E3S Web of Conferences **368**, 02025 (2023)
GeoAfrica 2023
https://doi.org/10.1051/e3sconf/202336802025

Factors affecting the deformation of facing elements for MSE wall design

Mohamed Al Abbady[1]*; *Mohamed* Bahr[1]; *Mohamed* Fouad[1]
[1] Professor of Geotechnical Engineering and Foundations, Al Azhar University, Cairo, Egypt

Abstract The deformation of the Mechanically Stabilized Earth (MSE) walls is one of the key factors which control the design of the MSE walls. In many practical cases, the size of facing panels concrete bedding is increased for high MSE walls. In the present study the effect of the dimensions and stiffness properties of the facing panels concrete bedding on the deformation of the facing elements and the axial forces developed in the geogrid reinforcements are analysed and discussed .
The study has been conducted using a finite element analysis Plaxis-2D. The used model has been verified with data attested in the references, [1]. The geometry of model consists of MSE wall with precast concrete facing panels to support reinforced soil zone.
The results shed the light on the influence of the dimensions and stiffness properties of facing panels concrete bedding on the deformation of the MSE facing panels. The results showed that for the cases considered in the study, increasing the width dimension of facing panels concrete bedding will decrease the deformations of the facing elements without significant changes in the axial forces developed in the geogrid reinforcing elements.

Introduction

Mechanically Stabilized Earth Walls (MSEWs) and Reinforced Soil Slopes (RSSs) are cost-effective soil-retaining structures that can tolerate much larger settlements than reinforced concrete walls [2]. The wall system consists of the original ground, concrete leveling pad, wall facing panels, coping (is used to tie in the top of the wall panels), soil reinforcement, select backfill and any loads and surcharges. All of these items have an effect on the performance of the MSE wall and are taken into account in the stability analysis. A change in any of these items could have a detrimental effect on the wall [3].

Many factors can influence the MSE wall performance and deformation behavior.
A. Hulagabali et al. [4], found that as the unit weight of retained soil increases, there was increase in wall deformations, and as the friction angle of the reinforced and foundation soil increased, wall deformations were reduced with increase in reinforcement length. Also, reinforcement stiffness and length were identified as influential parameters affecting the horizontal movement at a specific MSE wall height. The horizontal displacement decreased with an increase in reinforcement stiffness, length, and backfill soil friction angle at a fixed wall height [1].

*Corresponding Author: PhD. Student, Email: mmagedh@yahoo.com

 https://doi.org/10.1051/e3sconf/202336802025

C. Vieira et al. [5], found that, the pattern of the normalized horizontal displacements and the reinforcement tensile load distribution are largely influenced by facing panel bending stiffness.
The MSE wall concrete bedding (leveling pad) is an important part of the MSE wall system. Figures (1a and 1b) show photos for facing panel concrete bedding [3]. The concrete bedding should be constructed at proper depth so that the minimum embedment depth for walls from adjoining finished grade to the top of the leveling pad should be based on bearing capacity, settlement and stability considerations [6].

The U.S. Department of Transportation (FHWA) [1] stated that, the purpose of the facing panels leveling pad is to serve as a guide for facing panel erection and is not intended as a structural foundation support. The (FHWA) recommended that “A concrete leveling pad should have minimum dimensions of 150 mm (6 inches) thick by 300 mm (1 ft) wide and should have a minimum 13.8 MPa (3,000 psi) compressive strength” [1]. It is mentioned in the same publication that “Full height precast facing elements may require a larger leveling pad to maintain alignment and provide temporary foundation support.

It is intended in this research work to study the effects of Facing Panels Concrete Bedding (FPCB) dimensions and stiffness properties on deformation of facing panels and on the axial forces developed on geogrid reinforcement .

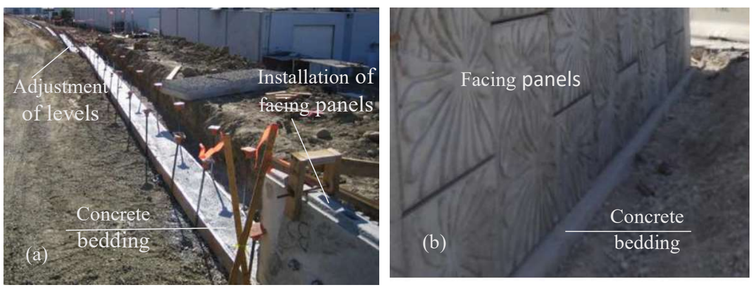

Fig. 1. (a) Concrete bedding preparation. (b) Facing panels installed on concrete bedding.

Verification of the output data

G. Kibria et al. had made a research work “Influence of Soil Reinforcement on Horizontal Displacement of MSE Wall” [1].

In their research work, a case study is presented which is MSE wall located on State Highway 342 in Lancaster, Texas. Two inclinometers were installed at the site to monitor any additional movement of the MSE wall. In their study, a Finite Element (FE) program “Plaxis 2D 2010” was used to simulate horizontal displacement and stability of the MSE wall. It was observed that the numerical modeling results were in good agreement with inclinometer results. Their research includes a parametric study to identify the effects of reinforcement length and stiffness on horizontal movement at varied wall heights and backfill conditions.

Since the results of the FE model used in the previous research work [1] were in good agreement with the results of the actual movement of the real MSE wall. Certain model used in their parametric study is used in the current research work. The model is shown in Figure (2) where the height (H) of the MSE walls is 8m. The reinforcement length (L) to MSE height (H) L/H ratio is taken as 0.8. Tables (1a) and (1b) show the soil and structural elements parameters used in the model [7]. Full definition of the FE model is presented later in the next section.

After developing the model, different linear stiffness values for reinforcement were used by the same manner mentioned in the previous research work [1]. Figure (3) shows the relation between Linear stiffness of reinforcement on logarithmic scale and maximum horizontal displacements on the facing elements of MSE wall for both models.

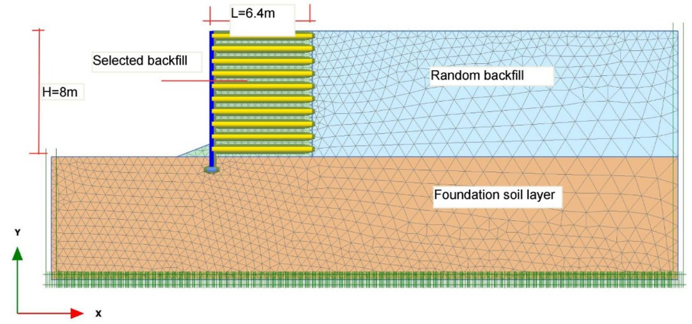

Fig. 2. The finite element model used in the study

Definition of the model

After verification of the FE model, the study was conducted using FE program (Plaxis 2D). The analysis was performed on plain strain (2D) conditions.
The geometry of FE model consists of MSE walls 8m height (H). The soil properties for the selected soil in the MSE wall zone, random soil zone behind the back of MSE wall and the foundation soil are shown in table (1a). Ground water level is considered deep enough, and does not affect stability.
The reinforcements are considered to be geogrid strips with properties provided on Table (1b). The length of geogrid reinforcement to the height of the wall ratio (L/H) is taken as 0.8.
The selected reinforcement length L = 0.8H is considered within the (L/H) range recommended by FHWA [2]. Vertical distance between the reinforcement layers was taken as 0.8 m with the first layer of strips being placed at 0.5 m from the foundation level.

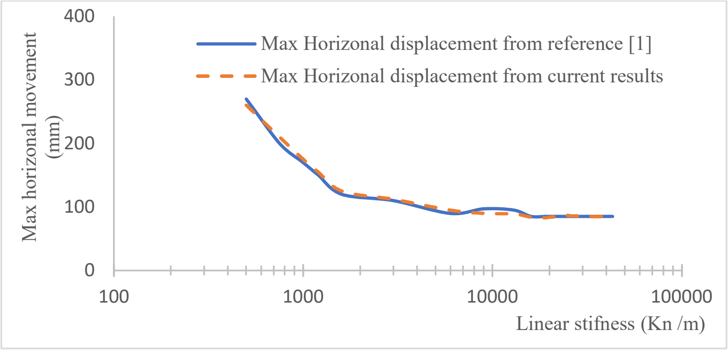

Fig. 3. The relation between Linear stiffness of reinforcement and maximum horizontal displacements on the facing elements of MSE wall. (Comparison between results for both studies)

 https://doi.org/10.1051/e3sconf/202336802025

Table (1a and 1b) Soil and structural elements parameters used in the model

	Select backfill	Random backfill	Foundation soil	Structural element	Axial stiffness (kN/m)	Bending stiffness (kN m^2/m)	ν Poisson's ratio
ϒ (unsaturated) (kN/m^3)	18.8	18.8	16				
ϒ (saturated) (kN/m^3)	22	22	16	Facing panel	3.08X10^6	4017	0.2
Φ (angle of friction) (degree)	34	30	27				
C (cohesion) (kN/m^2)	1	1	8.45	Geogrid	3000	_____	_____
Ψ (dilatancy angle) (degree)	4	0	0				
E (modulus of elasticity) (kN/m^2	12500	10000	5500				
ν Poisson's ratio	0.32	0.3	0.3				
(1a) Soil Parameters used in the Model				(1b) Structural Element Parameters used in the Model			

The facing panels is considered to be precast concrete panels with properties provided on Table (1b). The Facing Panels Concrete Bedding (FPCB) are considered as non-reinforced concrete bedding. Both facing panel and FPCB were represented in the model as Elastic Plate elements with Isotropic properties. The axial stiffness (EA) and bending stiffness (EI) for the FPCB is shown in Table (2). The Poisson's ratio (v) was taken as 0.2. The Ethylene Propylene Diene Monomer (EPDM) bearing pads between facing elements panels was not taken into consideration in the present study to keep the same geometry of the model used in the verification process. No surcharge loads were applied on the model.

Table (2) Stiffness properties used in the study cases for Facing Panels Concrete Bedding (FPCB)

FPCB thickness (m)	**0.15**	**0.15**	**0.2**
E (kN /m^2)	16.0X10^6	24.5X10^6	24.5X10^6
EA (kN/m)	2.4X10^6	3.675X10^6	4.9X10^6
EI (kN m^2/m)	4500	6890	16333.33
where E: Modulus of elasticity			
A: Cross section area			
I: Moment of inertia			

In the analysis, the material model for all types of soil used in the study was selected to be Mohr-Coulomb and the drainage type selected as Drained. The elastic-plastic Mohr-Coulomb model involves five input parameters, i.e., E and ν for soil elasticity; ϕ and c for soil plasticity and ψ as an angle of dilatancy [8].

The reinforcement was represented in the model as elastic Geogrid elements with Isotropic properties. To represent the interaction between soil / Geogrid and soil / plate elements, interface elements were added to the model.

The roughness of the interaction is modelled by choosing a suitable value for the strength reduction factor (R_{inter}) assigned to the surrounding material, [8]. This factor relates the interface strength to the soil strength (friction angle and cohesion). The possible values for R_{inter} are from 0.01 to 1. In the current study R_{inter} was taken as 0.67.

Vertical boundary was located at 23.36 m behind the back of the MSE wall and horizontal fixities (ux = 0) was imposed on vertical boundary of the model. The bottom boundary was located at 7.8 m from the bottom of MSE wall and full fixities (ux =uy = 0) were imposed on the bottom boundary of the model.

 https://doi.org/10.1051/e3sconf/202336802025

The mesh consisted of 15-node triangular elements, with 12 stress points each. Mesh generation was fine, leading to average element size 0.64 m

The FPCB is considered as continuous in the perpendicular plane to the 2D model plane. Three sets for stiffness parameters EA and EI are considered for the FPCB in the study and shown in table (2). Where E is the modulus of elasticity, I is the moment of inertia and A is the cross section area for plate element.

Four cases for FPCB width dimension are considered for each set of stiffness properties shown in table (2). In the first case the width of FPCB is taken as 0.4m and is changed to 0.6, 0.8 and 1.0m in the following cases.

The analysis is performed for all cases and the maximum horizontal displacement (Uxmax) and displacement values (Ux and Uy) at the upper top point of the MSE facing panel are obtained. Also, the maximum developed axial force in the geogrid reinforcements (Nmax) is determined for each case.

Results and discussions

Figures (4), (5) and (6) show the output results for horizontal and vertical displacements for facing panels. It shows the relation between the FPCB width dimension at different stiffness parameters values for FPCB (EA and EI) versus the facing panels displacements at the upper top point (Ux, Uy) and the maximum horizontal displacement at the MSE facing panels (Uxmax.) respectively.

The results showed that the vertical location (h) for the maximum horizontal displacement at the MSE facing panels (Uxmax) is changed slightly by increasing the width dimension of the FPCB. Considering that Uxmax located at the vertical distance measured from the lower point of the MSE wall (h) and (H) is the MSE wall height. At width dimension equals to 0.40m the point where Uxmax is occurred is located at h/H equals to 0.56. By increasing the width dimension to 1.0m the point of Uxmax is located at h/H equals to 0.45

The results showed also that the horizontal and vertical displacements measured at the upper top of the MSE facing panels are decreased by increasing the width of the FPCB. At FPCB thickness and width dimensions equal to 0.15m and 0.40m respectively (stiffness properties EI=4500kN m2/m and EA=2400000kN/m), the resulting Ux and Uy are equal to -0.100m and -0.160m respectively. The maximum horizontal displacement (Uxmax.) is equal to -0.111m. By keeping the same stiffness properties (EI and EA) and FPCB thickness and increasing the FPCB width to 1.0m, the resulting Ux and Uy are decreased to -0.070m and -0.132m respectively. Also, the maximum horizontal displacement (Uxmax.) decreased to -0.090m. At FPCB thickness and width dimensions equal to 0.20m and 1.0m respectively (stiffness properties EI=16333kn m2/m and EA=4900000kN/m), the resulting Ux and Uy are equal to -0.066m and -0.132m respectively. The maximum horizontal displacement (Uxmax.) is equal to -0.089m. The results show that the analyzed horizontal and vertical displacements decreased by increasing The FPCB width but their values did not change by increasing the FPCB thickness.

To study the impact of increasing the thickness and width dimensions for the FPCB on the maximum values for axial force (N_{Max}) in geogrid reinforcements, it was noted that there are no adverse impacts on the axial forces of geogrid reinforcements. As shown in Figure (7) the results show that the maximum axial force value N_{Max} developed in the MSE geogrid reinforcements is slightly increased by increasing the width of the FPCB. At FPCB width equals to 0.4m the resulting N_{Max} is equal to 19.294kN/m. By increasing the FPCB width to

1.0m the resulting N_{Max} is slightly increased to 20.926KpkN/m. At FPCB thickness and width dimensions equal to 0.20m and 1.0m respectively, the resulting N_{Max} is equal to 21.181kN/m.

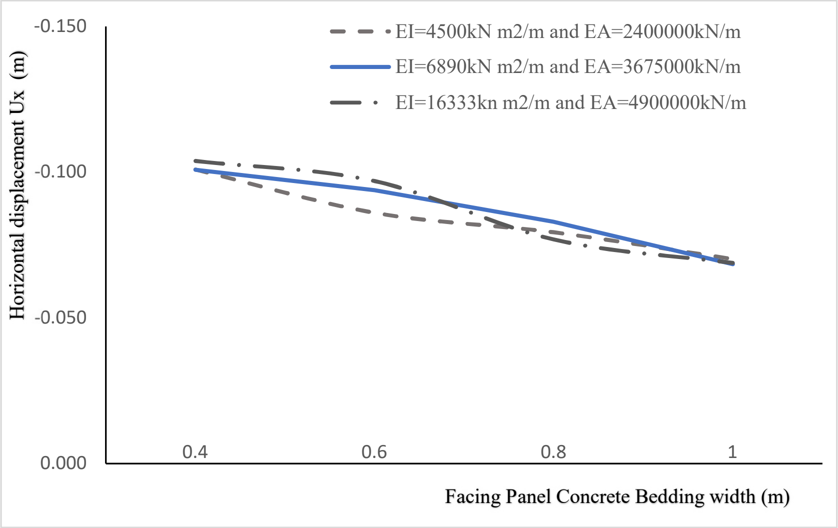

Fig. 4. The relation between the FPCB width versus the horizontal displacement (Ux) at the upper top point of the MSE facing panels at different stiffness parameters values for FPCB (EA and EI)

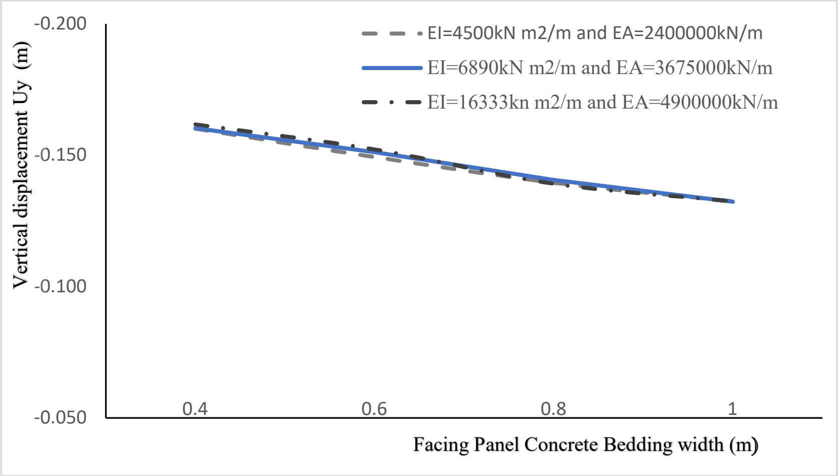

Fig. 5. The relation between the FPCB width versus the vertical displacement (Uy) at the upper top . .point of the MSE facing panels at different stiffness parameters values for FPCB (EA and EI)

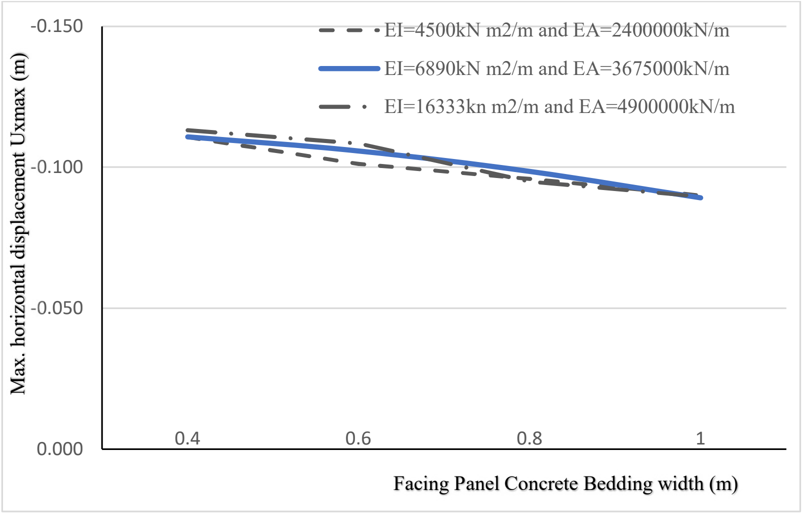

Fig. 6. The relation between the FPCB width versus the Max. horizontal displacement (Uxmax) at the MSE facing panels at different stiffness parameters values for FPCB (EA and EI)

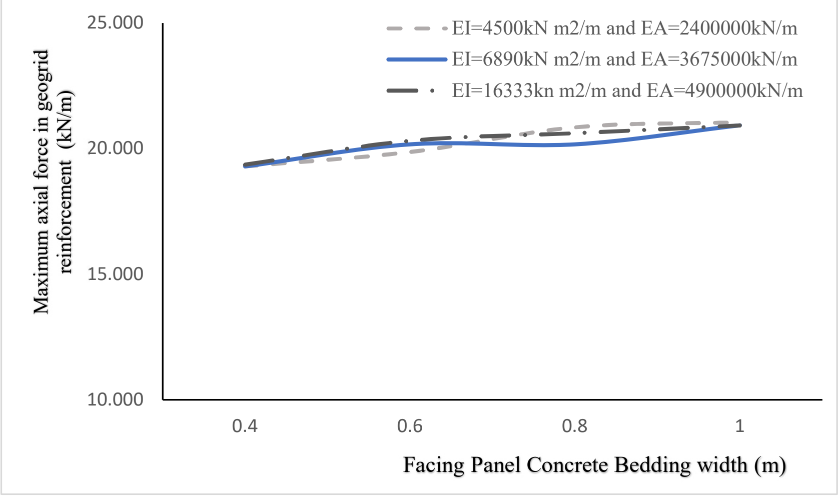

Fig. 7. The relation between the FPCB width versus maximum axial force value N_{Max} developed in the MSE geogrid reinforcements at different stiffness parameters values for FPCB (EA and EI).

 https://doi.org/10.1051/e3sconf/202336802025

Summary and Conclusion

The Facing panels concrete bedding is important part of MSE wall system. The current study was conducted using a numerical FE analysis (Plaxis 2D) version 20. Considering the concrete bedding is continuous in the longitudinal direction of MSE wall. The study showed that the horizontal, the vertical deformations occurred at the upper top of the MSE facing panels and the maximum horizontal displacement of the MSE facing panels were decreased by increasing the width dimension of facing panels concrete bedding. But no significant change in values of the above-mentioned displacements was occurred by increasing the concrete bedding thickness from 0.15m to 0.2m. The study showed also that, by increasing the width dimension of facing elements concrete bedding to 1.0m, there was no significant change on the axial forces developed in geogrid reinforcements.

References

1. G. Kibria, M. Hossain, M. Khan, *Influence of soil reinforcement on horizontal displacement of MSE wall*. International Journal of Geomechanics, Vol. **14**, No. 1, February (2014).
2. R. Berg, B. Christopher, N. Samtani, *Design and construction of mechanically stabilized earth walls and reinforced soil slopes,* Vol. **I**, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-NHI-10-024 FHWA GEC 011, November (2009).
3. P. Passe, *Mechanically stabilized earth wall inspector's handbook*, , Department of transportation, State of Florida, September, (2000), Revised by: J. Castellanos, June (2012). https://www.fdot.gov/docs/default-source/structures/Manuals/mse.pdf
4. A. Hulagabali, C. Solanki, G. Dodagoudar, *Behaviour of MSE wall with different soil properties and reinforcement length*, International Journal for Research in Applied Science & Engineering Technology (IJRASET) Vol. **6** Issue **I**, January (2018).
5. C. Vieira, M. Lopes, L. Caldeira, *Influence of facing panel rigidity on performance of reinforced soil retaining walls: a numerical study*, EuroGeo4 Paper number **244**, January (2008).
6. V. Elias, B. Christopher, R. Berg, *Mechanically stabilized earth walls and reinforced soil slopes design & construction guidelines*, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-NHI-00-043, March (2001).
7. M. Hossain, G. Kibria, M. Khan, J. Hossain, T. Taufiq, *Effects of backfill soil on excessive movement of MSE wall*. J. Perform Construction Facility, 10.1061/(ASCE) CF.1943-5509.0000281, 793–802, (2012).
8. Bentley systems, PLAXIS CONNECT Edition V20.04, *Material Models Manual*, (2020).