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Expansion of Cross Necklace and Startail Fish Fins in Mechanically Stabilized Earth Walls On Red Soil Layer

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KEYWORDS
MSE wall; rainwater infiltration; time duration, anchor; necklace bar; startail

ABSTRACT
Development in Indonesia is currently being actively carried out, especially development in the field of infrastructure, especially toll roads and bridges for opritnya, and due to development with limited Right Of Way (ROW) land, so that the oprit road body is not made slope with a certain slope, for that a construction that is not needed. The purpose of this study is to find out expansion of cross necklace and startail fish fins in mechanically stabilized earth walls on red soil layer. For this reason, precast soil retaining walls are needed, generally precast soil retaining walls such as Mechanically Stabilized Earth Walls use geosynthetics that are not heat resistant and strip plates, where the interlocking strip plates between soils are less strong, in connection with this there are often failures of MSE Wall failures which are caused by these two factors and are influenced by hydrostatic water pressure and soil layers that are not suitable for construction take land left and right of the road. In connection with the above, it is necessary to have novelty Mechanically Stabilized Earth Walls with anchor strength where along the anchor there is a crossbar necklace and at the end there is a fish fin startail whose function is strong to resist shear and interlocking the ground is getting stronger.

Introduction

Soil Retaining Wall is a construction built with a function to withstand the lateral active pressure force of a soil or water. Therefore, a soil retaining wall construction must be planned and designed in such a way as to be safe against forces that have the potential to cause failure of the building structure itself. One of the structures of the Soil Retaining Wall is the Mechanically Stabilized Earth Wall. The selection of MSE wall as an alternative to conventional DPT such as garvitation type DPT or catilever wall DPT (Leshchinsky et al., 2004).

The construction of soil retaining walls must be able to withstand forces in the form of rolling moments, own gravity, soil/water lateral forces both active and passive, sliding and lifting forces. Therefore, the planning of a wall must be designed to be able to withstand the above styles (Brinkgreve et al., 2016).

Soil retaining walls must be designed in such a way as to prevent a building from collapsing its natural slopes, where the stability of the building is affected by changes in shape, slope, and slope shape or construction, as well as by natural or artificial reliefs or characteristics of the subsoil itself (Khattab & Muhauwiss, 2022). If earthworks, such as excavations are carried out, especially if roads are built adjacent to rivers or lakes, soil retaining structures are created to maintain a stable slope of the soil on which slopes are made. In addition, the pressure generated by the mound and other loads including even loads, line loads, water pressures, and seismic loads, must also be taken into account by the strength of the soil retaining wall itself (Das, 2011).

Development in Indonesia is currently being actively carried out, especially development in the field of infrastructure, especially toll roads and bridges for opritnya, and due to development with limited Right Of Way (ROW) land, so that the oprit road body is not made slope with a certain slope, for that it requires a construction that does not take much land left and right of the road (Dhamdhere et al., 2018).

For this reason, precast soil retaining walls are needed, generally precast soil retaining walls such as Mechanically Stabilized Earth Walls use geosynthetics that are not heat resistant and strip plates, where the interlocking strip plates between soils are less strong, in connection with this there is often a failure of MSE Wall failures which are caused by these two factors and are influenced by hydrostatic water pressure and soil layers that are not suitable for construction (Koerner & Koerner, 2013)

While the failure of Mechanically Stabilized Earth Walls has a lot of influence on soil layers that have been saturated with water for a long period, considering that water dissipation is not channeled causing active pressure greater than passive pressure (Koerner & Koerner, 2018)

To anticipate the failure of such failures, it is necessary to innovate new technologies to adopt heat resistance, strong soil interlocking and resistant and strong to the intensity and duration of long rains. Failure of the containment system is a vulnerable thing caused by the intensity of rainfall and the duration of rain that occurs for a long time (Bathurst et al., 2022). The infiltration of rainwater into the ground causes the rise in water level behind the wall to increase, so that the lateral force received by the wall becomes greater. However, if the wall has good drainage, then the water behind the wall can flow immediately (Hidayat, 2021).

In connection with the above, it is necessary to have novelty Mechanically Stabilized Earth Walls with anchor strength where along the anchor there is a crossbar necklace and at the end there is a fish fin startail whose function is strong to resist shear and interlocking the ground is getting stronger (Helwany et al., 2021).

Landslide / failure of a construction is one of the most common on slopes/construction, due to increased shear stress of a land mass or decreased shear strength of a soil mass. The shear forces of a land mass are not capable of bearing the working load. The alternative design used is to use MSE Wall reinforcement, in connection with this it is necessary to identify problems that will arise in MSE Wall (Endayanti & Marpaung, 2019).

The problems in the MSE Wall often occur failures due to hydrostatic pressure and the intensity and duration of long rain as shown in Figure 1.

Figure 1 MSE Walls failure due to hydrostatic pressure and rainfall

Based on research from the Geosynthetic Institute (GSI) who is also a Professor of Drexel University, namely a researcher named Prof. Dr. Robert M Corner 2011 said that of 301 MSE Wall failures there were 191 failures caused by hydrostatic pressure and soil zone, in the Journal of Geo Engineering vol. 6 no 1 pp 3-13, April 2011.(Nasional, 2017)

Research Methods

Starting with data collection both laboratory data that are technically and numerically verified with the finite element program and checked for validity by field tests, as well as checking the shear stability, rolling stability and soil carrying capacity stability.

Research Location

In this study, the research location was chosen, namely the Construction of the Jababeka IX Industrial Estate Bridge located in the Jatireja area, East Cikarang, West Java, where because the Right of Way is Limited so that it uses Mechanically Stabilized Wall / with a crossbar necklace system and where the end is a fish fin startail

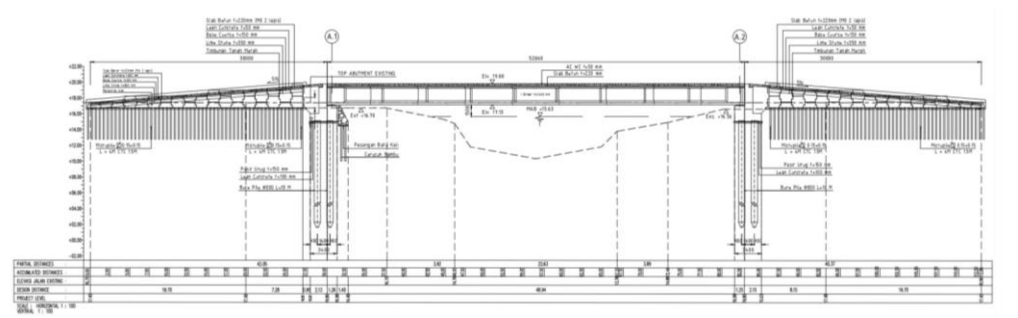

Figure 2 Front View of KIJ IX Bridge which is the Research Location Geolological and Soil Mechanics

Description of the soil at the Jababeka IX location is Silt clay, brown with a consistency ranging from soft to very stiff consistency with a hard soil layer reaching a depth of 18m (Nspt 60), using a stationary pile drill foundation of 80cm for both abutments and the allowable carrying capacity per one point for 80cm silent borpile is 170 tons

Research Steps

In addition to research based on field tests, for example with Inclinometer tests, Piezometers and with Total Station measuring instruments, it is also simulated with numerical programs based on soil data obtained. The use of MSE wall is because the limited Right of way (ROW) is limited and requires a Soil Retaining Wall, technically the technical calculation must follow the rules listed in SNI 8460 of 2017 and the implementation time must be faster than manually because the precast knock down system and implementation costs can be cheaper.

Results and Discussions

Interaction Analysis Struktur Mechanically Stabilized Earth Walls

According to (Benmebarek et al., 2016) in the Determination of the Length of the Strip **Plate case 2** is limited to the width of the road is 8-10m **with details (pedestrian width 2x@1-1.5m and road body 2x@3.5m**), while the width of the road above 10m is as stated in **case 1.**

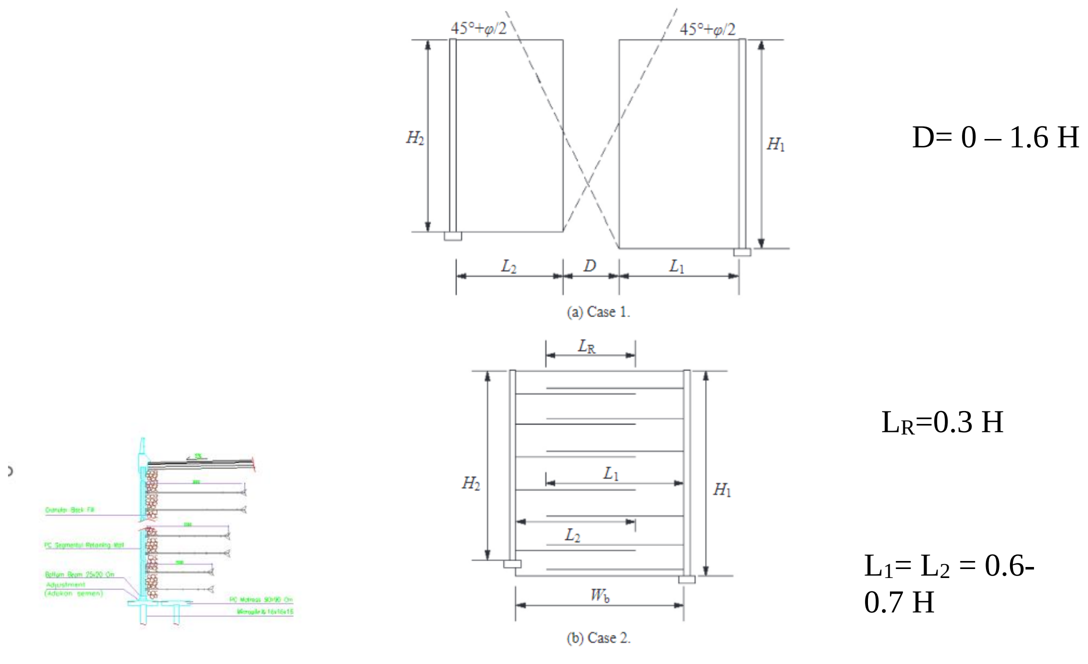

Figure 3 Determination of Strip/Anchor Plate Length (a) (Benmebarek, 2016)

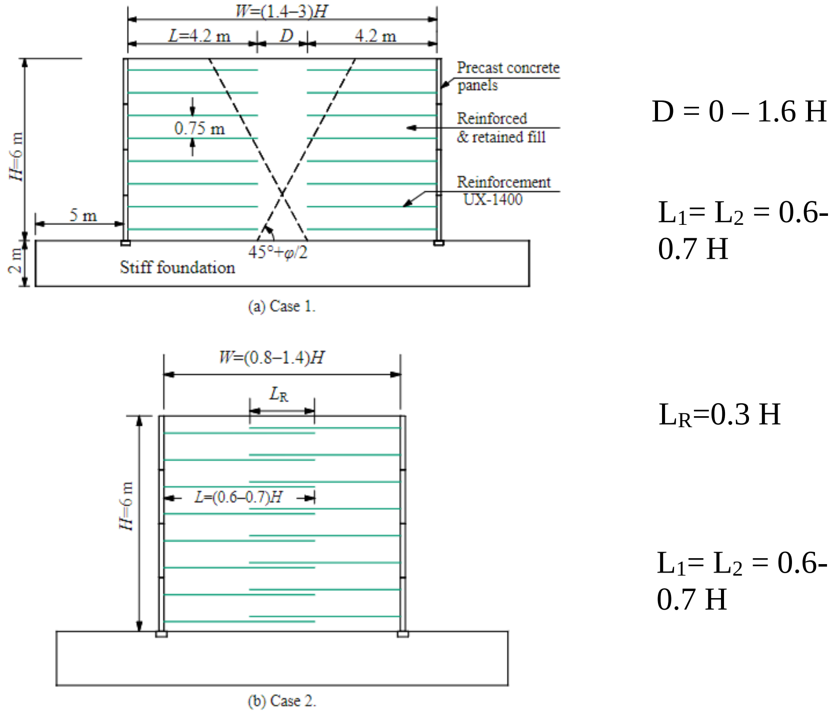

Figure 4 Determination of Strip/Anchor Plate Length (b) (Benmebarek, 2016) Effect of Wall Deformation and Vertical Descent on Deep Shear Angle

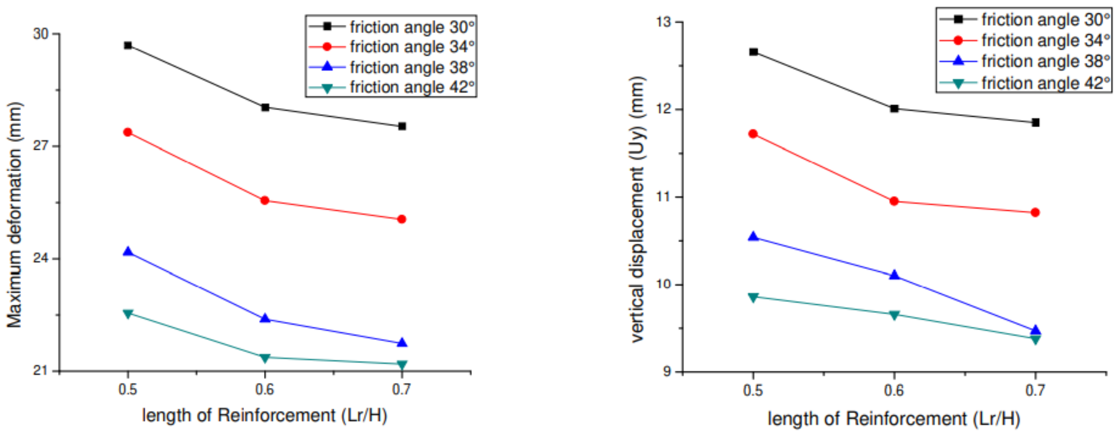

Figure 5 Variation of soil foundation against deep shear angle, Effect of overall MSE wall's on vertical deformation and subsidence (Hulagabali et al., 2018)

=>That according to (Hulagabali et al., 2018) for the determination of strip plate length depends on Lr/H, the smaller the deep shear angle, the greater the vertical deformation and displacement of the wall, the greater the deep shear angle, the smaller the deformation and vertical displacement wall

Modular Influence-Block Mechanically Stable Earth (MSE) Wall Using Field Instrumentation and Geogrid Layer

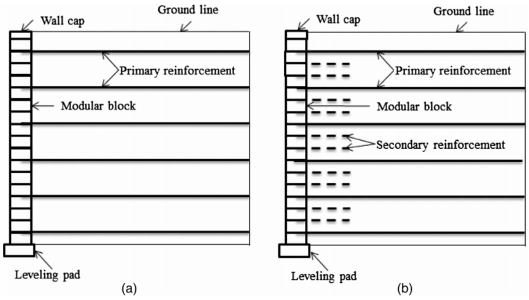

Fig. 1. Cross section of MSE wall: (a) MSE wall reinforced with primary reinforcements; (b) MSE wall reinforced with primary and secondary reinforcements

Figure 6 The effect of MSE Wall strength on the reinforcement of the Main layer and Second Layer (Y Jiang, 2016)

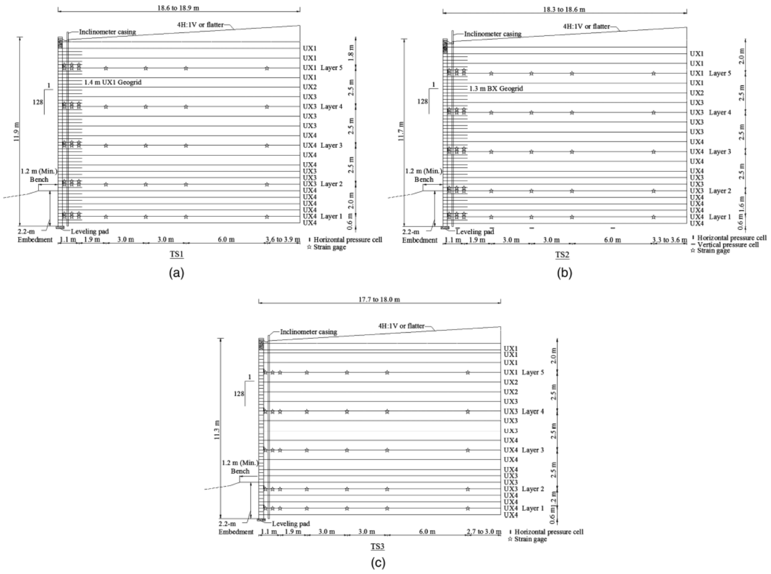

Fig. 4. Cross sections of the three test wall sections with instrumentation (not to scale): (a) TS1; (b) TS2; (c) TS3

Figure 7 Cross Section 3 models (Liu et al., 2016)

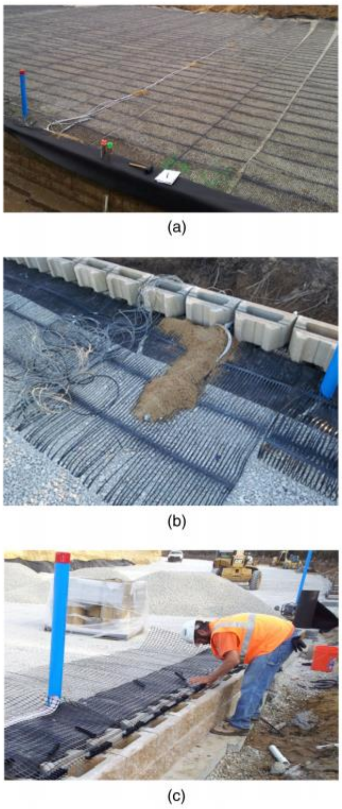

Fig. 8. Installation of geogrids: (a) primary geogrids; (b) secondary uniaxial geogrids; (c) secondary biaxial geogrids

Figure 8 Inclinometer installation with 3 models

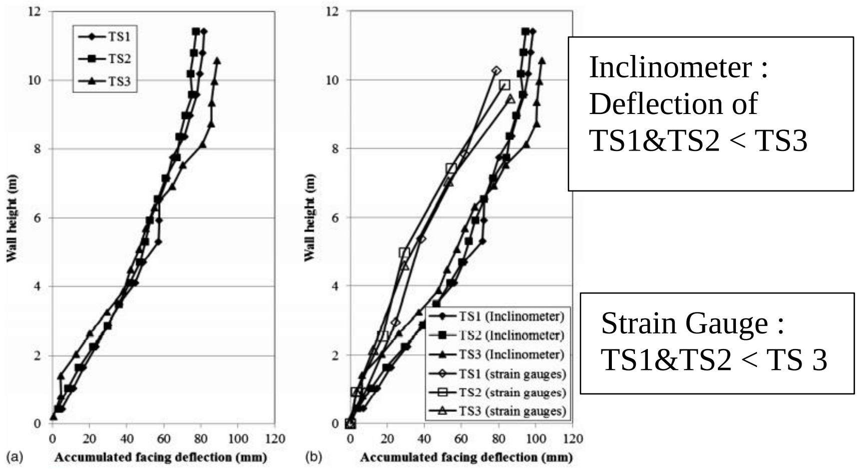

Fig. 9. Profiles of the wall deflections with full wall height: (a) before construction of the backslope; (b) after construction of the backslope

Figure 9 Results 3 model with inclinometer and strain gauge (a)

=>That according to (Y Jiang,2016) based on TS1 and TS2 Deflection **inclinometers** < TS1 and strain gauge **TS1&TS2 < TS3**

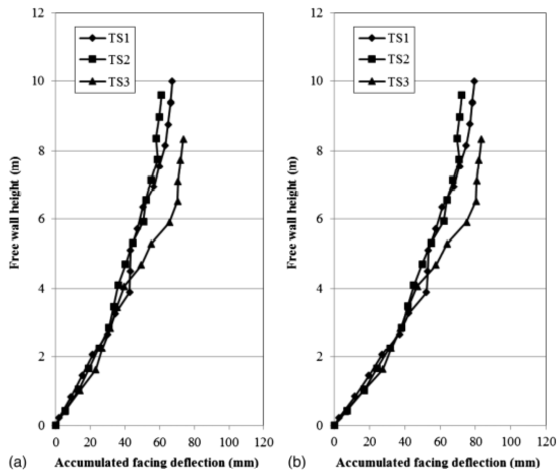

Fig. 10. Profiles of the wall deflections with free wall height: (a) before construction of the backslope; (b) after constructi backslope

Figure 10 Results 3 model with Inclinometer (b)

Advanced Constitutive Law

Soil behavior can be modeled in different ways with different levels of precision. They range from very simple models such as Hooke's law involving only two parameters, namely Young's modulus, E, and Poisson's ratio, v, to more complex models involving many soil parameters, such as the Soft Soil Model, Hyperbolic Model, etc.

Hooke's law, which is very simple, is generally too crude to model the behavior of soil and rocks. However, for mass modeling of massive structures or bedrock, linear modeling such as Hooke's law can be sufficient. Modeling that can capture the non-linear behavior of the soil is needed.

Elastic Linear Model

The Linear Elastic Model is based on Hooke's Law which applies to the elastic and isotropic behavior of materials.

This Linear Elastic Model involves only two soil parameters, namely, Young's Modulus, E, and Poisson Ratio, v.

This model is not suitable for modeling soil behavior, because soil behavior is generally not elastic linear and often not isotropic.

This model is suitable for modeling very rigid masses that are in the ground, for example: concrete concrete walls, river stone retaining walls, gabions, massive rock formations, and others. Especially to model where the stress conditions in the material are still far from the ultimate strength.

Model MOHR-COULOMB:

MOHR COULOMB is a linear elastic perfectly plastic model involving five parameters, namely:

1. Soil Stiffness Modulus (Mod.Young), E and Poisson Ratio, v, which model soil elasticity,
2. Cohesion, c, and, shear angles in soil, φ, which model the plastic behavior of soil, and
3. The angle of dilation, ψ, which models the behavior of soil dilation.

This model is quite good as a first order approach to soil and rock behavior. Here each layer of soil is considered to have a constant rigidity or increase linearly with depth. The weakness of this model is that it linearizes the stiffness of the soil (does not take into account the change in E value against the change in voltage)

Soft Soil Model

This model is based on the Cam-Clay theory developed at Cambridge.

As in the Mohr-Coulomb model, the strength limit of the soil is modeled with the parameters of cohesion, c, shear angle in soil, φ, and Angle of dilation, ψ. Soil stiffness is modeled using lamda, λ*, and kappa parameters, k*, which are stiffness parameters derived from triaxial or oedometer tests.

This model is good for compression-dominated loading, for example: heap analysis. Not suitable for excavation analysis.

Model HIPERBOLA (Hardening Soil Model)

Hardening Soil Model is basically a hyperbolic model, where the non-linear behavior of soil stress and strain is approached using hyperbolic equations.

This Hardening Soil Model is an advanced model for modeling soil behavior. As in the Mohr-Coulomb model, the strength limit of the soil is modeled with the parameters of cohesion, c, shear angle in soil, φ, and angle of dilation, ψ. However soil stiffness was modeled much more accurately using three different E-value inputs: Triaxial loading stiffness, E50, Triaxial unloading stiffness, Eur, and Oedometer stiffness, Eoed.

Unlike in the Mohr-Coulomb model which considers the value of E constant to the change in voltage, the change in the value of E to voltage is taken into account in this model. Therefore, the three E parameters mentioned above are always entered with an E value at a reference voltage of 100kPa (1 bar).

In this Hardening Soil Model, except for the parameters mentioned earlier, initial stress conditions such as pre-consolidation pressure that play a considerable role in estimating soil deformation can be modeled in this model.

This model is generally suitable for application in soil excavation analysis (unloading conditions).

Some disadvantages of the hyperbole model:

- This model takes into account strain hardening but does not take into account strain softening.

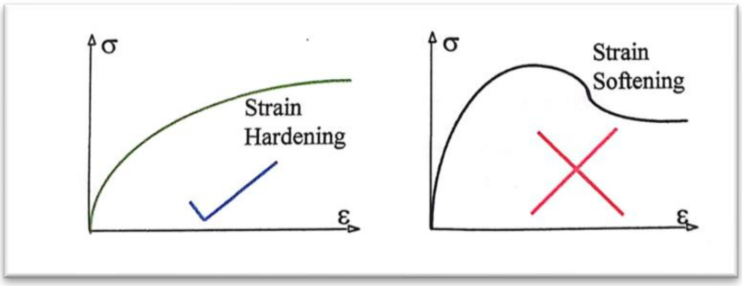

Figure 10 Relationship between Strain Hardening and Strain Softening

- Does not take into account changes in soil stiffness that enlarge at small strains and shrink at large strains.
- Does not take into account the effects of hystericis and cyclical load.

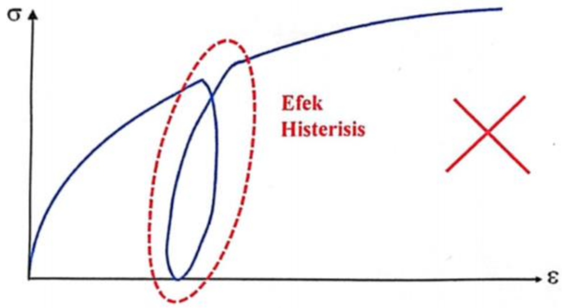

Figure 12 Relationship between the occurrence of hysterical effects
Small strain hyperbole model (HS small)

1. The HS small model is a further development of the hyperbole model (HS model).
2. Still using the same parameters as the HS model, namely:

c, φ, ψ, E50, Eoed dan Eur

3. But here two additional parameters are needed, namely:
4. 1. The initial shear modulus, or shear modulus for very small strains, is denoted as G0 (in other literature it is also called Gmax
5. 2. Shear strain at the level where the secant shear modulus Gs is at the level of 70% G0, denoted as Y0.7.
6. Used in very small defomated structures and for dynamic loads. For example: machine foundation, beheading effect, etc.

Soft soils creep model

1. This Soft Soil Creep model is a second-order model formulated based on the theory of Viscoplasticity.
2. This soil model is mainly used to simulate time-dependent soil behavior, such as normal consolidated soft clay, organic clay and peat.
3. The required parameters, the same as in the soft soil model, are: c, φ, ψ, λ*, K* with the addition of modified creep index parameters, u*

This soil model analyzes:

1. Primary decline and
2. Secondary subsidence of land.

Other models of Constitutive Law:

In addition to the constitutive law model above, there are many other constitutive law models, including:

1. Modified Cam Clay untuk analisa tanah lempung via critical state soil mechanics.
2. Hoek and Brown for rock formation analysis.
3. Jointed Rock for rock formation analysis.
4. UBC Sand (UBC3D – PLM) for liquefaction analysis.
5. NOR Sand for Liquifaction analysis via critical state model.
6. NGI-ADP
7. UDCAM-S
8. Sekiguchi-Ohta

MC Model – Melting Function Parameters &; Plastic Potential
Parameters of Melt Function and Plastic Potential Function

The Mohr-Coulomb melting field function is determined by two shear strength parameters c' and φ'

The function of the Mohr-Coulomb plastic potential field is determined by the parameters of the dilation, ψ, present on solid sand soils and over-consolidated loam.

The confluence between the two Mohr-Coulomb melting planes is sharp (see figure of the MC melting plane cone). In some geotechnical programs the transition of the meeting plane is made curved, in PLAXIS it is used according to the original MC theory which is sharp.

For c>o, the MC criterion allows for tensile stress. However, the soil practically cannot withstand tensile stress. To eliminate this tensile stress, **in PLAXIS** the TENSION CUT-OFF option is used. So in this case the Mohr circle with a positive main voltage (tensile stress) is not allowed.

Model MC – Tension Cut-off

Tension Cut-off

With this Tension cut-off option, three additional melting functions are added, namely:

$$f4 = s'_1 - s'_t \leq 0$$
$$f5 = s'_2 - s'_t \leq 0$$
$$f6 = s'_3 - s'_t \leq 0$$

When the TENSION CUT-OFF option is selected in PLAXIS, the allowable tensile stress, σ'_t, is taken equal to ZERO. However, if necessary the user can change this σ'_t value.

When the soil stresses are inside the melt plane cone, the soil behaves elastically and follows Hooke's law. Therefore, except for the plastic parameters c', φ', and ψ, stiffness parameters E' and v' are also needed.

Parameters for Drained Conditions

1. Effective Shear Strong Parameters
   1. Cohesion, c'
   2. Deep sliding angle, φ'
2. Deformation Parameters
   3. Land Kekauan, E'50
   4. Rasio Poisson, v'
3. Dilation Parameters
   5. ψ => ψ = 0 for last sand soil and NC clay
      $\Psi = \varphi' - \varphi'_{ult}$ for solid sand and loam soils OC

   All parameters use effective voltage parameters

Parameters for Undrained conditions

There are three ways to analyze undrained conditions, namely:

1. Undrained Analysis Parameters via:

Effective voltage analysis

Using Effective voltage parameters such as drained analysis i.e. c',φ', E'_{50}, v' and ψ

Benefits:

1. Produces excess pore water pressure
2. Because it produces excess pore water voltage, it can calculate the consolidation decrease
3. Can calculate the increase in undrained shear strength

Disadvantages:
In Mohr's model Coulomb could produce undraine shear strength that was greater than reality

Advantages of the MOHR-COULOMB model:
1. Relatively simple (elastic perfectly-plastic model)
2. Represents the first approach to soil behavior in general (First order approximation)
3. Suitable enough to be applied in various geotechnical practice applications.
4. The required soil parameters are quite easy to obtain.
5. In drained conditions, the behavior of soil collapse is quite well approachable.
6. The effect of dilation can be included in the calculation.

Disadvantages of the MOHR-COULOMB model:
1. The behavior of the soil is assumed to be isotropic and homogeneous
2. Soil behavior is assumed to be linear elastic until collapse occurs
3. The rigidity of the soil is considered constant and does not depend on the working voltage.
4. It does not distinguish between loading and unloading-reloading.
5. Continuous dilation (no critical void ratio)

- No time dependent behavior

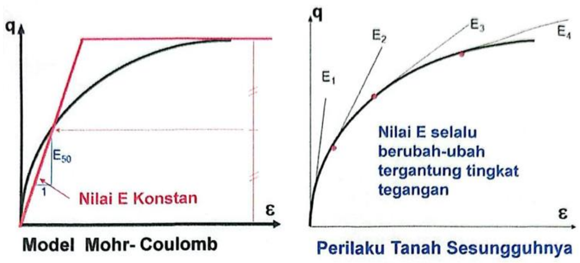

Figure 13 Mohr-Coulumb Model and Real Soil Behavior

As a result of assuming a constant value of E , the prediction of deformation in the MC model will not be precise.

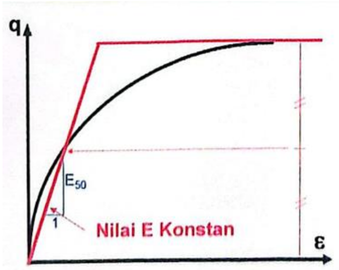

Figure 14 Constant E Value

When used E50 as widely used in practice, in low voltage. In other words the safety factor **of FK>2**, the MC model produces a fairly conservative deformation value (greater than reality)

But in large voltage means Safety Factor < 2, MC models produce too little deformation

Because MC theory uses a constant value of E, in mining modeling where Eunloading which is generally 2-5 times greater than Eloading cannot be modeled, as a result the prediction of deformation in excavations is not good, especially resulting in too large heaving deformation

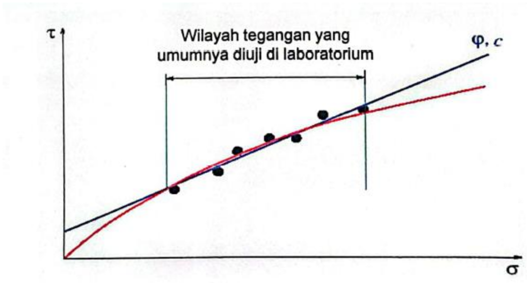

Figure 15 Linearization of the Collapse Field

The real linearization of the collapse plane is not linear. This can result in over predict strong soil shear. Therefore, during the triaxial test to be adjusted to the voltages arising in the field

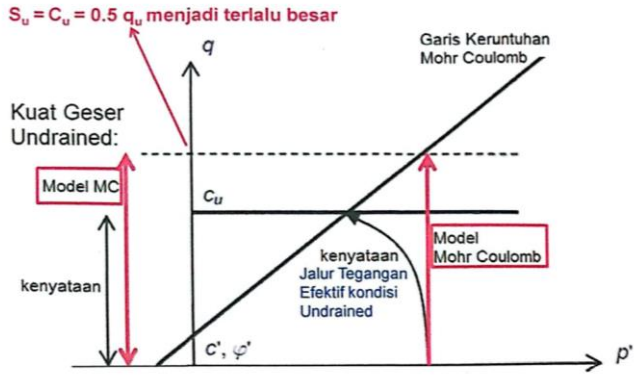

Figure 16 MC producing an undrained perpendicular stress path

MC produces an undrained stress path that is perpendicular, which should be curved.

Conclusion

Mechanically Stabilized Earth Wall used a knock-down system with a female male connection, on that connection inserted a 1/2 inch strain as a lock and knitter. In one full section of mse wall there are 4 anchors φ 19 with a crossbar necklace every 70cm and a fish fin startail measuring 30cmx30cm, whereas half the MSE wall has 2 anchors φ 19 with a crossbar necklace and a fish fin stratail. The length of the anchor must pass through the slip field and the inner sliding angle (φ). The heap land used is cohesive soil i.e. red soil

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