

A STUDY ON DESIGN ASPECTS OF REINFORCED EARTH WALL

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Abstract: *The paper deals with the design of Reinforced Earth wall with Geogrid as reinforcing material at five different heights. The design of reinforced earth wall is based on lateral earth pressure approach. In this design active earth pressure has been calculated and the checks for internal and external stability, overturning, sliding, pullout, shear and connection strength also has been done. The height of the wall is taken up to maximum 10m. The comparison is done between the designs and the impact of change of height. The calculation for the design is done on Microsoft Excel to bring out the better alternative among them. The paper also carries out the importance of Reinforced Earth Wall in the transformation of modern construction.*

KEYWORDS: Reinforced Earth wall; Geogrid; stability checks; overturning; sliding;

I.INTRODUCTION

Reinforced Earth is a composite material formed by cohesionless soil and flexible metallic reinforcing strips reinforcements. The strength and stability are obtained from the frictional interaction between the granular backfill material and the reinforcements that creates a unique composite construction material. The visible part of the structure is structurally the least significant. The facing panels are made of precast concrete. Reinforced Earth walls are an economical way to meet every-day earth retention needs for highway and bridge grade separations, railroads and mass transit systems, waterfronts, airports, loading docks, industrial facilities and commercial and residential developments. They are also used in response to difficult design conditions such as very high structures, restricted space, where obstructions within the MSE soil mass are present and poor foundation soils. The effect of reinforcement length, number of layers of reinforcement, distribution of reinforcement and wall height, etc. vary the forces developed in the reinforcement. The forces developed are largely independent of reinforcement length for L/H ratio equal to or greater than 0.7.

Before the invention of the Reinforced Earth wall, the retaining walls were used as the supporting member. Further, geogrids or geotextiles came in to practice for development of reinforced earthen concept [8]. Geosynthetics offer a variable and often economical alternative to metallic reinforcements for both permanent and temporary walls especially under certain environmental conditions[9]. The reinforced earth retaining walls are very cost effective compared to Cantilever Retaining Walls. Furthermore, these systems are more flexible than the conventional Retaining walls. In Reinforced Earth technology, only friction is taken advantage by providing specially prepared high adherence galvanized steel strips as reinforcement. Both these processes use precast different shaped panels as facial elements.

The Reinforced Earth technology serve the purposes more effectively as high adherence galvanized steel and mechanically stabilized earth is used in it but now a days geogrid, geotextiles and geosynthetics are more popular in use. Hence, Reinforced Earth wall is one of the examples of advanced structures in construction. The complete structure of Reinforced Earth Walls includes number of components which are shown in fig 1.

Components of reinforced soil retaining walls

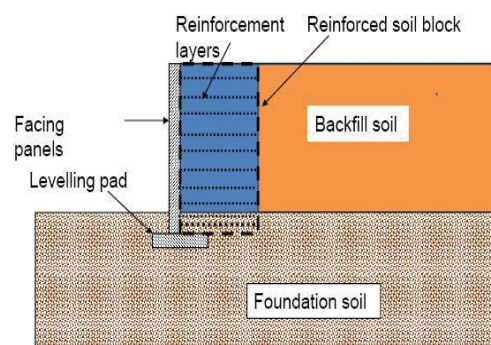


Figure1.Diagram showing components of Reinforced Earth wall

II. DATA FOR ANALYSIS

The design is done on the basis of guidelines given in the IRC:SP:102-2014[3]. The wall height varies from 3 to 10 m. A wide configuration was used so that the failure plane could pass behind the reinforcement. The reinforcement length to wall height ratio (L/H) was 0.7, which is typical for Mechanically Stabilized Earth (MSE) walls[7]. The backfill and retained soil were assumed to be the same, to be cohesionless, and to have a mean friction angle ranging from 25° to 40° and a mean unit weight ranging from 16 to 21 kN/m³. A strong cohesionless soil having internal friction angle of 30° and unit weight of 18.5 kN/m³ was assumed to be beneath the wall so that failure would not occur through the foundation. Strip load due to crash barrier is taken as 15.45 kPa and live load is considered as per provisions of IRC:78-2014(23 kPa). Water table is considered below the influence zone and General Shear Failure is also considered. The Concrete (minimum M35 concrete strength) facing panels should be of minimum 140mm thickness[3]. The images below showing the complete design of Reinforced Earth wall for 10m high wall. In these images horizontal forces, vertical forces, sliding moment, resisting moment, shear key and connection strength is calculated.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		ϕ (°)	γ (kN/m ³)	H (m)	L (m)	Q (Kpa)	Ql (Kpa)	C (Kpa)	Ka	ϕ (peak)	θ	Dm (m)	ffs	fs	fms	v	V (kN/m)
2	Reinforced soil data	32	18.5	10	7.6				0.307	28.9	4.23°		1.5	1.2	1.6	1406	2109
3	Retained Backfill soil Data	30	18.5	10	7.6												
4	Foundation soil data	30	18.5	10	7.6			0				1					
5	Crash Barrier Data				7.6	15.45										24.72	37.08
6	Live Load				7.6		23		0.33							174.8	262.2
7																	
8																	
9	where:																
10	ϕ =angle of internal friction																
11	γ =unit weight of soil																
12	H=height of Wall																
13	L=length of reinforcement																
14	Q=strip load due to crash barrier																
15	Ql=live load																
16	C=cohesion																
17	Ka=coefficient of active earth pressure																
18	ϕ p=peak angle of shearing resistance																
19	θ =wall batter																
20	Dm=minimum embedment depth																
21	ffs=partial factor applied to soil																
22	fs=partial factors of safety for sliding																
23	fms=partial safety factor applied to c'																
24	V=loads																
25																	

Figure2. Available data for Reinforced Earth Wall Design

	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	v	V (kN/m)	Horizontal forces (P kN/m)	Sliding Force (Rh kN/m)	Resultant vertical load (Rv kN/m)	$f_s \cdot R_h$	$\tan(\phi)$	$R_v \tan(\phi) / f_{ms}$	CL/fms	W+X			
2	1406	2109	457.875	571.725	2408.28	686.07	0.55203	830.9012402	0	830.9012			
3													
4													
5	24.72	37.08											
6	174.8	262.2	113.83										
7													
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Figure3. Evaluated Horizontal and Vertical forces for sliding failure

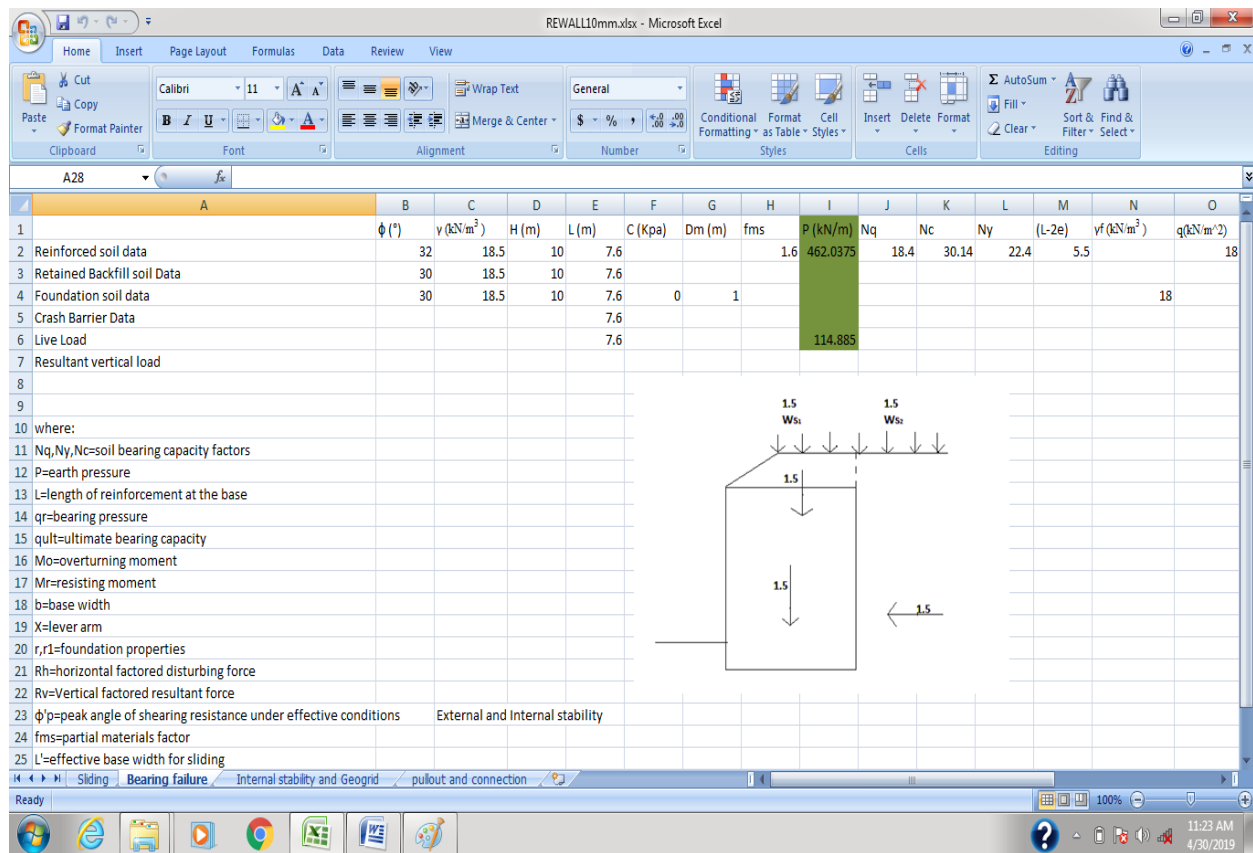


Figure4. Horizontal and Vertical forces in Bearing Failure

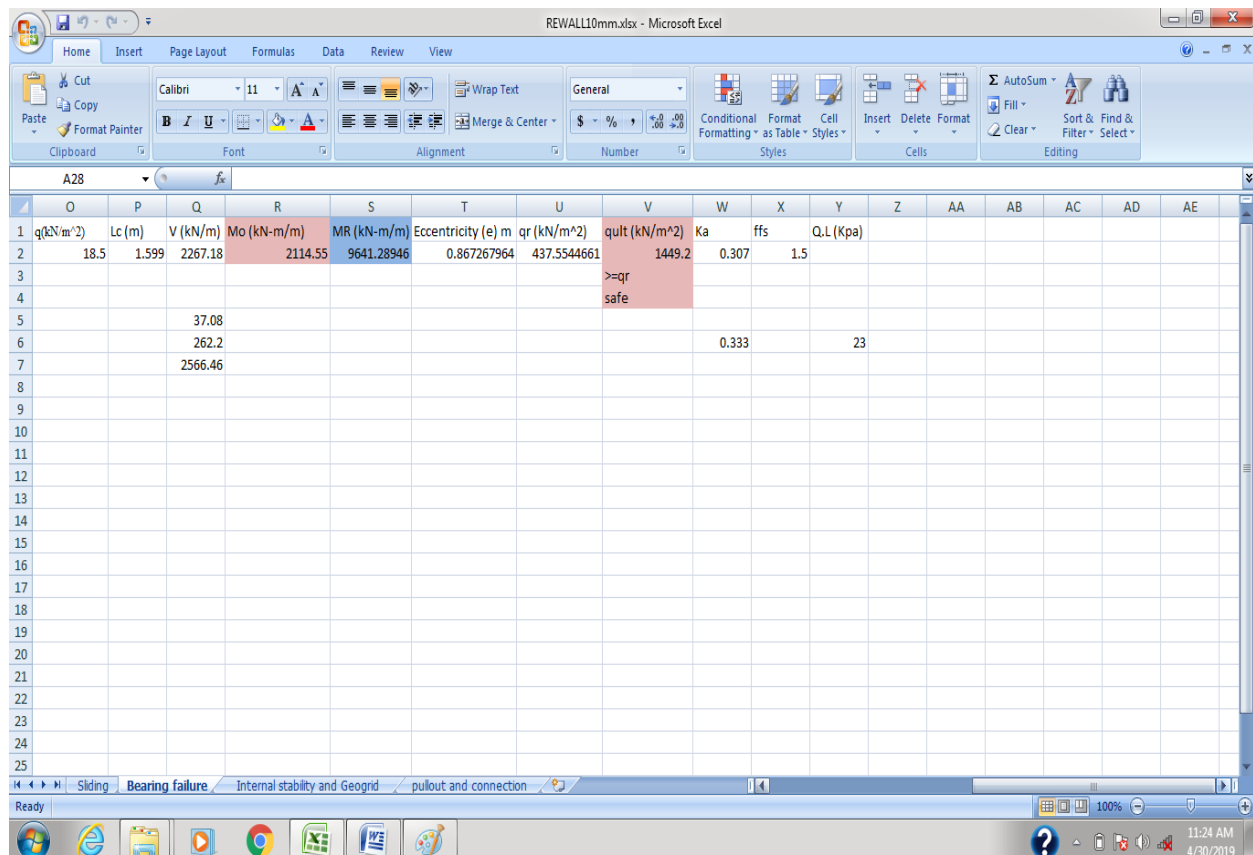


Figure5. Overturning and Resisting Moment in bearing Failure

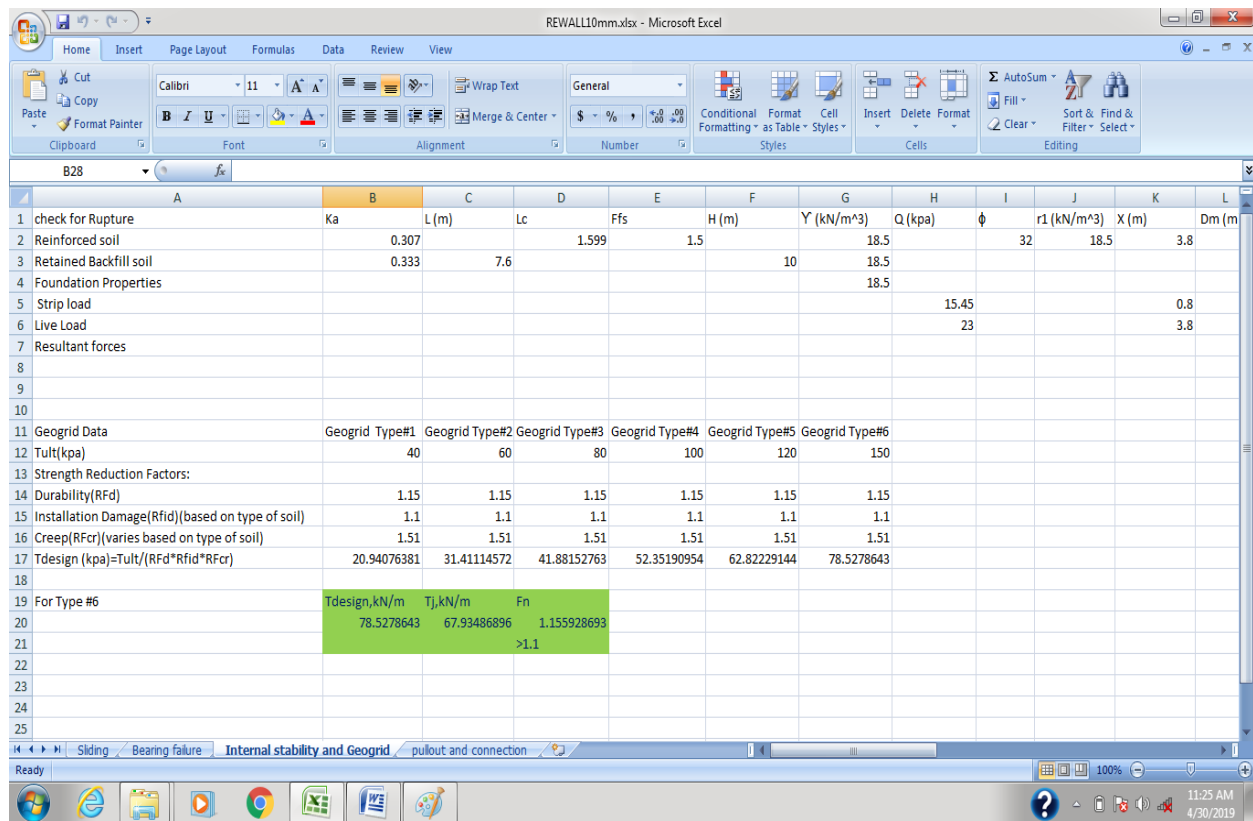


Figure6. Typical calculations for Reinforcement Material

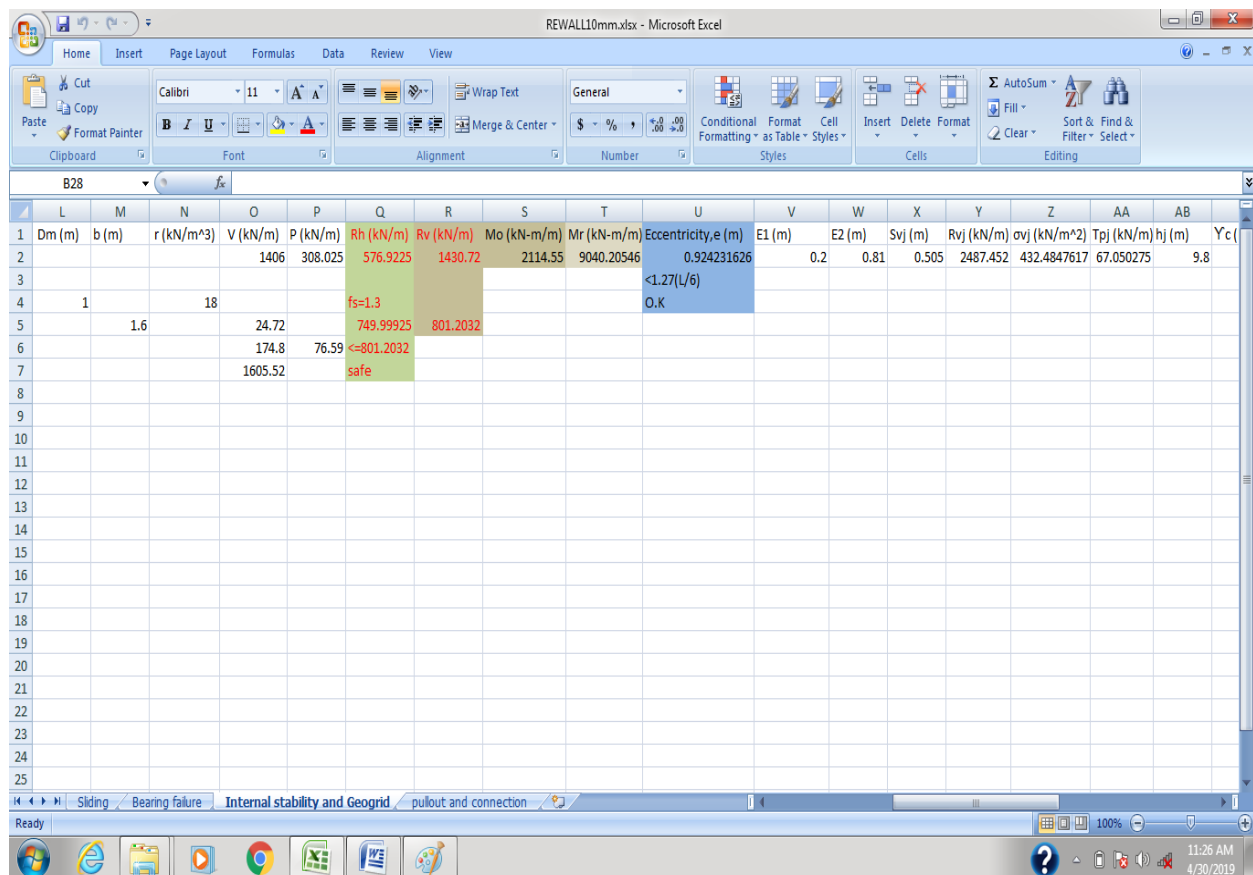


Figure7. calculations of Horizontal Factored disturbing force, Vertical factored resultant force, overturning moment, eccentricity, resisting moment for internal stability

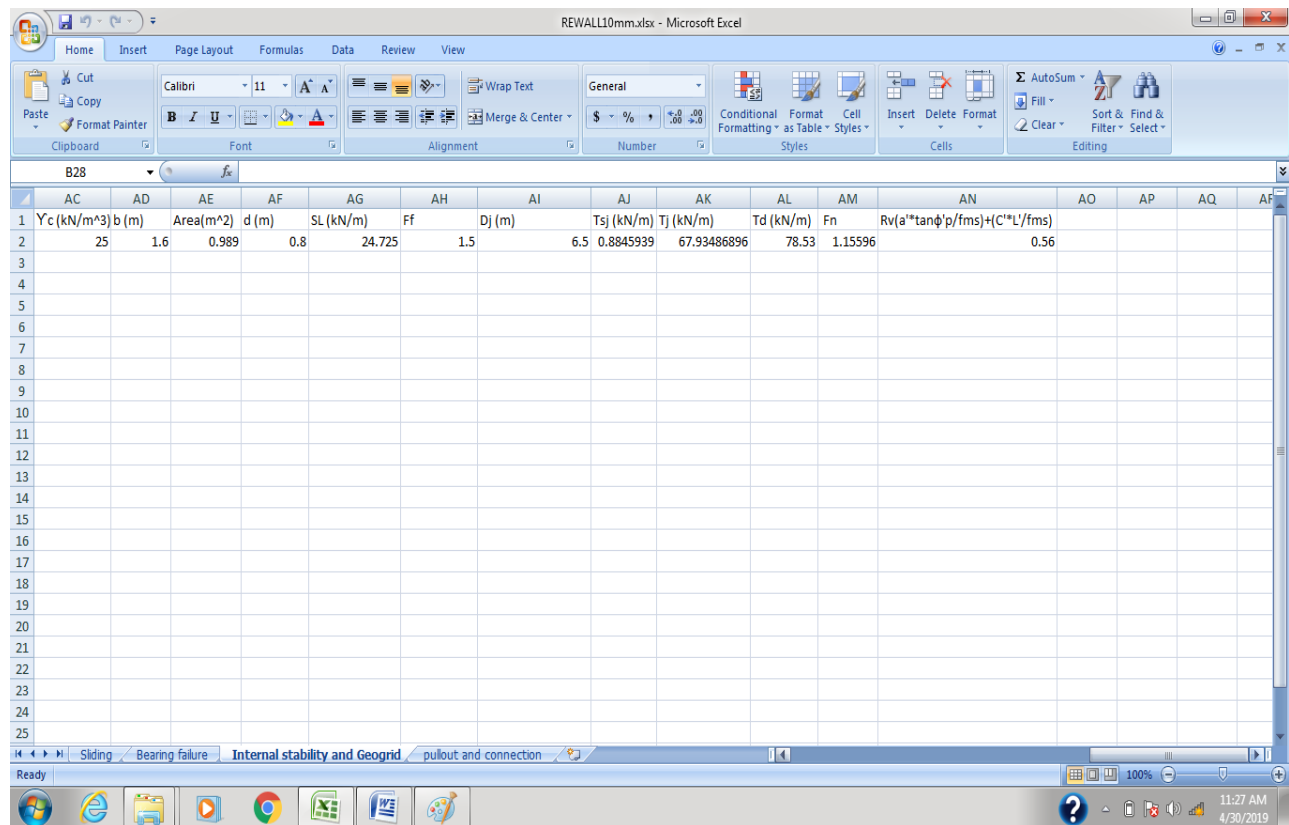


Figure8. Considering the crash barrier and calculating the tension due to the strip load of width 1.6m

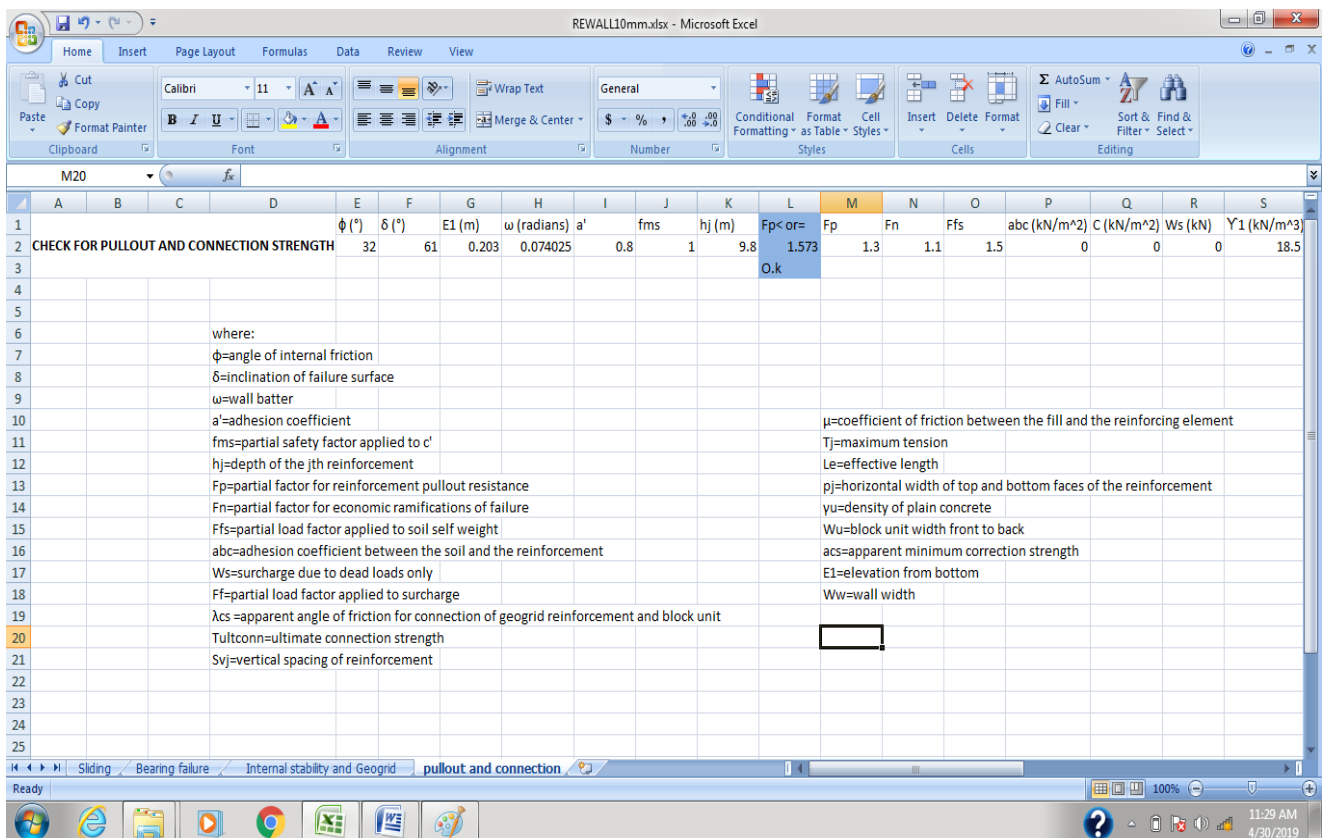


Figure9. Check for pullout and connection strength

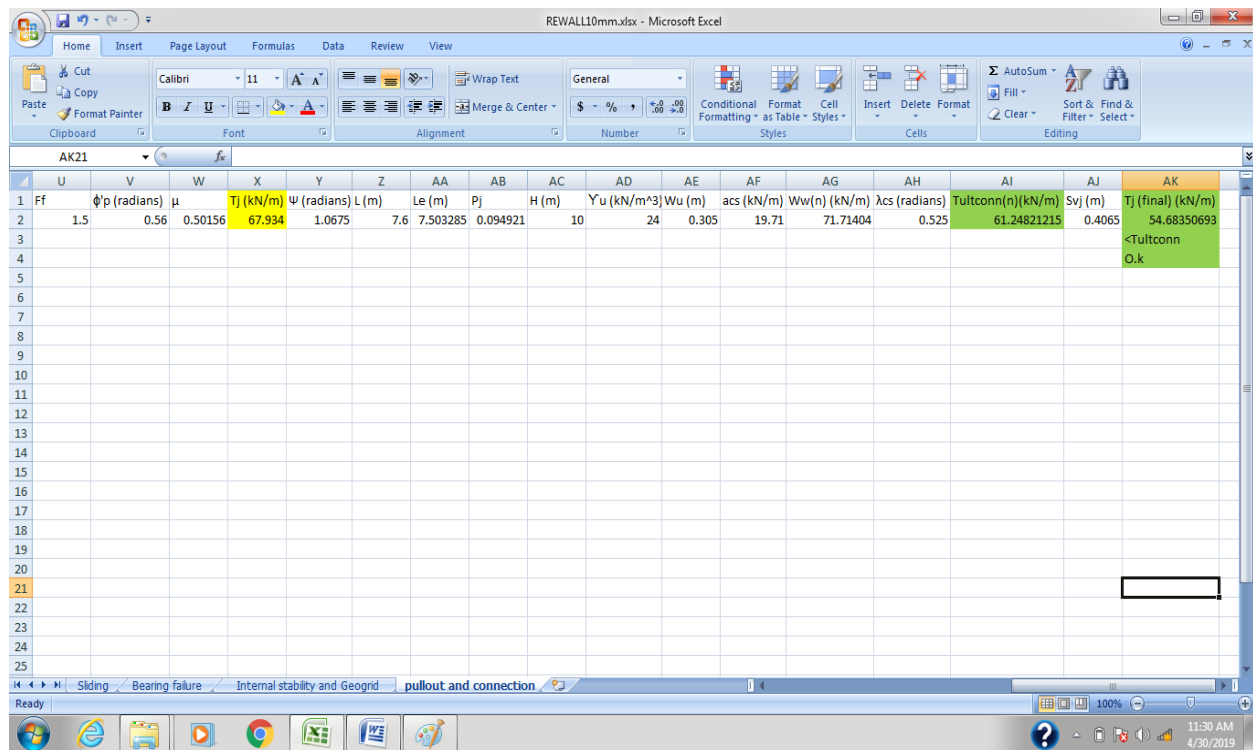


Figure10. Ultimate Tension strength is given

III. RESULTS

Table1. Effect of Changing Height on Earth Pressure

Wall Height	Earth Pressure					
	Sliding		Bearing Failure		Internal Stability	
	P1	P2	P1	P2	P1	P2
3m	41.2	34.15	41.58	34.46	27.72	22.97
5m	114.46	56.92	115.5	57.44	77	38.29
6m	164.83	68.31	166.33	68.93	110.88	45.95
8m	293.04	91.08	295.7	91.9	197.13	61.27
10m	457.85	113.85	462.03	114.88	308.025	76.59

In the above table, earth pressure is calculated for different heights in which pressure for Sliding, bearing failure and internal stability is considered for the check. As we increase the height of the wall, earth pressure also increases. Among all the forces, bearing pressure is highest and internal sliding force is lowest for all heights. Similarly, the horizontal forces are higher than all the vertical forces.

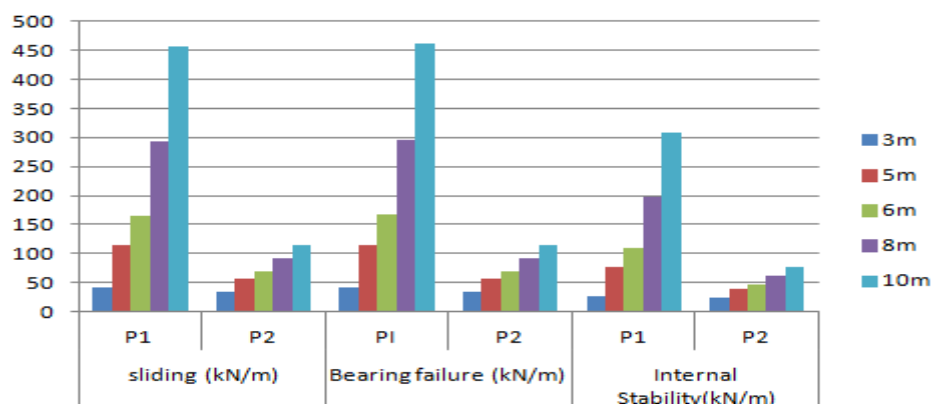


Figure11. Graph between different heights and earth pressure

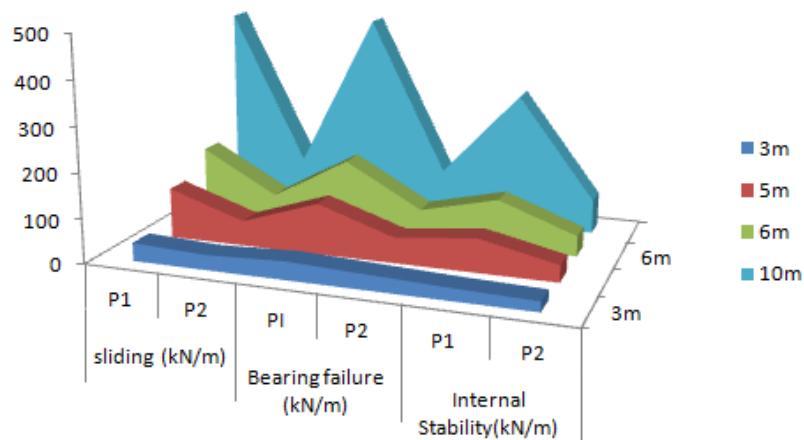


Figure12. Effect of earth pressure on surface area

The economy of design of reinforced earth wall is completely dependent on the height of the wall because when we increase the height, dead load increases due to self weight and this tends to increase its cost.

Table2. Wall height and Connection strength

wall height	Tult connection(kN/m)
3m	31.56
5m	40.04
6m	44.28
8m	52.76
10m	61.24

After finding all Earth pressures and doing check, the connection strength is also evaluated which brought out the best alternative. The wall of 10m height is most stable and would give the optimum cost. It can also be said that the height of the wall is directly proportional to its strength.

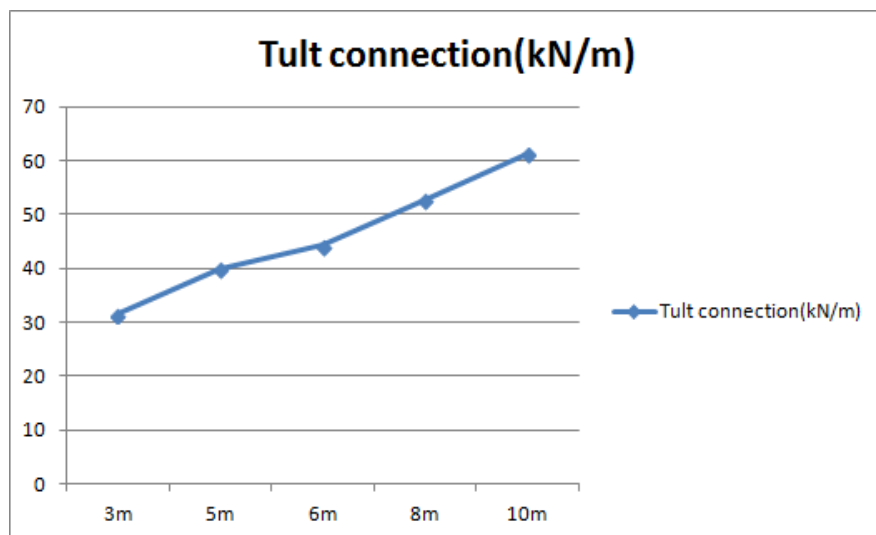


Figure13. Variations in connection strength on different heights

The ultimate connection strength at each geosynthetic reinforcement shall be calculated for bottom most Grid. As T_j is greater than ultimate connection strength, secondary reinforcement of 1.0m length is provided at an elevation of 0.609m.

Table3.Description of factor for ramifications of failure

Wall Height	Factor for ramifications of Failure,fn
3m	1.4
5m	1.377
6m	1.347
8m	1.266
10m	1.155

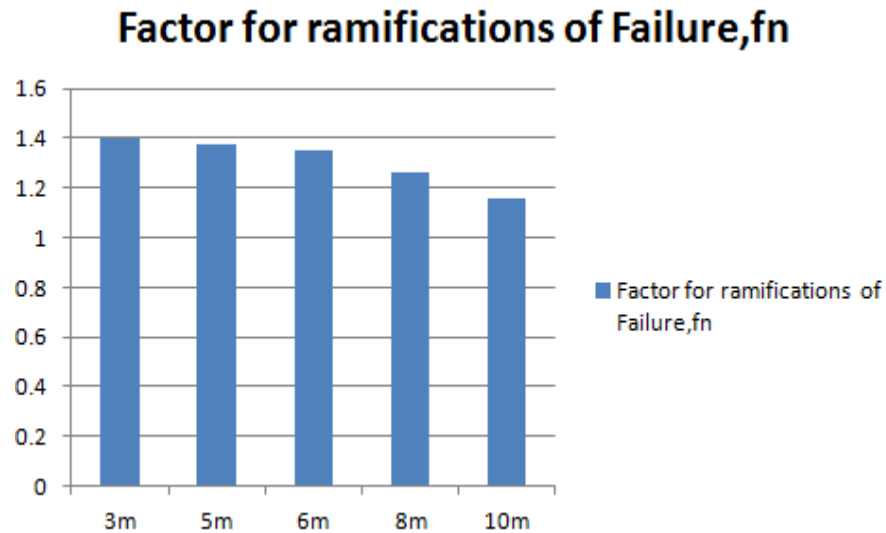


Figure14. Relationship between wall heights and partial factor of Ramifications

The factor for ramifications of failure in all cases is greater than 1.1. So geogrid can be provided for all heights. As T_j is greater than $T_{ultconn}(n)$ a secondary reinforcement of 1.0m length is provided at an elevation of 0.609m

IV. DISCUSSION

The Reinforced Earth Wall ensures minimum standard and criteria for acceptance of materials so that design life of 100 years is assured and to bring uniformity in partial load factors and partial material safety factors fulfilling a long standing need in the field of Highways and Bridges Engineering. Cohesive soils can also be used after improvement through Geocell mattresses/basal mattresses, stone columns, band drains with Preloading and chemical stabilization. The angle of internal friction also plays an important role in optimizing the cost of reinforced earth wall structure. Similarly, reinforcement can also be changed to make a wall more economical. The sliding force in 10m high wall is 571.72kN/m. The overturning moment and resisting moment in bearing failure is 2114.55kN-m/m and 9641.28kN-m/m whereas in internal stability it is 2114.55 kN-m/m and 9040.205kN-m/m respectively. The ultimate connection strength is 61.24kn/m.

V. CONCLUSION

On the basis of above results and discussions it can be concluded that:

1. The Reinforced Earth Technology serve the purposes more effectively at various heights as we use high adherence galvanized steel (Geogrid, Geotextiles, Geosynthetics) and mechanically stabilized earth in it.
2. If we change the geometry and loading conditions, composite material (backfill and reinforcing material), the Reinforced Earth wall will give better results and optimum cost.
3. On varying the height of the wall, the earth pressure also varies. If we will increase the height of wall the pressure will also increase and vice versa.
4. Geogrid is used as a reinforcement material because it is cheap, highly adhesive and feasible in comparison to other materials.
5. Reinforced Earth wall is the best alternative among all retaining structures in terms of technology, aesthetics, economy and applications.
6. The Horizontal forces due to sliding, bearing and internal stability are higher than the resultant vertical forces.

V. REFERENCES

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