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Analysis of influence of adjacent side length of deep foundation pit on pit angle effect

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Abstract. As a three-dimensional system with length, width and depth, the foundation pit is bound to have a pit angle effect. At present, the study of the foundation pit angle effect focuses on the influence of the "deep" of the foundation pit, while ignoring the analysis of the "wide". In this paper, the relationship between the length of the adjacent edge of the foundation pit and the foundation pit angle effect is analyzed by using the flac3d finite difference software. It is found that the ratio of the adjacent length to the depth does not change the functional relationship between the influence coefficient of the foundation pit angle effect and the ratio of the foundation pit angle distance to the foundation pit edge length. When the ratio of the length of the adjacent side to the depth of the foundation pit is less than or equal to 7, the influence coefficient of the foundation pit angle effect increases linearly with the ratio of the length of the adjacent side to the depth of the foundation pit. When the ratio of the length of the adjacent side to the depth of the foundation pit is more than 7, the influence coefficient of the foundation pit angle effect is a fixed constant. Finally, the rationality of the research results is verified by engineering examples.

1. Introduce

As a three dimensional space system with length, width and depth, it is inappropriate to regard the foundation pit as a plane strain problem in conventional design. Nowadays, a large number of scholars have studied the foundation pit space problem[1~4]. H P Shen[5] and X W Wang[6] put forward the calculation method of spatial deformation by multiplying the calculation result of plane strain and the influence coefficient of spatial effect. Z M Wu[7], Ou (1993[8],1996[9]) and H Li[10] studied the influence range of concave angle effect of foundation pit, and confirmed that the influence range of concave angle effect was about 1 times of excavation depth. J H Ding[11,12] believe that the displacement at the top of the cantilever structure is similar to the deformation of the simply supported beam under uniform load. Meanwhile, according to the displacement at the top of the cantilever structure, the coefficient of spatial earth pressure and the distribution of earth pressure are calculated in reverse. X Gao[13] proposed the functional relationship between the depth of foundation pit, the length of foundation pit and the influence coefficient of foundation pit angle effect. The current research on the influence of pit angle effect mainly focuses on the analysis of the influence range of the excavation depth of the foundation pit on the pit angle effect, while ignoring the influence of the adjacent length of the foundation pit on the pit angle effect. Based on flac3d numerical simulation software[14], the influence of adjacent length of

foundation pit on pit angle effect is analyzed, the relationship between the ratio of different adjacent length to excavation depth and the influence coefficient of foundation pit angle effect is proposed, and the rationality of the research results are verified through engineering examples.

2. Establishment of numerical model

This paper mainly studies the influence of adjacent length of foundation pit on pit angle effect. The excavation depth of the foundation pit is set at 10m, the fixed length of one side of the foundation pit is set at 100m, and the length of the other side is incremented within the range of 10m~90m. It ensures that the central part of the foundation pit is in the state of maximum deformation. The soil model is built based on foundation pit project in Weixian. The length, width and height of the soil model are 200m, 200m and 30m respectively. Model size covers all areas affected by foundation pit excavation. The model is built without any support. The interference of the supporting structure on the influence coefficient of foundation pit angle effect is avoided. In the simulation process, mohr-coulomb model is selected as the constitutive relation of soil. The weighted average value of soil is used for calculation. The mechanical parameters of soil layer of the model are shown in table 1. The calculation model and grid division are shown in figure 1.

Table 1. Mechanics parameters of the soil.

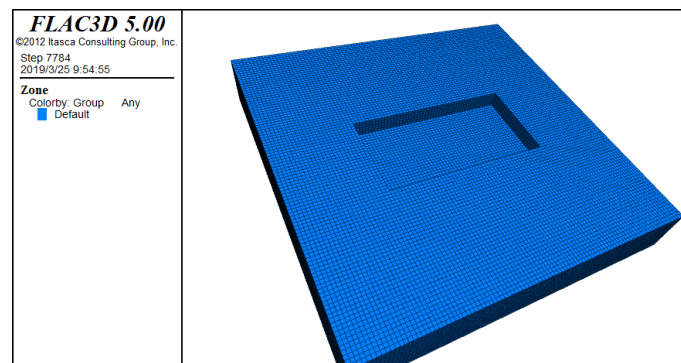| Name of soil layer	Thickness of soil layer(m)	γ(kN/m3)	c(kPa)	φ($^\circ$)
Miscellaneous fill	0.8	17.2	10.0	10.0
Silty clay	4.6	19.6	20.5	23.4
Sandy clay	3.6	19.3	17.1	29.6
Silty clay	4.2	18.2	20.3	8.6
Clay	2.1	19.2	55.0	14.6
fine sand	1.5	18.9	2.0	34.0

Figure 1. 100m×50m computing unit model.

3. Influence analysis of adjacent length on pit angle effect

The influence coefficient of foundation pit angle effect is defined: $K = w/w_{plane}$

When the length of the adjacent side is constant, the ratio of the horizontal displacement at any position of the foundation pit to the maximum horizontal displacement is defined: $Q = w/w_{middle}$

In the above equation, K is the influence coefficient of foundation pit angle effect. w is the horizontal displacement of the top of the foundation pit. w_{plane} is the horizontal displacement of the top space corresponding to the plane strain problem. w_{middle} is the maximum horizontal displacement under a certain adjacent length.

When the adjacent length is constant, the influence coefficient of foundation pit angle increases with the increase of x/L. When the influence coefficient of foundation pit angle effect increases to a certain

extent, it no longer changes with the increase of x/L, and its change curve shows an exponential function.

When A/H is constant, exponential function is used for fitting:

$$K_1 = A_1 \exp(-\varsigma / t_1) + w_1 \qquad (1)$$

$\varsigma = x / L$ (dimensionless) is the ratio of the distance of the foundation pit angle to the length of the foundation pit, $\varsigma = [0,1]$, K_1 is the influence coefficient of foundation pit angle effect. The fitting curves are shown in figure 2. The autocorrelation coefficients are all greater than 0.98. The curve has a high degree of fitting, and its changes meet the exponential function form.
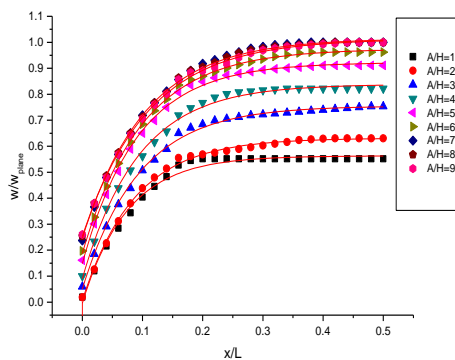

Figure 2. w/w_{plane} and x/L fitting curve under different A/H .
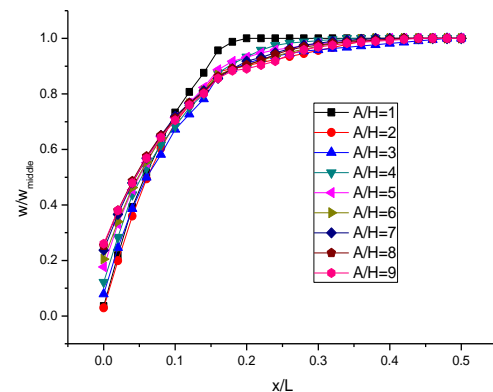

Figure 3. Relationship curve between w/w_{middle} and x/L under different A/H.

As can be seen from figure 3, when A/H is an arbitrary value, the deformation curves of w/w_{middle} and x/L coincide, and the change trend remains unchanged. The analysis shows that the change of A/H does not affect the geometric shape of the change curves of w/w_{middle} and x/L, but only affects the absolute value of the influence coefficient of foundation pit angle effect.

When x/L is taken as a constant value, w/w_{plane} increases with the increase of A/H, and no longer changes when it increases to a certain extent. As shown in figure 4, the change curve of w/w_{plane} with A/H can be divided into two stages. When A/H≤ 7, w/w_{plane} changes linearly with A/H. When A/H>7, w/w_{plane} no longer changes with the change of A/H.

When x/L is a constant and A/H ≤7, linear function fitting is adopted:

$$K_2 = A_2 \xi + w_2 \qquad (2)$$

$\xi = A / H$ (dimensionless), K_2 is the influence coefficient of foundation pit angle effect. The fitting curves are shown in figure 5. The autocorrelation coefficients are all greater than 0.96. The curve has a high degree of fitting, and it satisfies the linear function relationship.

The formula for calculating adjacent length of deep foundation pit and the influence coefficient of foundation pit angle effect can be obtained as follows:

$$\left. \begin{array}{ll} K = A\xi + w & A / H \le 7 \\ K = 7A + w & A / H > 7 \end{array} \right\} \qquad (3)$$
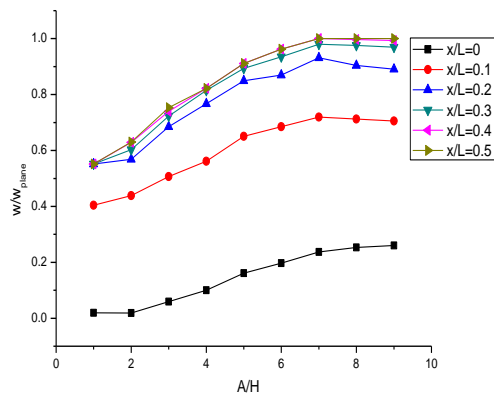
Figure 4. w/w$_{plane}$ and A/H fitting curve under different x/L.
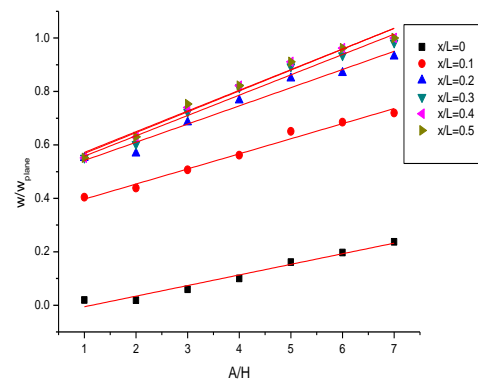

Figure 5. Curve of w/w$_{plane}$ with A/H under different x/L.

4. Engineering example of influence of adjacent length on pit angle effect

A foundation pit in Weixian is located on the west side of Century street and the north side of Tuanjie road. The depth of the foundation pit is 10.5 meters. The north-south length of the foundation pit is 94.6 meters, and the east-west width is 84.4 meters. The foundation pit support design adopts the form of slope protection pile, anchor cable and waterproof curtain. Location of excavation plan of the foundation pit is shown in figure 6.
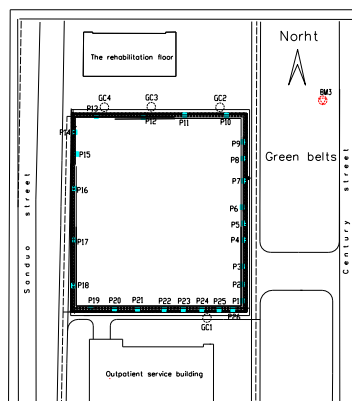

Figure 6. Location of excavation plan.

The influence coefficient of foundation pit angle effect is calculated based on the foundation pit monitoring data, and the influence coefficient of foundation pit angle effect is predicted by using the function relation of w/w$_{plane}$ changing exponentially with x/L. Figure 7 is the comparison curve between the measured and predicted values of the influence coefficient of the foundation pit angle effect on the south side of the foundation pit. Figure 8 is the comparison curve between the measured and predicted values of the influence coefficient of the foundation pit angle effect on the east side of the foundation pit.

It can be found from figure 7 and figure 8 that the predicted value of the influence coefficient of the pit angle effect on the east and south sides of the foundation pit is basically consistent with the change trend of the measured value. The predicted values curve is highly consistent with the measured values curve. The results show that the influence coefficient of the foundation pit angle effect can be predicted by the exponential function formula under any adjacent length of foundation pit.
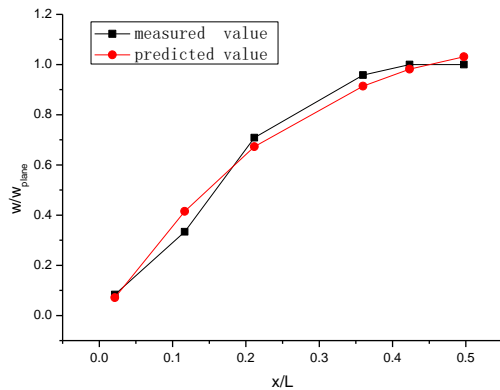
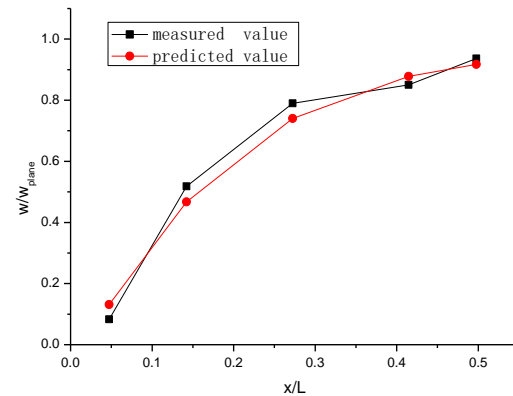**Figure 7.** Comparison curve between measured values and predicted values on the south side of foundation pit.

Figure 8. Comparison curve between measured values and predicted values on the east side of foundation pit.

Table 2. The measured and predicted values of the influence coefficient of the pit angle effect on the east and south sides of the foundation pit.

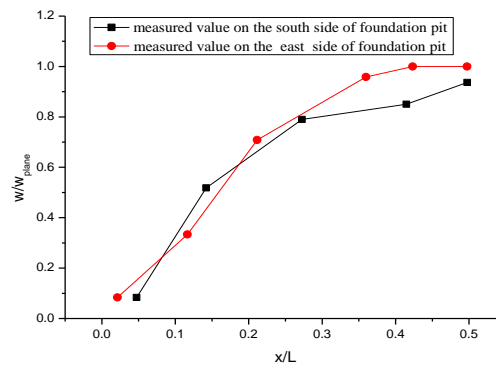| the	x/L	0.021	0.116	0.212	0.360	0.423	0.408
east	w/w_{plane} measured value	0.083	0.333	0.708	0.958	1	1
side	w/w_{plane} predicted value	0.071	0.415	0.673	0.914	0.982	1.031
the	x/L	0.047	0.142	0.273	0.415	0.498	
south	w/w_{plane} measured value	0.083	0.518	0.790	0.851	0.937	
side	w/w_{plane} predicted value	0.131	0.467	0.740	0.878	0.918	

Figure 9. Comparison curve of measured values of influence coefficient of pit angle effect on east and south sides of foundation pit.

The excavation depth of the foundation pit is 10.5m, the length of the east side of the foundation pit is 94.6m, and the length of the south side of the foundation pit is 84m. The ratio of A/H on both sides of the east and south sides is greater than 7. Both sides are affected by the length of the adjacent side. It can be found from figure 9 that the variation trend of the deformation curve of the foundation pit angle effect on both sides is basically the same. Due to the influence of foundation pit length, the influence coefficient of foundation pit angle effect is slightly deviated, and the deviation of the influence coefficient of foundation pit angle effect at the maximum displacement on both sides is 7.3%. The maximum deviation of the measured values of the influence coefficient of the foundation pit angle effect on both sides of the foundation pit does not exceed 17.5%. It is confirmed that when A/H>7, the influence coefficient of the foundation pit angle effect no longer changes with the change of the ratio of the length of the adjacent side to the excavation depth.

5. Conclusion

(1)The influence coefficient of foundation pit angle effect and the ratio of foundation pit angle distance to the length of foundation pit are exponential function, and any ratio of the adjacent length to the excavation depth will not interfere with this functional relationship.

(2) The ratio of the adjacent length of the foundation pit to the excavation depth does not affect the geometric shape of the curve of the influence coefficient of the foundation pit angle effect changing with the distance of the foundation pit angle, but only affects the magnitude of the absolute value of the curve.

(3) The curve of the influence coefficient of foundation pit angle effect changing with the ratio of adjacent length to excavation depth can be divided into two parts. When the ratio of adjacent length to excavation depth is less than or equal to 7, the influence coefficient of foundation pit angle effect increases with the increase of the ratio of adjacent length to excavation depth, and the relationship is linear. When the ratio of adjacent length to excavation depth is greater than 7, the influence coefficient of foundation pit angle effect no longer changes with the increase of the ratio of adjacent length to excavation depth, and the influence coefficient of foundation pit angle effect is a fixed constant.

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