GROUND ANCHORS

STRESSING AND TESTING

TYPICAL ANCHORAGES SYSTEM

2.20 length

2.20.1 fixed anchor length. The designed length of the anchorage over which the tensile load is capable of being transmitted to the surrounding ground, (see figures 19 and 22).

NOTE. This may be the same as the tendon bond length.

2.20.2 free anchor length. The distance between the proximal end of the fixed anchor and the anchor head.

2.20.3 apparent free tendon length, is calculated from the load/elastic displacement data following testing, (see **11.2.9**) to indicate the length of tendon which is apparently fully decoupled from the surrounding ground or grout.

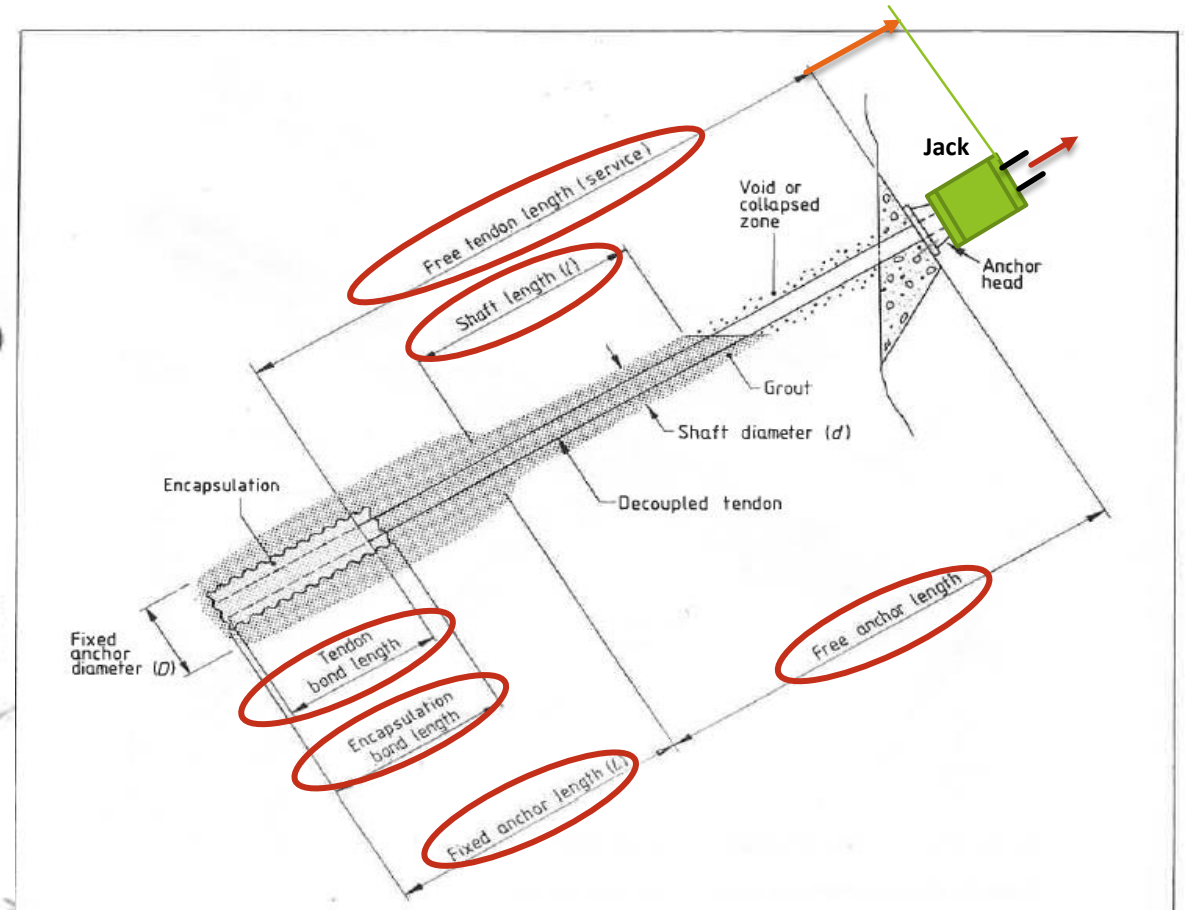
2.20.4 encapsulation bond length. The overall length of the outer perimeter of the encapsulation, which is bonded to the surrounding grout in the case of a protected anchorage.

2.20.5 shaft length. The length of grout filled hole in front of the proximal end of the fixed anchor. The grout is often placed prior to stressing and therefore is capable of mobilizing resistance to withdrawal.

2.20.6 free tendon length. The designed length of the tendon that is decoupled from the surrounding ground or grout during stressing.

NOTE. During the initial stressing operation, the free tendon length may be extended by the stressing length, depending on the type of stressing system employed (see figure 1(a)).

2.20.7 tendon bond length. The length of tendon that is bonded directly to the grout and capable of transmitting the applied tensile load.



(b) Typical anchorage in soil with fixed anchor protection

Figure 1. Ground anchorage nomenclature *(continued)*

ULTIMATE LOAD CAPACITY OF ANCHORAGE

- Dependent on the followings factors:
  - definition of failure;
  - mechanism of failure;
  - area of failure interface;
  - ground properties mobilized at failure interface;
  - stress conditions acting on the failure interface at the moment of failure.

TYPES OF ANCHORAGES

- Anchorage types refer
  - to anchorage pull-out capacity for a given ground condition is dictated by the anchorage geometry.
  - The transfer of stresses from the fixed anchor to the surrounding ground is influenced by construction technique, particularly the grouting procedure, and
  - to a lesser extent the method of drilling and flushing.
- BS8081 defines 4 anchorage types

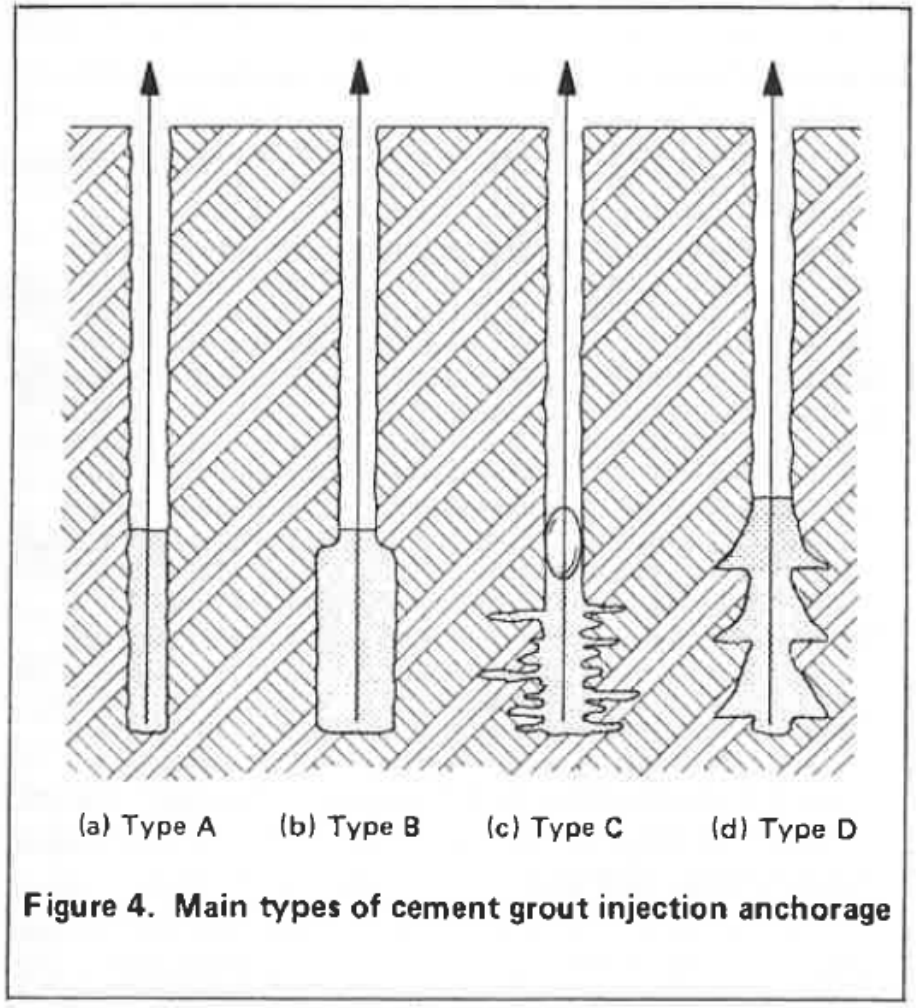


Figure 4. Main types of cement grout injection anchorage

TYPES OF ANCHORAGES

- **Type A anchorages:**
  - most commonly employed in rock and very stiff to hard cohesive soils (commonly used for anchored retaining wall system in Malaysia).
  - consists of tremie (gravity displacement) grouted straight shaft boreholes, which may be temporary lined or unlined depending on hole stability.
  - Resistance to withdrawal is dependent on side shear at the ground/grout interface.

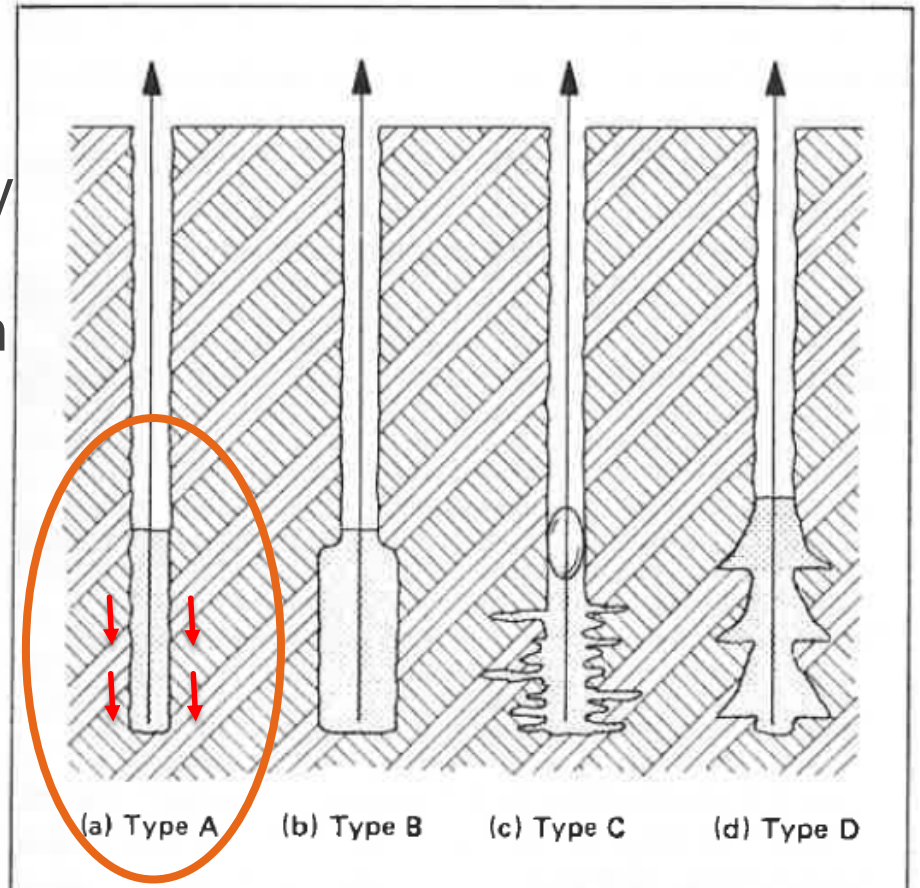


Figure 4. Main types of cement grout injection anchorage

TYPES OF ANCHORAGES

- **Type B anchorages**
  - Most commonly employed in weak fissured rocks and coarse granular alluvium, but also popular in fine grained cohesionless soils.
  - Consist of low pressure grouted boreholes via a lining tube or in-situ packer (typically grout injection with pressure <1000kN/m^2).
  - Dia. of the fixed anchor is increased with minimal disturbance as the grout permeates through the pores or natural features of the ground.
  - Resistance to withdrawal is dependent on side shear, but an end bearing component may be included when calculating the ultimate capacity.

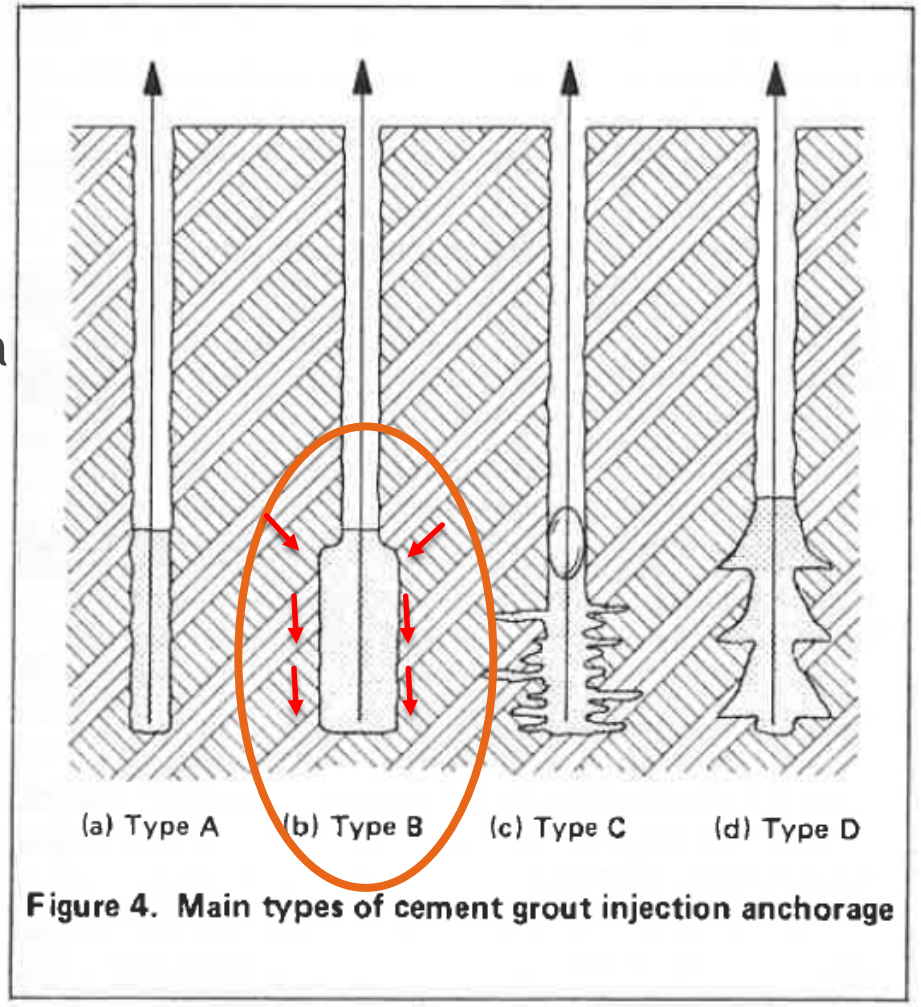


Figure 4. Main types of cement grout injection anchorage

TYPE OF ANCHORAGES

- **Type C anchorages**
  - Commonly applied in fine cohesionless soils with some success in stiff cohesive soils.
  - Consist of boreholes grouted to high pressure (typically > 2000kN/m^2), via lining tube or in situ packer, creating an enlarged fixed anchor length.
  - Fixed anchor length is enlarged by hydrofracturing of the ground mass to give a grout root or fissure system beyond the core diameter of the borehole.
  - Resistance to withdrawal is assumed uniform shear along the fixed anchor.

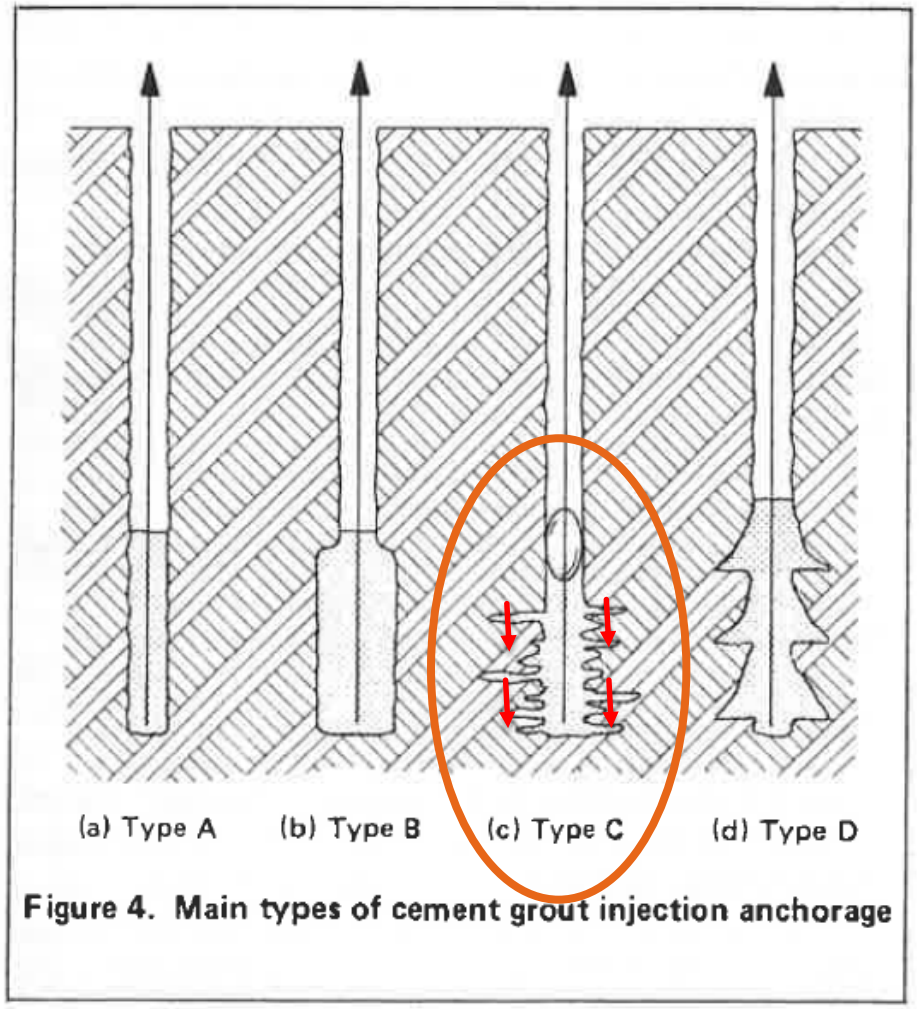


Figure 4. Main types of cement grout injection anchorage

TYPE OF ANCHORAGES

- **Type D anchorages**
  - This type is employed most commonly in firm to hard cohesive soils,
  - consist of tremie grouted boreholes in which a series of enlargements, either bells or underreams, have previously been formed.
  - Resistance to withdrawal is dependent on side shear and end bearing.

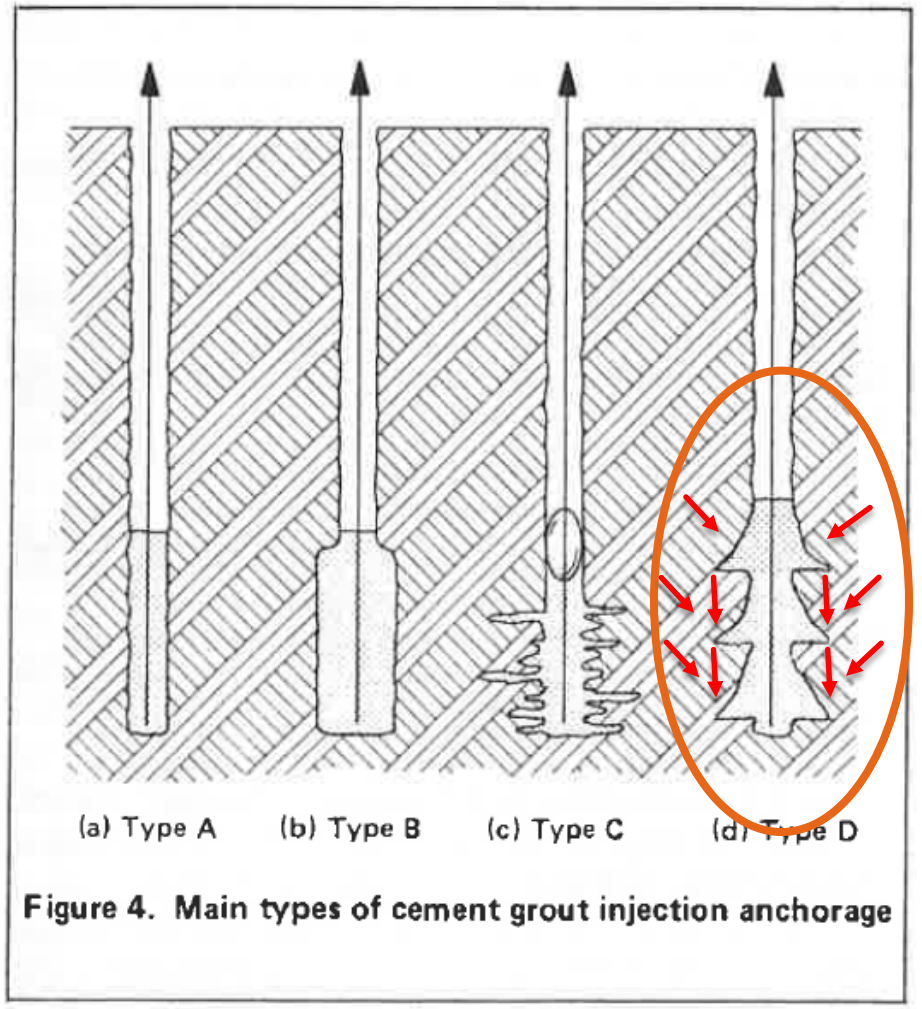


Figure 4. Main types of cement grout injection anchorage

TYPE A ANCHORAGE DESIGNS

6.2.3.2 *Type A anchorages.* For such anchorages, designs are based on the assumption of uniform bond distribution (Coates 1970), (Fargeot 1972), (Littlejohn 1972), (Mascardi 1973) and (White 1973). Thus the pull-out capacity of the fixed anchor T_f, in kN, is estimated from equation (1):

$$T_f = \pi D L \tau_{ult} \qquad (1)$$

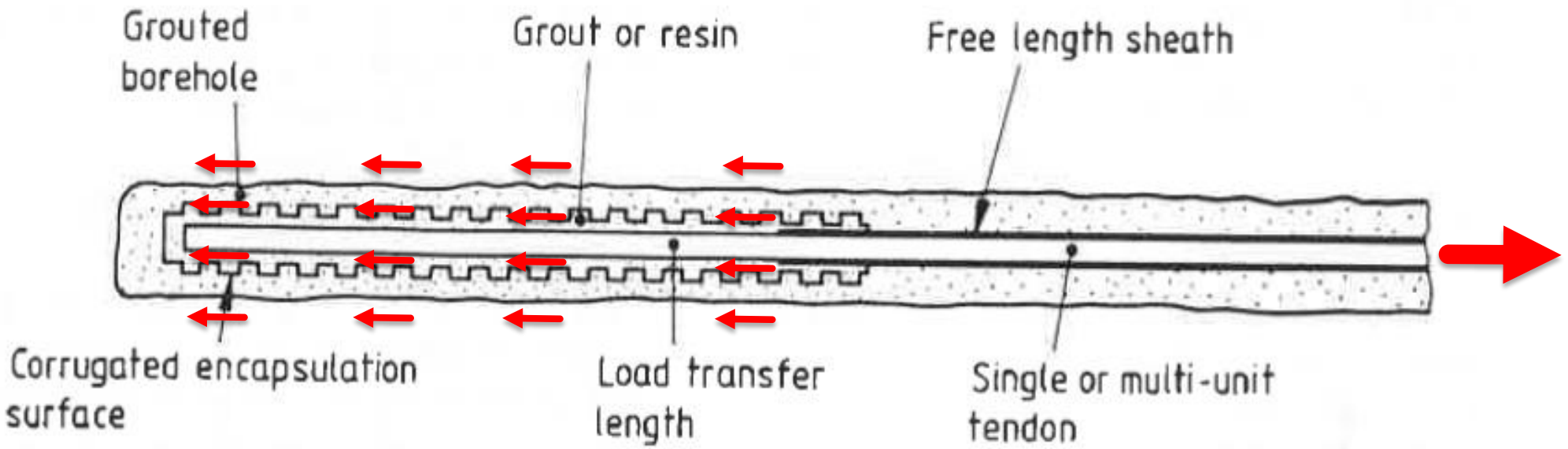
where:

τ_{ult} is the ultimate bond or skin friction at rock/grout interface (in kN/m^2);

D is the diameter of fixed anchor (in m);

L is the length of fixed anchor (in m).

TYPICAL LOAD TRANSFER MECHANISM OF ANCHORAGE



(a) Encapsulation with full length tendon load transfer

ANCHORAGE COMPONENTS

7-Wire Strands: 12.9mm, 15.2mm dia. commonly Used

Anchor Bracket & Metal Trumpet

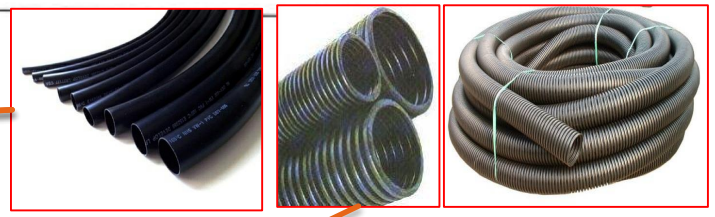
HDPE Corrugated Ducting & PVC Protective Sleeve

Anchor Blocks & Wedges

Plastic Spacers and Centralizers

TYPICAL DOUBLE PROTECTION OF BOND LENGTH

HDPE Corrugated Ducting & PVC Protective Sleeve



NOTE 1. For double protection it is essential that the polyester resin does not crack.
NOTE 2. If grout within corrugated sheath is cement based, then tendon bond length has only single protection.

Figure 19. Typical double protection of bond length of strand tendon using a single corrugated sheath and polyester resin

Plastic Spacers and Centralizers

TESTING (Clause 11)

- The testing procedures and acceptance criteria of ground anchorage complies in accordance with BS8081:1989 – "Code of practice for ground anchorage",
- BS8081:2015 (Aug.31,2015 release),
- BS8081:2015 +A1:2017 (latest) – Refer as "Code of practice for grouted anchors"
- Stressing of the ground anchors shall only be allow to commence once the compression tests on grout cubes of 100mm have achieved at least **30 Mpa** grout compressive strength.
- The BS standard required three (3) classes of tests to be performed on the anchorage as follows:
  - **On-site proving tests**, Clause 11.2
  - **on-site suitability tests**, Clause 11.3, and
  - **on-site acceptance tests**, Clause 11.4.

PROVING TESTS (Clause 11.2)

- Proving tests may be required to demonstrate or investigate to the designer, in advance of the installation of the working anchorages,
  - the quality and adequacy of the design in relation to the ground conditions and materials used in the assembly, e.g. tendons, anchor head assembly,
  - the levels of safety that the design provides , e.g. factors as load capacity, load extension behaviour, relaxation and creep.
  - Ideally tested to failure.
  - Carry out when detailed ground conditions are not known or prior experience of anchoring does not exist, or in some cases where previous anchorage knowledge is available.

ON-SITE SUITABILITY TESTS (Clause 11.3)

- **On-site suitability tests** provided in the contract are required to prove the suitability of the anchorages for the condition on site, may be applied to anchorages to be used in the works, or may be additional anchorage if allow in the contract.
- The anchorage used for the test should be constructed in exactly the same way and located in the same ground as the working anchorages and should be used as reference anchorages against which the performance of the working anchorage can be judged.
- At least the first **3 anchorages** should be subjected to suitability tests with further tests for each category of anchorages envisaged in the works. Category includes
  - Geometry, e.g. vertical or inclined
  - Ground type, e.g. clay, gravel or rock
  - Load capacity.
- The period of monitoring should be sufficient to ensure that the prestress or creep fluctuation stabilize within tolerable limits.

ON-SITE ACCEPTANCE TESTS (Clause 11.4)

- On-site acceptance tests are carried out on **all anchorages in the works**
- to demonstrate the short term ability of the anchorage to support a load that is greater than the design working load, and
- To demonstrate and assess the efficiency of load transmission to the fixed anchor zone.
- To compare the short term result with those obtained from on-site suitability tests that provide a guide to longer term behaviour.

STRESSING EQUIPMENT (Clause 9, 10.6.2)

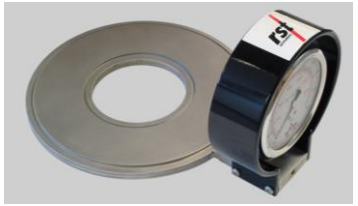
- **Hydraulic jacks**
  - commonly used are multi-strand type.
  - Should be capable of tensioning the tendon to not less than 80% of its characteristic strength and proof tested to at least 110% of its rated capacity.
  - should be initially calibrated by the manufacturer, and re-calibrated at the commencement of the project.
  - supplied with a calibration certificate for inspection at least every year using properly design test equipment with an absolute accuracy not exceeding 0.5% and the test records should tabulate the relationship between the load carried by the jack and the hydraulic pressure when the jack is in the active mode with load both increasing and decreasing.
- **Load cells**
  - Should be robust and properly protected for site work.
  - should be provided with calibration certificates and should be employed in the range 10% to 100% of its rated capacity.
  - Should be calibrated after every 200 stressings or after every 60 days use, whichever is more frequent, or yearly to provide an absolute accuracy of not exceeding 0.5%.
  - Load read-out or recording instruments should be calibrated with actual cable to be used on site.
  - The instrument should be provided with input voltage indicators, whether mains or battery operated.
- **Pressure gauge with hydraulic pumping unit**
  - should be calibrated initially against dead weight equipment or the equivalent, properly design for the works.
  - supplied with a calibration certificate for inspection.
  - Should be calibrated either after every 100 stressings or after every 30days, whichever is the more frequent, against properly maintained gauge or whenever they have been subjected to shock.
  - Pumping unit should be rated to operate through the pressure range of the stressing jack.
  - Pumping unit on which the gauge is mounted should not be more than 5m from the jack and reasonably free from vibration.
  - Maximum capacity of pressure gauges should lie within the range 80% to 160% of the characteristic strength of the tendon. **i.e. about 1,270kN to 2,550kN for 700kN anchorage**.

ANCHORS STRESSING EQUIPMENTS

Monojack, Hollow Multi-strands Hydraulic Jack

Stressing/Release Chair, Wedge Pin

Load Cells (Hydraulic, Strain Gauge or Vibrating Wire



Stressing Head & Keeper Plate

ANCHORS STRESSING AND TESTING SET-UP

TESTING (Clause 11)

- **Some common terms used in the testing include:**
  - Maximum Load = normally *80% of the characteristic strength (for proof load test)*
  - Lift-off-Load = minimum load at lift-off test.
  - Residual Load at lock-off = load remaining in the anchorage (110% of working load)
  - proof load = maximum testing load (150% working load of permanent ground anchorage)
  - Check-lifting or “lift-off” test
  - Working Load = safe load of the anchorage

2.21 load

2.21.1 lift-off load. The minimum load monitored during a restressing operation that permits a locking nut to turn on a bar tendon or provides a clearance or lift (see **10.6.3.2**) in the case of a wire or strand tendon.

2.21.2 lock-off load. The load transferred to the anchor head immediately on completion of a stressing operation.

2.21.3 proof load. The maximum test load to which the anchorage is subjected during the initial stressing phase.

2.21.4 proof load factor. The ratio of proof load to working load (see table 2).

2.21.5 residual load. The load remaining in the anchorage at any time during service.

2.21.7 working load. The safe load (T_w) of the anchorage.

2.22 mechanical anchor. A mechanical device attached to the distal end of a rock bolt which, when expanded against the sides of the borehole, generates friction to provide restraint for the tensile load.

TESTING (Clause 11)

- **Anchorage testing includes**;
  1) Load-Displacement Test – cyclic loading and unloading
     - Method 1: Plotting of Load-Displacement Data and observation of load loss at proof load, OR
     - Method 2: Plotting of Load-Time Data and observation of shortening of anchor head due to load loss at proof load.
  2) Monitoring of at Residual Load
     - Method 1: Rate of Prestress Loss, OR
     - Method 2: Rate of Displacement.
  3. Calculation of Apparent Free Tendon Length Limits

- **Main aims;**
  1. *to tension the tendon and to anchor it at its secure load,*
  2. to ascertain and record the behavior of the anchorage so that it can be compared with the behavior of control anchorages.

TESTING – (1) Load-displacement Test Clause 11.2.5, 11.3.3, 11.4.3

- Proof load is taken as **150% T_w (for on-site suitability test and on-site acceptance tests)**, for e.g. 700kN or 70tons working anchorage shall be 1,050kN or 105tons.
- But for "Proof load test" it is taken as 80% of the characteristic strength of the tendons.
- Load-displacement test.
  - Load-displacement data should be plotted continuously over the range 10%T_w to 150%T_w with load increments not greater than 50%T_w where displacements are being carefully monitored.
  - During unloading, displacements at not less than two load increments, in addition to the datum, should be measured, preferably at one third points with respect to the proof load.
    - *(Refer Table 13, 14 and Fig. 31, 32 for proof load tests)*
    - *(Refer Table 17 & Fig. 35 for on-site suitability tests);*
    - *(Refer Table 18 & Fig. 36 for on-site acceptance tests).*
- Each loading stage in the 1st cycle should be held only for the time necessary to record the displacement.
- But held for at least 1min for each stage loading in the 2nd, 3rd cycle and further cycles as requires, the displacement shall be recorded at the beginning and end of each period.
- At proof loads, this period extended to at least 15min with an intermediate displacement reading at 5min.
- On completion of the final cycle, reload in one operation to 110% T_w and lock-off. Reread the load immediately after lock-off to establish the initial residual load using Check-lift or lift-off test.
- This moment represents zero time for monitoring the load displacement-time behavior to be used for further monitoring of the Residual Load compliance.

TESTING – Recommended Loading Increments and Minimum period of Observation (Proof load tests)

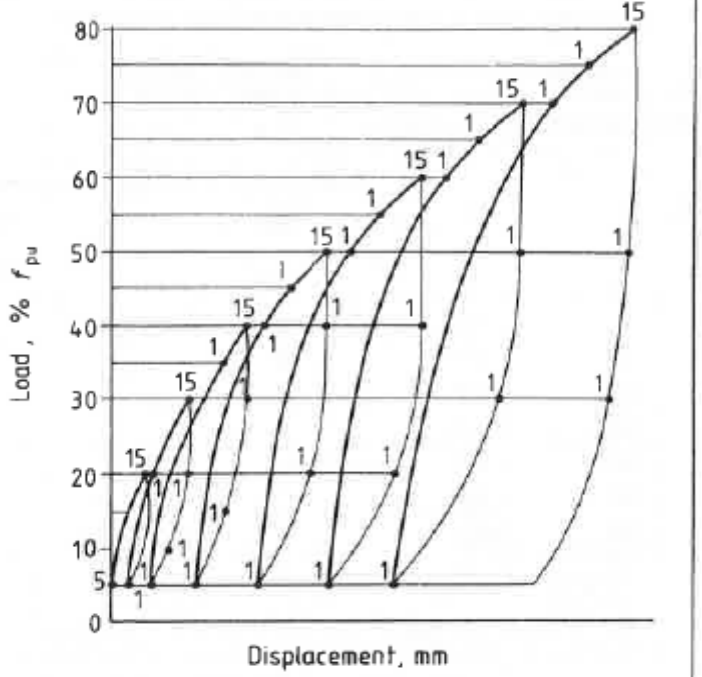


Figure 31. Recommended load increments and minimum periods of observation for proving tests on anchorages where the ground conditions are not known or prior experience of anchoring does not exist

Table 13. Recommended load increments and minimum periods of observation for proving tests on anchorages where the ground conditions are not known, or prior experience of anchoring does not exist

Load increments (% f_{pu})							Minimum period of observation
1st cycle	2nd cycle	3rd cycle	4th cycle	5th cycle	6th cycle	7th and 8th cycles	
%	%	%	%	%	%	%	min
5	5	5	5	5	5	5	1
10	20	30	40	50	60	70	1
15	25	35	45	55	65	75	1
20	30	40	50	60	70	80	15
15	20	30	40	40	50	50	1
10	10	15	20	20	30	30	1
5	5	5	5	5	5	5	1

NOTE. It is recommended that load-displacement results should be plotted as the test proceeds. In this way it should be possible at an early stage to observe trends and, in particular, the yield of the fixed anchor as failure approaches.

Table 14. Recommended load increments and minimun periods of observation for proving tests on anchorages where previous anchorage knowledge is available

Load increments (% f_{pu})		Minimum period of observation
1st cycle	2nd and 3rd cycles	
%	%	min
5	5	1
10	30	1
20	40	1
30	50	1
40	60	1
50	70	1
60	80	15
40	50	1
20	30	1
5	5	1

NOTE. As an alternative use table 17 where T_w is known.

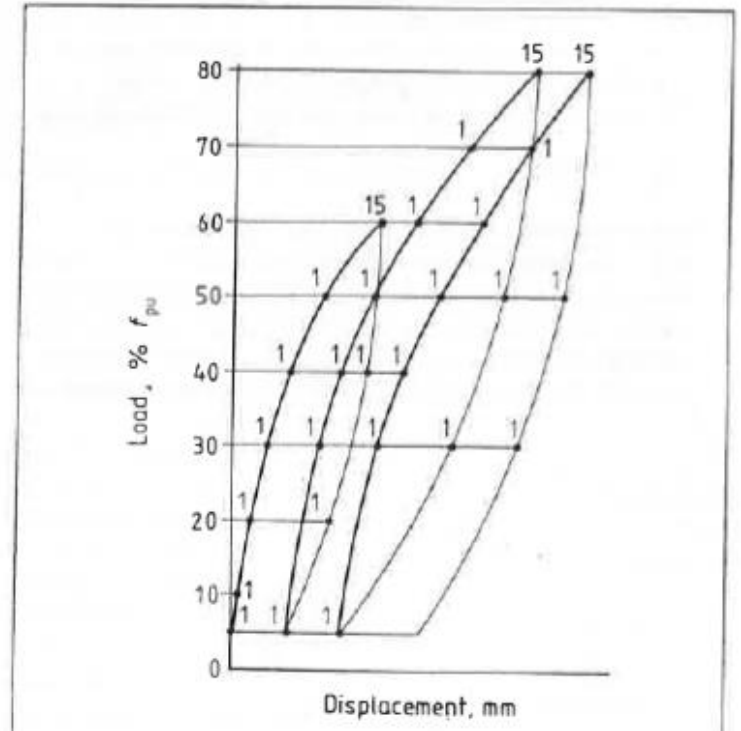


Figure 32. Recommended load increments and minimum periods of observation for proving tests on anchorages where previous anchorage knowledge is available
NOTE. As an alternative use figure 35 where T_w is known.

Proof load can taken as **80% of the characteristic strength of tendon**, for e.g. 700kN or 70tons working anchorage with 6 no. 7-wire strands shall be about 1,200kN.

TESTING – Recommended Loading Increments and Minimum period of Observation (On-site suitability and on-site acceptance tests)

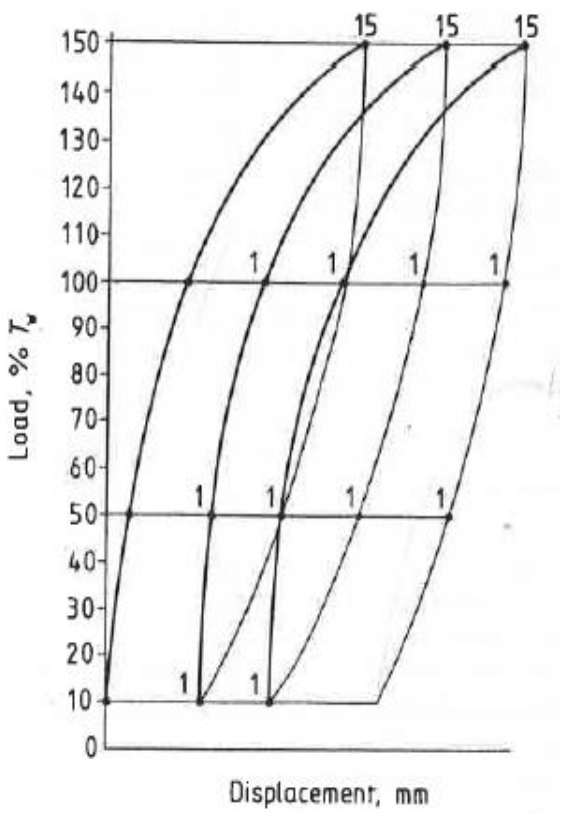


Figure 35. Recommended load increments and minimum periods of observation for on-site suitability tests

Table 17. Recommended load increments and minimum periods of observation for on-site suitability tests

Temporary anchorages load increment (% T_w)		Permanent anchorages load increment (% T_w)		Minimum period of observation
1st load cycle*	2nd and 3rd load cycles	1st load cycle*	2nd and 3rd load cycles	
%	%	%	%	min
10	10	10	10	1
50	50	50	50	1
100	100	100	100	1
125	125	150	150	15
100	100	100	100	1
50	50	50	50	1
10	10	10	10	1

* For this load cycle, there is no pause other than that necessary for the recording of displacement data.

Table 18. Recommended load increments and minimum periods of observation for on-site acceptance tests

Temporary anchorages load increment (% T_w)		Permanent anchorages load increment (% T_w)		Minimum period of observation
1st load cycle*	2nd load cycle	1st load cycle*	2nd load cycle	
%	%	%	%	min
10	10	10	10	1
50	50	50	50	1
100	100	100	100	1
125	125	150	150	15
100	100	100	100	1
50	50	50	50	1
10	10	10	10	1

* For this load cycle, there is no pause other than that necessary for the recording of displacement data.

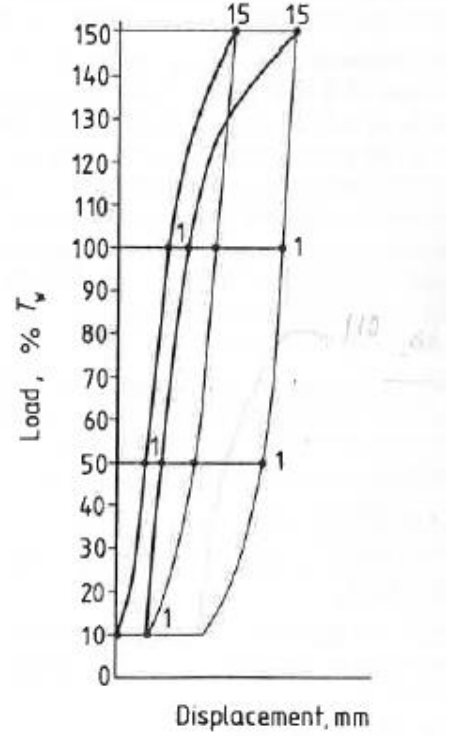


Figure 36. Recommended load increments and minimum periods of observation for on-site acceptance tests

- Proof load is taken as **150% T_w (for on-site suitability test and on-site acceptance tests)**, for e.g. 700kN or 70tons working anchorage shall be 1,050kN or 105tons.
- Commonly adopted incremental test loadings and unloadings are **20%, 50%, 100%, 150%, 100%, 50% and 20%**.

TESTING –at Proof Load Stage Clause 11.3.4, 11.4.4

- (Method 1) Proof load—time data
  - If the proof load at 150% T_w has not reduced during the 15 min by more than 5% after allowing for any temperature changes and movements of the anchored structure, the anchorage may be deemed to be satisfactory with this clause.
  - If a greater loss of prestress is recorded, the anchorage should be subjected to 2 further proof load cycles, and the behavior recorded.
  - If 5% criterion is exceeded on either cycle, the proof load should be reduced to a value at which compliance can be achieved, and the anchorage may be accepted as a lower capacity as appropriate.

- (Method 2) Displacement-time data
  - As an alternative, the proof load can be maintained by jacking, and the anchor head displacement monitored after 15min.
  - If the creep is less than 5% Δe, the anchorage may be deemed to be satisfactory.
  - If a greater displacement is recorded, the anchorage should be subjected to 2 further proof load cycles, and the behavior recorded.
  - Similarly, if 5% criterion is exceeded on either cycle, the proof load should be reduced to a value at which compliance can be achieved, and the anchorage may be accepted as a lower capacity as appropriate.

$$\Delta_e = \frac{\text{Initial residual load} \times \text{free tendon length}}{\text{Area of tendon} \times \text{elastic modulus of tendon}}$$

TESTING – at Residual Load Stage Clause 11.3.6, 11.4.6

- **(Method 1) Residual load-time data.**
  - At residual load, load-time data shall be monitored at 5min,15min and 50min, commencing at 110% T_w and continuing for 10 days (for on-site suitability test), with observation period as given in **Table 15** and using either load cell or pressure gauge.
  - Where the load has not attained a constant value after allowing for temperature, structural movements and relaxation of the tendon, the test shall be extended by monitoring at 7days intervals, approximately, for a period of up to 30 days or until the load becomes constant, whichever is the lesser period.
  - Reading within 1st 1500min or 25hrs should only be carried out using the monitoring equipment such as load cell that has a relative accuracy of at least 0.5%.
  - The rate of loss from initial residual load should reduce to 1% or less per time interval for the observation periods given in Table 15.
  - **Note:** If the rate of load loss exceed 1% for on-site acceptance test after 50min monitoring, further readings may be taken for observation up to 10 days.
  - If after 10 days, the anchorage fails to hold, the anchorage should be deemed not to comply.

Table 15. Acceptance criteria for residual load-time behaviour

Period of observation	Permissible loss of load (% initial residual load)
min	%
5	1
15	2
50	3
150	4
500*	5
1 500 (approx. 1 day)	6
5 000 (approx. 3 days)	7
15 000 (approx. 10 days)	8

* 500 min reading is not observed in routine practice.

TESTING – at Residual Load Stage Clause 11.3.6, 11.4.6

- **(Method 2) Residual Displacement-time data.**
  - At residual load, displacement-time data may be monitored at 5min,15min and 50min commencing at 110%Tw and continuing for 10 days (for on-site suitability test), with observation period as given in **Table 16** and using dial gauges and a steel rule.
  - Where the displacement has not reached a constant value after allowing for temperature, structural movements and relaxation of the tendon, the test should be extended by monitoring at 7days intervals, approximately, for a period of up to 30 days or until the displacement becomes constant, whichever is the lesser period.
  - Restressing or constant load methods may be used to monitor the displacement at initial residual load.
  - The rate of displacement should reduce to 1%Δe or less per time interval for the observation periods given in Table 16.
  - where 1% Δe is the displacement equivalent to the amount of tendon shortening caused by prestress loss of 1% initial residual load.
  - **Note:** If the rate of load loss exceed 1% for on-site acceptance test, further readings may be taken for observation up to 10 days.
  - If after 10 days, the anchorage fails to hold, the anchorage should be deemed not to comply.

Table 16. Acceptance criteria for displacement-time behaviour at residual load

Period of observation	Permissible displacement (% of elastic extension Δ_e of tendon at initial residual load)
min	%
5	1
15	2
50	3
150	4
500*	5
1 500 (approx. 1 day)	6
5 000 (approx. 3 days)	7
15 000 (approx. 10 days)	8

* 500 min reading is not observed in routine practice.

$$\Delta_e = \frac{\text{Initial residual load} \times \text{free tendon length}}{\text{Area of tendon} \times \text{elastic modulus of tendon}}$$

TESTING – Apparent Free Tendon Length

- The apparent free length of the tendon may be calculated from the load-elastic displacement curve over the testing range - **10% T_w to 150% T_w** (or proof load).
- Elastic modulus can be obtained from the manufacturer's mill certificate.
- Apparent Free Tendon Length Limits

Apparent free tendon length = $\frac{A_t E_s \Delta_e}{T}$

Where;

A_t = cross section area of the tendon

E_S = manufacturer's elastic modulus for the tendon unit

Δ_e = elastic displacement of the tendon monitored at peak cycle load minus the displacement at datum load, after allowing for structural movement

T = peak cycle load minus datum load

1

11.2.12 *Apparent free tendon length limits.* The apparent free tendon length calculated in accordance with **11.2.9** should be not less than **90 %** of the free length intended in the design nor more than the intended free length plus **50 %** of tendon bond length intended in the design or **110 %** of the intended free tendon length. The latter upper limit takes account of relatively short encapsulated tendon bond lengths and fully decoupled tendons with an end plate or nut (see figure **34**) (see also **M.11** for discussion on permanent displacement of fixed anchor where ground anchorage is subjected to cyclic loading during service).

2

3

Where the observed free tendon length falls outside the limits, a further two load cycles up to the proof load should be carried out in order to gauge reproducibility of the load-displacement data. If the anchorage behaves consistently in an elastic manner, the anchorage need not be abandoned (see **M.6** and appendix H).

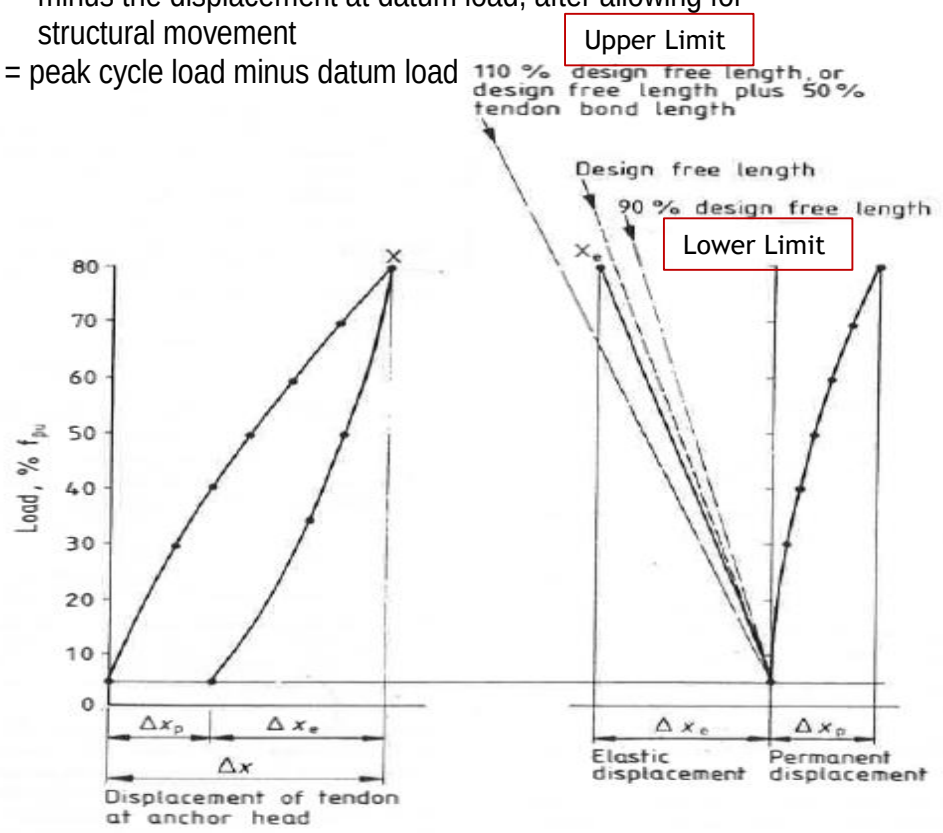


Figure 34. Acceptance criteria for displacement of tendon at anchor head

TYPICAL MILL CERTIFICATE OF PC STRANDS

Mill Test Certificate
南益預應力鋼絲
Southern PC Steel Sdn Bhd (55573-U)
No 5 Jalan Utas 15/7, Seksyen 15,
40200 Shah Alam, Selangor, Malaysia

Southern Ste.

Customer Information	WIJAYA DAYA SDN BHD LOT NO. 4-7, 8TH FLOOR, WISMA DAMAI POINT 88300 LUYANG, SABAH	Delivery To	WIJAYA DAYA SDN BHD LOT NO. 4-7, 8TH FLOOR, WISMA DAMAI POINT 88300 LUYANG, SABAH	Certificate No	300000PS794
Product Description	PC STRAND 15.24MM PL FL LHL			Date Of Issue	10.05.2013
Size	15.24 MM			PO No	PO67
Specification	ASTM A416/A 416M-2010 LOW RELAXATION			SO No	4030500620
				Delivery Order No	8030503695
				L/C No	
Container No				Quantity / No of Coils	9.994 MT / 3

	Mechanical Properties													
Batch No / No	Diameter (mm)	Section Area (mm2)	Breaking Load (kN)	Y/Strength 1% (kN)	0.2% Proof Load (kN)	Total Elongation (%)	Modulus Elasticity (kN/mm2)	Relax loss (%)						
B3095D0079	15.23	140.00	274.50	251.40	257.00	5.30	195.10	3.15						
B3095D0081	15.23	140.00	274.50	247.10	254.00	5.30	193.90	3.15						
B3095D0082	15.22	140.00	273.60	245.60	252.00	6.00	191.50	3.15						

TESTING – Assessment of Anchorages On-site Suitability Test

- The anchorage should be deemed satisfactory provided that the test results obtained from the **on-site suitability tests** for selected anchorage are in accordance with
  - Clause 11.2.12: Apparent free tendon length limits.
  - Clause 11.2.13: Rate of prestress loss,
  - Clause 11.2.14: Alternatively, rate of displacement of anchor head,
  - Clause 11.3.4: Proof load-time data – proof load not reduced after 15min observation.
  - **OR** Clause 11.3.5: Displacement load-time data at maintained proof load, creep should be less than 5% Δe after 15min observation.
  - Clause 11.3.6: Residual load-time data – permitted rate of load loss limited to 1% at 5min, 15min, 50min, 150min, 500min, 1day, 3days, 10days period of monitoring.
  - **OR** Clause 11.3.7: Displacement-time data at residual load – rate of displacement should reduce to 1% Δe or less per time interval for observation periods 5min, 15min and 50min, 150min, 500min, 1day, 3days, 10days period of monitoring.
  - Clause 11.2.15: Corrosion protection, and
  - Clauses 11.4.10 : Recommendation on Interaction of anchorage *(only for closed spaced fixed anchorages e.g. less than 1m apart)*
- **Note**: If load has not attained a constant value after 10 days, further monitoring may extend up to 30days at 7 days intervals.
- **Note**:- If the anchorages that are to be used in the works and, on satisfactory completion of the on-site suitability test, the cumulative relaxation or creep has exceed 5% initial residual load or 5%Δ_e, respectively, the anchorage should be restressed and lock-off at 110% Tw or the required design preload.

TESTING – Assessment of Anchorages On-site Acceptance Test

- The anchorage should be deemed satisfactory provided that the test results obtained from the **on-site acceptance tests** for **ALL** anchorage are in accordance with
  - Clause 11.2.12: Apparent free tendon length limits.
  - Clause 11.3.2: Achieved maximum proof load 150%Tw,
  - Clause 11.3.4: Proof load-time data – proof load not reduced after 15min observation.
  - **OR** Clause 11.3.5: Displacement load-time data at maintained proof load, creep should be less than 5%Δe after 15min observation.
  - Clause 11.4.6: Residual load-time data – rate of load loss should reduce to 1% at 5min, 15min and 50min monitoring period.
  - **OR** Clause 11.4.7: Displacement-time data at residual load – rate of displacement should reduce to 1% Δe or less per time interval for observation periods 5min, 15min and 50min.
- Note: if rate of load loss exceed 1% OR rate of displacement exceed 1% Δe , further monitoring may extend up to 10days. (Refer Table 15)
- **Note**: If the "Load-time data" or "Displacement-time data" testing is without load cell, each reading should be taken at least 3 times and results averaged in order to minimize errors, particularly where a re-stressing operation is involved.

TESTING - IN SUMMARY

On-site Suitability Tests	On-site Acceptance Tests
To be tested in advance on selected anchorage (minimum 3 nos., additional for differing type, ground condition, capacities, Inclination etc..).	To be tested in all anchorages except those already tested for on-site suitability test.
Load-Displacement Test - 3 minimum cyclic loading (from 10%/20% to 150%) and unloading test from 150% to 20%/10%), Observation period at start, 1min, 5min and 15min.	Load-Displacement Test - 2 minimum cyclic loading (from 10%/20% to 150%) and unloading test from 150% to 20%/10%), Observation period at start, 1min, 5min and 15min.
(1) If proof load reduce by more than 5% in 15min; OR (2) If displacement of anchor head exceed 5% of the Δe in 15min; Then, carry out 2 further proof load cycles and record its elastic behaviour.	(1) If proof load reduce by more than 5% in 15min; OR (2) If displacement of anchor head exceed 5% of the Δe in 15min; Then, then investigate and record diagnosis, abandon the anchorage if cannot achieved the required proof load.
If 5% criterion doesn't exceed, then proceed with the apparent free tendon length calculation.	If 5% criterion doesn't exceed, then proceed with the apparent free tendon length calculation.

TESTING - IN SUMMARY

On-site Suitability Tests	On-site Acceptance Tests
If apparent free tendon length falls outside the limits, carry out further 2 cycles up to proof load and observe its elastic behaviour.	If apparent free tendon length falls outside the limits, carry out further 2 cycles up to proof load and observe its elastic behaviour.
If anchorage behave elastically, proceed to residual load/time test for 5min, 15min and 50min and continue to 10days, may be extended upto 30 days at 7days intervals if load/time or displacement/time has not attained a constant value. (Prefer to be monitored with load cell of 0.5% accuracy)	If anchorage behave elastically, proceed to residual load/time test for 5min, 15min and 50min, may be extended for 3 days or if necessary upto 10days if load/time or displacement/time has not attained a constant value. (Can be monitored either with load cell or dial gauges of 0.5% accuracy)
Check rate of prestress loss or rate of displacement falls within allowable limits or not, then either (1) carry out creep test, if required (2) accept the anchorage or (3) reject the anchorage.	Check rate of prestress loss or rate of displacement falls within allowable limits or not, then either (1) abandon and replace or (2) reduce capacity or (3) restress the anchorage

ON-SITE SUITABILITY TEST SAMPLE RECORDS

ON-SITE SUITABILITY TESTS – 3cycles up with monitoring up to 10days

GROUND ANCHOR STRESSING RECORD (FORM GATR)Rev.3

Type of Test: ON-SITE ACCEPTANCE TEST ( ) OR ON-SITE SUITABILITY TEST (√)

PROJECT :Pembaikan Cerun Jalan Penampang-Tambunan-Keningau-Tenom, Pakej 2C

SLOPE NO. : KM56.97		ANCHOR NO. : BP-49		LEVEL NO. : L-3		DATE :	14/4/2012
Design Working Load (Tw)	: 700 KN	Dia. Of Strand (Ds)	: 15.24 mm	Tendon Length (Lt)	: 25.00 m		
Specified Preload (Tp)	: 300 KN	Area Of Strand (As)	: 140 mm^2	Bond Length (Lb)	: 6.30 m		
Proof Load (150% of Tw)	: 1050 KN	Nos. Of Strands (Ns)	: 6 nos.	Free Length (Lf)	: 17.18 m		
Angle Of Inclination	: 20 deg.	Elastic Modulus (Es)	: 200 KN/mm^2	Design Free Length	: 18.00 m		
Displacement Measurement System	: By Steel Ruler.			Jack Type / Capacity	: RHR 2508/150 tons		
Load Measurement System	: By Pressure Gauge (P.G.) [Yes] AND **Load Cell (L.C.) [Yes]						
*Effective Ram Area	: 346.5 (cm^2) 53.71 (in^2)	*Correlated Factor	: 4.18 (psi per KN)				
**Load Cell Ref. No.	: 1120219	**Gauge Factor	: 0.735 KN/digit	**Zero Reading	: 7415		

(1) APPARENT FREE LENGTH COMPLIANCE :-

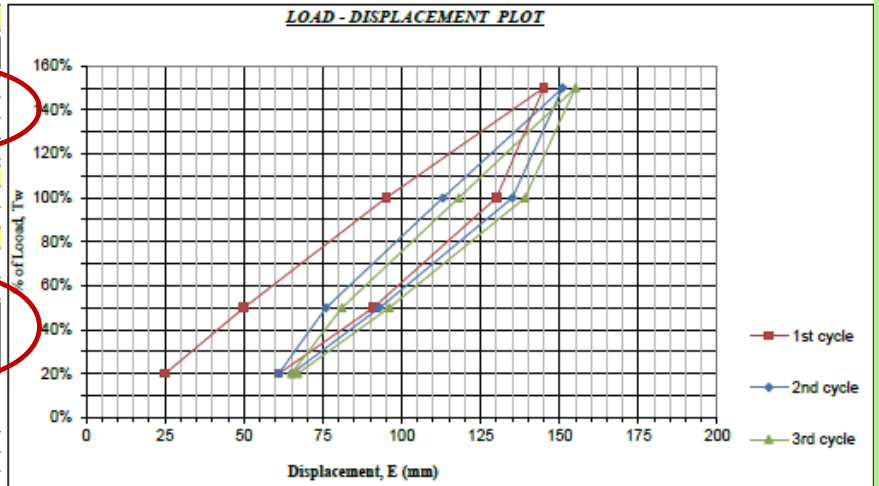
MONITORING OF "LOAD - DISPLACEMENT DATA"

Extrusion (from bearing plate) : 1.52 m

(a) Unused "Stressing" Length (*Lu) :	0.89 m	(b) Cal. Free Tendon Length (Lfs) = (Lt - Lb - Lu) :	17.81 m
(c) Min. App. Free Tendon Length (90% Lf):	15.46 m	(d) Max. App. Free Tendon Length (Lf + 50% of Lb :	20.33 m
		(e) OR Max. App. Free Tendon Length (110% of Lfs):	19.59 m

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
1st Cycle					20 (Ram displacement at zero initial reading)				
20%	144	21%	600		25	-	-	-	
50%	359	51%	1500		50	-	-	-	Plastic
100%	718	103%	3000		95	-	-	-	Disp. (ΔEp)
150%	1053	150%	4400		145	-	-	-	41 mm
100%	718	103%	3000		130	-	-	-	
50%	359	51%	1500		91	-	-	-	
20%	144	21%	600		61	-	-	-	
2nd Cycle									
20%	144	21%	600		61	61	-	-	Plastic
50%	359	51%	1500		76	76	-	-	Disp. (ΔEp)
100%	718	103%	3000		113	113	-	-	4 mm
150%	1053	150%	4400		151	151	151	151	
100%	718	103%	3000		135	135	-	-	Elastic
50%	359	51%	1500		92	93	-	-	Disp. (ΔEe)
20%	144	21%	600		65	65	-	-	86 mm

APPARENT FREE LENGTH = $\frac{(\Delta Ee \times Es \times Ns \times As)}{(\Delta Ta) \times 1000}$ = 16.26 m



(*Lu : Extruded length as measured from end plate of jack with strands straightened by the application of a minimum tension load.)

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
3rd Cycle			-	-	Note: use additional sheet if test required more than 3 cycles				
20%	144	21%	600		65	65	-	-	Plastic
50%	359	51%	1500		81	81	-	-	Disp. (ΔEp)
100%	718	103%	3000		118	118	-	-	2 mm
150%	1053	150%	4400		155	155	155	155	
100%	718	103%	3000		139	139	-	-	Elastic
50%	359	51%	1500		96	96	-	-	Disp. (ΔEe)
20%	144	21%	600		67	67	-	-	88 mm

REMARK : COMPLIED [√] / NOT COMPLIED [ ] / FAILED [ ]

(2) COMPLIANCE OF EITHER "RESIDUAL LOAD - TIME DATA" OR "DISPLACEMENT - TIME DATA" (Note: Test method depends on the accuracy of the test equipments that can measured within 0.5% change in load or displacement)

MONITORING OF "DISPLACEMENT - TIME DATA" AT DESIGN WORKING LOAD. - (Remark : The Applied Load is taken as 110% of Tw, OR otherwise as directed by Engineer.)

Time	Load (kN)	Ram Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading) Unit	kN	Loss of Load/ change in Disp. (%) Total	Interval	% Permissible (should be <1% per interval)	Remark
				6433		-	-	-	-
0 min.	722								
5 min.	720			6435.2	-1.62	-0.22%	-0.22%	1 %	O.K / Not Acceptable
15 min.	718			6438	-3.68	-0.51%	-0.29%	2 %	O.K / Not Acceptable
50 min.	717			6440	-5.15	-0.71%	-0.20%	3 %	O.K / Not Acceptable

*Note : The rate of displacement (% of Change) should reduce to 1% or less per time interval of observation period.

(4) EXTENDED RESIDUAL LOAD - TIME MONITORING (Further monitoring to be carried out on the anchor using load cell if the permissible loss of load or displacement exceed the 1% per interval as directed by the Engineer)

Time	Load (kN)	Ram Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading)		Loss of Load/ change in Disp. (%)		% Permissible (should be <1% per interval)	Remark
2 1/2 hrs.	713			6445	-8.82	-1.22%	-0.51%	4 %	O.K / Not Acceptable
8 hrs.	710			6449.3	-11.98	-1.66%	-0.44%	5 %	O.K / Not Acceptable
1 day	708			6452.2	-14.11	-1.95%	-0.30%	6 %	O.K / Not Acceptable
3 days	707			6453	-14.7	-2.04%	-0.08%	7 %	O.K / Not Acceptable
10 days	704			6456.6	-17.35	-2.40%	-0.37%	8 %	O.K / Not Acceptable

(3) ANCHOR LOCKED-OFF TEST & MEASUREMENT OF RESIDUAL LOAD. - (Remark : The Locked-Off Load is taken as 110% of Tp OR otherwise as directed by the Engineer if the load loss at lock-off is higher than 10%.)

% of Load	Load (KN)	* P.G. (psi)	** L.C. (Reading)		Ram Disp. (mm)
0%	0	0	7415		18
20% Tw	144	600	7235.2	132.2	24
110% Tp	335	1400	6974	324.1	46

RESIDUAL LOAD (By Immediate Lift-Off)		
* P.G.	1400	(psi)
** L.C.	6974	(Reading)
LOAD	324.1	(KN)

Remarks :
Δe = 76.5 mm

STRESSED BY : GONISIN SIMON (APG/Sri Jutaya)

RECORDED BY : EDWARD F. L. (COW/JWGC)

ENGINEER : CHESTER CHEE (RE/JWGC)

Calculate **APPARENT FREE TENDON LENGTH**:

- Design load, T_w= **700kN**,
- Proof load, T_p= **1050kN** (150% T_w),
- Bond length, L_b= **6.30m**,
- Free length (Stressing), L_{fs}= **17.81m**,
- $\{L_{fs} = L_t - L_b - L_u$ = 25.00 - 6.30 - 0.89}m

Apparent free length = $\frac{\Delta E_e \times Es \times Ns \times As}{(\Delta Ta) \times 1000}$ m

$L_{f\,(app)} = \frac{88 \times 200 \times 6 \times 140}{(1053-144) \times 1000}$ = **16.26m**

Limits should be between
≥ 90% L_f AND ≤ 110% L_{fs} OR ≤ {L_f + 50% L_b}
i.e. ≥ 15.46m AND ≤ 19.59m OR ≤ 20.33m

Calculate **APPLIED LOAD FROM PRESSURE GAUGE**:

- Eff. Ram area of jack= **346.5cm²**/2.54² = **53.71 in²**
- Applied stress conversion factor= Load/Area
  =2204/(53.71 x 9.81) Psi per kN
  =4.18 Psi per kN

Calculate **EQUIVALENT TENDON SHORTENING DUE TO PRESTRESS LOSS Δ_e** :

- For $T_{a\,(residual)}$ of **722kN**,
- Displacement at anchor head, Δ_e,

$\Delta_e = \frac{T_{a\,(resisual)} \times Lf \times 1000}{(A_s \times Ns) \times Es}$ mm

$= \frac{722 \times 17.81 \times 1000}{(140 \times 6) \times 200}$ = 76.5mm

1%Δ_e = 0.765mm, AND 1% load loss = 7.22kN

5%Δ_e = 3.825mm, AND 5% Load loss =36.1kN

ON-SITE SUITABILITY TESTS - 3cycles up with monitoring up to 10days

GROUND ANCHOR STRESSING RECORD (FORM GATR)Rev.3

Type of Test: ON-SITE ACCEPTANCE TEST ( ) OR ON-SITE SUITABILITY TEST (√)

PROJECT :Pembaikan Cerun Jalan Penampang-Tambunan-Keningau-Tenom, Pakej 2C

SLOPE NO. : KM56.97	ANCHOR NO. : BP-40	LEVEL NO. : L-2	DATE : 14/4/2012

Design Working Load (Tw)	: 700 KN	Dia. Of Strand (Ds)	: 15.24 mm	Tendon Length (Lt)	: 32.50 m
Specified Preload (Tp)	: 250 KN	Area Of Strand (As)	: 140 mm	Bond Length (Lb)	: 6.30 m
Proof Load (150% of Tw)	: 1050 KN	Nos. Of Strands (Ns)	: 6 nos.	Free Length (Lf)	: 24.68 m
Angle Of Inclination	: 20 deg.	Elastic Modulus (Es)	: 200 KN/mm²	Design Free Length	: 25.00 m
Displacement Measurement System	: By Steel Ruler.			Jack Type / Capacity :	RHR 2508/150 tons
Load Measurement System	: By *Pressure Gauge (P.G.) [Yes] AND **Load Cell (L.C.) [Yes]				
*Effective Ram Area	: 346.5 (cm²) 53.71 (in²)	*Correlated Factor	: 4.18 (psi per KN)		
**Load Cell Ref. No.	: 1113251	**Gauge Factor	: 0.732 KN/digit	**Zero Reading	: 7409.8

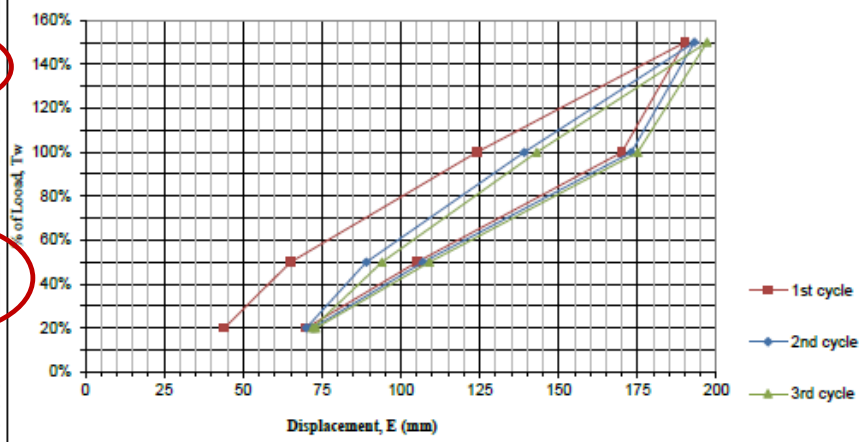
(1) APPARENT FREE LENGTH COMPLIANCE :
MONITORING OF "LOAD - DISPLACEMENT DATA"

Extrusion (from bearing plate) : 1.52 m

(a) Unused "Stressing" Length (*Lu)	: 0.86 m	(b) Cal. Free Tendon Length (Lfs) = (Lt - Lb - Lu)	: 25.34 m
(c) Min. App. Free Tendon Length (90% Lf):	22.21 m	(d) Max. App. Free Tendon Length (Lf + 50% of Lb)	: 27.83 m
		(e) OR Max. App. Free Tendon Length (110% of Lfs):	27.87 m

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
1st Cycle					41 (Ram displacement at zero initial reading)				
20%	144	21%	600		44	-	-	-	
50%	359	51%	1500		65	-	-	-	Plastic
100%	718	103%	3000		124	-	-	-	Disp. (ΔEp)
150%	1053	150%	4400		190	-	-	-	29 mm
100%	718	103%	3000		170	-	-	-	
50%	359	51%	1500		105	-	-	-	
20%	144	21%	600		70	-	-	-	
2nd Cycle									
20%	144	21%	600		70	70	-	-	Plastic
50%	359	51%	1500		89	89	-	-	Disp. (ΔEp)
100%	718	103%	3000		139	139	-	-	2 mm
150%	1053	150%	4400		193	193	193	193	
100%	718	103%	3000		173	173	-	-	Elastic
50%	359	51%	1500		107	107	-	-	Disp. (ΔEe)
20%	144	21%	600		72	72	-	-	121 mm

APPARENT FREE LENGTH = (ΔEe x Es x Ns x As) / (ΔTa) x 1000 = 22.92 m



(*Lu : Extruded length as measured from end plate of jack with strands straightened by the application of a minimum tension load.)

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
3rd Cycle			-	-	Note: use additional sheet if test required more than 3 cycles				
20%	144	21%	600		72	72	-	-	Plastic
50%	359	51%	1500		94	94	-	-	Disp. (ΔEp)
100%	718	103%	3000		143	143	-	-	1 mm
150%	1053	150%	4400		197	197	197	197	
100%	718	103%	3000		175	175	-	-	Elastic
50%	359	51%	1500		109	109	-	-	Disp. (ΔEe)
20%	144	21%	600		73	73	-	-	124 mm

REMARK : COMPLIED [√] / NOT COMPLIED [ ] / FAILED [ ]

(2) COMPLIANCE OF EITHER "RESIDUAL LOAD - TIME DATA" OR "DISPLACEMENT - TIME DATA" (Note: Test method depends on the accuracy of the test equipments that can measured within 0.5% change in load or displacement)

MONITORING OF "DISPLACEMENT - TIME DATA" AT DESIGN WORKING LOAD. - (Remark : The Applied Load is taken as 110% of Tw, OR otherwise as directed by Engineer.)

Time	Load (kN)	Ram Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading) Unit	kN	Loss of Load/ change in Disp. (%) Total	Interval	% Permissible (should be <1% per interval)	Remark
									-
0 min.	730			6412		-	-	-	-
5 min.	728			6415.9	-2.85	-0.39%	-0.39%	1 %	O.K / Not Acceptable
15 min.	726			6417.6	-4.1	-0.56%	-0.17%	2 %	O.K / Not Acceptable
50 min.	728			6415.4	-2.49	-0.34%	0.22%	3 %	O.K / Not Acceptable

*Note : The rate of displacement (% of Change) should reduce to 1% or less per time interval of observation period.

(4) EXTENDED RESIDUAL LOAD - TIME MONITORING (Further monitoring to be carried out on the anchor using load cell if the permissible loss of load or displacement exceed the 1% per interval as directed by the Engineer)

Time	Load (kN)	Ram Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading)		Loss of Load/ change in Disp. (%)		% Permissible (should be <1% per interval)	Remark
2 1/2 hrs.	726			6417.9	-4.319	-0.59%	-0.25%	4 %	O.K / Not Acceptable
8 hrs.	725			6418.8	-4.978	-0.68%	-0.09%	5 %	O.K / Not Acceptable
1 day	725			6419.2	-5.27	-0.72%	-0.04%	6 %	O.K / Not Acceptable
3 days	727			6416.6	-3.367	-0.46%	0.26%	7 %	O.K / Not Acceptable
10 days	728			6414.6	-1.903	-0.26%	0.20%	8 %	O.K / Not Acceptable

(3) ANCHOR LOCKED-OFF TEST & MEASUREMENT OF RESIDUAL LOAD. - (Remark : The Locked-Off Load is taken as 110% of Tp OR otherwise as directed by the Engineer if the load loss at lock-off is higher than 10%.)

% of Load	Load (KN)	* P.G. (psi)	** L.C. (Reading)		Ram Disp. (mm)
0%	0	0	7409.8		25
20% Tw	144	600	7253.9	114.1	39
110% Tp	287	1200	7057	258.2	56

RESIDUAL LOAD (By Immediate Lift-Off)		
* P.G.	1200	(psi)
** L.C.	7057	(Reading)
LOAD	258.2	(KN)

Remarks : Δe = 110.1 mm

STRESSED BY : GONISIN SIMON (APG/Sri Jutaya)

RECORDED BY : EDWARD F. L. (COW/JWGC)

ENGINEER : CHESTER CHEE (RE/JWGC)

Calculate **APPARENT FREE TENDON LENGTH**:

- Design load, T_w= **700kN**,
- Proof load, T_p= **1050kN** (150% T_w),
- Bond length, L_b= **6.30m**,
- Free length (Stressing), L_{fs}= **25.34m**,
- {L_{fs}= $L_t - L_b - L_u$ = 32.50 - 6.30 - 0.86}m

Apparent free length = $\frac{\Delta E_e \times Es \times Ns \times As}{(\Delta Ta) \times 1000}$ m

$L_{f\,(app)} = \frac{124 \times 200 \times 6 \times 140}{(1053-144) \times 1000}$ = **22.92m**

Limits should be between
≥ 90% L_f AND ≤ 110% L_{fs} OR ≤ {L_f + 50% L_b}
i.e. ≥ 22.21m AND ≤ 27.87m OR ≤ 27.83m

Calculate **APPLIED LOAD FROM PRESSURE GAUGE**:

- Eff. Ram area of jack= **346.5cm²**/2.54² = **53.71 in²**
- Applied stress conversion factor= Load/Area
  =2204/(53.71 x 9.81) Psi per kN
  =4.18 Psi per kN

Calculate **EQUIVALENT TENDON SHORTENING DUE TO PRESTRESS LOSS Δ_e** :

- For $T_{a\,(residual)}$ of **730kN**,
- Displacement at anchor head, Δ_e,

$\Delta_e = \frac{T_{a\,(resisual)} \times Lf \times 1000}{(A_s \times Ns) \times Es}$ mm

$= \frac{730 \times 25.34 \times 1000}{(140 \times 6) \times 200}$ = 110.1mm

1%Δ_e = 1.101mm, AND 1% load loss = 7.30kN

5%Δ_e = 5.505mm, AND 5% Load loss =36.5kN

ON-SITE ACCEPTANCE TEST SAMPLE RECORDS

ON-SITE ACCEPTANCE TESTS - 2cycles up with monitoring up to 50 minutes

GROUND ANCHOR STRESSING RECORD (FORM GATR)Rev.3

Type of Test: ON-SITE ACCEPTANCE TEST (√) OR ON-SITE SUITABILITY TEST ( )

PROJECT : Pembaikan Cerun Jalan Penampang-Tambunan-Keningau-Tenom, Pakej 2C

SLOPE NO. : KM56.97	ANCHOR NO. : BP-6	LEVEL NO. : L-1	DATE : 8/11/2011		
Design Working Load (Tw) : 700 KN	Dia. Of Strand (Ds) : 15.24 mm		Tendon Length (Lt) : 20.00 m		
Specified Preload (Tp) : 250 KN	Area Of Strand (As) : 140 mm²		Bond Length (Lb) : 6.30 m		
Proof Load (150% of Tw) : 1050 KN	Nos. Of Strands (Ns) : 6 nos.		Free Length (Lf) : 12.73 m		
Angle Of Inclination : 20 deg.	Elastic Modulus (Es) : 200 KN/mm²		Design Free Length : 13.00 m		
Displacement Measurement System : By Steel Ruler.			Jack Type / Capacity : RHR 2508/150 tons		
Load Measurement System : By *Pressure Gauge (P.G.)	[Yes] AND **Load Cell (L.C.) [ ]				
*Effective Ram Area : 346.5 (cm²)	53.71 (in²) *Correlated Factor :	4.18 (psi per KN)			
**Load Cell Ref. No.	**Gauge Factor :	KN/digit	**Zero Reading :		

(1) APPARENT FREE LENGTH COMPLIANCE - MONITORING OF "LOAD - DISPLACEMENT DATA"

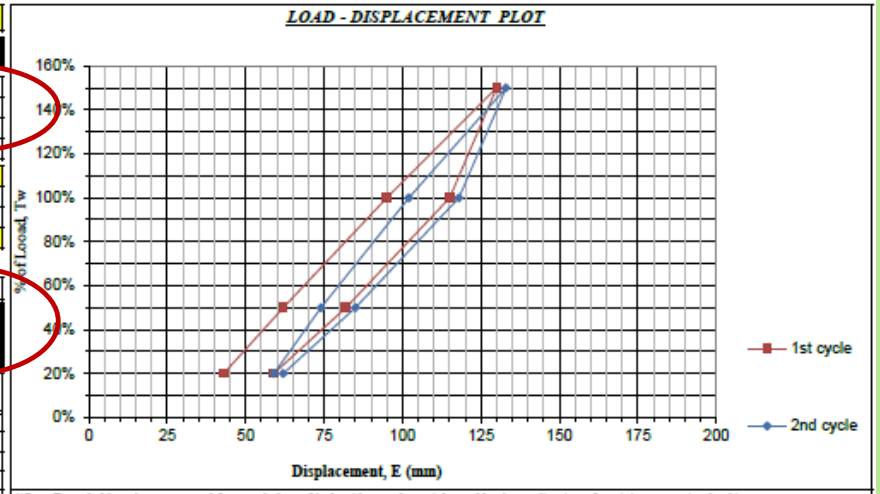
Extrusion (from bearing plate) : 0.97 m

(a) Unused "Stressing" Length (*Lu) : 0.28 m	(b) Dal. Free Tendon Length (Lfs) = (Lt - Lb - Lu) : 13.42 m		
(c) Min. App. Free Tendon Length (90% Lf): 11.46 m	(d) Max. App. Free Tendon Length (Lf + 50% of Lb) : 15.88 m		
	(e) OR Max. App. Free Tendon Length (110% of Lfs): 14.76 m		

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
1st Cycle					36 (Ram displacement at zero initial reading)				
20%	144	21%	600		43	-	-	-	
50%	359	51%	1500		62	-	-	-	Plastic
100%	718	103%	3000		95	-	-	-	Disp. (ΔEp)
150%	1053	150%	4400		130	-	-	-	23 mm
100%	718	103%	3000		115	-	-	-	
50%	359	51%	1500		82	-	-	-	
20%	144	21%	600		59	-	-	-	
2nd Cycle									
20%	144	21%	600		59	59	-	-	Plastic
50%	359	51%	1500		74	74	-	-	Disp. (ΔEp)
100%	718	103%	3000		102	102	-	-	3 mm
150%	1053	150%	4400		133	133	133	133	
100%	718	103%	3000		118	118	-	-	Elastic
50%	359	51%	1500		86	86	-	-	Disp. (ΔEe)
20%	144	21%	600		62	62	-	-	71 mm

APPARENT FREE LENGTH = (ΔEe x Es x Ns x As) / (ΔTa) x 1000 = 13.12 m

REMARK : COMPLIED [√] / NOT COMPLIED [ ] / FAILED [ ]



(*Lu : Extruded length as measured from end plate of jack with strands straightened by the application of a minimum tension load.)

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
3rd Cycle					Note: use additional sheet if test required more than 3 cycles				
20%	0	0%					-	-	Plastic
50%	0	0%					-	-	Disp. (ΔEp)
100%	0	0%					-	-	0 mm
150%	0	0%							
100%	0	0%					-	-	Elastic
50%	0	0%					-	-	Disp. (ΔEe)
20%	0	0%					-	-	0 mm

(2) COMPLIANCE OF EITHER "RESIDUAL LOAD - TIME DATA" OR "DISPLACEMENT - TIME DATA" (Note: Test method depends on the accuracy of the test equipments that can measured within 0.5% change in load or displacement)

(4) EXTENDED RESIDUAL LOAD - TIME MONITORING (Further monitoring to be carried out on the anchor using load cell if the permissible loss of load or displacement exceed the 1% per interval as directed by the Engineer)

MONITORING OF "DISPLACEMENT - TIME DATA" AT DESIGN WORKING LOAD. - (Remark : The Applied Load is taken as 110% of Tw, OR otherwise as directed by Engineer.)

Time	Load		Ram Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading)		Loss of Load/ change in Disp. (%)		% Permissible (should be <1% per interval)	Remark
	psi	kN	62		mm	mm	Total	Interval	-	-
0 min.	3200	766	109	47	27		-	-	-	-
5 min.	3200	766	109	47	27.14	0.14	0.23%	0.23%	1 %	O.K./ Not Acceptable
15 min.	3200	766	109	47	27.5	0.5	0.82%	0.59%	2 %	O.K./ Not Acceptable
50 min.	3200	766	109	47	27.75	0.75	1.23%	0.41%	3 %	O.K./ Not Acceptable

* Note : The rate of displacement (% of Change) should reduce to 1% or less per time interval of observation period.

Time	Load		Ram Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading)		Loss of Load/ change in Disp. (%)		% Permissible (should be <1% per interval)	Remark
2 1/2 hrs.									4 %	O.K./ Not Acceptable
8 hrs.									5 %	O.K./ Not Acceptable
1 day									6 %	O.K./ Not Acceptable
3 days									7 %	O.K./ Not Acceptable
10 days									8 %	O.K./ Not Acceptable

(3) ANCHOR LOCKED-OFF TEST & MEASUREMENT OF RESIDUAL LOAD. - (Remark : The Locked-Off Load is taken as 110% of Tp OR otherwise as directed by the Engineer if the load loss at lock-off is higher than 10%.)

% of Load	Load (KN)	* P.G. (psi)	** L.C. (Reading)	Displacement (mm)
0%	0	0		40
20% Tw	144	600		48
110% Tp	287	1200		66

RESIDUAL LOAD (By Immediate Lift-Off)		
* P.G. :	1200	(psi)
** L.C. :		(Reading)
LOAD :	287.1	(KN)

Remarks : Δe = 61.2 mm

STRESSED BY : GONISIN SIMON (APG/Sri Jutaya)

RECORDED BY : EDWARD F. L. (COW/JWGC)

ENGINEER : CHESTER CHEE (RE/JWGC)

Calculate **APPARENT FREE TENDON LENGTH**:

- Design load, T_w= **700kN**,
- Proof load, T_p= **1050kN** (150% T_w),
- Bond length, L_b= **6.30m**,
- Free length (Stressing), L_{fs}= **13.42m**,
- $\{L_{fs} = L_t - L_b - L_u$ = 20.00 - 6.30 - 0.28}m

Apparent free length = $\frac{\Delta E_e \times Es \times Ns \times As}{(\Delta Ta) \times 1000}$ m

$L_{f\,(app)} = \frac{71 \times 200 \times 6 \times 140}{(1053-144) \times 1000}$ = **13.12m**

Limits should be between
≥ 90% L_f AND ≤ 110% L_{fs} OR ≤ {L_f + 50% L_b}
i.e. ≥ 11.46m AND ≤ 14.76m OR ≤ 15.88m

Calculate **APPLIED LOAD FROM PRESSURE GAUGE**:

- Eff. Ram area of jack= **346.5cm²**/2.54² = **53.71 in²**
- Applied stress conversion factor= Load/Area
  =2204/(53.71 x 9.81) Psi per kN
  =4.18 Psi per kN

Calculate **EQUIVALENT TENDON SHORTENING DUE TO PRESTRESS LOSS Δ_e**:

- For $T_{a\,(residual)}$ of **766kN**,
- Displacement at anchor head, Δ_e,

$\Delta_e = \frac{T_{a\,(resisual)} \times Lf \times 1000}{(A_s \times Ns) \times Es}$ mm

$= \frac{766 \times 13.42 \times 1000}{(140 \times 6) \times 200}$ = 61.2mm

1%Δ_e = 0.612mm, AND 1% load loss = 7.66kN

5%Δ_e = 3.06mm, AND 5% Load loss =38.3kN

ON-SITE ACCEPTANCE TESTS -3cycles up with monitoring up to 50minutes

GROUND ANCHOR STRESSING RECORD (FORM GATR)Rev.3

Type of Test: ON-SITE ACCEPTANCE TEST (√) OR ON-SITE SUITABILITY TEST ( )

PROJECT :Pembaikan Cerun Jalan Penampang-Tambunan-Keningau-Tenom, Pakej 2C

SLOPE NO. : KM56.97	ANCHOR NO. : BP-12	LEVEL NO. : L-1	DATE : 15/8/2011

Design Working Load (Tw)	: 700 KN	Dia. Of Strand (Ds)	: 15.24 mm	Tendon Length (Lt)	: 25.00 m
Specified Preload (Tp)	: 250 KN	Area Of Strand (As)	: 140 mm^2	Bond Length (Lb)	: 6.30 m
Proof Load (150% of Tw)	: 1050 KN	Nos. Of Strands (Ns)	: 6 nos.	Free Length (Lf)	: 17.50 m
Angle Of Inclination	: 20 deg.	Elastic Modulus (Es)	: 200 KN/mm^2	Design Free Length	: 18 m

Displacement Measurement System	: By Steel Ruler.	Jack Type / Capacity :	RHR 2508/150 tons
Load Measurement System	: By *Pressure Gauge (P.G.) [Yes] AND **Load Cell (L.C.) [ ]		
*Effective Ram Area	: 346.5 (cm^2) 53.71 (in^2)	*Correlated Factor :	4.18 (psi per KN)
**Load Cell Ref. No.	:	**Gauge Factor :	KN/digit **Zero Reading :

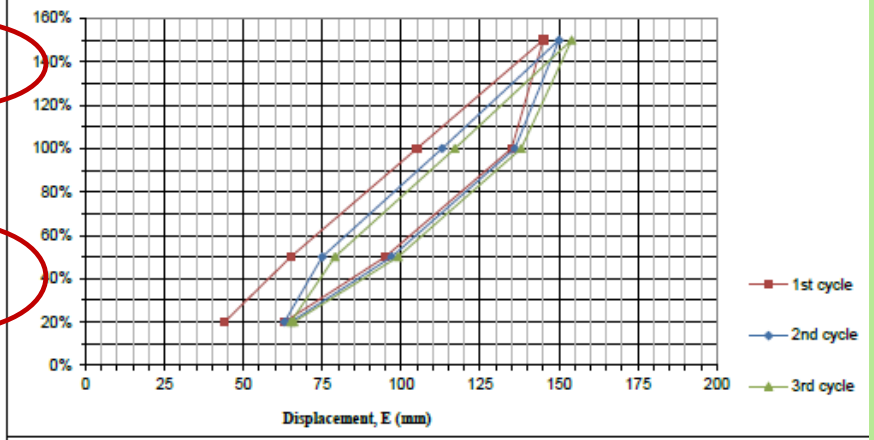
(1) APPARENT FREE LENGTH COMPLIANCE :-
MONITORING OF "LOAD - DISPLACEMENT DATA"

Extrusion (from bearing plate) : 1.20 m

(a) Unused "Stressing" Length (*Lu) :	0.54 m	(b) Cal. Free Tendon Length (Lfs) = (Lt - Lb - Lu) :	18.16 m
(c) Min. App. Free Tendon Length (90% Lf):	15.75 m	(d) Max. App. Free Tendon Length (Lf + 50% of Lb) :	20.65 m
		(e) OR Max. App. Free Tendon Length (110% of Lfs):	19.98 m

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
1st Cycle					38 (Ram displacement at zero initial reading)				
20%	144	21%	600		44	-	-	-	
50%	359	51%	1500		65	-	-	-	Plastic
100%	718	103%	3000		105	-	-	-	Disp. (ΔEp)
150%	1053	150%	4400		145	-	-	-	25 mm
100%	718	103%	3000		135	-	-	-	
50%	359	51%	1500		95	-	-	-	
20%	144	21%	600		63	-	-	-	
2nd Cycle									
20%	144	21%	600		63	63	-	-	Plastic
50%	359	51%	1500		75	75	-	-	Disp. (ΔEp)
100%	718	103%	3000		113	113	-	-	2 mm
150%	1053	150%	4400		150	150	150	150	
100%	718	103%	3000		136	136	-	-	Elastic
50%	359	51%	1500		97	97	-	-	Disp. (ΔEe)
20%	144	21%	600		65	65	-	-	85 mm

APPARENT FREE LENGTH = $\frac{(\Delta Ee \times Es \times Ns \times As)}{(\Delta Ta) \times 1000}$ = 16.45 m



(*Lu : Extruded length as measured from end plate of jack with strands straightened by the application of a minimum tension load.)

% of Tw	Load (Ta) (KN)		* P.G. (psi)	** L.C. (Reading)	Ram Displacement, E (mm) 0 min.	1 min.	5 min.	15 min.	Remark
3rd Cycle			-	-	Note: use additional sheet if test required more than 3 cycles				
20%	144	21%	600		65	65	-	-	Plastic
50%	359	51%	1500		79	79	-	-	Disp. (ΔEp)
100%	718	103%	3000		117	117	-	-	1 mm
150%	1053	150%	4400		154	154	155	155	
100%	718	103%	3000		138	138	-	-	Elastic
50%	359	51%	1500		99	99	-	-	Disp. (ΔEe)
20%	144	21%	600		66	66	-	-	89 mm

REMARK : COMPLIED [√] / NOT COMPLIED [ ] / FAILED [ ]

(2) COMPLIANCE OF EITHER "RESIDUAL LOAD - TIME DATA" OR "DISPLACEMENT - TIME DATA" (Note: Test method depends on the accuracy of the test equipments that can measured within 0.5% change in load or displacement)

MONITORING OF "DISPLACEMENT - TIME DATA" AT DESIGN WORKING LOAD. - (Remark : The Applied Load is taken as 110% of Tw, OR otherwise as directed by Engineer.)

Time	Load psi	Load kN	Ram. Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading) mm	mm	Loss of Load/ change in Disp. (%) Total	Interval	% Permissible (should be <1% per interval)	Remark
			65				-	-	-	-
0 min.	3200	766	123	58	12		-	-		
5 min.	3200	766	123	58	12.89	0.89	1.07%	1.07%	1 %	O.K./ Not Acceptable
15 min.	3200	766	123	58	13	1	1.21%	0.13%	2 %	O.K / Not Acceptable
50 min.	3200	766	123	58	13.02	1.02	1.23%	0.02%	3 %	O.K / Not Acceptable

(4) EXTENDED RESIDUAL LOAD - TIME MONITORING (Further monitoring to be carried out on the anchor using load cell if the permissible loss of load or displacement exceed the 1% per interval as directed by the Engineer)

Time	Load		Ram Disp. (mm)	Net Ram Disp. (mm)	**L.C. Or #D.G. (Reading)		Loss of Load/ change in Disp. (%)		% Permissible (should be <1% per interval)	Remark
2 1/2 hrs.									4 %	O.K./ Not Acceptable
8 hrs.									5 %	O.K./ Not Acceptable
1 day									6 %	O.K./ Not Acceptable
3 days									7 %	O.K./ Not Acceptable
10 days									8 %	O.K./ Not Acceptable

* Note : The rate of displacement (% of Change) should reduce to 1% or less per time interval of observation period.

(3) ANCHOR LOCKED-OFF TEST & MEASUREMENT OF RESIDUAL LOAD - (Remark : The Locked-Off Load is taken as 110% of Tp OR otherwise as directed by the Engineer if the load loss at lock-off is higher than 10%.)

% of Load	Load (KN)	* P.G. (psi)	** L.C. (Reading)	Displacement (mm)
0%	0	0		68
20% Tw	144	600		76
110% Tp	287	1200		98

RESIDUAL LOAD (By Immediate Lift-Off)		
* P.G.	1200	(psi)
** L.C.		(Reading)
LOAD	287.1	(KN)

Remarks :
Δe = 82.8 mm

STRESSED BY : GONISIN SIMON (APG/Sri Jutaya)
RECORDED BY : EDWARD F. L. (COW/JWGC)
ENGINEER : CHESTER CHEE (RE/JWGC)

Calculate **APPARENT FREE TENDON LENGTH**:

- Design load, T_w= **700kN**,
- Proof load, T_p= **1050kN** (150% T_w),
- Bond length, L_b= **6.30m**,
- Free length (Stressing), L_{fs}= **18.16m**,
- $\{L_{fs} = L_t - L_b - L_u$ = 25.00 - 6.30 - 0.54}m

Apparent free length = $\frac{\Delta E_e \times Es \times Ns \times As}{(\Delta Ta) \times 1000}$ m

$L_{f\,(app)} = \frac{89 \times 200 \times 6 \times 140}{(1053-144) \times 1000}$ = **16.45m**

Limits should be between
≥ 90% L_f AND ≤ 110% L_{fs} OR ≤ {L_f + 50% L_b}
i.e. ≥ 15.75m AND ≤ 19.98m OR ≤ 20.65m

Calculate **APPLIED LOAD FROM PRESSURE GAUGE**:

- Eff. Ram area of jack= **346.5cm²**/2.54² = **53.71 in²**
- Applied stress conversion factor= Load/Area
  =2204/(53.71 x 9.81) Psi per kN
  =4.18 Psi per kN

Calculate **EQUIVALENT TENDON SHORTENING DUE TO PRESTRESS LOSS Δ_e**:

- For $T_{a\,(residual)}$ of **766kN**,
- Displacement at anchor head, Δ_e,

$\Delta_e = \frac{T_{a\,(resisual)} \times Lf \times 1000}{(A_s \times Ns) \times Es}$ mm

$= \frac{766 \times 18.16 \times 1000}{(140 \times 6) \times 200}$ = 82.8mm

1%Δ_e = 0.828mm, AND 1% load loss = 7.66kN

5%Δ_e = 4.14mm, AND 5% Load loss =38.3kN

TYPICAL STRESSING RECORD SHEET

ANCHOR STRESSING RECORD

Contract Name :	Remedial Works Along Jalan Ranau - Telupid - Slope 16	Anchorage No:	BP17/GA 1st Layer
Anchorage Location :	Wall 2	Sheet No:	1
Type of Test :	[illegible]	Date:	5 - 11 - 97

Stressing Detail					
Date Stressed	5 - 11 - 97	Date Bonded		19 - 8 - 97	
Head Type	6 holes	No.of bars or Strands		6	No
Jack Type / Capacity	RRH-1508/1500KN	Dia. of bars or strands		15.25	MM
Load Measurement System	Pressure Gauge	Tendon free length (stressing)		13.43	M
Displacement measurement System	Steel Ruler	Tendon free length (service)		14.03	M
Datum Point	70 KN	Tendon bond length		6	M
Working Load	700 KN	Characteristic		260.7	KN
Test Load	1050 KN	Elastic Modulus		195	KN/mm2
Lock-off Load	350 x 1.1 KN	Tendon Area		840	MM2

Grout strength details : Cubes size : 150 x 150 x 150 mm

Identification	1	2	3	4	5	6
Date cast	19 - 8 - 97	19 - 8 - 97	19 - 8 - 97	19 - 8 - 97	19 - 8 - 97	19 - 8 - 97
Age(days)	7	7	28	28	28	28
Strength (N/mm2)	32.2	32.9	44	33.8	37.3	37.6

Load % Tw	Load KN	Psi	Displacement (mm) At 0 mm	From	Ram / Tendon Displacement (dd)	Anchor head Displacement mm	Corrected Displacement	Time	Remarks
			6.1			38.17		10:02	
1st Cycle									
10	70	496	69		0	44.09	0	10:03	
50	350	2481	98		29	37.82	29.27	10:04	
100	700	4962	131		62	37.21	62.88	10:05	
125/150	1050	7444	172		109	36.66	104.43	10:06	
After 5 min									
After 15 min									
100	700	4962	159		86	36.66	87.43	10:07	
50	350	2481	120		51	36.69	52.4	10:08	
10	70	496	86		17	37.81	17.28	10:09	
2nd Cycle									
10	70	496	86	86	17	37.81	17.28	10:10	2nd Cycle
50	350	2481	111	111	42	37.13	42.96	10:11	permanent
100	700	4962	142	142	73	36.92	74.17	10:12	Displacement
125/150	1050	7664	176	176	107	36.54	108.55	10:13	6.02 mm
After 5 min			176	176	107	36.52	108.57	10:18	
After 15 min			176	176	107	36.49	108.6	10:28	2nd Cycle
100	700	4962	161	161	92	36.45	93.64	10:29	Elastic
50	350	2481	127	127	58	37.65	58.44	10:30	Displacement
10	70	496	92	92	23	37.79	23.3	03:10	85.3 mm
3rd Cycle									
0									1st Cycle
10									permanent
100									Displacement
125/150									mm
After 5 min									
After 15 min									2nd Cycle
100									Elastic
50									Displacement
10									mm

Load / Displacement monitoring (Value/% Change)

0 min 155/36.15/0% 5 min 154.98/36.51/0.13%

15 min 154.96/36.63/0.06% 30 min 154.38/37.31/1.09% 2 1/2 hours / 8 hours /

1 day / 3 days / 10 days /

COMMENTS : Monitoring Load = 5439 psi (770 KN)Elongation" 83.13

Lock off at 2729 psi . The elongation is 32.0/4mm

The residual load is 2600psi.

ENGINEER

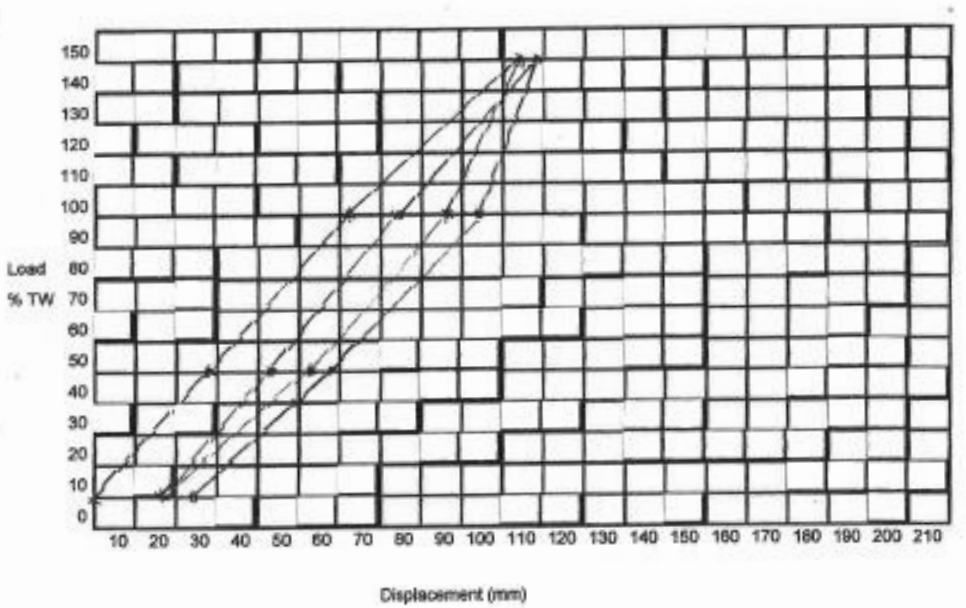
CONTRACTOR

SUBCONTRACTOR

ANCHOR STRESSING RECORD

Contract name : Remedial work along Ranau - Telupid slope 16	Anchorage no : BP 17 / GA 1st Layer
Anchorage location : Wall two	Sheet no : 2
	Date : 5 - 11 - 97

Tendon free length (stressing)	13.4	M
90 % free length	12.1	M
110% free length or free +50% bond length	14.8 / 16.4	M
Apparent tendon free length At . Es. Elastic displacement / T		
Apparent tendon free length - 2nd cycle	14.3	M
Apparent tendon free length - 3rd cycle		M



COMMENT:

ENGINEER :

CONTRACTOR :

SUBCONTRACTORS: