A comparative study of seismic and non seismic stability of the reinforced earth retaining wall using geo-strip reinforcing elements

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ABSTRACT:-

The objective of this study is to compare internal stability of 10.4 m height reinforced earth retaining wall for seismic and non-seismic (static) cases. To achieve the above goal the wall is analysed individually with five different strength reinforcing elements e.g. GS-35, GS-40, GS-50, GS-60 and GS-75 for both seismic and non-seismic cases. During the seismic analysis it is assumed that wall is subjected to forces corresponding to seismic zone IV and all other parameters like vertical spacing of reinforcements, soil properties, etc. are kept constant for both cases. The individual analysis is done with above said reinforcements and results for both seismic and non-seismic cases obtained in terms of factor of safety. A comparison is made between obtained factors of safety for both cases, keeping the consideration of accepted values of factor of safety. On comparison of factors of safety for both seismic and non-seismic cases, it is found that factor of safety obtained for seismic case are small as compared to that of non-seismic case. Since accepted factor of safety in case of seismic cases are relatively small, therefore in this particular case non-seismic cases govern the design.

Keywords: - Stability, Seismic, Non-seismic, Reinforced earth, Reinforcing elements, Factor of safety, Elevation (Height).

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INTRODUCTION

The reinforced earth retaining wall also known as mechanically stabilised earth wall belongs to flexible retaining wall category. The function of wall based on concept of reinforced earth, which was first mentioned by H. Vidal in 1960s. In reinforced earth, the earth reinforced with such type of materials which have capability to sustain the tensile stresses, generated during the functioning of wall. There are two conditions arrived first is that stresses developed in the wall due to its own stability point of view i.e. self weight consideration and another is due to external loading came from retained backfill material. The retaining wall has been analysed for internal stability for both seismic and non-seismic conditions. The internal stability depends on strength of reinforcing elements; shear strength parameters of reinforced earth fill material and interaction between reinforcement and reinforced earth fill. The stability analysis of reinforced earth retaining wall performed in terms of factor of safety (FOS). As we know during earth quake the wall will be subjected to seismic loading also, hence in the stability analysis of earth wall seismic condition should also be considered during analysis and design.

This paper envisages a comparative study of seismic and non-seismic stability of reinforced earth retaining wall with reinforcing elements having different strength, in terms of factor of safety for pullout, rupture, sliding etc. Calculation of factor of safety for pullout, rupture, sliding etc. has been carried out by using computer program.

EXPERIMENTAL METHODOLOGY

The list of input data used in computer programme during this experimental analysis is given as follows:-

A- Geometry of reinforced earth retaining wall with horizontal back slope and traffic surcharge: - Design height (H) of wall is taken as 10.4m for analysis purpose which include embedment depth also, therefore base length as per FHWA-043 clause 4.2 (C) is 0.7H or 2.5m, whichever is greater. Hence width or base length (L) of wall is calculated as 7.30 m which will also equal to length of reinforcing elements.

B-Loading considered during seismic and non-seismic analysis of reinforced earth retaining wall: - During the seismic and non-seismic analysis of reinforced earth retaining wall, as per article 3.20.3 and 5.8 of current AASHTO following loadings are considered.

Dead load	DL	15	[kN/SQMT]
Live load	LL	22	[kN/SQMT]
Strip load	Qv-d	8	[kN/SQMT]
Width of footing	(b)	1.8	[m]
Distance of the centre of foundation from wall face	(bx)	0.9	[m]

C-Engineering properties of soil used in analysis: - Sand of Narmada River is taken as both for reinforced earth fill as well as retained backfill material. The property of sand says Unit weight and angle of internal friction determined in the laboratory by lab density test i.e. Proctor compaction test and box shear test respectively. The desired property i.e. Unit weight and angle of internal friction for foundation soil is assumed for the analysis purpose. The above said soil properties are tabulated as below.

Reinforced earth fill		**Retained backfill**		**Foundation soil (Assumed)**	
Unit weight (γs)[kN/m3]	20	Unit weight(γr)[kN/m3]	20	Unit weight(γf)[kN/m3]	18
Obtained value of angle of internal friction (φs)	32	Obtained value of angle of internal friction (φr)	32	Assumed value of angle of internal friction (φf)	30

D-Properties of reinforcing elements used in seismic and non-seismic analysis of wall: - In the internal stability analysis of reinforced earth retaining wall the following five types reinforcing elements (Geo-strip) having different strength used, are tabulated as below.

Type of reinforcing elements	Tult	Rc	RFd	RFid	RFc	Tavailable	Friction angle	Reinforcement soil interaction factor
GS-35	145.83	0.48	1.1	1.05	1.46	41.51	27.97	0.85
GS-40	166.67	0.48	1.1	1.05	1.46	47.44	27.97	0.85
GS-50	208.33	0.48	1.1	1.05	1.46	59.30	27.97	0.85
GS-60	250.00	0.48	1.1	1.05	1.46	71.16	27.97	0.85
GS-75	312.50	0.48	1.1	1.05	1.46	88.95	27.97	0.85

Where

T_{ult}: - Ultimate Tensile Strength in KN/M.
R_c: - Coverage ratio.
RF_d: - Reduction factor for durability.
RF_{id}: - Reduction factor for installation damage.
RF_c: - Reduction factor for creep.
$T_{available}$: - Available Tensile strength of reinforcing elements used in analysis in KN/M.

E-Derived soil parameters: - The following soil parameters used in analysis derived from strength properties of soil which has been determined in the laboratory.

i) Lateral earth pressure coefficient Ka = (1-Sinφ)/ (1+Sinφ)

Reinforced soil	Retained soil
0.3073	0.3073

ii) Foundation soil Bearing capacity Coefficient for assumed strength soil parameter φ = 30 degree

Nc	30.14
Nq	18.40
Nγ	22.40

F-Seismic loading coefficient used in analysis: - During the analysis it is assumed that reinforced earth retaining wall which is the concern of study falls in seismic zone IV. As per AASHTO- 1999 clause 5.8.1, IS-1983 and FHWA-00-043 the coefficients tabulated as below which will be used in seismic analysis of the wall.

Max ground acc. Coeff.(A)=	0.0625
Max wall acc. Coeff.(Am)=	0.087
Angle factor for seismic case(ξ) =	4.956
Total seismic earth pressure Coeff. **(K_{AE})**=	0.3591

Mononobe-okabe expression for total seismic earth pressure coefficient (K_{AE}): -

$$K_{AE} = \frac{\cos^2(\varphi - \xi - 90 + \theta)}{\cos\xi\cos^2(90-\theta)\cos(I+90-\theta+\xi)\left[1+\sqrt{\frac{\sin(\varphi+I)\sin(\varphi-\xi-I)}{\cos(I+90-\theta+\xi)\cos(I-90+\theta)}}\right]^2}$$

where:

I = the backfill slope angle
ξ = arc tan (K_h/1 - K_v)
φ = the soil angle of friction
θ = the slope angle of the face

Section of a reinforced earth retaining wall: - Figure shows cross-section of reinforced earth retaining wall which help to understand the terminology used for internal stability of wall.

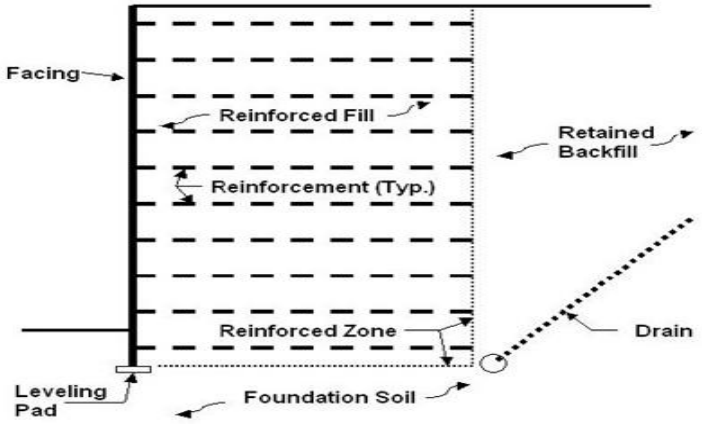


Figure-1 Cross-section of reinforced earth retaining wall

INTERNAL STABILITY ANALYSIS RESULTS FOR SEISMIC AND NON SEISMIC CASE: - Internal stability analysis of reinforced earth retaining wall with use of GS-35, GS-40, GS-50, GS-60 and GS-75 grade reinforcing elements done for seismic and non-seismic case and the results found as given below.

Table 1- Internal stability analysis results for seismic case

Grade of reinforcing elements →	GS-35	GS-40	GS-50	GS-60	GS-75	Accepted (FOS)
Elevation from TLP in m ↓	FOS-Strength (Seismic)	FOS-Strength (Seismic)	FOS-Strength (Seismic)	FOS-Strength (Seismic)	FOS-Strength (Seismic)	**Seismic= 1.125**
0.40	0.66	0.75	0.94	1.13	1.41	
1.20	0.70	0.80	1.01	1.21	1.51	
2.00	0.76	0.87	1.08	1.30	1.62	
2.80	0.82	0.94	1.17	1.40	1.76	
3.60	0.89	1.02	1.28	1.53	1.91	
4.40	0.98	1.12	1.40	1.68	2.10	
5.20	1.09	1.24	1.55	1.86	2.33	
6.00	1.22	1.39	1.74	2.09	2.61	
6.80	1.39	1.58	1.98	2.37	2.97	
7.60	1.60	1.83	2.29	2.75	3.44	
8.40	1.90	2.17	2.72	3.26	4.07	
9.20	2.33	2.66	3.33	3.99	4.99	
10.00	2.98	3.41	4.26	5.11	6.39	

Table 2- Internal stability analysis results for non-seismic case (Static)

Grade of reinforcing elements →	GS-35	GS-40	GS-50	GS-60	GS-75	Accepted (FOS)
Elevation from TLP in m ↓	FOS-Strength (Non-seismic)	FOS-Strength (Non-seismic)	FOS-Strength (Non-seismic)	FOS-Strength (Non-seismic)	FOS-Strength (Non-seismic)	**Non-seismic= 1.500**
0.40	0.71	0.81	1.01	1.21	1.51	
1.20	0.76	0.86	1.08	1.30	1.62	
2.00	0.81	0.93	1.16	1.40	1.74	
2.80	0.88	1.01	1.26	1.51	1.89	
3.60	0.96	1.10	1.37	1.65	2.06	
4.40	1.06	1.21	1.51	1.81	2.26	
5.20	1.17	1.34	1.67	2.01	2.51	
6.00	1.31	1.50	1.88	2.25	2.81	
6.80	1.49	1.71	2.13	2.56	3.20	
7.60	1.73	1.98	2.47	2.97	3.71	
8.40	2.06	2.35	2.94	3.52	4.41	
9.20	2.52	2.88	3.60	4.32	5.40	
10.00	3.24	3.70	4.62	5.55	6.93	

Table-3 stability of wall with different reinforcing elements under seismic and non seismic case

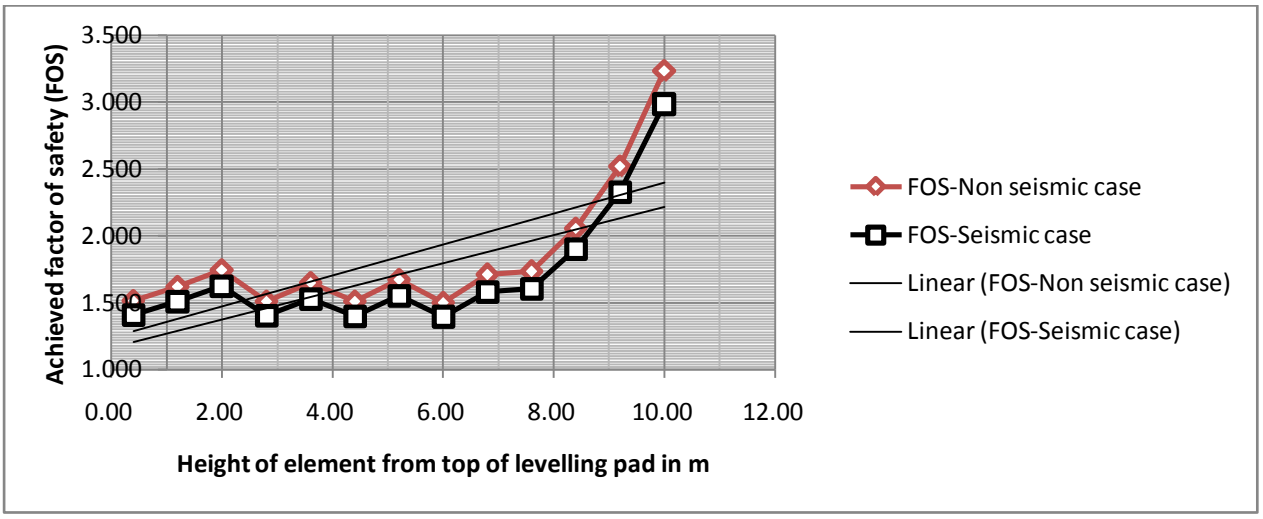
Grade of reinforcing elements	Elements give the internal stability up to height on individual basis. (elevation from top of levelling pad)		If individual inclusion used in complete height, wall will	
	Seismic case	Non-seismic case	Seismically	Non-seismically
GS-35	6.00 to 10.00	7.60 to 10.00	Unstable	Unstable
GS-40	5.20 to 10.00	6.00 to 10.00	Unstable	Unstable
GS-50	2.80 to 10.00	4.40 to 10.00	Unstable	Unstable
GS-60	0.40 to 10.00	2.80 to 10.00	Stable	Unstable
GS-75	0.40 to 10.00	0.40 to 10.00	Stable	stable

Discussion: - The analysis is done for internal stability under seismic and non seismic case using GS-35, GS-40, GS-50, GS-60 and GS-75 grade reinforcing elements having different strength. The factor of safety for strength under seismic loading conditions computed by taking the reinforcement individually and variation in factor of safety with respect to elevation of the reinforced earth retaining wall from top of levelling pad obtained for each and results are shown in table-3. On the basis of experimental results and its mutual comparison, it is

found that the performance of the wall in terms of factor of safety in non seismic case is more critical rather than seismic case.

Conclusions: -The test results obtained from analysis of 10.4 m height reinforced earth retaining wall using Geo-strips as reinforcing elements in different combination, the following conclusions can be made.

1) The factor of safety obtained for internal stability analysis are small for seismic case as compared to that obtained for non seismic case.
2) The acceptable factor of safety for seismic case recommended by various codes is small as compared to non seismic case. Therefore in this particular case the non seismic factor of safety are critical. The variation of factor of safety for both cases is shown in figure-2. This analysis is presented for reinforced earth wall located in seismic zone IV, therefore seismic coefficient taken for other seismic zone may affect the results**.**



Figue-2 *variation in factor of safety for seismic and non seismic case*

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