

Crack Maintenance Effect Model Testing Study of Mine Construction Metro Lining

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Abstract—Taking lining structure crack diseases on one line of Beijing subway as the research object, using indoor model test method to studying lining structure damage rule and crack maintenance effect. Through experiment, it was concluded the main conclusions as follows: Through the contrast test could be obtained that, the yield load of crack grouting reinforcement test beams could increased by 6% ~ 8%, the ultimate load of test beams could increased by 4%. The main purpose of crack grouting reinforcement technology was to restore structure overall stress form, and the bearing capacity of experimental beams increase is not obvious. The research conclusions have important theoretical guiding significance for the comprehensive treatment work on the tunnel lining structure cracks ,which during the next phase.

Keywords—lining structure; crack maintenance; model test

I. INTRODUCTION

In urban rail transit underground structure, the lining cracks are one of the most common diseases. The causes of lining crack about of the characteristics of concrete itself, low frequency vibration of motor vehicles and the surrounding environment load effect. Because of the different design form, each of the tunnel lining structure damage forms are different [1-3]. Related research data shows, Shanghai, Shenzhen, Tianjin, Guangzhou, Nanjing and other urban rail transit city all have structure lining crack, leakage and impellers of various structural diseases [4-9]. The root cause of leading to other related disease is the cracks of the lining and development. Some metro line is one of the most important lines in Beijing rail transit. Taking lining structure crack diseases on one line of Beijing subway as the research object, which has important significance to building Beijing "peace metro"[10], and ensuring the safety of capital of the people's travel.

II. DESIGN OF MODEL EXPERIMENT

A. Design of Test Beam

The tunnel structures are composite lining structure, single hole single horseshoe cross section, cross-section profile of tunnel lining structure shows in Figure I. The first tunnel lining is 250mm thick steel grille sprayed concrete, and the second tunnel lining is 300 mm thick plain concrete, some second tunnel lining is steel grille sprayed concrete.

The proportion of test beams using actual tunnel lining size, and take the upper tunnel arch structure as model. The test beam's span is 6100 mm, across is 5000 mm [11-13].

Test beam used ordinary Portland cement that design strength grade is C20, the coarse aggregate is less than 15 mm of gravel, the fine aggregate is river sand. The concrete mixture ratio is that cement, water, sand, stone = 1:0.41:1.32:2.45. Steel grating made of the main reinforcement, inclined reinforcement, stirrups and steel plate. The main reinforcement and oblique muscle welding connection, two pieces of steel plates are connected by a bolt. In order to facilitate loading test, it set beam loading platform, test beam supporting structure, and test beam hoisting structure. Test beam design profile shows in Figure II, test beam loading equipment shows in Figure III.

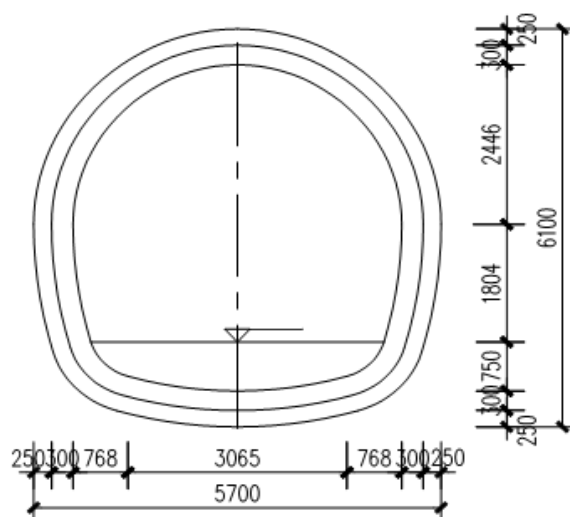


FIGURE I. CROSS-SECTION PROFILE OF TUNNEL LINING STRUCTURE

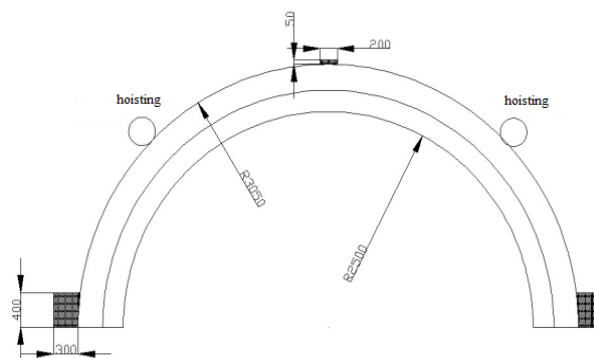


FIGURE II. TEST BEAM DESIGN PROFILE



FIGURE III. TEST BEAM LOADING EQUIPMENT

B. Testing Program

The purpose of the test is mainly as follows: (1) get the damage rule of lining structure by destructive test; (2) through the reinforcement technology of reinforcing effect to obtain the lining structure. It made five experimental beams, respectively for destructive test and the crack repair test under different damage states. Test beam number and damage reinforcement situation shows in table 1. The test beam reinforcement construction is completed, a week to maintenance in the laboratory, reinforcing material to carry out the destruction test after the strength to meet the design requirements.

TABLE I. TEST BEAM NUMBER AND DAMAGE REINFORCEMENT SITUATION

number	damage grade	Structure reinforcing way
BM-1	No damage	NO reinforcement
BM-2	No damage	NO reinforcement
BM-3	No damage	NO reinforcement
BM-4	After the main crack width up to 1.5 mm, unload and reinforcement	crack grouting reinforcement
BM-5	After the right crack width up to 1.8 mm and the middle crack width up to 1.5 mm, unload and reinforcement	crack grouting reinforcement

C. Damage Level Design

According to the test purpose, test beam to load before reinforcement, make its injury and craze. Contrast test beam (BM-1, BM-2, BM-3) steel bar strain is used to determine the size of the damage load. The contrast test beam testing take the conclusion that the steel yield strain is $2000 \mu\epsilon$, test the width of the main crack and the main reinforcement strain has good linear relationship. This test will be the main crack width is 1.5 mm, the corresponding reinforcement strain for $950 \sim 1050 \mu\epsilon$.

III. TEST RESULTS AND ANALYSIS

A. Destruction Process

Through crack grouting reinforcing experiment beam damage could have the conclusion:

The ultimate destruction form of the test beam mainly about on both sides arch feet and middle arch of the concrete is crush, and test beams rebar yield failure. The crack development law of test beam could be divided into four stages: The first stage for the test load of 110 KN, which the reinforcing crack on middle arc has cracking again. The second stage for the test load of 130 KN, which the cracks on two side hance have appear. The third stage for the test load of 130KN~250KN, which the reinforcing crack develop rapidly. The fourth stage for the test load of 250KN~330KN, which the concrete on arc and hance of test beam were crushed, and the transverse cracks were appeared on arc and hance of test beam which cross on longitudinal cracks.

It takes load on test beam to appear crack, then using grouting technology to reinforcement. The crack grouting reinforcement effect shows in Figure IV. After reloaded, most hoping and diagonal bar of test beam are in tension. With the increase of load, the stresses of hoping and diagonal bar near the middle crack are increase. When the test loads go to 110KN, the reinforcing crack on middle arc has cracking again. The grouting reinforcement crack development after reload shows in Figure V.



FIGURE IV. CRACK GROUTING REINFORCEMENT EFFECT



FIGURE V. THE GROUTING REINFORCEMENT CRACK DEVELOPMENT AFTER RELOAD

In the middle stage (the test load of 110KN~190KN): When the test loads go to 130KN, the edge position on two side hance of test beam began appear cracks. And these cracks are micro-fracture, which final width is not more than 0.2 mm. The width of reinforcing crack increasing with load increase, the width of the main crack and the stress of main steel bar are linear transformation relation.

In the last stage (the test load of 190KN~330KN): When the test loads go to 190KN, the main steel bar stage in yield, the width of the main crack and the stress of main steel bar are no-linear transformation relation. The main crack develops rapidly, and it throughout the whole test beam, and there began to appear bifurcation phenomenon on the top and the end of crack. When the last of the test, the concrete of two sides arch springing and arch top are crushed. The stress of steel bars near the main crack is beyond ultimate strength. Some stress of stirrup and oblique muscle obviously decreased. The width of reinforcing middle main crack is 8mm, the width of crack near two sides arch springing upper concrete are 2~3mm, the width of micro-crack less than 0.2mm. The vault of the maximum deflection is close to 13 mm. Eventually destroy form of reinforcing middle main crack shows in Figure VI.



FIGURE VI. EVENTUALLY DESTROY FORM OF REINFORCING MIDDLE MAIN CRACK

Through the crack grouting reinforcing experiments can be obtained, the new crack is still appears in the original reinforcing crack. In the middle test stage, the middle arch appears another crack, but the new crack appears obviously lagging, it shows that the grouting reinforcement could increase the intensity significantly in the early stage. Along the direction of fracture grouting resin uniform distribution, it shows that using the crack grouting construction technology can well ensure the compactness of grouting materials. Grouting material of curing time generally need to reach more than 1 month. Because the test time is tight, curing time is only 1 weeks, the bond strength of grouting material is only 30% of the ultimate strength. So the damage cracks appear along the existing cracks in the experiments.

B. Force Analysis

The relation schema of the main reinforcement strain and test load show in Figure VII. It can be obtained that in the whole loading process, relative to the contrast test beam, the

main reinforcement strain of test beam experience two mutations, which are reinforcement crack craze and rebar stress beyond the limit. The ultimate load of reinforcing test beam is close to contrast beam. On the basis of the original damage, in the early stages of the load, the strain of the reinforced beam steel is positive, the existing concrete cracking, steel main tensile stress. When the test load at 110 KN range, steel bar strain once mutations, shows that the beam have craze, as the beam cracking, steel bar strain growing. Reinforcement beam test load in 190 KN, steel bar strain is close to 2000, smooth curve in short, the beam has to yield. Test load of 250 KN within the scope of reinforcement is a big mutation, steel bar strain, as the load increases dramatically, strengthening experimental beams reinforced is beyond limit load.

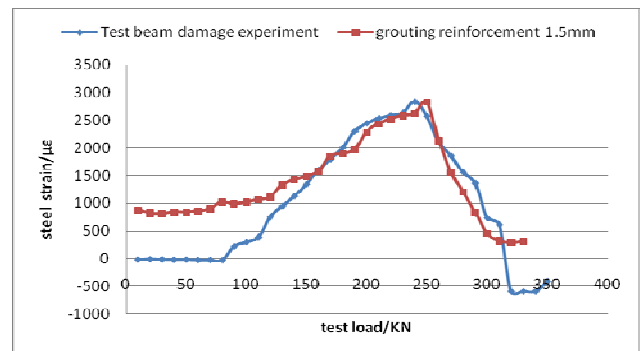


FIGURE VII. RELATION SCHEMA OF THE MAIN REINFORCEMENT STRAIN AND TEST LOAD

IV. CONCLUSION

Through experiment, it was concluded the main conclusions as follows: Through the contrast test could be obtained that, the yield load of crack grouting reinforcement test beams could increased by 6% ~ 8%, the ultimate load of test beams could increased by 4%. The main purpose of crack grouting reinforcement technology was to restore structure overall stress form, and the bearing capacity of experimental beams increase is not obvious. The research conclusions have important theoretical guiding significance for the comprehensive treatment work on the tunnel lining structure cracks ,which during the next phase.

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