Reinforcement Effect and Design Analysis Model of FRP Grid for Deformation Tunnel

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In recent years, many tunnels that have been in service for several decades have suffered damages in different degrees especially on lining concrete. In such tunnels, convergence continuously increases with the deterioration of lining concrete and surrounding rock mass, inducing the damages like cracking and spalling on lining concrete. To maintain the effective function of tunnels, a number of reinforcement methods are adopted to improve the integrity of lining concrete, typical ones of which are grouting, steel board bonding method, and carbon fiber sheet bonding method. Recently, Polymer Cement Mortar (PCM) shotcrete method using the FRP (Fiber Reinforcement Plastics) grid (the FRP-PCM method) was proposed for the purpose of reinforcement of concrete structures. The FRP grid has high strength, low weight, high workability, strong resistance to corrosion, and little influence on the existing structures. The operation and maintenance of the FRP-PCM method are fairly easy, which also adapts well to the environment of construction site of tunnel. The FRP-PCM method can improve the performance of existing concrete structures by installing FRP grid and spraying PCM on the surfaces of existing structures such as bridges, box culverts and tunnel lining. For example, if a concrete slab of a road bridge is reinforced by using the FRP-PCM method, PCM and slab will be integrated to increase the thickness of the slab, while FRP grid will help bear the tensile force, so that the total strength of the slab can be improved. The FRP-PCM method can also improve the corrosion resistance of concrete by providing a cover for the existing concrete in some harsh environments where carbonation, salt damage, alkali-aggregate reaction and so on are the mains reasons for the deterioration of concrete. At present, the construction cases for tunnel structures are still few, and the quantitative evaluation method and the rational design method of the FRP-PCM method for deformation tunnels have not been established.

In this research, a mechanical characteristic and a shear bond characteristic of the FRP-PCM method for tunnel reinforcement were established by direct shear test, and shear bonding parameters were calculated. Moreover, these shear bond parameters were input into the numerical model. Then, conducted case study for the estimation of the reinforcement effect of tunnel structures using finite different method (FDM) code of FLAC3D.

Reinforcement simulations focus on deformation factors. Then, reinforcement effects of each deformation factors were estimated from reinforcement simulation of the FRP-PCM method in deformed tunnel due to plastic pressure and loosened pressure. In particular, based on the reinforcement simulation result of deformed tunnel due to loosened pressure, the applicable condition was prepared for the FRP-PCM method.

The chapter 1 is introduction of this thesis. The present situations and problems of reinforcement method for deformed tunnels and reinforcement method using FRP grid were explained. Moreover, previous researches of reinforcement method of deformed tunnels were described.

In the chapter 2, classification and definition of the tunnel deformation were described. In particular, typical external force acting on the tunnels (plastic pressure, deviated pressure and loosened pressure) were defined, and deformed cases were shown.

In the chapter 3, the summary of the FRP-PCM method and using materials were described. Moreover, FRP-PCM test pieces combining PCM and lining concrete with FRP grid were manufactured, and direct shear tests were conducted on these test pieces to estimate the shear bond strength and the shear stiffness of the FRP grid.

In the chapter 4, the bend tests and reproduction simulations were conducted on FRP-PCM reinforced beam specimens to estimate the flexural reinforcement effect and to evaluate of reinforcement model. From reproduction simulation results, the realistic behavior can be reproduced by considering the parameters of bonding surface.

In the chapter 5, by focusing on the plastic pressure, case study considering time-dependent were conducted on the tunnel model having a back cavity, and reinforcement effect of the FRP-PCM method in deformed tunnel due to the plastic pressure was evaluated quantitatively. From simulation results, difference of reinforcement effect by reinforcement timing, reinforcement range and Srp values was elucidated, and the necessity of proper selection of reinforcement pattern or reinforcement timing was described.

In the chapter 6, by focusing on the loosened pressure, tunnel modeling technique using continuum simulation was proposed, and the effectiveness of modeling technique was verified by compared with the frame simulation. Moreover, deformation simulations due to loosened pressure by using proposed modeling technique was conducted. From simulation results, reinforcement effects were evaluated by loosened height, evaluation of rock loads, deterioration level of lining concrete, and the reinforcing index was prepared for the FRP-PCM method.

The chapter 7 is the conclusion by summarize achievement of each chapters.