Research Article

Experimental Study on the Mechanical Mechanism of Arch-Chord-Coupled Antisliding Structure

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Received 29 April 2022; Revised 24 June 2022; Accepted 1 July 2022; Published 18 July 2022

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Arch-chord-coupled antisliding structure is a new type of structure composed of multiple small-diameter piles for strengthening small- and medium-sized landslides, especially suitable for the reinforcement of slopes that are sensitive to deformation. In order to further explore the mechanical properties of the antisliding structure, physical model tests under four cases were carried out to study the deformation and stress characteristics of the structure under different types, and the optimal structural type was determined. The displacement test results show that even if there is no crown beam at the top of the piles, all the piles can deform in coordination, and when the number of rear piles is large, all the piles can basically deform synchronously. The test results of the bending moment of the pile body show that the crown beam has a great influence on the extreme value of the bending moment of each pile. For the structural type with more piles arranged in the rear row, the standard deviation of the extreme value of the bending moment of the pile body before and after adding the crown beam decreases from 2.0 to 1.03; the presence of crown beams effectively adjusts the internal force of each pile. The comprehensive analysis results show that the arch-chord-coupled antisliding structure with more piles in the rear row is the best.

1. Introduction

An antisliding pile is an effective and widely used landslide reinforcement measure [1, 2]. With the deepening of its application in the field of landslide reinforcement, single piles with different cross sections and group piles with different arrangements have been gradually derived [3, 4].

Existing studies have shown that most landslides have the characteristics of large sliding force in the middle and small sliding force on both sides [5], and the vertical displacement of soil in front of the thrust was compacted to form a wedge-shaped area under the limited width horizontal load [6], and the displacement of soil layers at different depths will also have obvious differences [7], so uneven pile arrangement can be considered. According to the characteristics of the sliding force of the landslide, Li et al. optimized the setting of the pile spacing, so that the pile spacing gradually increased from the middle to the two sides to provide the antisliding force suitable for the sliding body [8]. For pile groups or antisliding structure composed of multiple piles, some scholars have found that the thrust borne by the rear row piles will be significantly greater than that of the front row piles, and the layout of the front and rear row of piles has been optimized based on this feature [9, 10]. In addition, increasing the strength of soil is also an effective reinforcement measure, for example, analyzing the mechanical mechanism of soil affected by other factors [11], adding some fiber materials to the soil [12], or restricting the displacement of the soil around the pile [13].

In addition to optimizing the pile length and pile spacing, some scholars have also made specific arrangements for the position of the piles of the pile group structure [14], so that the rear and middle parts can provide greater antisliding force without increasing the number of piles, and the arch-chord-coupled antisliding structure is such a new type antisliding structure with these characteristics.
As a new type of antisliding structure, the mechanical properties of the arch-chord-coupled antisliding structure still need to be further explored in order to guide the design and construction. In view of this, the mechanical characteristics of the new antisliding structure are explored by means of a physical model test method [16, 17]. Through the comparison of the test results under four cases, the mechanical characteristics of the structure are analyzed and the best structural form is determined.

2. Introduction of Arch-Chord-Coupled Antisliding Structure

The arch-chord-coupled antisliding structure is a new type of antisliding structure composed of multiple piles in a specific way, and its spatial form is shown in Figure 1. The arch-chord-coupled antisliding structure generally consists of 16 piles, and if necessary, prestressed anchor cables can be added or the number of piles can be increased. The diameter of the piles that make up the structure is generally 0.3~0.5 m, and the spacing between the piles is generally 3~5 times the diameter of the piles. The width of the sliding body that can be reinforced by this structure is generally 16~18 m, and the typical application scenario is shown in Figure 1(c) [15].

Arch-chord-coupled antisliding structure is proposed based on uneven distribution characteristics of sliding force. The number of single piles in the antisliding structure is reduced from the middle to both sides according to certain rules, which can provide sufficient antisliding capacity and reduce the number of antisliding piles at the same time. When the arch-chord-coupled antisliding structure is subjected to driving force, a plurality of small coupling piles can be formed in it, as shown in Figure 1(b).

3. Model Test of Arch-Chord-Coupled Antisliding Structure

This paper is devoted to exploring the mechanism and deformation properties of antichord-coupled antisliding structure under different layout modes of the piles and fixing measures at the top of piles.

3.1. Model Box. The model test is designed according to the applicable position of the arch-chord-coupled antisliding
structure [18, 19]. According to the actual width of subgrade with two railways, the designed width of the loading area is 0.45 m. According to the actual deformation of the subgrade in the transition section of a high-speed railway, the length of the loading area is set to 0.6 m.

The length, width, and height of the model box are designed as 1.75 m, 1.6 m and 1.2 m, respectively, to meet the setting requirements of the subgrade, as shown in Figure 2. All frames of the model box are made of square steel pipes, with an overall dimension of 5 cm × 5 cm and a wall thickness of 0.5 cm. A steel plate with a thickness of 0.5 cm is laid at the bottom of the model box to support the soil. The four sides of the model box are made of toughened glass with a thickness of 1.0 cm, but the height of the front glass is set to 0.5 m to facilitate filling and personnel access, and the height of the toughened glass on the other sides is the same as that of the model box. In this test, only the top surface of the subgrade is loaded, and the side of the model box has little effect on the soil sliding, so no special treatment is carried out on the side of the model box to eliminate the boundary effect.

3.2. Loading Method

3.2.1. Loading Device. In this test, vertical pressurization is adopted as required. The loading tool is two jacks with force monitoring devices, which can view the applied external force in real time, and the reaction force required by jack is provided through the self-made reaction frame. The design of the reaction frame is shown in Figure 3(a), and its frame is composed of square steel pipes surrounded outside the model box, with the size of 15 cm × 15 cm and the wall thickness of 0.5 cm. The reaction frame device does not need to be fixed on the ground, and the force to prevent its upward movement is provided by the gravity of the soil in the model box; the self-weight of the soil filled in the box is so large that when the external force required to be applied is small, the test accuracy will not be affected. To ensure that
the pressure acting on the subgrade surface is uniform, the wood plate with the same width as the subgrade is placed under the base plate. The picture of the reaction frame working on site is shown in Figure 3(b).

### 3.2.2. Loading Procedures.

The maximum load value for this model is 20 kPa. First, an initial pressure of 0.2 kPa is applied, and the pressure is stabilized for 30 minutes, so that the components, soil, and monitoring instruments are closely attached. Then, step-by-step loading is carried out according to the increase of 2.0 kPa for each stage, and the stable monitoring data is recorded after each level of load is stabilized for 20 minutes, and then, the next stage of load is applied until the monitoring data cannot reach stability for a long time or the displacement value is large.

### 3.3. Model Materials.

The materials involved in the model test include sliding body soil, sliding bed soil, slip surface, and antisliding pile. The sliding soil is composed of cohesive soil and river sand, with a volume ratio of 0.4 : 0.6. The sliding bed is mixed with cohesive soil and cement, in which the volume proportion of cement is 5%. To control the compactness of sliding bed soil, an indoor geotechnical test shall be conducted before formal filling, and the amount of water required to reach the optimal moisture content shall be calculated, and then, the soil in the model box shall be mixed and fixed according to the results of the indoor test. The laminated plastic without a filler in the middle is used as the sliding belt. The thickness of the single-layer plastic cloth is 0.14 mm, the cohesion between the two layers is 4.5 kPa, and the internal friction angle is 16°. The relevant parameters

<table>
<thead>
<tr>
<th>Materials</th>
<th>Unit weight (kN/m³)</th>
<th>Young’s modulus (MPa)</th>
<th>Cohesion (kPa)</th>
<th>Friction angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sliding mass</td>
<td>17.5</td>
<td>26.3</td>
<td>3.2</td>
<td>24.5</td>
</tr>
<tr>
<td>Sliding bed</td>
<td>19.3</td>
<td>125.6</td>
<td>70</td>
<td>21.5</td>
</tr>
<tr>
<td>Antisliding pile</td>
<td>14.4</td>
<td>3500000</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

![Diagram](image1)  
**Figure 3:** Loading measures for the model test.

![Diagram](image2)  
**Figure 4:** Roughening treatment of the model pile.
of the materials involved in the model slope are shown in Table 1.

The model test pile is made of plexiglass pipe, with a length of 0.75 m, an outer diameter of 0.025 m, and an inner diameter of 0.005 m. Due to the smooth surface of plexiglass pile, its surface needs to be roughened. Firstly, the epoxy resin mixed with curing agent is evenly applied on the outer surface of the pile, and then, the piles are placed in the standard sand for 24 hours to make the surface of the pile firmly stick a layer of standard. To ensure the sticking quality of the strain gauges, the positions where the strain gauge is arranged are pasted with adhesive tape in advance. The model piles without rough treatment and completed treatment are shown in Figure 4.

3.4. Arrangement of Sensors. The sensors needed in the model test include earth pressure cell, strain gauge, and displacement sensor. Taking advantage of the symmetry of the arch-chord-coupled antisliding structure, the earth pressure cells and strain gauges are, respectively, arranged on 8 piles
on one side, which can not only measure the complete but also avoid the influence of a large number of wires on the test results, as shown in Figure 5.

As shown in Figures 5(a) and 5(c), 6 earth pressure cells are arranged near each pile, and 3 earth pressure cells are arranged in the loading section and anchorage section, respectively. According to the stress characteristics of anti-sliding pile, 3 earth pressure cells at the bottom are arranged in front of the pile, and the rest are placed behind the pile. Considering the complex stress distribution of the soil near the slip surface, the arrangement of the earth pressure cells is nonequidistant; the spacing of the earth pressure cells near the slip surface is small and vice versa [20]. The geometric spacing of the strain gauge arrangement is the same as that of the earth pressure cells, except that all the stain gauges are arranged behind the pile, as shown in Figure 5(b).

During the test, the displacement of the top of the pile or the crown beam is collected, and the collection instruments are multiple dial indicators distributed in different positions. When there is a crown beam at the top of the piles, the horizontal and vertical displacement of the crown beam shall be collected at the same time. On the contrary, only the horizontal displacement at the pile head shall be collected. The actual layout of the dial indicators is shown in Figure 6 [21].

3.5. Experimental Conditions. The arch-chord antisiding structure involves multiple rows of piles, and the number of piles in each row is different, so the antisiding effects produced are also different. At the same time, whether there is a crown beam on the top of piles is also an important factor affecting the antisiding performance of the structure. In view of these two influencing factors, four experimental conditions are set up in this paper to analyze the mechanical properties of the arch-chord antisiding structure, as shown in Figure 7. In cases 1 and 3, there is no crown beam at the top of the piles, which is represented by a dashed line.

4. Test Results and Analysis

The arch-chord-coupled antisiding structure contains a total of 16 piles, which need to be numbered to make the subsequent analysis clearer. According to the geometric characteristics of the new antisiding structure, the piles it contains are divided into 4 categories. The first category is the 6 piles located on the arch, which is represented by the letter “A- - (arch),” and the second category is the 6 piles located on the chord, represented by the letter “C- - (chord)”; the third category is the 2 piles located at the foot of the arch, represented by the letter “F- - (foot),” and the remaining 2 piles are represented by the letter “M- - (middle)” according to their position. In view of the symmetry of the structure, only half of the piles need to be numbered, and the numbering of piles according to the above rules is shown in Figure 8.

The existing research results show that the soil moisture content, temperature, and other factors will also have a great impact on the test results [22–25]. However, since the focus of this paper is on the composition of the new antisiding structure, the soil moisture content and temperature are set
as a fixed value, and the following research results are explained based on this condition.

4.1. Deformation of Pile Top under Different Cases. Figure 9 shows the displacement of pile top with loading. For the case where there is no crown beam at the top of the piles, the deformation of eight representative piles is recorded according to the symmetry of the antisliding structure. For the case with a crown beam at the top, the horizontal displacement of the crown beam and the vertical displacement of its front and rear shall be recorded at the same time.

Figure 9(a) shows the deformation of the pile top when the arch of the antisliding structure is at the rear (case 1 and case 2). It can be seen from the figure that after adding the crown beam, the maximum displacement of the pile top decreases from 16.7 mm in case 1 to 12.88 mm, with a reduction range of 22.8%; the existence of the crown beam enhances the antisliding effect of piles. The deformation characteristics of the piles under the two cases are as follows:

(1) When there is no crown beam at the top of piles (case 1), the deformation of the top of each pile varies greatly, and the difference increases with the increase in the load value. The deformation of the rear piles is obviously larger than that of the front pile. The maximum displacement occurs at the top pile A2, which is 16.48 mm, and the minimum displacement occurs at the top of pile F, which is 11.68 mm. The deformation of pile top shows the law of gradually decreasing from the middle to both sides and from the rear to the front.

(2) When there is a crown beam at the top of piles (case 2), the crown beam moves forward and deforms upward at the same time. The variation law of its horizontal displacement has a certain deviation from that in case 1, but the deformation value is between the deformation values of each pile in case 1. The upward displacement value of the rear part of the crown beam is 3.45 mm, and that of the front part is 1.02 mm, showing a forward turning trend.

Figure 9(b) shows the deformation of the pile top when the arch of the antisliding structure is at the front (case 3 and case 4). The deformation characteristics of the piles or crown beam under the two cases are as follows:

(1) When there is no crown beam at the top of piles (case 3), the deformation trend of all piles is the same, the horizontal displacement value of the pile top is relatively close, and the synergistic antisliding effect of all piles is better. The displacement of the pile top shows an increasing trend with the increase in the load. When the loading value is less than 15 kPa, the displacement of the pile top increases slowly, and when the loading value is greater than 15 kPa, the displacement increases rapidly. To a certain extent, it can be explained that it is more reasonable to arrange the piles in this way.

(2) When there is a crown beam at the top of piles (case 4), the crown beam rises slightly while moving forward, and the tendency to turn forward is not
obvious. With the increase in the loading value, the crown beam is mainly deformed in the horizontal direction. When the loading value is less than 12 kPa, the displacement growth rate is small, and the growth rate is larger when it exceeds 12 kPa.

(3) By comparing the deformation laws of the piles or crown beam in case 3 and case 4, it can be found that the horizontal deformation of the top of the piles in two cases is very close, and the deformation value of the crown beam in case 4 is all wrapped by the deformation curve of the pile top in case 3. It can be seen that if the piles are arranged in this way, even if the crown beam is not set on the top, all piles can share the thrust more evenly, and after the crown beam is added, all the piles can better imprisoned together, and the maximum displacement of the pile top can be reduced.

Figure 10: Moment distribution of different cases ($p = 20$ kPa).
4.2. Analysis of Bending Moment. The measured strain data were converted into bending moment [26], and when the loading value is 20 kPa, the distributions of pile bending moment under different cases are shown in Figure 10. In Figure 10, a positive value indicates that the front side of the pile is in tension and a negative value indicates that the rear side is in tension. It can be seen from the figure that the bending moment distribution of the piles under the four cases has the following common characteristics.

All pile bending moment curves show an inverse S-shape, with the front of the loaded section in tension and the rear of the anchored section in tension. All the extreme bending moments appear below the slip surface, and the extreme bending moments of case 1 to case 4 are 21.8 kPa, 21.2 kPa, 20.3 kPa, and 18.2 kPa, respectively. If the magnitude of the extreme value of the bending moment is used as the criterion for judging the quality of the structure, case 4 is obviously better than other cases.

For a pile group or antisliding structure composed of multiple piles, when the geometric dimensions and materials of each pile are the same, the uniformity of the internal force of each pile is a key index to evaluate whether the structure is reasonable. When all the piles are loaded at the same time, if the internal force difference is too large, individual piles will fail first while some piles have not yet worked.

In case 1 (Figure 10(a)), the extreme bending moment of pile “A1” is significantly greater than that of other piles, and the bending moment of each pile near the sliding surface varies greatly, so the coordinated stress capacity of all piles is not good. Compared with case 1, the discreteness of the extreme value of the bending moment of each pile in Figure 10(b) (case 2) is weakened, and the crown beam has a certain confinement effect on the piles, but the extreme values of the bending moment of piles “A1” and “F” are still significantly larger than those of the other piles, which is still unfavorable for the piles to play an overall antisliding effect. Compared with cases 1 and 2, although the extreme value of bending moment in case 3 has decreased, the discreteness of the extreme value of bending moment of each pile is still strong, as shown in Figure 10(c). Compared with the other three cases, the extreme values of the bending moment of the piles in case 4 are relatively small, and the extreme values of each bending moment are also relatively close, which indicates that the combined antisliding effect of each pile is better, as shown in Figure 10(d).

Standard deviation is the most commonly used indicator to reflect the degree of dispersion of the distribution of random variables [27]. In order to compare and analyze the effect of the joint work of the piles under different cases more intuitively, the extreme values of each pile bending moment under different cases were extracted, and their standard deviations under each case are analyzed, as shown in Table 2.

It can be seen from Table 2 that the average value of the extreme values of bending moments of all piles under each case is relatively close, but the difference in standard deviation is large. The standard deviation of the extreme bending moment of case 1 is the 2.03, which is the largest among the four cases, and this is 1.03 in case 4, which is the smallest among the four cases. Therefore, when the antisliding piles are set in the form of case 4, the force acting on each pile is relatively uniform, and the ratio of the minimum and maximum bending moment extremes is 0.82, which can avoid early failure of a certain pile.

4.3. Analysis of Earth Pressure. When the top loading pressure \( p = 20 \text{kPa} \), the earth pressure distribution of cases 1 and 2 is shown in Figure 11. Since the earth pressure can only record the pressure, not the tensile force, according to the arrangement of the earth pressure cells in Figure 5(c), a positive value in Figure 11 indicates that the rear of the pile is under compression, and a negative value indicates that its front is under compression. According to the test results, the earth pressure distributions of four cases are basically similar, and only the earth pressure distributions of the first two cases are listed in Figure 11.

It can be seen from the figure that taking the slip surface as the boundary, the earth pressure distributions in the upper and lower part regions are all triangular, and the maximum earth pressure values all appear at about 5 cm below the sliding surface. The maximum earth pressure in cases 1 and 2 appears on pile “A1,” while the maximum earth

<table>
<thead>
<tr>
<th>Pile</th>
<th>Case 1</th>
<th>Case 2</th>
<th>( M_{\text{max}} )</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>-18.20</td>
<td>-17.30</td>
<td>-15.18</td>
<td>-15.18</td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>-16.50</td>
<td>-16.10</td>
<td>-17.51</td>
<td>-17.51</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>-16.80</td>
<td>-21.20</td>
<td>-20.30</td>
<td>-18.20</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>-15.50</td>
<td>-17.50</td>
<td>-17.50</td>
<td>-16.80</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>-15.30</td>
<td>-16.30</td>
<td>-16.19</td>
<td>-16.33</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>-16.10</td>
<td>-16.10</td>
<td>-18.75</td>
<td>-16.75</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>-18.90</td>
<td>-17.20</td>
<td>-15.38</td>
<td>-14.88</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>-17.39</td>
<td>-17.74</td>
<td>-16.81</td>
<td>-16.54</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>2.03</td>
<td>1.80</td>
<td>2.00</td>
<td>1.03</td>
<td></td>
</tr>
</tbody>
</table>

Note: \( M_{\text{max}} \) extreme value of bending moment.
According to the plane layout of the piles, the extreme value of the earth pressure acting on each pile shows the basic law that the rear part is larger than the front part, and the middle part is larger than both sides. Divide the earth pressure borne by each pile in each case by the maximum earth pressure under this case, and the comparison of earth pressure is shown in Table 3. It can be seen from the table that the extreme value of earth pressure on each pile in case 4 is more uniform, and all the piles can work together better.

### Table 3: Comparison of extreme values of earth pressure on piles ($p = 20$ kPa).

<table>
<thead>
<tr>
<th>Pile</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>1</td>
<td>1</td>
<td>0.53</td>
<td>0.55</td>
</tr>
<tr>
<td>A2</td>
<td>0.82</td>
<td>0.85</td>
<td>0.57</td>
<td>0.6</td>
</tr>
<tr>
<td>A3</td>
<td>0.76</td>
<td>0.74</td>
<td>0.65</td>
<td>0.71</td>
</tr>
<tr>
<td>F</td>
<td>0.62</td>
<td>0.57</td>
<td>0.83</td>
<td>0.86</td>
</tr>
<tr>
<td>C1</td>
<td>0.54</td>
<td>0.61</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C2</td>
<td>0.51</td>
<td>0.54</td>
<td>0.97</td>
<td>0.92</td>
</tr>
<tr>
<td>C3</td>
<td>0.43</td>
<td>0.42</td>
<td>0.92</td>
<td>0.9</td>
</tr>
<tr>
<td>M</td>
<td>0.75</td>
<td>0.77</td>
<td>0.71</td>
<td>0.77</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.18</td>
<td>0.18</td>
<td>0.17</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Note: $E_i$: earth pressure on any pile; $E_{max}$: maximum earth pressure under this case.

Pressure in cases 3 and 4 appears on pile “C1.” According to the plane layout of the piles, the extreme value of the earth pressure acting on each pile shows the basic law that the rear part is larger than the front part, and the middle part is larger than both sides. Divide the earth pressure borne by each pile in each case by the maximum earth pressure under this case, and the comparison of earth pressure is shown in Table 3. It can be seen from the table that the extreme value of earth pressure on each pile in case 4 is more uniform, and all the piles can work together better.

### 5. Conclusions

As a new type of antisliding structure composed of multiple piles, the arch-chord-coupled antisliding structure has four conventional pile layouts. In order to explore the stress and deformation characteristics of antisliding piles under different combinations, four groups of physical model tests are carried out in this paper, and the main conclusions are as follows:

The displacement growth rate of the four different combination forms of the arch-chord-coupled antisliding structure is small in the early stage and large in the later stage after being subjected to thrust. However, the differences in the displacement values of the piles in cases 3 and 4 are small, and the displacement increases slowly before the top loading pressure is less than 12 kPa, while the displacement increases slowly in cases 1 and 2 only before the pressure is less than 8 kPa.

The existence of the crown beam can make the internal force of the piles contained in the structure more balanced. The standard deviation of the extreme value of the bending moment of all piles in case 4 is only 1.10, while the values in cases 1, 2, and 3 are 2.18 and 1.93, respectively. In addition, the coordinated effect of the crown beam on the force also enables the earth pressure to act more evenly on each pile.

Due to the shielding effect of the row piles, the rear row piles will bear a large thrust, and it should be considered to set up more antisliding piles in the rear row or increase the reinforcement in the rear row piles. According to the test results, the pile arrangement method of case 4 should be given priority in the actual engineering design.

### Data Availability

No data were used to support this study.
Conflicts of Interest

The authors have no relevant financial or nonfinancial interests to disclose.

Authors’ Contributions

Guoping Hu was responsible for the data curation and formal analysis and wrote the original draft. Yingzhi Xia was responsible for the supervision and reviewed and edited the paper. Mingxin Zheng was responsible for the data curation and formal analysis. Hui Li was responsible for the data curation. Xiaoxue Ruan was responsible for the data curation and formal analysis.

Acknowledgments

This study has been supported by the Science and Technology Project of Henan Province under Grant 222102320260 and Key Scientific Research Project of Colleges and Universities in Henan Province under Grant 22B580001.

References


