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A Review On Design Of Reinforced Earth Wall

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Abstract : The practice of adoption of Reinforced Earth (RE) walls in Highways and Railways in recent years has become substantial in India. Majority of the projects are designed based on BS code along with IS 1893:2000 for dynamic analysis. There are certain major differences between International codes with respect to design of RE wall. BS code considers the cohesive part of the soil also in the analysis. It uses the properties of soil under effective conditions for long term stability and undrained properties for short term stability. Australian code is more specific with respect to partial material factors, uncertainty and risk factors related to design. American Code gives formulation for seismic analysis apart from that provided by BS code. It does not allow using cohesion in the analysis. The long term tensile strength reduction factors by AS and AASHTO codes are comparatively high, therefore, there is an urgency in reviewing our designs following BS code.

Key Words: Load Factor, Partial factor, backfill, surcharge

INTRODUCTION

The analysis of geosynthetic RE wall is carried out by Limit State Design method involving Limit State of strength and serviceability. Tie back wedge method is followed for geosynthetic RE wall design [4]-[15]. The Limit State of Strength consists of stability of the structure externally in the form of sliding, overturning, bearing failure or slip failure. The internal instability may be in the form of failure of reinforcement due to rupture or slippage. The load in the reinforcement shall be determined at two critical locations, the zone of maximum stress and the connection with the wall face. Potential for reinforcement rupture and pullout are evaluated at the zone of maximum stress, which is assumed to be located at the boundary of active and resistant zones. The wall geometry plays an important role in the stability analysis. i.e., 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.

DESIGN PHILOSOPHY

The design of RE wall may be done by Limit State Design Method or by Working Stress method. All international codes follow Limit State Design method. The requirement in the design may be given as below.

Factored Overturning Forces ≤ Reduced Resisting Forces and
Factored Material Stresses ≤ Reduced Material Strengths

LOADS AND PARTIAL FACTORS

The forces acting on wall may be classified in to overturning and stabilizing. The pressure due to backfill, dead load surcharge and live load surcharge are the overturning in nature while the self weight due to soil, dead and live load surcharge are stabilizing in nature. The Coulomb's earth pressure coefficient is adopted in calculating the pressure. The partial factors are applied over characteristic loads and material strengths along with another factor depending upon the degree of damage that may be caused due to failure of the structure.

COMPARISON OF INTERNATIONAL CODES

i. Load Combinations

The load combination to be followed while designing by a given code is as given in Table 1.

ii. Partial Material Factors on Reinforcement

As per AS 4678:2002, Table 2 may be used to select partial material factors relating to the tensile strength of geogrid, if not available. BS and AASHTO codes have specific procedures to arrive at the same. D 6637 of ASTM provide procedure to determine tensile properties of geogrids by single or Multi rib tensile method.

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iii. Partial Material Factors on Soil

Partial Material factors shall be determined from Laboratory tests. However, in the absence of such data, values may be selected from a range as given in Table 3.

Table 1: Load Cases and Combinations

Load Case	Code	A	B	EQ_{max}	EQ_{min}	Serviceability
EV	BS	1.5	1.0	1.2	1.2	1.0
	AS	0.8	0.8	0.8	0.8	-
	AASHTO	1.35	1.0	1.5	1.35	1.0
EH	BS	1.5	1.5	1.2	1.2	1.0
	AS	1.25	1.25	1.25	1.25	-
	AASHTO	1.5	0.75	1.0	1.5	1.0
ES	BS	1.5	1.0	1.2	1.2	1.0
	AS	1.25	1.25	1.25	1.25	-
	AASHTO	1.5	0.9	0.75	1.5	1.0
LL	BS	1.5	0.0	1.2	0.0	0.0
	AS	1.25	0.0	0.6	0.48	-
	AASHTO	1.75	0.0	0.9	0.50	1.0
LS	BS	1.5	1.0	1.2	0.0	0.0
	AS	1.25	0.0	0.6	0.6	-
	AASHTO	1.75	0.0	0.5	0.5	1.0
WA	BS	1.0	1.0	1.0	1.0	-
	AS	1.0	1.0	1.0	1.0	-
	AASHTO	1.0	1.0	1.0	1.0	1.0
EQ	BS	0	0	1.2	1.2	-
	AS	0.0	0.0	1.0	0.0	-
	AASHTO	0.0	0.0	1.0	1.0	1.0

Table 2 : Partial Material Factors on reinforcement as per AS 4678:2002

Type of Factor	
Product uncertainty factor	
Guaranteed minimum strength	1.00
Guaranteed characteristic strength	0.95
Creep reduction Factor	
Polyster	
30 yrs service life	0.60
100 yrs. Service life	0.50
Polyethylene	
30 yrs service life	0.33
100 yrs. Service life	0.30
Polypropylene	
30 yrs service life	0.20

Table 3: Partial Material Factors on soil

Code	Type of Problem	Factor on Strength	Factor On Serviceability
BS 8006:1995	To be applied to shearing strength	1.0	1.0
	To be applied to c'	1.6	1.0
	To be applied to cu	1.0	1.0
AS 4678 : 2002	Partial factors on tan ∅,		
	For class 1 controlled fill	0.95	1.00
	For Class 2 controlled fill	0.90	0.95
	For uncontrolled fill	0.75	0.90
	For In situ natural soil	0.85	1.00
	Partial Factors on cohesion, ∅c		
	For class 1 controlled fill	0.90	1.00
	For Class 2 controlled fill	0.75	0.85
	For uncontrolled fill	0.50	0.65
	For In situ natural soil	0.70	0.85
AASHTO 2007	To be applied to shearing strength	1.0	1.0
	To be applied to c'	1.0	1.0
	To be applied to cu	1.0	1.0

Design Problem:

For the below data design of RE wall is carried out following BS, AS and AASHTO codes to compare the results.

Wall Data: H=6.0m;HW=2.0m

Reinforced Fill: $\varnothing_1=40^o$;$c_1=1.5kN/m^2$; $\gamma_1=19kN/m^3$;$\gamma_{s1}=21kN/m^3$

Backfill:$\varnothing_2=38^o$;$c_2=2kN/m^2$;$\gamma_2=18kN/m^3$; $\gamma_{s2}=20kN/m^3$

Load data: q=20 kN/m^2; ws=12 kN/m^2

Earthquake Zone:III

The Sections obtained are as shown in Fig. 2, Fig. 3 and Fig. 4.

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While designing as per AS 4678:2002, following partial material factors have been selected. **Design uncertainty factor of friction for infill and backfill**: 0.90 and 0.85
Design uncertainty factor for cohesion for infill and backfill : 0.75 and 0.70
Coefficient of sliding resistance :0.80
Coefficient of pullout resistance :0.80
Connection uncertainty factor:0.75

Results:

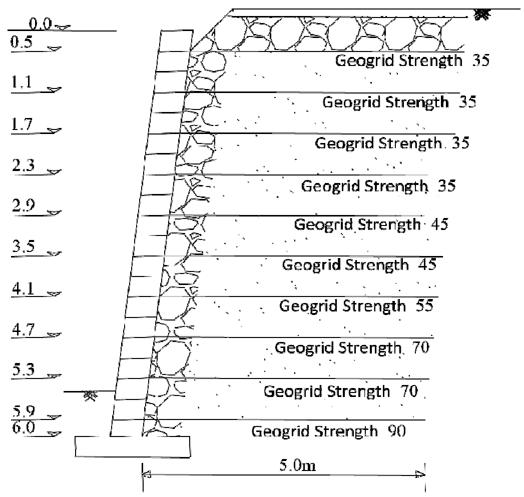

Fig. 2 Design Section as per BS 8006:1995

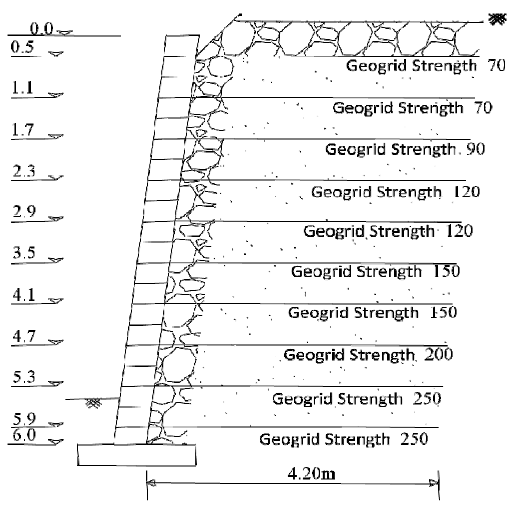

Fig. 3: Design Section as per AS 4678:2002

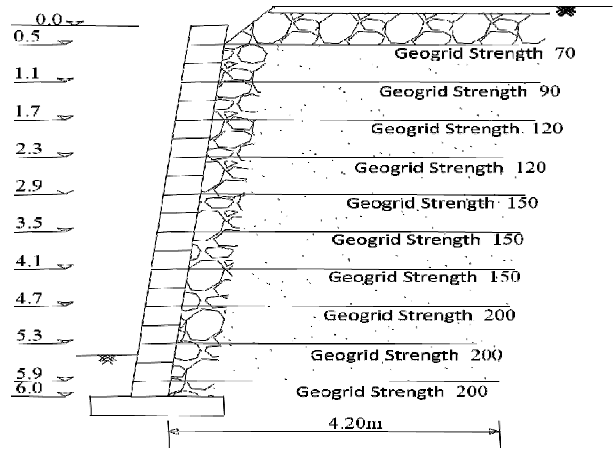

Fig.4: Design Section as per AASHTO 2007

The minimum long term tensile strength reduction factor applied over the geogrid is maintained as 2.0, used in one of the designs as per BS code whereas it is kept 5.29 in case of AS 4678:2002 and 7.0 in case of AASHTO 2007 design method.

CONCLUSION

BS code does not specify minimum long term reduction factor to be applied over the ultimate tensile strength of reinforcement, which is the main criteria in the internal stability analysis of the wall. It varies from material to material drastically, hence a thorough knowledge of geosynthetic material properties is very much essential. Assuming a lesser value in the design may result in wrong estimation. Australian code suggests a minimum value of 4 to 11 while, AASHTO code suggests minimum of 7.0. Hence a relook is necessary while following BS code.

NOMENCLATURE

c_1 Cohesion of soil of infill (kN/m^2)
c_2 Cohesion of soil of backfill (kN/m^2)
EV Load factor corresponding to vertical Dead load (dim)
EH Load factor corresponding to horizontal load due to Soil pressure (dim)
ES Load factor corresponding to horizontal Dead load surcharge (dim)
EQ Load Factor corresponding to Earthquake load (dim)
H Total Height of wall from base level (m)
H_w Depth of water table above base (m)
LL Load factor corresponding to vertical Live load surcharge above the wall (dim)
LS Load Factor corresponding to Horizontal

live load surcharge (dim)
q Live load surcharge (kN/m^2)
ws Dead load surcharge (kN/m^2)
WA Load Factor corresponding to Water load (dim)
$\varnothing_1$ Angle of internal friction of infill (Deg.)
$\varnothing_2$ Angle of internal friction of backfill (Deg.)
γ_1 Density of infill (kN/m^2)
γ_2 Density of backfill (kN/m^2)
γ_{s1} Saturated density of infill (kN/m^2)
γ_{s2} Saturated density of backfill (kN/m^2)

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