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POSSIBILITY CALCULATION MODEL OF THE BOLT-LENGTH IN FRACTURED ROCK ROADWAY

1. Introduction

The roof of roadway surrounding rock becoming unstable and falling of ground is a kind of frequent dangerous accident. So fixing the bolt-length has important engineering significance by studying the stability of roadway surrounding rock roof. We all know that the essential and abundant condition of falling ground in fractured rock roof in roadway is

$$\hat{s} \cdot sign(\hat{r} \cdot \hat{n}_i)\hat{n}_i > 0 \quad (1)$$

where, $\hat{s}$ is displacement direction of dangerous rock; $\hat{r}$ is external forces on dangerous rock; $\hat{n}_i$ is outer unit normal of .ith group structural plane.

Roadway surrounding rocks in fractured rocks can be considered as a blocks set cut by many different attitudes' structural planes. The block is called dangerous rock when meeting movement condition. The displacement directions of blocks and the dominant external force directions are identical when fall of ground. If the dominant external force is its weight then the block displacement direction is vertical. So on the roadway roof in vertical direction and no geometry restricting convex blocks can be seen as dangerous rocks. The support bolt-length is the first max falling height. Dangerous rocks existence has close relation with structural plane attitude. Structural plane attitude and distribution in rocks are random. The length of bolt used to consolidate the surrounding rocks is also random variable. So the theory of possibility can be used to set up the conjectural model.

2. Set up possibility space

Ω is been constituted by inter-set of structural plane traces. Event field. **Γ** is been seen as a closed range surrounded by excavation plane and structural plane trace possibility. A set function **P** in this event area can be defined as the possibility space（**Ω**，**Γ**，**P**）.

Giving, on the roadway transverse section two groups of traces are distributed and traces in the same structural plane are parallel. The space between traces obey minus exponent distribution, two groups parallel traces form quadrilateral set. The roadway sections are variable randomly to the net (Fig. 1). Supposing in the first group there are K1 traces on specimen plane. In the second group there are K2 traces. So there are (K1-1)× (K2-1) closing subsets are formed called ζ_i. Roadway transverse sections dropping into every subset has the same possibility. So

$$\Omega \in [\xi_i / i = (k_1 - 1) \times (k_2 - 1)] \quad (2)$$

As for the falling event the 9 conditions at the position which roadway section drops into the traces nets in fig.1 may occur, only ①、②、⑥、⑦、⑧ may lead to falling.0 represents impossible event. So the falling event subset has the range from 0 to some maximum (called ζ_{max}). And the event filed:

$$\Gamma \in [D \le \varsigma_i \le \varsigma_{max} / i = (k_1 - 1) \times (k_2 - 1)] \quad (3)$$

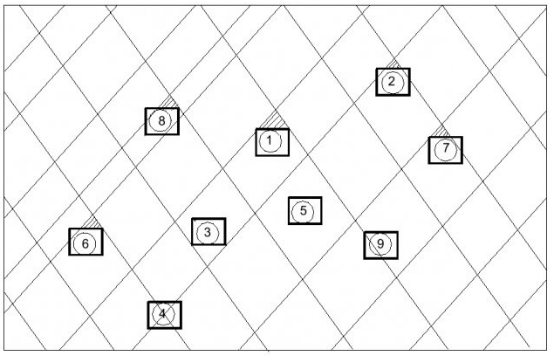

Fig.1. The relativity position of roadway cross section on the net of structural plane trace

Now we define the falling possibility as:

$$p = \sum_{i=1}^{(k_1-1)\times(k_2-1)} \frac{\varsigma_i}{\xi_i} \quad (4)$$

Thus, falling event has uniform distribution in specimen space. Its possibility value equalizes to the value of possibility, which the max height point is located on the max area made up by structural plane traces and excavation plane traces.

The event filed is the cutting set of two kind traces (such as fig.2).

3. The analysis of event field

Imagine there are two intersect traces and their length are l_1 and l_2 The max falling height is h_{max}. Given Z is random falling height. Z_{max} is the max falling height; x is projection height of trace l_1 , y is projection height of trace l_2. B is the trace length of excavation plane. We can find:

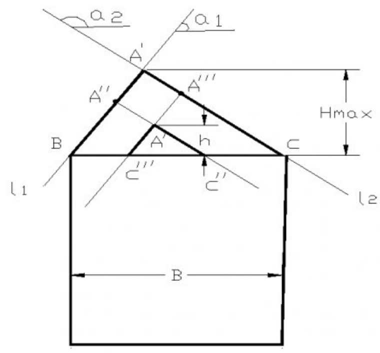

Fig.2. The distribution of falling

$$X=|l_1|\sin\alpha_1, Y=|l_2|\sin\alpha_2, h_{max}=B/\eta \quad (5)$$

where

$$\eta=|ctg\alpha_1|+|ctg\alpha_2|;$$

α_1, α_2 are respectively the intersecting angles between two structural plane trances and excavating plane trance

$$[1\ ,\ X\ ,\ Y]=[h_{Max}/h_{Max}\ ,\ X/h_{Max}\ ,\ Y/h_{Max}] \quad (6)$$

Analyzing the factor of event field we find that 3 cases may occur:

(1) $X>1, Y>1$ then

$$Z_{Max}=\min[1,X,Y]=1\ ,\ Z\in[0,1] \quad (7)$$

(2) $X<Y$ *and* $X<1$, $Y<1$ then

$$Z_{Max}=\min[1,X,Y]=X\ ,Z\in[0,X] \quad (8)$$

(3) $y<x$, *and* $x<1, y<1$ then

$$Z_{Max}=Y,\ Z\in[0,Y] \quad (9)$$

4. Condition possibility

(1) if $x>1$ $y>1, 0\leq z\leq 1$ then the possibility of falling unit height h<Z is (fig.3)

$$p(h\leq z/x,y)=1-\frac{\frac{1}{2}\eta(1-Z)^2}{\eta/2}=2Z-Z^2 \quad (10)$$

(2) if $x<y, x<1, y<1,\ 0\leq z\leq x$ then the possibility of falling unit height $h<Z$ is (fig.4)

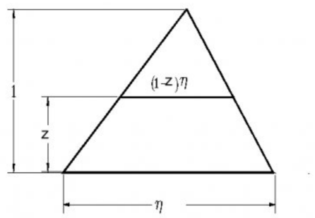

Fig.3. Event field and specimen space of first case

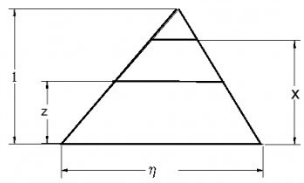

Fig.4. Event field and specimen space of the second case

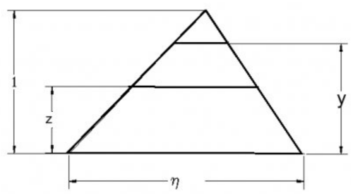

Fig.5. Event field and specimen space of the third case

$$p(h\leq z/x,y)=\frac{\frac{1}{2}(2\eta z-z^2\eta)}{\frac{1}{2}(2\eta x-x^2\eta)}=\frac{2z-z^2}{2x-x^2} \quad (11)$$

(3) if $y<x$, $x<1$, $y<1$, $0\leq z\leq x$ then the possibility of falling unit height $h<Z$ is (fig.5)

$$p(h\leq z/x,y)=\frac{2z-z^2}{2y-y^2} \quad (12)$$

5. Bolt length possibility

Supposing the distributions of x and y are independent respectively. So the falling height possibility may be described:

$$p(h<z)=\int\int_{xy} p(h/x,y)f_1(x)f_2(y)dxdy \quad (13)$$

where $f_1(x)$ and $f_2(x)$ are the distribution function of x and y respectively. Relational study indicate that structural plane trace obey minus exponent distribution. So, x and y are also obey minus exponent distribution respectively. The possibility needed bolt-length $L<Z$ can be deduced from those condition. We obtain with the figure integration

$$p(L \le z) = (2z - z^2)e^{-w_1} + \frac{2w_1 z(1-z)^3}{3(\bar{x}+\bar{y})} \times$$

$$[f_1(z) + f_2(z) + f_3(z), \quad 0 < z < 1;$$

$$p(L \le 0) = 0, \; P(L \le 1) = 1, \qquad (14)$$

where

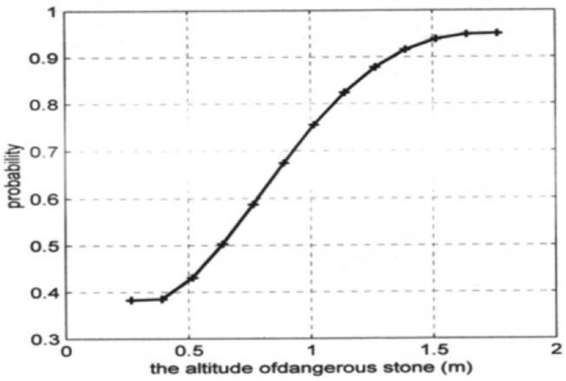

Fig.6. The possibility of needed bolt-length

$$f_1(z) = \frac{1}{6} e^{-\frac{1}{y}} \left[\frac{e^{-\frac{1}{\bar{x}} z}}{z(2-z)} + \frac{8e^{-\frac{1+z}{2\bar{x}}}}{(1+z)(3-z)} \right]$$

$$f_2(z) = \frac{e^{-w_1 z}}{6(2z - z^2)^2} + \frac{16e^{-\frac{w_1}{2}(1+z)}}{3(1+z)^2(3-z)^2} \qquad (15)$$

$$f_3(z) = \frac{8e^{-\left(\frac{z}{\bar{x}} + \frac{1+z}{2\bar{y}}\right)}}{3(2z - z^2)(1+z)(3-z)} + \frac{1024e^{-\left[\frac{1}{2\bar{y}} + w_2(1+z)\right]}}{3(1+z)(9-z^2)(2-z)}$$

w_1 and w_2 are distributing synthesize parameters.

Structural plane attitude and traces average

The number of planes	Dip angle	Dip direction angle	Trace length average (m)
P_1	67	90	1.523
P_2	57	80	1.381
P_3	65	99	2.355

6. Engineering example

A roadway, the dip angle is α=87.7° dip direction angle is β=277° . The height of transverse section of roadway is 4m and the span is 5m. According to geology explore and the result analyzed the structural planes can be divided into 3 groups in roadway surrounding rocks. Each group has a dominant direction. Every dominant directions'attitude and the length average value of structural plane trace in specimen windows are shown in Table .

Divided into three groups and calculation the result shows in fig.6.The possibility of needed bolt length <=1.775m is 0.95.The possibility of bolt length<=0.385 is 0.382 designed bolt length is 2m.

7. Conclusion

(1) The bolt length deduced from the model belongs to upper value.

(2) The bolt length deduced from this model is more convenient than the model of continuous medium mechanics model.

(3) As long as the basic parameter of structural plane and roadway geometry size are given the bolt length can be deduced primarily. With engineering advancing, the measuring statistic model and parameters will make perfect continuously and the result will trend to more and more precise.

MAIN REFERENCES

1. *Wang Weiming.* Dangerous rocks forecasting and application in surrounding rocks. Coal industry publishing house.