

Xichang Vanadium-Titanium Magnetite Mine, Panzhihua, Sichuan, China- Mine Monitoring

Background

The Panzhihua-Xichang area in Sichuan is the primary vanadium-titanium magnetite mineralization belt in China and one of the world's leading producers of similar deposits.

This mineralization belt, stretching approximately 300 kilometers from north to south with approximately 9.66 billion tons of geological reserves. The ore is low-grade and rich in useful components, including iron, titanium, vanadium, chromium, cobalt, nickel, and copper. The Panzhihua-Xichang vanadium-titanium magnetite is not only a significant source of iron, but also contains numerous other components, including vanadium and titanium, which have high comprehensive utilization value.

Instability of steep slopes in open-pit mines (typically >100m high and >45° in angle) is often not directly caused by surface displacement, but rather by underlying issues such as internal slip surfaces, crack expansion, and fault activation within the strata.

These potential hazards may appear as "nothing obvious" during surface displacement monitoring, but once they accumulate to a critical level, they can suddenly trigger large-scale landslides (capacity reaching hundreds of thousands or even millions of cubic meters), resulting in catastrophic consequences such as equipment damage, casualties, and mine shutdowns.

Deep displacement monitoring involves drilling holes in key slope areas (such as potential slip zones, rock interfaces, and fault fracture zones)

and installing an array of displacement sensors. This system accurately captures the displacement rate, direction, and cumulative amount of rock strata at different depths. This allows for:

- Identifying the hidden risk of "surface stability but deep slip" (e.g., surface soil remains intact, but underlying solid rock layers are shearing

along weak interlayers);

- Providing early warning of slope instability trends months to years in advance, rather than waiting for surface cracks to appear before reacting. This allows for ample time for personnel evacuation, equipment transfer, and emergency response.

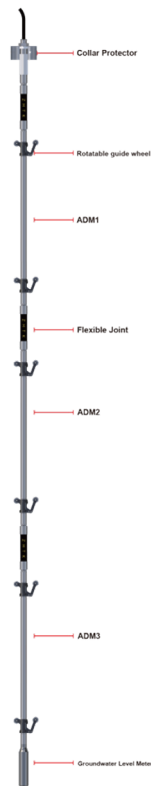


Monitoring Solution

During the system design phase, designers evaluated three established monitoring methods: manual inclinometers, in-place inclinometers, and array displacement meters (also known as flexible inclinometers). A comparison of their applicability is presented below:

Array Displacement Meter (ADM) :

Also commonly called flexible inclinometer, is a sensor array composed of equally spaced (0.5m/1m) inclinometer sensors connected together. It has no blind spots, accurate data and good continuity. It can also monitor groundwater level changes at the bottom, providing multi-dimensional data support for deformation analysis. Finally, after a comprehensive comparison, the user chose to use an array displacement meter for monitoring.



Portable Inclinometer system:

Require regular on-site observations by professional monitoring personnel, and cannot provide real-time monitoring (typically once a day). This makes implementation difficult in the complex environment of mines. Due to the large number of large-scale machinery in mines, the safety of monitoring personnel cannot be guaranteed. Furthermore, when deformation occurs, the safety risks of on-site observation personnel are even greater. However, mine safety monitoring requires high real-time performance, and monitoring frequency is increased during the slope deformation period to provide real-time understanding of the deformation rate and pattern. Therefore, manual inclinometers are not suitable for deep displacement monitoring of mine slopes.



In-Place Inclinometer System (IPI) :

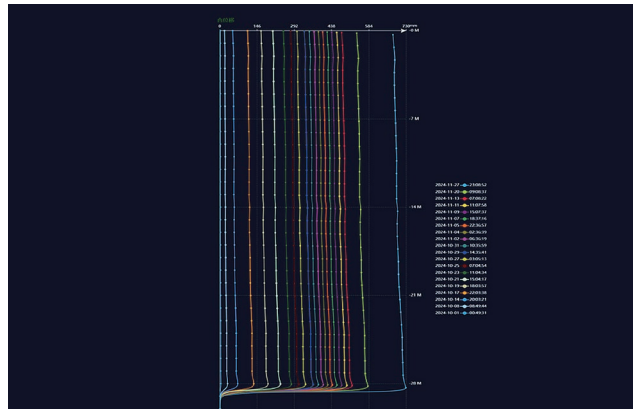
Multiple sensors are installed at regular intervals within the borehole, typically at intervals of 3-5 meters or even greater. The number of sensors is relatively small, and the data calculations involve numerous assumptions and approximations. They are generally used for deformation trend analysis, but cannot accurately determine the depth and amount of deformation, nor can they accurately calculate the deformation rate or cumulative deformation. Therefore, they are not suitable for this application.



Results

The owner's construction team began drilling and installation in April 2022, deploying 12 monitoring holes on both the south and north slopes, with an average depth of 38 meters. After 36 months of monitoring, the primary deformation depth was 28.5 meters below ground level. The total sliding volume was calculated to be 2,280,000 cubic meters (m³), with the maximum deformation exceeding 700 mm. As the deformation rate accelerated, mine management promptly reduced earthwork and reinforced the deformed areas. Following these rectifications, the deformation rate significantly decreased and stabilized, significantly reducing the mine slope safety risk and keeping it within controllable limits.





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Panzhuhua-Xichang vanadium-titanium magnetite open-pit mine, steep slope (height > 100m, inclination > 45°) that have long posed a significant risk of deep-seated hidden dangers. After comparing manual, fixed, and array-based inclinometers, the array displacement meter (flexible inclinometer) was ultimately selected.

This equipment has no blind spots, provides accurate and continuous data, and can also simultaneously monitor groundwater levels.

In April 2022, 12 boreholes (average depth 38m) were deployed on both the south and north slopes. Over 36 months of monitoring, the primary deformation zone at a depth of 28.5m was accurately captured, promptly identifying deformation exceeding 700mm and the risk of a landslide of 2.28 million cubic meters. Based on this information, we implemented earthwork reduction and reinforcement, significantly reducing and stabilizing the deformation rate, effectively ensuring mine safety. The solution is highly recognized by relevant experts. From the monitoring company designated by the open-pit mining owner of the Xichang vanadium-titanium magnetite mine in Panzhihua.