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Numerical Evaluation of Slope Reinforced with Deformed Steel bars Embedded in Tire Shred-Sand Mixture

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Abstract: *This study has been carried out about study numerical of Mechanically Stabilized Earth (MSE) wall Model having a size of 3x4x5 ft backfilled with sand tire shred mixture in a ratio of 80-20 % by volume. The Model is 4 ft long, 5 ft in height and 3 ft wide. The backfill material of sand tire shred mixture in a layer having 6 inches thickness with deformed steel bar of diameter #4 as reinforcement. This study reports the behavior of sand tire shred mixture backfill under different normal loading conditions. An initial normal load of 20 KPa is applied on the backfill material in order to investigate the strain in the reinforcement, vertical movement of the soil and the deflection in the facing of the wall. The backfill is again subjected to an increased normal load of 40 KPa, 60 KPa and a maximum of 80 KPa and the behavior of backfill is observed. A Finite Element Model commercial Geotechnical software PLAXIS 3D is used for numerical analysis. It can be concluded from this study that tire shreds are a very useful material to be used in civil engineering applications as they are inexpensive, light weighted and have good drainage properties. From the numerical study it can be concluded that extra care should be taken in the input parameters while using finite element commercial geotechnical software.*

Keywords: *Tire shreds, Finite Element Modeling, MSE walls, Praxis 3D, backfills.*

Introduction:

In Highway Engineering, to retain the load of Soil and load of Rocks, Structures are provided known as Retaining walls. The Role of the Retaining walls is very important in the development of modern infrastructure due to the environment, cost effectiveness and safety. The Purpose of this research is to assess the feasibility of using a mixture of tire shreds and sand as fill material for retaining walls on the basis of numerical study. A successful construction and performance of tire shred in retaining walls may result in large benefits to society by promoting the use of tire shred as fill material. Different types of Retaining walls that include Gravity retaining walls, MSE walls, cantilever Retaining Walls, Brick and Stone retaining walls. However, this study is related with MSE Retaining walls. Now what is MSE wall?

A MSE wall is also called Reinforced earth wall. A Reinforced earth wall may be defined as a combination of earth and linear reinforced strips that are capable of bearing large tensile stresses. There are a lot of advantages of MSE walls, which are given below.

1. MSE walls are cost effective.

2. There is no requirement of experienced craftsman possessing special skills.

3. They do not require large construction equipment’s.

4. They require less preparation at site than the other alternatives.

5. They need less place in front of the structure for construction.

The wastage of unrecycled tires due to their non-biodegradability, inflammability and chemical composition is an enormous global problem. Utilizing waste tires in geotechnical applications is one of the ideal options. Tires may be used as lightweight backfill for retaining walls, lightweight fill and insulation beneath the roads. Waste tires in engineering are used as shreds which are known as tire shreds or tire derived aggregates. There are several potential benefits of using tyre shreds as backfill behind Retaining walls. There are certain areas having the underneath soil very weak or compressible, in order to nether the effect of settlement and increase global stability tire shreds may be used, as the low unit weight of tire shreds apply a smaller vertical stress than conventional backfill. This may also result in a less expansive retaining wall design due to the fact that the horizontal stress on a retaining wall would be lower as compared to conventional backfill. The frost penetration would also be reduced due to the insulation qualities of tire shreds. Moreover, due to the high permeability of the tire shred, it would provide good drainage. In this study, tire shreds have been used with sand mixture as backfill material behind MSE Retaining wall reinforced with deformed steel bars. The retaining wall is analyzed using a Finite element geotechnical software PLAXIS 3D in order to find the maximum settlement and maximum deflection. So this study involves the full scale testing of Retaining wall using tire shred as backfill with two conditions at rest condition and active condition. However, very limited data is available on full scale testing of MSE walls having tyre shred-sand backfill with deformed steel bars as reinforcement.

Figure 1. Tire derived aggregates (TDA)

Tire derived aggregates consist of tires pieces of 2in by 2in and can be mixed with sand to use it as a backfill.

Figure 2. Access Ramp

Figure 3. Bridge Abutments

Problem statement:

From the above discussion it has been cleared, that very limited data is available on full scale testing of MSE walls having tire shred-soil backfill with deformed steel bars as reinforcement. Geotextiles are used as Reinforcement in Mechanically Stabilized Retaining walls in Pakistan which are very expensive, so there is a need to use economical means for soil reinforcement. Therefore, deformed steel bars are used in this research as they are very economical in construction industry. Moreover, one of the enormous Global problems is the wastage of unrecycled tires due to their non-biodegradability, their flammability and their chemical composition. Therefore, they are used as coarse aggregates in this research.

Objectives:

Main objectives of this research work given below.

1. To construct and test to failure of carefully monitored full scale model.
2. To acquire the detailed measurements of mechanical behavior of MSE walls with deformed steel bars as reinforcement using full scale model with sand as backfill material
3. To collect the data that can guide the development of physically correct models that are needed to design reinforced retaining walls and predict their performance in the field.

Literature Review:

Many Researchers used Tire shreds as backfill behind MSE walls throughout the world in their research work. The wastage of unrecycled tires due to their non-biodegradability, inflammability and chemical composition is an enormous global problem. Utilizing waste tires in geotechnical applications is one of the ideal options. Tires may work as backfill for walls, lightweight fill and insulation beneath the roads. Waste tires in engineering are used as shreds which are known as tire shreds or tire derived aggregates. There are several potential benefits of using tyre shreds as backfill behind Retaining walls. It has been noticed during recent years, the usage of tire shred in highway applications has increased. The tire shreds are the whole tires cut into pieces ranging from 1inch to 12 inches. Although it has been found from a study carried out by tweedie et al that three tire shred layers had experienced severe reaction of heating by itself, but general rules for design are available to avert this defect (Tweedie et al, 2009). There are certain areas having the beneath soil very weak or compressible, in order to lower the effect of settlement and increase global stability tire shreds may be used, This may also result in a less expansive retaining wall design. The frost penetration would also be reduced due to the insulation qualities of tire shreds. Moreover, due to the high permeability of the tire shred, it would provide good drainage. (Jeffrey J. Tweedie et al) tested full scale retaining wall using tire shred as backfill with two conditions at rest and active condition. However, very limited data is available on full scale testing of MSE walls having tyre shred-soil backfill with deformed steel bars as reinforcement. By taking into account the factor of rigidity of facing panel after constructing backfill and load of strip footing.

Various Researchers performed Numerical Analysis of the Experimental data from the field.

I.P Damians, R.J Bathurst et al (2014) supervised study on Minnow creek wall that was constructed with steel reinforced soil in United State in 1999. The said minnow creek wall was numerically analyzed by using FEM software to assess its quantitative performance. The major objective of this paper is to describe different questions arising by using a finite element model for numerical analysis of reinforced wall. Wall instrumented having various instruments such as strain gauges which were attached along the length of steel strips. To monitor the loads connection steel strip were attached to one set of strain gauge.

Tariq Abichoul et al (2004) carried out a study in which he tried to find out the performance of soil-tire chip backfill for a Block Modular Wall. In this study, by using conventional ways of construction a MSE wall with Geogrids or geotextiles and filled with a mixture of sand tire was designed in 25% chips by volume. Consecutive surcharges are placed responding to 42, 95, 148, and 200 KPa and then performance of soil tire chip backfill behind modular block wall was found under the above mentioned normal loading. Modular Block wall in the figure 4 as shown

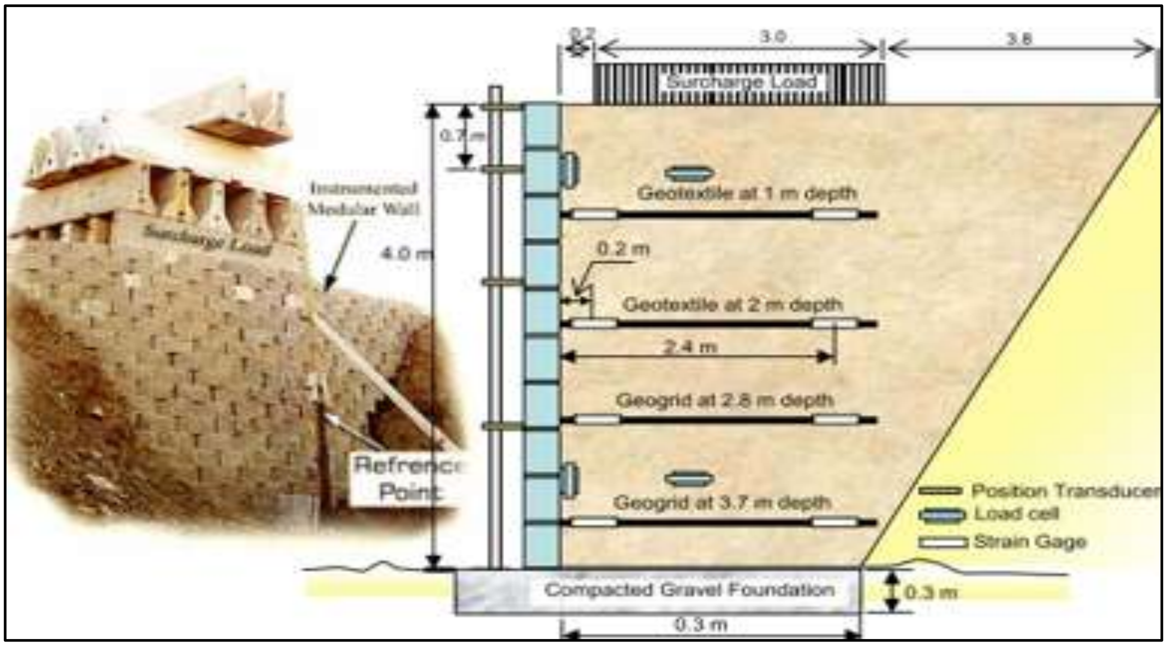

Figure 4. Schematic of MSE Wall

Methodology:

PLAXIS 3D has been used for numerical modeling in the research which is a FEM geotechnical software. PLAXIS 3D is a software which assumes numeric executing features of MSE wall Model. While in numerical modeling phase, Mohr coulomb failure criterion is used. Selecting input parameters and the boundary conditions has a great importance in the numerical modeling.

The major components of MSE wall are facing elements, Backfill material, reinforcement embedded in the backfill material. The Modeling of the MSE wall has been done according to the specifications stipulated in commercial geotechnical software program Plaxis 3D manual (2013). So Model is assumed in software then soil settlement is predicted and soil deformation determined in Plaxis 3D.

MSE model founded on 6 inches thick plain cement concrete base to neglect influence of foundation failure on the performance of MSE wall. Backfill material MSE wall is assumed to be of sand and the retaining material is assumed to be of soil to make the analysis simple. The facing of the MSE wall is designed as steel plate just to retain the backfill material. The Reinforcement of deformed steel bars are arranged in the MSE wall in such a way that length of the bars should be 0.75 times the wall height. The center to center distance of the reinforcement is 6 inches. A normal charge of 20 KPa is supposed to be surcharge over Reinforced backfill of MSE wall.

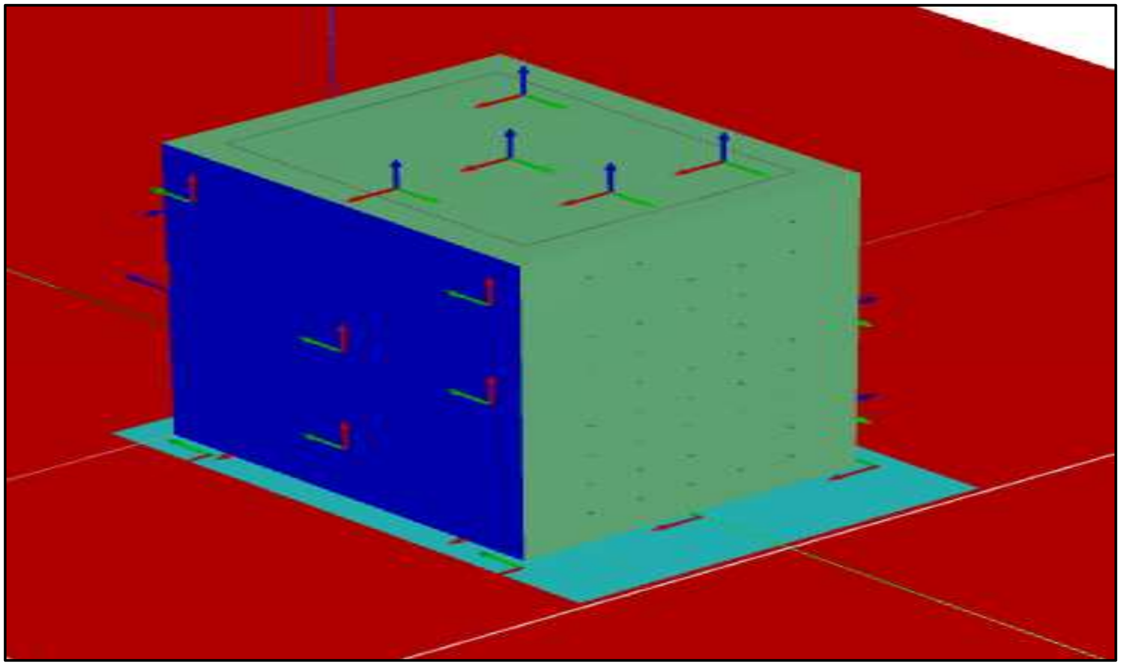

Figure 5. Dimensional Numerical Model

Table 1. Properties of Material and Specifications

Parameters	Backfill	Footing
Material	Drained	Total Stress
Drain Condition	Drained	Non-Porous
Plaxis 3D	Mohr-Coulomb	P.C.C Pad
Unit Weight	19 KN/m³	24 KN/m³
Young's Modulus, E	10x103 KPa	60x106 KPa
Poisson's Ratio, ν	0.35	0.29
Cohesion, c	2 KPa	400 KPa
Angle of Friction, ∅	29°	35°

Table 2. Properties of Wall Facing and Specifications

Parameters	Values
Material (Plaxis 3D)	Plates
Thickness, t	2mm
Width, w	0.9m
Unit Weight	24 KN/m3
Modulus of Elasticity, E	30x106 KPa
Poisson's Ratio, ν	0.15
Cross-sectional area, A	4m m2
Height, h	1.5m

Table 3. Reinforcement Material

Parameters	MSE Model wall
Reinforcement Material(Plaxis 3D)	Deformed steel bars
Thickness, t	12.5mm
Width, w	0.9m
Length L	1.2
Vertical Spacing, Sv	0.15m
Horizontal Spacing, Sh	0.15m
Area of cross section, A	0.20m2
Normal Stiffness, EA	25.8 KPa

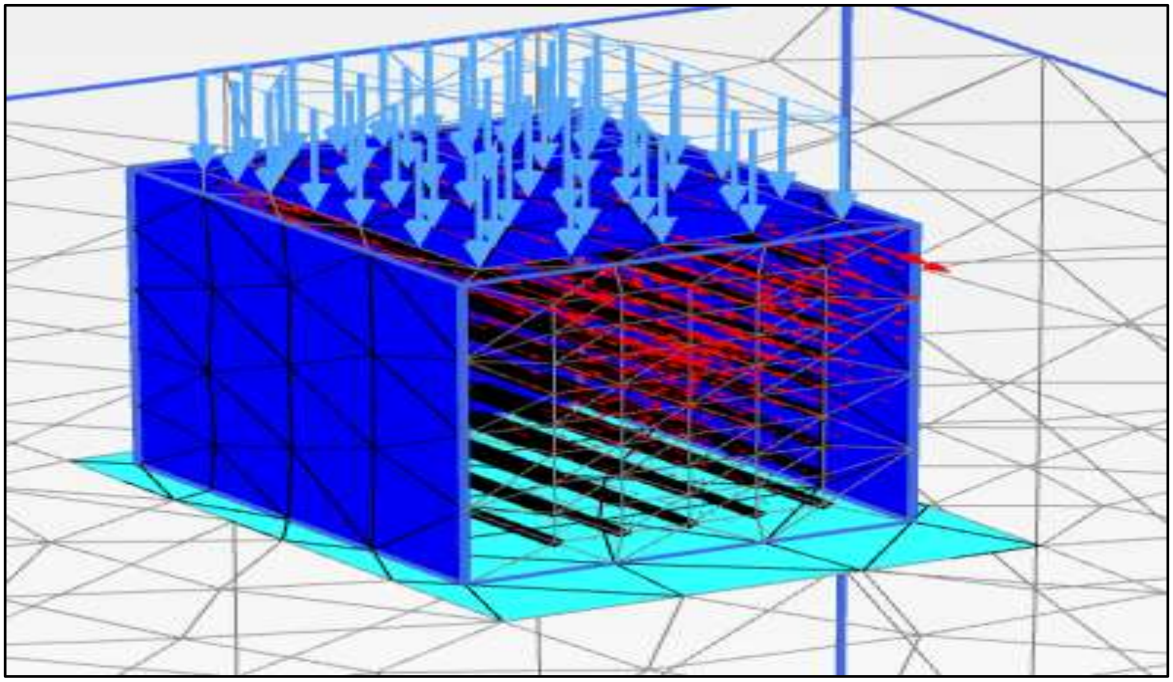

Figure 6. Model with reinforcement

Results:

Model with Reinforcement

After selecting the type of mesh and assigning properties to the Model, Both models are run through the numerical analysis in order to get the maximum deflection in staged construction phase and finally we get analyzed model, which is shown in the figure 7 and 8.

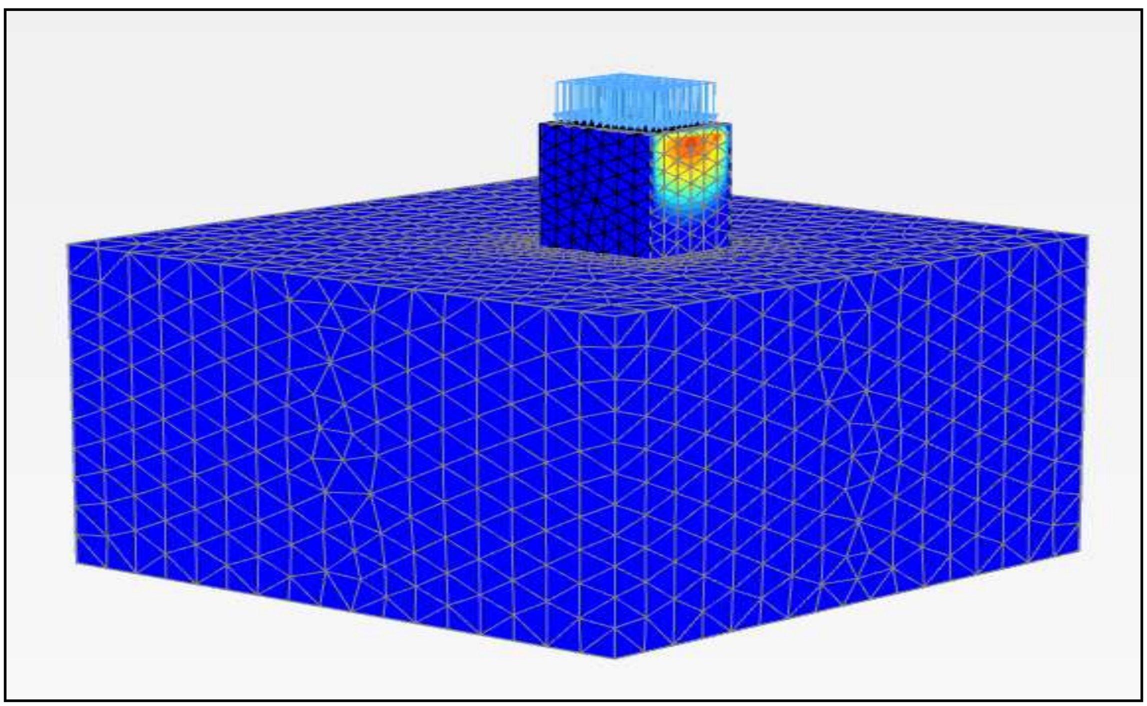

Figure 7. Fine Mesh for Model with Reinforcement

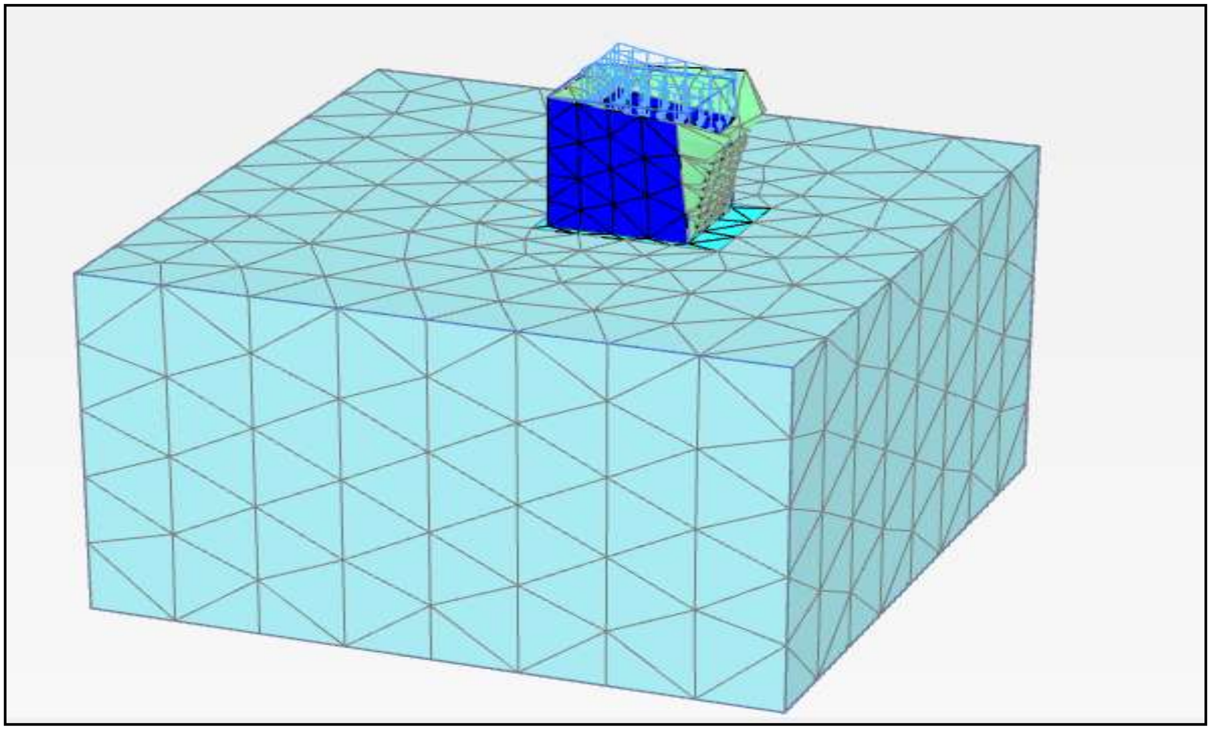

Figure 8. Coarse Mesh for model with Reinforcement

Figure 8. Shows lateral displacement of model after analysis.

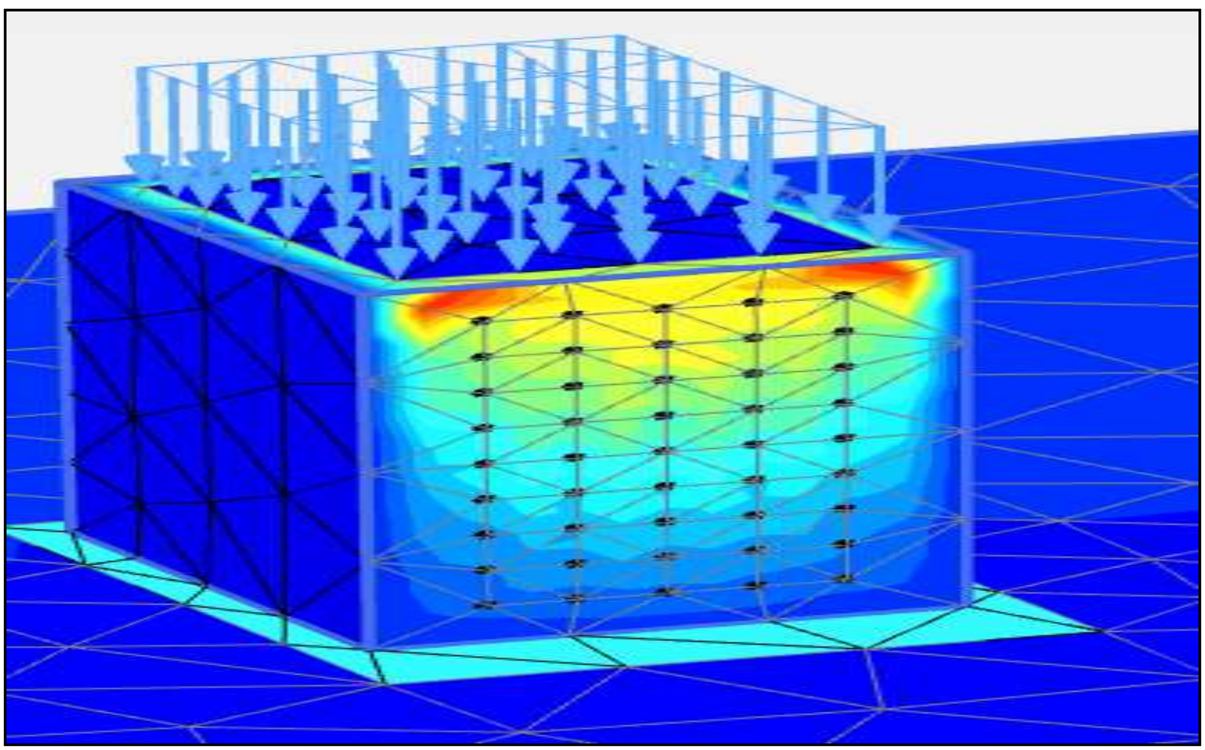

Figure 9. Analyzed model with reinforcement

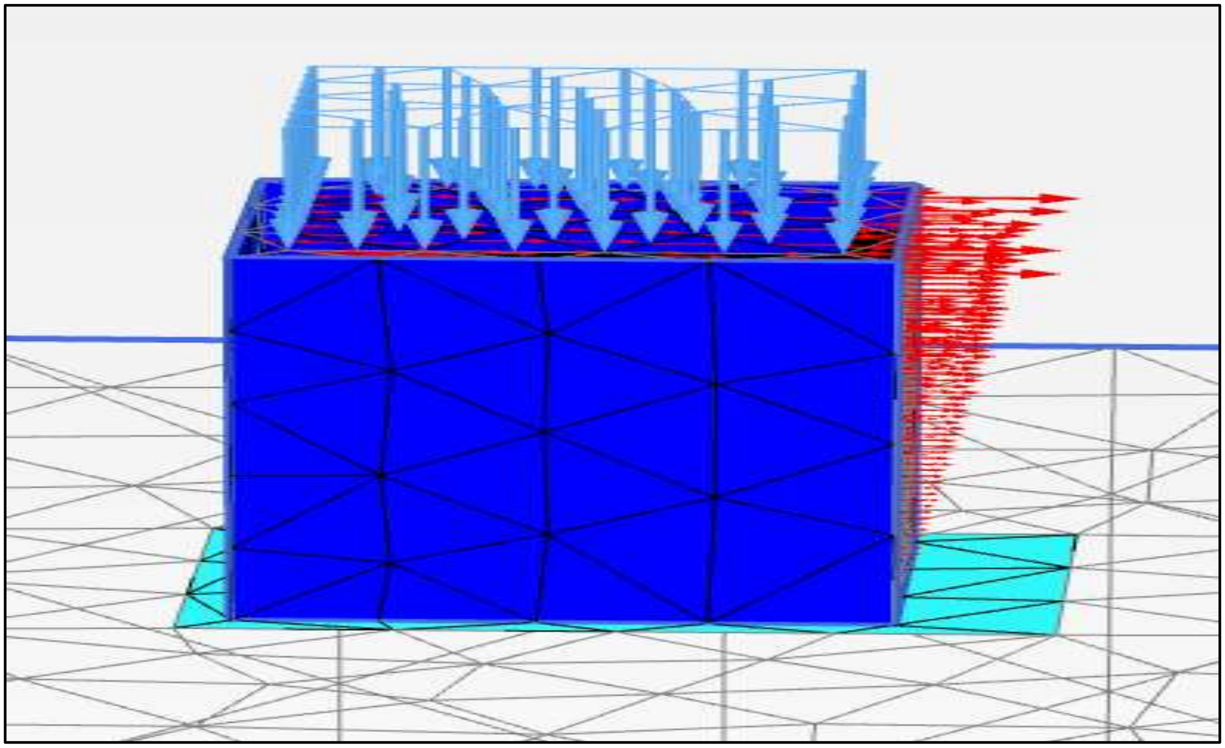

Figure 10. Analyzed model with reinforcement

Model with reinforcement under a maximum load of 80 KPa shows a considerable deflection of the backfill material which is shown in figure 4, 5. From the above figures the deflection in model with reinforcement is clearly visible, so the measured deflection in model is given in table below.

Table 4. Values of deflection compared to depth

Depth	Deflection
1.5m	3.7x10-3
1.2m	3.6x10-3
1.0m	3.3x10-3
0.8m	2.7x10-3
0.6m	1.8x10-3
0.4m	1.4x10-3
0.2m	0.15x10-3

From the above mentioned results obtained from the analyzed model with reinforcement, the maximum deflection or deformation is observed at the top of the wall i.e. 1.5m.

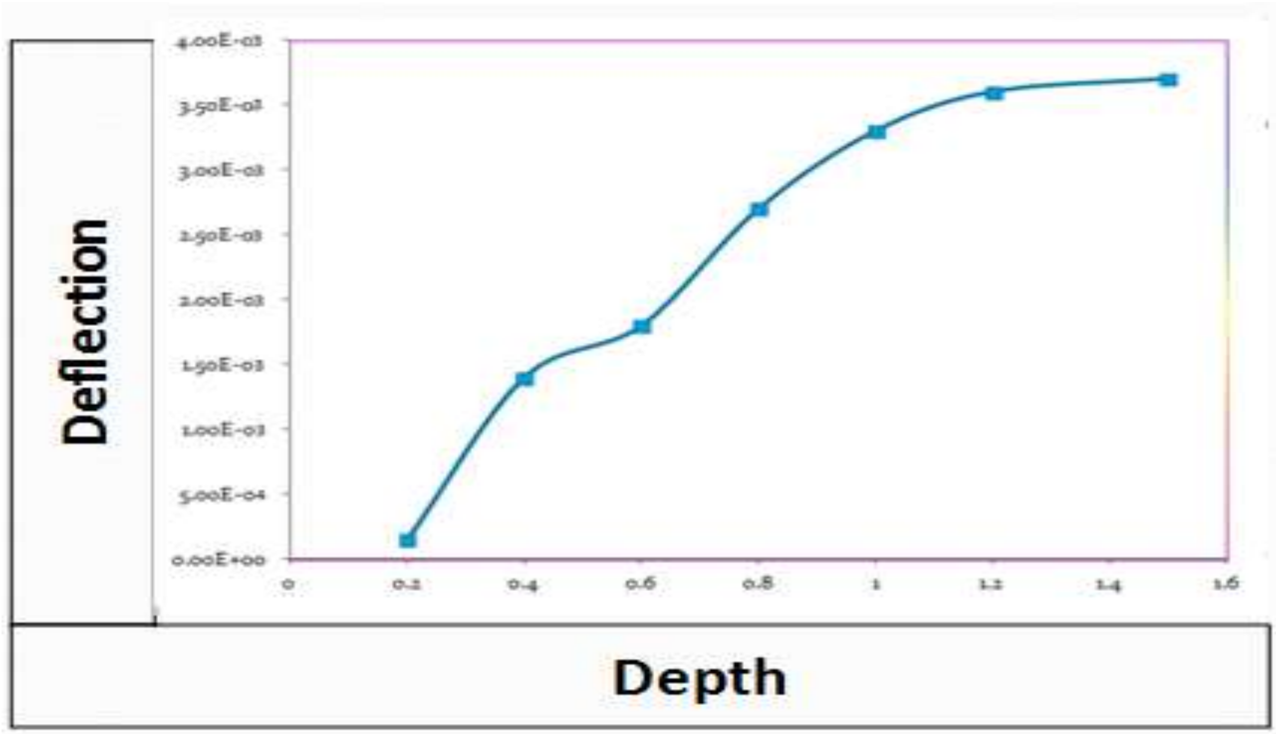

Figure 11. Graph of Depth Vs Deflection

A Graph between Depth Vs Deflection is drawn from the above table to show the results obtained from model with reinforcement graphically.

It can be observed clearly from the above graph that deflection or deformation in model appears to be highest at top of wall and further decreasing with decrease in depth and deflection becomes almost zero at bottom of the model which shows the influence of normal load on top of the backfill. The maximum deflection or deformation is observed at the top of the wall ie 1.5m, where deflection is observed to be 3.7x10-3m, at height 1.2m deflection is observed to be 3.6x10-3m and as the the depth of the model decreases the deflection is observed to be lowered. At depth of 1m, deflection is 3.3x10-3m, At 0.8m deflection appears to be 2.7x10-3m, At 0.6m deflection is 1.8x10-3m, At 0.4m deflection is 1.4x10-3m while at 0.4m the deflection appears to be 0.15x10-3m. In fact, deflection becomes almost zero at the bottom of model as shown in the above table.

Conclusions:

1. Deformed steel bars can be used in MSE wall instead of geosynthetic
2. The Model reinforced with deformed steel bars shown less deflection.
3. Tire shred can be used as backfill material as they light weighted, inexpensive and having good qualities of drainage.

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