Design of Anti-Blasting and Wave-Elimination Protection Layer in Surrounding Rock of Cavern Based on Computer Simulation Technology

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Abstract. Based on the computer numerical simulation software ANSYS and AUTODYN, this paper describes the construction concept and implementation method of a new type of anti-blasting and wave-elimination layer in the surrounding rock of cavern. Through the numerical simulation method, the wave-elimination effect of the hole group layer in the surrounding rock is analyzed, and the attenuation ratio of the hole group to the peak stress of explosion wave is quantified. This paper studies the wave-elimination effect of the crack zone of wave protection layer in surrounding rock and gives its construction technology. It is recommended to use computer numerical simulation technology to study and optimize the subsequent surrounding rock stability and fracture zone structure, so that the new wave-elimination protection technology can be applied in practical engineering as soon as possible.

Keywords: computer technology, numerical simulation, wave elimination, surrounding rock, protection.

1. Introduction

As a representative of the military hard power of great powers, underground protection engineering is confronted with the danger of being hit by large-yield ground-drilling weapons and related nuclear bombs. There are many technical measures to improve the protection ability of underground protection engineering against explosion and wave, among which one of the most important measures is to improve the resistance of tunnel surrounding rock. As a method to improve the resistance of surrounding rock, anchor reinforcement technology is a construction technical means with general applicability and good economy. To verify the improvement of rock bolt reinforcement technology on the anti-blasting ability of tunnel surrounding rock, domestic scholars carried out explosion tests, conducted a study on the effect of the spacing and quantity of bolt on improving the anti-blasting performance of surrounding rock, and set two groups of model test conditions of caverns with different density, as shown in the figure below.

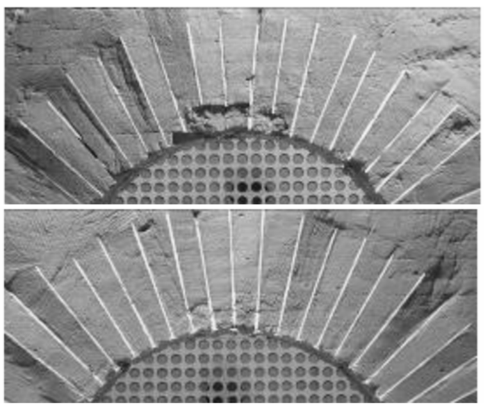

Fig. 1 Distribution of bolt in model test [1]

The vault displacement results of the model tests under the same explosion conditions show that the vault displacement of the cavern under the condition of encrypted bolt is smaller than that under the condition of unencrypted bolt. The above test results show that the surrounding rock after the encrypted bolt can effectively reduce the dynamic response caused by the explosion and provide guarantee for the safety protection of the cavern. However, according to the analysis of the test data in the following table, the effect of rock bolt encryption on reducing the vault displacement in the test is limited, which may be due to the fact that the propagation direction of the explosion stress wave is along the length direction of the bolt, and the reflection and refraction effect of the encrypted bolt on the stress wave is not obvious, resulting in the majority of the stress wave energy passing through the bolt group to the vault and acting near the vault. Overpressure impact is formed on the vault, resulting in the increase of the vault displacement. Therefore, although this kind of encrypted bolt can improve the resistance of the surrounding rock of the cavern, the effect of wave elimination and anti-blasting of different bolt layout methods needs to be further studied.

Table 1. Vault displacement of cavern [2]

Surrounding rock bolt	First shot	Second shot	Third shot	Fourth shot
Normal bolt placement	0.432 mm	0.810 mm	1.092 mm	1.051 mm
Encrypted bolt placement	0.428 mm	0.667 mm	0.876 mm	0.974 mm

2. Numerical simulation techniques

The above tests are conducted using traditional test techniques. Because the models in traditional explosion tests are often large in size, there are great difficulties in making the models. During the explosion test, the application of explosion load and the measurement of relevant data are not accurate, which leads to the inevitable systematic error and human error in the test results. In the face of such a situation, blindly using the test way to carry out the research of the tunnel surrounding rock wave protection layer needs to be improved.

In addition to improving the resistance of the cavern surrounding rock, the scholars put forward a new protection technology of laying holes in the surrounding rock. It means to build a certain distribution, size and scale of holes group in the surrounding rock mass outside a certain distance from the cavern structure, and use the interaction between the holes group and the explosion stress wave to weaken the ground impact energy and reduce the ground impact load strength, so as to reduce the structural damage. In theory, this kind of structure through the construction of air holes above the cave surrounding rock with infinitesimal wave impedance, when the number of holes is enough, the physical phenomenon of reflection, refraction and diffraction of explosion shock wave or stress wave will occur at the hole group, so as to cause the shock wave or related passivation stress peak value stress and other parameters to decrease significantly.

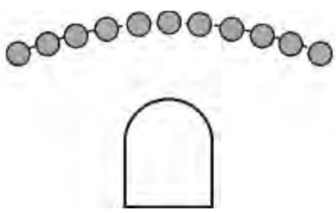

Fig. 2 Schematic diagram of the protection technology of the hole group [3]

Only the theoretical assumption of constructing a new wave elimination layer in the surrounding rock is insufficient to promote the anti-blasting ability of the surrounding rock of the cavern, so it is urgent to verify the correctness of the conjecture by new technical means. With the improvement of computer technology, the process simulation of explosion load has been developing rapidly. The numerical simulation software based on computer technology is gradually popularized, which provides a technical weapon for the study of new hole group wave elimination technology. With the help of the computer numerical simulation software Autodyn and Ansys and other large explicit dynamics software, the cave and surrounding rock were simulated and modeled, giving the surrounding rock material properties, 1:1 restoration of the simulation of realistic conditions. Using the computer simulation software to simulate the explosive process in the surrounding rock of the cavern, compare the stress nephogram under different working conditions, the computer intelligent mapping peak pressure curve, the above "hole group" wave elimination conjecture can be verified. In fact, as can be seen from the diagram of the explosion stress wave propagation in the following figure, the phenomenon of stress wave convergence and stress concentration begins to occur around the "hole group", the stress wave reflection and diffraction occur at the hole group, the travel of the stress wave increases, the energy dispersion of the stress wave front and the dissipation of the overall stress wave energy are intensified, and the stress wave energy is weakened at the hole. In the corresponding time-history pressure curve, the peak stress wave overpressure with "hole group" is only about 2.4MPa, which is reduced by about half compared with 4.5MPa without "hole group". Therefore, the existence of holes can weaken the strength of stress waves to a large extent, so as to protect the cavities or structures behind the holes.

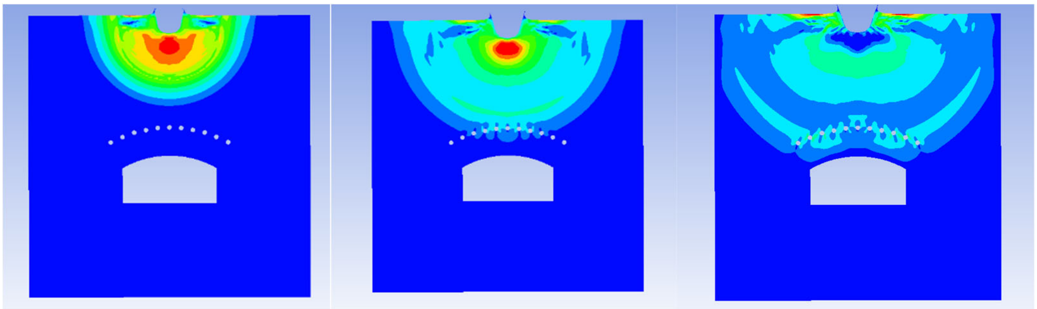

Fig. 3 Schematic diagram of the interaction process between the pore group and stress wave

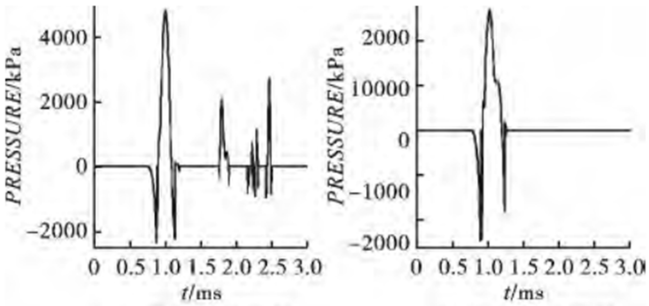

Fig. 4 Time history pressure curve with or without hole group [3]

Although the idea of "cavity group" can improve the anti-blasting capability and defensive effectiveness of important underground military projects, it only exists theoretically. In the actual engineering construction process, there is no technical realization of constructing holes of such size in the surrounding rock around the cavern. The current technical measures of laying "hole group" to improve the security of the cavern and achieve anti-blasting and wave-elimination are only suitable for the distribution layer of artificial anti-blasting structure. Using holes instead of ordinary layered media can maximize the effect of anti-blasting. Inserting holes in the distribution layer is an optimal anti-blasting and energy-absorbing design in theory and construction. To sum up, considering the feasibility of the construction of anti-blasting and wave-elimination technology in the cavern, it is impractical to construct holes or "hole groups" in the surrounding rock, at least there is no technical support at present. However, by relying on the surrounding rock of the cavern, the corresponding wave protection layer is constructed in the surrounding rock above the cavern, to achieve the protective effect of anti-blasting can be used for reference. The biggest difficulty in the construction of "hole group" or holes in surrounding rock is the construction technology. Therefore, it is feasible to find a way to build the corresponding wave elimination layer in surrounding rock by some construction technology means.

In actual engineering, it is difficult to construct artificial holes in the surrounding rock of cavern with the present equipment. Some studies have shown that physical phenomena such as reflection and refraction will occur in the crack interface when the explosion shock wave or stress wave passes through the crack, to attenuate the stress wave. Therefore, combined with the above situation of encrypted bolt layout and the relevant ideas of "hole group" protective layer, it is theoretically possible to achieve the anti-blasting and wave-elimination protection effect by constructing a given size and number of crack layers or weak interlayers in the surrounding rock of caverns.

At present, there are limited technical methods to make cracks in rock. Underground caverns are generally at a higher ground stress level, and hydraulic cutting has less disturbance to the whole surrounding rock, which is more conducive to the stability of the whole underground engineering. Therefore, with the help of hydraulic cutting technology, aiming at common types of surrounding rock, after repeated research and review of relevant literature, a technical method is proposed to use high pressure hydraulic cutting device to manually cut cracks in surrounding rock, so as to make directional artificial crack zone to improve the wave attenuation ability of underground engineering. Domestic ZGF-100 (A) ultra-high pressure hydraulic slit device can be high efficiency, wide application range, can fully cope with the vast majority of the cave surrounding rock cutting and cracking technology construction performance requirements. When working, the slotting device drills into the designated area along the anchor hole, uses high pressure water as power, and carries out rotary cutting on the rock mass around the slotting device through the ultra-high pressure water jet of mixed abrasive. After the cutting is completed, artificial slit of a given thickness and length will be formed in the rock to create a crack zone in the surrounding rock, so as to meet the requirements of the surrounding rock cracking construction technology.

The technical equipment has solved the method of constructing cracks in surrounding rock, but compared with the hole group, the wave elimination effect of crack zone in surrounding rock still needs to be studied. Also using the computer simulation technology, the numerical modeling of the surrounding rock containing the crack zone is carried out to simulate the process of explosion. To verify the protective effect of this kind of crack zone, two sets of different numerical model tests are set up and the explosion tests are carried out under the same explosion condition. Under specific conditions, the peak pressure values of each point in the model without crack cutting are larger than those in the model with crack cutting, and the corresponding attenuation of the peak stress wave pressure values is more than 50%. The above test results have also been verified by numerical simulation, and the results are similar, which fully shows that the cutting cracks in surrounding rock increases the "dispersion" effect of stress waves in the propagation process of surrounding rock, and increases the energy dissipation of stress waves, thus improving the defense capability of the protection engineering against knock and wave.

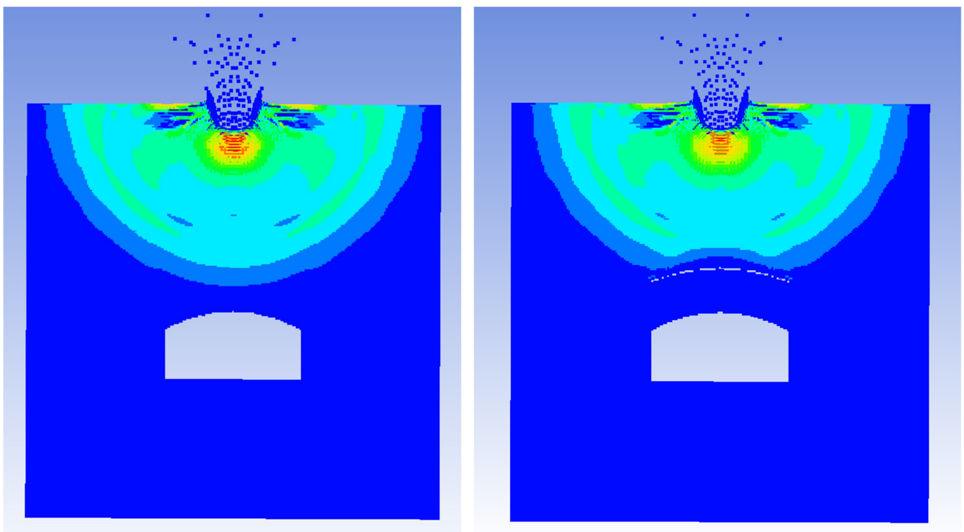

Fig. 5 Schematic diagram of the interaction process between the crack and stress wave

Table 2. Peak pressure of measuring points

Model working condition	Measuring point 1	Measuring points 2
No cut cracks	210kPa	117kPa
Have cut cracks	71kPa	31.7 kPa

3. Conclusion

The computer numerical simulation study proves the advantages of computer technology in the design of anti-blasting and wave-absorbing layer of surrounding rock of cavern, and further makes up for the shortcomings of model test. Considering the in-situ stress level of the surrounding rock in the cave, the artificial crack zone may be closed under compression. After the crack interface is closed, it will gradually melt, and the reflection and refraction effect of stress waves will be weakened, thus affecting the attenuation efficiency of stress waves in the crack zone protective layer. In addition, whether the construction of artificial crack zone in the surrounding rock will affect the stability of surrounding rock and lead to some engineering disasters such as cave collapse.

Based on the above results, the design of the wave suppression layer of surrounding rock based on computer technology not only meets the technical requirements of daily construction, but also provides the technical support of wave suppression for the shallow buried chamber to resist the attack of high-yield aerial bombs or small nuclear bombs by constructing artificial cracks of sufficient size and quantity in the surrounding rock to form a crack zone wave-elimination layer in the surrounding rock rock, and plays a military role in anti-detonation wave-elimination. In the later stage, the stability of surrounding rock can be verified by computer simulation technology. Since ensuring the stability of surrounding rock, a series of computer numerical simulation work such as the number, location and thickness of crack zone can be carried out to further optimize the design of wave-elimination, which has a promising prospect and considerable research value.

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