# Blasting Control Technology and Practical Application Methods in Urban Rail Transit Tunnel Construction

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**Abstract:** Urban rail transit tunnel construction is an important part of urban development, and the quality of its construction directly affects the safe and stable operation of subsequent projects. Tunnel blasting is the most common technique in rail transit construction, and blasting control is an important measure to ensure the smooth progress of blasting operations. In the construction of urban rail transit tunnel projects, in order to ensure construction safety and minimize the impact on the surrounding environment, relevant units need to conduct in-depth research on blasting control techniques. Based on this, this paper combines practical engineering cases to conduct specific research on blasting control techniques in urban rail transit tunnel construction, and proposes blasting control measures suitable for urban rail transit tunnel projects, effectively controlling blasting vibrations and noise during subway tunnel construction, providing reference for the construction of urban rail transit tunnel projects in China.
***Keywords*:** urban rail transit tunnel, blasting control technology, practical application methods

## 1. Introduction

Currently, the construction technology of urban rail transit in China is rapidly developing, and the application of blasting control technology in subway tunnel construction is becoming increasingly widespread. However, there are still certain problems in the practical application of blasting control technology during tunnel construction, which affects the blasting effect and construction quality. Therefore, this article analyzes and studies the practical application methods of blasting control technology in urban rail transit tunnel construction, elucidating the important role and application methods of blasting control technology in urban rail transit tunnel construction, with the hope of providing effective reference for relevant personnel.

## 2. Blasting Control Technology in Urban Rail Transit Tunnel Construction

Blasting construction is a common operation in urban rail transit tunnel construction, primarily aimed at improving construction efficiency and accelerating progress. However, in urban areas with dense pedestrian and vehicular traffic, as well as numerous buildings, transportation infrastructure, and municipal networks, the inherent hazards of blasting construction have significant impacts that must be controlled. Urban rail transit tunnel projects are primarily conducted underground, where the hazardous effects of blasting, such as flying rocks, can be contained within the underground space, while dust and harmful gases can be effectively controlled through forced ventilation. Therefore, it is crucial to focus on controlling the impacts of blasting vibration and noise on the surrounding environment during blasting operations in urban rail transit tunnel construction.[1]

The blasting control technology in urban rail transit tunnel construction mainly includes three aspects:

(1) By implementing scientifically and rationally designed blasting plans, the impact of blasting vibration and noise on the surrounding environment can be reduced, ensuring the safety of the construction process.

(2) Detailed blasting control plans should be formulated based on the construction site conditions to effectively protect the surrounding environment.

(3) Strengthening the management of the construction process and strictly controlling various issues that may arise during blasting operations.

Blasting control technology is an important measure to ensure the smooth progress of blasting operations and minimize the impact on the surrounding environment. Taking urban rail transit tunnel construction as an example, the construction environment is complex, and blasting vibration and noise are the main factors affecting the surrounding environment. Therefore, it is necessary to adopt reasonable and effective blasting control technology to minimize the impact on the surrounding environment in urban rail transit tunnel construction. Hence, the following points should be given attention:

(1) Control the scale of each blasting operation, with each operation not exceeding a charge of 500 kg. According to the Sadek-Sobolevsky formula:

$$Q_{\mathrm{MAX}} = \left(\frac{V}{K}\right)^{\frac{3}{\alpha}} \cdot R^3 \,(\mathrm{kg}) \quad (1)$$

The maximum charge quantity ($Q_{\mathrm{MAX}}$) for a single blast is positively correlated with the allowable critical vibration velocity (V) for protecting buildings/structures and the distance (R) between them and the blast zone. Due to the dense urban structures, the distance between them and the blast zone is often small, thus the blasting scale must be controlled.

(2) Adopt the correct charging method and charging structure to ensure that each blast hole is adequately charged.

(3) Control the depth of the blast holes within a reasonable range to avoid over-excavation.

(4) Determine reasonable parameters for the blast hole pattern.

(5) Strictly adhere to the design requirements for charging to avoid insufficient or excessive charges.

(6) Ensure the detonation of explosives and detonators with the same delay time, strictly control the deviation of delay time, and minimize the dosage error. It has been proven in practice that using millisecond-delay detonators with minimal delay intervals, preferably electronic detonators, can control the delay time within a small deviation range to meet construction requirements. Currently, the use of electronic detonators is mandatory in China, which is highly beneficial for controlled blasting in urban areas.

(7) Establish proper detonation network connections between blast holes to ensure correct connectivity among them.

(8) Ensure that undercut positions do not experience any displacement and maintain a reasonable undercut shape.

(9) Properly charge and block blast holes to ensure effective detonation.

## 3. The important role of blasting control technology in urban rail transit tunnel construction

In the process of urban rail transit tunnel construction, blasting control technology is commonly employed to facilitate the smooth progress of the project. Tunnel blasting technology primarily utilizes the explosive force of explosives to break the rock mass, thereby achieving the purpose of excavation through blasting. In the construction process of urban rail transit tunnels, construction methods and blasting parameters can be determined by analyzing the rock mass in different areas. Corresponding blasting methods are employed based on the differences in rock properties, strength, and mechanical characteristics. Smooth blasting, pre-split blasting, and millisecond-delay control blasting are commonly used excavation methods in urban rail transit tunnel construction.

Smooth blasting refers to concentrating the explosive force of the explosives on a specific point on the rock surface using smooth blasting machines, thereby achieving rock fragmentation and contour shaping of the rock surface. Pre-split blasting, on the other hand, involves pre-drilling boreholes and loading explosives to achieve rock damage and crack extension based on the differences in rock properties and strength in urban rail transit tunnel construction. (Smooth blasting mainly achieves high-quality tunnel wall shaping effects, while pre-split blasting not only achieves high-quality tunnel wall shaping but also helps reduce blasting vibration.) Millisecond-delay control blasting divides a single blast into multiple consecutive blasts with small time intervals and smaller charges, reducing the peak blasting vibration velocity controlled by the maximum charge. This approach minimizes blasting vibration. By using millisecond-delay control blasting, the interference or superposition of vibration waves generated by preceding and subsequent blast holes is avoided, resulting in a reduction in the maximum peak value of blasting vibration.

Practical engineering tests have shown that compared to instantaneous blasting, millisecond-delay blasting can achieve an average vibration reduction rate of 50%. The more delay segments used, the better the vibration reduction effect. Currently, millisecond-delay blasting technology has been widely applied in urban rail transit tunnel construction and has achieved significant results. Therefore, it is evident that the rational application of blasting control technology plays an important role and holds significance in urban rail transit tunnel construction [2].

## 4. Scientific Design of Blasting Control Techniques

When designing blasting control techniques, several aspects need to be considered. First, the selection of appropriate explosives is crucial. Explosives are essential materials in blasting operations, and their explosive energy directly affects the blasting effect. Therefore, factors such as quality, price, and transportation need to be taken into account when choosing explosives. In urban rail transit tunnel construction, using low-velocity explosives results in significantly less vibration compared to high-velocity explosives of the same mass. The selection of suitable explosive types should also consider the specific engineering conditions. Under similar blasting conditions and distances, even when the low-velocity CCR explosives have three times the dosage of commonly used ammonium nitrate explosives, the former still generates much less vibration than the latter.

Second, it is important to strengthen monitoring of the construction environment. Prior to blasting operations, a detailed investigation and analysis of the surrounding environment should be conducted to fully understand the presence of high-voltage power lines, cables, and other facilities. Appropriate measures should be taken if such facilities are present. Comprehensive inspections of surrounding buildings, underground pipelines, and other structures should also be performed to prevent safety hazards caused by blasting.

Third, a scientifically and reasonably designed blasting plan should be developed based on the actual conditions. The blasting plan should consider the specific circumstances of the project to ensure a safe and orderly construction process.

Fourth, calculations should be made regarding the impact of blasting vibrations and noise at different distances. By calculating the magnitude of blasting vibrations and noise at various distances, a better understanding of the extent to which blasting vibrations and noise affect the surrounding environment can be obtained [3].

# 5. Strengthening Blasting Vibration Control

In the construction of urban rail transit tunnels, blasting operations are primarily conducted based on site exploration and design. By selecting appropriate blasting parameters, the blasting vibrations can be controlled effectively, thereby ensuring the protection of the surrounding environment. The impact of blasting vibrations on the surrounding environment is mainly attributed to the different blasting methods used in urban rail transit tunnel construction.

Generally, tunnel rock blasting construction utilizes slotting blasting combined with surrounding smooth or pre-splitting methods. In urban rail transit tunnel construction, both commonly used blasting methods can cause a certain degree of impact on the surrounding environment. Therefore, it is necessary to strengthen the control of these two blasting methods during the construction process.

However, when using drilling and blasting techniques in urban rail transit tunnel construction, two aspects need to be considered. First, due to the shallow boreholes, low resistance lines, steps, or full-face methods commonly employed in urban rail transit tunnel construction, it is important to combine shallow boreholes with steps or full-face methods. Second, considering the unique environment and construction technical requirements in urban rail transit tunnel construction, high-precision detection instruments and skilled professionals should be employed to ensure construction quality.

Additionally, the use of pre-splitting blasting or vibration-reducing boreholes should be noted. Pre-splitting boreholes are highly effective in reducing the vibration effects of the main blasting boreholes, but the vibration effects of pre-splitting blasting itself should be considered. For the area between the blasting body and protected structures, single or double rows of vibration-reducing boreholes can be drilled without explosives, achieving a vibration reduction rate of 30% to 50%. The diameter of vibration-reducing boreholes can be selected between 35 to 65mm, with a spacing not exceeding 25cm.

# 6. Controlling Blasting Noise

The control of blasting noise in the construction of urban rail transit tunnels is mainly achieved through the rational selection of blasting parameters and enhanced management of the construction process. The control of blast shockwaves is an important measure to control blasting noise. When underground open blasting is conducted, the overpressure value ΔP of the blast shockwave is calculated according to the following formula:

$$\Delta P = 12\left(\frac{Q}{V}\right)\times 10^{5}\ (\text{Pa}) \quad (2)$$

where Q represents the amount of explosive used in a single blast, which can be adjusted and controlled; V refers to the volume of tunnel air disturbed by the air shockwave, which is generally not adjustable after the engineering plan is determined. It can be seen that the scale of blasting has a significant impact on the generation of blast shockwaves, so attention should be paid to controlling the scale of blasting during tunnel construction.

Blasting noise is the continuation of the air shockwave, and it is generally considered that the peak overpressure of the air shockwave is below 0.02 MPa (below 180 dB), after which the air shockwave transforms into noise.

Therefore, in the construction of urban rail transit tunnels, suitable blasting parameters should be selected based on the surrounding environment to effectively protect the surrounding environment. Generally, measures to control blasting noise include the following aspects:

First, control the charging structure. In urban rail transit tunnel construction, a reasonable charging structure should be chosen to reduce the impact of rock fragmentation on the surrounding environment.

Second, control the charging height.

Third, strengthen backfilling. According to measurements, the noise level recorded at a distance of 25 meters from an explosion of a detonator without cover was 115 dB. At the same distance of 50 meters, when the explosion was covered by a blasting body with 6 kg of explosive, the measured noise level was 85 dB. When 1.6 kg of explosive was detonated without cover, the noise level was 103 dB. Therefore, to prevent noise pollution, blasting must be covered and backfilled. Generally, the commonly used explosives in urban rail transit tunnel construction are initiators and micro-crack explosives.

Fourth, employ delayed blasting, which not only reduces the vibration effect of blasting but also lowers blasting noise. Practice has shown that as long as the layout is reasonable, using millisecond delayed blasting can reduce the intensity of noise by 1/3 to 1/2. To control the scale of blasting, it is important to avoid excessively long total delays in the blastholes.

Fifth, pay attention to directional effects. When tunnel blasting occurs, the blasting noise propagates within the sealed space of the tunnel. In the direction of the tunnel, the propagation distance of the noise increases significantly, and the exit position forms a barrel effect. Therefore, in the engineering design, it is important to avoid this phenomenon by setting the tunnel exit in areas with few buildings and less population, avoiding protective structures, and if necessary, installing noise shielding measures such as protective racks or wave barriers at the exit location to effectively reduce noise hazards.

# 7. Selection of Blasting Parameters

Blasting parameters are crucial factors that influence the blasting effect and serve as important criteria for ensuring blasting quality. In the construction process of urban rail transit tunnels, suitable blasting parameters are selected based on factors such as rock grade, section size, construction speed, etc. These parameters are rigorously calculated and determined before blasting to enhance the blasting effect. Generally, blasting parameters include the following aspects:

## 7.1 Unit Explosive Consumption

The unit explosive consumption is a key factor that affects the blasting effect. A lower unit explosive consumption allows for more efficient utilization of explosive energy, thereby improving the blasting effect. In practical blasting construction, a reasonable unit explosive consumption should be determined based on different construction and geological conditions. For example, under poor geological conditions, a smaller unit explosive consumption is generally chosen, and the length of the explosive charge in the blastholes is determined based on the actual project conditions.

## 7.2 Blasthole Diameter and Depth

The blasthole diameter and depth are important factors that affect the blasting effect. They have a significant impact on rock fragmentation and blasting vibration. In urban tunnel blasting, shallow blastholes are commonly used, and the maximum blasthole depth is controlled within 3 meters.

## 7.3 Explosive Allocation

During blasting operations, construction personnel need to develop a reasonable blasting control technical plan to ensure the blasting effect of tunnel construction. Specifically, the following requirements should be considered for blasting control in urban rail transit tunnel construction: no blasting in soil layers, blasting only in rock layers, and generally, blasting construction methods can be used for rock grades below Grade V. The explosive quantity should be controlled during tunnel blasting, typically kept below 500 kg. The allocation of explosive quantity should be determined based on factors such as rock grade, section size, etc. Generally, the allocation should be based on the tunnel excavation section area, excavation depth, rock properties, and explosive performance. For example, when the excavation area is larger, the explosive quantity should be appropriately increased. If the rock quality is good and the section is smaller, the explosive quantity can be reduced [4]. Increasing the dispersion of explosive distribution and the free face can reduce the values of K and $\alpha$ in the vibration velocity formula, thereby reducing the intensity of blasting vibrations.

## 7.4 Direction of Least Resistance Line

Choose the direction of the least resistance line. In blasting, the blasting vibration intensity is the smallest in the direction of the least resistance line, largest in the opposite direction, and intermediate in the lateral direction. However, the direction of the least resistance line is also the main throwing direction. Considering vibration damping and controlling flying rock hazards, the protected objects should generally be positioned on both sides of the least resistance line.

# 8. Selection of Slotting Methods

In the construction of urban rail transit tunnels, the selection of slotting methods is an important aspect that affects the blasting effect and construction quality. The selection of slotting methods needs to be based on actual conditions and reasonable design according to practical needs. This is a crucial element in ensuring the blasting effect and construction quality of the tunnel. The slotting methods for tunnel blasting are mainly divided into two types: inclined-hole slotting and straight-hole slotting. Inclined-hole slotting, also known as wedge-shaped slotting, is the primary form of slotting in tunnels and can be further classified into single-stage wedge-shaped slotting and multi-stage compound wedge-shaped slotting. The selection of wedge-shaped slotting forms depends on tunnel sections, cycle lengths, rock hardness, and explosive properties. Straight-hole slotting can be further divided into small-diameter hollow straight-hole slotting and large-diameter hollow straight-hole slotting. Wedge-shaped slotting has higher efficiency but requires greater demands on the spacing between construction blastholes compared to straight-hole slotting. Straight-hole slotting uses empty holes that are not charged with explosives, providing only temporary free surfaces, which reduces blasting efficiency. In wedge-shaped slotting, in order to achieve the desired slotting effect, the slotting blastholes should be simultaneously detonated. Therefore, the minimum simultaneous initiation explosive quantity is the sum of the explosive charges in the slotting blastholes. On the other hand, in straight-hole slotting, initiation can be performed sequentially on a per-hole basis, and the minimum simultaneous initiation explosive quantity within a section is the maximum charge in a single slotting blasthole. It can be seen that straight-hole slotting can reduce the explosive quantity to the level of a single blasthole, which is useful in environments with strict blasting vibration requirements.

Based on these considerations, the selection of slotting methods in urban rail transit tunnel construction should be based on practical conditions and rational design. During the actual construction process, the blasting parameters should be set and adjusted in strict accordance with relevant regulations. It is also essential to choose the appropriate blasting equipment to avoid unsatisfactory blasting effects due to inadequate equipment. Furthermore, when selecting the slotting method, the damage and impact caused by peripheral eye blasting on the surrounding rock should be taken into account to choose a reasonable slotting method.

## 9. Analysis of Post-blasting Effects

Statistical data on the post-blast tunnel sections indicate that the profiles of the tunnel sections are relatively regular and there are not many cracks or collapses. This indicates that the blasting control techniques have effectively controlled the construction. There are few cracks observed in the post-blast tunnel, suggesting that the blasting control techniques not only ensure the quality and progress of tunnel construction but also improve construction efficiency. The application of blasting control techniques in urban rail transit tunnel engineering can also reduce environmental damage. Through the analysis of blasting control techniques in urban rail transit engineering, it can be observed that the application of control blasting techniques in tunnel blasting construction effectively reduces the impact on the surrounding environment. To further study the application methods of blasting control techniques in urban rail transit engineering, analysis and research can be conducted from the following two aspects: first, analyzing the application of blasting control techniques in urban rail transit engineering to determine which blasting control techniques are used in the project; second, when applying control blasting techniques in actual urban rail transit engineering, suitable blasting control schemes should be selected based on the specific project conditions and construction requirements to improve the construction quality and efficiency of urban rail transit tunnels [5].

## 10. Conclusion

The application of blasting control techniques is crucial in the construction of urban rail transit tunnels as it effectively improves the quality and safety of tunnel construction. During the actual construction process of urban rail transit tunnels, it is important to recognize the significant role of blasting control techniques and select scientifically and reasonably based on the specific tunnel conditions. Strict adherence to construction processes should be followed to improve construction quality and efficiency, and to avoid adverse consequences resulting from improper application of blasting control techniques, ensuring the construction quality of urban rail transit tunnels.

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