"EFFECTS OF DIFFERENT BACKFILL ON REINFORCED MSE WALL"

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ABSTRACT

A mechanically stabilized earth (MSE) wall acting as flexible element is able to resist loading and deformation of the wall due to interaction between the reinforcement and backfill material. Shall have good compressive strength and reinforcement have the capacity to resist/transfer the load so that Geo-synthetic reinforced soil wall have been used successfully as earth retaining structure. A model study on MSE wall is carried out to study of load displacement behavior of the wall. Model size of 990mm X 710mm X 750mm, making from MS angle section and side wall are from acrylic sheet for observation of the ME wall. For the finding the interaction between reinforcement and backfill material modified box shear has been done at the laboratory. In MSE wall material use as backfill are silty sand, poorly graded sand and silty sand in dry condition, which are filled in model at different relative densities which are 40%, 55%, 70% and 85%. Reinforcement length, spacing, stiffness, type and geometry are constant during all the tests on MSE wall. Axial loading is applied through the hydraulic on footing plate and the study of the deformation of facing panel and settlement of the footing plate.

Keyword: - *Load-Displacement1, Slope stability2, Geo-synthetic3, Relative density4, MSE wall5.*

1. INTRODUCTION

Use of mechanically stabilized earth (MSE) wall retaining walls has gained popularity as an alternative to conventional cast in-place concrete walls because of its cost effectiveness, less site preparedness and is technically more feasible compared with conventional concrete walls. The stability of the MSE wall depends on the frictions and bearing resistance between the reinforcing elements and the soil. Reinforcements are placed in layers in the backfill soil. The type of reinforcement and facing of a MSE wall is varied depending on the site condition, purpose of application, and wall height. The performance of the MSE wall strongly depends on the behavior of the backfill soil and reinforcement materials used in their construction.

1.1 Reinforcement Length

The Author has carried out experimental study on the performance of MSE wall on model size of 1.5m (L) X 0.4m (W) X 0.8c (H) in static and dynamic loading, taking influence factor, length of Geo-grid as a reinforcement, offset distance of strip footing and connection mode between Geo-grid and facing. Experimental work performing with the size of footing is 120mm × 150mm and 600mm × 700mm and thickness 25mm.The experiment result showed that with 0.7H (H= height of RE wall) long reinforcement reached maximum bearing capacity with both mechanical connection and frictional connection at the offset distance 0.3H and 0.4H respectively. The ratio of the lateral deflection of the RE wall facing to the height of the wall was generally smaller than 2% with reinforcement length 0.7H and for 2H reinforcement length deformation smaller than 1%. **[1]**

The excessive movement of the MSE wall may be a following factors, backfill as the clayey sand poor water presser developing without the drainage facility and if the facility of dissipate of the poor water pressure will not provide in the wall it possible cause of failure of the wall. Their inadequate length of the reinforcement which causes of major deformation of the wall. With the clayey backfill long term horizontal movement cause problem in RE wall. **[5]**

1.2 Reinforcement Stiffness

MSE wall height 6m, 8.2m, 10m, and consider construction time 6days, 14days, and 17days respectively. For each height ratios of reinforcement length 0.6H to 0.7H. With variation in space of reinforcement, backfill material and reinforcement stiffness as 500kN/m, 1300kN/m, 2000kN/m, 3200kN/m and 4000kN/m. Results conclude that lateral deformation largely governed by reinforcement stiffness. Increasing the reinforcement strength provided increased stability and bearing capacity in context of constant surcharge or increasing surcharge, respectively. **[3]**

1.3 Reinforcement spacing

This parametric analysis studied the effects of non-uniform reinforcement spacing on bearing capacity and factor of safety of footing placed upon the reinforced soil of MSE walls, as well as the factor of safety of un-surcharged MSE walls. Top- down approach provide most benefit in bearing capacity or stability of MSE wall with surcharge, depend on footing setback distance. In case of un-surcharged MSE walls, the bottom-up approach provides the greatest benefit in term of stability. **[4]**

1.4 Backfill material

The performance of the MSE wall depends on the backfill material and also depend on the construction of the backfill material from soil and rock material. The behavior of the earthen material and their interaction with the reinforcement of the MSE wall are critical importance for wall design and performance MSE wall require good-quality of backfill for the durability, good drainage, constructability, and good interaction of soil with reinforcement. For the clayey sand special requirement good drainage facility to drain out poor water pressure. Amount of water present in the soil that effects on the behavior of the MSE wall. Drainage material were not dissipated sufficient amount of the water, it leads to excessive deformation of the wall and sometime its lead to failure. **[5]**

2. EXPERIMENTAL PROGRAM

2.1 Model and wall configuration

A model test was conducted to investigate the behavior of the RE wall on a rigid foundation subjected to static loading by a hydraulic jack through the footing plate of 12mm thick. The main component of the apparatus included a loading frame with a platform, a test tank, loading plate, hydraulic jack, and mechanical dial gauges. The tank with inside dimensions of 0.99m (length) × 0.71m (width) × 0.75m (height), was made of steel sheet in back and bottom. And both sides of tank 10mm thick polyethylene plastic sheets for the observation. Fig-1 shows the schematic diagram of the test apparatus.

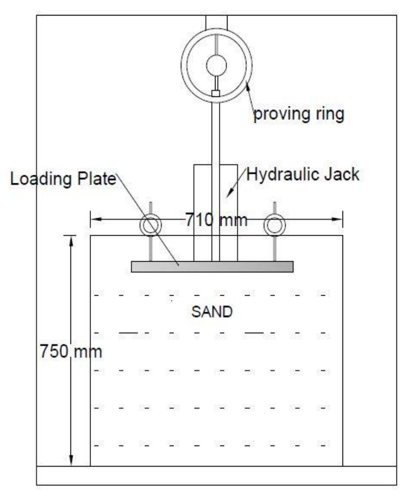

Fig- 1 Schematic diagram of the test apparatus

2.2 Footing and Backfill

A steel plate of width was used 300mm × 300mm and thickness of 12mm for the load distribution. As a backfill material there different grade of sand are silty sand (SM), poorly graded sand (SP) and well graded sand (SW) and which are filled at the different relative density of 40%, 55%, 70% and 85%. Achieving 40% relative density by the rain-fill method (Fig-2) and other remaining (55%, 70% and 85%) relative density achieving by vibratory motor (Fig-3). Stage filling is taking in consideration to achieving proper relative density. Index property of the different backfill material is finding as per the IS – 2720 Indian standard code. Different index properties are grain size distribution, specific gravity, and relative density.

Fig- 2 Rain fill method

Table-1 Index property of Silty sand

Grain size distribution (IS: 2720-4)	Specific gravity (IS: 2720-3)	Relative density (IS:2720-14)
Cu = 6.75 Cc = 0.818	2.60	ρ_{dmax} = 18.12kN/m^3 ρ_{dmax} = 15.77kN/m^3

Table-2 Index property of Poorly graded sand

Grain size distribution (IS: 2720-4)	Specific gravity (IS: 2720-3)	Relative density (IS:2720-14)
Cu = 1.8 Cc = 0.80	2.64	ρ_{dmax} = 17.75 kN/m^3 ρ_{dmax} = 15.75 kN/m^3

Table-3 Index property of well graded sand

Grain size distribution (IS: 2720-4)	Specific gravity (IS: 2720-3)	Relative density (IS:2720-14)
Cu = 6.19 Cc = 1.11	2.7	ρ_{dmax} = 18.81 kN/m^3 ρ_{dmax} = 17.15 kN/m^3

2.3 Geo-grid as reinforcement and facing panel

A Geo-grid is obtained having an ultimate tensile strength 50KN/m from the STRATA Geo - system (India) P.v.t. Ltd. Spacing and length of reinforcement of the 0.4H and 0.7H, respectively. The wooden facing panel used in reinforced earth wall model is thickness 35mm of appropriate size as per requirement in BS 8006. For the connection between geo-grid and facing panel L steel section clamps are used, this joint was known as mechanical connection show in Fig-4. The importance of connection between geo-grid and panel has been widely recognized in the application of RE walls. In this study mechanical connection was used for the joint between geo-grid and facing panel by steel clamps. The mechanical connection was created by L shape section jointed back to back between clamps geo-grid was placed and fixing it by Steel nut bolt dia. of 10mm. Under such a condition, the geo-grid would not be pulled out from the facing between the clamps. Schematic diagram for the place of the reinforcement, dial gauges, loading plate is shown in Fig-5.

Fig- 3 Vibratory motor

Fig- 4 Mechanical connection of geo-grid with steel clamps

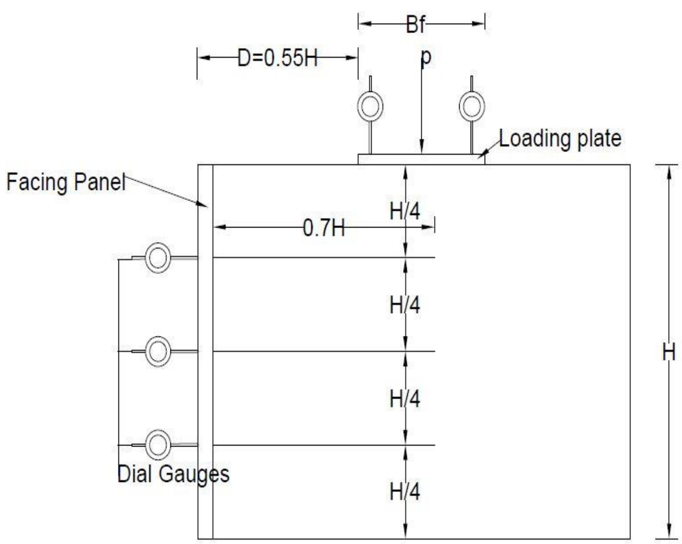

Fig- 5 Schematic diagram of MSE wall

Table-4 Properties of the geo-grid (provide by the manufacturer)

Index properties	
Ultimate tensile strength (kN/m)	50
Minimum rib thickness (mm)	1.5
Aperture dimensions (mm)	40 x 35

2.3 Modified shear box for interface friction between sand and geo-grid

For the finding interaction between the geo-grid and backfill material modified box shear test is conducted at the laboratory. The geo - grid is sandwiched between the two layers of the of the backfill material at the proper relative density.Fig-6 show the arrangement of modified box shear. Table-5 shows different angle of friction at different relative density with and without geo-grid. Interface friction shows the improvement in angle of friction between the soil particles and reinforcement as geo-grid. Interface friction also depend on the size, type, and material of the reinforcement and also mostly the type of the backfill material.

Fig- 6 Arrangement of modified box shear

Table-5 Angle of friction and interface friction at different relative density by modified box shear.

Backfill material	Relative Density	Angle of friction	Interface friction
Silty Sand (SM)	SM_40	30°	33°
	SM_55	32°	35°
	SM_70	33°	37°
	SM_85	34°	40°
Poorly Graded Sand (SP)	SP_40	32°	35°
	SP_55	34°	38°
	SP_70	35°	40°
	SP_85	36°	42°
Well Graded Sand (SW)	SW_40	33°	37°
	SW_55	35°	39°
	SW_70	36°	41°
	SW_55	38°	43°

2.4 Facing panel

Wooden material was used as the facing panel for the flexibly of the panel in MSE Wall. Thickness of facing panel was 35mm and size of panel describe below. For joint of wooden facing panel grove are made in of 18mm as shown in Fig: 8

(i) 177.5 mm X 300 mm (4 no) (ii) 177.5 mm X 350 mm (4 no) and (iii) 177.5 mm X 90mm (4 no).

Fig- 7 Wooden facing panel

3. TEST PLAN

Set up MSE wall model at the laboratory and pre-pair with pain and the mandatory marking on it. Than model tank filling with different backfill material (SM, SP and SW) at the different relative density (40%, 50%, 70% and 85%) in the model density achieving by filling fix amount of weight of backfill in to the single layer, all four layer of backfill fill by that method. 40% relative density achieving by the method of the rein fill to avoid the compaction of the below layer of the backfill material. In model other relative density (55%, 70% and 85%) achieving by the vibratory compaction motor. Size of footing plate is 300mm X 300mm and 12mm thick which is place at the top of the material and its horizontal distance from the wooden facing panel is 0.55H (H is height of the wooden facing wall). Geo-grid is use as the reinforcement in the MSE wall and placing at the 0.4H vertical distance of the facing panel. Geo-grid is mechanically connected with the two L section clamps and fixing with 10mm bolt. 10mm bolt is connecting clamps with wooden facing panel. Axially load is applied by the hydraulic jack on the backfill material through the footing plate. Using proving ring capacity up to 100kN to maintain the loading at the constant interval of the 2kN. After the loading of the 2kN displacement being constant than the reading are observed from the mechanical dial gauges. Two dial gauges are place at the top of the footing plate to observe settlement of the footing plate and five dial gauges are place on the facing panel to observe the horizontal displacement of the facing panel.

Table-6 Location of dial gauges on the facing panel.

Designation	D31	D32	D4	D51	D52
Horizontal Distance (mm) L/R	175	525	350	175	525
Vertical Distance (mm) T/B	555	555	370	185	185

Note: - Horizontal distance is measured from left to right and vertical distance is measured from bottom to top.

After the all the arrangement on the model of MSE wall of dial gauges, footing plate, hydraulic jack on it, proving ring etc. Than loading is increase gradually 2kN up to the 30kN and observe the deformation of the facing panel and noted the reading of the mechanical dial gauges. Maximum deformation of the facing panel is observed at the center of the facing panel.

Fig- 8 Location of mechanical dial gauges on the facing panel

4. TESTS RESULTS AND DISCUSSION

The tests are conducted on MSE wall with different backfill as silty sand (SM), poorly graded sand (SP) and well graded sand (SW) at the different relative density are 40%, 55%, 70% and 85%. Load displacement are obtained for backfill at different relative density. Displacement after part-tensioning to remove slack in joint is 3 to 15mm as per BS 8006. In reinforced earth wall geo-grids are used having ultimate tensile strength 50kN/m. It is placed in three layers at 185 mm vertical spacing. The length of the geo-grid provided in the reinforced earth wall is 525 mm. All the parameters in this reinforced earth wall model such as reinforcement length, spacing, type of facing panel, size of facing panel are same for different backfill material and relative density. Test were performed on reinforced earth wall model and result obtained from test presented following.

4.1 Settlement of footing plate of MSE wall.

The loads versus displacement characteristic obtained from the tests are compared below in graph for different backfill material and different backfill relative density at particular dial gauges location.

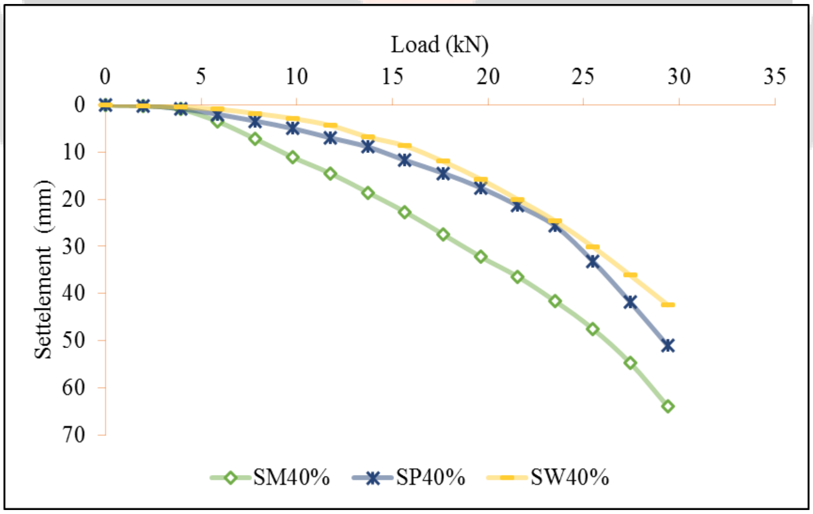

Fig- 9 Load versus Settlement at Id=40%

Maximum settlement is observe at the 40% relative density. Maximum settlement observe for the silty sand and minimum for the well graded sand.

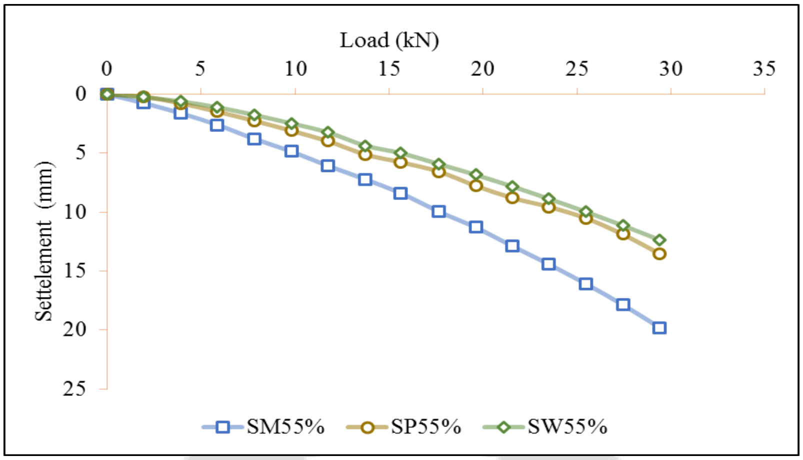

Fig- 10 Load versus Settlement at Id=55%

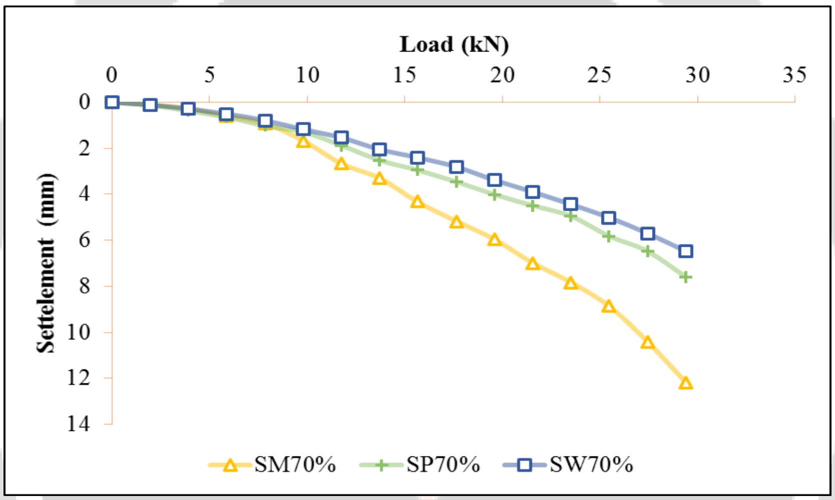

Fig- 11 Load versus Settlement at Id=70%

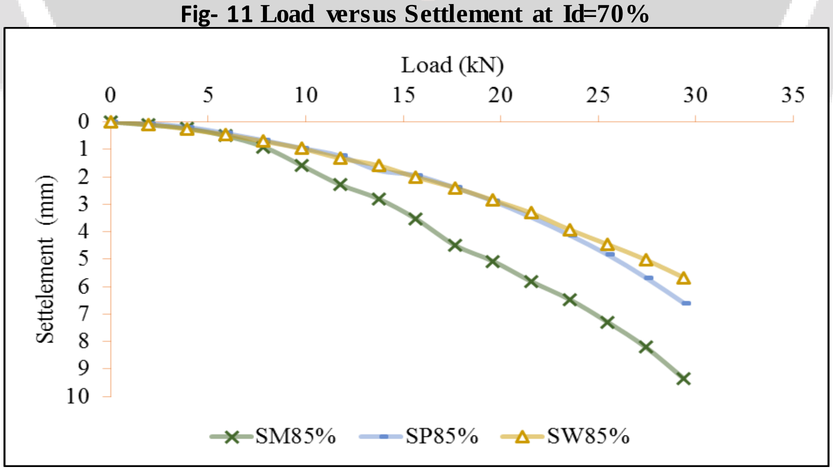

Fig- 12 Load versus Settlement at Id=85 %

Maximum settlement 63.97 mm is observe at 40% relative density for silty sand and minimum settlement 5.67mm at 85% relative density for the well graded sand for the loading by hydraulic jack up to 30kN. Other detail settlement are shown in Fig-9, 10 11 and 12. With increasing relative density decreasing of the settlement of the footing plate for the all type of backfill material but rate of settlement depends the type on the backfill material, With grater angularity of the material give reduction in the settlement of footing and going toward the near of clay particle increasing in the settlement reducing of load caring capacity of the MSE wall. Average 18% of reduction at the 40% relative density for backfill SM to SP to SW. for the 40% of relative density during the loading particles of backfill material comes over footing plate its show the bearing failure of the that sand, that failure observes at the low relative density 40% for the silty sand, poorly graded sand and well graded sand.

4.2 Displacement of facing panel of MSE wall.

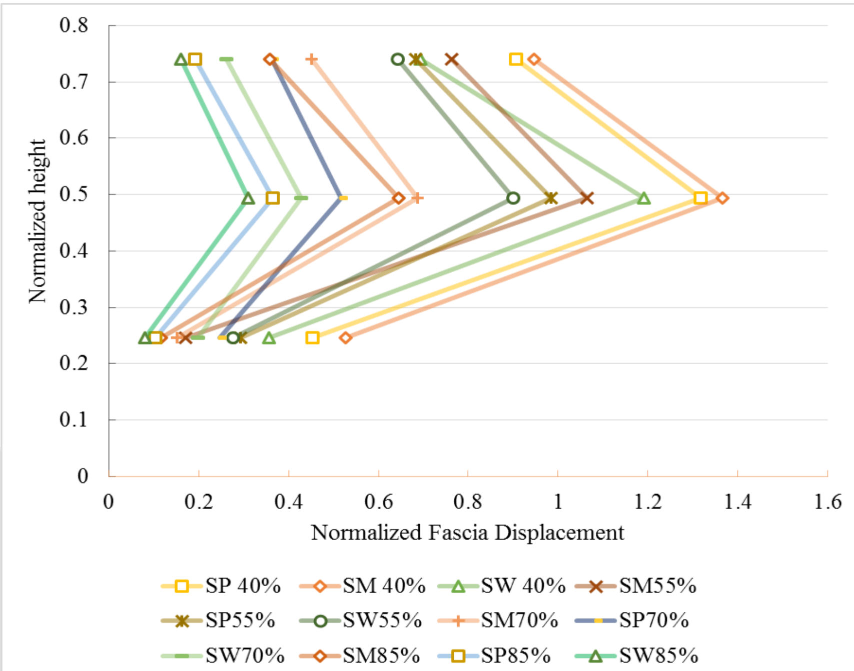

Fig- 13 Normalized fascia displacement

Where δ is displacement and y is distance from bottom of the wall. Maximum normalized fascia displacement is noted for silty sand at 40% relative density and minimum fascia displacement is noted for well graded sand at 85% relative density. Results shows that displacements are for different the backfill material at different relative density. For the well graded sand low displacement of fascia panel with respect to SP and SM. Interaction of geo-grid with the backfill material play an important role, with increasing relative density of the backfill material interaction with reinforcement as geo-grid is increase. Fig-13 shows the displacement of the facing panel at the three various height for the backfill material silty sand, poorly graded sand and well graded sand at the relative density are 40%, 55%, 70% and 85%. Maximum displacement observed at the center of the facing panel, with increasing relative density reduction in the displacement of the facing panel. Displacement of the facing panel at the bottom is minimum and top panel displacement is more than bottom but smaller than the center. There with increasing relative density developing of the tensile stresses in the reinforcement and its transfer the load active zone to the resistive zone so that the with increasing relative density decreasing in the displacement of panel. Maximum stresses are develop in reinforcement at the center reinforcement.

5. CONCLUSIONS

A reinforced earth wall model having dimension 990 mm x 710 mm x 750 mm was used in this study. There are three different backfill materials such as silty sand (SM), poorly graded sand (SP) and well graded sand (SW), at a different relative density are 40%, 55%, 70% and 85% taken into study. A wooden facing panel having thickness 35 mm are used in a rectangular shape in appropriate size. A reinforced earth wall model having a vertical slope which is reinforced with a HDPE Geo - grid having an ultimate tensile strength of 50 kN/m was used.
The load displacement characteristic of reinforced earth wall was obtained for the different backfill material (SM, SP and SW) at a different relative density, such as 40%, 55%, 70% and 85%. Angle of friction and interface friction obtained by the box shear test in a laboratory. The results of the test were analyzed and the following conclusions were obtained from this study.

- In all types of backfill material maximum displacement is observed at the centre and minimum displacement observed is at bottom and top. A deformation at the top is higher with respect to bo ttom. The deformation observed at the bottom and top are the minimum which may be due to end constraints.
- Change in the angle of friction with the changing relative density of the backfill, at 40% relative density very low angle of friction, it gradually increase with increasing relative density of backfill material. Implementation of Geo-grid in backfill that increases the interface friction between backfill material and geo-grid, for the well graded sand angle of friction are 33°, 35°, 36° and 38° and interface friction are 37°, 39°, 41° and 43° for different relative density of 40%, 55%, 70% and 85% respectively.
- The normalized fascia displacements are observed for 40% relative density at 1.367, 1.318 and 1.190 for SM, SP and SW respectively, at 0.493 normalized heights for 30kN load. Averaged 34% and 65% of less deformation of the top and the bottom facing panel with respect to the center displacement of facing panel. For silty sand (SM) average decrease in displacement at the center with respect to relative density 40% to the 55%, 70%, and 85% are 22% 49% and 53% respectively.
- Minimum displacement at the bottom of RE wall for SM, SP and SW are 0.87mm, 0.77mm and 0.6mm respectively at 85% relative density. For the 40% relative density displacement of bottom facing panel for SM, SP and SW are 3.95mm, 3.395mm and 2.665mm that are 77% high displacement of facing panel than the 85% relative density.

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