Influence of depth-thickness-ratio on the ground surface subsidence of different overburden in overhead transmission line

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Abstract

In this paper, the calculation-analysis model of super-stratum, coal seam and baseplate in a typical mining area is established using FLAC^{3D} finite element software. Taking typical loess and sandstone in soil as example and considering the depth of super-stratum, the subsidence law of the surface is analyzed when the depth-thickness ratio of overhead transmission line is different. Results show that the subsidence value and rate increase gradually with the decrease of the depth-thickness ratio; the surface subsidence value and rate of the sandstone corresponding is smaller than that of the loess corresponding. The surface subsidence increases significantly when the depth-thickness ratio is less than 30. Generally, the surface subsidence value and subsidence rate are affected by mining depth greatly. The fitting function of mining depth and mining influence distance relationship is achieved when the super-stratum is loess and sandstone respectively. Under the same conditions of depth-thickness ratio, mining depth and mining thickness, the influence distance of sandstone is smaller than that of loess. On this basis, put forward advice on transmission lines and tower position selection in the mining area, which can provide a reference for stability evaluation on transmission line in the mining area.

Keywords

Depth-thickness ratio; loess; sandstone; the ground surface subsidence; numerical analysis.

1. Introduction

With the construction of transmission lines in quantity, which leads to that some transmission towers had to be built in the mined-out area or built across the mined-out area. The surface deformation of the mined-out area can cause tower tilted, component deformation and foundation settlement, which influences the safe operation of transmission lines seriously [1-6]. The influence of ground surface deformation which affects significantly on the truss members is necessary to be studied for the transmission tower built in the coal mining areas [7]. The uniform settlement of tower did not significantly affect the sag and stress of overhead transmission line [8].Therefore, the stability of the ground surface evaluation, overhead transmission lines plan and specific operation technical scheme determination has an extremely important practical significance.

When surveyor and designer make overhead transmission line designs, depth-thickness ratio is generally used to consider whether take uneven settlement measures of foundation and upper structure or not, and the referred main index that what kind of treatment measures should be adopted. It has been pointed out that decreasing the depth-thickness ratios influenced the bedding slope stability significantly [9]. The ground deformation became small gradually with the increase of the mining depth. However, it became bigger quickly with the increase of the mining thickness [10]. It has been took mining thickness ratio of 30 as the threshold standard of building yard suitability evaluation[11]. The overhead transmission line planning, construction and operation of the technical scheme and measures in the mining area were determined on the basis of depth-thickness ratio [12].

The present research on depth-thickness ratio is mainly on the basis of field observation and field investigation [13-15], on the basis of whom to analyze the severity of the ground surface subsidence, the suitability of tower building and main structural measures is determined. However, it lacks of theoretical basis and without considering the thickness and properties of super subsidence. There is a serious security hidden danger to the surface stability evaluation and planning, construction and operation determination of overhead transmission line.

This article uses $FLAC^{3D}$ finite difference software. Two properties of stratums, loess and sandstone as super subsidence in the mining area of overhead transmission line are considered, the calculation and analysis model of super subsidence, coal seam and baseplate of the typical mining area are built, and the relationship of depth-thickness ratio and ground surface subsidence is analyzed. The law between depth-thickness ratio and driving forward influence distances is studied and a reference for safety evaluation of overhead transmission lines in mined-out area is provided.

2. $FLAC^{3D}$ model

The paper adopts Mohr Coulomb Model for modeling analysis. Material Parameters of Mohr Coulomb Model are shown in Tab.1.

Table 1. Material Parameters of Mohr Coulomb Model

No.	Keyword	Illustration
1	bulk	elastic bulk modulus, K
2	shear	elastic shear modulus, G
3	cohesion	cohesion, c
4	friction	internal friction angle, φ
5	tension	tensile strength, σ_t
6	density	density, ρ

The model is divided into three layers as super subsidence, coal seam and baseplate respectively, and the length of mining area along the direction of working face advancing is 622 m and the width vertical to the direction of working face is 320m. Considering the large influence of coal seam mining on the surface, therefore, the model size is bigger than mined-out area and 1020 m model length and 720m width are taken. Under the condition of fixed mining thickness h0 of coal seam, research depth-thickness ratio $\lambda = H_0 / h_0$, take the ground surface deformation under 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100. Considering the mining thickness h0 of coal seam is 1m and 2m, the corresponding coal seam depth H0 is shown in Tab.2.

Table 2. Depth of coal seam with Fixed Mining Thickness (m)

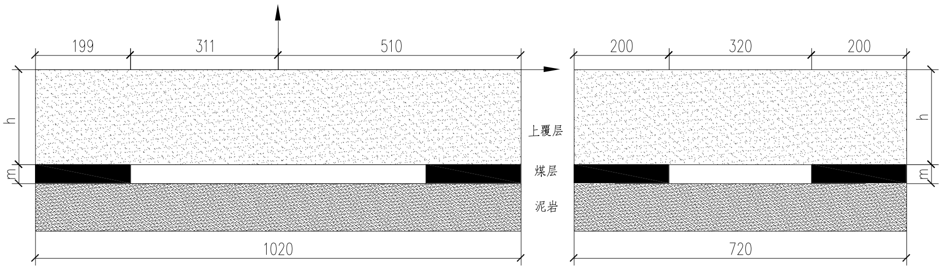
Depth-thickness ratio / Mining thickness	10	20	30	40	50	60	70	80	90	100
1m	10m	20m	30m	40m	50m	60m	70m	80m	90m	100m
2m	20m	40m	60m	80m	100m	120m	140m	160m	180m	200m

At the same time, in order to consider the influence of super subsidence nature on the ground deformation, the super subsidence is single rock stratum. Take loess and sandstone as presentation respectively and the mudstone is selected as baseplate. The physical and mechanical parameters of each rock stratum are shown in Tab.3.

Table3.Physical and Mechanical Parameters of Rock (Soil) Layer

lithology	bulk modulus/Pa	shear modulus/Pa	friction angle/°	tensile strength/Pa	cohesion/Pa	density/kg·m-3
loess	1.50E+08	7.80E+07	23	1.00E+03	5.00E+04	1960
sandstone	4.41E+09	3.45E+09	44	1.03E+05	1.30E+07	2661
coal	1.43E+09	4.40E+08	26	2.86E+06	6.00E+05	1360
mudstone	2.92E+09	1.04E+09	31	5.95E+06	1.00E+05	2620

It can be seen from Table 2, the maximum influence depth of the model is 202 m (maximum mining depth 200m, maximum mining thick 2m). It can be known from Tab.3, the largest internal friction angle of the stratum is 44°, therefore, the largest possible influence distance of mining is 202×tan44°=195.1m. For easy monitoring arrangement, deformation curve drew and selection of calculation model size is shown in Figure 1.

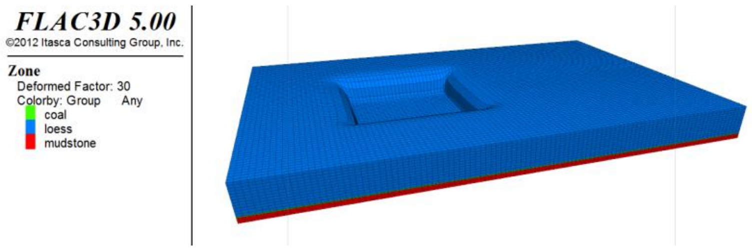


(a) The direction along driving face (b) The direction vertical to driving face

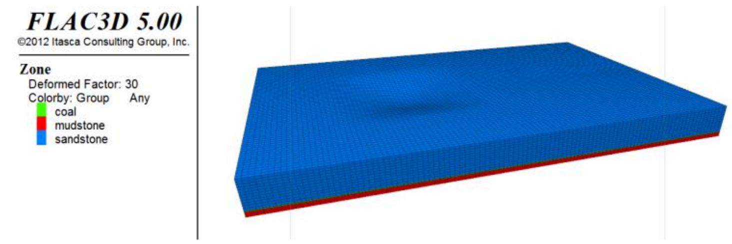
Figure 1. Model Section Size

According to the model size in Figure 1 and Tab. 2, $FLAC^{3D}$ is adopted to establish 3D analysis model with plane size 1020m×720m, whose height is determined by mining thickness and depth-thickness ratio. The model with loess and sandstone as super subsidence is established respectively. According to the parameters in Tab. 3, the model with physical and mechanical properties is provided and interface between coal seam and other stratums is set.

Self-weight consolidation calculation of super-stratum in actual engineering is simulated for the above $FLAC^{3D}$ model; coal seam excavation is made in the FLAC according to the size of Figure 1 for excavation calculation. From surface point (510, 0) to (510, 0), taking 10 m as intervals to set 103 points and the surface subsidence after consolidation to stability of surface subsidence excavation deformation is recorded. Take mining thickness 2 m and depth-thickness ratio 30 as example, 3D Effect Graphs of mining subsidence after model calculation is shown in Figure 2.



(a) Super stratum with soil



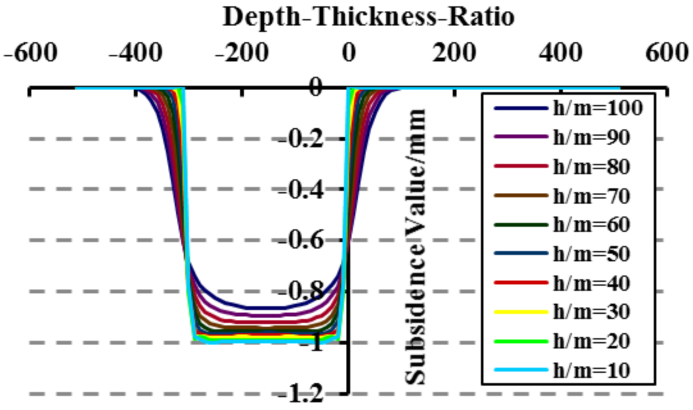
(b) Super stratum with sandstone

Figure 2 Three-Dimension Effect Graphs of Mining subsidence

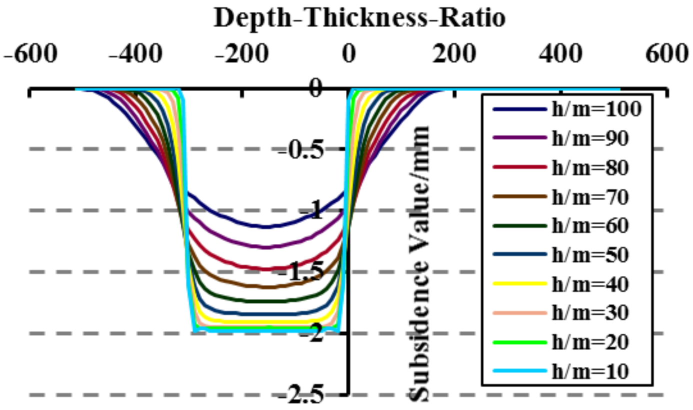
3. Simulation results and analysis

3.1 The relationshipbetween depth-thickness ratio and surface subsidence

According to the subsidence value of each measuring point under the different depth-thickness ratio, the surface subsidence curve is drawn respectively when the loess and sandstone have different depth-thickness ratio, as shown in Figures 3 and 4.



(a) Mining thickness 1m



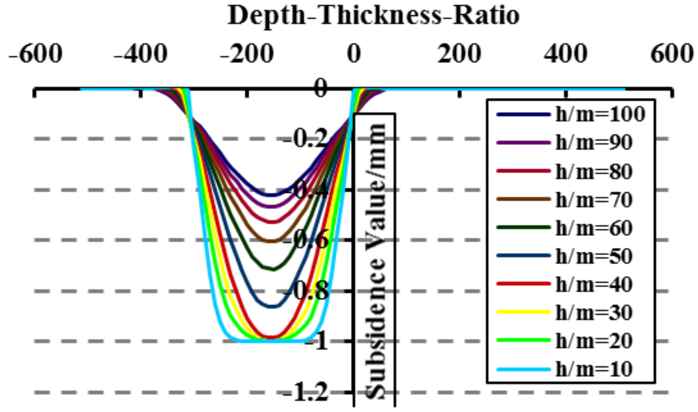
(b) Mining thickness 2m

Figure 3.Relationship between Depth-Thickness-Ratio and Subsidence (Loess)

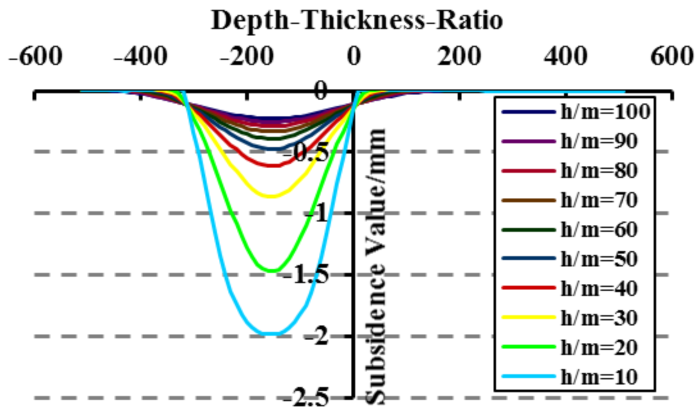
It can be seen from Figure 3, when the super-stratum is loess, with the decrease of depth-thickness ratio and surface subsidence increases gradually. In Figure 3 (a), when the mining thickness is 1m, the maximum range of surface subsidence deformation is 0.9 -1 m, and the subsidence value increases with the decrease of the depth-thickness ratio. In Figure 3 (b), when the mining thickness is 2 m, the maximum range of surface subsidence deformation is 1.5 ~ 2 m.

It can be known from Figure 4, surface subsidence increases gradually with the decrease of depth-thickness ratio gradually when the super-stratum is sandstone. In Figure 4 (a), when the mining thickness is 1m, the range of surface subsidence deformation is 0.4-1m. In Figure 4(b), the range of the maximum surface subsidence deformation is 0.2-2 m when the mining thickness is 2 m.

Generally, the surface subsidence value of each depth-thickness ratio corresponding is smaller than the surface subsidence value of loess under the same conditions when the super stratum is sandstone. Surface subsidence deforms violently, its deformation aggravates rapidly with the decrease of depth-thickness ratio till after reaching subsidence maximum for stability.



(a) Mining depth1m



(b) Mining depth2m

Figure 4. Relationship between Depth-Thickness-Ratio and Subsidence (Sandstone)

3.2 Relationship between Depth-Thickness Ratio and the front influence distance of driving face

According to Figures 3 and 4, the relation curve between depth-thickness ratio and the influence distance of mining depth and mining, is shown in figures 5 and 6, respectively. From Figure 5, the influence distance of driving face increases with the increase of depth-thickness ratio, the corresponding influence distance of mining depth 1m is smaller than mining depth 2 m. Loess as a kind of loose medium, its tensile strength is smaller than sandstone. When the loess deforms in the surface, it is more easily affected than the forane loess. Therefore, under the same conditions of mining depth and depth-thickness ratio, the influence distance of loess is farther than that of sandstone.

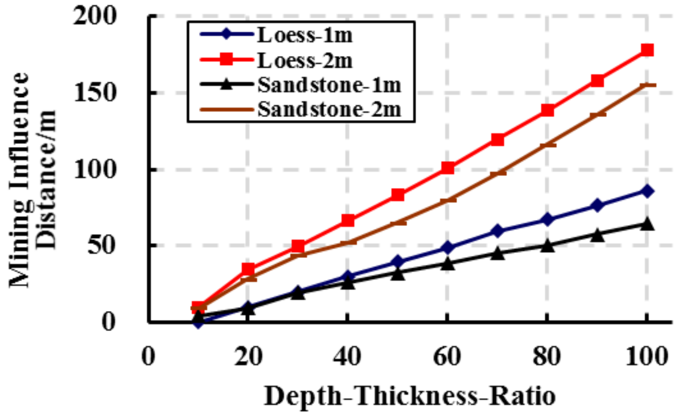


Figure5. Relationship between Depth-Thickness-Ratio and Mining Influence Distance

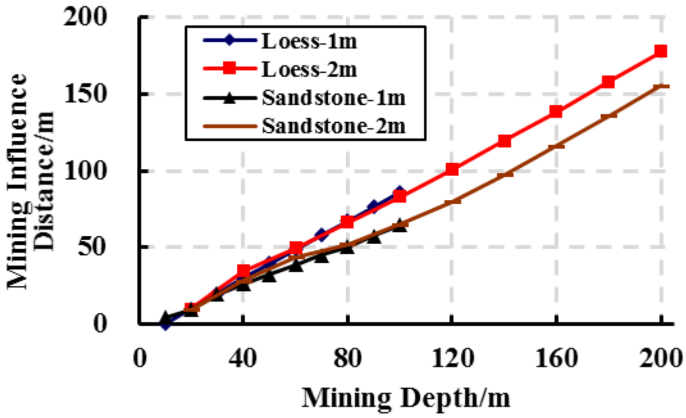


Figure 6. Relationship between Mining Depth and Mining Influence Distance

In Figure 6, the change of mining thickness and mining is ignored, only the relationship of mining depth and influence distance is considered. Form Figure 6, it can be known that the curve of mining thickness 1 m and 2 m corresponding almost coincides, the front influence distance of driving face mainly affected by mining depth, the mining depth is bigger and the influence distance is farther. The tensile strength of loess is smaller than the he tensile strength of sandstone; therefore, it can be seen from Figure 6 that the influence distance of loess is farther than sandstone when the mining depth is the same. Therefore, when make coal mining under the lower part of loess area, settlement observation should be made early and corresponding measures should be taken. The fitting function of mining depth and mining influence distance relationship can be obtained from Figure 6 when the super-stratum is loess and sandstone respectively, which is shown in equation (1) and (2).

When it is loess, $L = 0.91H_0 - 6.24$ (1)

When it is sandstone, $L = 0.78H_0 - 7.79$ (2)

Where, L is the influence distance of mining, H_0 is mining depth.

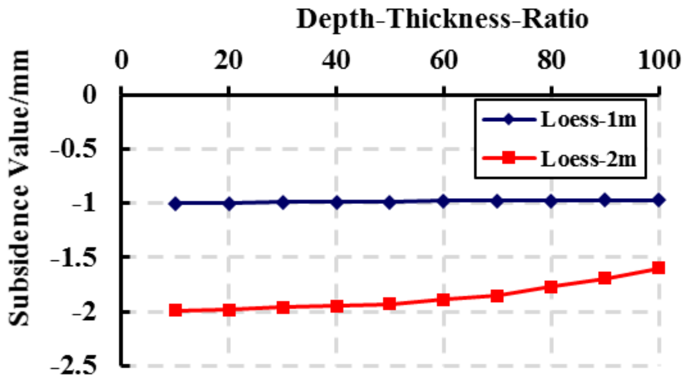
3.3 Relationship between depth-thickness ratio and the maximum surface subsidence value

The subsidence value of the maximum point in the surface of Figures 3 and 4 with each depth-thickness ratio is elected and the relation curve between depth-thickness ratio and the maximum surface subsidence value is drawn. The proportion of the maximum subsidence value is set if surface and mining depth to be the maximum surface subsidence rate and the relation curve between depth-thickness ratio and the maximum subsidence rate of surface is drawn. The above relation curve is shown in Figures 7-9.

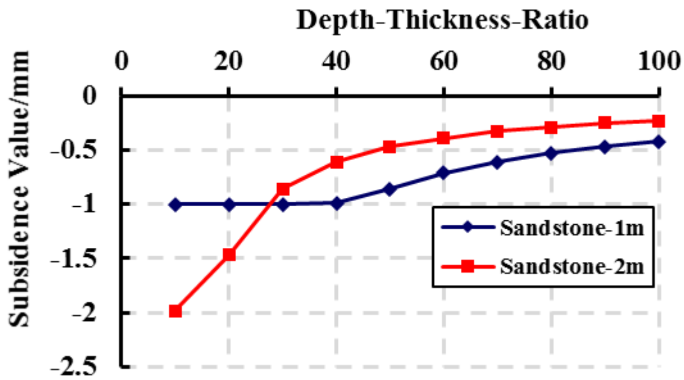
Figure 7(a) is the relation curve of depth-thickness ratio and the maximum subsidence value with mining depth of 1 m and 2 m respectively when the super stratum is loess. Figure 8 (a) is the relation curve of the corresponding maximum subsidence rate. From Figures 7(a) and 8(a), it can be seen that the subsidence value and rate of loess both decrease with the increase of depth-thickness ratio. Under the condition of the same depth-thickness ratio, the subsidence value of mining thickness 2 m corresponding is larger than the subsidence value of mining depth 1m, and the subsidence rate of mining thickness 2 m is smaller than the subsidence rate of mining thickness 1m.

Figure 7(b) is the relation curve of depth-thickness ratio and the maximum subsidence value with mining depth 1 m and 2 m respectively when the super stratum is sandstone. Figure 8 (b) is the relation curve of the corresponding maximum subsidence rate. From Figure 7(b) and Figure8 (b), it can be seen that the subsidence value and rate of sandstone both decrease with the increase of depth-thickness ratio. When the depth-thickness ratio is bigger than 30, the subsidence value of mining depth 2 m corresponding is smaller than the subsidence value of mining depth 1 m. However, at the same depth-thickness ratio, the subsidence rate of mining thickness 2 m corresponding is always smaller than the subsidence rate of mining thickness 1 m.

Figure 9(a) is the relation curve of depth-thickness ratio and the maximum subsidence value with mining thickness 1m when the super stratum is loess and sandstone respectively. Figure 9(b) is the relation curve of depth-thickness ratio and the maximum subsidence value with mining thickness 2m when the super stratum is loess and sandstone respectively. From Figure 9, it can be seen that no matter the mining thickness is 1m or 2 m, the subsidence value of sandstone is always smaller than the loess at the same depth-thickness ratio.

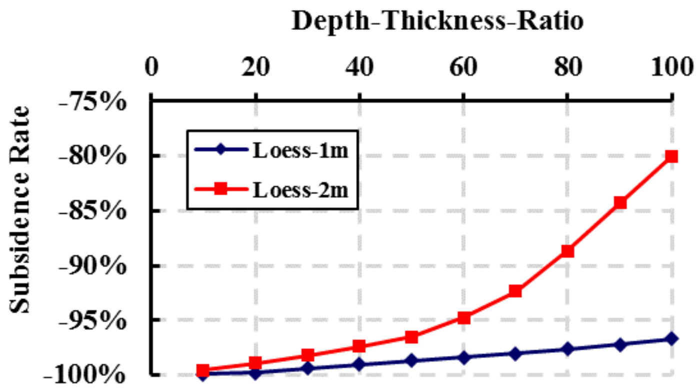


(a) loess

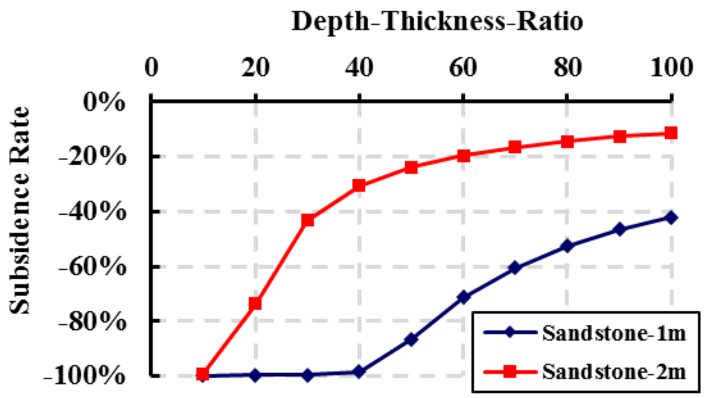


(b) sandstone

Figure7. Relationship between Depth-Thickness Ratio and Maximum Subsidence Value (Different Mining Thickness)

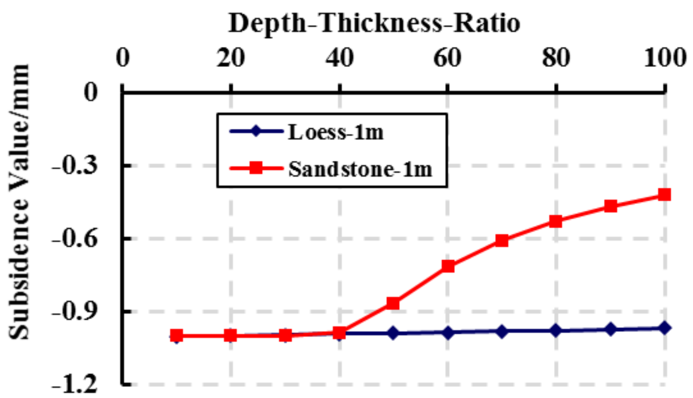


(a) loess

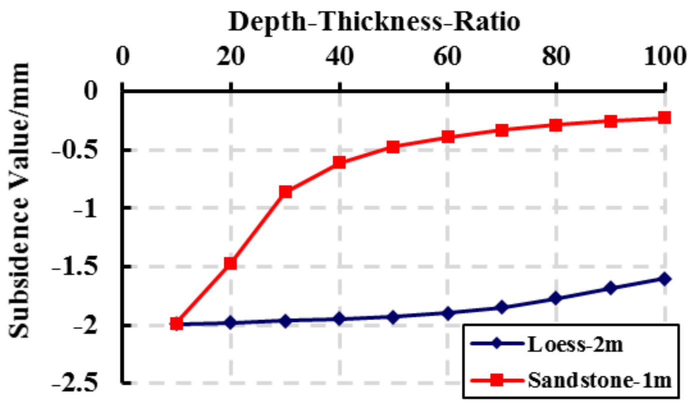


(b) sandstone

Figure 8. Relationship between Depth-Thickness-Ratio and Maximum Subsidence Rate (Different Mining Thickness)



(a) loess



(b) sandstone

Figure 9. Relationship between Depth-Thickness-Ratio and Maximum Subsidence Value (Different Layers)

4. Conclusion

(1) With the decrease of the depth-thickness ratio, sinking value and the subsidence rate both increase gradually. The subsidence value and rate of sandstone corresponding are both smaller than the subsidence value and rate of loess. When make transmission line selection, should try to stay away from the thick loess area and consider the big loess subsidence ratio, and analyze the influence of the ground distance.

(2) When the depth-thickness ratio is less than 30, the corresponding surface subsidence of sandstone has significantly increased (mutation). Therefore, when transmission line selection making, it should try to avoid the area with depth-thickness ratio less than 30.

(3) The fitting function of influence distance relationship of mining depth and mining is achieved when the super-stratum is loess and sandstone respectively. Under the same conditions of depth-thickness ratio, mining depth and mining thickness, the influence distance of the sandstone is smaller than the loess. Therefore, when making coal mining under the bottom of transmission line in the loess area, settlement observation should be made early and corresponding measures should be taken to ensure the safety of the transmission line.

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