FORTEC

GEOTECHNICAL
DIVISION

CONSTRUCTION
ENGINEERING
GEOTECHNICAL
SPECIALISTS

Fortec's Geotechnical Division is an established and valued contractor to clients in the oil and gas, mining, government, utilities, and infrastructure sectors.

Fortec Geotechnical delivers a range of specialist geotechnical and engineering solutions incorporating ground anchoring, soil nails, micro piling, dam anchoring, permeation grouting and slope stabilisation works to clients across Australia.

We have many years of experience and expertise and an extensive list of owned plant and equipment with a fully flexible and mobile workforce.

All works are performed in accordance with our Safety, Quality and Environmental Management Systems compliant with ISO 45001, ISO 9001, ISO 14001 and State Legislation requirements.

The Fortec Geotechnical Division offers total solutions and value for money and with our project management and technical experience we can ensure that projects are delivered within design requirements and to the satisfaction of our clients.

Fortec Geotechnical has developed a reputation for undertaking challenging & complex projects that require high standards of quality, environmental and safety controls.

OUR SERVICES

ANCHORING: PERMANENT & TEMPORARY

Ground anchors provide stability and support to structures and have a wide range of uses. Fortec Geotechnical can provide a design, installation service including stressing/load testing for the following applications:

- Temporary and permanent active anchor systems for a range of structures including:
  - Dams, Bridge and Wind Towers
- Temporary sheet pile and retention systems
- Dead man anchor systems
- Jetty and dolphin pile tension ground anchors

SLOPE STABILISATION

Slope stabilisation is used to secure embankments or to rectify walls and slopes that have succumbed to natural forces which require stabilization to ensure the safety of the structure and the surrounding environment.

We provide a diverse range of solutions for a variety of applications including:

- Rock fall barriers and debris flow barriers
- Soil nailing – temporary or permanent passive soil nails
- Rock bolting and FRP systems
- Shotcrete and retaining walls
- Erosion control

PERMEATION & PRESSURE GROUTING

This technique is generally used to reduce permeability and strengthen and stiffen the existing ground. The process typically consists of grout filling the accessible pores between the solid particles in the existing permeable soil. Common applications include:

- Ultra-fine cement grouting
- Void filling (under slab filling or naturally occurring voids)
- Underpinning and subsidence stabilisation
- Pressure grouting and grout curtains

MICROPILING

A micropile is a small diameter, drilled and grouted non-displacement pile that is typically reinforced. The micropile is installed by drilling a borehole, placing reinforcement and grouting the hole. Micropiles can be installed using relatively small drill rigs and equipment. Common applications include:

- Conventional bored or CFA pile redesign and alternate micropile replacement
- Micropiles can act in tension and compression
- Micropiles can be retro fit into existing structures, difficult access, or low head room where conventional bored and CFA method are not practical or economical.

MULTISTRAND ANCHORING PERMANENT & TEMPORARY

Multistrand anchoring utilises specialist materials, technology, and stressing equipment to apply a uniform force to each strand within a multistrand anchor assembly. The post tensioning of the multistrand system is undertaken after the grouted body has cured and reached a specified compressive strength. The individual strands are simultaneously jacked and locked off at the live end by wedges.

Fortec Geotechnical provides both temporary and permanent multistrand ground anchors. Depending on the design life and application multistrand anchors can be certified for a design life up to 100 years. Long term service durations are achieved by implementing HDPE corrugated plastic sheathings, hot dipped galvanised elements, anti-corrosion greases/agents, etc. Anchor capacities can range from 250kN – 25,000kN and beyond.

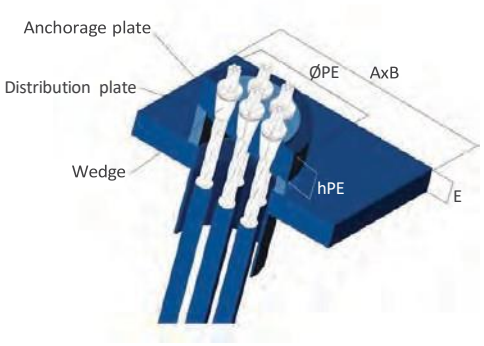
The typical system of a permanent multistrand anchor comprises of a high tensile steel element encapsulated within a HDPE corrugated sheath (physical barrier for corrosion protection). There is a bonded length and a free length. The bond length is the section of the system that is anchored into the competent ground and transfers the load into the surrounding rock/soil. The free length is constructed with the addition of a smooth wall sheathing filled with anti-corrosion grease and placed over the steel element to provide additional protection and allows elastic elongation when tensioned. The inner and outer annulus of the HDPE corrugated sheathing is simultaneously grouted to transfer load and to provide long term durability.

To completely seal and protect the anchor heads/ wedges from corrosion, hot dipped galvanised caps filled with anti-corrosion void fillers are installed after the anchors are stressed.

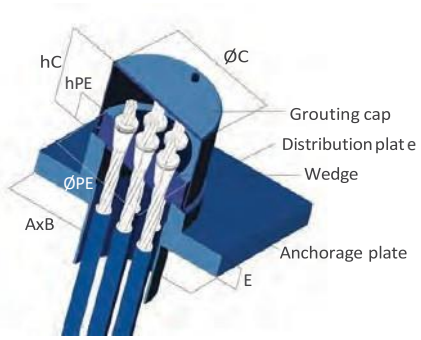
Fortec Geotechnical provides re-stress able and monitorable anchors and offers specialised anchor heads that permits the connection of load cells and monitoring equipment.
The system allows the anchor to be test loaded to determine the residual load in the anchors and allow restressing if required.

The application of the re-stressable and monitorable anchors are most commonly used in dam, bridge tunnelling construction.

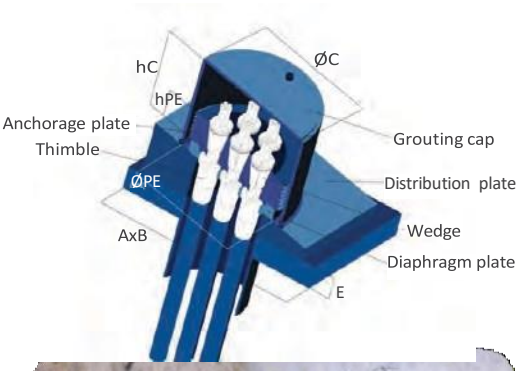
TEMPORARY ANCHOR HEAD

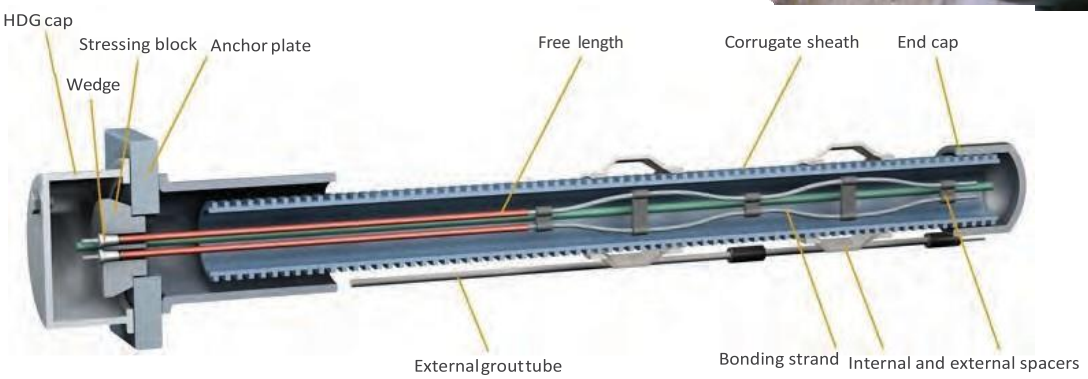


PERMANENT ANCHOR HEAD



RESTRESSABLE BEARING PLATE



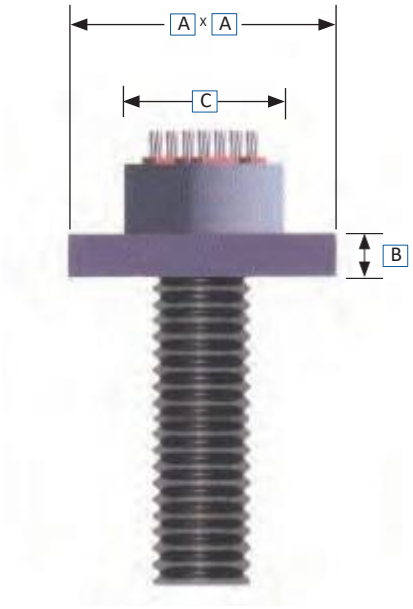


TYPICAL ANCHOR DATA

FULLY ENCAPSULATED PERMANENT GROUND ANCHORS (15.2MM STRAND)

No. of 15.2mm Strands	Ultimate Breaking Load (kN)	Safe Working Load (kN)	Bore Hole Diameter (mm)	Min. Corrugated Tube Diameter (mm)	
				ID	OD
2	522	295	100	50	65
4	1044	591	135	65	85
7	1827	1034	135	80	96
9	2349	1330	175	100	125
13	3393	1920	175	100	125
19	4959	2807	210	127	152
27	7047	3989	280	210	230
37	9657	5466	280	210	230
43	11223	6352	280	210	230
55	14355	8125	280	210	230
65	16965	9602	280	210	230
99	25839	14625	320	250	270

Note: Anchors larger than 100 x 15.2 strands are available subject to design certification. Minimum external cover is 10mm. Smooth high-density polyureethane sheath is available for the free length of tendon and load cells can be supplied for electrical and hydraulic systems. Safe working load as per AS4678.



TEMPORARY GROUND ANCHORS (15.2MM STRAND)

No. of 15.2mm Strands	Ultimate Breaking Load (kN)	Safe Working Load (kN)	Bore Hole Diameter (mm)
2	522	313	100
4	1044	626	135
7	1827	1096	135
9	2349	1409	175
13	3393	2036	175
19	4959	2975	210
27	7047	4228	280
37	9657	5794	280

PERMANENT GROUND ANCHORS BEARING PLATE & STRESSING BLOCK SIZES (15.2MM STRAND)

No. of 15.2mm Strands	Min. Bearing Plate Size	Anchor Head	
		A	B
2	180	80	60
4	200	110	60
7	300	150	75
9	350	180	90
13	400	180	90
19	450	225	110
27	500	260	135
37	550	320	158
43	600	330	160
55	680	360	190
65	700	360	190
99	Specifically designed to suit		

Note: Where the free length of tendons must be encased, dimensions vary accordingly. Jack sizes are as for the multistrand system. Anchors can be monitorable and restressable.

TEMPORARY GROUND ANCHORS (12.7MM STRAND)

No. of 12.7mm Strands	Ultimate Breaking Load (kN)	Safe Working Load (kN)	Bore Hole Diameter (mm)
2	368	220	75
4	736	440	75
7	1,288	770	90
13	2,392	1,430	100
19	3,496	2,090	125
27	4,968	2,970	150

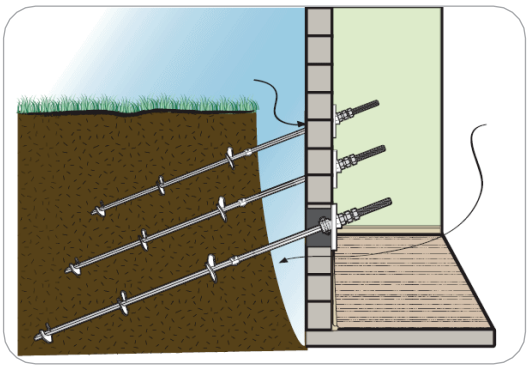
HIGH DENSITY POLYETHYLENE SINUSOIDAL DUCT

The sinusoidal duct is used to provide corrosion protection in permanent anchors and can allow for electrical isolating of rock anchors and multistrand systems.

SOIL NAILS, BAR ANCHORS, ROCK BOLTS & FIBRE REINFORCED PLASTIC (FRP)

Soil nails and bar anchors offers support to slopes or batters for stability/remedial applications such as unstable batters/slips or for excavations where batter steepening is needed. The system entails drilling a hole into a face at a declining angle from horizontal to a predetermined depth followed by the insertion of a bar placed centrally into the hole and encapsulated with cement grout.

Soil nails and bar anchors are installed in a uniform grid pattern across the batter and support/reinforce the face. The load is transferred by a cogged bar or nut and plate and typically combined into the designed surface structure (shotcrete) or ground stabilization technologies (rockfall netting or geo grids).

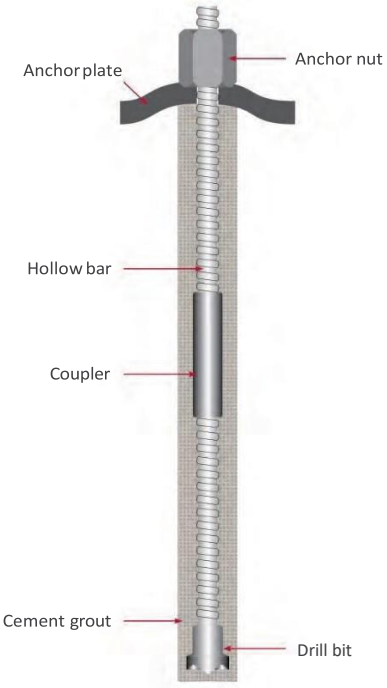


Soil nails are typically a “passive system” and bar anchors are typically an “active system”. Loads can range from 150kN – 3,690kN and beyond (dependent on bar). The Passive system is when an installed element is not stressed. The active system is when an installed element is stressed/loaded and locked off.

Depending on the design application and service life, soil nails and bar anchors can be temporary or permanent and can be certified for a design life up to 100 years. Long term service durations are achieved by implementing HDPE corrugated plastic sheathings, hot dipped galvanised elements, anti-corrosion greases/agents, etc.

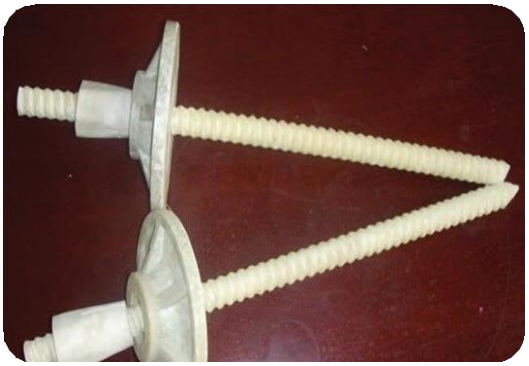
ROCK BOLTS: STANDARD & MECHNICAL

Rock bolts are used for slope stabilisation, in batters and tunneling where a steelor GFRP rod is inserted into a drilled hole in the surface or walls of a rock formation to provide support. Rock bolt reinforcement can be used in any excavation and is simple and quick to apply, and is relatively inexpensive. The installation can be fully mechanised. The length of the bolts and their spacing can be varied, depending on the reinforcement requirements.



Generally, there are three major ways of anchoring the rock bolts: mechanical, grouted, and friction. The most common form of mechanically anchored rock bolt uses an expansion shell. A wedge attached to the bolt shank is pulled into a conical expansion shell as the bolt is rotated. This forces the shell to expand against the wall of the borehole. The two mechanisms by which the shell is anchored against the borehole wall are friction and interlock. A preload can be applied to the rock surface by tensioning the bolt with an attached hanger or face plate, which are designed to distribute the load uniformly onto the surrounding rock.

The most common grout-anchored rock bolt is the fully grouted rebar, a threaded bar made of steel. Cement or resin is used as the grouting agent. A cable bolt is a reinforcing element made of steel wires in the form of a strand or rope; it is installed in the borehole with cement grout. Self-drilling and hollow bar anchors/bolts are common with the relatively easy handling and installation methods due to fully mechanized systems.



Friction-anchored rock bolts represent the most recent development in rock reinforcement techniques. Frictional resistance to sliding is generated by a radial force against the borehole wall over the whole length of the bolt.

FIBRE REINFORCED PLASTIC (FRP)

Fibreglass reinforced plastic is a continuously threaded solid bar which forms a high load carrying bar anchor or soil nail. The use of FRP soil nails or bar anchors are selected for specific requirements but typically used for temporary works for the ease of removal/future excavation though the element.

FRP systems have advantages:

- FRP is non-ferric (non-metallic) and possesses non-corrosion properties (rust and acid resistant)
- FRP eliminates electrical currents/conductivity
- FRP is light weight, easily handled and high tensile strength
- FRP is easily demolished when service is not required

TYPICAL SOIL NAIL PROPERTIES

Steel Grade 500	Nominal Diameter mm	Cross Sectional Area (mm^2)	Minimum Yield Strength (MPa)	Minimum Tensile Strength (MPa)	Yield Load (kN)	Ultimate Load (kN)	Elongation A >(%)	Liner Weight ((kg/m)
Threads are left hand Available in HDG and epoxy coated	20	314	500	600	157	188	6	2.47
	25	491	500	550	245	270	6	3.85
	28	616	500	550	308	339	6	4.83
	32	804	500	550	402	442	6	6.31
	40	1257	500	550	628	691	6	9.86
	50	1964	500	550	982	1080	6	15.41
	63.5	3167	555	550	1758	2217	6	24.86

Steel Grade 930	Nominal Diameter mm	Cross Sectional Area (mm^2)	Minimum Yield Strength (MPa)	Minimum Tensile Strength (MPa)	Yield Load (kN)	Ultimate Load (kN)	Elongation A >(%)	Liner Weight ((kg/m)
Threads are right hand Available in HDG and epoxy coated	25	491	930	1080	457	530	6	4.1
	32	804	930	1080	748	868	6	6.65
	36	1018	930	1080	947	1099	6	8.41
	40	1257	930	1080	1169	1358	6	10.34
	50	1954	930	1080	1827	2121	6	16.28

EXPANSION SHELL ROCK BOLTS

Borehole Diameter mm	Type	For Bar Sizes													Rock Quality	Length of Cone
		15F	16T	16W	18TR	20T	20W	22TR	25T	25TR	26WR	28T	28TR	30TR	32T	
33/37	2,128	●	●		●											Hard	35
34/38	2,184	●		●	●											Medium	50
34/38	2,185			●												Medium Hard	65
34/38	2,135	●	●		●											Hard	35
39/46	2,117	●	●		●	●										Hard	50
44/47	2,185				●		●	●								Medium	85
43/48	2,136	●	●		●	●		●								Hard	47
50/58	2,137	●	●		●	●		●	●	●	●	●	●	●		Hard	50
59/60	2,221								●	●	●	●	●	●	●	Hard	65

HOLLOW BAR PROPERTIES

Anchor/ Pile Type	Unit	30/16	30/11	40/20	40/16	52/26	73/56	73/53	73/45	73/35	108/78	103/51	103/43	127/103
Nominal Outside Diameter ø	mm	30	30	40	40	52	73	73	73	73	103	103	103	127
Nominal Inside Diameter ø	mm	16	11	20	16	26	56	53	45	35	78	51	43	103
Effective Cross Section A_{eff}	mm^2	340	415	730	900	1,250	1,360	1,615	2,239	2,714	3,140	5,680	6,023	3,475
Ultimate Load F_u	kN	245	320	540	660	925	1,035	1,160	1,575	1,865	2,270	3,660	4,155	2,320 [2]
Yield Point $F_{0,2,k}$	kN	190	260	425	525	730	830	970	1,270	1,430	1,800	2,670	3,398	2,030
Yield Stress $f_{0,2,k}$	N/mm^2	560	625	590	590	585	610	590	560	530	565	470	565	585
Axial Rigidity E x A [1]	10^3 kN	63	83	135	167	231	251	299	414	502	580	1,022	1,202	640
Flexural Rigidity E x I [1]	10^6 $kMmm^2$	3.7	4.6	15	17	42	125	143	178	195	564	794	838	1,163
Weight Approx.	kg/m	2.7	3.29	5.8	7.17	9.87	10.75	13.75	17.8	21.0	25.3	44.6	47.3	28.9
Standard Length	m	3	2/3/4	3/4	2/3/4	3	6.25	3	3	3	3	3	3	3
Thread Left/Right Hand	-	Left	Left	Left	Left	Left/ Right	Right	Right	Right	Right	Right	Right	Right	Right

PERMEATION & PRESSURE GROUTING

Permeation grouting can be used to solidify and to create a 'stable mass' from the existing unstable sands and other non-cohesive soils at depths.

Permeation grouting is generally carried out in defined zones utilising injecting lances inserted into the ground at desired distances. This method allows the grout to be injected at a specified location with typical depths ranging up to a few metres.

Specialist grilling rigs and equipment is often used for larger depths or as required for the specific project and ground conditions.

General purpose, microfine or ultrafine cement, sodium silicate or other chemicals (epoxy or polymer) is injected at low to medium pressures into the treatment zones at pre-determined depths and pressures. Volumes and flows are monitored to ensure that the 'flowable injected material' is acting at the required location.

The injected liquid permeates/flows through the soil/stratum to bond the particles together. It is vital to carefully set out the injection pattern to achieve full cohesion in the desired location and for its intended purpose.

Typical applications of permeation grouting are:

Existing footing/structure improvement due to settlement. Increasing the bearing capacity and/or structural nature of in-service elements.

- Void filling under subsided existing reinforced slabs and footings. Arresting any further subsidence of the structure by filling the 'space' with grout. Slabs and joints can be further pressure injected to correct and/or level sunken areas to reinstate/remediate the surface to the previous design surface level

- Ground consolidation – pre or post excavation. Prior to excavation, the known boundaries of an excavation or slope can be grouted hence providing a safe and solid face for excavation. Consolidation can reduce or eliminate the need for additional temporary shoring

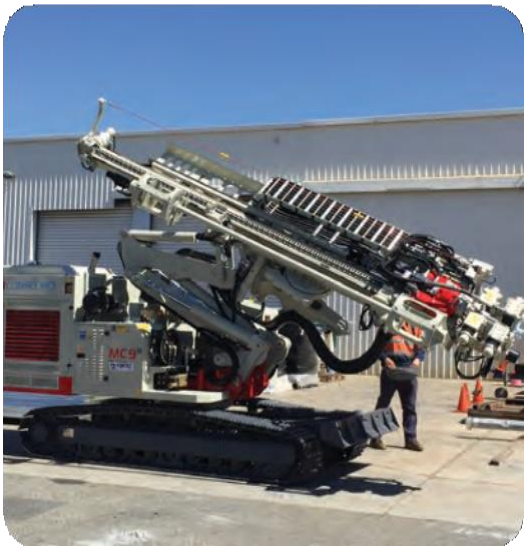
- Grout curtains/cut off walls - a grout curtain is a barrier that protects the foundation of a dam from seepage and can be made during initial construction or during repair. Additionally, they can be used to contain subterranean flows

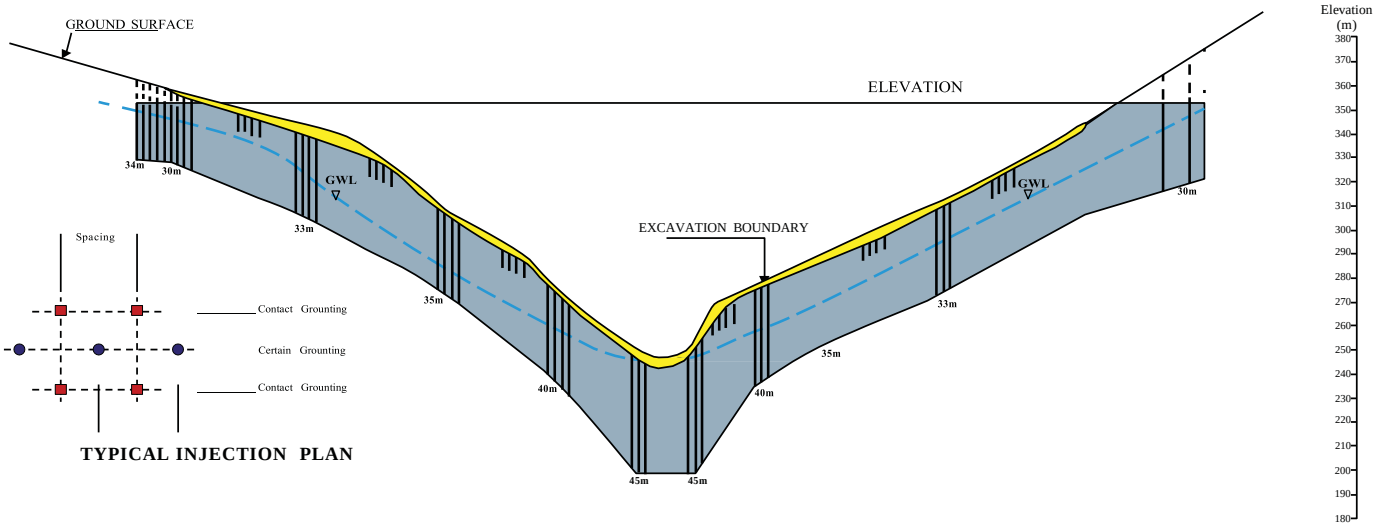
Permeation grouting is a treatment to existing strata to increase and improve strength and bearing for loads and stability. It is the injection of grout at determined and varied pressures into the soil matrix to permeate or fill the voids between individual soil particles without otherwise disturbing the natural state of the soil or increasing its volume. It is a highly cost-effective alternative to conventional shoring systems.

Permeation grouting method is used to improve a specific soil's ability to bear loads by reducing its permeability, its cohesion, the makeup of the soil, or a combination of these outcomes.

The installation methods involve placing a series of grout tubes (either sacrificial or removable) pipes in drilled holes that intersect the soil mass to be stabilized and stiffened. Generally, the grout delivery pipes are installed with one-way valves, keeping soil fluids outside the pipe but allowing the grouting mixture to get out. Grout is pumped through the sleeves into the soil under pressure. Generally, the pressure is low and constant whilst constantly monitoring pressures, flows and volumes. This results in grout permeating the spaces between the soil grains creating a solid mass and not fracturing the original strata material.

Natural and fill materials exhibit varied conditions and physical properties. Fortec creates site specific solutions for individual site characteristics and properties by evaluating the optimum grout mix to suit the soil type, cohesion, degree of soil compaction (current and desired), grain size distribution, grout set durations, equipment placement and proper pump pressure.





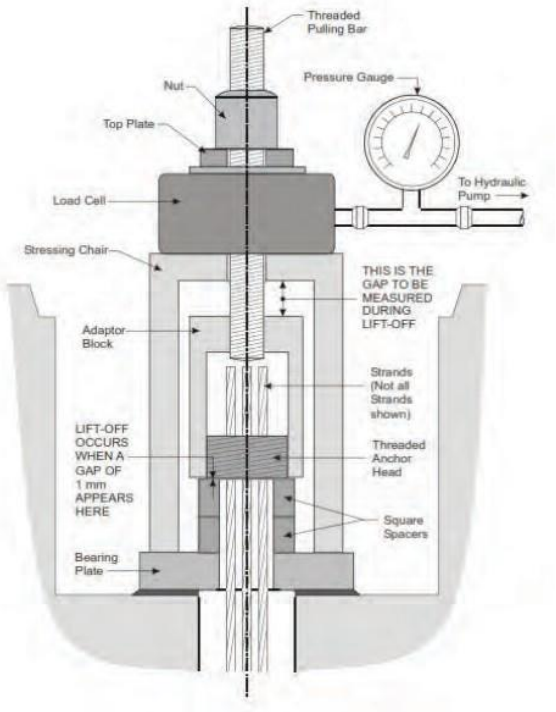
DAM INFRASTRUCTURE – MONITORING & LIFT OFF TESTING

Long term testing, maintenance and monitoring of anchored structures are another area of expertise for Fortec Geotechnical. Dependent on the project requirement and specifications, short and long term lift off testing and monitoring can be undertaken.

The use of our engineered de-stressable and re-stressable systems allow safe testing of the in-service structure. Each anchor head consists of a wedge plate with an external thread and a load bearing sleeve with an internal thread to allow adjustments of the system. Therefore, the anchor head is positioned at the required height at the same time as maintain the multistrand anchor load. Our systems provide the ability for multiple de stressing and de-stressing cycles.

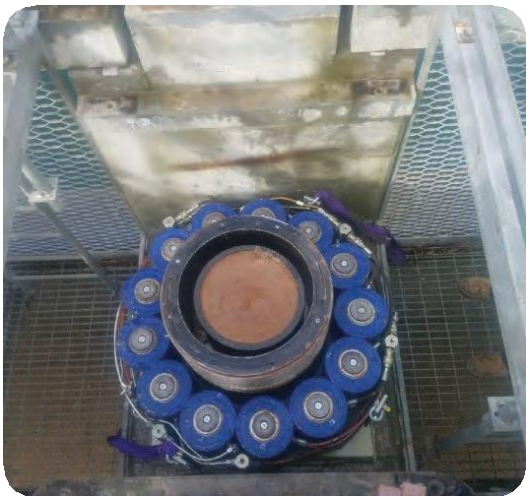
Replacement and maintenance of the corrosion protection elements are undertaken during the load mentoring stage.

Fortec Geotechnical is experienced in the implementation, integration and use of load cells and remote monitoring systems.



CASE STUDY: WELLINGTON DAM ANCHOR MONITORING

Wellington Dam is a 34m high concrete gravity dam on the Collie River south of Perth located approximately 200 kilometres east of Bunbury. The dam wall was strengthened between 2009-2011 with the installation of 40 post tensioned anchors of up to 91 strands.



Monitoring of the anchors was required to verify the residual force in the anchors after 8 years of service and additionally to visually inspect the anchorage assemblies and reapply the corrosion protection (denso grease and tape) as required.

Fortec tested 8 permanent anchors:

- 1 x 31 strand
- 1 x 55 strand
- 7 x 91 strand

The monitoring methodology was conducted using the original Canning Dam load cell in the 91 strand Load Cell configuration with 13 x 1,412 KN hydraulic cylinders with a new strand pulling barrel fabricated to suit the Wellington Dam anchorheads. The hydraulic cylinders were serviced, resealed, hydraulic hoses & fittings replaced as required and the load cell recalibrated for the project.

Project highlights:

- All works were self-performed by Fortec
- Client was able to modify existing equipment

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