Formation and Governance of Well Dashen-1 Landslide in Northwest Sichuan Gas Field

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Abstract: The formation mechanism of Well Dashen-1 landslide in Northwest Sichuan Gas Field was analyzed in the work, combined with numerical fitting and stability calculation of changes in slope terrain. Thus, the landslide was determined as an old landslide. Recently, new signs of instability had emerged due to "April 20th" Lushan Earthquake. Based on actual situation of the slope, reasonable and effective measures of reinforcement were proposed with landslide characteristics, thus providing references for awareness and analysis of hazard similar to landslide.

1 PROJECT OVERVIEW

Well Dashen-1, built in 1998, is a major natural gas well with annual output of more than 130,000 cubic meters of natural gas. It is located in Group 4, Xingfu Village, Shunlong, Danleng at Northwest Sichuan. The landslide is an old soil landslide located in a slope of southeast side of Shunlong. There are multiple stairs on slope body, with 140 of slope gradient. Deformations have existed in the well site of Well Dashen-1 since its establishment. Especially after "April 20th" Lushan Earthquake, the landslide presented new evidence of deformation.

2 LANDSLIDE DEFORMATION AND NUMERICAL ANALYSIS

According to the survey on Well Dashen-1 landslide in Northwest Sichuan Gas Field, longitudinal length of landslide was 240m, lateral width 100m, area 2.40 × 104m^2, average thickness 7m, volume 16.8 × 104m^3, landslide sliding direction about 179°, and slope about 13°. Landslide was chair-like shape, with gullies on both sides; the gullies intersected after landslide margin, forming "Two Ditches from One Source" landscape. Characteristics of Well Dashen-1 landslide deformation were mainly reflected on the following aspects: drooping trailing edge, raised stone retaining wall in central wellsite of the landslide, forming scarps, snipping highway in front-central landslide, and slump in notches. New deformations appeared after "April 20th" Earthquake, including transverse cracks in wellsite, settling ground, echelon-type cracks on housing ground at the right side of wellsite, new drum deformation in leading edge of stone retaining wall, and deformed highway at the front of landslide. Another characteristic of Well Dashen-1 landslide was that intense deformation existed at the back of landslide margin near well site, with relatively weaker deformation at the front and central edge.

2.1 Numerical Fitting Analysis on Slope Terrain Changes

Profiles were extracted along the slope. Spatial changes of slope terrain were analyzed through numerical fitting on elevation h and x-coordinate of each profile with MATLAB. Based on numerical fitting relationship between elevation and coordinates of four profiles along the slope, it could be seen that there was a linear relationship between elevation and x coordinate, with about 133° of slope. The upper part and lower part were both stable according to the numerical fitting. Through landslide site as well as fitting relationship analysis, the slope before and after well site appeared slides, resulting in mutation of ground elevation. It indicated that there was slope sliding or human intervention in wellsite construction, leading to accumulation of local soil. Thus, the elevation of back wellsite was as lower as the well site. The elevation of lower-part wellsite was significantly lower than that of theory elevation. Further down along the slope, the ground

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elevation exceeded over theory value. However, this part of slope was in a strong deformation area, consistent with the site investigation and visiting situation. Therefore, the slope near well site was determined as an old landslide.

2.2 Affecting Factors of Slope Deformation

The underground water level of landslide was relatively shallow. Drains were all near the well site, without any drainage facilities outside. Therefore, water from drains and rear catchment of wellsite directly flew into the lower part of landslide. Due to open mountain terrain of trailing edge and steep gradient, it was conducive to collection of surface water. The poor drainage of slope surface resulted in seeper of localized low-lying areas. Then, the weight of landslide was increased with decline of soil shear strength of slide surface. Meanwhile, the leading edge of landslide was exposed to air; the slope was consistent with occurrence of bedrock, thus providing topography and geological conditions for slide of landslide.

Special geological structure of wellsite landslide was another main factor causing instability of landslides. The first layer of stratum was Quaternary Holocene artificial filling soil (Q4ml), mainly composed of gravel, breccia and powder clay, with sepia color. Dimension stone was mainly composed of mudstone, siltstone and shale red quartz sandstone. Dimension stone occupied about 60 percent, with angular shape and poor roundness; silty clay had high saturated water ratio, occupying about 40% content. The second layer was landslide accumulation body (Q4del), mainly composed of silty clay clip gravel. The content of clay was about 45% with saturated water and hard plastic. The third layer was mudstone and argillaceous siltstone (K2g). Mudstone was brown and weathered; argillaceous siltstone was from gray to brown, weathered.

In addition, influenced by the shake and loading of "April 20th" Lushan Earthquake, the soil of landslide began loosening—another factor for resurrection of landslide.

In conclusion, special geological structure and impact of earthquake were main factors causing instability of landslides.

3 STABILITY CALCULATION

The premise of reasonable landslide control was to correctly determine the stability of landslide and its development trend. For physical and mechanical properties of ground in Well Dashen-1 landslide in Northwest Sichuan Gas Field, calculation parameters were determined combined with the inverse analysis of typical section. It was based on references of related parameters and value of experience data in other survey reports of Danleng. according to the results of geological mapping and drilling profiles, characteristics of Well Dashen-1 landslide deformation were mainly reflected on: drooping trailing edge, raised stone retaining wall in central wellsite of the landslide, forming scarps, snipping highway in front-central landslide, and slump in notches. New deformations appeared after "April 20th" Earthquake, including transverse cracks in wellsite, settling ground, echelon-type cracks on housing ground at the right side of wellsite, new drum deformation in leading edge of stone retaining wall, and deformed highway at the front of landslide. Intense deformation existed at the back of landslide margin near well site, with relatively weaker deformation at the front and central edge. The most unfavorable slip surface should be broken line along the base. Calculation of stability was analyzed mainly according to site geological judgment.

Factors of rainfall and earthquakes were considered in the calculation, according to the features, various possible load cases and their combinations of disasters. The following three conditions were selected for calculation of disaster stability and surplus sliding force:

Condition 1: Natural conditions (weight + groundwater)

Condition 2: Storm conditions (weight + ground + storm)

Condition 3: Earthquake conditions (weight + ground + earthquake)

The checking computations of landslide stability was performed based on 50 years, adjusting basic seismic intensity as □ degree, peak ground motion as 0.15g, response spectra characteristic period of ground motion as 0.30s. Line Search Method of Lizheng software was used for calculation of stability factor and surplus sliding force for the three conditions. According to results of qualitative analysis and quantitative calculation, Well Dashen-1 landslide in Northwest Sichuan Gas Field was stable in natural conditions; the typical profile of whole landslide was unstable in earthquake conditions, while the local part was in less stable state; the local profile was unstable in storm conditions. Evaluation results were consistent with deformation characteristics of landslide status quo. On the whole,

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the landslide stability was poor in storm conditions, thus measures should be made for prevention and governance of the landslide. In addition, local landslide was in basically-stable to less-stable state in storm conditions, possibly generating new slip surface.

The calculation results of surplus sliding force showed that, in Condition 2, the deformation area had possibility of localized and wide range of sliding along the interior soft surface of inside soil. Stability of deformable bodies should be improved to achieve safety fortification levels of slope, preventing destruction of secondary slip deformation, ensuring safety of people and buildings on the landslide. Appropriate preventive measures should be taken to deal with this issue.

4 CONTROL MEASURES OF LANDSLIDE

Based on qualitative analysis of stability and causes of the landslide, heavy rainfall was the main factor inducing landslide deformation. Well Dashen-1 landslide had a whole slide 30 years ago, since when the landslide had been in a steady state. However, new deformation emerged in the landslide after "April 20th" Lushan Earthquake, with resurrection of old landslide, road deformation of front landslide, settlement of well site field, as well as formation of multiple fractures. These were signs that the landslide had revived in the earthquake—it would slide under rainfall. Especially at the well site, the landslide was prone to generating secondary landslide due to higher artificial filling soil with an air face. The slide area was about 6000m2, average moving thickness about 6m, and earthwork of about 3.6 × 104m3.

In accordance with characteristics and dangers of geological disasters, harm degree of booster stations was second level, and the complexity of geological conditions in work area was simple type. Therefore, the level of disaster prevention project was comprehensively determined as Level II.

The seismic intensity within region was Degree VII, and ground acceleration of design peak was 0.15g, according to "China Seismic Zonation Map" (China Earthquake Administration, 1990) and "Seismic Design of Buildings" (GB50011-2001).

Loads and combination design should be considered in the control project. For loads in the design, the dead weight of landslide under natural state was taken into account; surface construction load was calculated with 15KN / m2 * building floors* building density; road vehicle load was computed by 20KN/m uniform load. Under storm conditions, saturated shear strength, 1/2 soil height and 1/3 soil height above stable water level were used to calculate permeability of landslide and deformation, and impact degree of storm on rise of stable groundwater levels, respectively.

The work analyzed landslide mechanism and stability calculation, describing the development trend of structure, terrain and topography of Well Dashen-1 landslide. Therefore, reinforcement measure of "anti-slide pile + cut-off drains" was proposed to control Well Dashen-1 landslide, with consideration of technical soundness, safety, reliability, feasibility and economy. A row of 18 anti-slide piles were built in the walled side of Well Dashen-1 based on stability and landslide thrust. They were distributed into A-type pile, B-type pile and C-type pile according to depth of sliding surface. A-type pile: length 12.0m, pile center distance 5.0m, pile-section 1 × 1.5m. Four A-type piles were arranged in right-most landslide while three in left-most landslide. The section buried into bedrock should not be less than 5.0 m. B-type pile: length 16.0m, pile center distance 5.0m, pile-section 1 × 1.5m. There were 4 B-type piles, 2 piles were arranged in left and right position, respectively. The anti-slide pile embedded in bedrock should not be less than 6.0m. C-type pile: length 18.0m, pile center distance 5.0m, pile-section 1 × 1.5m. Seven piles were set in central slope, and anti-slide pile embedded in bedrock was not less than 6.0m. C-type piles in wellsite and seven arranged anti-slide piles were combined into double rows of plum-shaped anti-slide piles for retaining the landslide. Anti-slide piles were arranged in stone retaining wall of well site. In case of pipeline in excavation, the position of anti-slide piles could be adjusted. Retaining plates should be set among the piles, with thickness of 0.3m, height 2.0m, and total length of 82m. Measures for interception of water should be adopted for further improvement of landslide stability factor, building anti-slide piles to increase stabilizing force

5 CONCLUSIONS

Landslide disaster is an important issue of mountain area construction. Landslide in mining areas can cause heavy losses including destroying mine facilities with staff casualties, destruction of plants, and downtime of mine production. Only with full understanding and analysis of formation mechanism

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and predisposing factors of landslides could they obtain better governance. The work comprehensively analyzed the special structure, formation mechanism and predisposing factors as well as deformation of Well Dashen-1 landslide in Northwest Sichuan Gas Field. Simulation of its stability was conducted, proposing targeted measures of landslide, thus providing references for the same type of landslide analysis.

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