Civil engineering design geotechnical design engineering essay

A design of an elevated motorway embankment have prepared in this report. A sets of calculation of settlement, bearing capacity and slope stability had calculated to make sure the motorway embankment are reached the requirement which can be remains at a level above the predicted flood level for 10 years. A construction option which used to overcome the collision between the main motorway and Moor Road had mention in this report. Staged construction was required to allow shear strength to develop in clay layer in order achieve acceptable factor of safety. Multiple layers were used to guarantee the embankment in place which ensures the bearing capacity of soil will not be exceeded during construction. Drains design by pre-loading and Vertical ‘ Band’ Drain were introduced in this project which used to reduce the time of consolidation. Various slip surface of soil were examined for long term criteria by using Circle Arc Analysis with method of slices. AutoCAD was used to lineout the drawing which needs to use in project such as circular arc analysis and embankment design. Microsoft Excel was used to do the calculation of this project.

Introduction

This report shows a construction of a motorway embankment is proposed at the rural area of South Humberside. A suitable embankment design has been chosen to solve the problem of the motorway which will cross through the existing Moor Road as shown in the figure below (Figure 1).

Figure 1: Location Plan between two point and existing Moor Road

There have several design constraints which needed overcome by the development in this project. In the first instance, a motorway gradient should be at least of 1: 300 is required to meet surface water runoff requirements. Secondly, the 10 year return period flood level is 52. 3m AOD. Besides, all earthwork embankments are to be constructed to a gradient of 1: 2 due to land-use constraints. Furthermore, a minimum clearance of 5. 2m is required between road level and the underneath of a bridge deck. On the other hand, the width of a new side road carriageway including verges is to be 10m. Last but not least, no connection is to be provided between Moor Road and the Motorway.

The main objective of this project is to investigate the geotechnical issues in regard to design procedure. The calculations of settlement, bearing capacity and slope stability are shown in this report. There are no costs discussed in this report but only concepts of vertical drain design and ground improvement. There is no horizontal alignment discuss in this project but only vertical alignment. Ground condition and soil properties are related to the site investigation which are including in the concepts of ground improvement and vertical drain design.

Design Solution

First of all, there have two construction options for overcoming the collision between the main motorway and Moor Road which are bridge and tunnel. There have several key points which have to overcome before decide which designs have to used. First of all, the location to build a tunnel or bridge is very important. This location consider an area where would get flood easily. Therefore, if a tunnel was chosen as the construction design, the path may be blocked during the flood. Therefore, build a bridge will be a better choice which could overcome this problem in this situation.

Besides, cost is a main point which has to considerate. The cost to build a tunnel will be much higher than build a bridge. With the bridge the motorway will need to be raised above flood level with 5. 2m above the road. For tunnel, excavation would be required to adhere to the 12m clearance required which shown in Figure 2 below. The total area of required fill of tunnel at Moor Road intersection is 14608m2. Therefore, the motorway for tunnel would be raised above the level which is much higher than bridge required. In this situation, the cost of maintain and build a bridge is much lower than build a tunnel. In the conclusion, bridge will be chosen because it has more advantages than build a tunnel.

Figure 2: Tunnel at Moor Road intersection (Total Area of required fill = 14608m2)

Furthermore, the design below shows the design of the intersection between the motorway and Moor Road. Figure 3 shows the minimum level at Moor Road intersection. This design was chosen in terms of cost, fill volume and soil removal cost. The total area of required fill of this design is 6540m2.

Figure 3: Minimum level at Moor Road intersection (slope 1: 300)

Total Area of required fill = 6540m2

Settlement

Figure 4 below shows the cross-section profile of embankment at point D. This design had chosen after the minimum height of fill that would be needed to overcome the flood level of the post settlement had calculated. The amount of fill had calculated which need to maintain its height above the flood level before and after the settlement for period 10 years. The result of the minimum fill needed is 4. 95m which is the ground level for the motorway. The minimum gradient of the road is 1: 300. Therefore, it is better to split the motorway's gradient into two sets rather than one gradual gradient to get the minimize amount of fill required which shown in Figure 3 above.

Figure 4: Cross-section view at point D

Ultimate Settlement can be defined as:

is represent by ultimate settlement. is represent by Coefficient of compressibility which assumed as a constant value of 0. 0005 m2/kN. values would be more accurate when vary the deposits which can be split up into layers as illustrated when applied stress varies. Besides, is represent by change in total stress which is 99kN/m2 in point D. Last but not less, H represent by initial thickness of the soil layer. The result of ultimate settlement is 1m. All points as shown in Table 1 have positive values of height above flood level which will satisfy the flood level requirement.

Point

A

C

D

E

B

Initial Height (m)

55. 0

56. 0

55. 0

56. 0

55. 0

Settlement (m)

0. 972

1. 173

1. 00

1. 202

1. 00

Height After Settlement

54. 028

54. 827

54. 00

54. 789

54. 00

Height Above Flood Level

1. 728

2. 527

1. 700

2. 489

1. 700

Table 1: Distance between flood level and embankment height.

The time consolidation was calculated by using Terzaghi 1-D formula in this report. Terzaghi 1-D consolidation can be defined as the formula below,

where, defined as Time factor for 1-D consolidation, defined as Coefficient of consolidation, vertical direction, defined as Length of drainage path and t defined as time.

where, k defined as coefficient of permeability and defined as Bulk unit weight of water.

Table 2 shows the results which had calculated of time consolidation for different percentage of consolidation.

Uv(%)

10

20

30

40

50

60

70

80

90

Tv

0. 008

0. 031

0. 071

0. 126

0. 196

0. 287

0. 403

0. 567

0. 848

t

0. 127

0. 492

1. 126

2. 00

3. 11

4. 55

6. 39

8. 99

13. 44

Table 2: Time consolidation for different percentage of consolidation.

Drainage Design

Time consolidation of 94% was calculated in this report which is 13. 6 years. This time consolidation took too long and it will make the cost of construction higher. Therefore, there have several type drainage design can be apply in this project to solve this problem which is sand drains, pre-loading and vertical ‘ Band’ Drains. Pre-loading had applied in this construction and the height of pre-loading surcharge is 13. 85m. Besides, 10 months of time consolidation had suggested using in this construction. Therefore, the spacing of sand drains had calculated which shows the results is 2. 8m and spacing of vertical ‘ Band’ Drain is 2. 1m in 10 months.

Vertical ‘ Band” Drain was fairly close spacing much shorter horizontal drainage paths are created allowing faster dissipation of pore pressure, removal of pore water and accelerated consolidation settlement (Barnes 2000). By comparing the sand drains method, sand drain could be very slow in construct and it would produce larger amount of spoil and be surface damage. Therefore, ‘ Band’ drain was found to be an appropriate choice for this construction. There have two type of vertical drain which is square arrangement and triangular arrangement as shown in Figure 6 below. Triangular arrangement would be chosen since it has smaller radius is 0. 525s.

Figure 5: Sand Drainage Figure 6: Type of vertical Drain

Bearing Capacity of clay

The bearing capacity of clay had to be calculated in the weakest part of clay which is 2m below the surface which shown in Figure 7 below. The ultimate bearing of the foundation soil (saturated clay) was calculated from the formula qu = 7. 5 Cu where Cu is the undrained shear strength of the soil. qu = 7. 5 Cu = 7. 5 Ã- 5 = 37. 5 kPa, where Cu = 5kN/m2 which is the lowest value of shear vane results accounting worst case scenario as shown in Figure 7 below.

Figure 7: Shear Vane Results (Cu kPa)

Besides, factor of safety was calculated in this report. The value for factor of safety in this case should be 1 or greater. It is quite different with normal factory of safety which is 3 or greater because pore water pressure will decrease due to water being drained way which results in load being transferred to the soil during construction. The change in total stress on the existing clay layers in the ground can be calculate by6. 175 x 20 = 123. 5kN/m2 where h= 6. 175 is the highest fill height point at point B.

The change in total stress which is 123. 5kN/m2 was used to find factor of safe. The factor of safety was calculated by,

Factor of Safety = = = 0. 304 < 1 F. O. S inadequate

Therefore, the factor of safety is considered fail since the value is 0. 304 which is smaller than 1. The construction should occur in layers to achieve the required height of the fill while maintaining sufficient factor of safety. The consolidation process is form when the effective stress increase in the clay underneath and pore pressure decreases as the embankment is built in first layer.

The factor of safety can be calculated by, cu= (0. 11 + 0. 037 Ã- 0. 3) P0′ = 0. 11111 P0′ where 0. 3 is plasticity index and P0′ (overburden pressure) can be defined as Hb. The plasticity index is 0. 3 in this case because it used as a parameter in calculating the increased shear strength due to consolidation. Three layers were chosen to undergo this process and the results of factor of safety for each layer are 6. 29, 1. 84 and 1. 02 respectively. Therefore, the Factor of safety has reached the requirement which is 1 or greater.

Slope Stability

Circular arc analysis was calculated in this report as shown in Figure 8 below. The critical circle was to find the circular arc which gives the lowest factor of safety. Different radius of circle had analysed in the same way but with different circle centres and different points where the circle cut the slope. The various slopes was analysed on each of the three different depths as shown in Figure 9 below. Each slices approach was useful because the soil profile consists of different layers and where there are others forces to consider such as a water-filled tension crack and a foundation at the top of the slope. The Factor of safety was calculated by,

Factor of safety = = = 1. 116

Therefore, minimum Factor of safety was found to be 1. 116 with radius 18. 5m at a depth of 4. 0m.

Figure 8: Circular arc analysis- undrained condition using slices.

Figure 9: The various slopes analysed on each of the 3 different depths.

In frictional soil the shear strength, S, depends on the value of N (which represent to the reaction of self weight of the soil which in turn varies depending on the position of water table) and the cohesion which shown in Figure 10 below. The self weight force of the fill is held in position by resistance of the shear strength of the underlying soil. The resistance of slip would form when the self weight force excels to it. The effective normal stress is directly proportional to the critical shear strength of the soil.

Figure 10: Direction of self weight, W and shear strength, S

A tension crack would occur when the condition of limiting equilibrium develops with the factor of safety close to 1. The tension crack will form near to the top of the slope through which no shear strength can be developed and if it fills with water a horizontal hydrostatic force will increase by the disturbing moment (Barnes 2000). Shorter length of circular arc along which shearing resistance was mobilised would reduce the factor of safety.

Conclusion

In the conclusion, all the design has met the minimum requirement in bearing capacity, slope stability and settlement. Besides, bridge had chosen to build to pass over the motorway from Moor Road because it could minimise the cost fill volume compared with tunnel. Furthermore, to minimize the amount of fill required, the motorway's gradient have to split two sets rather of inclines and declines rather than one gradual gradient which shown in Figure 3. On the other hand, the clay would fail if the embankment not been laid in layers. The bearing capacity of the clay would increase when the embankment had to be laid in layers. This is because pore water pressure in the soil could dissipate and increase the effective stress. Other than that, a triangular ' Band' drain was chosen rather than sand drain due to it had closer spacing which can greatly reduce the consolidation time. Therefore, this would help to save the cost of construction and time. Not only that, the time of construction of this project will reduces when ' Band' drain and layers was used in the embankment. Last but not least, by using circular arc analysis, its shows the weakest parameter of the embankment will not fail since the factor of safety is 1. 116 which above 1.