Summary

The present research on cut-and-cover tunnels gives a theoretical contribution to the understanding of the behaviour of these structures up to their ultimate limit state.

A simplified method inspired on the convergence-confinement method is investigated and applied systematically to several practical cases. This method, based on the failure mode of the structure, gives an approximate solution of the equilibrium between the soil and the structure. It enables a better understanding of the complex soil-structure mechanisms, typical of these constructions, constituting in this way a design tool.

The behaviour of the soil which interacts with the structure comprises typically two main phases. The elastic phase is followed by the progressive yielding of parts of the soil until a plastic mechanism is formed (plastic phase). Depending on the geometrical and the mechanical parameters, the structure takes more or less advantage of the soil contribution in carrying the loads.

The main conclusion of this work is the demonstration of the existence of different modes of behaviour. Three main modes of practical interest, defined mainly by the phase of the soil governing the structural behaviour, are distinguished : elastic soil, elasto-plastic soil and completely plasticized soil. The identification of the mode then enables an efficient design and analysis of the structure.

The theory of plasticity (upper bound) was applied to two soil-structure systems, a surface strip footing submitted to a centred load and a lateral wall of a frame-type cut-and-cover tunnel under construction, aiming at studying their behaviour at the ultimate limit state. This study clearly emphasizes the favourable or unfavourable role played by the soil-structure interaction in the collapse of such structural systems. A proper consideration of the structure failure kinematics is thus fundamental to a proper representation of the ultimate limit state.

A new safety format is proposed to define the ultimate limit state when the finite element method is used. This safety format is compatible with the new SIA codes of practice and clarifies the structural design procedure.

The research also showed that the structure’s ductility plays a major role in the development of the structural soil capacity. Several ductility limits are emphasized for cut-and-cover tunnels.

For frame structures, the deformation capacity of the top slab is very small if no shear reinforcement is provided in the zones of significant shear forces. Stirrups are thus recommended in these structures.

For arch structures, the spalling of the concrete cover can limit the deformation capacity of the structure. Experimental tests performed within this research showed that this phenomenon was affected negatively by plastic deformations of the steel reinforcement and by reinforcement splices and anchorages. SIA 262 (2003) code of practice design criterion is judged insufficient.

The structural design of cut-and-cover tunnels with important plastic redistributions is thus possible only if certain ductility conditions are fulfilled.

Keywords : cut-and-cover tunnel, structure, soil, backfill, compaction, soil-structure interaction, compatibility, convergence-confinement method, reinforced concrete, ductility, shear, spalling of concrete cover, test, safety format, conceptual design, dimensioning