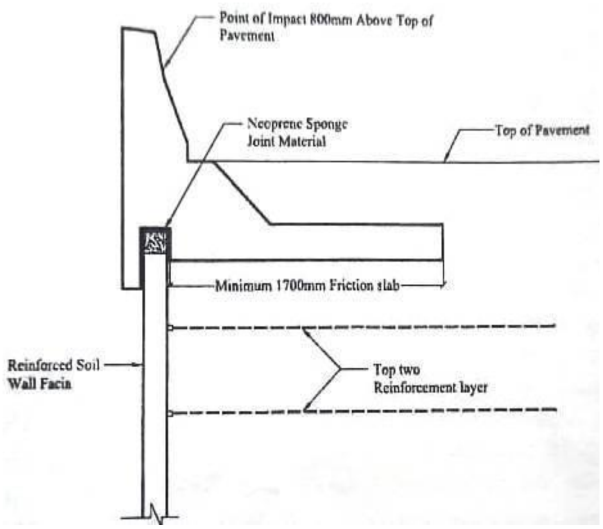

Fig. 3.2: Typical section of traffic barrier

Different types of reinforcement used in reinforced soil earth walls are:-

- Inextensible Reinforcement – Metallic elements like bars, strips, plates, metallic reinforcement in form of mesh
- Extensible Reinforcement – Polymeric elements like strips, grids, rods, mesh etc.

3.Basic Design Parameters :

Basic design assumptions are given in table 3.1 as shown below:

1.	RCC Facia Panel	Size of facia panel – 1600(Length) x 1600(Width) x 180(Thick.) mm Grade of Concrete- M35 Grade of steel- Fe500
2.	Reinforced Soil Retaining Wall	Height of wall – 8.00m, 10,00m, 12,00m Length of reinforcement – 6,50m, 8,50m, 9,50mrespectively Embedment depth in soil – 1.00m Batter of wall – 90 Degree
3.	Backfill Soil and Reinforced Fill Property	Unit weight of soil – 18 kN/m3 Angle of internal friction – 32 Degree
4.	Foundation SoilProperty	Unit weight of soil – 18 kN/m3 Angle of internal friction of soil – 30 DegreeCohesion - 0
5.	Seismic Data	Seismic zone – II Ground peak co-efficient – 0.10 (As per IS 1893:2016) Max. hor. Acceleration coefficient – 0.14 (As per IRC SP 102:2014, Eq.A3.1)
6.	Reinforcement Type	Extensible Reinforcement
7.	Strip Details	Width of strip – 2.00m Distance from Wall Edge to Centre of Strip Load – 1.00m

Partial load factors (as per IRC SP 102:2014, Table 3) to be applied for design of thereinforced soil wall is given in table 3.2 below:

Table 3.2: Partial load factors and loads combinations for extensible reinforcement

Partial factors		ULS		
Soil materials factors				
To be applied tanØ'p	(f_{ms})	1.0		
To be applied C'	(f_{ms})	1.6		
To be applied C_u	(f_{ms})	1.0		
Soil/rinforcement interaction factors				
Sliding across surface of reinforcement	(f_s)	1.3		
Pullout resistance of reinforcement	(f_p)	1.3		
Partial factors of safety				
Foundation bearing capacity to be applied to q_{ult}	(f_{ms})	1.4		
Sliding at base of the structure or any horizontal surface where there is soil-soil contact	(f_s)	1.2		
Partial load factors for load combination associated with walls				
Effects		Combination		
		A	B	C
Mass of reinforced soil body	(f_{fs})	1.5	1	1
Mass of backfill on top of reinforced soil wall	(f_{fs})	1.5	1	1
Earth pressure behind the structure	(f_{fs})	1.5	1.5	1
Traffic load on reinforced soil block	(f_{fs})	1.5	1.5	0
Behind reinforced soil block	(f_q)	1.5	1.5	0
Earthquake load		-	-	1

Rankine's coefficient of earth pressure is considered to find the coefficient of active earthpressure.

- For reinforced fill:

$Ka = (1 – \sin \Phi) / (1 + \sin \Phi) = 0.307$

- For backfill soil:

$Ka = (1 – \sin \Phi) / (1 + \sin \Phi) = 0.307$

(Note :- Refer table 3.1 for value of Φ)

The basic loads to be applied for design of reinforced soil walls are as follows:

- Self weight of structure: - Self weight of structure including weight of reinforcement andreinforced fill is considered. The weight of the facia panels is not considered.
- Strip load :- Strip load due to weight of crash barrier, friction slab and road crust is considered as **40.00 kN/m^2**.
- Live load :- Live load on the reinforced soil wall as per IRC:78-2014 provision is considered as **24.00 kN/m^2**.
- Earth pressure behind facia panel :- Active earth pressure for overall height of wall is considered. Earth pressure exert a lateral force on wall.
- Surcharge load :- When the live load is applied above the wall it exert a lateral force at some intensity in lateral direction which is term as surcharge load.
- Earthquake load :- When the earthquake become active it cause the vibration among the structural elements and also retained soil which exert an certain amount of forces on wall for which the reinforced soil wall is also to be check and designed. The earth load is calculated in terms of horizontal inertia force (P_{IR}) and seismic thrust (P_{AE}) which are calculated as per the IRC: SP: 102-2014 guidelines.

The various checks for safety of the structure in terms of stability and safety are givenbelow:

External Stability:

The external stability of wall is consist of safety of the structure in terms of sliding. overturning, limiting eccentricity and bearing pressure at the base of wall.

- Bearing and tilt failure :- Bearing Pressure exerted by reinforced soil mass on the foundation strata should be such that there is sufficient margin against failure. The design should achieve a factor of safety of at least 1.4 in the limit state, after consideringeccentricity and resultant pressure. The eccentricity should be less than L/6 and L/3 for static load cases and seismic load cases respectively to avoid development of tension. Passive pressure in front of wall should not be considered. Minimum depth of embedment should be 600 mm or H/20 whichever is more.
- Sliding and overturning :- Factor of safety toward sliding and overturning due to lateral pressure developed should adequate. Factor of safety of at least 1.2 for static load cases and for seismic cases 75% of factor of safety given for static load cases in the limit state should be adopted.

Internal Stability:

- Rupture of reinforcement :- The rupture of reinforcement due to the tension force acting on the wall and reinforcement should satisfy the rupture failure criteria. The rupture of reinforcement for static load cases can be calculated by two methods, i.e. "Tie Back Wedge Method" and "Coherent Gravity Method". As per IRC: SP: 102-2014 and BS 8006-1:2010 guidelines, tie back wedge method is suitable for extensible reinforcement and coherent gravity method is suitable for inextensible reinforcement. As the present work is using the extensible reinforcement as soil reinforcement, "Tie Back Wedge Method" is used in the design of reinforcement soil retaining wall. For seismic cases clauses of IRC:SP:102-2014, annexure A3, clause A3.1.2 and A3.1.4 is used.
- Pull-out failure of reinforcement :- The pull out is adherence property check for the reinforcement. For static load cases IRC: SP:102-2014, annexure A2 is being used. The pull out resistant factor for this case is 1.3 as per load factor table. For seismic cases clauses of IRC:SP:102-2014, annexure A3, clause A3.1.3 is used where factor of safety against pull out should be ≥ 1.5.
- If the criteria of rupture failure is not satisfied for all reinforcement layers, the reinforcement length has to be increased and/or reinforcement with greater pullout resistance per unit width must be used or vertical spacing must be reduce to reduce maximum tension forces occurring on reinforcement.

4. RESULT

The computation of results of design of reinforced soil retaining wall is presented below:

Table 4.1: Sliding and resisting forces for load case A

Sr. No.	Forces (Case A)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Sliding force (kN/m)	424.75	630.49	876.06
2	Resisting force (kN/m)	1098.52	1700.27	2212.04

Table 4.2: Sliding and resisting forces for load case B

Sr. No.	Forces (Case B)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Sliding force (kN/m)	424.75	630.49	876.06
2	Resisting force (kN/m)	781.09	1197.25	1545.93

Table 4.3: Sliding and resisting forces for load case C

Sr. No.	Forces (Case C)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Sliding force (kN/m)	365.30	554.20	782.12
2	Resisting force (kN/m)	634.87	1006.04	1332.22

Table 4.4: Overturning and resisting moments for load case A

Sr. No.	Moments (Case A)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Overturning moment (kN.m/m)	1061.89	1935.73	3185.66
2	Resisting moment (kN.m/m)	5443.50	11174.25	16365.00
3	Design factor of safety	5.13	5.77	5.14
4	Required factor of safety	1.20		

Table 4.5: Overturning and resisting moments for load case B

Sr. No.	Moments (Case B)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Overturning moment (kN.m/m)	1061.89	1935.73	3185.66
2	Resisting moment (kN.m/m)	3882.50	7883.00	11451.50
3	Design factor of safety	3.66	4.07	3.60
4	Required factor of safety	1.20		

Table 4.6: Overturning and resisting moments for load case C

Sr. No.	Moments (Case C)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Overturning moment (kN.m/m)	737.69	1420.69	2431.80
2	Resisting moment (kN.m/m)	3122.00	6582.50	9827.00
3	Design factor of safety	4.23	4.63	4.04
4	Required factor of safety	0.90		

Table 4.7: Minimum eccentricity for load case A

Sr. No.	Min. Eccentricity / max. bearingpressure (Case A)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Computed eccentricity (m)	0.76	0.85	1.03
2	Required eccentricity (m)	1.08	1.42	1.58
3	Bearing pressure (kN/m^2)	352.67	400.70	475.43

Table 4.8: Minimum eccentricity for load case B

Sr. No.	Min. Eccentricity / max. bearing pressure (Case B)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Computed eccentricity (m)	0.99	1.15	1.41
2	Required eccentricity (m)	1.08	1.42	1.58
3	Bearing pressure (kN/m^2)	276.98	308.63	370.24

Table 4.9: Minimum eccentricity for load case C

Sr. No.	Min. Eccentricity / max. bearing pressure (Case C)	Height of wall		
		8.00 m	10.00 m	12.00 m
1	Computed eccentricity (m)	0.90	1.04	1.28
2	Required eccentricity (m)	2.17	2.83	3.17
3	Bearing pressure (kN/m^2)	216.47	251.08	307.32

3. CONCLUSION

The conclusion base on analysis and design of reinforced soil wall for 8.00m, 10.00m and 12.00m is presented in this chapter. The conclusion base on the work done and observation through field experience are presented here.

The wall failure can occurs mainly on of the following ways,

A) Sliding of wall from the base
B) Sliding of soil in reinforcement
C) Rupture of reinforcement due to tension forces
D) Pull out failure of reinforcement

from the paper it is concluded that reinforced soil retaining wall have better stability and can be constructed for a large height of wall as compared to the rigid retaining walls. It has ability to perform better in seismic condition as it is flexible in nature. Increase in length of the reinforcement improves the stability of the wall by increasing the resisting forces acting on wall. With increase in reinforcement length the base pressure is also distributed over a large area. Rupture and pull out failure of reinforcement cause due to forces acting on wall and the friction between the soil and reinforcement layers which generate tension forces.

If a reinforcement layer fails in rupture then reinforcement of higher tension carrying capacity must be used. If the criteria of pull out failure are not satisfied then length of reinforcement has to be increased and/or reinforcement with a greater pull out resistance per unit width must be used or vertical spacing of reinforcement must be reduce which would reduce the tension forces acting on wall.

The internal friction angle of soil is also most important parameter as the basic principle of mechanically stabilization of earth depends on it. If soil is weak choose backfill soil of high internal angle of friction. Strata of foundation soil do not affect that much on safety of reinforced soil wall in terms of bearing pressure. As reinforced soil wall has larger area for the distribution of pressure coming from wall to transfer to the base. If soil has low bearing capacity then, length of reinforcement needs to be increase which will also increase contact area of pressure with the foundation soil or other soil improvement techniques should be adopted.

Facia panels play important role in stability of wall. It perform action of retaining the soil in reinforcement layers, used as anchoring media for reinforcement layers and resist the earth pressure and tension forces coming on it. So, facia panels of higher grade of concrete must be used and must be design to resist the earth pressure, surcharge loads and tension forces coming from reinforcement layers. Generally IRC and MORT&H guidelines suggested to use minimum M35 grade of concrete with minimum 140 mm thickness as per IRC: SP:102-2014 and 180 mm thick as per MORT&H 2013 guideline. Design of precast RCC facia panels do not required heavy reinforcement as per design.

REFERENCE

[1] Armin W. Stuedlein, Michael Bailey, Doug Lindquist, John Sankey and William J.Neely, "Design and Performance of a 46-m-High MSE Wall" (2010).

[2] Mahi Sharma and Mr. H. S. Goliya, "Design and Economic analysis of reinforced earth wall" (2014).

[3] Siddharth Mehta and Siddharth Shah, "Seismic analysis of Reinforced Earth Wall: AReview" (2015).

[4] Haresh D. Golakiya, Mittal D. Lad, "Design and Behavior of Mechanically StabilizedEarth Wall" (2015).

[5] Okechukwu, Okeke, Akaolisa, Jack, L. And Akinola, " Reinforced Earth: Principlesand application in Engineering Construction" (2016).

[6] Dr. Orabi Al Rawi, Maale Al Abade, "Design of Geo-Syntetic Retaining Walls as an Alternative to the Reinforced Concrete Walls in Jordan" (2017).

[7] Akhila Palat and B.Umashankar, "Analysis of Back-to-Back Mechanically Stabilized Earth Walls" (2017).

[8] Mukesh M, Murali M, Aravind B, Paankumar

R, Mogan Raj. M, "Behaviour ofReinforced Soil using Geogrid" (2017).
[9] Nida Nasir, S.N. Sachdeva, "A study on Design Aspect of Reinforced Earth Wall" (2019).
[10] P.Shivananda and Bincy. V. K, "Experimental Behavior of Model MSE Wall" (2019).
[11] R. Sathish Kumar, "Construction of Segmental Block Reinforced Earhen Wall UsingGeogrids"
[12] Chart Solution for Analysis of Earth Slopes", by John h. Hunter, Robert L. Schuster.
[13] "BS 8006-1985, "Code of practice for strengthened/reinforced soils and other fills".
[14] Ministry of Road Transport & Highway (Specification of Road & Bridges Work) 5th Revision 2013, Section 3100.
[15] IRC SP -102-2014, "Guidelines for Design and Construction of Reinforced Soil Walls".
[16] IRC 78-2014, "For Road Bridges (Section - Vii) Foundation And Substructure (Revised Edition)".
[17] IS: 1893 (Part 1) – 2016; "Criteria for Earthquake Resistant Design of Structures – general provisions and buildings"; Bureau of Indian Standards, New Delhi.
[18] IRC 75-2015, "Guidelines for design of High Embankment".
[19] IRC 6-2017, "Standard Specification and Code of Practice For Road Bridges, Section : II".