Response Mechanism of Metro Tunnel Structure under Local Collapse in Loess Stratum

Junling Qiu

Chang'an University School of Highway; Key Laboratory of Urban Underground Engineering of Ministry of Education, Beijing Jiaotong University

Feifei Fan

Chang'an University School of Highway

Chengping Zhang

Key Laboratory of Urban Underground Engineering of Ministry of Education, Beijing Jiaotong University

Jinxing Lai (✉ laijinxing@chd.edu.cn)

Chang'an University School of Highway <https://orcid.org/0000-0002-1558-9482>

Ke Wang

China Railway First Survey and Design Institute Group Co Ltd

Fangyuan Niu

China Construction Silk Road Construction Investment Co Ltd; Xi'an Jiaotong University School of Human Settlements and Civil Engineering

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Abstract

Due to the frequent occurrence of large-scale water inrush accidents in metro tunnels under the condition of local collapse of loess stratum, there are few reports on the response mechanism of loess metro tunnel under the condition of local collapse. Based on the actual project of tunnel water gushing in a certain section of Xi'an Metro Line 4, the research method of combining theoretical derivation with numerical simulation is adopted, the expressions of internal force and deformation of loess metro tunnel structure under different collapsibility conditions are derived and verified by finite difference method . The results show that the development of water transport channels and the law of collapsibility morphology of loess under local collapsibility are analyzed. Based on the elastic foundation beam model, the structural response model and analytical solutions of internal force and deformation of metro tunnel under different collapsibility conditions (upper collapsibility, side collapsibility and bottom collapsibility) are derived. Combined with the actual data of water inrush accident, the calculation case of the supporting project under the upper collapsible condition is analyzed. When the water head height is 7.5 m, the internal force and deformation of the tunnel structure only occur at about 20 m of the collapsible center. The internal force and deformation of the segment in the main influence range show an obvious non-linear trend, and the strong, weak and no influence zones are defined. Moreover, the numerical simulation results are consistent with the theoretical results under the supporting conditions, which verifies that the theoretical results can effectively predict the influence range of metro tunnel structure under local collapsibility of loess stratum. This research can provide new ideas for the construction, operation and disaster prevention of metro tunnels under the condition of local collapsibility in loess stratum.

Full Text

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Tables

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Water inrush in metro tunnel caused by pipeline damage and leakage

Figure 2

Spatial pattern of water migration path in loess stratum under local collapsible environment

Figure 3

Mechanical calculation model of beam on elastic foundation. a Stress state of beam on elastic foundation. b Cross section of beam.

Figure 4

Calculation model of tunnel under upper collapsibility condition

Figure 5

Calculation model of tunnel under lateral collapse condition

Figure 6

Calculation model of tunnel under collapsibility. a Overall calculation model. b Calculation model of 1-section beam. c Calculation model of 2-section beam. d Calculation model of 3-section beam.

Figure 8

Internal force and deformation curve of tunnel structure under upper collapsible condition. a Deflection distribution of tunnel structure under upper collapsible condition. b Angle distribution of tunnel structure under upper collapsible condition. c Bending moment distribution of tunnel structure under upper collapsible condition. d Shear force distribution of tunnel structure under upper collapsible condition.

Figure 9

Overview of 3D numerical model

(a)

(b)

(c)

(d)

Figure 10

Comparison between numerical simulation and theoretical calculation of internal force and deformation of tunnel lining structure. a Comparison of deflection distribution. b Comparison of corner distribution. c Comparison of bending moment distribution. d Comparison of shear distribution.

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