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FINITE ELEMENT PERFORMANCE WITH DIFFERENT MESH SIZE OF RETAINING WALLS

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ABSTRACT

Finite element analysis is one of the efficient technique to support modern engineering practice. In the finite element analysis, mesh size assumes a significant role as it can determine the quality of the finite element analysis results. This paper investigates the influence of mesh size on finite element performances of concrete cantilever retaining walls. The finite element analysis of the concrete cantilever retaining walls was made using GeoStudio software consisting of SIGMA/W and SLOPE/W. Three mesh sizes are used to compare the accuracy of the model analysis, which is fine, medium and coarse size. The results of finite element analysis were compared with the results of field monitoring in order to validate the model. The finite element analysis results show the influence of the mesh size did not make a significant difference. It was discovered that the finite element models with fine mesh gave more close results when contrasted with field monitoring results. The results of finite element analysis and field monitoring were in good agreement.

Key words: Finite element, mesh size, performance, retaining wall

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1. INTRODUCTION

Retaining wall is designed to prevent lateral movement, retain earth or other materials which have the tendency to slide, and may help to support vertical loads. There are a few sorts of retaining wall, for example, gravity wall, cantilever wall, counterfort wall and buttressed wall. One of the most common types of retaining wall is cantilever walls. It consists of vertical wall, heel slab and toe slab which act as cantilever beams. Normally, the height of the cantilever retaining walls can be built up to a maximum of 6 m. It can be built in-situ or pre-cast method [1]. Compared to traditional gravity retaining walls, this retaining wall is more economical as the design requires less concrete. According to Bakr *et. al.* [2], the cantilever retaining wall is a flexible wall structure. Therefore, it's design requires good structure and need to consider the global stability due to lateral earth pressure. Components to be reasoned for design of cantilever retaining walls includes stability checking in terms of overturning, sliding and bearing capacity.

Due to the quick advancement of increasingly powerful computers in the most recent decades, software is created to help users in making their errand simpler [3]. The evolution of software has contributed widely to the field of civil engineering such as helping engineers solve complex calculations, modeling, drafting, planning practices and some analysis processes for infrastructure [4]. There are various facilities that engineers can use to help them in utilizing the software, ranging from simple methods of limit equilibrium method (examples: finite element limit analysis, follow-up optimization) to complex and modern techniques (finite/distinct-element codes) [5].

Currently, finite element analysis (FEA) is a significant technique and widely used among of researchers. The FEA is the simulation of any given physical phenomenon utilizing the numerical technique called finite element method. This technique utilizing a methodology of processing responses over a discrete number of focuses over the area of intrigue [6]. Normally, FEA is used to solve problems that cannot be solved using analytical solutions such as problems with complex geometry, loading, and material properties. For instance, comprehensive analysis of retaining wall performance such as soil movement, deformation and impact on construction activities can be obtained through FEA [7].

In the FEA, the size of mesh is a captious issue. Some researchers have evaluated the influence of mesh size on the FEA performances. Shayanfar *et. al.* [8] investigated the influence of mesh size on the analysis of nonlinear finite elements on concrete structures. Results have indicated that the size of the mesh does not make a significant difference on the behavior of different reinforced concrete structures including load-displacement and load-strain characteristics, crack pattern and ultimate load. It is found that the finite element model results also give close similarity to the experimental results. Choi and Kwak [9] studied the influence of mesh size using nonlinear finite element analysis on the behavior of reinforced concrete structures. The results show that values calculated using relatively small mesh sizes are found to be closer to experimental results and errors from numerical analysis cannot be observed. The influence of mesh size on numerical results was further studied by Shi *et. al.* [10] that utilized coarse and fine mesh to see the numerical results of the blast wave propagation and its interaction with the structure. The study found that the models using coarse mesh tended to initiate errors in the determination of the positive reflected peak pressure in blast scenario compared to models using fine mesh. Hadi [11] evaluated the mesh size consisting of very coarse, coarse, medium, fine and very fine on the numerical analysis of reinforced soil walls. It is found that the effect of changes of mesh size is minimal. Besides that, the mesh size of 15 nodal element gave better and more accurate results than to element with six nodes. Koslan *et. al.* [12] studied the influence of mesh size on deformation result in simulation for blast loading applications. The results show that the percentage of errors in the deformation results is reduced when using small mesh sizes. However, the cost increases because it involves a long calculation period. More and Bindu [13] indicated that finite element models using fine mesh produce very accurate results but take longer computing time. While finite element models using coarse mesh produce less accurate results but can save more computing time.

This paper describes the FEA of the concrete cantilever retaining walls using GeoStudio software. The aim of this paper is to evaluate the performance of FEA using different mesh size of concrete cantilever retaining walls.

2. MATERIALS AND METHODS

2.1 Software

Commonly, the design of cantilever retaining walls only considering an external stability checking in it's design analysis, which is FOS for overturning, sliding and bearing capacity. It is carried out using limit equilibrium method (LEM). In this study, the combination of external and internal stability checking was performed in order to provide a comprehensive design analysis and produce the overall stability. The internal stability involved checking for maximum foundation settlement, maximum surface settlement, maximum deflection, and global stability. The LEM design analysis was carried out using PROKON software. Meanwhile, FEA were performed to checking the internal stability. Therefore, this paper only focus on internal stability checking since it is using FEA in it's design analysis.

The FEA of the concrete cantilever retaining walls was made using GeoStudio 2012 software consisting of SIGMA/W and SLOPE/W. Simulations were performed using a two-dimensional FEA to calculate (i) maximum foundation settlement, (ii) maximum surface settlement, (iii) maximum deflection, and (iv) global stability. SIGMA/W is used to determine the value of maximum foundation settlement, maximum surface settlement, and maximum deflection. Then, it coupled with SLOPE/W in the software package to calculate the global stability. According to Asthma and Heba [4], GeoStudio software is a finite element program extensively used in a wide variety of engineering activities such as geotechnical, geoenvironmental, civil, and mining. Mohammed *et. al.* [14] stated that the GeoStudio software is suitable used for analysis like stress strain, flow, slope stability, dynamic analysis and rapid water drop in the reservoir. This software has amazing capacity, powerful GUI, easy to operate, and is one of the most popular worldwide geotechnical engineering software packages [15].

2.2. Finite Element Method

2.2.1. Finite Element Model Dimension

The dimension of the concrete cantilever retaining walls is shown in Figure 1. The height of the wall is 4 m with a top width of 0.25 m and base width of 3.75 m. The slope angle behind the wall is 45 degrees. For finite element models (Figure 2), the original soil width at the front of the wall was set at 5.8 m and the original soil width behind the wall was 13.35 m. Meanwhile, the height of the original soil in front of the wall was 1.0 m and have a depth of 4.0 m below the base of the wall. The left and right sides of the model are prevented from horizontal movement, while the bottom side is prevented from both horizontal and vertical movements. Axial models have been analyzed in two-dimensional plane strain condition.

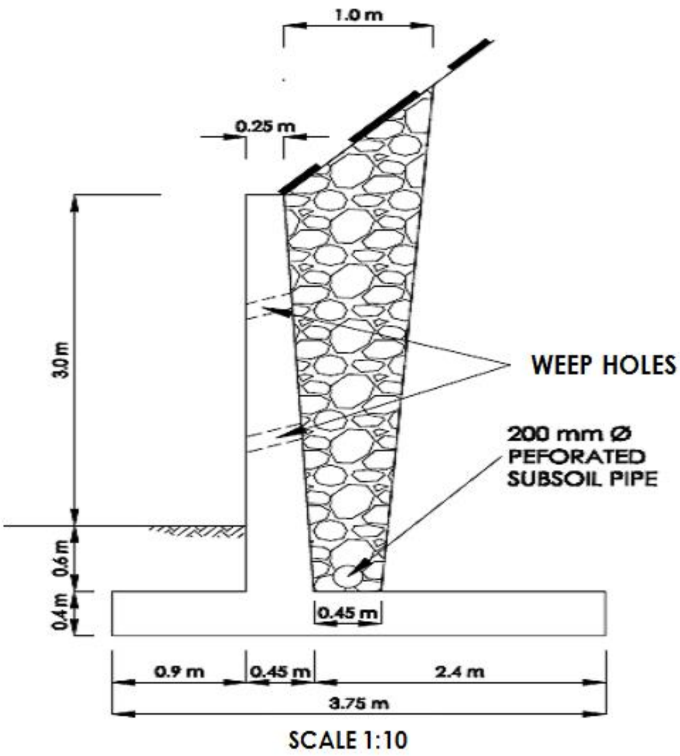


Figure 1. Dimension of retaining walls

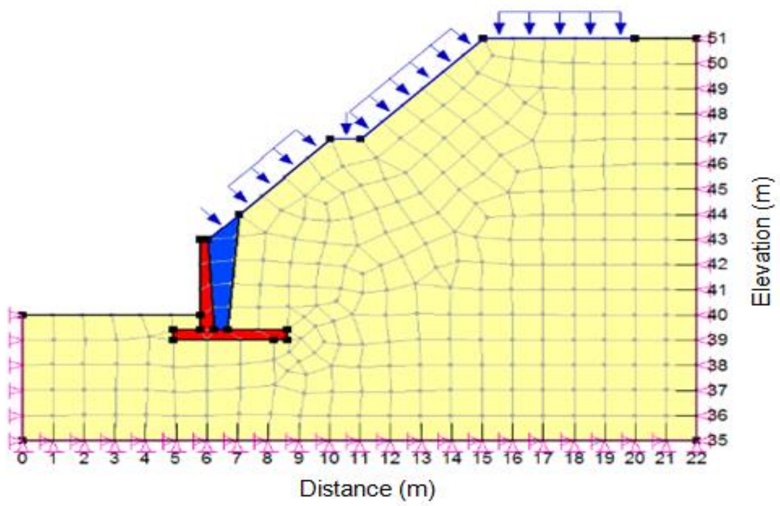


Figure 2. Finite element models

2.2.2. Material Properties

Table 1 shows information on the properties of materials used in finite element modeling. The grade of concrete used in modeling is M35. The soil layer is modeled using the dried Mohr-Coulomb model (elastic-plastic), meanwhile concrete wall and backfill using linear elastic. In addition, other required parameters are unit weight, cohesion, frictional angle, Young's modulus, and Poisson's ratio for soil layer, concrete wall, and backfill. According to Chetan and Vijay [3], the significant parameters to be included are unit weight of backfill soil, and concrete type. This is because these parameters affect the base length of concrete cantilever retaining wall, toe and heel lengths, as well as the base thickness.

Table 1 Properties of materials for finite element model

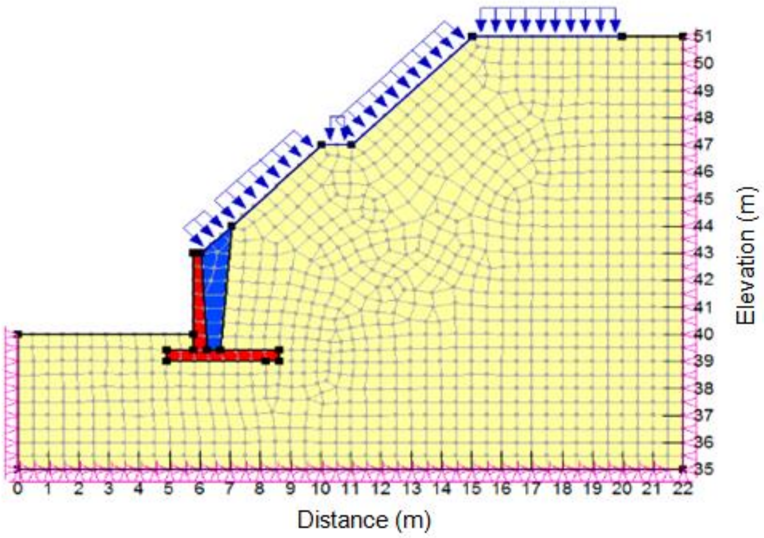
Material	Model	Unit Weight γ (kN/m³)	Cohesion c (kN/m²)	Frictional Angle ϕ (Degree)	Young's Modulus E (kPa)	Poisson's Ratio ν
Soil layer (Clay)	Elastic-Plastic (Mohr-Coulomb)	17	29.6	26.5	50×10^3	0.3
Concrete wall (Concrete grade = M35)	Linear Elastic	24	500	45	30×10^6	0.2
Backfill	Linear Elastic	18	0	48	200×10^3	0.3

2.2.3. Mesh Size

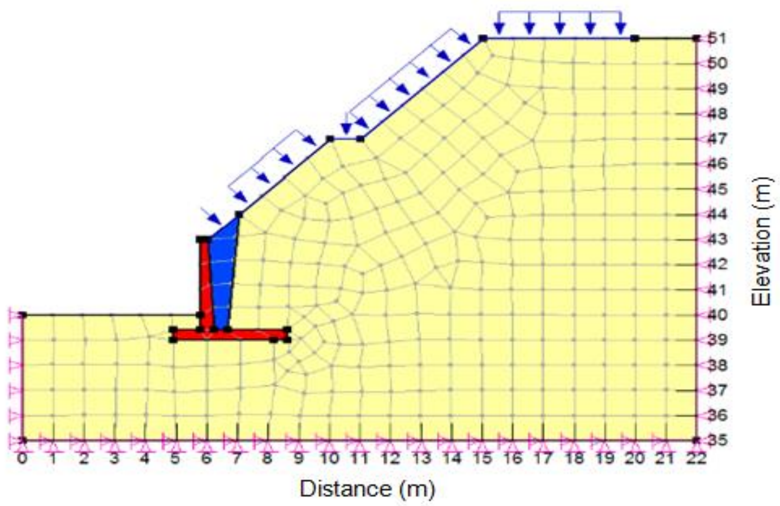
To ensure that the modeling performed is accurate and appropriate, the influence of the mesh size on the computational results was performed on the finite element model. Table 2 show three types of mesh size used for finite element models with their element size, number of node and total element. Figure 3 shows the three meshes considered which include the fine, medium and coarse meshes used in the finite element models.

Table 2 Three types of mesh size used for finite element model

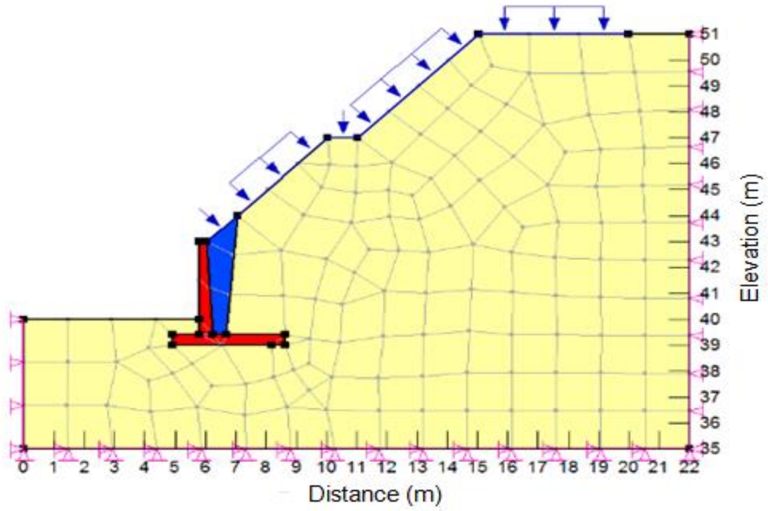
Mesh size	Element Size (m)	Node	Total element
Fine	0.5	1085	1025
Medium	1.0	316	287
Coarse	1.5	164	146



(A) Fine size



(B) Medium size



(c) Coarse size

Figure 3. Three meshes used in the finite element model

2.2.4. Validation of the proposed finite element model

Validation is the procedure to check whether the simulation results indicate true results. In this study, validation of the proposed finite element model for maximum foundation settlement, maximum surface settlement and maximum deflection were performed by field monitoring. The FEA results was compared with the field monitoring results using the original design of reinforced concrete cantilever retaining wall structure. The comparison between the FEA and field monitoring results would help engineer to get better understanding of the real soil behavior compared to finite element modeling.

3. RESULTS AND DISCUSSION

3.1. Finite Element Performances

Two-dimensional FEA has been carried out in effort to investigate the influence of mesh size on the numerical simulation performances of concrete cantilever retaining wall. The results of FEA using different mesh sizes are shown in Table 3. Not significant differences can be seen between the three cases for the internal stability of cantilever retaining walls, which is maximum foundation settlement, maximum surface settlement, maximum deflection and global stability. This result is similar to the results obtained by Shayanfar *et. al.* [9], where the influence of the mesh size did not make a significant difference. The differences between the three sizes of mesh can be clearly seen in Figure 4. The results revealed that the value of maximum foundation settlement and maximum deflection increases with increase in the mesh size.

Table 3 Performances of FEA using three sizes of mesh

Mesh size	FEA Output			
	Maximum foundation settlement (mm)	Maximum surface settlement (mm)	Maximum deflection (mm)	Global stability
Fine	11.61	20.04	4.17	2.254
Medium	11.77	21.43	4.34	2.342
Coarse	11.86	19.88	4.69	2.133

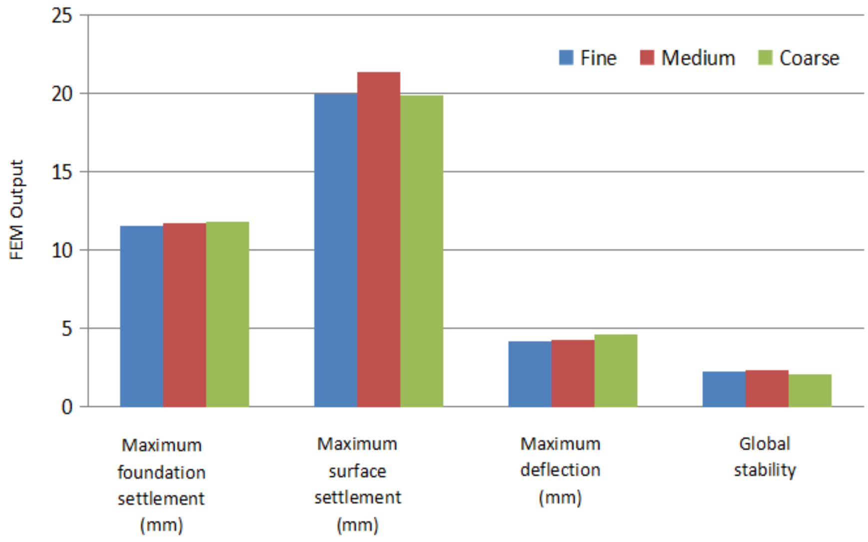


Figure 4. The difference of FEA results between three sizes of mesh

3.2. Validation of FEA through Field Monitoring

Table 4 shows the comparison of FEA and field monitoring results. From the finite element performances, it was found that the results obtained using fine mesh size were close to the field measurement results for all parameters, so this value was used for comparison. It was indicates that the finite element simulation model is reliable because it produces results that are very similar to those obtained in the field monitoring. It is found that the percentage difference between FEA and field measurements results for all three parameters is less than 5%. The comparisons elucidate that the developed finite element model is satisfactory in its performance. It may be inferred that the finite element models with fine mesh can give more precise results. However, it will take longer computational time and the storage capacity of the computer was increased.

Table 4 Comparison of FEA and field monitoring results

Internal stability parameter		**FEA** (Fine mesh size)	Field monitoring	Difference (%)
Maximum foundation settlement	(mm)	11.61	11.20	3.53
Maximum surface settlement	(mm)	20.04	20.00	0.20
Maximum deflection	(mm)	4.17	4.00	4.08

4. CONCLUSIONS

This study has successfully identified the influence of mesh size on finite element performances of concrete cantilever retaining walls. The influence of mesh size using three different types of mesh sizes namely fine, medium, and coarse size have been explored on the FEA performances. It was found that the size of the mesh does not make a significant difference on the FEA results of concrete cantilever retaining walls. The increment of mesh size was increased the maximum foundation settlement value and maximum deflection value. However, this situation does not apply to maximum surface settlement and global stability. The mesh size has a relationship with the accuracy of the FEA result acquired. The models of finite element with fine mesh produced very similar results with field monitoring results. It can be concluded that the proposed finite element model in this study gives good agreement with the field monitoring results.

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