Dewatering differences

The importance of planning to avert disaster

Groundwater is not popular with tunnellers and shaft sinkers; other things being equal, most designers and contractors would prefer a 'dry' job to a 'wet' one.

Groundwater encountered during tunnelling can either be a nuisance, reducing operational efficiency and making life underground less pleasant, or it can create major problems, which can threaten the viability of a project if not handled well.

However, with careful planning and execution almost any groundwater conditions can be managed to allow successful tunnelling.

Sump pumping during shaft sinking in clay strata

GROUNDWATER AND TUNNELS

Most tunnellers and designers recognise that the presence of groundwater, even in copious quantities from permeable strata, need not be a major impediment to construction. Even so, many practitioners view groundwater control as a black art best left to the cognoscenti. This need not be the case.

Successful tunnelling requires an understanding of ground behaviour, a realistic attitude to risk and uncertainty, and the application of flexible and responsive working methods. The same approach can be successfully applied to dewatering and groundwater control.

It is useful to understand how tunnels interact with groundwater. A tunnel with an open face below groundwater level will act as a 'drain' and water will flow into the tunnel via the face, and via any unlined sections. If the rates of groundwater inflow are manageable and, importantly, do not cause instability at the face, then water can be simply managed by pumping to keep the face workably dry.

This unsophisticated approach is proven and successful in hard-rock tunnels. Bigger challenges come if the rate of water inflow is very large, or if the tunnel is in soil or soft rock that can be destabilised by groundwater seepage.

Facing these challenges, tunnellers developed technologies to effectively pressurise the tunnel to balance the external groundwater head at the face, thereby keeping the water out. The earliest technique to achieve this, developed in the 19th century, was compressed-air working where the tunnel is pressurised with air to balance the groundwater pressure.

However, there are health risks associated with operatives working in compressed air, and the use of the technique is now less common, apart from in special circumstances (such as interventions to replace cutter heads) under close medical controls.

An alternative technique, the full-face tunnel boring machine (TBM) was developed in the latter half of the 20th century. These complex machines use either the earth pressure balance (EPB) or slurry method to balance external ground and groundwater pressures and can allow a shirt-sleeve working environment in tunnels, even deep below groundwater level.

However, there are cases when the use of a full-face TBM may not be appropriate or feasible, and groundwater-control techniques may be needed to deal with potential groundwater problems in the tunnel.

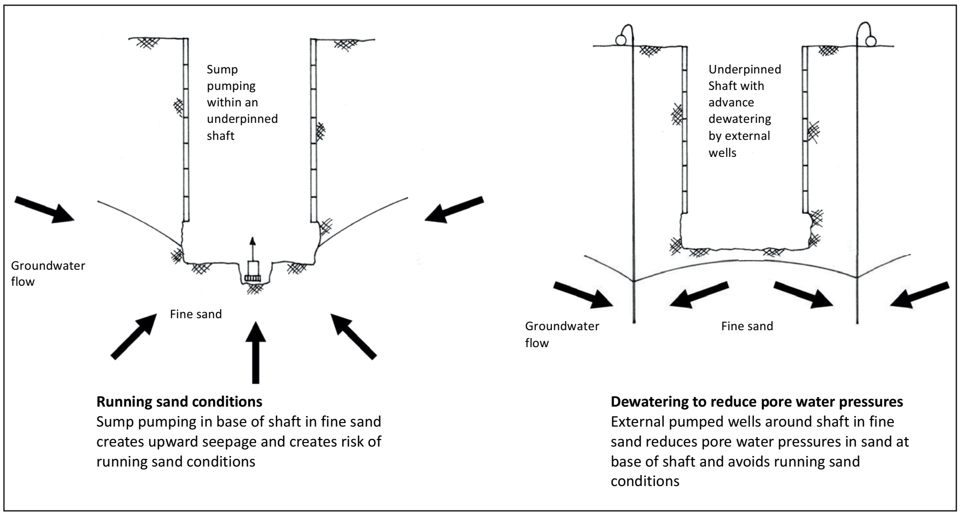
DIVERSE PROBLEMS

There is an important distinction between two different types of problem caused by groundwater. First is flooding or inundation of the tunnel by groundwater inflow. Second is face instability due to groundwater seepage.

In relatively stable ground conditions (such as fissured rock) the main challenge is to find the space to deploy pumps of sufficient capacity to handle the water, without excessively hindering excavation and lining. If inflows are too large to handle, grouting can be used to reduce the permeability of the material ahead of the face; this can reduce (but not eliminate) inflows.

However, some inflow can be good, and in hard-rock tunnels ▸

> **"Many practitioners view groundwater control as a black art best left to the cognoscenti. This need not be the case"**



Above: running sand conditions controlled by pumped-well dewatering

Above right: pumped wellpoints installed internally within tunnel for cross-passage construction

the urge to seal every inflow should be resisted, as the inflows may usefully depressurise the ground ahead of the face, and inflows to the tunnel may reduce with time.

In soils and soft rocks, face stability is the principal concern. Here even small quantities of water seeping into a tunnel face or the base of a shaft can cause significant instability and loss of ground, especially in fine-grained sands and silts.

Such unstable soils are often described as 'running sand', an evocative phrase that is an accurate description of how such material behaves. When a face is cut or an excavation is made in running sand, the exposed soil will flow or 'run' into an excavation, filling it up with fluid sand.

This is obviously a problem and is hated by tunnellers. But what is not widely realised is that running sand is not a type of material. It is actually a state in which a granular material can exist, when pore water pressures are high, causing low effective stresses, as result of which the soil looses all its strength and becomes fluid.

When this is understood, it can be seen that dewatering can reduce pore-water pressures and transform running sand into more stable ground. This approach has been widely used on the Crossrail project, where depressurisation wells drilled out from the tunnels were used to reduce pore-water pressures in layers of fine sand and silt within the Lambeth Group to prevent instability and running sand conditions.

APPROACHES TO DEWATERING

The geotechnical process commonly known as dewatering is more correctly described as groundwater control. There are two principal groups of groundwater-control technologies, as shown in the table. The first group is pumping methods, where groundwater is pumped from an array of wells or sumps to temporarily lower groundwater levels.

The second group is exclusion methods that use low-permeability cut-off walls or zones of ground treatment (such as grout curtains) to exclude groundwater from the excavation or tunnel. Pumping and exclusion methods may be used in combination.

The nature of the ground conditions, particularly the permeability of soils or rocks, is obviously an important factor in the selection of the most appropriate dewatering methods. Furthermore, for tunnelling projects, available access space and geometry are key factors.

For shafts the construction compound often allows sufficient space and surface access to install vertical dewatering wells or vertical cut-off walls or grout curtains around the shaft.

However, on many projects surface access for drilling for dewatering wells or grout curtains from above the tunnel alignment is either limited or impossible, and in most cases this precludes conventional

GROUNDWATER CONTROL METHODS

Pumping methods	Exclusion methods
• Sump pumping • Vertical wellpoints • Horizontal wellpoints • Deep wells with submersible pumps • Ejector wells • Passive relief wells • Electro-osmosis	• Steel sheet-piling • Vibrated beam walls • Cement-bentonite or soil-bentonite slurry walls • Concrete diaphragm walls • Bored pile walls • Grout curtains (permeation grouting; rock grouting; jet grouting; mix-in place methods) • Artificial ground freezing

dewatering measures drilled from surface for tunnel construction.

Where EPB or slurry TBMs are used, this does not cause a problem, because these technologies do not usually need external dewatering.

However, dewatering requirements can be much more onerous where cross-passages, tunnel enlargements or other headings are to be dug by hand or mechanical excavation. If the main tunnels are constructed by TBM, often these cross-passages and other excavations may be the only works that need dedicated groundwater control, to deal with conditions when the tunnel lining is broken out.

These can be difficult dewatering tasks, with short or irregularly shaped tunnel drives, often in areas with little ground-investigation information. In these circumstances, groundwater exclusion methods can be attractive; grouting and artificial ground freezing around cross-passages and headings have been used successfully in the past.

Groundwater drainage wells (typically pumped by a wellpoint system to give a greater lowering of groundwater pressures) can be drilled radially out from the tunnels to depressurise the surrounding soil or rock. This approach was used on several Crossrail contracts for tunnel enlargements and connections.

In conclusion, tunnellers are unlikely ever to look forward to a job where they know they will have to deal with groundwater, but there is certainly no need to fear it. With good ground investigation information to give some foresight to the likely problems, there is a good 'toolkit' of pumping and groundwater-exclusion techniques to deal with a wide range of ground conditions and tunnel geometries.

This article was written by Dr Martin Preene, dewatering specialist and groundwater engineer, Preene Groundwater Consulting

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