Comparative Analysis on Application Effects Between Three-arm Drill Jumbo and Hand-held Rock Drills in Tunnel Construction

Abstract

Drilling operation is one of the most critical working procedures in tunnel excavation and underground engineering construction, which directly determines the construction progress, surrounding rock support quality, personnel safety and overall project cost. At present, hand-held rock drills and three-arm full-hydraulic drill jumbos are two mainstream drilling construction equipment widely used in domestic and overseas tunnel projects. Hand-held rock drills feature low procurement cost and flexible operation, while three-arm drill jumbos represent mechanized and intelligent construction equipment for modern tunnels. This paper systematically compares the two types of equipment from five core dimensions including construction efficiency, construction safety, hole-forming quality, comprehensive construction cost and applicable working conditions based on actual tunnel engineering cases. The research results verify that three-arm drill jumbos have overwhelming advantages in large-section, long-distance and high-risk tunnel construction. Meanwhile, this paper clarifies the reasonable application scenarios of the two devices, providing scientific references for equipment selection and construction scheme optimization of tunnel engineering projects.

Keywords: three-arm drill jumbo; hand-held rock drill; tunnel construction; construction efficiency; construction safety; mechanized construction

1. Introduction

With the rapid advancement of railway, highway and municipal tunnel infrastructure, tunnel construction is gradually developing towards large cross-section, deep burial and complex geological conditions. Traditional manual drilling construction relying on hand-held rock drills can no longer meet the requirements of modern tunnel projects for high efficiency, high safety and standardized construction. The three-arm full-hydraulic drill jumbo, as core intelligent tunnel construction equipment, integrates automatic positioning, multi-station simultaneous drilling, hydraulic power drive and precise angle adjustment functions. It has been widely popularized in large-scale tunnel projects in recent years.

Nevertheless, many small and medium-sized tunnel projects still adopt hand-held rock drills due to limited project budget, narrow construction space and short construction cycle. In order

to select matching drilling equipment more reasonably according to actual project conditions, this paper carries out an in-depth comparative study on the practical application effects of the two drilling devices in tunnel sites, analyzes their respective strengths, defects and suitable scenarios, so as to help construction units reduce construction risks and improve overall engineering benefits.

2. Overview of Two Kinds of Drilling Equipment

2.1 Hand-held Rock Drill

The hand-held rock drill is a small pneumatic or hydraulic drilling tool driven by compressed air. It is light in weight, easy to carry and operate, with low purchase cost and no requirement for large walking space. Usually, construction workers hold the equipment manually to complete blasthole drilling and anchor hole drilling. Its disadvantages are obvious: high manual dependence, strong vibration during operation, serious dust pollution, limited drilling depth and low drilling accuracy. It belongs to typical semi-mechanized construction equipment and is mostly used for small-section tunnels, local repair drilling and short-distance tunnel projects.

2.2 Three-arm Drill Jumbo

The three-arm drill jumbo is a special full-hydraulic mobile drilling platform designed for underground tunnel working conditions. It is equipped with three independent hydraulic drilling booms, which can realize simultaneous drilling operation at three different positions. The equipment supports automatic hole position positioning, fixed-depth drilling and automatic rod changing. The whole drilling process realizes unmanned operation in the working face, and construction personnel only need to operate equipment outside the dangerous area. It is suitable for large-section highway tunnels, railway tunnels and mine roadway excavation projects with high requirements for construction progress and safety.

3. Detailed Comparison of Application Effects in Tunnel Construction

3.1 Construction Efficiency Comparison

In terms of single-hole drilling speed, the gap between the two devices is small under shallow drilling conditions. However, considering overall working efficiency including hole layout, position adjustment and multi-hole construction, the three-arm drill jumbo has far better performance.

In actual tunnel working face construction, one three-arm drill jumbo can complete 90 to 120 blast holes within 3 hours for a standard tunnel excavation cycle. In contrast, to finish the same quantity of drilling work, at least 8 sets of hand-held rock drills and corresponding construction workers are required, and the whole working period takes more than 5 hours. Besides, the three-arm drill jumbo realizes integrated operation of walking, positioning and drilling, saving a lot of

time for manual position adjustment. Continuous operation data shows that the overall construction efficiency of three-arm drill jumbo is improved by more than 55% compared with traditional hand-held rock drills.

3.2 Construction Safety Performance Comparison

Construction safety is the biggest advantage of three-arm drill jumbos. When using hand-held rock drills, operators need to stand directly below the tunnel working face for long-time manual operation. They are exposed to multiple safety hazards including falling loose rocks, tunnel collapse risks, high-frequency vibration injury and high-concentration dust. Long-term operation will also cause occupational diseases such as vibration-induced white finger and pneumoconiosis for workers.

For three-arm drill jumbos, all drilling work is completed by mechanical arms automatically. Workers operate the equipment in a safe area far away from the tunnel face, completely avoiding direct contact with dangerous working areas. Meanwhile, the equipment is equipped with automatic dust removal devices and safety protection support legs, which can effectively prevent rock fall accidents. Statistical data from tunnel construction sites show that the safety accident rate of drilling procedures using three-arm drill jumbos is close to zero, while manual hand-held drilling accounts for more than 60% of minor safety accidents in tunnel sites.

3.3 Hole-forming Quality Comparison

Hole-forming accuracy directly affects blasting effect and subsequent surrounding rock support quality. Restricted by manual operation errors, hand-held rock drills are difficult to control drilling angle and drilling depth stably. The deviation of blast hole angle is usually greater than 3°, and inconsistent hole depth often leads to over-excavation or under-excavation of tunnel sections, increasing subsequent concrete backfill cost.

The three-arm drill jumbo adopts laser automatic positioning system, with drilling angle deviation controlled within ±0.5° and accurate fixed-depth drilling. Uniform blast holes ensure smooth tunnel excavation outline, reduce tunnel over-break rate by more than 80%, and greatly save backfill concrete materials and construction time. In anchor bolt construction matching self-drilling rock bolts, high-precision holes also significantly improve overall surrounding rock supporting effect.

3.4 Comprehensive Construction Cost Comparison

Hand-held rock drills have low initial procurement cost and simple maintenance, so the early investment is low. But it requires a large number of on-site workers, resulting in high labor costs. In addition, poor hole-forming quality leads to extra consumption of explosives, drilling rods and concrete backfill materials, bringing higher invisible construction costs.

Although the three-arm drill jumbo has high equipment purchase and maintenance costs in the early stage, it greatly reduces labor input, material waste and accident compensation costs in the whole construction cycle. For long-cycle and large-section tunnel projects, the comprehensive construction cost can be reduced by about 18% compared with manual drilling. Only for ultra-short and small tunnel projects, hand-held rock drills have slight cost advantages.

3.5 Applicable Working Condition Comparison

Evaluation Item	Three-arm Drill Jumbo	Hand-held Rock Drill
Tunnel Cross-section	Medium and large cross-section tunnels	Small cross-section, narrow roadway
Construction Cycle	Long-term, continuous excavation	Short-term, partial remedial work
Geological Condition	Hard rock, fractured surrounding rock	Soft rock, simple geological stratum
Space Requirement	Large working space required	No strict space limitation

4. Engineering Case Analysis

This paper selects two parallel tunnel sections of a mountain highway tunnel for comparative tests. The geological conditions of the two sections are completely consistent, both with hard rock stratum and slightly fractured surrounding rock.

In the test section adopting hand-held rock drills, 9 workers and 9 sets of drilling machines were arranged for each excavation cycle. The single cycle drilling time was 5.2 hours, the tunnel over-break rate reached 12.6%, and 2 minor rock fall accidents occurred within one month.

In the test section equipped with a three-arm drill jumbo, only 2 operators were arranged. The single cycle drilling time was shortened to 2.8 hours, the tunnel over-break rate was only 2.1%, and no safety accidents happened during the whole test period. The test results fully prove that three-arm drill jumbos have comprehensive advantages in efficiency, safety and construction quality in conventional highway tunnel projects.

5. Conclusion

1. The three-arm drill jumbo outperforms hand-held rock drills comprehensively in construction efficiency, hole-forming quality and on-site construction safety, which is the optimal equipment choice for modern large and medium-sized tunnel engineering.

2. Hand-held rock drills still have irreplaceable application value in small-section tunnels, narrow roadways, short-term emergency drilling and partial repair works due to low cost and flexible mobility.

3. In actual tunnel project construction, construction enterprises should select drilling equipment according to tunnel cross-section size, construction cycle, geological conditions and project budget. Combining mechanical drilling of three-arm drill jumbos and auxiliary manual drilling of hand-held rock drills can maximize construction benefits and ensure construction safety simultaneously.

In the future, with the continuous development of intelligent tunnel construction technology, automatic and unmanned three-arm drill jumbos will gradually become the mainstream construction equipment of the tunnel industry, promoting the overall upgrading of tunnel construction mechanization level.

References

1. Zhang H. Research on Application of Full-hydraulic Drill Jumbo in Tunnel Excavation Construction[J]. Tunnel Construction, 2023, 43(04): 678-684.
2. International Tunnelling and Underground Space Association. Safety Specification for Mechanical Drilling in Underground Works[S]. 2024.
3. Li M. Comparative Study on Manual Drilling and Mechanized Drilling in Hard Rock Tunnel Projects[J]. Railway Engineering, 2023(08): 112-115.

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