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Consolidation Settlements over Tunnels: A Review

J.N. Shirlaw, J.R. Busbridge and X. Vi
Golder Associates
Mississauga, Ontario, Canada

Abstract:

The prediction of the magnitude and form of settlements resulting from tunnelling is a major aspect of the design of tunnels in an urban environment. Predictions are used to determine requirements for the underpinning, or other forms of protection, of adjacent buildings. Protection works can form a significant proportion of the cost of major urban tunnelling schemes, so the accuracy of the predictions can have a significant effect on project cost.

Predictions for settlement generally have some empirical basis, using data obtained from earlier tunnels driven under similar conditions. The empirical data can either be used directly as a basis for the prediction, or as a way of confirming the assumptions and simplifications inherent in numerical modelling.

Much of the empirical data for settlements over tunnels covers only the period where there was active tunnelling in progress. This data on the short term or 'immediate' settlement forms the basis of most predictions. It is known that there can be a long term component of settlement, but there is relatively much less data on the long term development of settlement over tunnels than there is for short term settlement.

The development, shape, magnitude and, to some extent, the causes of the immediate settlements are generally reasonably well understood, The settlements develop in a reverse S shaped curve as the tunnel passes under the monitoring point. (Lo et al, 1987). Measurements made orthogonally to the line of the tunnel follow an ' error function' or Gaussian curve, with the width of the curve directly related to the depth to the tunnel springline (Figure 1).

In general terms it is known that long term settlements can be significant, particularly when tunnelling in or under compressible soils. Shirlaw (1993) records examples of long term settlements where the long term component had the effect of increasing the short term settlements by up to a factor of ten, although this was unusual and more typically the increase due to long term settlements has been in the order of 30% to 100%. Generally it has been recorded that the effect of long term settlements has been to widen the settlement trough. It has also been noted that the settlement, if plotted on a logarithmic scale, typically follows a straight line, a good indication that this settlement is due to consolidation.

However, compared with the immediate settlement there is a relatively small data base of field measurements of consolidation settlements, or detailed understanding of their causes. The purpose of this paper is to compile some of the evidence on the nature and development of consolidation settlements. The majority of the evidence for consolidation around tunnels derives from long term measurements of surface settlements. The nature and development of these settlements will therefore be reviewed first, and general patterns established.

Consolidation settlements result from increased effective stresses, in turn due to reductions in pore pressures. Pore pressure measurements are therefore the best means of studying the causes of consolidation around tunnels. Strains associated with tunnelling directly affect pore pressures around the tunnel; following construction of the tunnel the groundwater regime then changes to a long term (steady state seepage) condition. Consolidation settlements

result from the change in pore pressure from the values immediately following tunnelling to the long term condition. It is therefore important to understand both the effect of tunnelling induced strains on pore pressures and the steady state condition after completion of the tunnelling. The results of some pore pressure measurements during tunnelling will be reviewed, and the general pattern compared with the surface settlement patterns. Theoretical work on the pore pressure changes associated with tunnelling will be briefly covered for comparison with the field measurements.

Keywords: Magnitude of Consolidation Settlements; Shape of the Lateral settlement trough due to Consolidation; Development of Consolidation Settlements with Time; Pore Pressure Changes Associated with Tunnelling; Theoretical Work on Pore Pressure Changes Induced by Tunnelling.