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Comparison and Analysis of Computations for Tiered Reinforcement Retained Wall

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ABSTRACT
This paper uses Software MSEW3.0 to check computations for stability of reinforcement retained wall under different conditions such as different width of step, various wall height, and complex slope method, then makes comparison and analysis on variations of calculated length and strength of reinforcement elements, which provide reference for computations of similar retaining walls.

KEY WORDS
Tiered reinforcement retained wall, Width of step

RESUME
Reinforced earth retaining wall is widely used in various fields of geotechnical engineering with its good adaptability to foundation deformation, available for local materials and good seismic performance. However, for the higher reinforced retaining wall, the single-tiered high retaining wall tends to cause problems such as uneven stress distribution, increased pressure on the foundation of the wall, and much difficulty in construction. In practical application, the single-tiered reinforced soil retaining wall is not high, generally less than 12m. However, under special topographic conditions, high reinforced soil retaining wall is widely used. For the retaining wall with height more than 12m, multi-tiered retaining wall is adopted, which can adjust the horizontal deformation of the wall, reduce the stress of the wall face applied on the foundation, and facilitate the construction operation.

For the tiered reinforced retaining wall, the difference of step width and upper/lower wall height is the most prominent characteristic of the tiered retaining wall, which is different from single-tiered ones. The variation of step width and upper/lower wall height has great influence onto the length of reinforcement, base stress, amount of reinforcement materials and overall stability, which is an important content to be considered in the design of tiered retaining wall.

Taking design software MSEW3.0 as a tool, we make a comparison and analysis for two-tiered retained wall stability computation results that are got under different step widths, different upper/lower wall heights, it also make comparison on variation of minimum lengths required for reinforcement elements under different conditions, so as to evaluate the economical layout types of reinforcement element.

1. DATA USED FOR CALCULATIONS

In the calculation, the uniformly distributed live load applied onto the top of the retaining wall is 15kPa, the unit weight is 19.0kN/m and design value of internal Angle of friction is 30° for reinforced soil and retained soil, the unit weight is 20.0kN/m and design value of internal Angle of friction is 35° for foundation soil.

The reinforcement material used in the calculation is HDPE uniaxial geogrid which is made by extruding a sheet of HDPE,punching an accurate pattern of holes,then streching the sheet under controlled temperature. The main technical indexes of geogrid are shown in table 1.

Table 1. Basic specifications of geogrid

Product	Tensile Strength/ (kN/m)	Tensile load at 2% Strain/ (kN/m)	Tensile load at 5% Strain/ (kN/m)	Typical Strain at Peak Load/ %	Ultimate Creep Limited Strength For 120 Year （20° C）/(kN/m)
EG90R	≥90.0	≥23.7	≥45.2	≤10.0	≥34.9
EG130R	≥130.0	≥38.0	≥75.5	≤10.0	≥50.4
EG170R	≥170.0	≥52.5	≥103.0	≤10.0	≥55.9

2. INFLUENCE OF DIFFERENT STEP WIDTHS ONTO REINFORCEMENT

Under the condition that the overall height of the geogrid reinforced retaining wall and the height of the upper and lower walls remain the same, the influence of the reserved step width between the upper and lower walls is compared and analyzed.

2.1 Effect on the length of reinforcement element

Taking the stepped reinforced retaining wall with the total height of 20 meters and the height of the upper wall and the lower wall of 10 meters each as an example, the influence of the reserved step width between the upper wall and the lower wall on the reinforced retaining wall is compared and analyzed.

When the step width is 2m, the minimum length of geogrid required for the bottom of the lower wall is 12.42m, and the minimum length of geogrid required for the top of the upper wall is 10.32m. By calculation the minimum length of the required geogrid appears in the middle/lower position of the upper wall, and the minimum length of the required reinforcement element is 5.52m, as shown in FIG.1.

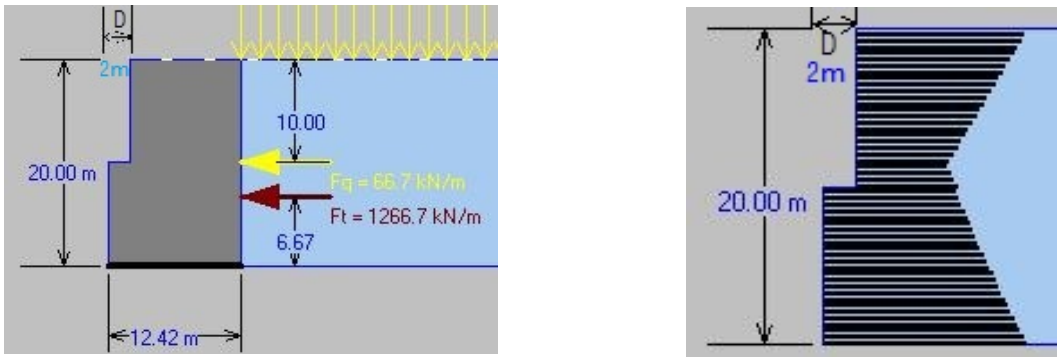


FIG. 1 minimum length of reinforcement element required for stability checking when step width is at D=2m

When the step width is 3m, the minimum length of geogrid required for the bottom of the lower wall is 12.92m, and the minimum length of geogrid required for the top of the upper wall is 9.32m. By calculation the minimum length of the required geogrid appears in the middle/lower position of the upper wall, and the minimum length of the required element is 5.02m, as shown in FIG.2.

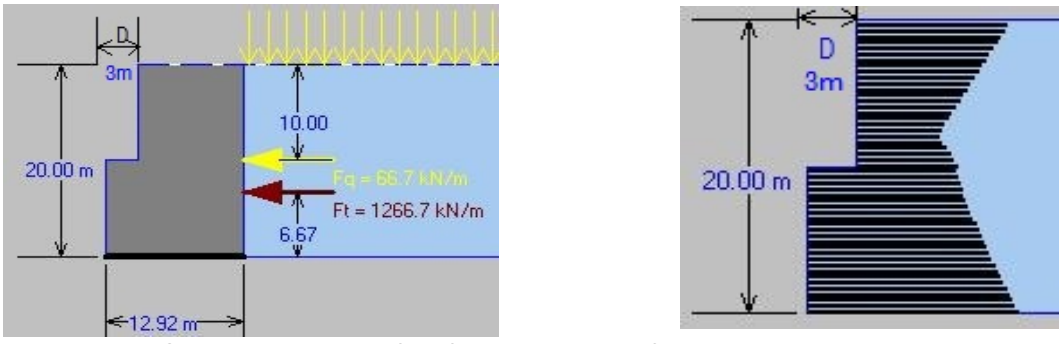


FIG. 2 minimum length of reinforcement required for stability checking when D=3m

When the step width is 4m, the minimum length of geogrid required for the bottom of the lower wall is 13.42m, and the minimum length of geogrid required for the top of the upper wall is 8.32m. By calculation the minimum length of the required geogrid appears in the middle/lower position of the upper wall, and the minimum length of the required element is 4.59m, as shown in FIG.3.

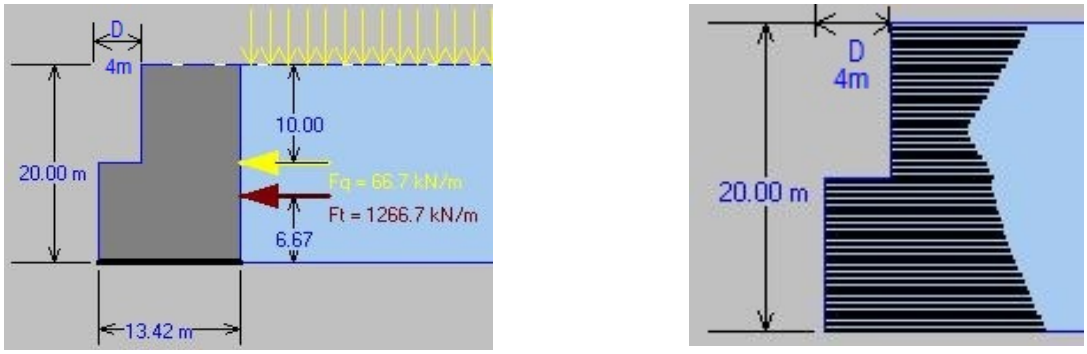


FIG. 3 minimum length of reinforcement required for stability checking when D=4m

From the above comparative analysis, it can be concluded that:
With the increase of step width steadily, the length of the geogrid required for the lower wall increases gradually, while the length of the geogrid required for the upper wall decreases gradually. The minimum length of the geogrid appears in the middle/lower part of the upper wall.

The same conclusion can be obtained by checking and analyzing the total height and the height of the upper and lower wall of the variable stepped reinforced retaining wall.

2.2 Effect on the amount of reinforcement element

The influence of the change of step width on the amount of geogrid is an important content of analysis, which is directly related to construction cost. Taking H=8m-24m and equal height for upper wall and the lower wall as examples, the influence of the reserved step width between the upper wall and the lower wall on the amount of geogrid reinforcement is analyzed and compared.

When the height of reinforced retaining wall is 8 meters and the width of step D=1m, the required amount of geogrid reinforcement for each meter of retaining wall is 79.93m2. With the increase of step width, the amount of geogrid reinforcement decreases gradually. When the width of step increases to 1.5m, the required amount of geogrid reinforcement is reduced to minimum 79.47m2. With the width of the step continues to increase, the amount of geogrid required for calculation gradually increases, from 79.47m2 when the step width is 1.5m to 99.08m2 when the step is 5m wide.

Summarize the minimum amount of geogrid needed when the height of reinforced retaining wall H=8m-18m and the width of different steps, as shown in FIG. 4. With the increase of the height of retaining wall, the amount of geogrid needed for calculation increases gradually. For the reinforced retaining wall of the same height, with the change of step width, the calculation of the required amount of geogrid also changes.

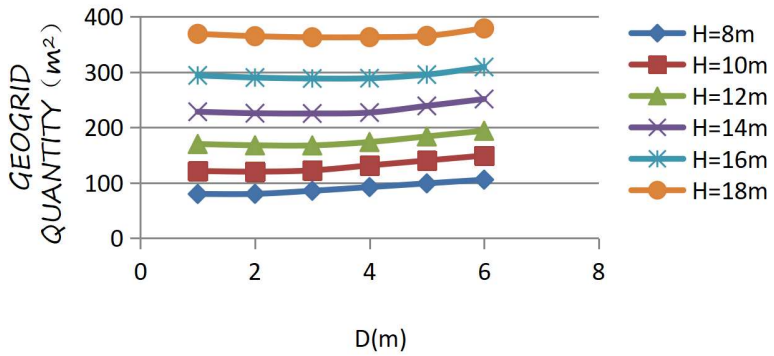


Figure 4 amount of geogrid at different width of steps and height of retaining wall

When different step widths are used, the required amount of geogrid reinforcement is different. Figure 5 summarizes the step width when the amount of geogrid reinforcement is the smallest at different retaining wall heights. With the increase

of the height of retaining wall, the step width corresponding to the minimum amount of geogrid material needed for calculation also tends to increase.

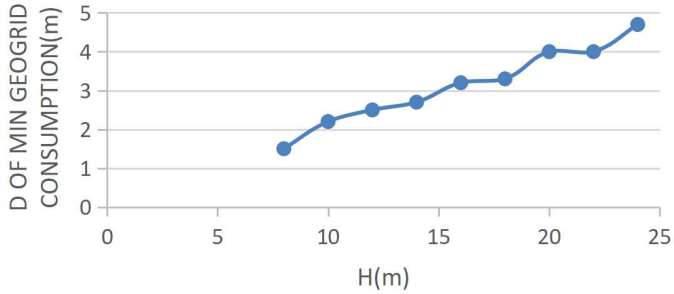


FIG. 5 step width with minimum amount of reinforcement at different retaining wall heights

When the height of retaining wall is 8 meters, the step width D=1.5 m corresponding to the minimum amount of reinforcement for each meter of retaining wall geogrid is calculated. Thus, it can be concluded that the ratio of step width D with the smallest amount of reinforcement to the height of lower wall H2 is 0.37. Similarly, for the stepped reinforced retaining wall of different heights, we can get the values of step width and corresponding height of lower wall (D/H2) that meet the minimum amount of geogrid bars required for stability, as shown in FIG. 6.

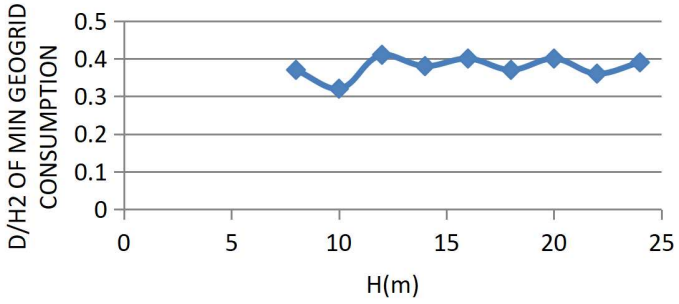


FIG. 6 D/H2 with minimum amount of reinforcement at different retaining wall heights

From the above analysis, it can be concluded that:

(1) With the height of retaining wall increases, the amount of geogrid required increases gradually, and the step width corresponding to the smallest amount of geogrid required increases.

(2) For the reinforced retaining wall of the same height, with the increase of step width, the amount of geogrid reinforcement required is gradually reduced to the minimum value; With the width of step continues to increase, the amount of geogrid is gradually increased.

(3) The ratio of step width D/ lower wall height H2 to the minimum amount of reinforcement required for retaining walls of different heights is about 0.31-0.41.

3. INFLUENCE OF HEIGHT VARIATION OF UPPER AND LOWER WALLS ON REINFORCEMENT

Under the condition that the total height and step width of the geogrid reinforced retaining wall remain the same, the influence of the upper and lower height of the stepped reinforced retaining wall is compared and analyzed.

3.1 Effect on the length of reinforcement

Taking the height of reinforced retaining wall H=10m and step width D=2m as examples, when the height of the upper wall H1=2m, the minimum length required to meet the design requirements is 6.38m for the bottom layer of the lower wall and 4.54m for the top of the upper wall. The minimum length of the required geogrid is 4.01m, as shown in FIG. 7.

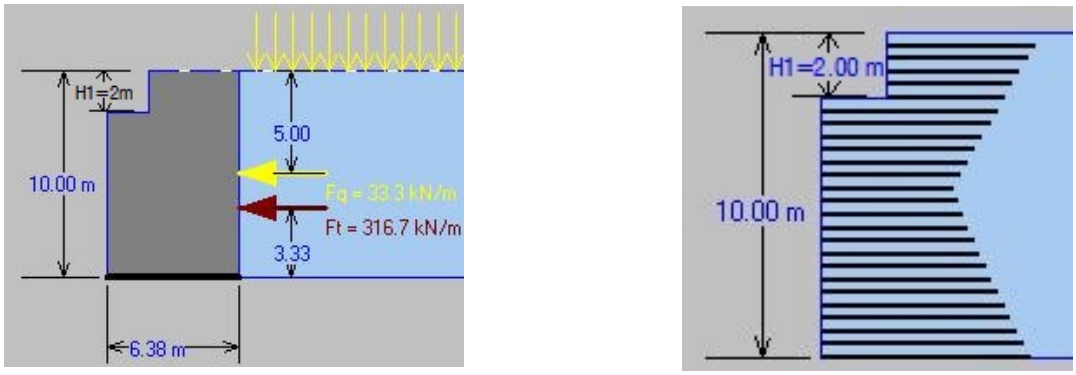


FIG. 7 minimum length of reinforcement required for stability checking when upper wall height H1=2m

When the height of the upper wall H1=4m, the minimum length of the bottom geogrid bars required to meet the design requirements is 6.78m, and the minimum length of the top geogrid required for the upper wall is 4.54m. The minimum length of the required geogrid is 2.70m, as shown in FIG. 8.

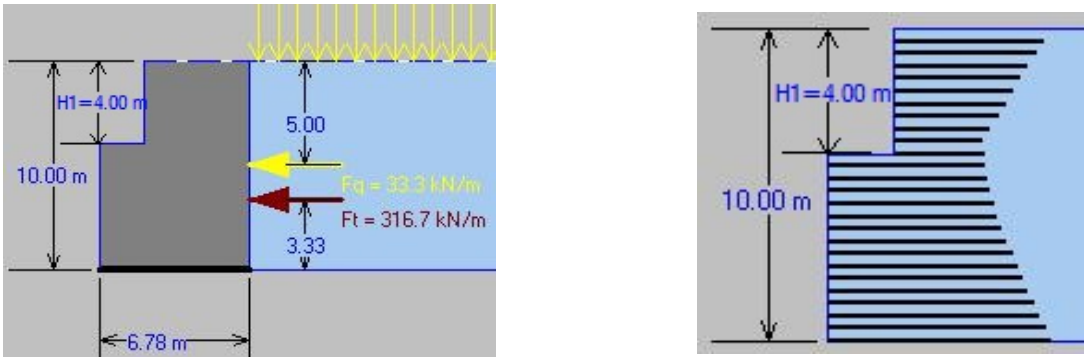


FIG. 8 minimum length of reinforcement required for stability checking when upper wall height H1=4m

When the height of the upper wall is H1=6m, the minimum length of the geogrid at the bottom of the lower wall is 7.18m, and the minimum length of the geogrid at the top of the upper wall is 4.54m. The minimum length of the required geogrid is 2.70m, as shown in FIG. 9.

From the above comparative analysis, it can be concluded that:

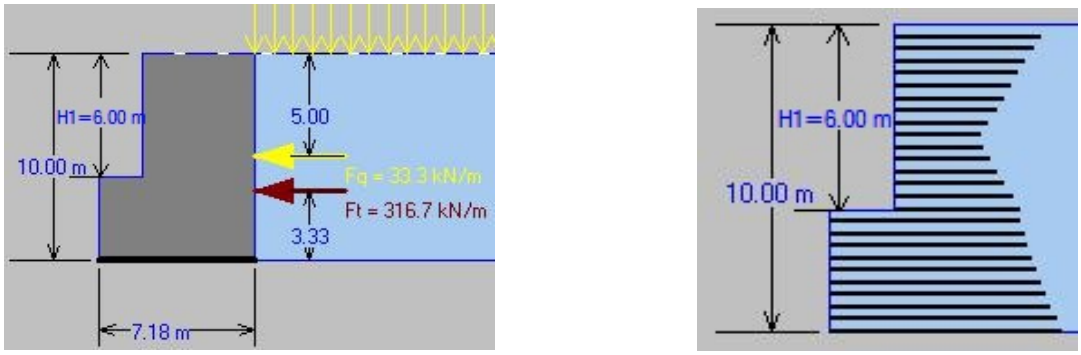


FIG. 9 minimum length of reinforcement required for stability checking when upper wall height H1=6m

with the increase of the height of the upper wall, the length of the geogrid required for the lower wall gradually increases,

while it has not much influence on the length of the geogrid required for the upper wall.

The same conclusion can be obtained by checking the total height and step width of the variable stepped reinforced retaining wall.

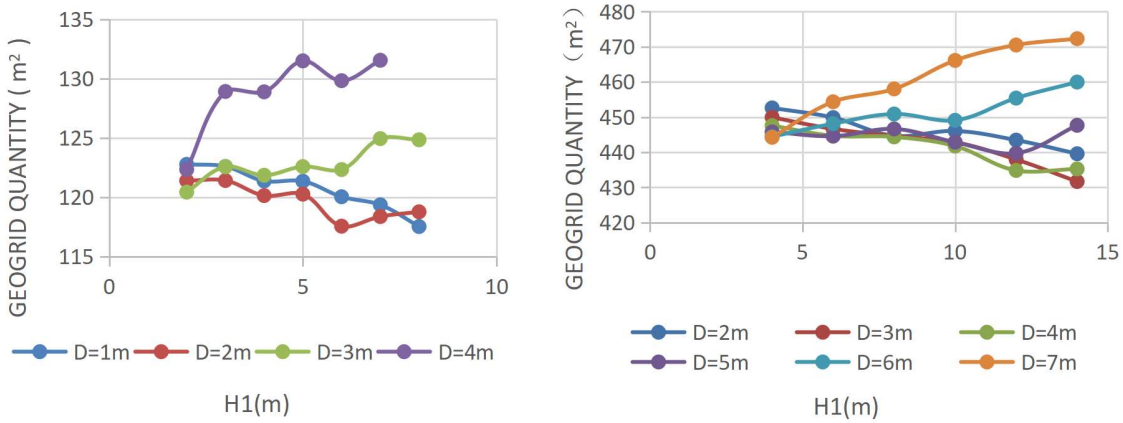
3.2 Effect on the amount of reinforcement

Taking the reinforced retaining wall with a height of 10 meters and 20 meters as examples, the minimum amount of reinforcement required for stability is compared by changing the height of upper and lower walls and the width of steps, so as to evaluate the more economical layout of reinforcement.

For reinforced retaining wall with retaining wall height H=10m and step width D=1m, when the upper wall height H1=2m, the required amount of geogrid for each meter of retaining wall is 122.78m2. With the increase of the height of the upper wall, the amount of geogrid decreases gradually, from 122.78m2 when the height of the upper wall is 2m to 117.54m2 when the height of the upper wall is 8m.

For reinforced retaining wall with retaining wall height H=10m and step width D=2m, when the upper wall height H1=2m, the required amount of reinforcement material for each meter of retaining wall is 121.4m2. With the increase of the height of the upper wall, the amount of geogrid decreases gradually. When the height of the upper wall increases to 6.0 m, the amount of geogrid needed is reduced to 117.57 m^2. As the height of the upper wall continues to increase, the amount of geogrid needed for calculation gradually increases.

The minimum amount of geogrid required for calculation of different step widths and upper wall heights of stepped reinforced retaining wall H=10 m and H=20 m are summarized, as shown in FIG.10. When the width of step is small, the amount of reinforcement decreases with the increase of the height of the upper wall. When the width of step is larger, with the increase of the height of the wall, the amount of reinforcement increases.

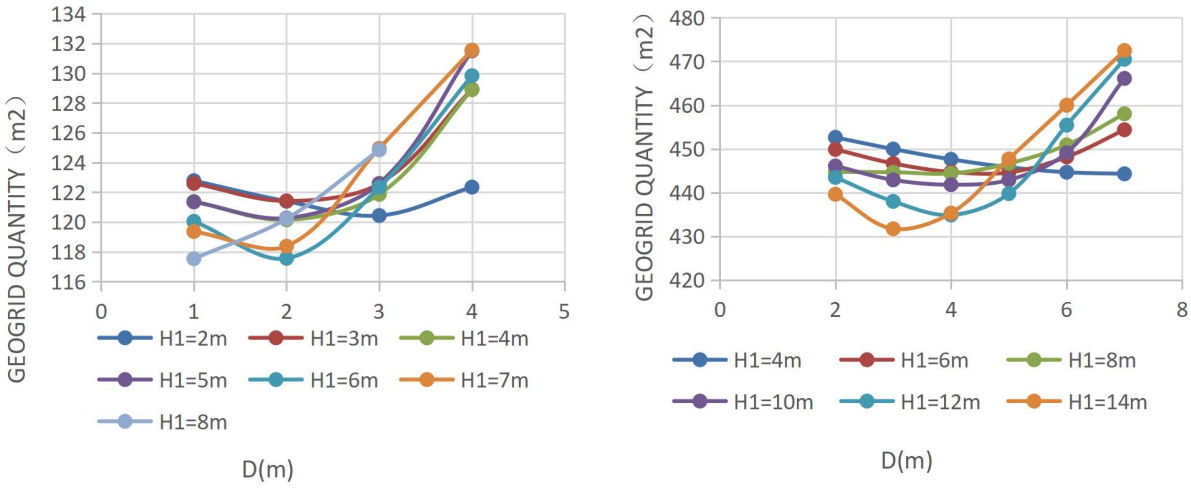


(a)H=10 m (b)H=20 m

Figure 10 amount of reinforcement at different step widths and wall heights

For reinforced retaining wall with height H=10m and upper wall height H1=2 m, when step width D=1m, the required amount of geogrid for each meter of retaining wall is 122.78 m^2. With the increase of step width, the amount of geogrid decreases gradually. When the step width increases to 3.0m, the amount of geogrid needed for calculation reduces to 120.44 m^2. With the width of step continues to increase, the amount of geogrid needed to calculate will increase gradually.

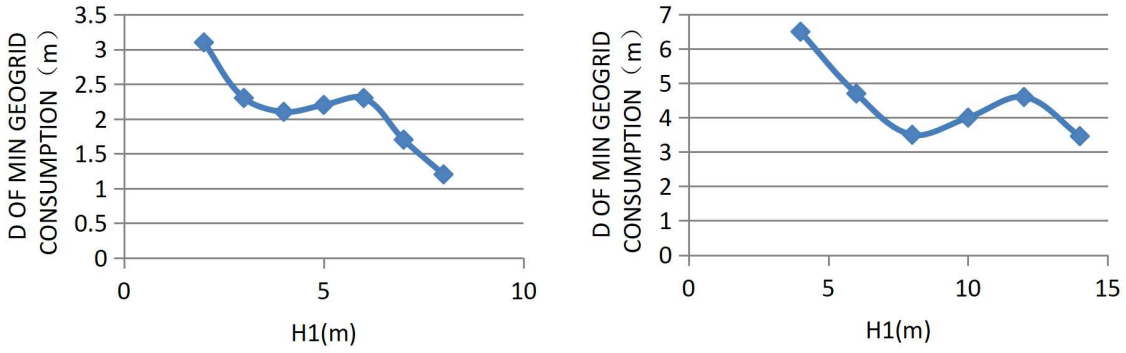
Summarize the minimum amount of geogrid needed when the height of reinforced retaining wall H=10 m and H=20 m are different, and the width of step are different, as shown in FIG.11. Generally speaking, with the width of the steps increases, the amount of geogrid needed to meet the requirements of stability decreases gradually at first, then increases gradually after reaching a certain value.



(a) H=10m (b)H=20m

Figure 11 amount of reinforcement at different step widths and wall heights

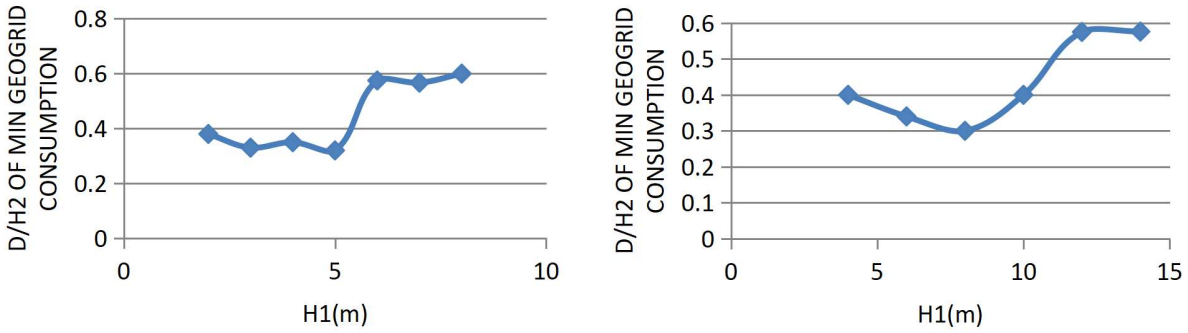
When different step widths are used, the required amount of geogrid reinforcement is different. FIG.12 summarizes the step widths when the amount of geogrid reinforcement is the smallest at different upper wall heights. With the increase of the height of the upper wall, the step width corresponding to the minimum amount of geogrid material needed for calculation shows a decreasing trend.



(a)H=10m (b)H=20m

FIG. 12 width of step with minimum amount of reinforcement at different retaining wall heights

For reinforced retaining wall with H=10 m and upper wall height H1=2m, calculate the step width D=3.1 m corresponding to the minimum amount of reinforcement material for each meter of retaining wall. Thus, it can be concluded that the ratio of step width D with minimum amount of reinforcement material to the height of lower wall H2 is 0.38. Similarly, for the reinforced retaining wall with different upper wall heights, we can get the ratio between the step width and the corresponding lower wall height (D/H2) with the minimum amount of geogrid required for stability, as shown in FIG.13.



(a) H=10m (b) H=20m

FIG. 13 D/H2 with minimum amount of reinforcement at different retaining wall heights

From the above analysis, it can be concluded that:

(1) Under the condition that the total height of retaining wall remains unchanged, when the width of steps is relatively small, the amount of reinforcement material will decrease when the height of the upper wall increases. Therefore, when the width of step is small, geogrid usage will be less if the upper wall is higher than the lower wall.

(2) Under the condition that the total height of retaining wall remains unchanged, when the width of steps is relatively large, the amount of reinforcement material will increase when the height of the upper wall increases. Therefore, when the width of step is large, geogrid usage will be less if the lower wall is higher than the upper wall.

(3) When the height of the upper wall is less than or equal to that of the lower wall, the ratio of step width D/ height H2 of the lower wall with the minimum amount of reinforcement is about 0.30-0.40.

4. CONCLUSION

MSEW3.0 was adopted to compare and analyze the influence of the width of the steps and the height of the upper and lower walls on the length and amount of reinforcement materials, and useful conclusions were drawn:

（1）Under the condition that the total height of the stepped reinforced retaining wall and the height of the upper and lower walls remain unchanged:

（a） With the increase of step width, the length of the geogrid required for the lower wall increases gradually, while the length of the geogrid required for the upper wall decreases gradually. The minimum length of the geogrid appears in the middle/lower part of the upper wall.

（b） For the reinforced retaining wall of the same height, with the increase of step width, the amount of geogrid reinforcement required is gradually reduced to the minimum value; With the width of step continues to increase, the amount of geogrid is gradually increased.

（c） The ratio of step width D/ lower wall height H2 to the minimum amount of reinforcement required for retaining walls of different heights is about 0.31-0.41T.

(2) Under the condition that the total height and step width of geogrid reinforced retaining wall remain unchanged

(a) With the increase of the height of the upper wall, the length of the geogrid required for the lower wall gradually increases, while the length of the geogrid required for the upper wall has little influence.

(b) When the width of steps is relatively small, the amount of reinforcement material will decrease as the height of the upper wall increases. Therefore, when the width of step is small, geogrid usage will be less if the upper wall is higher than the lower wall.

(c) When the width of steps is relatively large, the amount of reinforcement material will increase as the height of the upper wall increases. Therefore, when the width of step is large, geogrid usage will be less if the lower wall is higher than the upper wall.

(d) When the height of the upper wall is less than or equal to that of the lower wall, the ratio of step width D/ height H2 of the lower wall with the minimum amount of reinforcement is about 0.30-0.40.

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