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Study of the Influence of Damage Structures in Coal Seam Floors on the Damage of Small Hidden Faults

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Abstract: In order to study the catastrophe law of small hidden faults along the floors of deep quarries under the coupled conditions of high stress and strong seepage, this paper proposes a concept of damage structure that can replace the overall performance of a population of tiny fracture swarms within a non-homogeneous rock mass. Numerical simulation software is used to simulate and analyze the influence of damage structure on the evolution of surrounding rock, regarding its plastic zones, shear stress, and displacement, and the pore water pressure distribution in small hidden faults along coal seam floors. This study shows that under the influence of damage structure, the shear stress of the rock above the fault shows "N"-type change, the displacement of the surrounding area shows "S"-type change, and the shear stress of the rock below the fault and the pore water pressure above the fault show "M"-type change. The damage structure changes the performance of the coal seam floor's water barrier by reducing the strength of the rock surrounding the fault, blocking the release rate of the shear stress of the surrounding rock, weakening the support pressure of the fault, reducing the degree of expansion of the surrounding rocks and shifting the direction of concentration of the pore water pressure. The results of this study can provide a reference for technology for water damage prevention and control of coal seam floors containing small hidden faults, under the influence of non-homogeneous rock bodies.

Keywords: damaged structure; small hidden fault; water inrush from the coal seam floor; numerical simulation

Citation: Yin, L.; Zhang, Y.; Chen, J.; Wang, B.; Zeng, Y.; Liu, Q. Study of the Influence of Damage Structures in Coal Seam Floors on the Damage of Small Hidden Faults. *Sustainability* **2023**, *15*, 15010. https://doi.org/10.3390/su152015010

Academic Editors: Bin Gong and Naser Golsanami

Received: 12 August 2023
Revised: 8 September 2023
Accepted: 10 September 2023
Published: 18 October 2023

1. Introduction

The geological conditions of deep coal mines and quarries are complex, and deep well water damage accidents are a major source of disaster that restricts the safe mining of coal in China [1].The coal seam floor is often affected by mining disturbances [2,3], which can easily lead to the damage of small hidden faults, extended deformation, and instability rupturing, and then bring about primary fissures, forming water conduction channels, which bring serious threats to coal mining production [4–6]. In this paper, the geological structure is distributed in the water barrier layer of the coal seam floor with a fall difference of less than 3 m, changing the water blocking performance of the water barrier layer, and leading to obvious changes in the hydraulic characteristics of the coal seam floor rocks, called a small hidden fault. Small hidden faults have the characteristics of small morphology, complex structure, and wide distribution and are difficult to detect [7]. There is a large difference between these and the disaster-causing law and characteristics of medium and large faults, so it is unscientific to continue to follow the traditional theory of large faults in the study of the evolution law of the sudden flooding of small hidden faults [8–10].

Modern scholars conduct research on the water emergence laws and mechanisms of small hidden fault activation from different perspectives. Some scholars use numerical simulation technology on broken water barrier base plates of small hidden faults, and analyze the full dynamic development process of water emergence channel conduction [11]. Many scholars have utilized theoretical analysis [12–15], indoor testing methods [16–18], and research tunneling processes concerning the stress fields of the surrounding rock, as well as their displacement field and plastic zone evolution. In practice, a large number of faults are "buried" small hidden faults, located between mined coal seams and the water-bearing layer [19]; the non-homogeneity of the coal seam floor's water-isolating layer leads to the development of intrinsic micro-fractures under the action of mining stress and hydraulic coupling to form a group of micro-fractures, whose cracks easily connect with small hidden faults and accelerate the formation of water-conducting channels. Scholars have studied the whole process of activation, expansion, and penetration of small hidden faults under the influence of different factors, but they have not considered the influence of the non-homogeneity of the coal seam floor's rock layer on the disaster law of small hidden faults. Areas of fracture concentration in the inhomogeneous rock mass weaken the effect of the basement diaphragm, altering the diaphragm performance of the basement group and impacting the growth of these small hidden faults. Understanding the influence of micro-fractures on the extension and evolution law of small hidden faults can provide a theoretical basis and reference significance for the early warning and prediction of water damage under these conditions.

When a water-conducting channel is not formed in a coal seam floor with small hidden faults, it does not mean that it is safe [20–22]. Based on the "lower three zones" theory, this paper divides the water surge mode of a coal seam floor with small hidden faults into the "Single structure sudden water disaster type" and the "Damage structure sudden water disaster type". The damaged structure is used to replace the micro-fracture group inside the non-homogeneous rock body. Through the establishment of numerical models of small hidden faults in the coal seam floor of a deep quarry, we analyze the evolution of a water surge disaster of a bottom plate with damaged structures and small hidden faults under the coupling of high stress and strong seepage, and conclude by discussing the influence of damage structures on the evolution of small hidden faults, so that we can inject new influencing factors into the technology of preventing and controlling water surge disasters of small hidden faults, and then provide theoretical bases for the design of safe mining plans.

2. Analysis of the Mechanism of Sudden Water Damage

Small hidden faults are geologic formations that are distributed in basement water barriers with a drop of less than 3 m. These faults change the water resistance of water barriers and may lead to significant changes in the hydraulic characteristics of the basement rock. The extension evolution of the small hidden faults into rifts is generated by the joint action of compressive shear stress and permeable water pressure [23]. When a fissure generated by the small hidden faults causes the water barrier to disappear completely, that is, the upper part of the fault fissure extension area (height U1) connects to the baseboard damage zone, and the lower part of the fissure extension area (height U2) connects to the pressurized water conduction zone. The basement damage zone, the rift extension zone above the fault, the small hidden faults, the rift extension zone below the fault and the pressured water conduction zone are connected to form a water conduction channel. The small hidden faults are affected by the activation evolution of the coupling of high stress and strong seepage, and it is very easy to induce a coal bed water disaster [24]. The small hidden faults-caused water disaster process is shown in Figure 1.

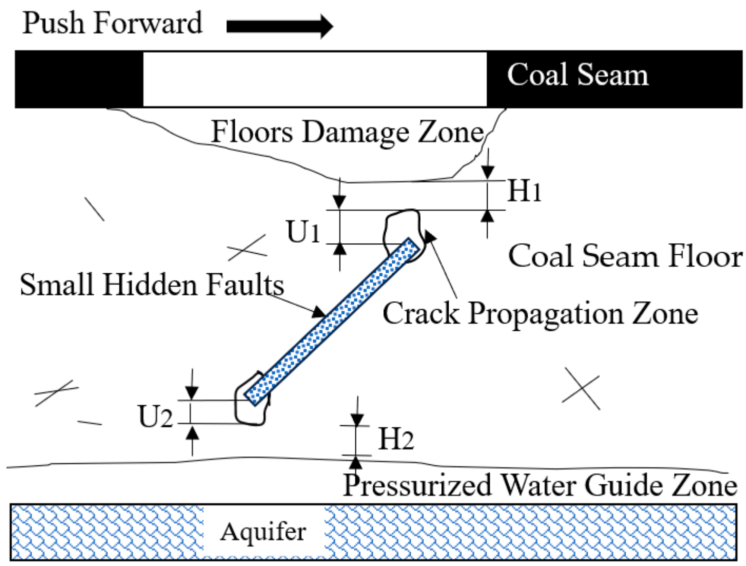


Figure 1. Schematic diagram of small hidden faults water inrush disaster. H1—thickness of the water barrier above the small hidden faults; H2—thickness of the water barrier below the small hidden faults; U1—height of crack propagation zone above; U2—height of crack propagation zone below.

Small hidden faults are generally considered to be compression-shear cracks subjected to composite-type loading [23], and the crack tips at the ends of the small hidden faults undergo a cycle of stress concentration, crack development, expansion, and stress re-concentration. Crack expansion is a process of progressive elevation [24], and the expression for the length of growth of the crack expansion zone at stage I is:

$$\Delta U = \frac{\pi K_{1c}^2}{[(\sigma_{1i} - \sigma_{3i})\sin\alpha \sin 2\alpha + (p_i - \sigma_{3i})\pi]^2} \tag{1}$$

K_{1c} is crack tip strength factor; σ_{1i} is Phase I vertical stress; σ_{3i} is Phase I horizontal stress; P_i is crack tip subjected to penetrating water pressure; α is tilt of small hidden faults.

Because the ends of "buried" small hidden faults are subjected to simultaneous stresses and osmotic water pressures in all directions, the expression for the cumulative extension height, U, at each stage of the rift at the ends of the small hidden faults is:

$$\Delta U_1 = \sum_{\mathrm{i}=1}^{\mathrm{n}} \Delta U_{ui} = \frac{\pi K_{\mathrm{u1}c}^2}{[(\sigma 1 - \sigma 3)\sin\alpha \sin 2\alpha + (p_{\mathrm{u}} - \sigma_3)\pi]^2} \tag{2}$$

$$\Delta U_2 = \sum_{\mathrm{i}=1}^{\mathrm{n}} \Delta U_{li} = \frac{\pi K_{\mathrm{l1}c}^2}{[(\sigma 1 - \sigma 3)\sin\alpha \sin 2\alpha + (p_{\mathrm{l}} - \sigma_3)\pi]^2} \tag{3}$$

ΔU_1 is cumulative thickness above small hidden faults; ΔU_2 is cumulative thickness beneath small hidden faults; K_{u1c} is crack tip strength factor above a small hidden fault; K_{l1c} is crack tip strength factor at the lower end of a small hidden fault; P_u is penetrating water pressure exerted at the crack tip above a small hidden fault; P_l is fracture tips at the lower end of small hidden faults, which are subjected to infiltration water pressure.

From this, it can be inferred that the direction of the rift extension of small hidden faults is the direction of maximum compressive stress [25]. When the water-isolating layer of the coal seam floor containing small hidden faults cannot withstand the actions of mining stress and pressurized water pressure, a water damage accident occurs on the coal seam floor. Due to the complex mechanical structure of the coal seam floor in a deep quarry, different influencing factors are involved in the formation of the water-conducting channel in the small hidden faults, which in turn form different water surge modes. Due to the differences in the local morphology of the coal seam floor water barrier, the mechanical behavior of the water barrier exhibits different degrees of anomalies [26,27], forming micro-fractures. If these micro-fractures in the distribution are concentrated in a region of the water barrier layer and the fissure group has not yet formed an obvious fracture structure [28,29], the hydraulic properties are changed and this also changes the water resistance performance of the water barrier in the coal seam floor. If the fissure group is connected with a hidden structure in the water barrier layer or adjacent to the spatial location, it is very easily able to expand and evolve to connect the small hidden faults prevailing in the coal seam floor, which promotes the formation of water-conducting channels in the coal seam floor, and increases the threat of small hidden faults causing a disaster to the working face. To aid the study of damage in structural micro-fracture groups, their presence in the rock mass and the form of damage is shown in Figure 2.

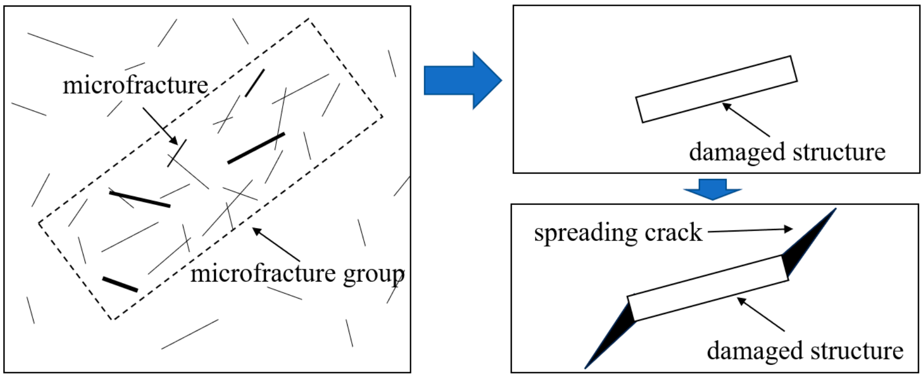


Figure 2. Schematic diagram of the destruction process of the damaged structure.

Following the above analysis, the sudden water disaster is categorized into two types, as shown in Figure 3:

(1) Single structure sudden water disaster type: under the coupling of high stress and strong seepage, the small hidden faults of the coal seam bottom plate are subjected to the action of compression and shear stress to produce extended cracks. The crack extension zones at the two ends of the small hidden faults are connected to the pressurized water conduction zone and the damage zone of the bottom plate, which results in the complete failure of the water-insulating layer and the formation of a bottom-plate water conduction channel, which leads to the occurrence of the water disaster accident.

(2) Damage structure sudden water disaster type: the rock of the base plate water barrier, containing a small hidden fault, has a damage structure, which leads to changes in the hydraulic properties of the base plate rock and changes the water resistance performance of the base plate water barrier. A large number of damage structures are connected with the hidden structure in the water barrier, which promotes the formation of a water conduction channel, and increases the possibility of the occurrence of a sudden water disaster at the base plate.

The rift ends of small hidden faults in the rock system are very prone to stress concentration [30–32]. The extended damage and the fracture extension zone of the small hidden fault connects to the damaged structure in the rock below, which in turn connects to the damaged zone of the coal seam floor and the zone of the pressurized water conductivity, and causes uplift. The water-insulating layer of the coal seam floor fails, which finally induces the water breakout accident on the working face. The schematic diagram of the water breakout of the small hidden faults is shown in Figure 4.

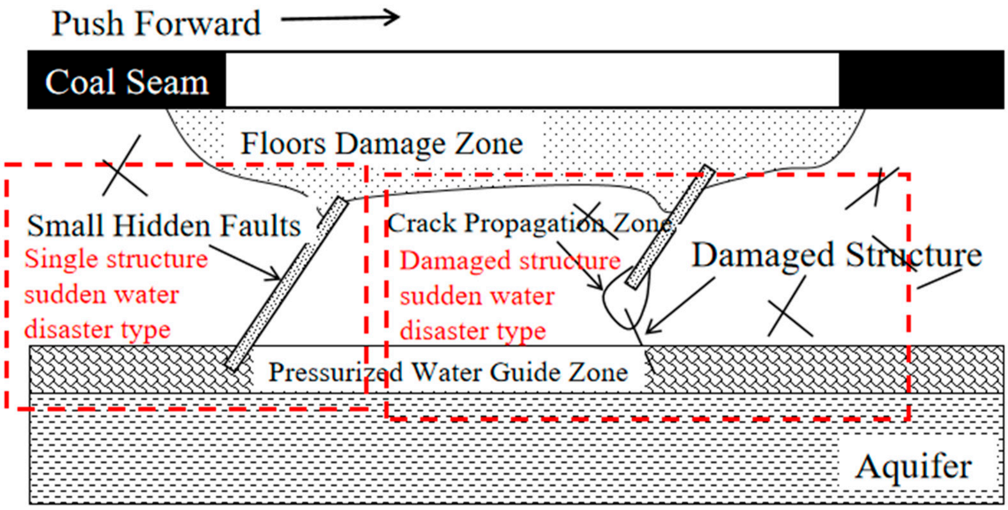


Figure 3. Schematic diagram of water disaster type with small hidden faults.

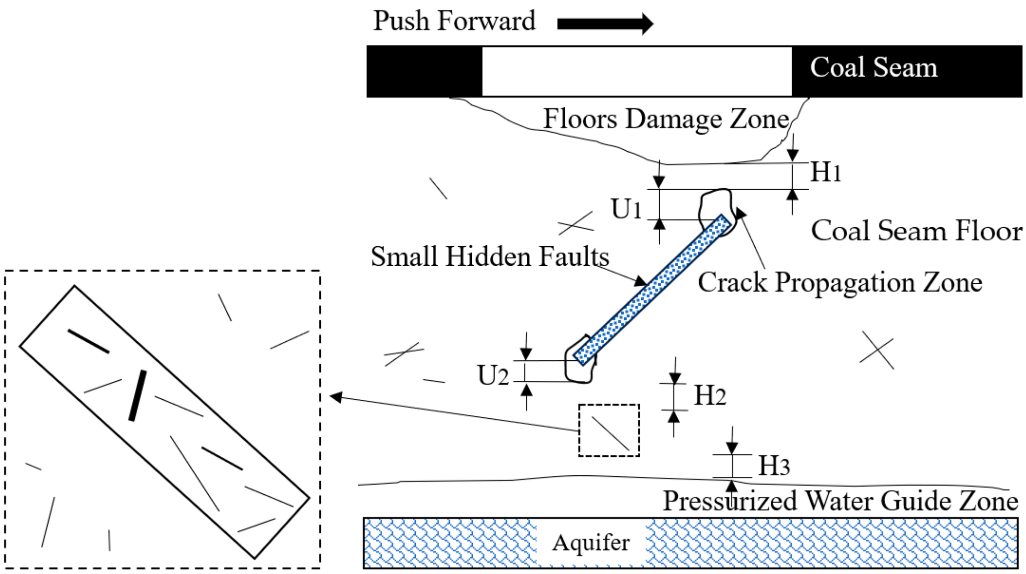


Figure 4. Schematic diagram of water disaster type with a damaged structure.

3. Exploring the Pattern of Bottom-Slab Water Emergence

The absence of water-conducting channels does not exclude the risk of water emergence, and the presence of a large number of damaged structures in the basement rock can promote the formation of water-conducting channels. Damage structure affects the performance of the coal seam floor's water barrier layer, which leads to changes in the activation of the small hidden faults and the water damage law. In this section, we reproduce the whole process of a water breakout in the coal seam floor by using the numerical simulation method of FLAC to study the process of small hidden faults and investigate the influence of the damage structure on the water damage law of the small hidden faults.

3.1. Modeling

This section takes the actual geology of a mine in Henan Pingdingshan Coal Mine as the research background, as shown in Table 1. Under the premise of the existence of small hidden faults in the rock layer of the coal seam floor of a deep quarry, to investigate the influence of evolution law on a sudden water disaster, the coal seam is mined at a depth of H = 1024 m, and the numerical model of a sudden water disaster due to small hidden faults in the bottom plate of the deep quarry is established by using the numerical simulation software of FLAC 3D 6.0.

Table 1. Physical and mechanical parameters of mine strata.

	Thickness/m	Bulk Modulus/GPa	Shear Modulus/GPa	Tensile Strength/MPa	Bond Strength/MPa	Internal Friction Angle/°	Porosity/%	Permeability Coefficient/cm·s
R9	30.00	5.8	4.5	3.6	4.2	37	0.3	3.0×10^{-7}
R8	9.00	5.1	4.2	3.8	4.1	36	0.2	2.4×10^{-7}
R7	5.00	4.8	4.3	3.9	3.6	34	0.4	1.4×10^{-7}
R6	5.00	4.5	2.6	3.6	3.9	34	0.3	1.9×10^{-7}
R5	4.00	4.8	3.9	3.8	4.3	37	0.5	2.8×10^{-7}
R4	3.00	4.2	4.5	3.2	3.7	43	0.4	3.1×10^{-7}
R3	2.00	4.5	4.9	3.9	3.9	40	0.4	2.1×10^{-7}
R2	3.00	3.9	4.2	3.8	3.7	34	0.3	1.8×10^{-7}
R1	3.00	3.8	4.3	1.9	4.6	43	0.4	2.8×10^{-7}
C	2.00	3.1	2.2	3.8	2.1	34	0.2	1.2×10^{-7}
F1	7.00	3.9	3.9	3.6	3.7	43	0.5	3.2×10^{-7}
F2	6.00	3.4	3.4	4.2	4.1	40	0.6	1.5×10^{-7}
F3	14.50	3.9	3.8	3.9	3.6	37	0.4	2.5×10^{-7}
F4	5.00	4.0	4.2	3.4	3.7	34	0.5	2.1×10^{-7}
F5	13.00	5.9	3.6	3.1	4.1	37	0.4	1.5×10^{-7}
F6	11.00	4.9	4.8	3.8	3.6	43	0.5	1.2×10^{-7}
F7	8.00	5.7	4.7	3.9	3.7	36	0.2	1.0×10^{-7}
F8	50.00	5.3	3.9	4.2	3.9	43	1.0	1.5×10^{-7}

The model is 300 m long, 200 m wide, 180 m high, and the thickness of the coal seam is 2 m. The load at the top of the model is 25 MPa. The bottom X and Y directions of the model are set as the boundary without displacement. By establishing the numerical model of the coal seam floor containing small hidden faults (numerical model 1 is shown in Figure 5) and the numerical model of the coal seam floor containing small hidden faults and a damaged structure (numerical model 2 is shown in Figure 6), we can obtain the influence of the existence of a damaged structure on the evolution of a base plate containing small hidden faults. The bottom plate of Model 1 contains a small hidden fault 25 m away from the coal seam, which has a dipping angle of 60°, a drop of 3 m, and a length of 17 m. The coal seam floor of Model 2 contains a damaged structure 8 m away from the lower end of the small hidden fault, which has a dipping angle of 75°, and a vertical height of 8 m. The bottom plate of Model 2 contains a damaged structure 8 m away from the lower end of the small hidden faults, with a vertical height of 8 m.

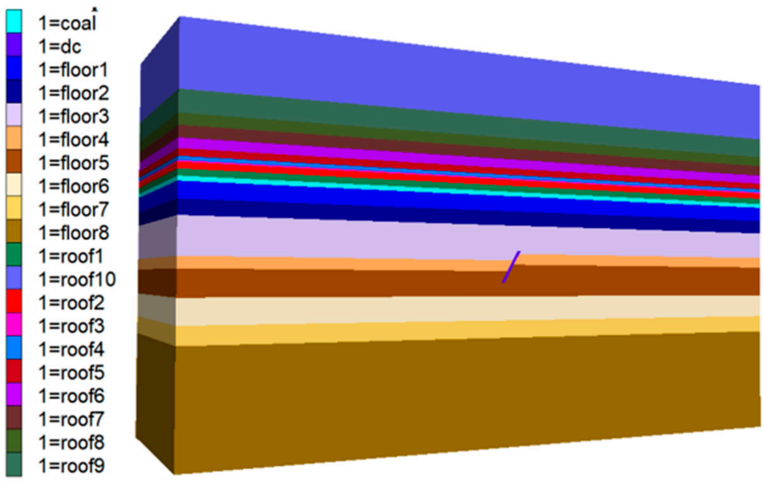


Figure 5. Numerical Model 1.

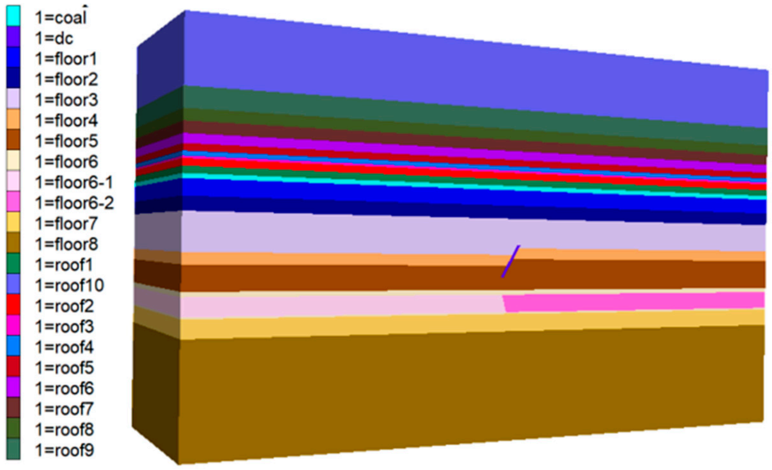


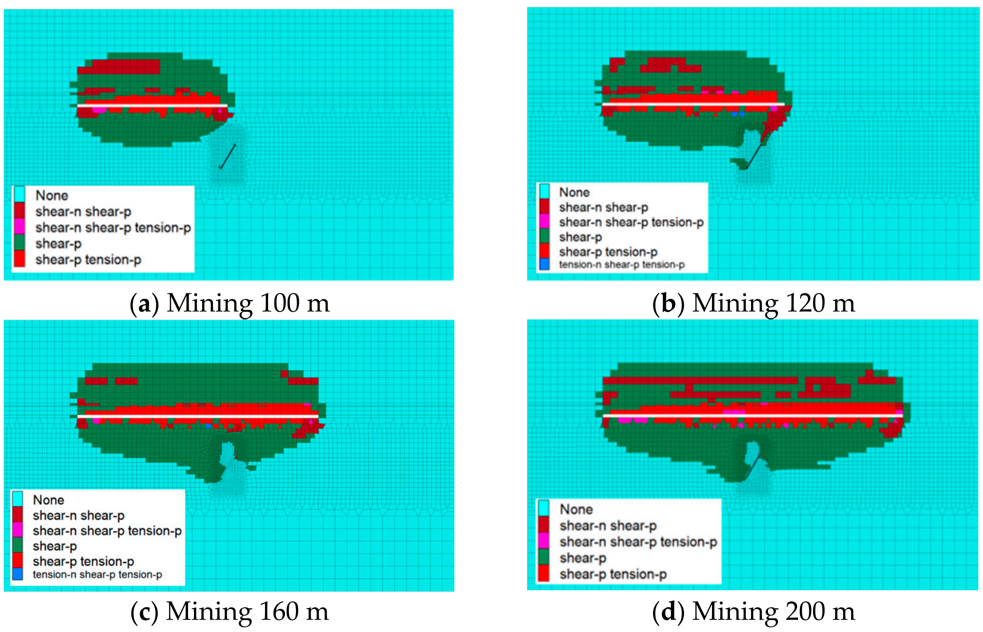
Figure 6. Numerical Model 2.

The simulated water pressure is 3.96 MPa, and the initial seepage field is formed by a linear increase in hydraulic gradient. The simulation of the mining coal seam is at 2 m. At the beginning of the simulation excavation, we set a mining full height, excavation cycle spacing of 10 m, and the number of excavation steps at 20 steps.

3.2. Analysis of Results

3.2.1. Plastic Zone

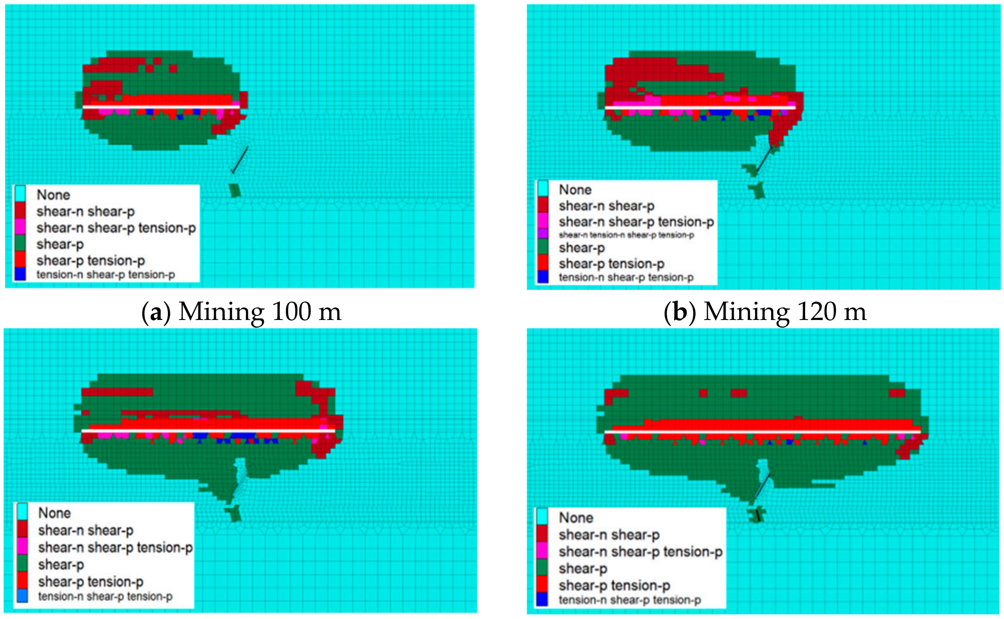
As shown in Figure 7 for the distribution of the plastic zone in Model 1, when the working face was directly above the fault, the plastic damage zone appeared at both ends of the hidden fault; during the mining of the coal seam, the plastic damage zone continued to expand and connected with the mining pressure damage zone in the coal seam floor at the mining depth of 120 m, and gradually formed the combined plastic damage zone of the small hidden fault and the bottom plate mining pressure damage zone. The final destructive height of the lower end of the small hidden fault was 4 m, and the maximum destructive depth of the combined plastic damage zone of the fault and the base plate damage zone was 45 m.



(**a**) Mining 100 m (**b**) Mining 120 m (**c**) Mining 160 m (**d**) Mining 200 m

Figure 7. Plastic zone distribution of Model 1.

As shown in Figure 8 for the distribution of the plastic zone in Model 2, when the working face advanced to the small hidden fault directly above and the two ends of the small hidden fault began to extend, the damaged structure surrounding the rock appeared in the damage zone; at the mining depth of 120 m the damaged structure connected to the coal seam floor damage zone, and continued to expand upward; at the mining depth of 160 m, the small hidden faults connected to the bottom plate mining pressure damage zone and the damaged structure. The damaged height of the lower end of the hidden fault was 8 m, the maximum damage depth of the combined plastic damage zone was 48 m, the maximum plastic damage height of the upper and lower ends of the damaged structure were 3 m and 2 m, respectively, and the maximum damage depth of the base plate was 59 m, which was only 6 m away from the aquifer. It was very easy to connect to the pressurized water conduction zone and form a water-conducting channel, to cause a sudden flooding disaster.



(**a**) Mining 100 m (**b**) Mining 120 m

(**c**) Mining 200 m (**d**) Mining 160 m

Figure 8. Plastic zone distribution of Model 2.

Compared with Model 1, the damaged structure made the plastic zone of the surrounding rock of the coal seam floor fault expand more slowly in the mining direction, and the maximum damage depth of the combined plastic damage zone of the coal seam floor mining pressure damage zone and the fault increased. The damaged structure played the role of a natural water conduction channel in the process of a water disaster caused by the small hidden faults, and it was easy to connect the combined plastic damage zone of the coal seam floor in the process of vertical damage development, which promotes the formation of a water conduction channel, accelerates the evolution speed of the water disaster, and poses a greater threat to the safety of the coal seam mining.

3.2.2. Shear Stress Distribution

In the process of coal seam mining, shear stress plays an important role in the expansion and destruction of a base plate containing small hidden faults and damaged structures. The existence of damaged structures makes a local difference in the distribution of shear stress on the base plate containing small hidden faults, which contributes to the increase of high shear stress in the distribution area on the rock surrounding small hidden faults, and the range of the plastic damage zone of the base plate will continue to increase in the subsequent mining process, from which it will be very easy to form a water-conducting channel, and then a water surge accident may occur.

Figure 9 shows the shear stress change curves on the small hidden faults in Model 1 and Model 2. The shear stress on the upper end of the small hidden faults increases continuously during the coal seam excavation until the working face is directly above the small hidden faults, the shear stress of Model 1 reaches the maximum value of 11.69 MPa; then the shear stress decreases continuously to 8.2 MPa when the horizontal distance between the working face and the center of the small hidden faults is 30 m; then it increases again and reaches 9.75 MPa when the horizontal distance between the working face and the center of the small hidden faults is 40 m. Therefore, the shear stress at the upper end of the small hidden faults in Model 2 shows an N-shaped change trend of "slowly decreasing–rapidly increasing–rapidly decreasing", with the shear stress at the working face and the center of the small hidden faults reaching a maximum value of 11.69 MPa. The upper end shear stress of the small hidden faults shows an "N"-type trend of "slowly decreasing–rapidly increasing–rapidly decreasing" and reaches the maximum value of 11.43 MPa when the horizontal distance between the working face and the center of the small hidden faults is 20 m; at this time, the small hidden faults are connected to the water-conducting damage zone of the base plate. With the continuous digging of the working face, the shear stress decreases and stabilizes to 8.4 MPa at the horizontal distance of 40 m between the working face and the center of the small hidden faults. From this, it can be concluded that the damage structure blocks the release rate of shear stress in the upper part of the fault and reduces the release amount of shear stress in the upper part of the rock.

Figure 10 shows the change curve of rock shear stress under the small hidden faults in Model 1 and Model 2. The rock shear stress under the small hidden faults of the coal seam basement containing the damaged structure is higher than that at the lower end of the small hidden faults of the rock seam basement without the damaged structure, and it shows an "M"-type change trend of "increase-decrease-growth-decrease". When the working face is 120 m deep, the rock shear stress under the fault rises to 11.62 MPa, and the upper part of the hidden fault fails; when the rock shear stress under the fault drops to 9.12 MPa for the first time, the hidden fault connects to the damaged structure, and the water-conducting channel is formed. The damaged structure increases the amount of rock shear stress released at the bottom of the fault, and the plastic damage zone at the lower end of the hidden fault will continue to expand under the influence of the shear stress, connecting more damaged structures, and then creating a threat of water breakout on the working face.

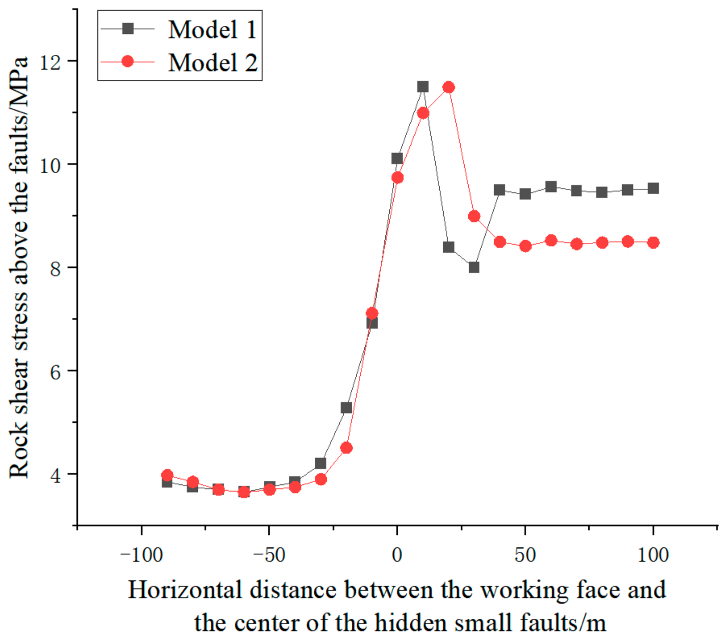


Figure 9. Shear stress variation curve at the upper end of small hidden faults.

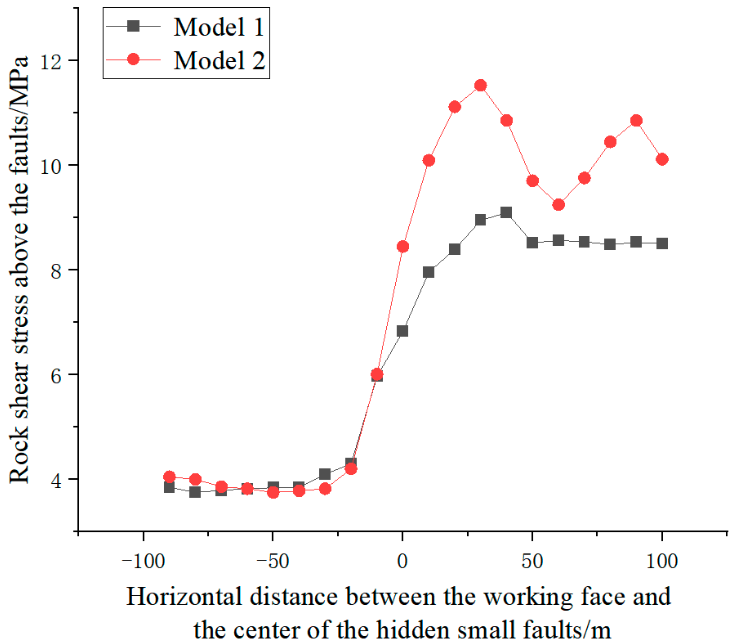


Figure 10. Shear stress variation curve at the lower end of small hidden faults.

3.2.3. Displacement Division

The displacement change curves of the upper and lower ends of the small hidden faults are shown in Figures 11 and 12, from which it can be obtained that the vertical displacement changes in the upper and lower ends of the small hidden faults in the coal seam floor of the deep quarry in Models 1 and 2 show the "S" type change trend of "slowly decreasing–rapidly increasing–slowly decreasing". The two ends of the small hidden faults are subject to the effect of support pressure, and the surrounding rock is less compressed. When the mining face passes through the small hidden faults, the rock surrounding the small hidden faults enters the base plate decompression zone, and expands. As the face continues to dig, the influence of the disturbance on the small hidden faults is gradually weakened, and the vertical displacement of the small hidden faults tends to be stabilized.

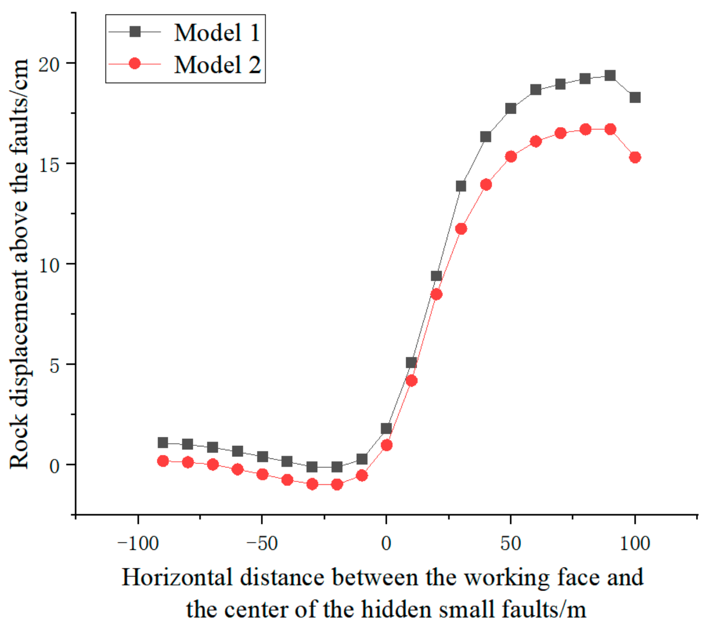


Figure 11. Displacement curve of the upper end of small hidden faults.

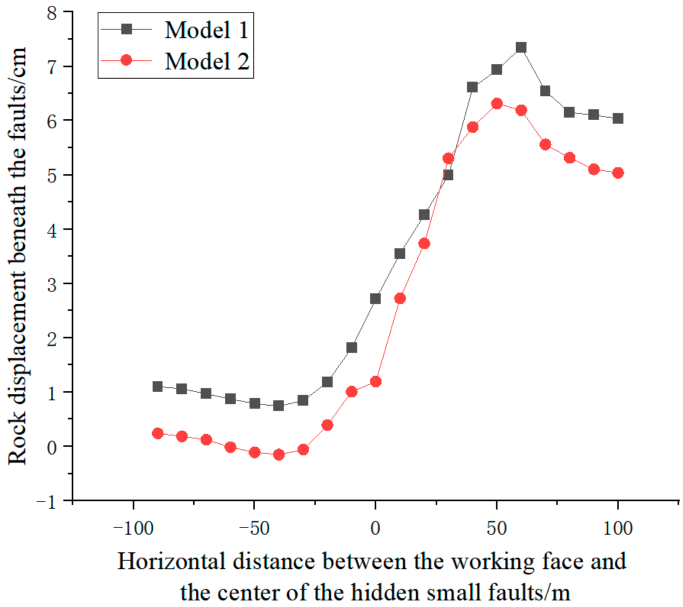


Figure 12. Displacement curve of the lower end of small hidden faults.

The rock displacements at both ends of the fault in Model 2 are smaller than those at both ends of the fault in Model 1, which suggests that the damaged structure contributes to the weakening of the support pressure on the fault, and the compression of the rock at both ends of the fault decreases. As mining proceeds, the degree of expansion of the surrounding rock at both ends of the fault decreases slowly after the complete failure of the water barrier layer.

3.2.4. Pore Water Pressure

The change curves of pore water pressure at the upper and lower ends of the small hidden faults are shown in Figures 13 and 14. It can be seen that the rock pore water pressure under the small hidden faults in the coal seam floor of the deep quarry in Model 1 and Model 2 shows a decreasing trend, and the damaged structure enhances the permeability of the rock from the lower end of the small hidden faults to the aquifer, which leads to an increase in pore water pressure at the lower end of the small hidden faults in the coal seam floor of the damage-containing structure. The pore water pressure at the upper end of the fault in Model 2 is smaller than that at the upper end of the fault in Model 1, and the existence of the damage structure concentrates the pore water pressure of the fault on the surrounding rock at the lower part of the fault. In Model 2, the change in pore water pressure on the fault in the coal seam floor shows the "M"-type trend of "increase–decrease–increase–decrease", and when the coal seam advances by 120 m, the fault connects with the water conduction damage zone on the coal seam floor, and the pore water pressure on the top of the fault decreases to the minimum value of 0.5 m. The rock decreased to the minimum value of 0.126 MPa initially, then increased to 0.138 MPa and continued to decrease; at this point, the water-conducting channel was formed, and the coal seam floor's water-isolating layer was completely invalidated.

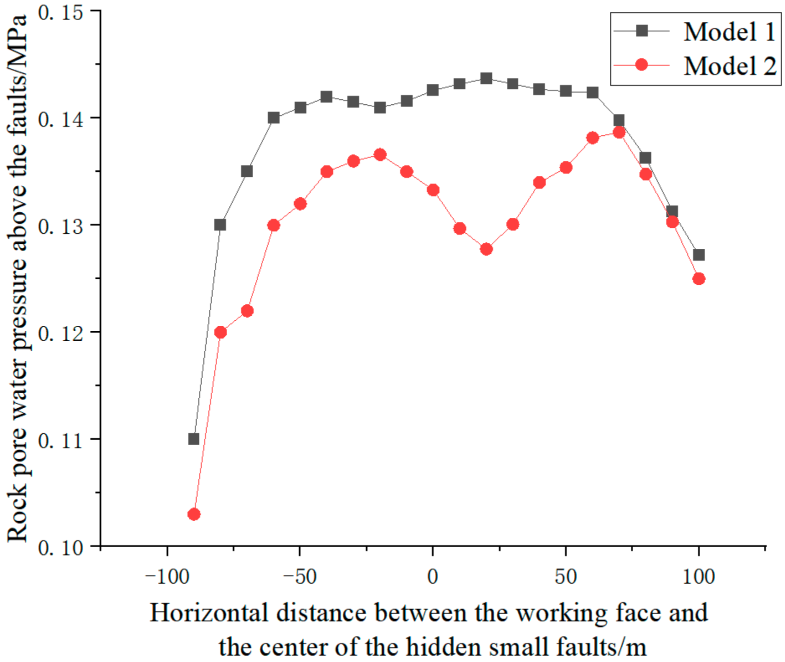


Figure 13. Change curve of pore water pressure at the upper end of small hidden faults.

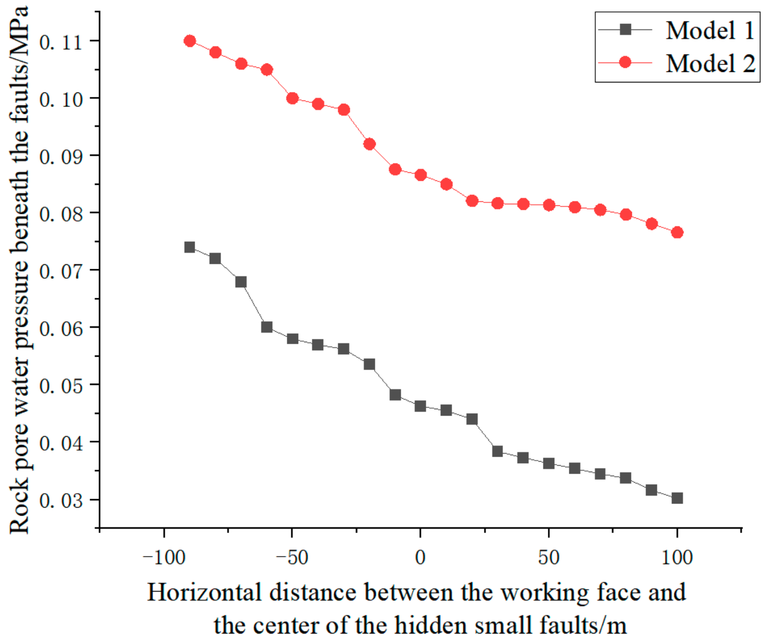


Figure 14. Change curve of pore water pressure change at the lower end of small hidden faults.

In summary, the damaged structure not only changes the extension and evolution of the fault, accelerates the formation of the water-conducting channel, but also changes the water-barrier performance and the characteristics of the coal seam floor water barrier. By comparing the influence of the small hidden faults and a damaged structure on a base plate, it was found that the damaged structure makes the shear stress of the rock surrounding the small hidden faults increase, increases the depth of the plastic damage of the coal seam floor containing small hidden faults, and reduces the amount of displacement change in the rock surrounding the fault. In the process of preventing and controlling water damage on a coal seam floor containing small faults, the influence of a damaged structure on the disaster-causing mechanism should be fully considered. The characteristics of the damaged structure should be used to adjust the safety evaluation system of small faults, the early warning and monitoring system, and the extended evolution formula derivation and other design programs, which are of great importance in the process of safe mining of coal seam floors containing the small faults.

Sustainable development means achieving development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In modern coal production, water damage caused by geological structures accounts for 80% of all water damage accidents, with small hidden faults being a common geological structure in the floors of coal seams. Small hidden faults have the characteristics of strong concealment and difficult detection, posing a serious threat to the working face of coal seams. Therefore, understanding the influence of small hidden faults on water-inrush disasters law is an important requirement for contemporary coal mine production. As coal mining goes deeper, the geological environment becomes more complex and the evolution of small hidden faults becomes more complicated. Numerous micro-fractures exist in heterogeneous aquifers, which can change their water-blocking performance. This paper proposes the concept of damage structure, attempting to use the damage structure to replace the overall performance of micro-fracture clusters. The existence of damage structure changes the destruction law of the floor containing small hidden faults. To prevent this destruction of the floor and the occurrence of water inrush accidents, on-site monitoring equipment, early warning devices, and derivation formulas are needed. The damage structure can also serve as a conduit for water flow, weakening the strength of the aquifer and changing the distribution of shear stress, the plastic zone, pore water pressure, and displacement. It is unscientific to only analyze the expansion law of small hidden faults without considering the influence of damage structure. Only by comprehensively analyzing the influence of damage structure on the destruction law of the floor can monitoring and early warning equipment, empirical formulas, and mining plans be adjusted in a timely manner, providing reference for safe mining under such geological conditions. Therefore, the research results not only meet the important requirements of contemporary coal mine production but also eliminate the harm of water damage accidents in future coal mining. This study reveals the relationship between coal seam floor damage structure and small hidden faults. Through a deep understanding of coal seam geological characteristics and underground structures, potential geological disasters can be better predicted and prevented, reducing the occurrence of mine accidents and ensuring the safety of miners. In addition, the research results provide guidance for coal mining and resource utilization. By analyzing the damage characteristics of coal seam floors, mining processes can be optimized, reducing resource waste and environmental pollution. This has a positive impact on promoting sustainable coal mining and the construction of a resource-saving society. The research results provide important theoretical support and technical guidance for mine safety and resource utilization, satisfying the concept of sustainable development and promoting the sustainable development of mine safety production. Due to the limitations of geological exploration technology, the parameters related to small hidden faults have not been fully detected. Therefore, the application value of the research content in this paper will increase with the development of exploration technology.

4. Conclusions

This paper investigates the formula for calculating the damage heights of the upper and lower ends of "buried" small hidden faults, through theoretical analysis. The water surge disaster types that can occur on a base plate containing small hidden faults are categorized as "single structure water surge disaster type" and "damage structure water surge disaster type", thereby replacing the overall performance of the extended damage of a mass micro-fracture cluster with the activation characteristics of the damaged structure.

Under the influence of the damaged structure, the rock shear stress in the upper part of the small hidden faults shows an "N"-type change, the displacement change in the surrounding rock shows an "S"-type change, and the change in rock shear stress below the small hidden faults and the pore water pressure of the rock above it show an "M"-trend. By comparing the processes of different water surge disaster-causing types, it can be seen that the damaged structure can change the water-blocking performance of the water barrier of the basement layer, containing small hidden faults, by reducing the strength of the rock surrounding the fault, blocking the release rate of shear stress of the surrounding rock, weakening the support pressure borne by the fault, lowering the degree of expansion of the surrounding rock and shifting the direction of the concentration of the pore water pressure.

Since the present exploration technology cannot accurately capture the data of small hidden faults, this paper can provide a theoretical basis for the detection of small hidden faults. In addition, knowledge of the extension evolution of small hidden faults under the influence of damage structure has changed accordingly, which introduces new influencing factors to the future study of the technology for preventing and controlling sudden water disasters, and makes corresponding changes on the basis of the original understanding of the process of disasters caused by small hidden faults. This provides new reference elements for prediction and early warnings of small hidden faults contained in a coal seam floor, exploration and prevention, and so on.

Author Contributions: Conceptualization, Y.Z. (Yuanhang Zhang) and L.Y.; methodology, Y.Z. (Yuanhang Zhang) and L.Y.; software, B.W. and Q.L.; validation, J.C.; formal analysis, Y.Z. (Yifeng Zeng); investigation, L.Y.; data curation, Y.Z. (Yuanhang Zhang); writing—original draft preparation, Y.Z. (Yuanhang Zhang); writing—review and editing, L.Y. All authors have read and agreed to the published version of the manuscript.

Funding: Natural Science Foundation of Shandong Province ZR2020ME102 Liming Yin.

Institutional Review Board Statement: This study did not require ethical approval.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Due to the needs of the project, the experimental data cannot be disclosed for the time being.

Conflicts of Interest: The authors declare no conflict of interest.

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