Application of Pipe Jacking Technology to Underground Mine Portal Construction under Weak Rock Mass Condition

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1. Introduction

Determination of an appropriate excavation method and supporting system is critical in adit development of underground coal mine because adit of underground coal mine is usually characterized with shallow strata and weak rock properties. It is well known that, in shallow strata, the mechanical properties of rock mass is more likely soil properties instead of rock properties, and surrounding rock mass is more easily to be deformed. Considering negative impacts that may arise in underground mine entrance with weak geological condition, the major objective of this research is to study the applicability of pipe-jacking method to maintain mine entrance stability and to prevent surface subsidence above adit of underground coal mine under weak rock mass condition. To fulfill this objective, the GDM underground coal mine located in East Kalimantan, Indonesia was selected as a research mine site.

2. Research Methodology

In this research, in order to clarify the behavior of pipe, tunnel crown deformation generated by pipe jacking method, and mine portal stability, the numerical simulations are carried out by using three-dimensional FEM program, *3D-σ*. Firstly, in order to evaluate the failure proximity of jacking pipes, numerical simulations were conducted in different tunnel inclination (5°, 10°, 15°) and different highwall slopes (7.54°, 15°, 30°) models with different jacking pipes shapes as shown in Figure 1. After that, the response of ground around the tunnel was investigated in the numerical model as shown in Figure 2. Finally, in order to understand the deformation behavior of surrounding rock at tunnel entrance, the analysis was made for the stability of mine portal by changing highwall slope angle. Basic parameters of rock properties used in these analyses are obtained laboratory tests using exploration drilling cores from GDM coal mine in Indonesia as shown in Table 1.

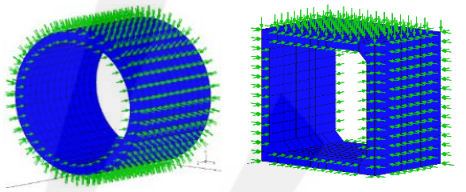


Figure 1 Numerical model of jacking pipes

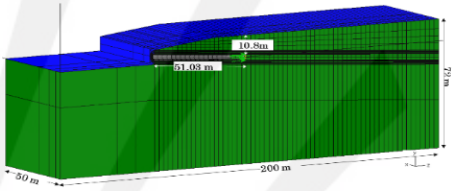


Figure 2 Numerical model of mine entrance

3. Results and Discussions

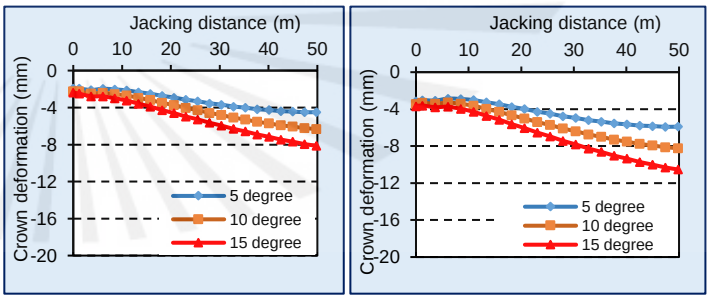
According to the simulation results, the failure proximity of jacking pipes rise with increasing degrees of tunnel inclination due to increasing earth pressure as well as pipe frictional resistance as shown in Table 2. Moreover, it can be seen that the rectangular-shaped pipe reaches its failure state earlier than that of circular-shaped pipe because the arching effect of circular-shaped pipe makes friction resistance smaller than that of rectangular-shaped pipe; accordingly, the jacking force is lower. Regarding to the tunnel crown deformation, the results shows that the crown deformation increases with increasing degree of tunnel inclination as shown in Figure 3. According to above results, it is suggested that pipe jacking construction with smaller tunnel's inclination is better to get longer jacking distance and minimum tunnel crown deformation. Moreover, if the surrounding rock properties are very weak, the tunnel crown deformation is larger than thickness of over-cutting area. This situation should be carefully noticed especially in case of pipe jacking construction for weak surrounding rock because the risk of pipe failure become high when the pipe and rock mass are contacted. Based on this situation, an improvement of surrounding rock is needed to avoid pipe failure. From the simulation results of mine entrance stability, it is observed that the failure conditions of surrounding rock around the tunnel increase with increasing highwall slope angles due to the rise of ground stress movement. Therefore, a careful planning and designing around the transition area are great important when an opening is excavated from the highwall especially under weak rock properties.

Table 1 Mechanical properties of rock and concrete pipe

	ρ (MN/m^3)	E (MPa)	υ (-)	τ (MPa)	φ (°)	*T* (MPa)
Claystone	0.0217	153	0.26	0.14	28.5	0.21
Concrete pipe	0.026	33,000	0.17	7	45	3.8

Table 2 Pipe's failure on maximum jacking distance due to different tunnel inclinations

Pipe shape \ Degree	5°	10°	15°
Circular-shaped	48.60 m	36.45 m	31.59 m
Rectangular-shaped	41.31 m	31.59 m	29.16 m



(a) Circular-shaped tunnel (b) Rectangular-shaped tunnel

Figure 3 Tunnel crown deformation due to different tunnel inclinations

4. Conclusions

Considering this simulation results, it can be said that an underground coal mine is designed and developed from open-cut highwall in poor rock mass condition, special attention must be paid on safe and stability of mine portal. With the abilities and advantages of pipe jacking technology, it can be adopted on underground coal mine to solve problems on development of adit especially when the surrounding rock is weak. It is suggested to improve the surrounding poor rock by reinforcing with grouting material before the project advancement to avoid the opening collapse and surface subsidence. However, more researches, study and measurements from suitable places are needed in order to fully understand the applicability of pipe jacking technology in a mining industry.