Abstract: The stability of water-preventing coal pillar plays an important role in preventing gob water inrush. The gob side of the water-preventing coal pillar is soaked in a certain height of mine water. Different soaking heights may affect the stability of coal pillars. Few studies have been conducted on the properties of coals with different water-soaking heights. We carried out uniaxial compressive tests on coal specimens with different water-soaking heights to gain a better understanding of different water-soaking-height-induced weakening characteristics of coal. Results show that: (1) The water content of coal specimens increases with the soaking height. Water significantly weakens the strength of coal specimens. However, the extent of strength weakening of the coal specimen does not increase with the increase of the soaked height. The strength of the fully soaked coal specimen is lowest among all groups of coal specimens. The strength of the three groups of partially soaked coal specimens is between the fully soaked coal specimens and the coal specimens without being soaked in the water. In the three groups of partially soaked coal specimens, the strength of the coal specimens increases with the increase of the soaking height. (2) The acoustic emission activities of complete water soaking and nonsoaking coal specimens are relatively concentrated, occurring mainly in unstable fracture expansion stage and post-peak destruction stage, and acoustic emission exhibits main-shock mode. Partially soaking coal specimens, especially the 25% water-soaking height and 50% water-soaking height coal specimens, produces obvious acoustic emission activities during the fracture expansion stabilization phase, and then generates more acoustic emission activities during the unstable expansion stage and the post-peak stage. The acoustic emission presents foreshock—main shock mode. (3) The softening effect of the water soaking on the coal specimens is obvious. It was further found that the deformation of coal specimens with partial water soaking is not synchronized in different layers, the nonuniform deformations of partially soaked coal specimens aggravate its damage.

Keywords: water-soaking height; AE characteristics; local strain characteristics; nonuniform deformation

1. Introduction

Water-conducting fissures will be formed in overburden strata during the coal mining process, which results in a large amount of mine water in gob area [1]. The coal and rock mass around gob will inevitably be in a certain mine water environment [2]. Due to the difference in water supply and drainage in the gob, the amount of water in the gob will be different. The water-preventing coal pillars may be soaked in water-accumulated gob with different water amounts, then the soaked height of the coal pillars in the gob water will be different. Coal is a porous medium [3], water will be absorbed from the bottom to the upper part of the coal pillar due to capillary force, while the gravity will hinder
the diffusion of water in the longitudinal direction [4]. Consequently, the diffusion of moisture in the coal pillar has a certain range [5]. Different soak heights result in a nonuniform distribution of water in the longitudinal direction of the coal pillar.

Due to the water–rock interaction, deformation and failure characteristics of coal pillars soaked in water will change significantly. Water–rock interaction is a widespread and challenging issue in rock mechanics and engineering [6].

A considerable number of studies have been carried out to investigate the influence of water content on mechanical properties and failure characteristics of coal and rock mass [7–12]. According to former studies, the uniaxial compressive strength, elastic modulus, and tensile strength of the rock all decline as moisture content increases.

Acoustic emission (AE) monitoring is a useful technique to capture the failure process of rocks [13,14]. Many researchers [15–19] analyzing the mechanical properties of coal and rock with different water content combined acoustic emission data. Previous results have shown that there is a negative relation between the acoustic emission count and water content, and the increasing moisture content promotes creep damage in coal and rock.

In terms of the damage model of coal and rock mass affected by water content, Yao [15] applied statistical damage theory and strain equivalent hypothesis to derive a damage constitutive model of coal specimen which can reflect the influence of water content. Wang et al. [20] prepared uniaxial compression tests of raw coal samples and briquette samples with different water contents, analyzed the relationship between mechanical parameters and water content of two coal samples, and established a segmental damage constitutive model considering moisture content. Based on the generalized strain equivalence principle and the statistical microscopic damage mechanics theory, Kang [21] established a damage constitutive model considering the weakening effect of water and uniaxial load.

Most of the former research focused on the influence of water content on the mechanical properties of coal and rock mass. However, such studies treated the water content as the only variable affecting the mechanical behaviors of the coal and rock specimens, neglecting the effects of the water distribution within them. Tang [22] and Li [23] found that the distribution of water affects the mechanical properties of rock mass materials.

The stability of coal pillars has an important impact on safe and efficient mining for coal mines [24]. Coal pillars in the gob water may be soaked in different heights due to different amounts of accumulated water, the water distribution within coal pillars may be different as a result. There are few studies on the deformation and failure of coal pillars with different soaking heights. Laboratory uniaxial compressive tests for different soaking heights of coal specimens are carried out to investigate the failure characteristics and mechanisms. It is helpful to gain a deeper understanding of the damage mechanism of water-bearing coal and rock mass and provide more scientific guidance for the retention of water-preventing coal and rock pillar.

2. Materials and Test Procedure

The coal specimens were prepared with the cylindrical specimens. The tests were performed with WAW1000 Electro-hydraulic servo universal testing machine which is made by Jinli Test Technology Company, Jilin, China the acoustic emission monitoring system, and the strain testing system. Data logging was controlled by a computer during testing. First, the coal specimens were divided into five groups and placed into the distilled water for different soaking heights. The coal specimens were taken out of the water when the water content of coal specimens reached a steady state under their respective water-soaking conditions. Then, the specimens were placed on the fixed lower head of the testing machine. Subsequently, the compressive load was applied to the specimen with a strain rate of 0.002 mm/s.
2.1. Coal Specimens

A coal block sample was taken from the Tazigou Coal Mine (Fuxin, China), and the coal type is lean coal. The detailed properties of the coal sample are shown in Table 1. First, cylindrical coal specimens were drilled with a diameter of 50 mm perpendicular to the coal seam bedding plane. Then, coal specimens were cut to a height of 100 mm by a cutting machine. Last, coal specimens with a diameter of 50 mm and a height of 100 mm were polished with a grinding machine. The ends of the specimens and diameter deviations along the specimens’ axis met the standard suggested by the International Society for Rock Mechanics [25]. A total of twenty-five specimens were divided into five groups, each group had five specimens (see the specimens in Figure 1).

Table 1. The detailed properties of the coal sample.

| Coal Lithotype | Geological Age   | Industrial Grade | Moisture % | Ash %  | Volatile % |
|----------------|------------------|------------------|------------|--------|------------|
| dull coals     | Carboniferous period | Lean coal        | 0.39       | 9.56   | 15.21      |

Figure 1. Experimental coal specimens.

To reduce statistical effects on the experimentally measured mechanical properties, compression experiments with the same loading conditions were performed on five specimens for each water-soaking height [22]. And, we removed the maximum and the minimum values from the test data of each group, the results of the remaining three coal specimens tests in each group were used for subsequent analysis.

2.2. Equipment

The testing system was mainly composed of three parts. The WAW-1000 electro-hydraulic servo testing machine was used for the application of uniaxial compression. The CM-2B Strain Testing System is made by Xinheng Electronic Technology Company, Qinhuangdao City, China. And it was used to collect the strain data of the coal specimens. The DS5-8B Acoustic Emission Monitoring System is made by Beijing Softland Times Scientific & Technology Company, Beijing, China. And it was used to monitor the AE number and AE energy during the coal specimens’ compression. The testing equipment is shown in Figure 2.

2.2.1. Uniaxial Loading System

The WAW-1000 electro-hydraulic servo testing machine was composed of a control system, a loading system, and an automatic data acquisition system. The data acquisition frequency was once per second. The maximum loading capacity was 1000 kN. The displacement loading mode was adopted with a strain rate of 0.002 mm/s in this study.

2.2.2. Strain Testing System

Along the coal specimens’ axis, strain rosettes were attached to the surface of the coal specimens with cyanoacrylate at the height of 25 mm, 50 mm, and 75 mm from the lower end of the coal specimens.
The data of strain rosette was collected by a CM-2B strain testing system, and the acquisition frequency was once per second, which was consistent with the data acquisition frequency of the press.

2.2.3. AE Monitoring System

Four acoustic emission sensors with a diameter of 18 mm (RS-2A) were placed on the surface of the specimens. The two sensors’ center position was 25 mm from the lower end of the coal specimens, and the other two sensors’ center position was 25 mm from the upper end of the coal specimens. Four acoustic emission sensors were coated with Vaseline to ensure the coupling effect. Then they were attached to the surface of the coal specimens by scotch tape. The specific arrangement of the strain rosette and acoustic emission sensor is shown in Figure 3.

2.3. Water Soaking Experiment

Five groups of coal specimens with different water-soaking heights (0 mm, 25 mm, 50 mm, 75 mm, 100 mm) were prepared for the tests, which are listed in Table 2 and shown in Figure 4.
Before the start of the water-soaking test, all the coal specimens were placed in the oven, maintained at 105 °C temperature [26,27], and dried for 24 h. Then the weights of the dried specimens were measured. Subsequently, the water soaking test was carried out. The first group of coal specimens were placed in a glass bucket without water.

The other four plexiglass barrels were filled with the same volume of distilled water, then the coal specimens were placed in the plexiglass barrels according to their respective groups. The upper end of the coal specimens were clamped on the plexiglass lid by the holster, and the height of the holster was adjusted to achieve the soaking heights of the coal specimens, which were 25 mm, 50 mm, 75 mm, 100 mm, respectively. The coal specimens were taken out every 2 h during the first eight hours as the amount of water soaked during that period was relatively large. Then the surfaces of the coal specimens were wiped with wet towels so that the surface did not drip, and then weighed with an electronic scale. After 8 h, the weights of the coal specimens were measured every 12 h according to the above operation. The water-soaking test was continued until the mass change of the coal specimen was less than 0.01 g.

### 3. Results and Discussion

#### 3.1. Water Soaking Experiment

In order to study the influence of the soaking height on the water absorption law of coal specimens, the water-soaking tests of the coal specimens under five different soaking heights were carried out. The results are shown in Figure 5. In the Figure, the abscissa is the water-soaking time of the coal specimen, and the ordinate is the water content of the coal specimen. The water content is calculated using the following formula (ISRM, 1979 [28]):

$$w_t = \frac{(m_t - m_0)}{m_0} \times 100\%$$

where $w_t$ is the water content, $m_t$ is the mass of the wet coal specimen at time $t$, and $m_0$ is the mass of the dry coal specimen.

The results showed that the evolution of water content of coal specimens with 25 mm, 50 mm, 75 mm, and 100 mm water-soaking heights was almost the same. The moisture content of coal specimens shows a nonlinear growth trend and can be divided into three stages [19]: Rapid water absorption stage, slow water absorption stage, and stabilization water absorption stage. In the first 8 h, the moisture content of the coal specimens increased rapidly. Subsequently, the water absorption rate of
the coal specimens decreased rapidly. With the increase of the water-soaking time, the water contents of the coal specimens increased slowly until 104 h. The moisture contents of the coal specimens treated by each group reached a relatively stable value. After 104 h, the coal specimens’ contained water rate hardly changed, and it can be considered that the saturation state was reached under the conditions of the respective soaked height.

![Figure 5. Evolution of water content with soaking duration for five groups of specimens.](image)

After 104 h, the moisture contents of all coal specimens no longer changed, when it could be considered that the water content reached a stable state.

Due to different soaking heights in the water, the degree of contact between each group of coal specimens and water was different, then the final moisture content was different. It shows that the coal specimens of the nonsoaking Group absorbed moisture in the air slowly, the final moisture content was the lowest among all the testing groups, and the average water content was 1.01%.

As the soaking height increased, the final moisture content of the coal specimen increased. The coal specimen with 25 mm water-soaking height had a final moisture content of 15.13%. The coal specimen with 50 mm water-soaking height had a final moisture content of 16.68%. For the coal specimens with 75 mm water-soaking height, the final average moisture content was 18.18%. The coal specimens with 100 mm water-soaking height had the final moisture content of 19.11%.

The water content data of coal specimens with water-soaking heights of 25 mm, 50 mm, 75 mm, and 100 mm were linearly fitted (Figure 6). It was found that there is a good linear fitting relationship between the final moisture content of the coal specimen and the soaking height. The fitting relationship is expressed in Equation (2):

\[ y = 13.91234 + 0.0537x \quad R^2 = 0.98 \quad (2) \]

### 3.2. Uniaxial Compression Test

The stress–strain curves of the coal specimens with different water-soaking heights are basically similar. The stress–strain curve of a 100 mm soaking height coal specimen is analyzed as a typical example (Figure 7). It can basically be divided into five stages [29–31]: (I) Microcrack closure phase (OA); (II) Linear elasticity phase (AB); (III) Fracture expansion stabilization phase (BC); (IV) Unstable fracture expansion stage (CD); (V) Post-peak destruction stage (DE). As shown in Figure 8, the average strength of the coal specimens in the nonsoaking group was 13.66 MPa, which was the highest in the five groups. While the average strength of the coal specimens in the fully soaking group was 7.42 MPa, which was the lowest in the five groups. The softening effect of water on coal is obvious. The strength of the coal specimens under partial soaking state (25 mm soaking height, 50 mm soaking height, 75 mm soaking height) was between the nonsoaking group and the fully soaking group. The strength of the coal specimens with 25 mm soaking height was the lowest in the cases of partial water soaking. The strength of coal specimens with different water-soaking heights did not decrease gradually with the
increase of water content. In addition to the water content factor, different water-soaking conditions also affect the deformation and failure characteristics of coal specimens [22]. In the following, the effects of different soaking heights on the mechanical properties and deformation characteristics of coal specimens are further studied by analyzing the acoustic emission characteristics and local strain evolution laws during the deformation and failure of coal specimens.

**Figure 6.** Water contents of coal specimens with different water-soaking heights.

**Figure 7.** Stress–strain curves of 100 mm soaking height coal specimen.

**Figure 8.** Comparison of peak strength of coal specimens with different water-soaking heights.
3.3. Acoustic Emissions Records

In order to study the failure characteristics of coals with different soaking heights, this paper analyzes the AE energy and AE cumulative energy characteristics by combining the stress–strain curves of coal specimens during compression process.

During the uniaxial compression process, the development, expansion, and damage of fractures of coal will release stress–strain energy, which can be captured by AE [32–34]. The stress–time, acoustic emission energy–time, and acoustic emission cumulative energy–time curves of five groups of coal specimens with different water-soaking heights are shown in Figure 9:

![Stress–time, acoustic emission energy–time, and acoustic emission cumulative energy–time curves](image)

Figure 9. Stress–time, acoustic emission energy–time, and acoustic emission cumulative energy–time curves. (a) 0 mm water-soaking height; (b) 25 mm water-soaking height; (c) 50 mm water-soaking height; (d) 75 mm water-soaking height; (e) 100 mm water-soaking height.

The evolution of acoustic emission of coal specimens with different water-soaking heights was similar: At the beginning of the loading, there was a quiet period of acoustic emission. And when the coal specimens was about to be destroyed, the acoustic emission event surged and there was an active phase of acoustic emission [17]. Combined with the stress–strain curves of coal specimens
with different water-soaking heights, the development of stress is divided into compaction closure stage, linear elastic stage, fracture expansion stabilization stage, unstable fracture expansion stage, and post-peak destruction stage [21]. In the compaction closed stage and the linear elastic stage, little acoustic emission energy was generated only when the internal microcracks of the test piece were closed. In these two stages, the five groups of coal specimens were at AE quiet period.

In the fracture expansion stabilization stage, the coal specimens in the 25 mm water-soaking height group and the 50 mm water-soaking height group produced more acoustic energy than the other three groups. The different soaking heights made the softening degree of different layers of coal specimens different, so that the deformation of different horizons was not synchronized during the loading process. The stress concentration was caused by the local position of the uncoordinated deformation, then the instability of the coal specimen was aggravated. In the unstable fracture expansion stage and the post-peak failure stage, the acoustic emission events of the five coal specimens were active, the acoustic emission energy was enhanced, and the cumulative energy quantity increased rapidly.

Overall, the failure process and acoustic emission evolution characteristics of the five groups of coal specimens had a good correspondence. Before the linear elastic phase, the coal specimen was basically in a quiet period of acoustic emission. At the beginning of the crack propagation stage, the acoustic emission events of the 25 mm and 50 mm soaking height coal specimens were more active than those of the other three groups. In the unstable fracture expansion stage, the acoustic emission events of the five coal specimens occurred intensively, the acoustic emission energy became larger, the cumulative energy of acoustic emission increased rapidly, and reached the highest point after the peak damage.

Many scholars [35,36] have studied the relationship between rock homogeneity and acoustic emission mode, and the results show that the mode of acoustic emission depends on the homogeneity of the rock. The more heterogeneous the material, the more obvious the precursor information before the main rupture occurs. Considering the characteristics of the above five groups of acoustic emission vs. time, it shows that the 25 mm soaking height and 50 mm soaking height coal specimens had obvious acoustic emission activities at the initial stage of crack propagation compared with the other three group coal specimens, which indicated that the heterogeneity of the 25 mm and 50 mm coal specimens was significantly higher than that of the other three groups. As the water-soaking heights were different, the distributions of water in the coal specimens were uniform, and the softening degree of the local position of the coal specimen was not uniform, which aggravated the occurrence of uneven deformation and damage of the original coal specimens. Among the five groups of coal specimens, the 25 mm water-soaking height group and the 50 mm water-soaking height group were relatively in a partially water-containing state, and the nonuniform distribution of water was most obvious. Therefore, the above two groups of coal specimens showed more obvious uneven deformation and damage characteristics during compression.

The acoustic emission activities of fully soaked coal specimens and nonsoaking coal specimens were relatively concentrated, occurring mainly in unstable fracture expansion stage and post-peak destruction stage. Partially soaking coal specimens, especially the 25% water-soaking height and 50% water-soaking height coal specimens, produced obvious acoustic emission activities during the fracture expansion stabilization phase, and then generated more acoustic emission activities during the unstable expansion stage and the post-peak stage. In short, the acoustic emission activities of fully soaked coal specimens and nonsoaking coal specimens were intense, while the acoustic emission activities of partially soaking coal specimens were more dispersed. The characteristics of acoustic emission showed that the heterogeneity of the partially soaking coal specimens was more obvious than that of the fully soaked coal specimens and nonsoaking coal specimens. The soaking part of coal specimens was weak compared with the nonsoaking part, and partial soaking increased the extent of heterogeneity of the coal specimens.
3.4. Local Strain Characteristics

In order to further study the deformation characteristics of different soaking heights coal specimens during compression, the local strain at different positions of the coal specimens was monitored by the CM-2B strain monitor. According to the setting of the strain rosette at the beginning of the test, local strains at heights of 25 mm, 50 mm, and 75 mm from the bottom of coal specimens were analyzed. The local strain development for specimens with different soaking heights is presented in Figure 10a–e. To gain a deeper understanding of the local strain, the time–stress curves of specimens with different soaking heights are also shown by the black curves.

![Figure 10](image)

**Figure 10.** Evolution of the axial stress and local strain for different soaking heights specimens at different loading times. (a) 0 mm water-soaking height; (b) 25 mm water-soaking height; (c) 50 mm water-soaking height; (d) 75 mm water-soaking height; (e) 100 mm water-soaking height.
It can be seen from the axial strains at different positions of coal specimens that the local strains of coal specimens with water-soaking height of 0 mm, 75 mm, and 100 mm were relatively consistent at different positions during the loading process.

It shows that the deformations of the upper, middle, and lower layers of the coal specimens were synchronized, and the whole exhibited uniform deformation characteristics during the loading and deformation of the three groups of coal specimens. In the 25 mm and 50 mm water-soaking height groups, the local strains at different positions were quite different. At the initial stage of loading, different deformation amplitudes were exhibited, and the overall deformation exhibited uneven characteristics. For the coal specimens in the 25 mm water-soaking height group, along the height of the coal specimens, the local strain at 25 mm height was the most significant, while the strains at 50 mm and 75 mm height were relatively flat, and the changes between the two positions were not much different. For coal specimens in 50 mm water-soaking height groups, along the height of the coal specimens, the strains at 25 mm and 50 mm were more significant, and the variation amplitudes of the two were not much different, while the strain at 75 mm was relatively flat.

From the perspective of local strain changes, water soaking had a significant effect on the deformation of coal specimens. For coal specimens immersed in water of 25 mm height, the coal specimen was in full contact with water below 25 mm height. The softening effect of water on the coal specimen at this part was obvious. During the loading process, the strain changed greatly. The moisture content of the coal specimens at 50 mm and 75 mm was less than 25 mm, the corresponding strain changes were small.

The softening effect of water on the coal specimen was obvious through experiments. On one hand, because the coal specimen was immersed in water, the friction between the coal particles was weakened. On the other hand, due to the existence of capillary force and pore pressure, the water-soaked coal specimen produced more microcracks, which made the overall strength of the coal specimen weak. The softening extents of different layers of coal specimens were different, the extents of deformation of the corresponding layers were different, resulting in nonuniform deformation of the overall coal specimens.

In previous studies, the water content was taken as an absolute value to investigate the mechanical properties of water-bearing coal specimens under different water contents. Through this experiment, it was found that the uneven distribution of water also affects the mechanical properties of coal. This was verified in the local strain and acoustic emission characteristics of coal specimens.

In order to further analyze the influence extent of water-soaking height on the nonuniform deformation and failure of coal specimen from the perspective of local strain, the nonuniform deformation index $S_i$ was introduced to quantitatively evaluate the nonuniform failure characteristics of coal deformation (as the Equation (3)).

$$S_i = \frac{S_d}{S_e}$$ (3)

where $S_e$ is the overall strain before the fracture expansion of the specimen, $S_d$ is the axial strain difference before crack propagation of the specimen (It is shown in Figure 11).

The overall deformation of the coal specimen is in a relatively uniform phase before crack propagation. It is reasonable to use the overall strain at this stage as an indicator to evaluate the uniform deformation of the specimen. At this stage, there is no obvious dislocation on the surface of the coal specimen. The strain rosette attached to different positions on the surface of the coal specimen will not be damaged due to the displacement of the surface of the coal specimen, so the strain data can be continuously detected. Therefore, the overall strain and local strain difference before the crack expansion stage can reflect the nonuniform deformation characteristics of coal specimens well.

According to five groups of coal specimens with different water-soaking heights, the water-soaking interface was distributed at 25 mm, 50 mm, and 75 mm height of coal specimens. Through the previous local strain analysis, the uneven degree of strain at the coal specimens of 25 mm and 75 mm is relatively large. Therefore, in order to unify the comparative analysis, the local strain difference value was made
by the axial strain at heights of 25 mm and 75 mm. The uneven deformation index $Si$ can be calculated, and the specific calculation results are shown in Table 3.

![Figure 11. Analysis of axial strain difference index.](image)

Table 3 shows that the nonuniform deformation index of coal specimens with the 25 mm water-soaking height was the largest, and the corresponding strength was the smallest among three partial water-soaking groups (25 mm, 50 mm, 75 mm), which indicated that the nonuniform deformation of the specimen exacerbated the damage of the specimen and reduced the strength of the specimen.

| Water-Soaking Heights | 25 mm | 50 mm | 75 mm | 100 mm |
|-----------------------|-------|-------|-------|--------|
| $Si$                  | 0.6029| 0.4257| 0.00059| 0.12   |
| Peak strength         | 6.95  | 7.32  | 8.6   | 5.86   |

Furthermore, the axial strain difference was analyzed combined with the overall stress and the acoustic emission energy. Figure 12 shows local strain difference–time, stress–time, acoustic emission energy–time curve.

Figure 12 shows that the axial strain difference increased with loading and increased significantly in the stage of stable crack expansion. The axial strain difference first reached the maximum before the specimen reached the peak strength. A sharp increase of the axial strain difference on the specimen surface can be used as a precursor to the instability of the specimen.

The axial strain difference of partially soaking coal specimens was more significant during the loading process. The large axial strain difference of the specimen represents that its nonuniform deformation is obvious. The specimen became unstable and destroyed quickly after the occurrence of a larger axial strain difference.

The acoustic emission mode and local axial strain evolution law were very good to show that the inhomogeneity of the coal specimen with 25 mm height water soaking was the largest, which led to the weakening of its strength. The coal specimen with 25 mm water-soaking height had the lowest strength among the coal specimens with partial water soaking due to the obvious nonuniform deformation characteristics. Although the water content of the coal specimens increased with the increase of the water-soaking height, the strength of the coal specimen did not decrease as the water content increased. Nonuniform deformation will reduce the strength of coal specimen to some extent.
Table 3 shows that the nonuniform deformation index of coal specimens with the 25 mm water-soaking height was the largest, and the corresponding strength was the smallest among three partial water-soaking groups (25 mm, 50 mm, 75 mm), which indicated that the nonuniform deformation of the specimen exacerbated the damage of the specimen and reduced the strength of the specimen.

Table 3. Comparison of nonuniform deformation index and peak strength under different water-soaking heights.

| Water-Soaking Heights | 25 mm | 50 mm | 75 mm | 100 mm |
|-----------------------|-------|-------|-------|--------|
| Si                    | 0.6029| 0.4257| 0.00059| 0.12   |
| Peak strength         | 6.95  | 7.32  | 8.6    | 5.86   |

Furthermore, the axial strain difference was analyzed combined with the overall stress and the acoustic emission energy. Figure 12 shows local strain difference–time, stress–time, acoustic emission energy–time curve.

Figure 12. Evolution of axial stress and local strain difference for different soak heights specimens at different loading times. (a) 0 mm water-soaking height; (b) 25 mm water-soaking height; (c) 50 mm water-soaking height; (d) 75 mm water-soaking height; (e) 100 mm water-soaking height.

4. Conclusions

In this paper, laboratory tests were conducted to understand the effect of water-soaking height on the deformation and failure of coal in uniaxial compression. The main conclusions are:

1. Water contents of coal specimens increase with the soaking height. Water significantly weakens the strength of coal specimens. The strength of nonsoaking coal specimens was the highest, and the strength of fully soaked coal specimens was the lowest. The strength of coal specimens with different water-soaking heights did not decrease with the increase of water content, and the unevenness of water distribution had a significant impact on the strength of coal specimens. Uneven distribution of moisture exacerbates deformation and damage of coal.

2. Acoustic emission activities of fully soaked coal specimens and nonsoaking coal specimens were relatively concentrated, occurring mainly in unstable fracture expansion stage and post-peak
destruction stage. Partially soaking coal specimens, especially the 25% water-soaking height coal specimens and 50% water-soaking height coal specimens, produced obvious acoustic emission activities during the fracture expansion stabilization stage, and then more acoustic emission activities were generated during the unstable expansion stage and the post-peak stage. The characteristics of acoustic emission showed that the heterogeneity of the partially soaking coal specimens was more obvious than that of the fully soaked coal specimens and nonsoaking coal specimens.

(3) The nonuniform deformation index $Si$ can reflect the nonuniform deformation characteristics of coal specimens with different water-soaking heights to some extent. The larger the $Si$ value of the nonuniform deformation index, the greater the extent of nonuniform deformation of the coal specimens. According to the $Si$ index, it was also shown that the nonuniform deformation of the 25% water-soaking height coal specimens was most obvious among all the coal specimens.

**Author Contributions:** R.Q. carried out the experiments, analyzed the results, conducted the theoretical explanations, as well as wrote the manuscript. G.F. conceived and designed the framework. P.W. reviewed the technology concepts, assisted to analyze the AE data, and performed significant review and editing of the technical paper. J.G. provided some help about the mechanical analysis. H.J. guided the structure of the article. Q.S. and S.L. assisted to conduct the experiments.

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