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SURROUNDING ROCK LOOSING ZONE MEASUREMENT IN UNLINED TUNNELS OF UNDERGROUND CRUDE OIL STORAGE

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ABSTRACT

The surrounding rock loosing zone is one of the most critical factors of the tunnels stability. This paper applies the ultrasonic wave method to measure the surrounding zone. In this project, five holes with the diameter of 90 mm and the depth of 7 m are bored in each section. The measured datas indicate that the range of the loosing zone of the tunnel is 1.2 ～ 1.8 m. In order to verify the accuracy of the ultrasonic testing data, the system of borehole television measurement is adopted in the main tunnel. The measurement results are in good agreement with the results of the ultrasonic testing. The results can provide the verification for the rationality of bolt support and the practical experiences and guideline for the design of support system for loosing zone of surrounding rock in the similar tunnel conditions.

Keyword: *Loosing Zone(LZ), Ultrasonic Wave(UW), Borehole Television(BT), Bolt Support(BS), Crude Oil Storage(COS)*

1. INTRODUCTION

The excavation of underground space destroys the original equilibrium of the stress state, and makes the peripheral radial stress of the hole room relieved. However, the tangential stress of the hole room increases violently and it is inevitable to get the stress redistribution of the surrounding rock. Along with the tunnel excavation the rock goes into the plastic state, therefore the rock surrounding cavern is destroied first of all, and then the stress transfers into the deep rock mass. Surrounding rock damage area is gradually expanding until the surrounding rock stress is less than or equal to the strength of the rock mass. When it turns out to form a new balance, it will bring an end to the surrounding rock damage. Therefore, a fracture zone is formed arround the hole room which is called surrounding rock loosing zone[1]. The surrounding rock loosing zone is one of the most critical factors of the tunnels stability.

Calculation of the sound velocity in elastomer

Classical elasticity derived velocity plane wave in infinite elastic body can be calculated by the following types. Wave velocity in the plane of the infinite elastomer can be calculated by the following formulas[2].

$$v_P = \sqrt{\frac{E(1-\mu)}{\rho(1+\mu)(1-2\mu)}} \quad (1)$$

$$v_S = \sqrt{\frac{E}{2\rho(1+\mu)}} \quad (2)$$

v_P — velocity of longitudinal wave (m/s);

v_S — velocity of shear wave (m/s) ;

ρ — density (g/cm^3) ;

μ — poisson ratio ;

Formula 3 can be obtained by solving simultaneous equations 1 and 2.

$$\mu = \frac{v_P^2/2 - v_S^2}{v_P^2 - v_S^2} \quad (3)$$

As long as v_P and v_S are known, μ can be obtained by formula 3, and the values of elastic modulus E can also be obtained by formula 1 and 2. However, because shear waves cannot propagate in the liquid, the measuring method is more complex and easier to produce error in jointed rock mass. Considering the relatively stable property of the poisson ratio, it can be regarded as a fixed value. After that, the elasitc modulus E can be obtained only in the case of measurement of the longitudinal wave.

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$$E = \frac{(1+\mu)(1-2\mu)}{1-\mu}\rho v_P^2 \quad (4)$$

$$\frac{(1+\mu)(1-2\mu)}{1-\mu} = C \quad (5)$$

$$E = \rho C v_P^2 \quad (6)$$

Let the acoustic wave velocity in undisturbed rock be v_{P0} and elastic modulus be E_0, so the relaxation coefficient of the loosing zone α can be obtained.

$$\alpha = \frac{E}{E_0} = \left(\frac{v_P}{v_{P0}}\right)^2 \quad (7)$$

2. ENGINEERING BACKGROUND

This project is currently the first one in China ongoing large-scale underground crude oil reserve. The project site belonged to the hilly landscape. The mountain strike of the cavern site is about east-west. The elevation of ridge is 280~350 m and the topographic slope is about 35~55°. The storage rock caverns strike is about north-west, 600 m wide from east to west, 838m long from south to north, 300×10^4 m^3 design capacity, and 50a design life. The underground storage has 9 holes which are set parallel to the north and south. Each hole has 20m design hole cross, 30m hole high, and the straight wall round arched for the section shape (figure 1).

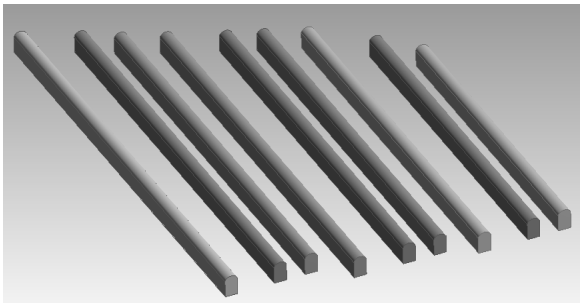

Figure 1. Model Of The Underground Crude Oil Storage Caverns

3. LOOSING ZONE MEASUREMENT

3.1 Measure Point Arrangement

The main cavern drilling for loosing zone measurement is shown in figure 2. Five holes with the diameter of 90 mm and the depth of 7 m are bored in each section. In order to make full coupling for surrounding rock and coupling agent in the test process, considering the actual situation and the surrounding environment, water is used as coupling agent. Because the ultrasonic instrument has the balloon, there is enough air to ensure the good water seal. The ultrasonic testing instrument is shown in figure 3. The test position is shown in table 1.

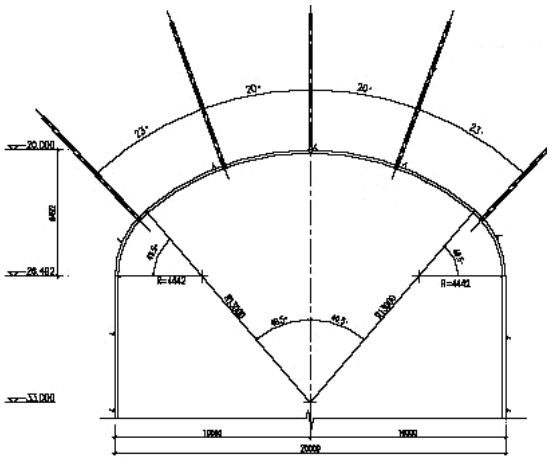

Figure 2. The Main Cavern Drilling

Figure 3. The ultrasonic testing instrument

3.2 Measure Method

Firstly, the air bag is filled with gas, ensuring enough pressure [3-6]. Secondly, a emission probe and two receiving probe are put in the same drilling. After the emission probe launchs ultrasonic wave, the No.1 receiving probe immediately receives the first wave and the sound waves can be converted into electrical energy [7]. The data is shown in the ultrasonic instruments. Firstly, the bottom of the hole is measured, then every 200 mm along the hole is measured until 30 mm far from the orifice. Finally, the wave velocity-time plot for the drilling can be drawn. Field measurement situation is shown in figure 4 [8-9].

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Table 1. The Test Position

Serial number	Position	Pile number	Rock class
1	main tunnel of number 1	0+100	II
2		0+198	III_1
3		0+292	III_2

Figure 4. Field Measurement

3.3 Results Of The Measurement

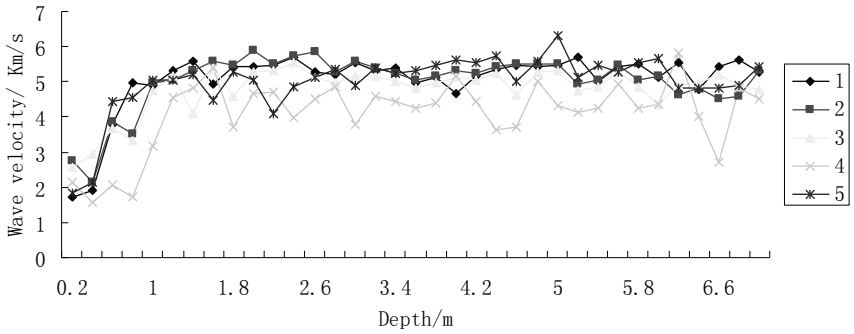

Figure 5. Wave Velocity Of 0+100 Section

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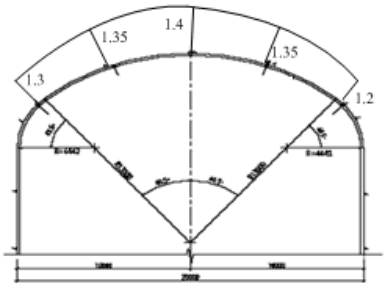

Figure 6. The Range Of The Loosing Zone

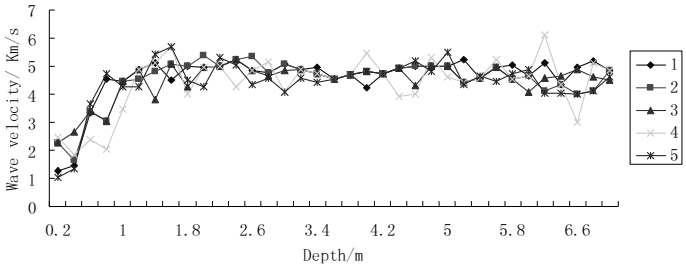

Figure 7. Wave Velocity Of 0+198 Section

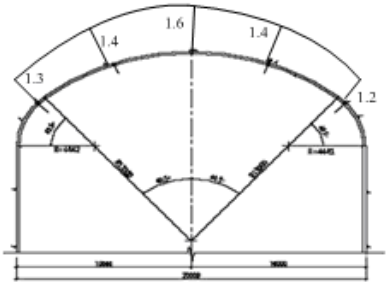

Figure 8. The Range Of The Loosing Zone

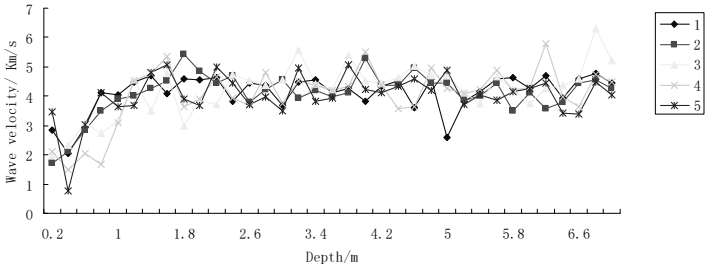

Figure 9. Wave Velocity Of 0+292 Section

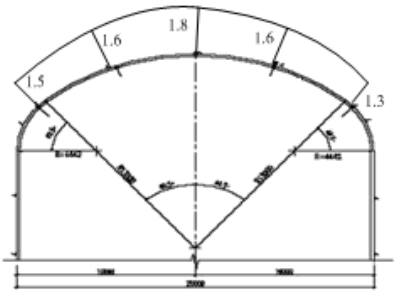

Figure 10. The Range Of The Loosing Zone

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The wave velocity of 0+100, 0+198 and 0+292 section are respectively shown in figure 5, figure 7 and figure 9. The range of the loosig zone are respectively shown in figure 6, figure 8 and figure 10. Take the 0+198 section for example, in figure 7, it is can be found that the wave velocity is small at the orifice section (the smallest is 1254 m/s). The results indicate that there is a broken surrounding rock area because of blasting. Then the acoustic wave velocity increases gradually along with the depth of the hole. It also indicates that the impacts of blasting gradually dimish. The acoustic wave velocity reaches the maximum value in depth about 1.3 m of the hole (5120 m/s). This result holds that the perturbed impacts gradually reduce after this place (1.3 m).

In addition, loosing zone testing can also determine the type of surrounding rock. In general, the lower the level of surrounding rock is and the greater the loosing zone is, simultaneously, the smaller the wave velocity is. The average wave velocity of the 0+100, 0+198 and 0+292 section are respectively 4.77 km/s, 4.46 km/s and 4.08 km/s. It is completely consistent with the actual rock type situation.

Through the loosing zone test, the anchor arrangement way and its parameters can be optimized. Not only the anchor length should exceed the range of the loosing zone, but also the density of the anchor arrangement should be considering the range of the loosing zone.

3.4 Borehole Television Measurement

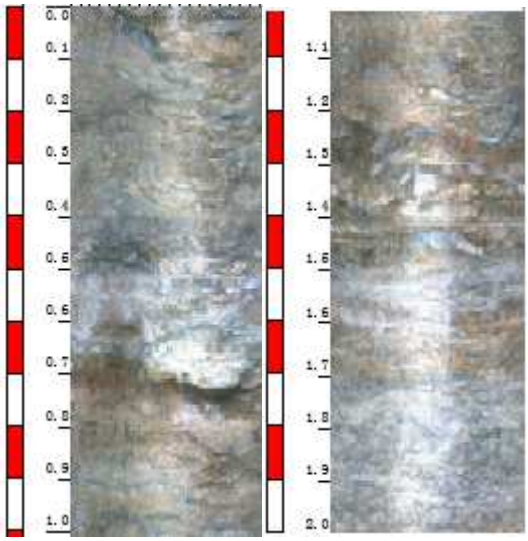

Figure 11. Result Of Borehole Television Measurement

The system of borehole television measurement can put a waterproof camera probe with the light source into an underground borhole. By the system we can observe clearly the formation lithology, rock structure, the degree of the rock integrity, the development characteristic of the primary fractures, the condition of the broken rock[10-11].

In order to verify the accuracy of the ultrasonic testing data, the system of borehole television measurement is adopted in the section of 0+198 in the main tunnel. The result is shown in figure 11. From the picture, we can find clearly that there is a lot of broken rock between 0 m and 1.4 m in the borehole. The measurement results are in good agreement with the results of the ultrasonic testing[12-13].

4. CONCLUSION

Above the engineering test results analysis, the range of the loosing zone is about 1.2 m to 1.8 m. The existing support form completely satisfy the requirement of this project.

5. AKNOWLEDGEMENT:

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