SOME INFORMATION ON INVESTIGATIONS
FOR THE PLANNING AND DESIGN OF ROCK EXCAVATIONS

Most types of investigations applied for underground excavations (based on: Palmström and Stille: Rock Engineering (2010)

When and where the investigation is performed			Types of Investigations
MOSTLY DURING THE PLANNING STAGES	OBSERVATIONS in outcrops, cuttings, test adits, shafts, or in existing tunnels		– Geological mapping – Engineering geological mapping – Joint survey – Core drilling and logging of drill cores – Test adit
	MEASUREMENTS AND TESTS in situ	Geophysical methods*) in surfaces, on sea or lakes, or in underground excavations	– Seismic reflection (acoustic) measurements – Bathymetric measurements – Seismic refraction measurements – Cross hole tomography measurements – Resistivity measurements – Georadar, electromagnetic measurements – Gravity measurements
		Various field measurements and tests	– Shear strength measurements of joints – Deformation measurements in excavations – Modulus measurements of rockmasses – In situ stress measurements – Hydraulic fracturing tests – Permeability tests or water loss tests – Pumping tests
	LABORATORY TESTS on samples	Measurements of geological and mechanical properties of rock samples (and, if possible, limited volumes of rockmasses)	– Mineral composition and texture – Uniaxial compressive strength – Tensile strength and point load strength – Shear strength – Elastic constants – Density, porosity, anisotropy – Durability – Slaking and swelling
DURING EXCAVATION	OBSERVATIONS AND TESTS in excavation	Mapping of ground conditions and behaviour / detection of adverse ground	– In situ stress measurements – Hydraulic fracturing tests – Permeability tests or water loss tests – Geo-observations and mapping in excavation – Probe drilling ahead of tunnel working face – Geophysical measurements ahead of face – Deformation measurements
In addition there will be investigations for maintenance during the operation of the excavation			

*) The relevance of some geophysical methods

METHOD	MAIN INFORMATION	MAIN LIMITATIONS	APPLICATION
Seismic refraction	- Thickness of soil layers - Location of ground water table - Location of rock surface - Approx. quality of rockmass	- "Blind zones" (if velocity does not increase with depth) - Side reflection	Extensively used on land and sea
Seismic reflection	- Locations of different layers (soil, rock, sea bottom, etc.) - Soil/rock structure	- "Blind zones" - Side reflection - Interpretation for great depths	Limited use (mainly used for sub-sea tunnels)
Crosshole tomography	- Rock mass quality - Karst caverns etc.	- Interpretation uncertainty	Increasingly used
Electric resistivity	- Location of ground water table/rock surface - Approx. character of weakness zones	- Interpretation - Stray current/buried metal	General use
Electromagnetic (radar)	- Location of ground water table/soil structure - Openings	- Restricted mainly to soft ground	Limited use
Magnetic	- Structural geology	- Interpretation	Minimal use
Gravitational	- Structural geology	- Interpretation	Minimal use

Schematic overview of usefulness of main field investigation methods

Method	Purpose	Geological setting and rock distribution	Rockmass qualities and distribution	Depth to rock surface	Rock or rockmass properties	Weakness zones	Rock stresses	Ground water conditions
Observations	Geological mapping	x				(x)		
	Engineering geological observations	(x)	x	-		x	-	(x)
	Joint survey	-	x					-
	Core drilling *) and logging of cores	- / (x)	x	-	(x)	x		(x)
Geophysical measurements	Bathymetric and Acoustic measurements			(x)				
	Refraction seismic measurements		(x)	x		x	-	-
	Resistivity measurements		-	(x)		(x)		
	Seismic tomography		(x)	(x)		(x)		-
Other measurements and tests	Rock stress measurements						x	
	Rockmass deformation measurement				x			
	Ground water tests and measurements							x
	Investigations during tunnel excavation**)		x	-		x		(x) / x
	Georadar measurements		(x)	(x)		(x)		-
	Optical televiewer		(x)	-		(x)		(x)
	Measurements While Drilling (MWD)		(x)	-		(x)		-

X Well suited method; (x) Method may be useful; - Method may be give some information

*) other types of boreholes, test adits, or shafts in rock may also be made for similar purposes
**) includes: probe drillings, geophysical measurements including seismic tomography

from: Palmstrom and Stille: Rock Engineering (2010)