Steel Fibers as Reinforcement for Precast Tunnel Segments

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Abstract

Steel Fiber Reinforced Concrete (SFRC) is a composite material with a cementitious matrix and discontinuous reinforcement (steel fibers); among the structural applications of SFRC, there is a growing interest in precast tunnel segments used with the Tunnel Boring Machine (TBM), where steel fibers may substitute, partially or totally, the conventional reinforcement.

The structural behaviour of the tunnel segments for the Line 1 of Valencia Metro (Venezuela) are numerically simulated with FE analyses using DIANA release 8.1.2.

The TBM-excavated tunnel has a diameter of about 9 m, a length of about 4 km and is located from about 11 to 21 m below the surface. The tunnel is made of 5 segments with an average length of about 4.6 m and a smaller key segment.

After the experimental characterization of the mechanical properties of Steel Fiber Reinforced Concrete (SFRC), inverse numerical analyses allowed to define bilinear laws that are used to describe the fracture properties of SFRC.

According to these laws, the total strain rotating crack model provided in DIANA was adopted for the FE simulations of the tunnel segments with different types of reinforcement under significant loading conditions.

In a previous study concerning the Line 9 of Barcelona Metro, it was demonstrated that the total reinforcement may be reduced by using an optimized combination of steel fibers and a conventional reinforcement present in two chords along the two longer sides of the segment. According to this research work, similar chords combined with steel fibers have been adopted for the Valencia Metro.

The numerical analyses were carried out by considering two significant loading conditions: (1) the temporary high compression force exerted by the 30 TBM actuators on the ring during excavation and (2) the ground-water pressure during the service conditions of the tunnel.

The numerical analyses for the first loading condition show that a splitting crack, due to a concentration of radial tensile stresses under the loading areas of the actuators, starts to open at about 1.5 times the service load. In particular, the study of the distribution of local radial stresses under the loading areas shows how locally the conventional rebars of the proposed chords works properly.

By using DIANA it was also possible to clearly demonstrate that, because the stress-redistribution along the longitudinal direction of the segment (that is made possible by the toughness provided by steel fibers), the splitting crack can propagate in a stable way until reaching the ultimate load.

The results from the tunnel under ground and water pressure (service conditions) provides some information on the role of springs often used in practice and of the different positions assumed for joints between segments.

Keywords: Precast Tunnel Segments, Steel Fiber Reinforced Concrete.