DESIGN AND BEHAVIOUR OF MECHANICALLY STABILIZED EARTH WALL

[1]Haresh D. Golakiya,[2]Mittal D. Lad
[1]Assistant Professor,[2]Designation of 2nd Author
[1]Civil Engineering Department,
[1]Governent Engineering College, Dahod, Dahod,India

Abstract— Increasing in vehicular demands a large number of flyovers, moreover there is tremendous increase in the number of highways, in hilly areas. Here earth retaining structures are essential. For many years, retaining structures were made of reinforced concrete and were designed as gravity or cantilever walls which are essentially rigid structures and cannot accommodate significant differential settlements unless founded on deep foundations. For solving this problem Mechanically Stabilized Earth Technique is used. It is a construction technique with alternate layers of compacted soil and reinforcing elements to build retaining walls and embankments. The reinforcing elements, which can be either steel or synthetic, interact with the soil by friction and confinement and provide tensile capacity. The combination of soil and reinforcement behaves as a gravity mass that retains lateral earth pressures. The two materials produce a composite structural material that combines their best characteristics. The structure, which is constructed by this technique i.e. Mechanically Stabilized Earth Wall, is much flexible and due to this it can accommodate large settlement. And 35% to 50% cost saving is done over RCC wall. In this paper, introduction of MSE wall, literature review, material and its properties, behaviour, construction techniques and steps, design concepts, design and then discussion for results of design, is includes. This paper addresses to evaluate and verify the performance of MSE wall in different condition of retained soil and backfill soil with different types of reinforcement with variable vertical spacing. Here how the reinforcing material and soil properties as well as vertical spacing between reinforcing element are affecting on stability of MSE wall is studied. Design of MSE wall is done as per BS 8006:1995 for out of water condition. Here design work is carried out for three different types of retained soil by adopting different backfill soil and reinforcing materials. In first case i.e. A, stability is checked for only one type of backfill soil. Where as in the second case i.e. B, two types of backfill soil and in third case i.e. C three types of backfill soil, are used to check the stability. In each case four types of reinforcing elements are used for four different vertical spacing.

***IndexTerms*—Mechanically Stabilized Earth Technique,construction techniques,settlement**

I. INTRODUCTION

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 is given by Earth Retaining Structure.

For many years, retaining structures were made of reinforced concrete and were designed as gravity or cantilever walls which are essentially rigid structures and cannot accommodate significant differential settlements unless founded on deep foundations. With increasing height of soil to be retained and poor subsoil conditions, the cost of reinforced concrete retaining walls increases rapidly and structure try to overturn due to the earth pressure.

For solving this problem Mechanically Stabilized Earth Technique is used. Here soil itself act as a retaining structure and facing units act as a supporting system and this structure is called "Mechanically Stabilized Earth Wall"(MSE Wall). In this technique, first facing units of first row are installed, which are made up of precast concrete panels, dry cast modular blocks, metal sheets and plates, gabions, welded wire mesh, wood lagging and panels, and wrapped sheets of geosynthetics. Then backfilling earth should be properly compacted and reinforced by means of reinforcing elements like steel strips or bars, welded wire mats, polymer grids or geotextile sheets. These reinforcing elements mechanically stabilize the earth.

Mechanically stabilized earth (MSE) is a construction technique with alternate layers of compacted soil and reinforcing elements to build retaining walls and embankments. The reinforcing elements, which can be either steel or synthetic, interact with the soil by friction and confinement and provide tensile capacity. The combination of soil and reinforcement behaves as a gravity mass that retains lateral earth pressures. The two materials produce a composite structural material that combines their best characteristics. The judicious placement of reinforcements in the selected soil mass serves to restrain the deformation of the soil in the direction parallel to the reinforcement.

The behaviour of reinforced soil is similar to reinforced concrete. Soil is weak in tension just like concrete. The addition of reinforcing strips or mats in the horizontal direction compensates for the weak tensile strength of soil.

The basic mechanics of Reinforced Earth were well understood by Vidal and were explained in detail in his early publications. A simplification of these basic mechanics can be illustrated by Figure 1As shown in Figure 1(a), an axial load on a sample of granular material will result in lateral expansion in dense materials. Because of dilation, the lateral strain is more than one-half the axial strain. However, if inextensible horizontal reinforcing elements are placed within the soil mass, as shown in Figure these reinforcements will prevent lateral strain because of friction between the reinforcing elements and the soil, and the behaviour will be as if a lateral restraining force or load had been imposed on the element. This equivalent lateral load on the soil element is equal to the earth pressure at rest. Each element of the soil mass is acted upon by a lateral stress equal. Therefore, as the vertical stresses increase, the horizontal restraining stresses or lateral forces also increase in direct proportion. Reinforced Earth is, therefore, composite material, combining the compressive and shear strength of compacted granular fill with the tensile strength of horizontal, inextensible reinforcements.

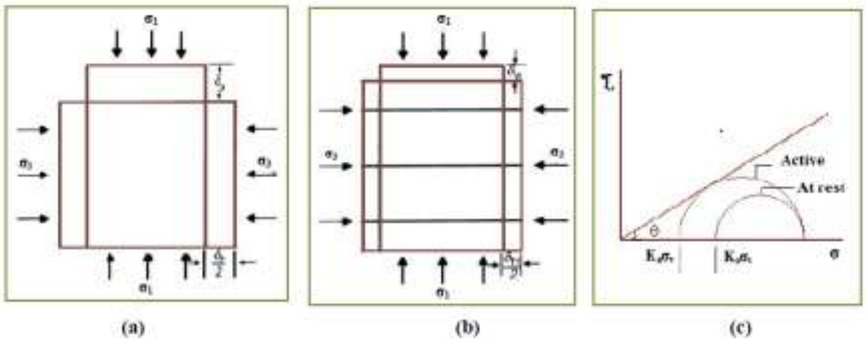

Fig. 1 (a) Elements of Unreinforced Soil (b) Element of Reinforced soil (c) State of Stress in Reinforced Soil

II. Research Objectives

Mechanically stabilized earth wall have gained substantial acceptance as an alternative to conventional masonry and reinforced concrete cantilever retaining wall structures due to its simplicity, rapidity of construction, less site preparation and space requirement for construction operation. In addition to technical and performance advantages, another primary reason for the acceptance of mechanically stabilized earth retaining wall has been its inherent economy. It is reported that, mechanically stabilized retaining structures, beside its outstanding performance, a cost saving of up to 30% to50% below alternate solutions have been achieved. Seismic loading, differential heave and settlement requirements make rigid masonry and concrete cantilever walls very difficult to achieve the desired safety factor. Whereas, mechanically stabilized earth system when subjected to seismic loads and differential earth movement has shown exceptional performance due to its flexibility and inherent energy absorption capacity. Even though reinforced earth is widely used in different parts of the world, it has not been well introduced in our country. Hence, it requires detail study to adopt this technology for locally available material.This paper aims at evaluating and verifies the performance of mechanically stabilized earth walls in different condition of retained soil and backfill soil with different type of reinforcement with variable vertical spacing.

III. LITERATURE REVIEW

Peter Anderson and Keith Brabant Have presented Increased Use of MSE Abutments. In this paper they first explain basic mechanism of Reinforced Earth which was well understood by Vidal. Then description about materials i.e. facing, reinforcement and backfill is given. This paper also covers behaviour of MSE abutments with respect to service life, settlement and seismic performance and types of abutments. Finally conclusion is given that due to good service life, good capacity to handle large and differential settlement without significant distress or loss of function, good seismic resistance, low cost and ease of construction, use of MSE abutment is increased. Subrata Rai has presented Construction Aspects of Flyover Approaches using Reinforced Soil Technology vis-a-vis Conventional Retaining Wall. This paper highlights some off the construction aspects of reinforced soil technology such as cost economy, speed of construction and aesthetics in relation to conventional retaining wall system. The reinforced soil technology is an improvement over conventional retaining wall. It offers speed of construction than conventional retaining wall, so problem of accommodate the traffic can be overcome. It saves 30% to 50% cost over conventional retaining wall. Prof. V. S. Chandrasekaran (1998) has presented Mechanics of Reinforced Earth Retaining Walls. In this paper mainly fundamental design aspects for reinforced earth retaining walls are covered. Here it is point out to need for undertake analytical and experimental studies under static and seismic condition on parallel walls containing soil backfill. Here it is also explained that type of reinforcement will have to selected based on fill material environmental conditions and cost and the system which allows to use locally available fill material will be beneficial. J. E. Sankey and P. Segration have presented Evolution of Seismic Performance in Mechanically Stabilized Structures. In this paper they discuss the performance of MSEW after the earthquake in Northridge, Kobe and Izmit. It is observed that in some cases seismic acceleration exceeded the design acceleration, even then little distress resulted. In some cases ductility of reinforced earth may allow minor permanent deformations to occur without distress. In some cases differential settlements were occur and due to these panels were separated up to 75mm, even then structure did not collapse. Even then for safety they suggest that during designing height of the wall should be keep in mind. R. A. Bloomfield, A. F. Soliman and A. Abraham have presented Performance of MSE Wall over Compressible Soil. This paper covers Two – Stage Wall System for constructing the MSE wall. In compressible soil differential settlement is occur and on this type of soil to construct MSE wall, adoption of ‘Two – Stage Wall System’ is preferable because it can resist more than 1% differential settlement. In this technique, first wire facing unit is constructed, minimum 600mm away, behind the permanent precast concrete facing and reinforced strip should be connected with wire facing unit. In second step permanent precast concrete facing connect with wire facing unit by means of coil rod and coil loop system, but all connection should be pin connection. Abu-Hejleh, Hearn, McMullen and Zornberg

(2003) have presented MSE Wall with Independent Full-Height Facing Panels. In this paper they give information about MSE wall with independent full height facing which was constructed by CDOT in 1996. In this type of wall construction begins by placing panels in shallow trench filled with flow material and panels should be supported by temporary bracings. Then backfilling, reinforcement of that soil and anchor placement – three process done simultaneously. Here anchors are placed to anchor the facing. Here full - height facing is independent of earth reinforced material so lateral pressure on facing can be minimized. Dr. V. M. Sharma (1998) has presented Steel Strips Reinforcements for Reinforced Earth Technology. In this paper basic strength properties of steel, long term behaviour, strength aspect and creep aspect are explained. Here effect of pH, chlorides sulphates and UV rays, on steel reinforcement also explained clearly. It is point out that in steel has good tensile strength and easy to work with it but it has problem of corrosion. And this problem can be sole by galvanized coating on steel. Here process of hot deep galvanization of steel strip also explained. B. S. Berke, A. A. Sagues and Rodney G. Powers have presented Long Term Corrosion Performance of Soil Reinforcement in MSE Walls. This paper covers survey of corrosion rate of galvanized steel strip in Florida. MSEW, around Florida were instrumented through their concrete covers to survey corrosion rates of galvanized strip soil reinforcement by polarization measurements. First survey was done from 1995 to 1997. In this survey corrosion rate in 13 – 25 year old MSE walls for galvanized steel were average 0.02 ± 0.01 mpy. After 10 years when second survey was started in 2006, at that time also corrosion rate was almost in stable condition. So by this survey it can be understable that galvanized steel strip has good durability and good resistance to corrosion. D.V. Reddy has presented Long Term Behaviour of Geosynthetic Reinforced MSE Wall Systems. This paper covers experimental work carried out for observing the behaviour of geosynthetic in MSE wall during loading condition. Geosynthetic has good durability and good corrosion resistance properties so its use is increases but creep is occur under sustain loading at high temperature, so its behaviour for long term is not exactly recognize therefore research work was carried out. For this experimental work small scale testing was carried out on prototype to evaluate the failure and distress mechanisms in MSE walls, so it could help to construct full scale wall. For small scale testing four prototypes were made and among these two prototypes were reinforced with UX-1400 HDPE geogrid and other two were reinforced with Miragrid 3XT geogrid. After small scale testing, full scale wall was constructed in Florida for long term testing and planed for loading to failure. Observation of this experiment is that when structure was loaded to very high stress level, only excessive deformations occurred—there were no incidences of catastrophic failure occur.P. Jagannatha Rao (1998) has presented Design, Construction and Monitoring of Reinforced Earth Walls. This paper deals with case histories of two reinforced earth retaining walls forming part of flyovers in New Delhi. High tensile geogrid was used as the reinforcing inclusions and fly ash was used as a backfilling material. The paper deals with design, construction and monitoring aspects of these projects. The behaviour of the reinforced earth walls was monitored by measuring periodically the movement of facing panels by inclusion of inclinometer. The measurements have shown that reinforced earth walls were in the safe condition. The performance of these fill was found satisfactory, as the pavements continue to be smooth under the heavy traffic load. Dr. S. V. Mhaiskar (1998) has presented Facia Element in Reinforced Soil Walls. In this paper mainly point out the importance of facia element. Here it is suggested that a designer has pay good attention while designing detail of facia elements because it provide a supporting system to the mechanically stabilized earth mass. It also provides a connection of reinforcement. So quality of facing material should be checked properly. In this paper function and types of facing units, construction of facing unit and construction with facing units – all these important points are covered.

IV. BEHAVIOUR OF MSE WALL

SETTLEMENT PERFORMANCE:

The MSE wall can accommodate total settlement up to 3feet (90cm) and differential settlement more than 1% without loss of structural functions and without showing facing panel distress. The ability of MSE wall to withstand extreme settlement is a one of the good benefit of this construction technology and because of this its use is increases.

In recent years a new technique is created for the site where settlement expected to greater than 3–4feet (90cm – 120cm) and more chance of differential settlement, called 'Two – Stage Construction System'. In this technique, first wire facing unit is constructed, minimum 600mm away, behind the permanent precast concrete facing and reinforced strip should be connected with wire facing unit. In second step permanent precast concrete facing connect with wire facing unit by means of coil rod and coil loop system, but all connection should be pin connection.

SEISMIC PERFORMANCE:

Due to flexibility of MSE wall, it can nicely handle the seismic forces. The seismic performance of MSE wall in all over the world is proven very good in comparison of rigid traditional earth retaining structure.

V. DESIGN CONCEPTS OF MSE WALL

LIMIT STATE PRINCIPLES:

Limit state principles are applied to the design of MSE walls. The two limit state considered in design are the ultimate limit state and serviceability limit state. Ultimate limit states are associated with collapse or other forms of structural failure. Margins of safety against attaining the limit state of collapse are provided by the use of partial material factors and partial load factors. Serviceability limit states are attained if the magnitudes of deformation occurring within the design life exceed prescribed limits or if the serviceability of the structure is otherwise impaired.

PARTIAL FACTORS:

Limit state design for mechanically stabilized earth employs four principal partial factors all of which assume prescribed numerical values of unity or greater. Two of these are load factors applied to dead loads, third is applied to live loads and fourth is use to take into account the economic ramification of failure.

DESIGN LOADS:

Load may be either dead loads or live loads. The dead loads are calculated using an unfactored characteristic value which is the worst credible value. For calculating the magnitude of disturbing loads and forces, the shear strength parameters of the soil are used unfactored. The numerical value of the total stress is multiplied by a prescribed load factor to obtain the design load.

DESIGN STRENGTH:

A fundamental principal of limit state design is that the design strength should be equal to or greater than the design load. The stability of the MSE structures is checked for two conditions: External stability and Internal stability. In the case of external stability, the design load may be resisted by forces generated in soil. In internal stability, the design load may be resisted by forces generated in the soil and the reinforcement.

FUNDAMETAL MECHANISM:

The fundamental mechanism of mechanically stabilized earth is somewhat similar to the reinforced concrete. Soil has inherently low tensile strength, but high compressive strength, which is only limited by soil to resist applied shear stresses, thereby reducing the load which might otherwise cause the soil to fail in shear or by excessive deformation.

SOIL REINFORCING MECHANISM IN WALL:

Figure 2 shows a steep slope in a dry cohesionless soil with a face inclined at a an angle to the horizontal, where is greater than the internal angle of shearing resistant without reinforcement, the active zone is unstable and tends to move outwards and downwards with respect to the resistance zone. If soil reinforcement is installed across the active and resistant zones it can serve to stabilize the active zone. If the reinforcement develops an adequate bond and adequate tensile stiffness, it will absorb tensile strains developed in the soil in the active zone.

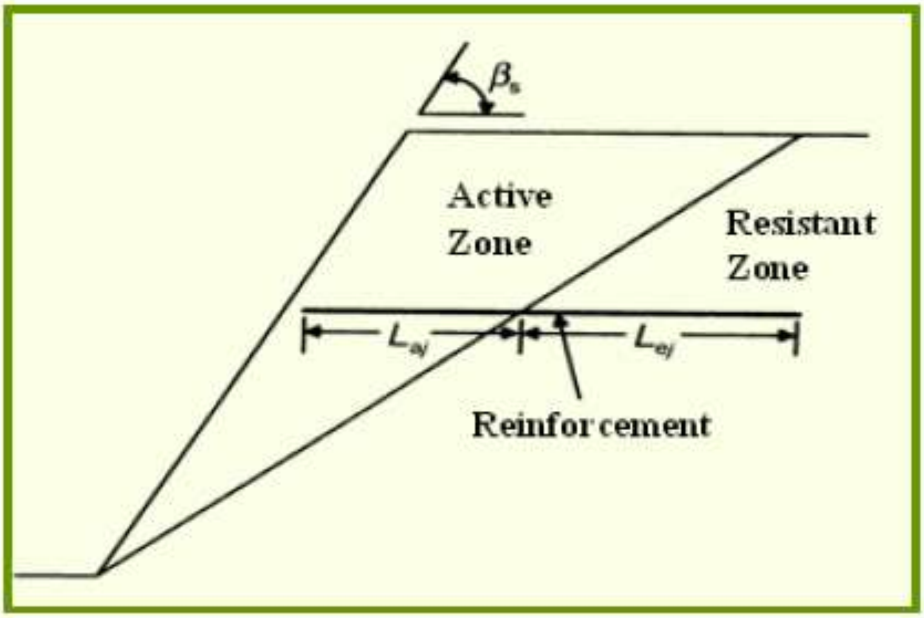

Fig 2 Reinforcing Mechanism in MSE Wall

SOIL REINFORCEMENT INTERACTION:

For the reinforcement should be effective, it should interact with the soil to absorb the stresses and strains which would otherwise cause failure. The precise mechanism by which the interaction occurs is affected by the characteristics of the soil, the reinforcement and their inter relationships. Since loads are transfer from soil to reinforcement by relative movement between these two components, it is essential that the reinforcement is axially stiff in comparison to the soil. The design of the soil reinforcement system requires an evaluation of the long-term pullout performance with respect to three basic criteria: Pullout capacity, i.e., the pullout resistance of each reinforcement should be adequate to resist the design working tensile force in the reinforcement with a specified factor of safety. Allowable displacement, i.e., the relative soil-to-reinforcement displacement required to mobilize the design tensile force should be smaller than the allowable displacement. Long-term displacement, i.e., the pullout load should be smaller than the critical creep load.

DESIGN PHILOSOPHY:

Mechanically stabilized earth is a combination of structural and geotechnical engineering. The evolution of limit state design in structural engineering has led to the definition of a number of partial load factors which are applied to loads in design combinations and material factors which are applied to the structural components.

BASICS OF DESIGN PROCEDURE:

For convenience analysis of MSE wall, it is usually considered in two parts covering external and internal stability. External stability covers the basic stability of the reinforced soil structure as a unit, whilst internal stability covers all areas relating to internal behaviour mechanisms, consideration of the stress within the structure, arrangement and behaviour of the reinforcements and backfill properties.

While assessing the external stability, the effects of dead loads and other loads and forces acting on the structure should be considered. Stability should be checked for bearing and tilt failure, forward sliding, and slip circle failure and settlement of the structure. Both short and long term soil properties should be considered to allow for the construction and in-service conditions and changes in pore water pressures. Passive earth pressures exerted on the foot of the wall or structure below ground level should be ignored when considering stabilizing forces.

Stability within a MSE structure is achieved by the reinforcing elements carrying tensile forces and transferring them by friction, friction and adhesion, or friction and bearing. The forces can be transferred through fill trapped by the reinforcing elements. The fill is then able to support the associated shear and compressive forces.

Internal stability is concerned with the integrity of the reinforced volume. The structure has the potential to fail by the rupture or loss of bond of the reinforcements. Consideration should be given to the local stability of individual layers of elements, sliding on horizontal planes and the stability of wedges. The arrangement and layout of reinforcing elements should be chosen to provide stability and to suit the size, shape and detail of the facing. For simplicity a uniform distribution of identical reinforcing elements may be used throughout the height of the wall.

It is essential to ensure safety of MSE wall against failure over potential sliding plane. The corresponding analysis is called wedge stability analysis. Wedges are assumed to behave as rigid bodies and may be of any size and shape. Stability of any wedge is maintained when friction forces acting on the potential failure plane in connection with the tensile resistance/bond of the group of reinforcements embedded in the fill beyond the plane is able to resist the applied loads tending to cause movement. Different wedge plane should be selected at different depth of the wall. The forces acting on each wedge should be resolved into two mutually perpendicular directions. Wedge stability should be checked for two conditions: The tensile resistance of reinforcing element and The adherence or frictional resistance of the element embedded in the fill outside the failure plane.

METHODS FOR DESIGN OF MSE WALL:

There are two methods currently used for the design of MSE structures: Tie Back Wedge Method and Coherent Gravity Method. The tie back wedge method follows basic by design principles currently employed for classical or anchored retaining walls. It has evolved from the use of all forms of permitted reinforcements. The coherent gravity method is based on the monitored behaviour of structures using inextensible reinforcements and has evolved over a number of years from observations on a large number of structures, corroborated theoretical analysis. Both methods are identified for internal stability. Both methods require the ultimate limit state and serviceability limit state.

Field observations have shown that lateral earth pressures in the upper reaches of a wall will be influenced by the axial tensile stiffness of the reinforcement. In coherent gravity method lateral earth pressure should be taken for at rest condition. In tie back wedge method, lateral earth pressure should be taken for active condition.

VI. DESIGN OF MSE WALL

DESIGN STRUCTURE:

In this study, design of MSE wall is done for three different types of retained soil. Stability of MSE wall is checked by varying backfill soil, reinforcing elements and vertical spacing between reinforcing elements. In the chart completely design structure is shown.

In first case i.e. A, stability is checked for only one type of backfill soil. Where as in the second case i.e. B, two types of backfill soil and in third case i.e. C three types of backfill soil, are used to check the stability. In each case four types of reinforcing elements are used for four different vertical spacing.

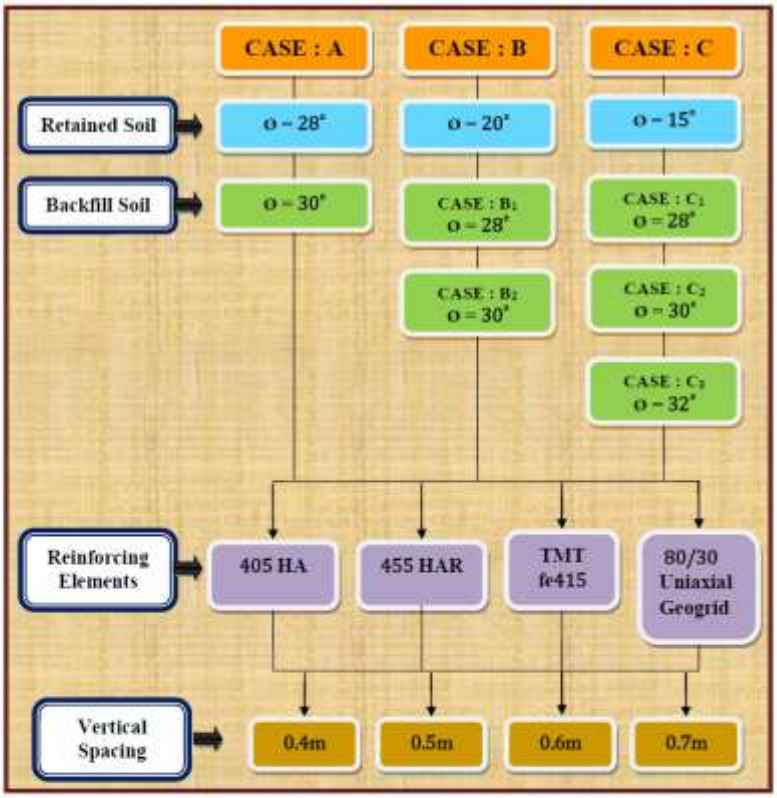

Fig 3 Soil and Reinforcing Element Properties:

In this study total three types of retained soil and three types of backfill soils and four numbers of reinforcing elements of three types of reinforcing materials are used. The properties of these materials are listed in following tables.

Table1 Soil Properties

Case	Retained Soil			Backfill Soil-1			Backfill Soil-2		
	Ø (degree)	*γ (kN/m³)*	*c (kN/m²)*	*Ø (degree)*	*γ (kN/m³)*	*c (kN/m²)*	*Ø (degree)*	*γ (kN/m³)*	*c (kN/m²)*
A	28^0	18	2	30^0	18	0	-	-	-
B	20^0	18	2	28^0	19	0	30^0	18	0
C	15^0	18	2.5	28^0	19	0	30^0	18	0
							32^0	18	0

Table 2 Reinforcing Element Properties

GALVANIZED CARBON STEEL		TMT fe 415	80/30 UNIAXIAL GEOGRID
Reinforcing elements of GCS	***Design strength TD (kN/m)***	***Design strength TD (kN/m)***	***Design strength TD (kN/m)***
405 HA	44.957	55.333	45.596
455 HAR	49.390		

Design of MSE wall done as per the flow chart for different material properties and all the necessary checks has been carried.

VII. RESULTS AND DISCUSSIONS

In these designs total two types of reinforcing material [Steel (Galvanized carbon steel strips, TMT steel) and Polymeric material (Uniaxial geogrid)] and total four number of reinforcing elements(405 HA, 455 HAR, TMT fe 415 and 80/30 Uniaxial Geogrid) are used.

If Polymeric Material is use as a reinforcing material, then there is no chances of corrosion but in this material more chances of creep. This material is spread lengthwise of the wall so more material is required and ultimately cost of construction be high. While working with polymeric material, extreme care should be taken. Compacted backfill soil should be perfectly in leveled otherwise wall get distress or some time major rupture could be arise. Due to requirement of more care, time requirement to construct the wall, is an increase. And to divert the traffic for long time is very difficult task because due to the diversion, people get disturbed and too much harassment is occurs to them. In this world of competition, easy, fast, safe and economic construction is required. These requirements can't be satisfied by polymeric material, it is satisfied by steel. So it is batter to use steel as a reinforcing element instead of polymeric material. So in these designs it batter not to choose 80/30 UG as a reinforcing element.

If Steel is use as a reinforcing element then it could provide higher tensile strength. Steel strips are installed at regular vertical as well as horizontal interval, so less material is required in comparisons to polymeric material. So ultimately cost of construction is low in comparisons of structure constructed by using polymeric material as a reinforcing element. Steel strips can easily handle and not so much care is required, while working with it. So time required for construction is less in comparison to working with polymeric material. But in steel, there is more chances of corrosion and due to corroded strips structure may get distress. But this problem can be solved by covering the strips with galvanized coating. Galvanized coated steel strips provide long service life to the structure and it is proven.

Among all four reinforcing elements, TMT fe 415 has higher tensile strength so it gives good results. But it has more chances of corrosion in compare to carbon steel. Its cost is also higher than carbon steel. In Carbon Steel carbon contents are more, so it has high corrosion resistivity and low tensile strength in comparison to TMT steel but it is sufficient to carry tensile force induced in the structure. If last two to three layers get ruptured then area of the reinforcement of those ruptured layers can be increases. Carbon steel also provides more grips with soil.

In these designs, carbon steel is good option as a reinforcing element for safety as well as economy point of view. But if in some case of MSE wall, height of wall is more than 10m and retained soil is too much weak then reinforcing element has to carry large tensile force and to carry large tensile force it should have high tensile strength. In this case galvanized TMT steel can be used. In this case cost of construction will be high but it is safe and economic than carbon steel. Because if galvanized carbon steel strips used as a reinforcing element then vertical spacing between reinforcement should keep 0.2 or 0.3 m, on other hand if TMT steel used as a reinforcing element then vertical spacing between reinforcement should keep 0.5m or 0.6m. So when carbon steel used then material requirement will be high and when TMT steel used then material requirement will be less. So cost of construction of wall with TMT steel is equal or somewhat higher than carbon steel. So in adverse condition like this, galvanized TMT steel is preferable.

SUITABILITY OF MATERIALS:

Here suitability of materials is discussed for all three cases. According to retained soil type, suitability of backfill soil, reinforcing element and vertical spacing, is discussed.

CASE : A

Retained soil has sufficient angle of internal friction so it satisfy all condition of external stability. Internal stability mainly depends on backfill soil, material of reinforcing element and vertical spacing between reinforcing elements. Here backfill soil has also sufficient angle of internal friction so tensile force induced in the structure body is easily carried by reinforcing elements. For stability and economy point of view, 405 HAR (TD = 44.957 kN/m) with 0.6m vertical spacing or 455 HAR (TD = 49.390 kN/m) with 0.7m vertical spacing, are preferable to use as a reinforcing element.

CASE : B

Retained soil has not sufficient angle of internal friction. It is weaker than retained soil of Case:A. Retained soil has not adequate bearing capacity so sliding of the structure can be occur. To improve bearing capacity and to avoid the sliding, foundation soil replaced by backfill soil. Backfill soil of angle of internal friction of 28° and 30°, provide a good external as well as internal stability to the structure but it is preferable to use backfill soil of internal friction angle 30°, as stability point of view. For stability and economy point of view, 405 HAR (TD = 44.957 kN/m) with 0.5m vertical spacing or 455 HAR (TD = 49.390 kN/m) with 0.6m vertical spacing, are preferable to use as a reinforcing element. Here area of last layer of reinforcing element is increased because last layer is ruptured.

CASE : C

Retained soil has not sufficient angle of internal friction. It is too much weak than retained soil of Case:A and Case:B. To improve bearing capacity and to avoid the sliding, foundation soil should be replaced by backfill soil. Backfill soil of angle of internal friction of 28°,30°and 32°. Here bearing capacity is sufficiently increased by these three types of backfill soil but backfill soil of angle of internal friction 28° and 30°can't prevent the structure against sliding. In Case:C3, structure is safe against sliding, so backfill soil of angle of internal friction 32°, is preferable. Here it is also can be done that, soil of angle of internal friction 28° or 30° is use as a backfill soil and to avoid the sliding foundation soil is replaced by soil of angle of internal friction 32°. For stability and economic point of view, 455 HAR (TD = 49.390 kN/m) with 0.5m vertical spacing, is preferable to use as a reinforcing element. If cost of construction is no matter then TMT fe415 (TD = 55.333 kN/m) with galvanized coating is also preferable as a reinforcing element to get higher tensile strength.

VIII. CONCLUSION

The wall failure occurs mainly in one of following three ways,

i. Tension in reinforcement
ii. Sliding of wall from base
iii. Wedge failure of soil backfill

from the paper it is concluded that the angle of internal friction Ø is the most important of all other parameters as the basic principal of mechanically stabilization of earth depends on it. As soil is weak, chose backfill soil of higher angle of internal friction. If foundation soil is too much weak then bearing capacity should be improved by replacing the foundation soil by soil of higher angle of internal friction or soil improvement techniques like stone column. Length of the reinforcement totally depends on height of the wall. Length of reinforcement layers increases as height of wall increases. Design strength of reinforcement and vertical spacing between two reinforcements are also main factors. According to soil condition as well as tensile force induced in structure, reinforcing elements as well as vertical spacing between them are selected. If backfill soil of sufficient angle of internal friction is available then it is preferable to use reinforcing element with design strength equivalent to design load or with higher design strength by keeping larger vertical spacing between two reinforcements. While checking local stability, if in some layer/layers design strength including the factor of ramification of failure of reinforcing element is lesser than required then area of reinforcing element should be increased or replace with reinforcing element of higher tensile strength for particular ruptured layer.

REFERENCES

1. Abraham A., Soliman A. F. and Bloomfield R. A., “Performance of MSE Wall Over Compressible Soils”, The Reinforced Earth Company, Vienna, Virginia – USA, Technical paper.
2. Abu-Hejleh, Hearn, McMullen, and Zornberg “MSE Wall with Independent Full-Height Facing Panels”, Technical paper after annual meeting of TRB, 2003.
3. Anderson Peter and Brabant Keith “Increased Use of MSE Abutments”, The Reinforced Earth Company, Norcross GA, Technical paper, 2006.
4. Arora K. R. “Soil mechanics and foundation engineering”, Standard Publishers Distributors.
5. Basudhar P.R and Syed Mohd.Ahemad, “Behavior of reinforced soil retaining wall under static loading using finite element method”, Technical paper after 12th international conference of IACMAG, Goa, India,2008.
6. Basudhar P. K., Vashistha Amol, Deb Kosik and Dey Arindam “Cost Optimization of Reinforced Earth Wall”, published online 16th August, 2007.
7. Berke B.S., Sagüés A.A. and Powers Rodney G., “Long Term Corrosion Performance of Soil Reinforcement in MSE Walls”, corrosion 2008 conference and expo.
8. Bhattacharya P., Chattopadhyay B. C., Debjit Bhowmik, Mukherjee S. P. “Pullout Behaviour of Square Anchors in Reinforced Clay”, Technical paper after 12th International Conference of IACMAG at Goa, India, 2008.
9. Bhide M.C. “Reinforced soil retaining walls”, published by Indian Institute of Bridge Engineers.
10. Bridge Construction Manual “Mechanically Stabilized Earth (MSE) Walls”, Kansas Department of Transportation, Version 8/08.
11. British standard code of practice for “Strengthen / reinforced soils and other fills” – BS 8006:1995.
12. Bujang B. K. Huat ,Azlan A. Aziz, Loh Wooi Chuan,“Application of Scrap Tires as Earth Reinforcement for Repair of Tropical Residual Soil Slope” EJGE Vol. 13, Bund. B,2008.
13. Carlos A. Lazarte, Victor Elias, R. David Espinoza, Paul J. Sabatini “Soil Nail Walls”, Technical Manual, 2001-2002.
14. Chandrasekaran V. S. “Mechanics of Reinforced Earth Retaining Walls”,Technical paper after 16 th National event of IIBE at Mumbai in 1998.
15. Chonkar R. R., “Review of design of reinforced earth retaining walls for flyovers”, The Indian Concrete Journal, December – 2001.
16. Christopher Barry R., Ryan R. and Victor Elias, “Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction”, Publication No. FHWA-NHI-00 043, U.S. Department of Transportation, March- 2001.
17. Colin JFP and Jones “Earth Reinforcement and Soil Structure”, Butterworth and co.(publishers) Ltd,1985.
18. Chungsik Yoo and Kwang-Moon Lee, “Instrumentation of Anchored Segmental Retaining Wall”, Geotechnical Testing Journal, Vol. 26, No. 4.
19. Deb Kousik, Chandra Sarvesh, Basudhar P. K. “Settlement Response of Granular Fill-Soft Soil Reinforced with Extensible Geosynthetics and Stone Columns”, Technical paper after 12th International Conference of IACMAG at Goa, India,2008.
20. Design manual for “Reinforced Earth Walls”, The Reinforced Earth Company, Vienna, Virginia – USA, October – 2005.
21. Dr. Sharma V. M., “Steel Strips Reinforcements for Reinforced Earth Technology”, Technical paper after 16 th National event of IIBE at Mumbai, 1998.
22. Dutta Manoj and Gulhati Shashi K., “Geotechnical Engineering”, published by Tata McGraw- Hill Publishing Company Ltd. ., Chapter 25-Earth Retaining Wall, pp 416-425, Chapter 32-Reinforced Soil, pp 565-576.
23. Geotechnical Design Manual “Abutments, Retaining Walls, and Reinforced Slopes”, Chapter 15, December 2006.
24. IND HA 01, Technical Specification for earth structure with HA/HAR Galvanized Steel Strips, Reinforced Earth India Pvt. Ltd.
25. Joseph E Bowler, “”Foundation analysis and design”fifth edition,McGraw Hill international editors, chapter 12-Mechanically Stabilized Earth Retaining Walls, pp 675-724.
26. Joshi M. M. “Soil Engineering” Published by Atul Prakashan, Chapter 7-Retaining Wall & Earth Pressure, pp 112-126.
27. Khalid Farrag, Murad Abu-Farsakh Mark Morvant “stress and strain monitoring of reinforced-soil test wall”, TRB 2004 Annual Meeting CD-ROM.
28. Maccaferri - “Case History - MSE Structure Supports Development”, technical paper USA031- Rev:00,2004, Las Vegas, NV, USA.
29. Mahajan Rajesh “Choice of soil reinforcement system”, Technical paper after 16th National event of IIBE at Mumbai, 1998.
30. Mhaiskar S. V. “Facia Element in Reinforced Soil Walls", Technical paper after 16th National event of IIBE at Mumbai, 1998.

31. Ministry of Road Transport and Highways (MORTH), "Specifications for Road and Bridge Work", published by the Indian Road Congrees on behalf of Govt. of India.
32. Mirafi – "Permanent and Temporary MSE Walls Reinforced Soil Slopes Embankments", technical paper for material specification.
33. More S. B. and Jahangirdar S. S. "Foundation Engineering" Published by Nirali Prakashan, Chapter 11-Geosynthetic, pp 11.1-11.26.
34. Nalawade R.D. and Nalawade D.R. "Stability and Cost Aspects of Geogrid Reinforced Earth Wall of Flyover", Technical paper after 12th International Conference of IACMAG at Goa, India, 2008.
35. Porbaha, A., 1996, "Geotextile Reinforced Lime Treated Cohesive Soil Retaining Walls", Geosynthetics International, Vol. 3, No. 3, pp. 393-405.
36. Punmia B. C. "Soil Mechanics and Foundation Engineering", Laxmi publisher.
37. Sivakumar Babu G. L. "An introduction to Soil Reinforcement and Geosynthetics", Published by Universities press (India) Privet Ltd.,2006.
38. Rai Subrata "Construction Aspects of Flyover Approaches using Reinforced Soil Technology vis-a-vis Conventional Retaining Wall" Technical paper after 16th National event of IIBE at Mumbai, 1998.
39.
40. Rao P. Jagannatha, "Design, Construction and Monitoring of Reinforced Earth Walls" Technical paper after 16th national event of IIBE at Mumbai, 1998.
41. Reddy D.V., "Long Term Behaviour of Geosynthetic Reinforced MSE Wall Systems", Florida Atlantic University, Jan - 2003.
42. Sankey J. E. and Segration P. "Evolution of Seismic Performance in Mechanically Stabilized Structures", The Reinforced Earth Company, Vienna, Virginia – USA, Technical paper.
43. Sharma V. M. and Uppal K.B. "Design of soil reinforced structures using metallic strips", Technical paper after 16 th National event of IIBE at Mumbai,1998.
44. Tatsuoka, F., Tateyama, M., Uchimura, T. and Koseki, J., 1997,"Geosynthetic-Reinforced Soil Retaining Walls as Important Permanent Structures", Geosynthetics International, Vol. 4, No. 2, pp. 81-136.
45. Truong K.M., Berkebile M.J. & Gladstone R.A. "Ultra-high hybrid wire and concrete-faced Reinforced Earth bridge abutments", The Reinforced Earth Company, Vienna, Virginia – USA, technical paper.
46. Tsukamoto, Y., Ishihara, K., Higuchi, T. and Aoki, H., 1999, "Influence of Geogrid Reinforcement on Lateral Earth Pressures Against Model Retaining Walls", Geosynthetics International, Vol. 6, No. 3, pp. 195-218.
47. Xiao-jing Feng, Qing Yang, Shou-long Li, Mao-tian Luan "The Influence of Facing Stiffness on the Performance of Geogrid Reinforced Retaining Walls", EJGE Vol. 13, Bund. K, 2008.