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Study on the foundations of transmission lines in mining area with the risk of geological hazards

The influence of mining area on the 'ground surface' is mainly divided into three categories: the movement and deformation of vertical direction (subsidence, inclination, curvature), the movement and deformation of horizontal direction (horizontal movement, stretching and compression) and the shear deformation of surface plane, which are mainly reflected by discontinuity deformations including surface cracks, collapse pits, subsidence troughs, etc. These kinds of deformation directly act on the iron tower foundation of transmission lines, causing varying degrees of damage on iron tower foundation, such as sink, tilt, displacement, distortion, etc. and thus influence safety of the iron tower and the stable operation of the entire transmission lines. Therefore, this paper reviews the actual situation of the mining area, compares the features of different foundations, and proposes a method of applying the independent big slab foundation. This foundation can resist uneven settlement in a mining depth to thickness ratio of 90 to 150, and adjust anchor bolt to assist for processing surface uneven settlement and deformation. In this way, the risks of geological hazards in the meaning area could be eliminated significantly.

Keywords: *Geological hazard, independent big slab foundation, mining area, mining depth to thickness ratio, the deformation discontinuity.*

1. Introduction

Guizhou province is said to be with the richest coal resources and is known as "the coal sea in southwestern China". The coal-bearing area of Guizhou makes up more than 40% of the whole area. Except the eastern area which is in coal shortage, most areas in the province have coal outputs. 74 of 86 counties (cities) are producing coals. Therefore, transmission lines inevitably go through mining areas. According to incomplete statistics in December 2015, there are 360 iron tower foundations in mining areas in Guizhou in which 280 of them are affected by coal mining, 55 of them are suffered from deformed foundations and tilting towers and 55 were removed and transformed, resulting in economic losses of about 80-million yuan. Coal mining has always been a major geological hazard affecting the safe operation of transmission lines. At present, evasion is the most effective way to eliminate the influence of major geological hazards. However, it requires large investment, covers a wide range and is difficult to implement. Moreover, there exist complicated issues such as path selection, repeated pressing of coals and long construction period. Through analyzing different foundations and their resistance to the deformation caused by coal mining, this paper aims to provide methods to solve the problem of tower deformation to some extent [1].

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2. Characteristics of the surface deformation

The coal seams of Guizhou occur in Permian Longtan Group (P3l) and Wujiaping formation (P3w). The lithology of the roof is mainly dominated by soft rocks, such as argillaceous siltstones and mudstones. There are also a small amount of lamellar marls and limestones with thin to medium thicknesses. The thickness of a single layer of coal ranges from 0.5 to 2.0m. The depth to thickness ratio is between 50 and 200. Retreating longwall mining is the main mining method. Caving method is used in roof management. Factors affected the ground integrity include the depth to thickness ratio, the terrain slope and the completeness of the roof strata [2-3].

2.1 The relationship between surface deformation and depth to thickness ratio

According to investigations on the surface deformation in mining areas within Guizhou, conclusions are as follows:

When depth to thickness ratio (H/m) is more than 150, the surface deformation and movement of the mining area are regular and continuous. Obvious deformations such as cracks, collapse pits and subsidence troughs are not found in mining areas within Guizhou.

When depth to thickness ratio (H/m) is between 90 and 150, the surface deformation and movement should be irregular and discontinuous theoretically. Obvious deformations including cracks (about 0.1~10m in length, 0.1~0.5m in width and 0.1~1.5m in depth), collapse pits (0.2~1.5m in length, 0.1~1.5m in width and 0.1~1.0m in depth) and subsidence troughs (0.1~5m in length, 0.3~0.5m in width and 0.1~1.5m in depth) are found. However, there is no trace for large-scale deformations.

When depth to thickness ratio (H/m) is less than 90, the surface deformation are regarded as irregular and discontinuous. Large collapse pits (with 10m in length, 8m in width and 15m in depth) are found within the mining areas, as well as large-scale deformations.

2.2 The relationship between surface deformation and terrain slope

In regions with surface deformation, the change of the terrain slope and strata inclination is in proportion to the velocity and the scale of the surface deformation. When the terrain slope is more than 35, the surface deformation is more severe. Partial collapse and small-scale landslide may happen. [4]

3. Analyses on the potential geological risks on transmission lines

3.1 The impact of settlement on the iron tower of transmission lines

When uniform settlement occurs where transmission poles and towers stand, it will not put additional stress on their structures. In such circumstances, in spite of the changed position, there is little harm to the poles and towers. However, severe settlement as well as high groundwater level results in puddles on the ground, which may change the environment. It will not only influence the poles and towers but also the strength and durability of their foundations due to the long-term ground seeper and excessive moisture. Thus, the normal operation of the poles and towers may be negatively affected. [5-8]

3.2 The impact of slopes on the iron tower of transmission lines

The tilt of the ground will lead to the inclination of the tower foundation. It may result in the deviation of the center of gravity and the increment of the overturning moment of the poles and towers. Therefore, the security of the tower is significantly affected. The inclination of the poles and towers may lead to the redistribution of the stress in wires. Moreover, the offset of the suspension string will result in imbalanced tensile force in spans. The inclination of the tower may lead to insufficient distance of the wire to the ground. Uneven inclination will enlarge or narrow the distances between the poles or the spans.

3.3 The impact of curvature deformation on poles and towers

Curvature deformation may change the original flat plane into a curved one. The movement of the curvature deformation is complicated including settlement in vertical direction and movement in horizontal direction. The curvature destroys the original balance between the base load and the support of the bottom surface. Due to the redistributed counter-force of the groundwork, the transmission poles and towers will be confronted with additional bending moment and shear force.

3.4 The impact of horizontal deformation on transmission poles and towers

Horizontal deformation refers to the stretching and compression of the surface. It results in relative movement between supporting legs and thus creates large additional stresses. It has great impact on iron towers with single foundation and will enlarge (or narrow) the root span at the bottom. In general, transmission poles and towers have greater resistance to stretching than to compression.

4. Foundation selection for transmission lines in mining areas with potential geological risks

The depth to thickness ratio should be larger than 90 (between 90 and 150) when building transmission towers in mining areas. In order to ensure the stability of the foundation of the newly built tower, the location should avoid areas which are steep or with highly developed structures. Constructing big slab foundation and adjusting anchor bolts can be effectively used to confront with uneven settlement and collapse. The big slab foundation can be divided into independent big slab foundation and raft foundation, both of which can effectively deal with uneven settlement.

4.1 Raft foundation (combined foundation)

In terms of its resistance to uneven settlement and its completeness, it can be used in goaf.

The foundation can fix the whole tower on the raft and transform the tower into a rigid body, which can eliminate the impact of topographic changes on the tower. According to geologic surveys, the integrity of the big slab can be taken advantaged in resistance to partial collapse of the foundation.

When the base inclines, both the foundation and the whole tower will also incline. When the inclined value (represented

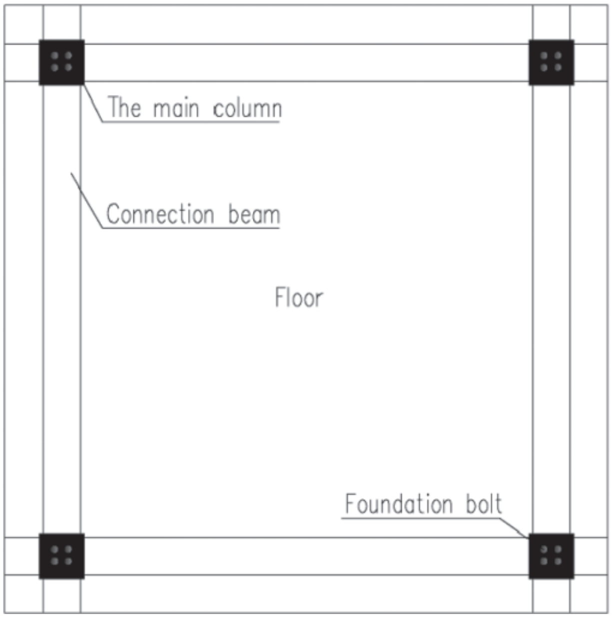

Fig.1 Raft foundation

by Δh in Fig 2) is more than 42mm, the calculated immunity may exceed the criteria and the safety standards without restoration. In this circumstance, the edge of the raft foundation can be hollowed out and through using a matched lifting jack with the same tonnage and adjusting anchor bolts, the iron tower can be righted to the original horizontal position. Even there is partial collapse in the foundation slab, the stability of the tower and the foundation can still be ensured.

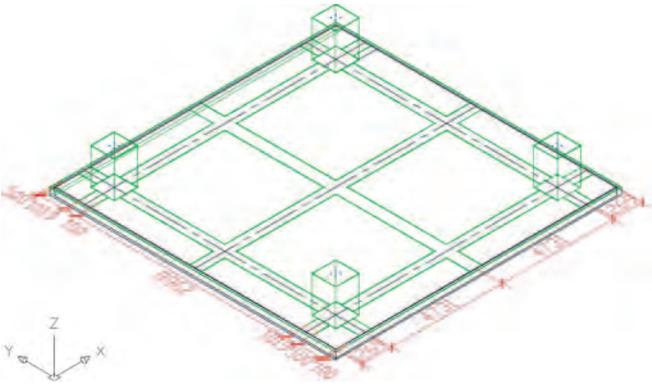

Fig.2 Combined big slab

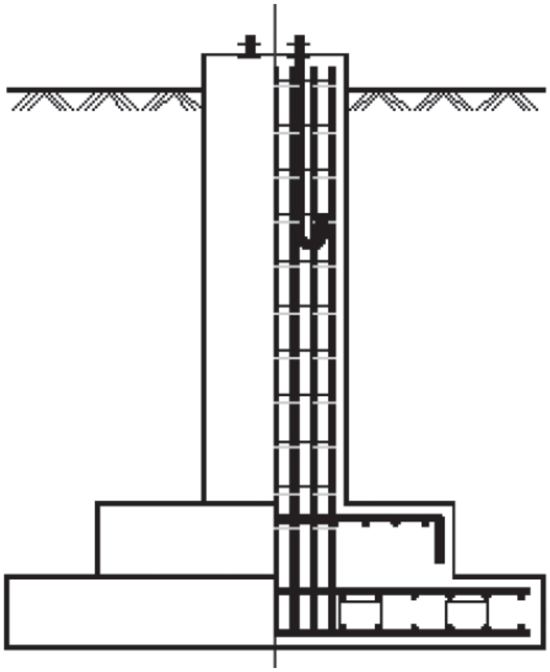

Fig.3 Independent straight column foundation

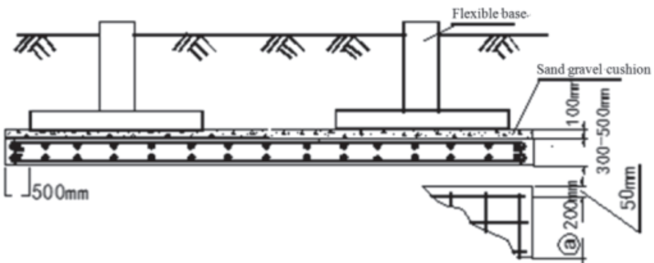

Fig.4 Big slab foundation

4.2 Independent big slab foundation

The independent big slab foundation, also called flexible straight column foundation, is often used in transmission line projects. The four legs ABCD were supported by their own straight column foundations separately. The applied force of each leg is undertaken by its own foundation. Due to the large force stress area, the slab can resist the partial uneven settlement of the groundwork. Moreover, if the collapse of the groundwork occurs where one leg stands, restoration will be easier to carry out with this foundation.

In order to eliminate or reduce the displacement of the foundations, a big slab which is made of reinforced concrete can be installed at the bottom of the foundation. The concrete big slab reinforced with rebar both at upper and bottom surfaces can resist the bending moment which is produced by uneven settlement. In order to use jacking force to right the tower and reduce frictional resistance, a gravel cushion was laid between the slab and the foundation.

The independent big slab foundation allows shrinkage in the length of anchor bolt thread and enlarges the aperture of the bolt of the base slab. The space can be reserved which is limited by the angle of inclination. If the anchor bolt is too long or the angle of inclination is too large, the horizontal displacement between the anchor bolt and its hole will increase. In this case, the bolt and the hole are too stuck with each other to be adjusted to right the tower. As a result, the tower may collapse due to the abnormal operating conditions.

When there is collapse or cracks at the foundation that leads to small inclination of the iron tower (the length of the anchor bolt represented by Δh cannot exceed 200mm), adjusting the reserved anchor bolt can help the tower retain stability by reverting to its horizontal position.

4.3 Comparison between combined foundation and independent big slab foundation

Both foundations belong to big slab foundation and can resist uneven settlement and inclination to some extent. Their features are discussed as follows:

4.3.1 Resistance to the uneven settlement or the inclination of the base

Both foundations can right the tower to horizontal position when confronting with slow collapse or inclination rather than abrupt collapse with a big drop. However, independent foundation can achieve this by adjusting the reserved length of the anchor bolt when there is small-scale settlement, and pushing the foundation when there is horizontal displacement.

4.3.2 Economy

Combined foundation is bulky due to its integrity. Therefore, the construction cost of it is much higher than that of the independent foundation according to budget estimates of different cases. In terms of economy, independent foundation outweighs combined foundation.

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