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http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

Numerical Experiment on Floor Water Inrush Failure in Pressurized Mining Based on ANSYS

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***Abstract*—With the method of numerical simulation, this paper investigates the floor inrush water on the effect of many factors in using ANSYS. With mining, there appears drawing stress area in the middle of coal floor. Peak value Stress of area is in the 10~15 meter to rock wall.in the mining area two sides. Distributing of stress in floor continually changes. Plastic area in floor deep develops during mining.**

***Keywords* —ANSYS, Floor, Numerical Simulation, Water Inrush**

I. INTRODUCTION

China boasts abundant coal reserves with extensive distributio n of coal mines. A significant portion of these coal-bearing stra ta belong to the Carboniferous-Permian coal measures, charact erized by a basement composed of Ordovician carbonate rocks containing gypsum, developed karst features, and strong water -bearing capacity. Due to the presence of confined limestone a quifers at the base of coal measures, mining operations are freq uently threatened by karst-confined water inrushes during extr action processes.

As mining depth increases, the water-inrush risk from confined water through floor strata becomes increasingly severe[1].Yan Xia et al.[2], in their study of six roof/floor lithology combina tions in the No. 8 deep coal seam of the Ordos Basin, found th at greater differences in mechanical properties between the flo or and coal seam correlate with smaller horizontal principal str esses in the coal seam. This pattern provides theoretical suppor t for optimizing roof-floor lithology combinations to select low -stress zones in fracturing engineering. Zhu Weibing et al.[3] broke through the traditional focus on roof strata in goaf area management, innovatively utilizing floor pressure-relief zones as resource utilization targets. They proposed three source dam age-reduction floor control technologies: grouting filling techn ology, liquid-injection expansion arch-building technology, an d blasting fracturing technology. They further expanded floor resource utilization by developing groundwater diversion and a quifer reconstruction technology to transfer water from roof aquifers to floor water storage layers. Dang Jiaxin et al. [4] revealed that floor coal-rock masses undergo a four-stage defo rmation process (initial-acceleration-stable-final) under mining -induced effects, forming an inverted triangular failure zone, with pressure-relief areas showing annular compaction distribu tion (most pronounced near coal walls and cut openings).Zou Weikun et al.[5] employed numerical simulations to investigate stress evolution and permeability characteristics in floor strat a under mining impacts, identifying 20-meter-deep floor dama ge in goaf areas dominated by bedding-parallel fracture system s. Their work uncovered the interconnected mechanisms of pre ssure relief-permeability enhancement-fracture propagation in underlying strata of goaf areas, providing theoretical foundatio ns for fracturing design and safety control in coalbed methane development.

This study aims to investigate the failure mechanisms of confi ned water floor strata under combined geological conditions d uring coal seam extraction, conduct relevant analyses, and exp lore the evolutionary patterns of floor rock strata during minin g activities.

II. DEVELOPMENT OF THE COMPUTATIONAL MODEL

The numerical model is established based on the geological co nditions of Tunlan Mine under Xishan Coal and Electricity Gr oup. Below the No. 3 coal seam, the limestone aquifer is locate d approximately 31 meters beneath, with interbedded lithologi es including carbonaceous shale, coal-mudstone alternations, f ine sandstone, medium sandstone, coal, and fine sandstone. Co nsidering the characteristics of numerical calculations and the constraining effects[6,7], the computational model for the conf ined water floor is shown in Figure 1. The model covers a rect angular domain of 200 m × 150 m (length × height), with a mi ning height of 5 m. The burial depth of the coal seam varies be tween 300 m, 400 m, and 600 m. Displacement boundary cond itions are applied: horizontal constraints on the left and right b oundaries, and vertical constraints on the bottom boundary. Ex cavation starts 50 m from the left boundary, totaling 66 m in le ngth. Stratigraphic layers with similar physical properties with in the model are simplified into homogeneous layers. Based on field geological data, the numerical model is reduced to a five -layer structure. From top to bottom, the simplified layers inclu de fine sandstone, mudstone, coal, medium sandstone, and cla y. The material parameters of each layer are listed in Table 1.

III. MODEL LOADING AND MESHING

Based on actual geological conditions, a surface load is applied above the model to simulate the self-weight stress of overlying strata acting on the mining area. Variations in surface load are introduced to represent changes in overburden weight, thereby simulating variations in mining depth. Faults are modeled as weak structural zones, with bonded interfaces between fault planes and surrounding rock masses, and a fault width of 1 meter. Following the line-to-line contact principle in ANSYS

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software, fractures in the floor strata are constructed. In accordance with actual fracture conditions in rock masses, the interfaces between rock masses on either side of fractures remain unbonded.

The model employs 8-node quadrilateral isoparametric elements. Hydraulic units are assigned to simulate aquifer characteristics, and nodal forces are applied at the model's base to replicate the water pressure from the Ordovician limestone aquifer[8-10]. The entire simulation domain uses elements sized at 2.5×2.5 m, with first-level mesh refinement applied to the study area of the mining floor. The finite element mesh is illustrated in Figure 2. The Drucker-Prager plastic yield criterion is adopted as the constitutive model for material yielding:

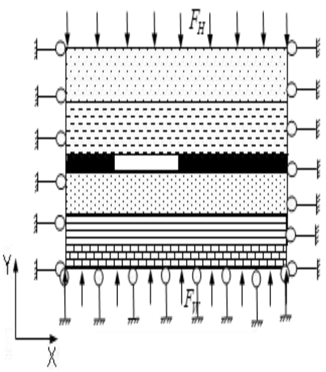
$$f = \alpha I_1 + \sqrt{J_2} - K$$

In the equation: I_1 – First stress invariant,
J_2 – Second deviatoric stress invariant,

$$\alpha = \frac{2\sin\varphi}{\sqrt{3}(3-\sin\varphi)},$$

$$K = \frac{6C\cos\varphi}{\sqrt{3}(3-\sin\varphi)},$$

(C —cohesion; φ—internal friction angle)



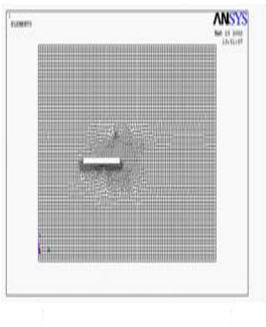


Fig. 1. Finite Element Computational Model of Floor Strata **Fig. 2** Mesh Schematic of Intact Floor Model

Table 1. Material Parameters for Numerical Simulation

Lithology	E (MPa)	P (λ)	IFA (θ)	C (MPa)	FC (μ)	D (kg/ m^{-3})
Fine sandstone	6.57	0.30	33	5.48	0.65	2500
Mudstone	5.34	0.24	28	4.45	0.53	2600
Coal	1.45	0.38	22	1.21	0.40	1500
Medium sandstone	4.84	0.30	30	4.03	0.58	2400
Clay	4.04	0.22	28	3.37	0.53	2000

E: Elastic modulus P: Poisson ratio IFA: Internal friction angle
C: Cohesion FC: Friction coefficient D: Density

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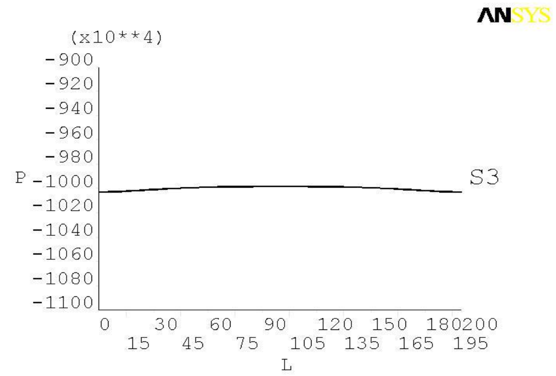
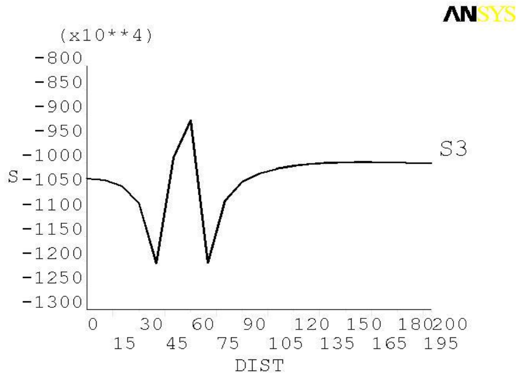
IV. ANALYSIS OF COMPUTATIONAL RESULTS

A. Stress Distribution in Floor Strata

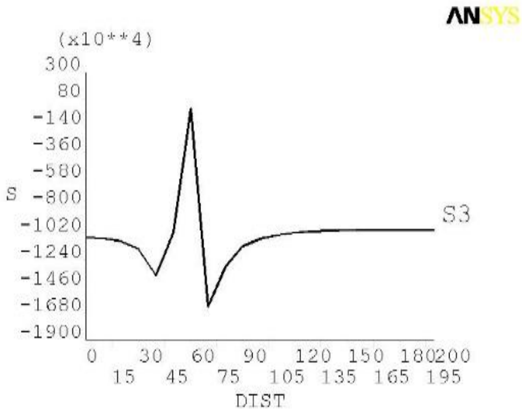
Taking the coal wall of the open-off cut as the zero reference point, with the positive direction aligned to the advance direction of the working face, analysis points are selected at 5-meter intervals. Numerical simulation results reveal the stress distribution characteristics in the floor strata during mining, as illustrated in Figure 3.



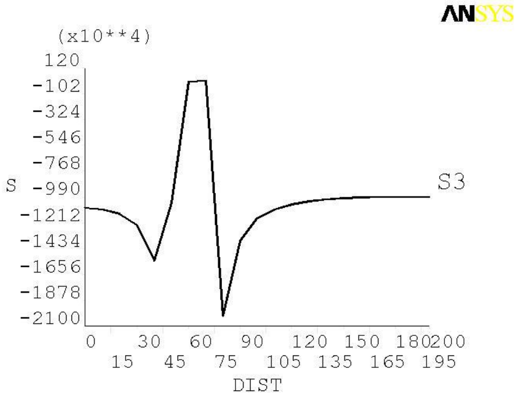
Pre-mining State



Mining Step 1



Mining Step 2



Mining Step 3

Fig. 3. Stress Distribution in Floor Strata

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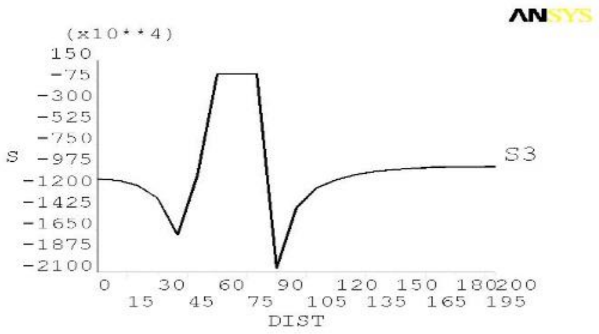
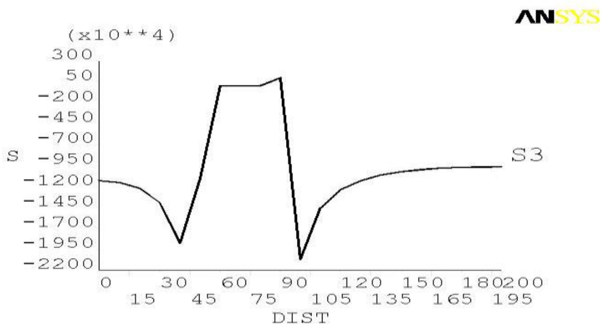
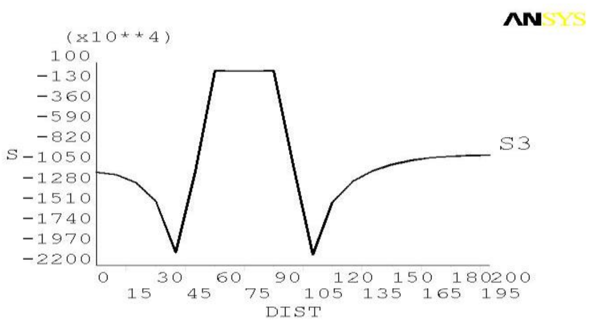


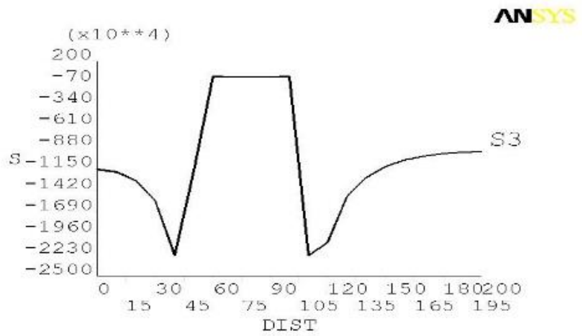
Mining Step 4



Mining Step 5



Mining Step 6



Mining Step 7

Fig. 3. Stress Distribution in Floor Strata

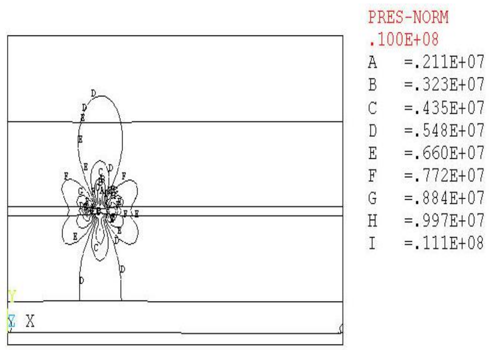
a. In the horizontal direction of the coal seam floor, two stress concentration zones are observed within the coal walls on both sides. The stress value ahead of the working face is slightly higher than that behind the mined-out area. This occurs because the stress concentration zone behind the working face maintains a relatively stable stress state during mining. Although small, it gradually releases the stored strain energy in the rock mass. In contrast, the rock mass ahead of the face accumulates strain energy due to insufficient time for release as mining advances.

b. Significant stress fluctuations occur near the coal walls and the mined-out area. Particularly adjacent to the coal walls, abrupt stress changes readily induce failure, forming fractured zones. In the central portion of the mined-out area, tensile stresses may develop in the floor strata, leading to tensile failure and the formation of crushed zones. As the mined-out area expands, the tensile stress region in the central zone progressively enlarges, resulting in extensive floor damage and heightened water-inrush risks.

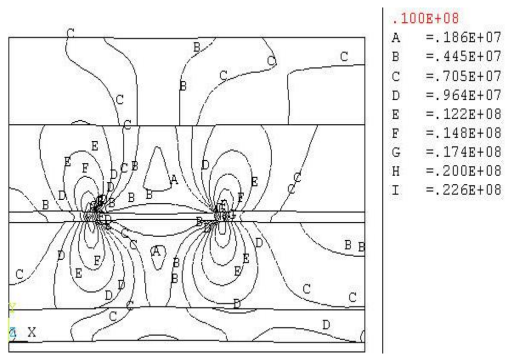
c. Within the coal walls on both sides, the horizontal stress in the floor rock mass exhibits a gradual reduction trend, eventually stabilizing to the in-situ stress level.

B. Progressive Failure in Floor Strata

Prior to excavation, the floor strata were entirely under compression, exhibiting uniform and gradual internal stress distribution. As coal seam extraction progressed, stress redistribution occurred within the floor strata, forming stress concentration zones on both sides of the mined-out area. The plastic zones on both sides displayed symmetrical distribution patterns. These plastic zones adopted an "inverted horseshoe" morphology (in Figure 4). A permanent plastic failure zone developed in the floor strata near the open-off cut. The plastic failure zone at the coal wall ahead of the working face progressively advanced forward as mining continued. Concurrently, the stress peak in the floor strata gradually intensified during face advancement, with the plastic failure zone expanding downward in a fan-shaped pattern.



Open-off Cut



Post-Step 7

Figure 4 Stress Contours

Near the coal wall, stress concentration in the floor strata induces compressive-shear failure. During mining, the maximum failure depth of the floor continuously increases, and the failure zone progressively expands. Stress field analysis reveals that the plastic failure of the floor is a direct result of stress redistribution caused by load transfer from overlying strata. As the working face advances, the plastic zone in the floor gradually enlarges. Notably, the plastic zone ahead of the working face exhibits greater depth and width compared to the zone behind.

As the working face advances, stresses within the floor strata of the mined-out area decrease sharply, leading to the emergence of tensile stress zones. These tensile stress regions expand progressively and propagate downward at an angle of approximately 60° to the horizontal. Concurrently, the maximum tensile stress intensifies. High compressive stresses in the floor rock mass initially generate closed fractures, which subsequently open and widen under tensile forces, forming failure zones. These failure zones continuously propagate forward with the advancement of the working face.

V. CONCLUSIONS

This study investigates the influence of various geological con ditions and contributing factors on stress distribution and failur e depth evolution in the floor strata beneath a mining face. Key findings include:

1.Horizontally, stress concentration zones are observed in the floor strata on both sides of the mined-out area. The peak stres s occurs 10–15 meters inward from the coal walls, where the floor rock masses enter a plastic state prematurely.

The stress peak ahead of the working face is slightly higher than that behind the mined-out area.

2.When the working face advances 20–30 meters, the stress at the midpoint of the mining area decreases sharply, and tensile stress zones begin to form in the central floor strata.

3.During the initial mining stage, the failure depth of the floor strata undergoes rapid changes. As mining progresses, the plas tic zone extends deeper into the floor, but the expansion rate slows. The maximum failure depth stabilizes, while the plastic zone continues to expand laterally.

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