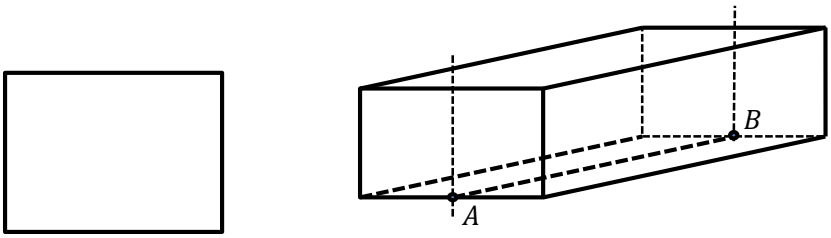
CUMCM-2025 Problem D

Mine Flood Spreading Model and Emergency Escape Strategy

Mine flood disaster is the foremost of the “five major hazards” in safe mining production, which can easily cause significant casualty and property losses. Due to the complex hydrogeological conditions in mines, incidents of water flood are difficult to prevent. When mine flood occurs, quickly deducing the spreading process of water flow and formulating a scientific disaster relief plan along with evacuation routes can significantly reduce the risk of personnel and minimize economic losses.

The mine tunnel system is usually designed based on the distribution of mineral deposits and the orientation of mineral veins, forming a complex three-dimensional network structure with intersecting tunnels. There are various shapes of tunnel sections (such as rectangular, arched, trapezoidal, etc.), but all the following problems only consider rectangular cross-sections, with the bottom edge parallel to the horizontal plane (see Figure 1(a)). A section of tunnel is represented by the line connecting the midpoints of the bottom edges of its two endpoints as shown in Figure 1 (b), represented by the line segment AB.



(a) Rectangular tunnel cross-section (b) A section of tunnel

Figure 1 3D schematic diagram of the section of tunnel

Figure 2 is a schematic diagram of a mine tunnel network, where black dots denote the midpoints of the bottom edge of the tunnel section, red dots denote the exits of the mine tunnel network, and the line segments connecting two points represent a section of the mine tunnel. Annex1 and annex2 provide data on two different mine tunnel networks.

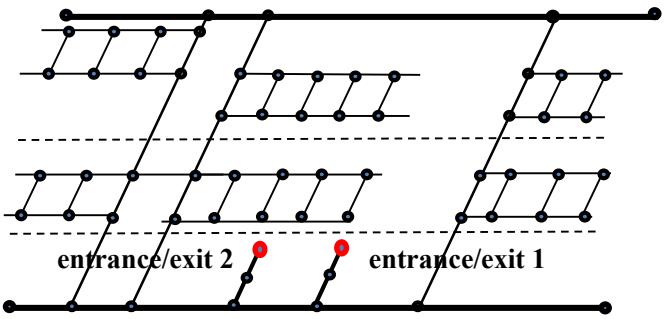


Figure 2 Schematic diagram of mine tunnel network

Assuming that the cross-section of each tunnel is a rectangle with a width of 4 m and a height of 3 m. The water flow spreads forward at an initial level of 0.1 m (the height can be maintained after the water flow first arrival). Upon reaching the branching point of the tunnel, the water flow spreads evenly to the horizontal and downward tunnels while maintaining its initial water level. The beginning time of water inrush is zero, and the volume of the water inrush is 30 m^3/min.

Please establish mathematical models to solve the following problems:

Problem 1 If there is a sudden water inrush at a certain point in the tunnel, please analyze the water flow process and establish a water flood spreading model in mine tunnel network.

For the two mine tunnel networks provided in annex1 and annex2, please give the water spreading process in each tunnel, where the water inrush point in annex1 is located at A1(5349.03,4931.90,10.00), while in annex2 is located at A2 (4143.12,4376.28,6.33). Please save the results to the files result1-1.xlsx and result1-2.xlsx respectively (the template files are provided in annex3, and all results are rounded to two decimal places, the same below), in which "Arrival time" refers to the time when the water flow first reaches that particular endpoint and "Filling time" refers to the time when the water level in the tunnel reaches the highest point of the tunnel.

Problem 2 When a sudden water inrush occurs, the Safety Production Department can immediately monitor the situation and should develop an effective escape plan for each miner as soon as possible. According to the water flood spreading model established in Problem 1, please assist the department in designing the optimal escape route for each miner.

Assuming that the traveling speed without water flow of the miner is 4 m/s. When the water level is less than or equal to 0.3 m, the upstream speed is 1 m/s and the downstream speed is 2 m/s. When the water level exceeds 0.3 m, wading through water is not advisable.

Assuming that an evacuation notice is issued 1 min after the water inrush, please provide the optimal escape routes for each miner for the two mine tunnel networks provided in annex1 and annex2 respectively. Specifically, in annex1, the entrances/exits are located at points (3252.16,3326.63,10.00) and (3173.10,2819.97,10.00), respectively, while the miners are positioned at points (5808.18,5367.75,10.00), (5194.00,4785.31,10.00), and (6190.81, 3434.29,10.00). The exits in annex2 are located at (6336.99,6073.22,36.15) and (6416.05, 6579.88,8.69), and the positions of the miners are (4395.15,4614.53,6.59), (3398.34, 5965.56,1.31), and (3879.44,4125.47,6.22). Please save the results to the files result2-1.xlsx and result2-2.xlsx, respectively (the template files are provided in annex3).

Problem 3 If there are two water inrush points in a mine, please analyze the water flow process and establish a water flood spreading model.

For the two mine tunnel networks provided in annex1 and annex2, please give the water spreading process in each tunnel, where the second water inrush point is located at B1(3760.40,3808.33, 10.00), and water inrush begins 4 min after the inrush at point A1, and the second water inrush point is located at B2(5883.14,5643.35,40.37), and water inrush begins 5 min after the water inrush at point A2. Please save the results to the files result3-1.xlsx and result3-2.xlsx respectively (the template files are provided in annex3).

Problem 4 When the second water inrush point occurs in the mine, the Safety Production Department can immediately monitor the situation and should adjust the escape plan as soon as possible. Please assist the department in adjusting the optimal escape route.

According to the previous problems, assume that 1 min after the second water inrush, the

department issues an adjusted escape plan. Provide the adjusted optimal escape paths for each miner for the two mine tunnel networks provided in annex1 and annex2. Please save the results to the files result4-1.xlsx and result4-2.xlsx (template files are provided in annex3).

Description of annexes

Annex1.xlsx and annex2.xlsx are data files of two different mine tunnel networks, both including two worksheets entitled “Endpoint” and “Tunnel”. The “Endpoint” worksheet records the 3D coordinates (X, Y, Z) of each endpoint of the tunnel (where XY represents the horizontal plane and Z represents the elevation); the ‘Tunnel’ worksheet records the number of two endpoints of each tunnel.

Annex3 is a folder of the template files for the results, which includes

result$i$-j.xlsx template file for the results of Mine j in Problem i