RESEARCHING ON POSITION OF CALCULATION SLIDE CENTER IN COMPUTING THE STABILITY OF ROAD BED BY SLIDE CIRCULAR ARC METHOD

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Abstract: *Investigating the slope stability of the road is a problem which has been researched since long time. There had existed many methods but the most popular in over the world is W.Fellenius' proposal based on "slide circle arc" suppose. A specially improtant issue when applying this method is determining position of the most dangerous slide arc tha t is its center, hereby called "caculation slide center" and correspondently is "caculation slide arc". However, it is so complicate that up to now there have been many road scientists proposing different methods for that. This presents the result of resea rching to discover the position of calculation slide center in computing the stability of road bed by slide circular arc method.*

Key Word: *Road bed stability; Embankment stability; road slope stability*

I. APPROACH

Investigating the slope stability of the road is a problem which has been researched since long time. There had existed many methods but the most popular in over the world is W.Fellenius' proposal based on "slide circle arc" suppose [1],[2],[3],[4],...

A specially improtant issue when applying this method is determining position of the most dangerous slide arc that is its center, hereby called "caculation slide center" and correspondently is "caculation slide arc". However, it is so complicat e that up to now there have been many road scientists proposing different methods to specify this :

According to W. Fellenius: "calculation slide center" bases on a line and he proposed the manner to specify it as fig. 01.

Some experts as Gonstein, D.W. Taylor, N.N. Maslov, N.A. Txytovitr, G.Pilot… established the monograps, tables or shew the lines on which calculation slide center existing.

In the past, that calculation based on experience, is complex and large quantity; it is limited by computation facilities, thus the quantity of investigation had been not so enough. In other hand there has not been instruments which has ability to specify whether minimum factor of safety (or calculation slide centre") is correct or not?

Stability of road slope is influenced by many factors: road bed elevation, talus grade; height, width of banquette lateral; gravity unit, friction angle, cohesive force of soil; ponding situation…

It is problem that: situations of different embankments, essentially, how different stabil ity of road bed are?

Specially, key issue of this problem: how to properly determine the position of "calculation slide arc"?

Methodology:

Firstly, we establish utility software for automatically determining factor of safety of road bed. This program is flexible instrument for computing and then being used to investigate the stability of various cases such as factor of safety, the position of calculation slide arc centre…according to the various parameters of embankment.

II. SOME MANNERS TO SPECIFY POSITION OF CALCULATION SLIDE CENTER

2.1. Proposal of W. Fellenius

According to W. Fellenius, position of calculation slide center is determined as below (refer to fig. 01):

Firstly, determining line EF; E is specified as figure with a depth H and a length 4.5H fr om toe of talus; F is specified by the angles β1 and β2

Correspondingly with fill slope (referring to table 01)

Table 01. *Values of β1 and β2*

Talus grade	β_1 (Deg.)	β_2 (Deg.)
1:5	25	37
1:3	25	35
1:2	25	35
1:1,5	26	35
1:1	28	37

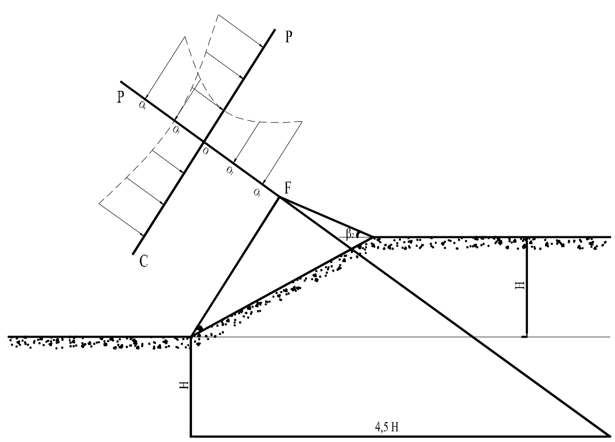

Fig 01. *Determining Calculation slide center by W. Fellenius*

On line EF lengthening, to suppose the points as the centers of slide arcs: O1, O2, O3 ...Oi, ... On…(distance between them may be 0.25H -0.3H). Corresponding to center Oi, establishing the slide arcs then specifying their factor of safety (K) and determining minimum value of them (Kmin). With n of supposed centers we will get n of Kmin . Using EF as coordination axle, based on the centers Oi to establish the graph of the values of Kmin then determine minimum value Min [K_{min}(i)] and we will have center O_{min}1 on EF, correspondingly.

Basing on O_{min}1 to draw line CD being perpendicular with EF. Basing on CD to repeat gradually trial process as above, we will determine the point O_{min}2, center of the most dangerous slide arc.

This method has not instructed the location of firstly supposed centers O1, O2… on EF, more over computation quantity is so large.

2.2. Some other proposals

To determine calculation slide arc (the arc which has minimum facto r of safety), there are others manners being presented as: graphic, tabulate,… by D.W. Taylor, Gonstein, G. Pilot [1], [2], ... among them attention to two conclusion should be paid:

1. As proposal of G.Pilot, D.Taylor: calculation slide centers will ba se in vertical line MN which is across middle point of fill slope and perpendicular with bottom line of road bed (Fig.02), [3], [4].

2. As proposals of other scientists, scope of calculation slide center is bisector PQ of angle NPK; PK is perpendicular with talus at middle point P (refer to Fig. 3)

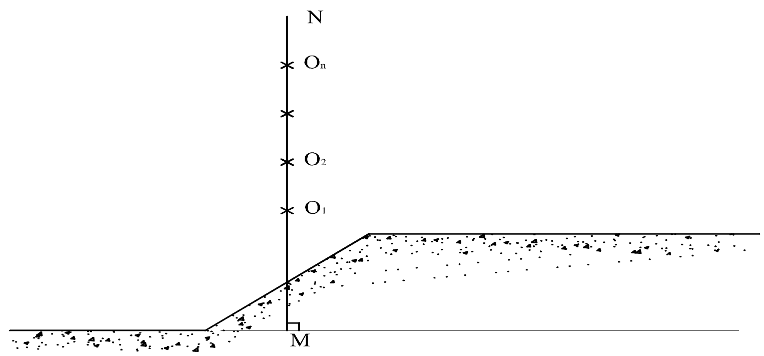

Fig 02. *Scope of calculation slide center by Pilot, Taylor*

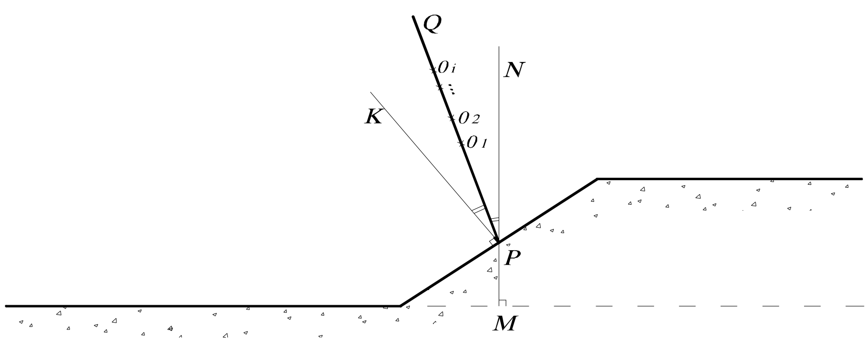

Fig 03. *Scope of calculation slide center by experiment*

In spite of gradually trial determination of calculation slide arc, the manners above mentioned helped to limit the scope of finding calculation center out and pointed out that scope are the lines. However, they just only considered particular cases and the results were not coincided. In fact, by our calculation many cases, it is proved that calculation centers have not been in scopes pointed out by those methods.

III. ORIENTATION FOR INVESTIGATING POSITIONS OF CALCULATION SLIDE CENTERS

Using Utility Program, after pilot trial calculating more than 200 problems of different road beds which are various by dimension, fill soil mechanic, natural soil properties; we discovered that there are many cases their calculation center position were relatively suitable with G. Pilot's Proposal, but so much other one, they are different. In other hand, should be noted that G. Pilot only investigates with fill up soils being grain (C=0); and natural soil are merely cohesive soil (φ=0); the influence of flooding permeable water compressor also is neglected. Thus the result may not be correct with general case (fill up soils and natural soils have φ,C; and ponding water compressor…).

By experimental computation on PC, we also invent that the scope of Calculation slide center can be determine definitely by basing on two orient lines (refer to Fig.4):

- First line (line I) is perpendicular with base line of embankment and across through "equivalent talus"

- Second line (line II) is perpendicular with base line of embankment and pass through middle point of banquette lateral

Position of lines I and II are specified by xI and xII

"Equivalent talus" can be understood as below:

In general form, embankment has banquette (with general talus form: MNEFH) and can be converted in to form of homogeneous talus with out banquette (line IPQK). P and Q in turn are middle point of sub taluses NE and FH; so we have two couples of triangle which are equal each other: S1=S2 and S3=S4. It is proved by Varinogn Law that two these forms are equivalent in slope stability.

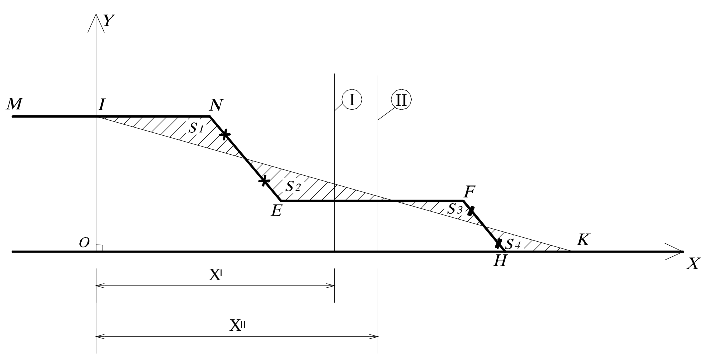

Fig 04. *Orient schema for investigating the position of calculation slide center*

IV. EXPERIMENTAL COMPUTING TO DETERMINE THE POSITION OF CALCULATION SLIDE CENTER

After orientation of investigation scope, experimental computation and ste p 2 of research are conducted. In this research, all parameters such as height of embankment; height and width of banquette; talus grade; traffic load; gravity unit, internal friction angle, cohesive force unit of fill soil and natural soil,… are in turn v ariable; then by using utility software, corresponding to those cases, the investigation were implemented to specify the rule of the scope which will cover all calculation slide centers.

Because the rule of position of calculation slide centers have been d etermined yet, so in this stage we have investigate on very large grid of slide center to cover all points may be calculation center.

The cases of experimental computing and investigating are:

1. Position of Calculation Slide Center (PCSC) is in cases o f various slope grades;
2. PCSC is in cases of various height of road bed (H);
3. PCSC is in cases of various height of banquette;
4. PCSC is in cases of various width of banquette;
5. PCSC is in cases of various cohesive unit of fill soil of road bed;
6. PCSC is in cases of various internal friction angle of fill soil;
7. PCSC is in cases of various cohesive unit of natural soil;
8. PCSC is in cases of various internal friction angle of natural soil;

Deriving from experiment computing results we discovered a rule:

It exist an Area of Calculation Slide Center (ACSC), in which, all positions belonging to are ACSC have minimum factor of safety.

The coordination of ACSC is as below:

$$(xI - 1) \le O.x \le (xII + 1)$$

$$H \le O.y \le 2.5H$$

V. RELIABLE EVALUATION OF ESTIMATION

To evaluate the correct and reliable level of estimation, many computing problems are implemented and planned as below:

$B = 10 \div 20$ (m)

$H = 2 \div 8$ (m)

$L = 0 \div 20$ (m)

$h/H = 0 \div 0.5$

$Tg\beta = 0 \div 1$

hd = hh = 0

hd - hh = $0 \div 0.4$

$H_1/H = 0.5 \div 2.0$

Cdry = $2.0 \div 5.0$ (T/m^2)

φdry = $14 \div 22$ (deg.)

Cn_1 and $Cn^2 = 0.5 \div 6.0$ (T/m^2)

φn_1 and $\varphi n^2 = 8 \div 20$ (deg.)

Of which:

B - road bed width

H - road bed height

L - banquette width

h - banquette height

Tgβ- slope grade

hd and hh- highest and lowest water level

Cdry - cohesive force unit of dry fill soil

φdry - internal friction angle of dry fill soil

Cn_1 and Cn_2 – cohesive force unit of natural soil lay 1 and lay 2

φn_1 and φn_2 – internal friction angle of natural soil lay 1 and lay 2

Criteria of natural soils of the layers are presented in table 02

Table 02. *Criteria of natural soils*

Stae of soil	Criteria	Clay	Loamy	Sandy
Semi-hard $0< B \leq 0.25$	C	6.0	40	2.0
	φ	20	23	28
Plast-firm $0.25< B < 0.5$	C	4.0	2.5	1.5
	φ	18	21	26
Plast-soft $0.25< B < 0.75$	C	2.0	1.5	1.0
	φ	14	17	24
Plast- liquit $0.75< B < 1.0$	C	1.0	1.0	0.5
	φ	8	13	20

That planning can cover all problems existing in fact. The data are random selected.

Dimension of test samples is: n = 250; of which: 6 cases are out of estimated area with deflection is 1m; thus error is less than 1%.

Error ratio is: f = 6/250 = 0.024.

Deducing from that: to gain the correctness of estimation: ε = 0.02 then reliability of estimation (γ) is as below:

$$t = \frac{\varepsilon\sqrt{n}}{\sqrt{f(1-f)}} = 2{,}07$$

Referring to table of Laplast integral:

$$zz\varphi(t) = 0.4808$$

$$\gamma = 2\ \varphi(t) = 0.962$$

Thus, the estimation of rule of ACSC above mentioned has error about 0.7% ÷ 4.7%; and reliability is: 96.2%.

VI. RECOMMENT AND CONCLUSION

Based on experiment research, investigating many cases we have t he conclusions:

1. Position of calculation slide center is various when geometric parameters of road bed, mechanic and physical criteria of soil (fill soil and natural soil) are changed. However almost of them is located in specific scope. Coordinati on of this area is specified as below:

Abscises are limited by two lines which are perpendicular with base of road bed and pass through middle point of banquette and “equivalent talus”;

Ordinate is limited by height of road bed (H) and 2.5 H

To have high reliable this area need to be wider, thus it should be:

$$(xI - 1) \leq O.x \leq (xII + 1)$$

$$H \leq O.y \leq 2.5H$$

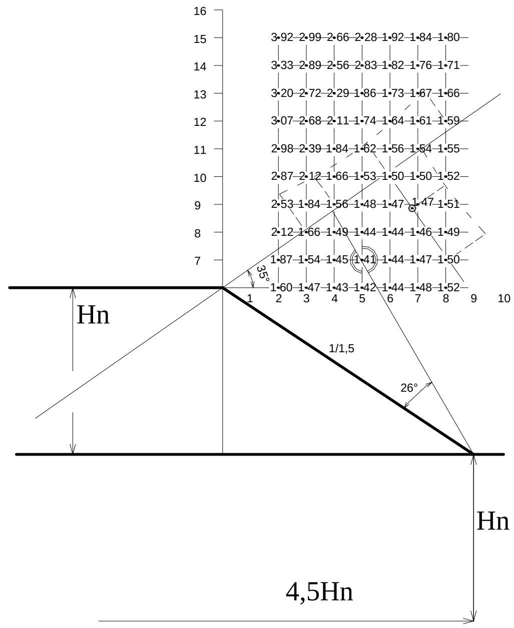

__Fig 05.__ Result of Computing case No.110

2. To review the position of calculation slide center proposed by W. Felenius and other autho rs:

Using utility software, by experiment computing many cases, drawing the grids with minimum factor of safety corresponding to their intersect -points; synchronously establishing the calculation slide center by W. Fellenius for comparing.

It is shown in Fig. 05 as an example. Those experiment computations presented that:

W. Fellenius' proposal has not given minimum factor of safety as request and has a deflection of position of calculation slide center . More over, Fellenius' proposal is only appli ed for particular case of talus is line (with out banquette).

3. By the experiment computations we discovered that:

It is existed an area of calculation slide center in which any point has calculation factor of safety is similar and equal minimum factor of safety.

We called that area is Area of Calculation Slide Center (ACSC) and determined it as above mentioned.

The ACSC is able to apply correctly for general case of road bed with banquette. In case of talus is merely line, the proposal of Taylor and Pilot is similar.

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