The Project for
Capacity Development of Road and Bridge Technology
in the Republic of the Union of Myanmar (2016-2019)

QUALITY CONTROL MANUAL FOR PRESTRESSED CONCRETE GIRDER

(1st Edition)

April ***2019***

Ministry of Construction, the Republic of the Union of Myanmar

Japan International Cooperation Agency

PREFACE

In the exercise of its primary mandate as the construction arm of the government, the Ministry of Construction endeavors to keep abreast with systematic quality control and the latest construction techniques, with the ultimate objective of being at par with the more advanced countries in ASEAN.

This quintessential goal cannot be achieved without having to adopt clear-cut, uniform, systematic and definitive procedures on Construction Supervision on Quality/Safety Control in the first place. It is a given prerequisite that Quality Infrastructure must be a direct result of good management and project implementation.

This manual, which was jointly prepared by the MOC Engineering Staff and the Experts assigned for the Project for Capacity Development of Road and Bridge Technology in the Republic of the Union of Myanmar (2016-2019) under the Japan International Cooperation Agency (JICA), serves an effective reference material to field engineers of road and bridge construction, instrumental in our pursuit of the aforementioned ambitious objective.

With this manual, the field engineers should become familiar with and knowledgeable of the overall process in Quality Control and Safety Control, thus making them more competent in constructing government projects that are in accordance with and in strict compliance to the specification/contract requirements of the project.

April 2019

U Han Zaw
Union Minister
Ministry of Construction,
the Republic of the Union of Myanmar

INTRODUCTION

BACKGROUND

The bridge construction technology has maintained in certain technological level since "Bridge Engineering Training Center (BETC) Project (1979-1985: JICA), however, new technology has not been transferred and bridge types that can be constructed in Myanmar are still limited. Besides, insufficient training for national engineers has hampered sustainable transfer of technology in bridge engineering. In this context, the Government of Myanmar requested "the Project for Capacity Development of Road and Bridge Technology" (hereinafter referred to as "the Project") to the Government of Japan. Through series of discussion, Ministry of Construction (MOC) and JICA concluded the Record of Discussion (R/D) in January 2016 to implement the Project focusing on capacity development on construction supervision of bridges and concrete structures.

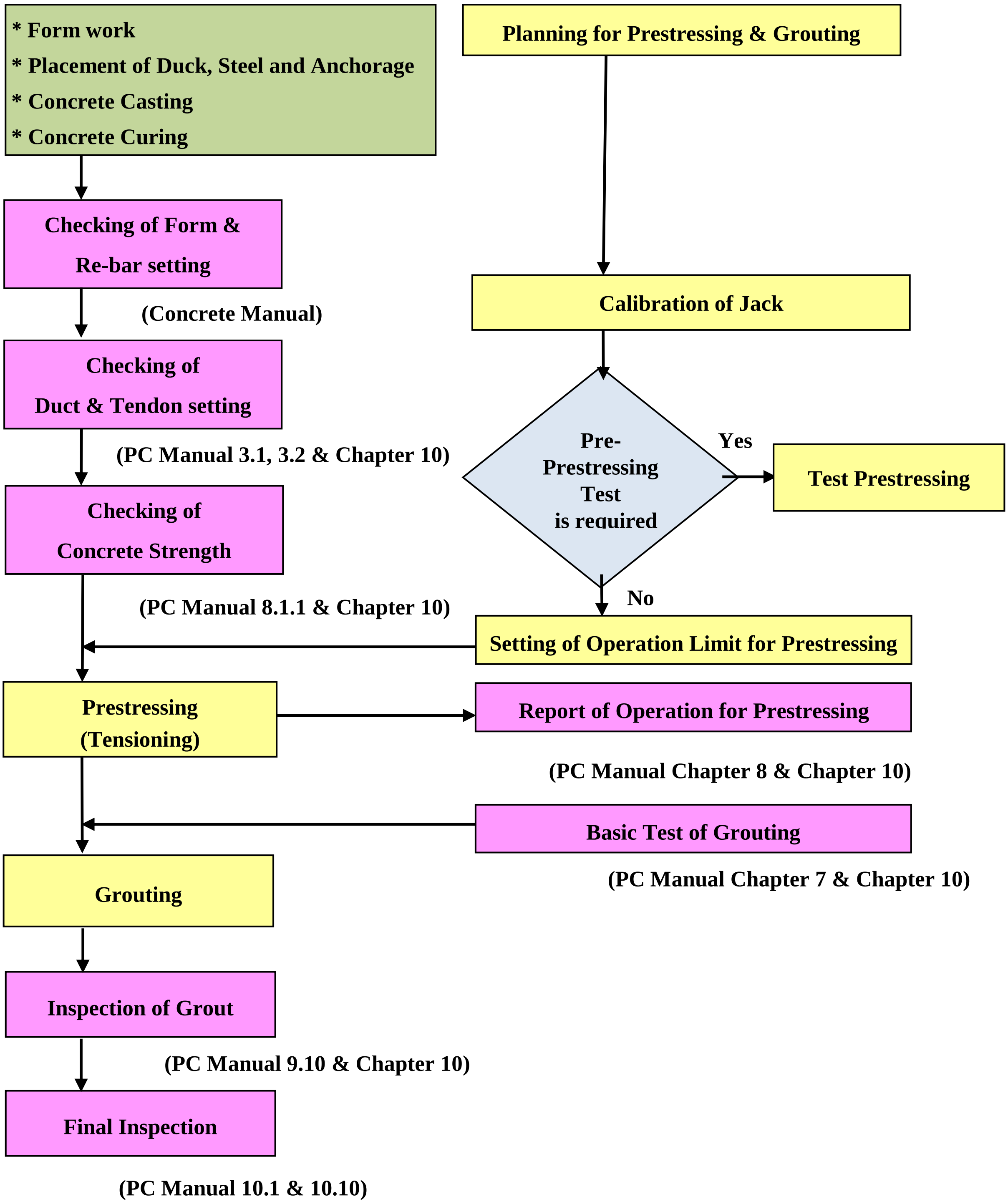
The Project was implemented for 3 years since 2016 in corroboration with MOC staff officer and JICA Experts aiming at improvement of quality as well as safety in construction of bridges and concrete structures. As the achievement of the Project, the Manuals on Quality and Safety Control for Bridge and Concrete Structure were developed in 2019 after several workshop and discussion.

REFERENCES

Following technical documents were referred as references.

1) Specification for Highway Bridges (2012, Japan Road Association, Japan)
2) Standard Specifications for Concrete Structures (2012, Japan Society of Civil Engineering)
3) Manual for Construction of Bridge Foundation (2015, Japan Road Association)
4) AASHTO LRFD Bridge Construction Specifications (3rd Edition, 2010)
5) The Guidance for the Management of Safety for Construction Works in Japanese ODA Projects (2014, JICA)
6) Manual for Construction Supervision of Concrete Works. (2016, NEXCO)
7) Manual for Construction Supervision of Road and Bridge Structures. (2016, NEXCO)
8) Construction Contract MDB Harmonized Edition (Version 3, 2010 Harmonized Red Book)

FLOWCHART OF QUALITY CONTROL FOR PRESTRESSED CONCRETE GIRDER



QUALITY CONTROL MANUAL FOR PRESTRESSED CONCRETE GIRDER

TABLE OF CONTENT

ABBREVIATIONS

AASHTO:	American Association of State Highway and Transportation Officials
ASTM:	American Society for Testing and Materials
JIS	Japan Industrial Standard
PC	Prestressed Concrete
MIL	Military Specification in USA
Re-bar	Reinforcing Bar

CHAPTER1. GENERAL

1.1 References

This Manual has been prepared with reference to LFRD Bridge Construction Specifications (AASHTO), Specification for Highway Bridge (Japan Road Association), Construction Manual for Structure (Japan's Nippon Expressway Company Limited) among others.

1.2 Scope of application

This Manual shall be applied mainly to PC Girder (post-tensioning and pre-tensioning), basically the span of which is less than 33m with regards to current situation of bridges constructed by MOC.

Some instructions in the Manual may not necessarily be adopted adequately. Hence, additional references are provided, the site engineer could adopt the better method considering the current situation of the bridge construction in Myanmar.

1.3 Implementation of Inspection:

Basically, implementation of all items mentioned in this Manual is important, but of utmost importance is the constant implementation of key items for Quality Control at all construction sites.

Therefore, important inspection items shall be implemented, referring to "CHAPTER10 Instructions for Inspection".

1.4 Revision of the Manual

The Manual shall be revised in accordance with the improvement of bridge technology (new structure type, continuous type, long span, etc.) in Myanmar.

1.5 Understanding of the Design

The current practice in Myanmar is that design and construction are considered as separate aspects; so, it is common that at the project site, there is no Design Report (calculation sheets) and the site engineers do not bother themselves with the design. But design and construction are intertwined, with one affecting the other. Therefore, checking the design at the site is indispensable, and by doing so the site engineers shall understand the design outline and will be able to check the calculation sheets roughly.

1.6 Description

This work shall consist of prestressing precast or cast-in-place concrete by furnishing, placing, and tensioning of prestressing steel in accordance with details shown in the contract documents, or in documents indicated by MOC design section to the construction site and as specified in this Manual. It includes prestressing by either the pre-tensioning or post-tensioning method or by a combination of these methods. This work shall include the furnishing and installation of any appurtenant items necessary for the particular prestressing system to be used, including but not limited to ducts, anchorage assembles, and grout used for pressure grouting ducts.

1.7 Details of Design

Where the design for prestressing work is not fully detailed in the contract documents, the Contractor shall determine the details or type of prestressing system to be used and select the materials and details conforming to this Manual, as needed, to satisfy the prestressing requirement specified. The prestressing may be performed by either pre-tensioning or post-tensioning method, unless the contract documents only specify pre-tensioning details. If the contract documents only specify pre-tensioning details, the use of post-tensioning system shall be allowed only if complete details of any necessary modifications are approved by the Engineer or MOC Project Manager.

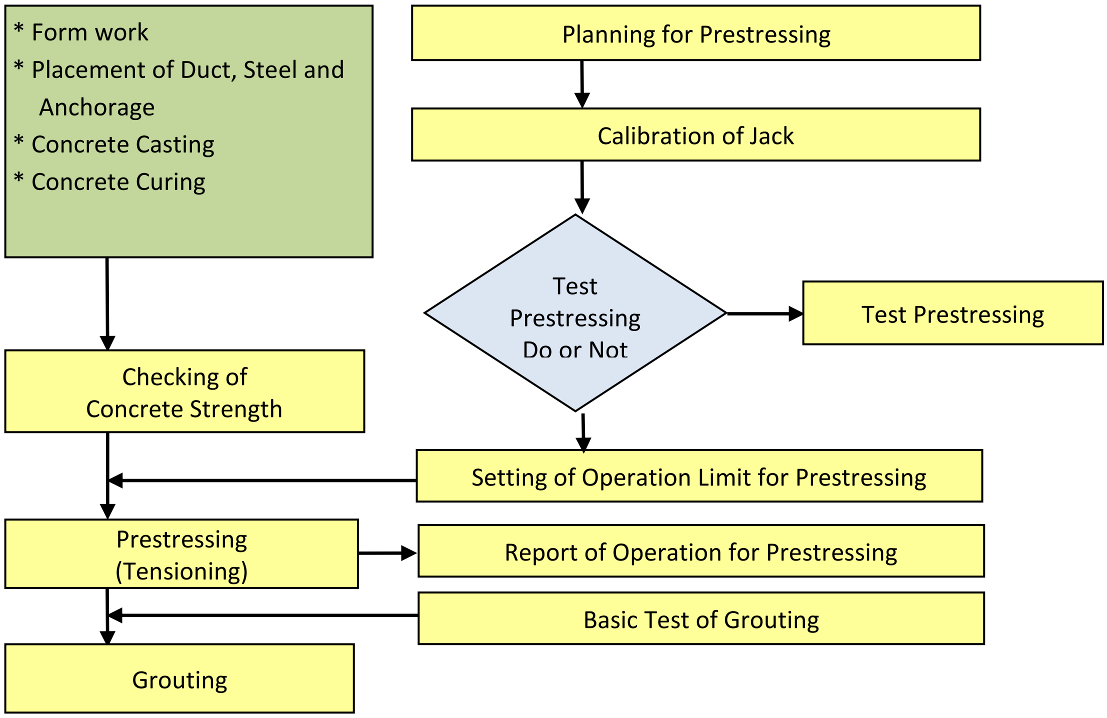


Figure 1.7-1 Post-Tensioning Flowchart

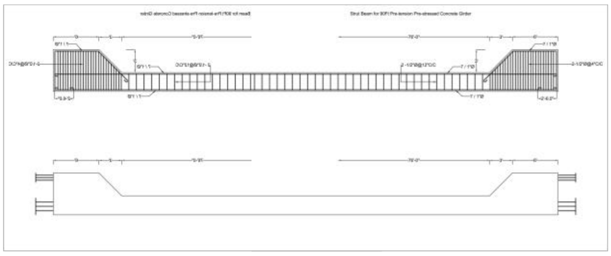
Machine for Prestressing

Setting of reinforcing bars

Formwork

Casting of concrete and Removal of form

Figure 1.7-2 Sequence of Pre-Tension Girder (At the Factory)



Strut Beam for Mold

Construction of Strut Beam

Steel Reinforcement Fixing

Pre-stressing of HT Wire

Concreting of Girder

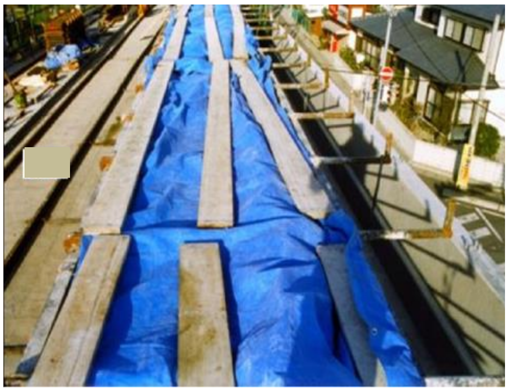
Placing of PC Girder

Figure 1.7-3 Sequence of Pre-Tension Girder (At the Site)

Setting of Re-bars and PC tendon

Formwork

Casting of concrete



Curing of concrete

Prestressing

Grouting

Figure 1.7-4 Sequence of Post-Tension Girder

CHAPTER2. THE MATERIALS

2.1 Prestressing Steel and Anchorage

Prestressing reinforcement shall be high-strength seven-wire strand, high-strength steel wire, or high-strength alloy bars of the grade and type called for in the contract documents. Table 2.1-1 and Table 2.1-2 shall be use as references.

Table 2.1-1 Applicable Standards for Strength of Prestressing Steel (ASTM- A416/A416M (USA)

Breaking Strength Requirements

Strand Designation No.	Diameter of Strand, mm	Minimum Breaking Strength of Strand, kN	Steel Area of Strand, mm²	Weight of Strand kg/1000 m
Grade 1725				
6	6.4	40	23.2	182
8	7.9	64.5	37.4	294
9	9.5	89	51.6	405
11	11.1	120.1	69.7	548
13	12.7	160.1	92.9	730
15	15.2	240.2	139.4	1094
Grade 1800				
9	9.53	102.3	54.8	432
11	11.11	137.9	74.2	582
13	12.7	183.7	98.7	775
13a	13.2	200.2	107.7	844
14	14.29	230	123.9	970
15	15.24	260.7	140	1102
18	17.78	353.2	189.7	1487

Table 2.1-2 Specifications for Highway Bridge (Japan Road Association)

Mechanical properties, nominal cross-sectional area and unit mass of steel wires and steel strands for prestressed concrete

Symbol	Nominal diameter	Loading at 0.2% permanent elongation (kN)	Tensile load (kN)	Elongation (%)	Relaxation value (%)		Nominal cross-sectional area (mm²)	Unit mass (kg/m)
					N	L		
SWPR7AN SWPR7AL	9.3mm 7 strands	75.5 or over (1.45 or over)	88.8 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	51.61	0.405
	10.8mm 7 strands	102 or over (1.45 or over)	120 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	69.68	0.546
	12.4mm 7 strands	136 or over (1.45 or over)	160 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	92.9	0.729
	15.2mm 7 strands	204 or over (1.45 or over)	240 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	138.7	1.101
SWPR7BN SWPR7BL	9.5mm 7 strands	86.8 or over (1.45 or over)	102 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	54.84	0.432
	11.1mm 7 strands	118 or over (1.45 or over)	138 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	74.19	0.58
	12.7mm 7 strands	156 or over (1.45 or over)	183 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	98.71	0.774
	15.2mm 7 strands	222 or over (1.45 or over)	261 or over (1.7 or over)	3.5 or over	8 or less	2.5 or less	138.7	1.101

N: Normal products L: Low-relaxation products

2.2 Post-Tensioning Anchorages and Couplers

All anchorages and couplers shall be developed to at least 96 percent of the actual ultimate strength of the prestressing steel, when tested in an unbonded state, without exceeding the anticipated set. The coupling of tendons shall not be reduced to the elongation at rupture below the requirements of the tendon itself. Couplers and/or coupler components shall be enclosed in housings long enough to permit the necessary movements. Couplers for tendons shall be used only at locations specifically indicated in the contract documents or in documents indicated by MOC design section to the construction site and/or approved by the Engineer. Couplers shall not be used at points of sharp tendon curvature.

Figure 2.2-1, Figure 2.2-2 and Figure 2.2-3 shall be used as reference.

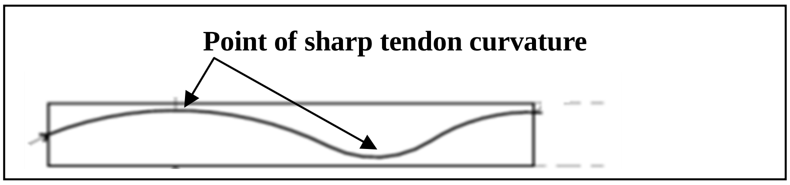
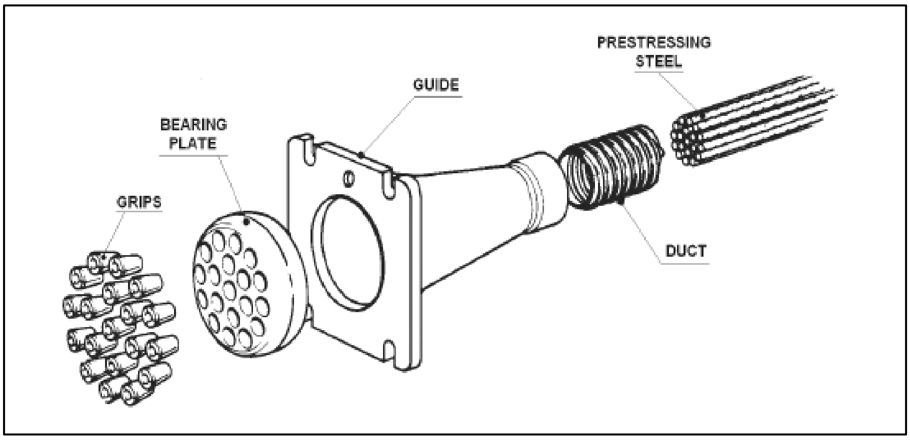
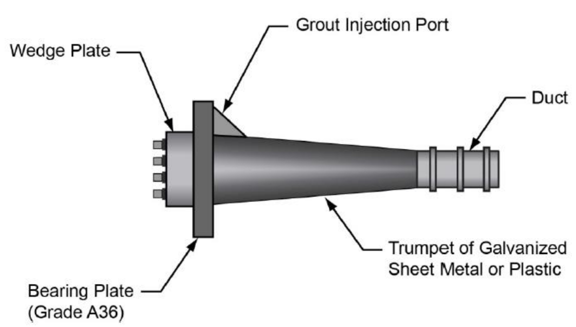


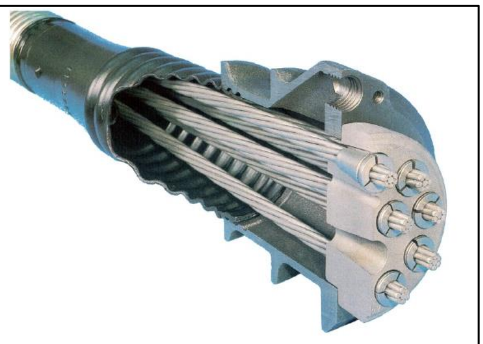
Figure 2.2-1 Point of Sharp Tendon Curvature

Figure 2.2-2 Typical Anchorage in Myanmar

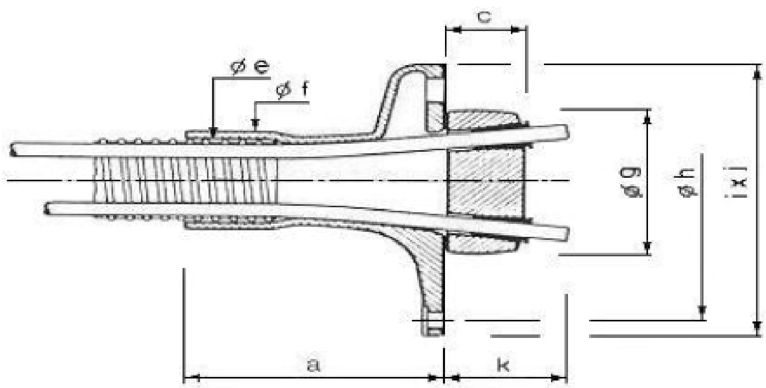




Basic Bearing Plate Anchorage System



Multi-Plane Anchorage System (Courtesy of VSL)



ANCHORAGE TYPE		a	c	e	f	Ø g	Ø h	i	j	k
4 K 13	-	104	45	45	56	85	158	147	147	75
7 K 13	4 K 15	103	50	62	72	120	184	160	160	85
12 K 13	7 K 15	180	55	84	100	140	254	220	235	90
19 K 13	12 K 15	190	60	95	105	160	190	244	244	95
27 K 13	19 K 15	270	70	127	136	200	234	275	293	105
37 K 13	27 K 15	395	78	171	190	252	425	365	365	115
-	37 K 15	467	85	178	206	270	495	425	425	125

Figure 2.2-3 Examples of Anchorage

CHAPTER3. PLACEMENT OF DUCTS, STEEL, AND ANCHORAGE HARDWARE

3.1 Placement of Ducts

3.1.1 General

Ducts shall be rigidly supported at proper locations in the forms by ties to reinforcing steel which are adequate to prevent displacement during concrete placement. Supplementary support bars shall be used where needed to maintain proper alignment of the duct. Hold-down ties to the forms shall be used when the buoyancy of the ducts in the fluid concrete would lift the reinforcing steel.

Polyethylene duct and metal duct for longitudinal or transverse post-tensioning in the flanges shall be supported at intervals not to exceed 0.6m. Polyethylene duct in webs for longitudinal post-tensioning shall be tied to stirrups at intervals not to exceed 0.6m, and metal duct for longitudinal post-tensioning in webs shall be tied to stirrup at interval not to exceed 1.2m.

Joints between sections of duct shall be coupled with positive connections which do not result in angle changes at the joints and will prevent the intrusion of cement paste.

After placing of ducts, and reinforcement and forming are complete, an inspection shall be made to locate possible duct damage.

All unintentional holes or openings in the duct shall be repaired prior to concrete placing.

Grout openings and vents shall be securely anchored to the duct and to either the forms or to reinforcing steel to prevent displacement during concrete placing operations.

After installation in the forms, the ends of ducts shall at all times be sealed as necessary to prevent the entry of water or debris.

3.1.2 Duct Inlets and Outlets

All ducts for continuous structures shall be supplied with outlets at the high and low points of the duct profile, except where the profile changes are small, as in continuous slabs, and at additional locations as specified in the contract documents or in documents indicated by MOC design section to the construction site. Low-point outlets (Figure 3.1-1 point F) shall remain open until grouting starts. and Figure 3.1-2 shall be used as reference.

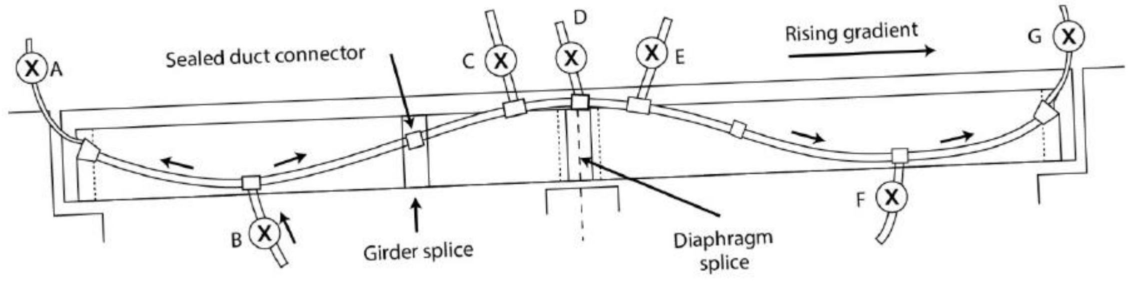
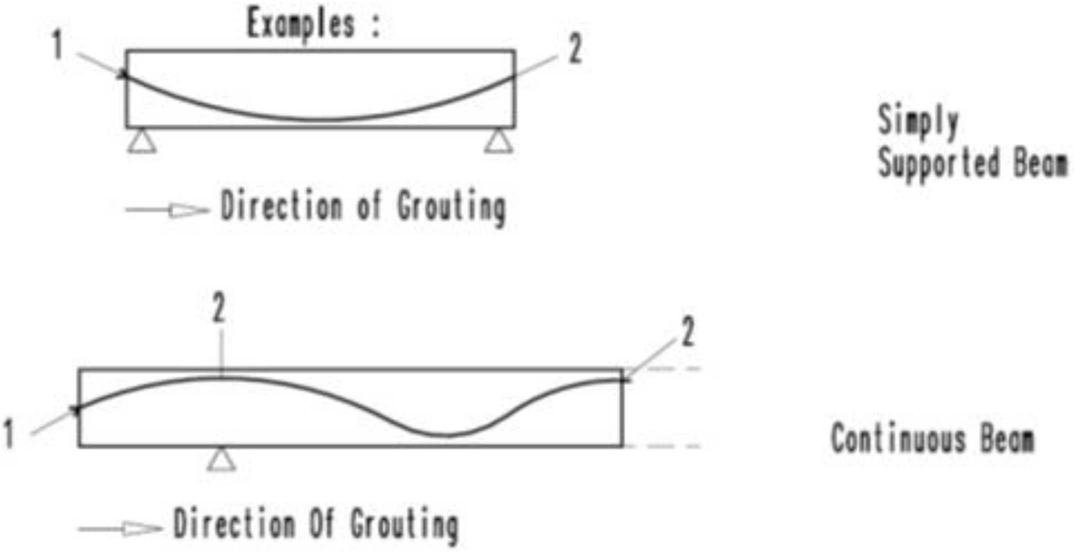


Figure 3.1-1 Example of Low-Point Outlet



1: Inlet   2: Outlet

Figure 3.1-2 Example of Setting Inlet and Outlet

3.1.3 Proving of Post-Tensioning Duct

Upon completion of concrete placement, the Contractor shall prove that the post-tensioning ducts are free and clear of any obstructions or damage. The following is the method for checking the ducts in the U.S; but nowadays this method is not popular in Japan, where the ducts are usually checked by visual inspection.

3.1.4 Checking by using "Torpedo"

Ducts are able to accept the intended post-tensioning tendons by passing a torpedo through the ducts. The torpedo shall have the same cross-sectional shape as the ducts, and 6mm smaller all around than the clear nominal inside dimensions of the duct. No deductions shall be made to the torpedo section dimensions for tolerances allowed in the manufacture or fixing of the ducts. For straight ducts, a torpedo at least 60cm long shall be used. For curved ducts, the length shall be determined so that when both ends touch the outermost wall of the duct, the torpedo is 6mm clear of the innermost wall. If the torpedo will not travel completely through the duct, the Engineer shall reject the member, unless a workable repair can be made to clear the duct, to the satisfaction of the Engineer. Upon completion of the repairs, the torpedo shall be made to pass through the duct easily, by hand, without resorting to excessive effort or mechanical assistance.

Checking by using torpedo is not commonly done in Japan anymore.

3.1.5 Duct Pressure Field Test

Before stressing and grouting internal or external tendons, install all grout caps, inlets, and outlets then test the tendon with compressed air to determine if duct connections require repair. In the presence of the Engineer, pressurize the tendon 0.35N/mm^2 and lock-off the outside air source. Record pressure loss for 1 min. A pressure loss of 0.17N/mm^2 is acceptable for tendons having a length of equal to or less than 46m, and a pressure loss of 0.10N/mm^2 is acceptable for tendons longer than 46m. If the pressure loss exceeds the allowable, repair leaking connections using methods approved by the Engineer or MOC Project Manager, and retest.

3.2 Placement of Prestressing Steel

3.2.1 Placement for Pre-tensioning

Prestressing steel shall be accurately installed in the forms and held in place by the stressing jack or temporary anchors and, when tendons are to be draped, by hold-down devices. The hold-down devices used at all points of change in slope of tendon trajectory shall be of an approved low-friction type.

Prestressing steel shall not be removed from its protective packaging until immediately prior to installation in the forms and placement of concrete. Opening in the packaging shall be resealed as necessary to protect the unused steel. While exposed, the steel shall be protected as needed to prevent corrosion.

3.2.2 Placement for Post-tensioning

All prestressing, steel preassembled in ducts and installed prior to the placement of concrete shall be accurately placed and held in position during concrete placement.

When the prestressing steel is installed after the concrete has been placed, the Contractor shall demonstrate to the satisfaction of the Engineer or MOC Project Manager that the ducts are free of water and debris immediately prior to installation of the prestressing steel. The total number of strands in an individual tendon may be pulled into the duct as a unit, or the individual strand may be pulled or pushed through the duct.

Anchorage devices or block-out templates for anchorages shall be set and held so that their axis coincides with the axis of the tendon, and anchor plates are normal in all directions to the tendon.

The prestressing steel shall be distributed so that the force in each girder stem is equal or as required by the contract documents or documents indicated by MOC design section to the construction site. Figure 3.2-1, Figure 3.2-2, Figure 3.2-3, and Figure 3.2-4 shall be used as references.

Figure 3.2-1 Steel Wire Sock for Installing Multi-strand Tendon

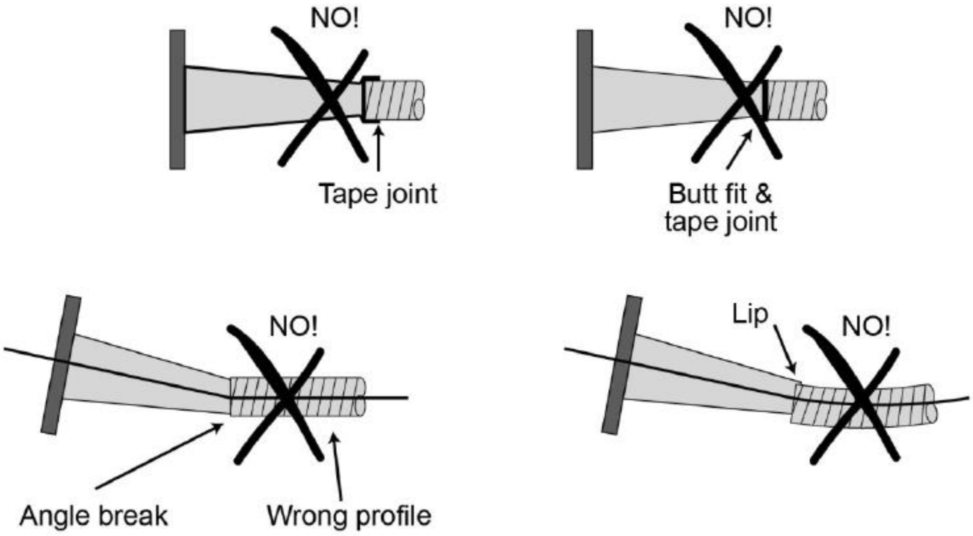
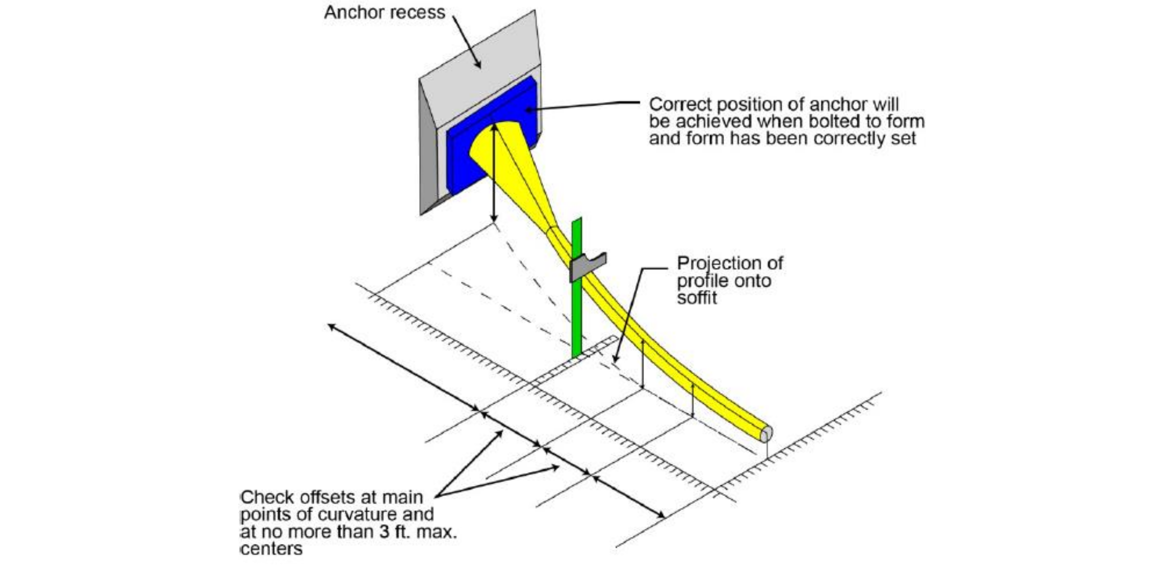
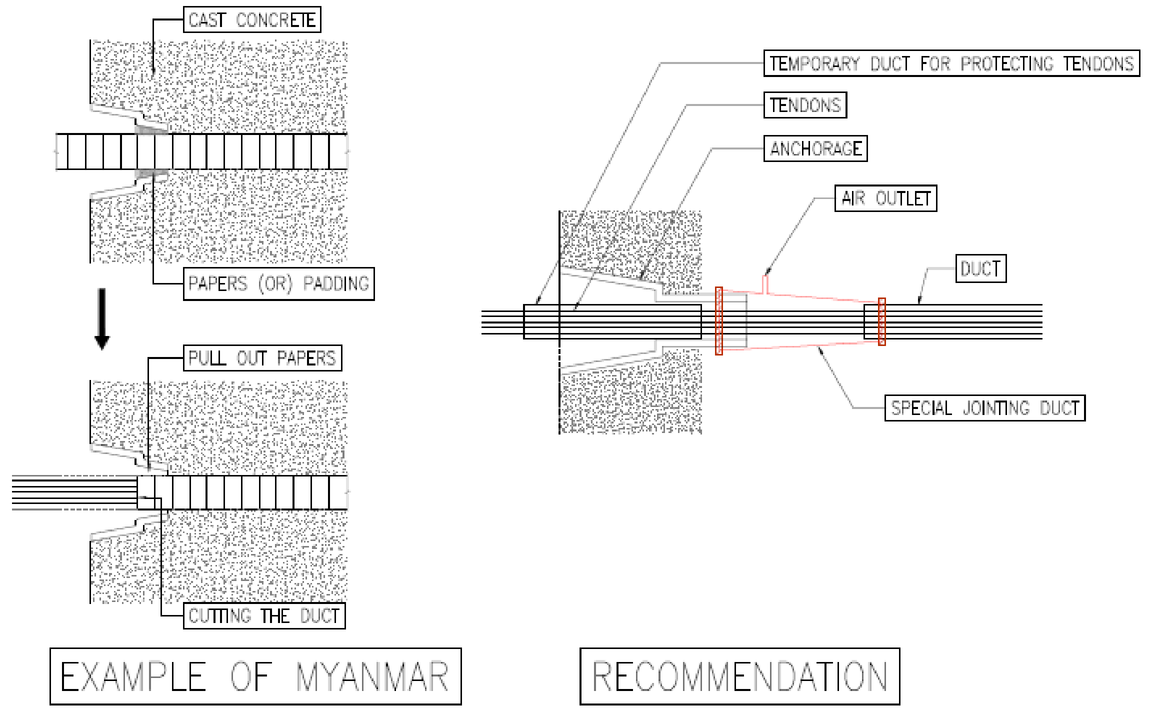


Figure 3.2-2 Unacceptable Duct Connections and Mistakes



(Sometimes, it is necessary to check an alignment in three-dimension from a fixed surface or reference line.)

Figure 3.2-3 Anchor Recess and Checking of Duct Alignment



(In case of the example usually practiced in Myanmar, there is possibility of hardening the tendons by cutting the duct.)

Figure 3.2-4 Duct Setting to Anchor

(1) Protection of Steel After Installation

Prestressing steel used in post tensioned concrete members that is not grouted within the time limit specified below, shall be continuously protected against rust or other corrosion by means of a corrosion inhibitor placed in the ducts or directly applied to the steel. The prestressing steel shall be protected until grouted or encased in concrete. Prestressing steel installed and tensioned in members after placing and curing of the concrete and grouted within the time limit specified below will not require the use of a corrosion inhibitor, and rust that may form during the interval between tendon installation and grouting will not be caused for rejection of the steel.

The permissible interval between tendon installation and grouting without use of a corrosion inhibitor for various exposure conditions shall be taken as follows:

- Very Damp Atmosphere or over Saltwater (Humidity ＞ 70%) ; 7 days
- Moderate Atmosphere (Humidity from 40% to 70%) ; 15 days
- Very Dry Atmosphere (Humidity ＜ 40%) ; 20 days

After tendons are placed in ducts, the openings at the ends of the ducts shall be sealed to prevent entry of moisture. When steam curing is used, unless anchorage systems mandate its installation, steel for post-tensioning shall not be installed until the steam curing is completed.

Such tendons shall be protected against corrosion by means of a corrosion inhibitor placed in the ducts or on the steel, or shall be stressed and grouted within seven days after steam curing.

3.3 Placement of Anchorage Hardware

The Contractor is responsible for the proper placement of all materials according to the design documents of the Engineer-of-Record and the requirements stipulated by the anchorage device supplier. The Contractor shall exercise all due care and attention in the placement of anchorage hardware, reinforcement, concrete, and consolidation of concrete in anchorage zones.

When a strand has been jacked to the required force and jack is released, the wedges are drawn into the wedge plate until they bite and secure the stand. Typically, the amount of anchor set is between 6.4mm and 9.5mm.

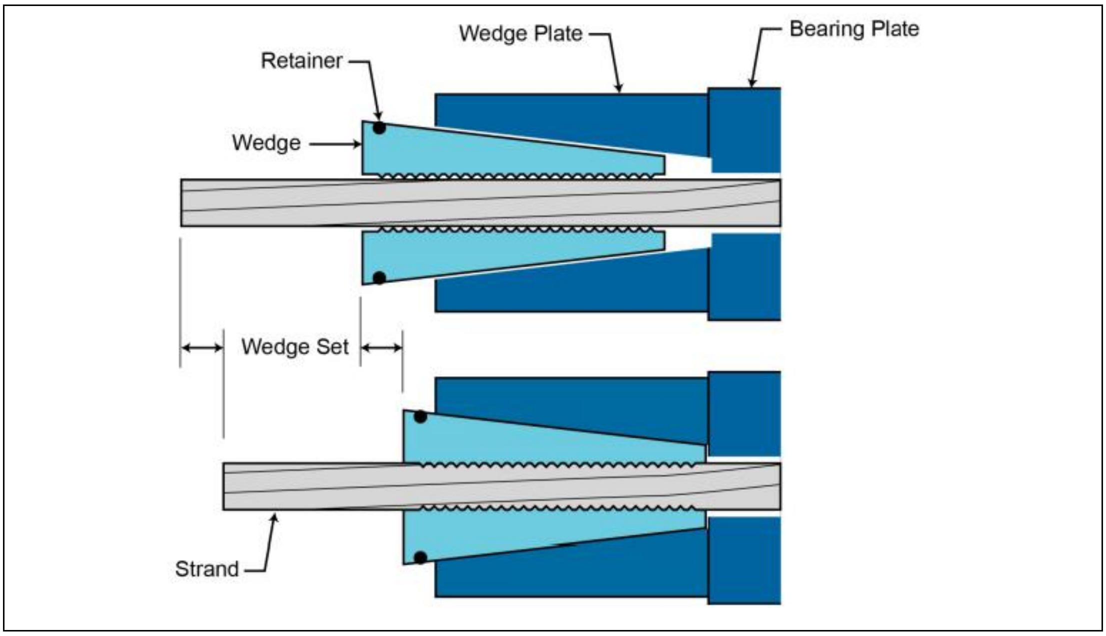


Figure 3.3-1 Anchor Set or Wedge Set

CHAPTER4. IDENTIFICATION AND TESTING

All wires, strands, or bars to be shipped to the site shall each be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be shipped shall be likewise identified.

Each lot of wires or bars and each reel of strand reinforcement shall be accompanied by a Manufacturer's Certificate of Compliance, a mill certificate, and a test report. The mill certificate and test report shall include:

- chemical composition (not required for strand),
- cross-sectional area,
- yield and ultimate strength,
- elongation at rupture,
- modulus of elasticity, and
- stress strain curve for the actual prestressing steel intend for use.

CHAPTER5. PROTECTION OF PRESTRESSING STEEL

All prestressing steel shall be protected against physical damage and rust or other results of corrosion at all times from manufacture to grouting. Prestressing steel shall also be free of deleterious material, such as grease, oil, wax, or paint. Prestressing steel that has sustained physical damage at any time shall be rejected. The development of pitting or other results of corrosion, other than rust stain, shall be cause for rejection.

Prestressing steel shall be packaged in containers or shipping forms for the protection of the strand against physical damage and corrosion during shipping and storage. A corrosion inhibitor (MIL-P-3420F-87 shall be used as references) which prevents rust or other results of corrosion shall be placed in the package or form or shall be incorporated in a corrosion inhibitor carrier-type packaging material, or when permitted by the Engineer, may be applied directly to the steel. The corrosion inhibitor shall have no deleterious effect on the steel or concrete or bond strength of steel to concrete or grout. Packaging or forms damaged from any cause shall be immediately replaced or restored to original condition.

The shipping package or form shall be clearly marked with a statement that the package contains high-strength prestressing steel, and the type of corrosion inhibitor used, including the date packaged.

All anchorages, end fittings, couplers, and exposed tendons, which will not be encased in concrete or grout in the completed work, shall be permanently protected against corrosion.

CHAPTER6. DUCTS

6.1 Metal Ducts

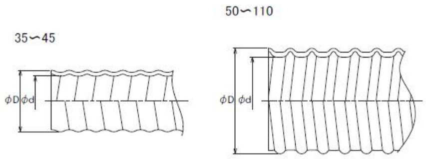
Sheathing for ducts shall be metal, except as provided herein. Such ducts shall be galvanized ferrous metal and fabricated with either welded or interlocked seams. Galvanizing of welded seams will not be required. Right (rigid) ducts shall have smooth inner walls and capable of being curved to the proper configuration without crimping or flattening. Semi-right (semi-rigid) ducts shall be corrugated and, when tendons are to be inserted after the concrete has been placed, their minimum wall thickness shall be as follows: 0.45mm for ducts less than or equal to 67mm diameter, and 0.60mm for ducts greater than 67mm diameter.

Figure 6.1-1 Corrugated Metal Duct from the USA

6.2 Plastic Ducts

For locations in saltwater environment or exposure to deicing chemicals, plastic duct material shall be considered and the one recommended. In Japan, plastic ducts are popular. Corrugated plastic duct to be completely embedded in concrete shall be constructed from either polyethylene or polypropylene. Ducts shall have a white coating on the outside or shall be of white material with ultraviolet stabilizers added as protection from ultraviolet rays. Rigid smooth black polyethylene ducts for use where the tendon is not embedded in concrete shall be rigid pipe manufactured from 100 percent virgin polyethylene resin. Figure 6.2-1,Figure 6.2-2,Table 6.2-1 and Table 6.2-2 shall be used as references.

Figure 6.2-1Corrugated Plastic Ducts from the USA



Polyethylene Ducts Type-A Dimension Table

Nominal Dia.	35	38	45	50	55	65	70	75	80	85	95	105	110
D (mm)	42.5	45.5	52.0	62.0	67.0	78.0	83.0	88.5	94.0	98.5	115.5	125.5	130.0
d (mm)	35.0	38.0	45.0	50.0	55.0	65.0	70.0	75.0	80.0	85.0	95.0	105.0	110.0

PC Cable Correspondence Table

<table>
<tr><th colspan="2">Nominal Dia.</th><th>35</th><th>38</th><th>45</th><th>50</th><th>55</th><th>65</th><th>70</th><th>75</th><th>80</th><th>85</th><th>95</th><th>105</th><th>110</th></tr>
<tr><td rowspan="2">PC Cable.</td><td>Bare</td><td>Bφ23
1S19.3
1S21.8</td><td>Bφ26
1S21.8</td><td>Bφ32
1S28.6</td><td colspan="2">7S12.7</td><td colspan="2">12S12.7</td><td colspan="2">12S15.2</td><td>12S15.7</td><td rowspan="2">19S15.2</td><td colspan="2" rowspan="2">27S15.2</td></tr>
<tr><td>Trunking</td><td>ECF1S15.2
ECF1S15.7
ECF1S17.8</td><td>–</td><td>プレグラウト
1S21.8</td><td colspan="2">プレグラウト
1S28.6</td><td>–</td><td>–</td><td>ECF
12S12.7</td><td>–</td><td>ECF
12S15.2
12S15.7</td></tr>
</table>

Figure 6.2-2 Plastic Ducts (Polyethylene Ducts) in Japan

Table 6.2-1 Plastic Duct Thickness (AASHOTO)

Duct Shape	Duct Diameter mm	Duct Thickness mm
Flat	any size	2.032
Round	22.86	2.032
Round	60.325	2.032
Round	76.2	2.54
Round	85.09	2.54
Round	101.6	3.048
Round	114.3	3.556
Round	130.175	4.064
Round	145.034	4.064

Table 6.2-2 Quality of PE Ducts: Construction Manual for Structure

(Nippon Expressway Company Limited in Japan)

Test Item	Required Quality	Test Method
1. Resistance against uniform external pressure	Buckling pressure shall be over 0.075MPa	JPCI-A001-2015
2. Resistance against local external pressure	No damage in appearance, and No water leak	JSCE-E 704
3. Flexibility	No water leak	JSCE-E 706
4. Check of connection parts	No water leak	JSCE-E 707
5. Characteristic of bending	Calculated supporting span shall be over designated span	JPCI-A002-2015
6. Resistance against abrasion	Residual thickness shall be over 1.5mm	JPCI-A003-2015
7. Adhesiveness	Adhesive strength shall be over 4.0N/mm^2	JSCE-E 710
8. Leak of Coupler Segment	No water leak in test of testing piece	JPCI-A004-2015

6.3 Duct Fittings

Coupling and transition fittings for ducts formed by sheathing shall be of either ferrous metal polyolefin (polyethylene or polypropylene), and shall be airtight and watertight, and of sufficient strength to prevent distortion or displacement of the ducts during concrete placement and/or tendon grouting.

All ducts or anchorage assemblies shall be provided with pipes or other suitable connections at each end of the duct for the injection of grout after prestressing. As specified in 3.1.2, “Duct Inlets and Outlets”, ducts shall also be provided with ports for venting or grouting at high points and for draining at intermediate low points.

Vent and drain pipes shall be at least 19mm diameter for strand and at least 13mm diameter for single-bar tendons and three or four strand flat duct tendons. Connection to ducts shall be made with metallic or plastic structural fasteners. The vents and drains shall be mortar tight, taped as necessary, and constructed with either mechanical or shrink wrap connections. Vents and drains shall provide means for injection of grout through the vents and for sealing to prevent leakage of grout.

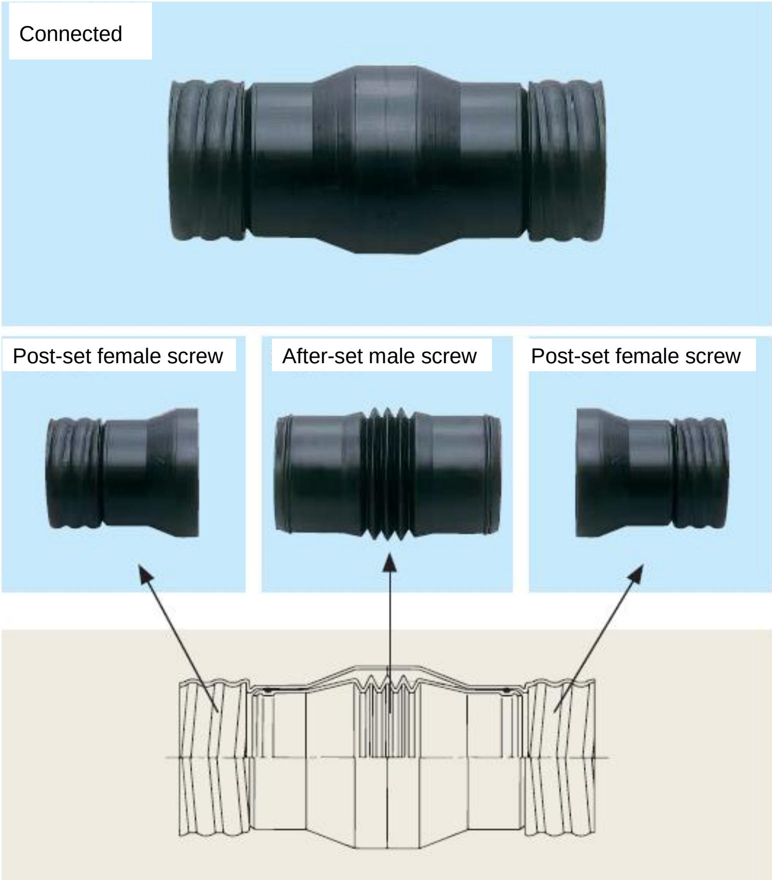


Figure 6.3-1 Example of connection duct

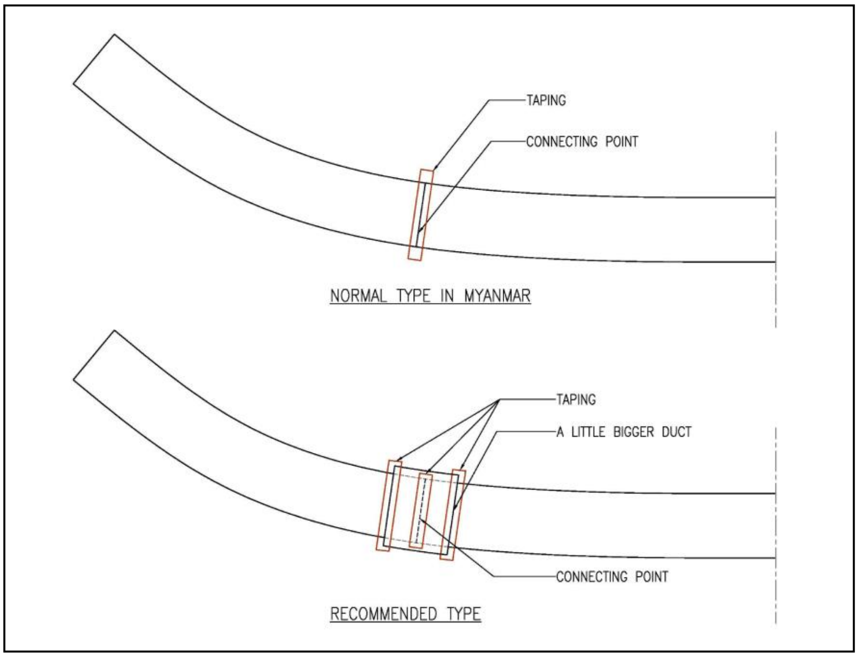


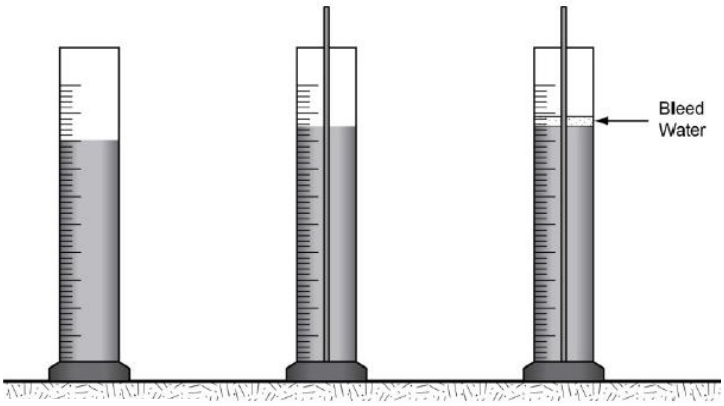
Figure 6.3-2 Recommendation for connection of duct

CHAPTER7. GROUT

Post-tensioning grout shall meet the grout physical properties stated in Article 7.3, “Grout Physical Properties.” Grouts may be either a unique design for the project or supplied in a prebagged form by a grout manufacturer. For uniquely designed grouts, the cement and admixtures utilized in the laboratory trial batches of the proposed grout shall not be changed during the construction without testing. Freshness of the cement should be in accordance with AASHTO M 85 (ASTM C150) or JIS R5210, except as specified herein. Daily field testing of the grout for the following properties shall be required:

- fluidity,
- bleed at 3 h, and
- expansion (volume changing).

A preapproved, prebagged grout supplied by a grout manufacturer may be used as an alternative to the required field testing. These grouts shall be prebagged in plastic lined or coated containers, stamped with date of manufacture, lot number, and mixing instructions. Any change of materials or material sources shall require retesting and certification of the conformance of the grout with the physical property requirements. A copy of the Quality Control Data Sheet for each lot number and shipment sent to the job site shall be provided to the Contractor by the grout supplier and shall be submitted to the Engineer or MOC Project Manager. Materials with a total time from manufacture to usage in excess of six months shall be retested and certified by the supplier before use, or shall be removed from the job site and replaced.



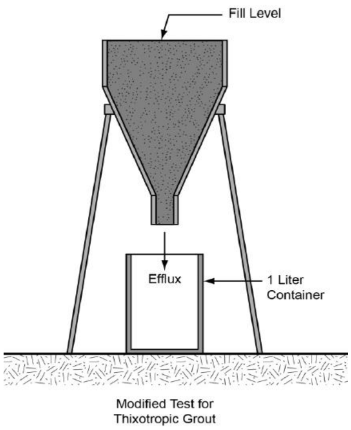
Measured bleed for up to 3 hours

Insert 100mm of either13 mm or 15 mm diameter strand

Measured bleed for up to 3 hours

Seven wire strands in a cylinder with a height of 1,000 mm and diameter of 80 mm, filled with 900 mm of carefully prepared grout, and record the bleed water above the grout. A bleed of 0.0% after 3 hours at normal ambient room temperature of 20 ºC is acceptable.

Figure 7-1 Wick-Induced Bleed Test



The efflux time should be between 9 and 20 seconds immediately after mixing. After allowing the grout to stand for 30 minutes without agitation and then remixing for 30 seconds, the efflux time should be less than 30 seconds.

Figure 7-2 Flow Cone Testing (Modified ASTM C939)

7.1 Approval

Manufacturers of post-tensioning grout shall submit for approval certified test report from an audited and independent Cement Concrete Research Laboratory which shows that the material meets all the requirements specified herein.

7.2 Mixing

The material shall be mixed in accordance with the Manufacturer’s recommendation. The water used in the grout shall be portable, clean, and free of injurious quantities of substances known to be harmful to Portland cement or prestressing steel. The water used in the grout shall meet the physical properties stated in “Concrete Structure Manual”.

7.3 Grout Physical Properties

Grouts shall achieve a nonbleeding characteristic. Grout shall contain no aluminum powder or gas-generating system that produces hydrogen, carbon dioxide, or oxygen. Cementitious grout shall meet or exceed the specified physical properties stated herein.

Grout classes and grout properties are shown in Table 7.3-1Table 7.3-2Table 7.3-3Table 7.3-4.

Table 7.3-1 Grout Physical Properties (AASHTO)

Class	Exposure	Constituent Materials								Required Testing
		Cement kg	Fly Ash (Type F) , %	Slag , %	Silica Fume (dry), %	Water/ Cementitious Material ratio {W/(c+m)]	High-Range Water Reducer (Type F or G), g/kg	Calcium Nitrite, kg/m³	Other Admixtures	
A	Nonaggressive : Indoor or nonaggressive outdoor	99.8	0	0	0	0.45 max.	0	0	–	3.7.3
B	Aggressive: Subject to wet/dry cycles,marine environment,deicing salts	99.8	0 min 25max.	0 min 55max.	0 min 15max.	0.45max.	0 min 28.8max.	0 min 27.2 max.	As per Manufacturer's recommendation	3.7.3
C Prepackaged	Aggressive or nonaggressive	–	–	–	–	0.45 max.	–	–	–	
D Special		Determined by the Specifying Designer								3.7.3

Table 7.3-2 Grout Physical Properties (AASHTO)

Property	Test Value	Test Method
Total Chloride irons	Max. 0.08% by weight of cementitious material	ASTM C1152/C1152M
Fine Aggregate (if utilized)	Max. Size ≤No. 50 Sieve	ASTM C33
Volume Change at 28 days	0.0 % to+ 0.2 % at 24h and 28 days	ASTM C1090
Expansion	≤2.0% for up to 3h	ASTM C940
Compressive Strength 28day (average of 3 cubes)	≥ 41 Mpa	ASTM C942
Initial Set of Grout	Min. 3h Max. 12h	ASTM C953
Fluidity Test** Efflux Time from Flow Cone a)Immediately after Mixing b) 30 min after Mixing with Remixing for 30s	Min.11s Max.30s or Min. 9s Max. 20s Max. 30s Max. 30s	ASTM C939 ASTM C939*** ASTM C939 ASTM C939***
Bleeding at 3h	Max. 0.0%	ASTM C940****
Premeability at 28 days	Max. 2500 coulombs at 30 volts for 6h	AASHTO T277 (ASTM C1202)

Table 7.3-3 Grout Physical Properties

(Construction Manual for Structure (Nippon Expressway Company Limited in Japan)

1. Grout shall be non-bleeding and non-expansion type.
2. Cement shall be non-weathered one suitable to JIS R 5210.
3. Water shall be suitable to JIS A 5308.
4. Admixture or premix material shall be suitable to Test Method 419.
5. Water-binder ratio shall be under 45%.
6. Volume of chloride ion in non-hardened grout shall be under 0.08% of cement volume (kg/m^3).
7. Compressive strength 28 days of grout shall be over 30N/mm^2.
8. Quality control method shall be confirmed.

Table 7.3-4 Comparison between AASHTO and Japanese Manual

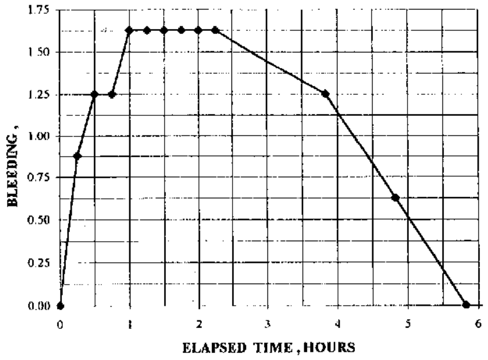
Properties	**AASHTO**	**Japanese Manual**	**Purpose**
Water/Cementitious Materials Ratio	0.45 max	0.45 max	
Fluidity Test	Efflux Time 0 Min: Min 9s Max 20s 30 Min: Max 30s	Depend on factory High-viscosity: Min 14s Low-viscosity :6~14s Super low-viscosity 3.5~6	Workability
Bleeding	Max 0.0% (At 3hr)	Max 0.3% Beginning 0.0% Final	To avoid the cause of air remaining
Volume Change	0.2%(28days)	±0.5%	To avoid shrinkage of volume, then avoid air remaining
Compressive Strength	>41N/mm2	>30N/mm2	
Total Chloride Ions	<0.08 by weight of cementitious materials	<0.08 by weight of cementitious materials	

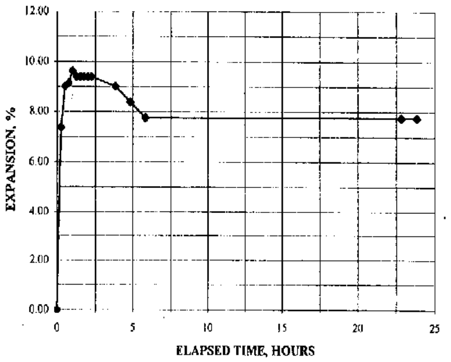
Table 7.3-5 Examples of Grout Materials in Myanmar

	Unit 9	**Belu Chaung Bridge**	**Saing Du Br. First Stage**	**Saing Du Br. Second Stage**
Materials for Grout	Sika214-11	Mortar +Non-Shrink Grout + Intraplast ZX(Sika) 1:2+1~2%	Mortar + Expandfluid 1 + 2%	Mortar + Intraplast ZX(Sika) 1 + 2%
Water/Cementitious Materials Ratio	0.45	0.45	0.45	0.45
Compressive Strength				

Table 7.3-6 Examples of Testing by Material Company in Myanmar

Cement 10kg + Sika INTRAPLAST ZX 100g (1%) ,   W/C ratio = 0.44





Bleeding 1.6% at 3 Hours	Expansion 9% at 3 Hours

Total chloride ions test shall be explained in “Concrete Structure Manual”.

How to use a Quantabs...

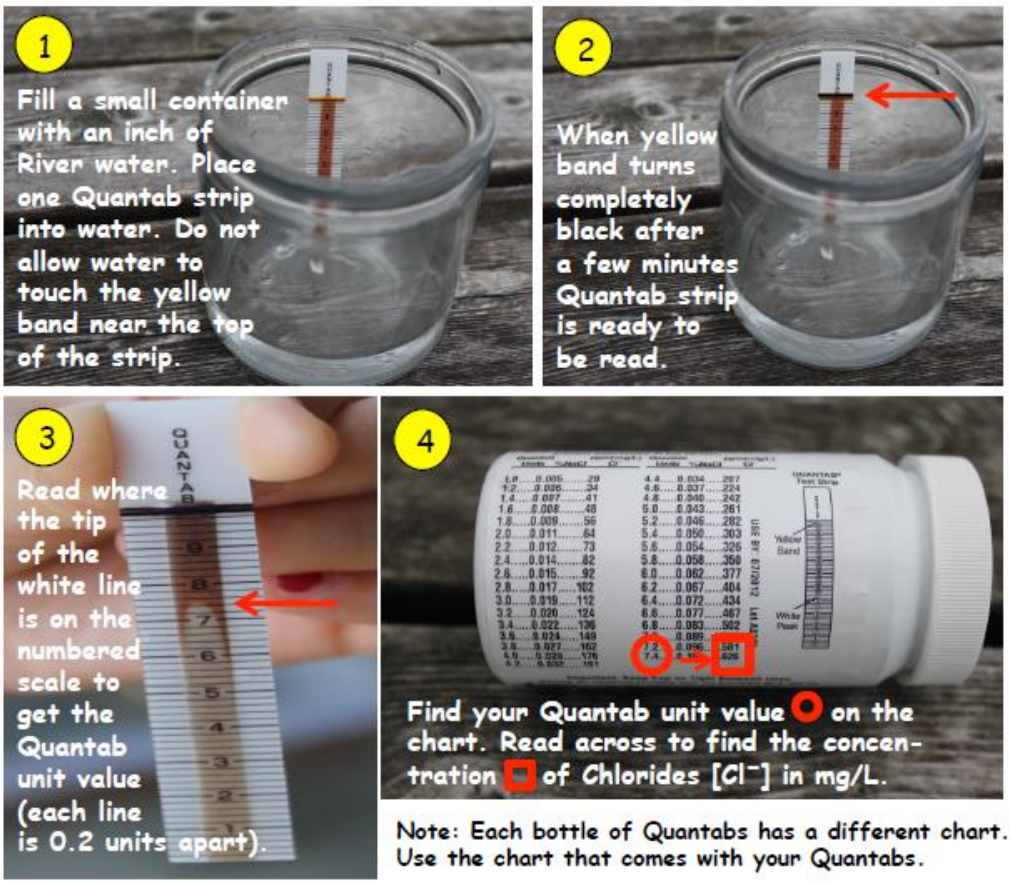


Figure 7.3-1 Example of Method for Checking Chloride Ions

CHAPTER8. TENSIONING

8.1 General Tension Requirements

Prestressing steel shall be tensioned by hydraulic jacks so as to produce the forces specified in the contract documents or on the approved working drawing with appropriate allowances for all losses. For post-tensioned work, the losses shall also include the anchor set loss appropriate for the anchorage system employed.

For pre-tensioned members, the standard stress prior to seating (jacking stress) shall not exceed 80% of the minimum ultimate tensile strength of the prestressing steel.

For post-tensioned members, the strand stress prior to seating (jacking stress) and the stress in the steel immediately after seating shall not exceed allowable values.

Tensioning may be accomplished by pre-tensioning, post-tensioning, or the combined method; as specified in the contract documents, approved working drawings, or approved in writing by the Engineer or MOC Project Manager.

During stressing of strand, individual wire failures may be accepted by the Engineer or MOC Project Manager, provided not more than one wire in any strand is broken and the area of broken wires does not exceed 2% of the total area of the prestressing steel in the member.

8.1.1 Concrete Strength

Prestressing forces shall not be applied or transferred to the concrete until the concrete has attained the strength specified for initial stressing. In addition, cast-in-place concrete for other than segmentally constructed bridges shall not be post-tensioned until at least ten days after the last concrete has been placed in the member to be post-tensioned.

Table 8.1-1 Concrete Strength for Initial Stressing (N/mm^2)

[Construction Manual for Structure (Nippon Expressway Company Limited in Japan)]

Concrete design strength	36	40	50
Concrete strength for initial stressing	30	32.5	36

8.1.2 Prestressing Equipment

Hydraulic jacks used to stress tendons shall be capable of providing and sustaining the necessary forces and shall be equipped with either a pressure gauge or a load cell for determining the jacking stress. The jacking system shall provide an independent means by which the tendon elongation can be measured. The pressure gauge shall have an accurately reading dial of at least 150mm in diameter or a digital display, and each jack and its gauge shall be calibrated as a unit with the cylinder extension in the approximate position that it will be at final jacking force, and shall be accompanied by a certified calibration chart or curve.

The load cell shall be calibrated and shall be provided with an indicator by means of which the prestressing force in the tendon may be determined. The range of the load cell shall be such that the lower 10% of the Manufacturer's rated capacity will not be used in determining the jacking stress. When approved by the Engineer, calibrated proving rings may be used instead of load cells.

Recalibration of gauges shall be conducted at least annually and whenever gauge pressures and elongations indicate materially different stresses.

Only oxygen flame or mechanical cutting devices shall be used to cut strand after installation in the member or after stressing. Electric arc welders shall not be used. In case of Pretension Girder (Site Product), sometimes the End Anchorage Beam is diverted. In that case, the End Anchorage Beam shall be inspected carefully for presence of fatal deformation.

Figure 8.1-1 Prestressing Equipment for Pre-tension Girder (At the Factory)

Figure 8.1-2 Prestressing Equipment (Strut Beam) for Post-Tension Girder (At the Site)

Pressure Gauge and Jack

Figure 8.1-3 Prestressing Equipment for Post-Tension Girder

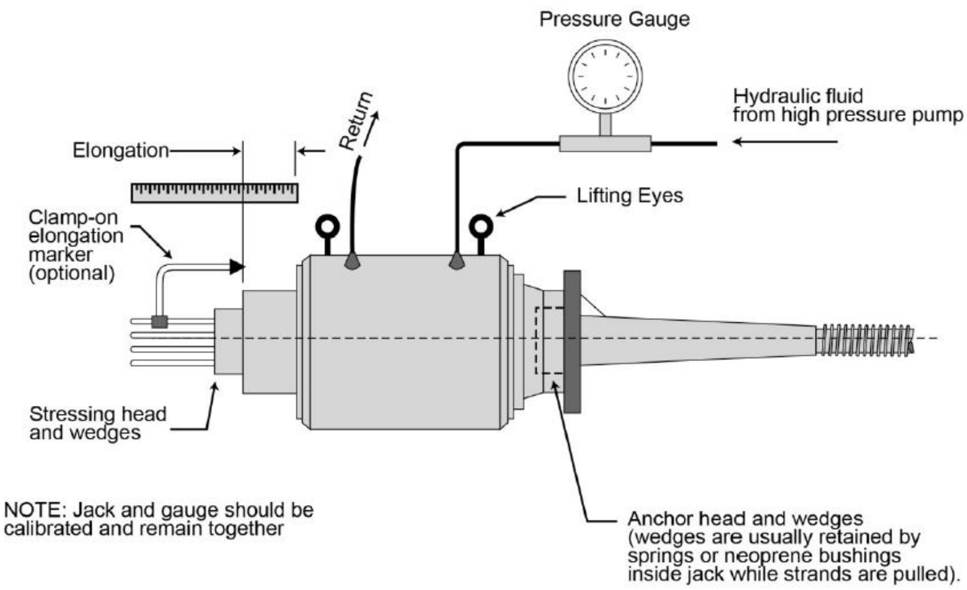
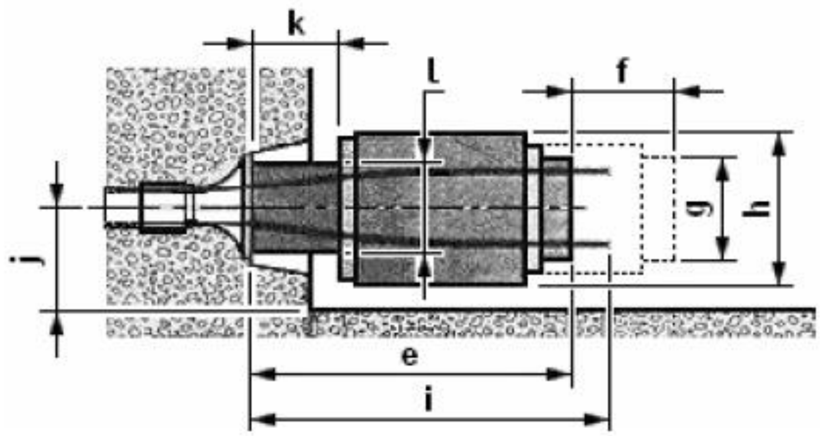


Figure 8.1-4 Typical Multi-Strand, Center Hole, Stressing Jack



K-RANGE JACKS

The table below can be referred for the selection of the Jack for Prestressing of Cables:-

JACK TYPE	ANCHORAGE TYPE		e	f	g	h	i	j	k	l
K 100	4 K 13	-	635	200	185	275	785	190	126	192
	7 K 13	4 K 15	635	200	185	275	785	190	126	192
K 200	7 K 13	4 K 15	720	200	220	350	875	230	228	274
	12 K 13	7 K 15	726	200	220	350	875	230	231	274
K 350	12 K 13	7 K 15	820	250	267	440	970	270	235	324
	19 K 13	12 K 15	820	250	267	440	970	270	230	324
K 500	19 K 13	12 K 15	940	250	267	515	1090	310	230	410
	27 K 13	19 K 15	933	250	267	515	1090	310	222	410
K 700	27 K 13	19 K 15	881	260	350	610	1030	360	142	478
	37 K 13	27 K 15	973	260	350	610	1125	360	104	478
K 1000	37 K 13	27 K 15	1062	220	400	710	1220	410	268	535
	55 K 13	37 K 15	1171	220	400	710	1320	410	279	535

Figure 8.1-5 K-RANGE JACK TYPES (Used in Myanmar)

8.1.3 Jack Calibration

Jack calibration is usually done by the supplier of the system or by a local, approved laboratory.

At the site, it is done by using Master Gauge supplied by maker.

Figure 8.1-6 shows the set-up for jack calibration. In addition to the normal set-up for stressing, two instruments are added: the load cell between the jack and the anchorage and a master gauge attached to the pressure gauge to be calibrated. The load cell is normally placed in front of the jack, as shown. The load cell allows an accurate readout of the force applied to the prestressing tendon.

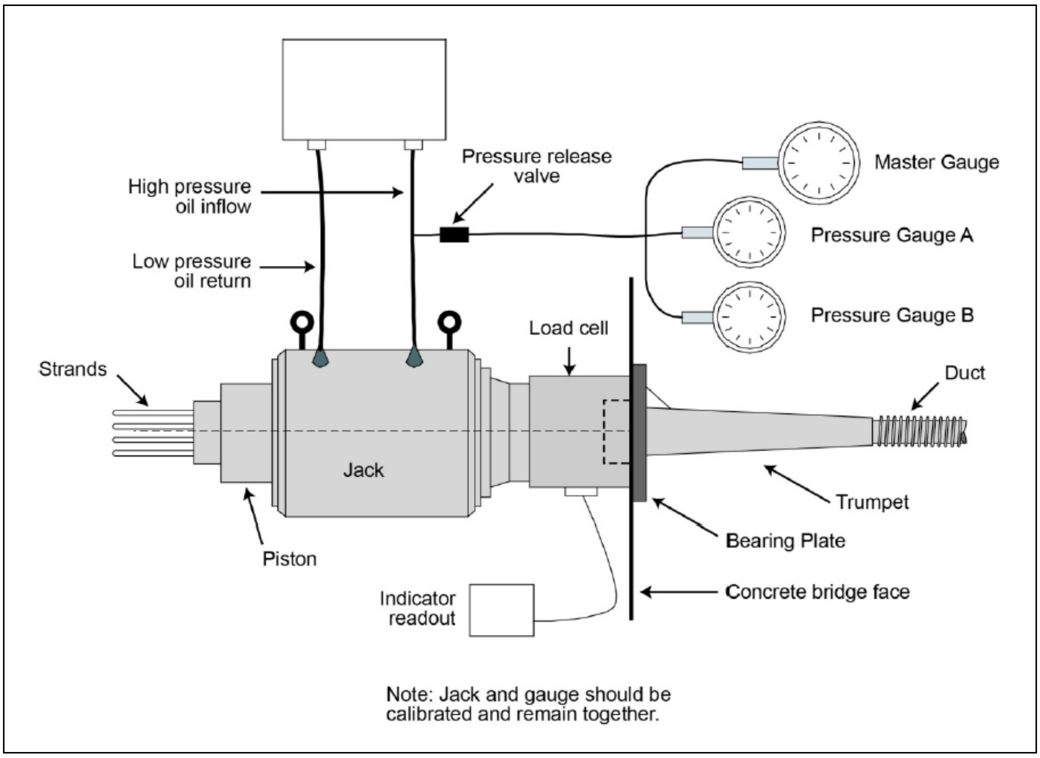


Figure 8.1-6 Jack Calibration

Table 8.1-2 Timing of Calibration for Jacks and Gauges
Construction Manual for Structure (Nippon Expressway Company Limited in Japan)

Timing of calibration for jacks and gauges is as follows: 1. Just before the initial prestressing of first tendon 2. After prestressing about 50 tendons 3.After repair of jacks or pumps 4.In case of changing of combination of jack and pump 5. An occurring of abnormal condition of cable tension Strength Control Chart 6. At the restarting of prestressing works after long interruption of prestressing works

8.1.4 Measurement of Stress

Tensioning is especially important for PC bridge because tensioning will affect the safety of girder directly. In general, an error should occur between design prestressing and actual prestressing because of the following reasons:

- A scatter of friction between tendon and duct
- A scatter of friction of jack or anchorage
- A scatter of elastic modulus of tendon
- An error of jacks

As mentioned above, the tensioning should be controlled to keep the tension force of the tendon not to be under Design stage.

A record of gauge pressures and tendon elongation for each tendon shall be provided by the Contractor for review and approval by the Engineer or MOC Project Manager. Elongation shall be measured to an accuracy of 1. 5mm. Stressing tails of post-tensioned tendons shall not be cut off until the stressing records have been approved.

The stress in tendons during tensioning shall be determined by the gauge or load-cell readings and shall be verified with the measured elongations. Calculations of anticipated elongations shall utilize the modulus of elasticity, based on nominal area, as furnished by the Manufacturer for the lot of steel being tensioned, or as determined by a bench test of strands used in the work.

All tendons shall be tensioned to a preliminary force as necessary to eliminate any take-up in the tensioning system before elongation readings are stated. This preliminary force shall be between 5 and 25% of the final jacking force. The initial force shall be measured by a dynamometer or by other approved method, so that its amount can be used as a check against elongation as computed and as measured. Each strand shall be marked prior to final stressing to permit measurement of elongation and to ensure that all anchor wedges are set properly.

It is anticipated that there may be discrepancy in indicated stress between jack gauge pressure and elongation. In such event, the load used as indicated by the gauge pressure shall produce a slight overstress rather than under-stress. When a discrepancy between gauge pressure and elongation of more than **5%** in tendons over 15.3m long or 7% in tendons of 15.3m or less in length occurs, the entire operation shall be carefully checked and the source of error determined and corrected before proceeding further.

Recommended method for Tensioning operation shall be shown in Appendix A.

	
Figure 8.1-7 Measurement of Elongation	**Figure 8.1-8 Measurement of Camber**

8.2 Pre-tensioning Requirements (Factory Product)

Stressing shall be accomplished by either single-strand stressing or multiple-strand stressing. The amount of stress to be given to each strand shall be as shown in the contract documents or in the approved working drawings.

All strands to be stressed in a group (multiple-strand stressing) shall be brought to a uniform initial tension prior to being given their full pre-tensioning. The amount of the initial tensioning force shall be within the range specified in Article 8.1.4 “Measurement of Stress,” and shall be the minimum required to eliminate all slack and to equalize the stresses in the tendons as determined by the Engineer or MOC Project Manager. The amount of this force will be influenced by the length of the casting bed and the size and number of tendons in the group to be tensioned.

Draped pretensioned tendons shall either be tensioned partially by jacking at the end of the bed and partially by uplifting or depressing the tendons, or they shall be tensioned entirely by jacking, with the tendons being held in their draped positions by means of rollers, pins, or other approved method during the jacking operation.

Approved low-friction devices shall be used at all points of change in slope of tendon trajectory when tensioning draped pretensioned strands, regardless of the tensioning method used.

If the load for a draped strand, as determined by elongation measurements, is more than 5% less than that indicated by the jack gauges, the strand shall be tensioned from both ends of the bed, and the load as computed from the sum of elongation at both ends shall agree within 5% of that indicated by the jack gauges.

When ordered by the Engineer or MOC Project Manager, prestressing steel strands in pretensioned members, if tensioned individually, shall be checked by the Contractor for loss of prestress not more than 3 hours prior to placing concrete for the members. The method and equipment for checking the loss of prestress shall be subject to approved by the Engineer or MOC Project Manager. All strands that show a loss of prestress in excess of 3% shall be re-tensioned to the original computed jacking stress.

Stress on all strands shall be maintained between anchorages until the concrete has reached the compressive strength required at time of transfer of stress to concrete.

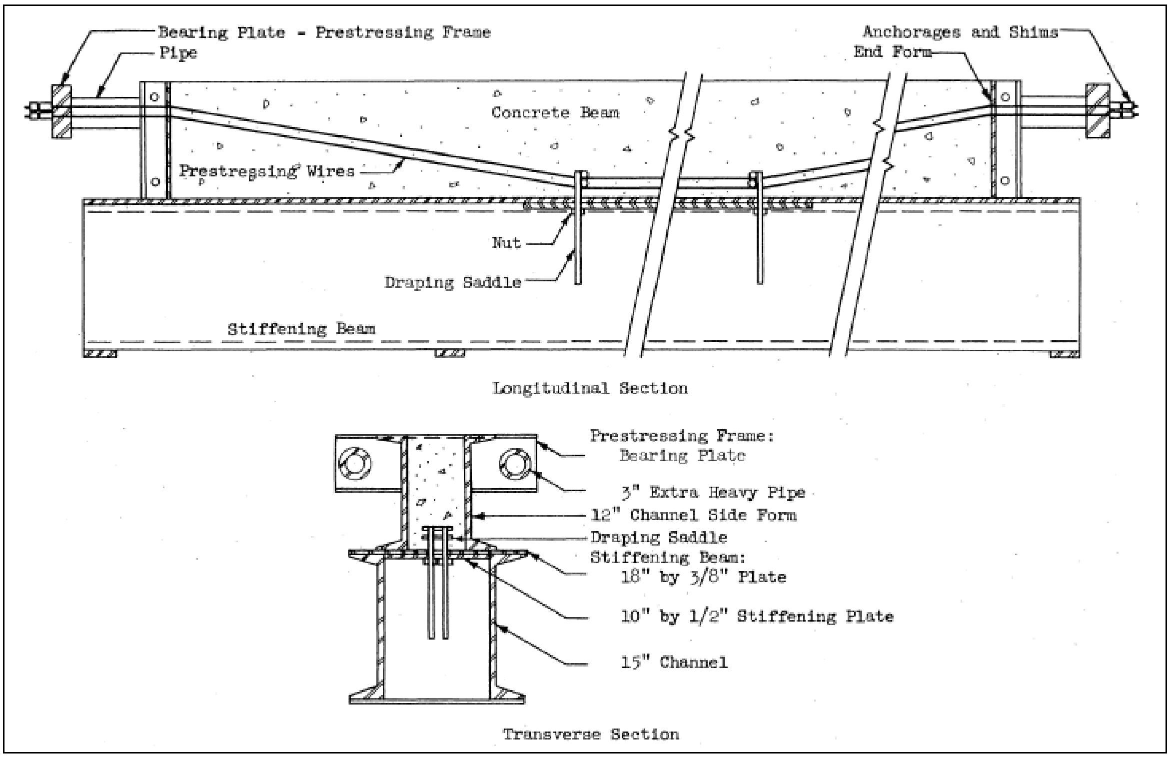


Figure 8.2-1 Draped Pretensioned Tendons

When prestressing steel in pretensioned members is tensioned at a temperature of more than -4°C lower than the estimated temperature of the concrete and the prestressing steel at the time of initial set of the concrete, the calculated elongation of the prestressing steel shall be increased to compensate for the loss in stress due to the change in temperature, but in no case shall the jacking stress exceed 80% of the specified minimum ultimate tensile strength of the prestressing steel.

Strand splicing methods and devices shall be approved by the Engineer or MOC Project Manager. When single-strand jacking is used, only one splice per strand will be permitted. When multi-strand jacking is used, either all strands shall be spliced or no more than 10% of the strands shall be spliced. Spliced strands shall be similar in physical properties, from the same source, and shall have the same “twist” or “lay.” All splices shall be located outside of the prestressed units.

Side and flange forms that restrain deflection shall be removed before release of pre-tensioning reinforcement.

Except when otherwise shown in the contract documents, all pretensioned prestressing strands shall be cut off flush with the end of the member, and the exposed ends of the strand and a 2.54cm strip of adjoining concrete shall be cleaned and painted. Cleaning shall be by wire brushing or abrasive blast cleaning to remove all dirt and residue that are not firmly bonded to the metal or concrete surfaces. The surfaces shall be coated with one thick coat of zinc-rich paint. The paint shall be thoroughly mixed at the time of application, and shall be worked into any voids in the strands.

8.3 Pre-tensioning Requirements (Site Product)

8.3.1 General

The basic important points are the same as in Factory Product (8.2). But circumstances at the site could be worse than at the factory, so quality control shall be implemented more carefully.

And the quality and durability shall not be estimated to be the same as factory product, the quality shall be estimated same as post-tension girder.

Figure 8.3-1 Tensioning of Pre-tensioning Material (Site Product)

8.3.2 Protection for End of Girder

Figure 8.3-2 shall be used as a reference.

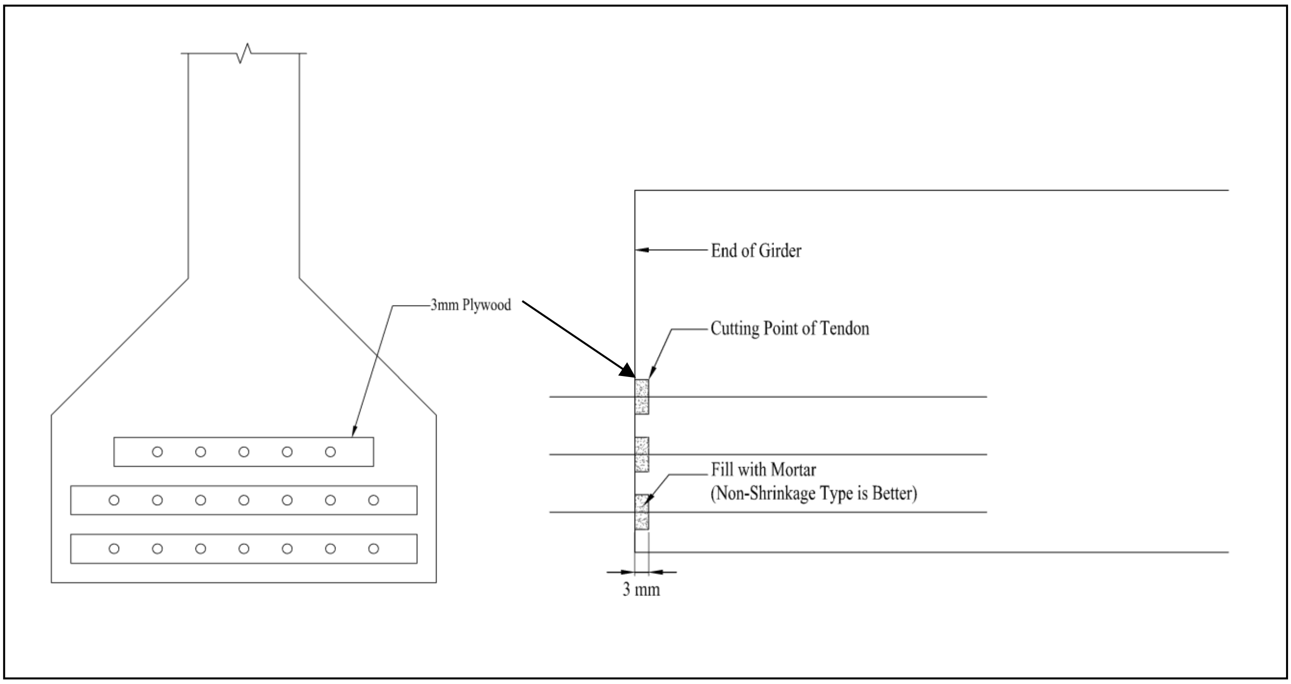


Figure 8.3-2 Example of Girder End Protection

8.4 Post-Tensioning Requirements

Prior to post-tensioning any member, the Contractor shall demonstrate to the satisfaction of the Engineer or MOC Project Manager that the prestressing steel is free and unbonded in the duct.

All strands in each tendon, except for those in flat ducts with not more than four strands, shall be stressed simultaneously with a multi-strand jack.

Tensioning shall be accomplished so as to provide the forces and elongation specified in AASHTO M 204M/M203.

Except as provided herein or when specified in the contract documents or in the approved working drawings, tendons in continuous post-tensioned members shall be tensioned by jacking at each end of the tendon. For straight tendons and when one stressing is shown in the contract documents, tensioning may be performed by jacking from one end or both ends of the tendon at the option of the Contractor.

The planning report for tensioning, where the calibration of jacks, calculation of tensioning, procedure of tensioning, and inspection of tensioning are reported, shall be submitted to the Engineer or MOC Project Manager before tensioning.

Tensioning shall be implemented under supervision by a skilled engineer, who shall confirm also that the appropriate tension is installed. Inspection sheets shall be kept permanently.

 Tendons shall be protected until tensioning work	 **Avoid ends for safety**
Figure 8.4-1 Protection for Tendons	**Figure 8.4-2 Post-tensioning Work**
	
Figure 8.4-3 Insertion of Bearing Plate	**Figure 8.4-4 Setting of Jack**

8.5 Record of Stressing Operation

A record of the following post-tensioning operations shall be kept for each tendon installed:

- Project name, number,
- Contractor and /or subcontractor,
- Tendon location, size and type,

- Date tendon was first installed in ducts,
- Coil/reel number for strands or wires and heat number for bars and wire,
- Assumed and actual cross-sectional area,
- Assumed and actual modulus of elasticity,
- Date stressed,
- Jack and gauge numbers per end of tendons,
- Required jacking force,
- Gauge pressures,
- Elongations (anticipated and actual),
- Anchor sets (anticipated and actual),
- Stressing sequence
- Stressing mode (one end/two ends/simultaneous),
- Witnesses to stressing operation (Contractor and Inspector)
- Date grouted, days from stressing to grouting, grouting pressure applied, and injection end,
- Record of any other relevant information including pour back.

The Engineer or MOC Project Manager shall be provided with a complete copy of all stressing operations and the jack calibration forms.

8.6 Protection of Tendon

Within 4 hours after stressing and prior to grouting, tendons shall be protected against corrosion or harmful effects of debris by temporarily plugging or sealing all openings and vents; cleaning rust and other debris from all metal surfaces which will be covered by the grout cap; and placing the grout cap, including a seal, over the wedge plate until the tendon is grouted.

CHAPTER9. GROUTING

9.1 General

When the post-tensioning method is used, the prestressing steel shall be provided with permanent protection and shall be bonded to the concrete by completely filling the void space between the duct and the tendon with grout. Grout should be injected from low points pumping toward the high-point vent.

All grouting operation shall be carried out by experienced superintendents and foremen that have received instructional training and have at least 3 years of experience on previous project involving grouting of similar type and magnitude.

A grouting operation plan shall be submitted for approval. Written approval of the grouting operation plan by the Engineer or MOC Project Manager shall be required before any grouting of the permanent tendons in the structure takes place.

At a minimum, the following items shall be provided in the grouting operation plan.

- Provide names and proof of training and experience record for the grouting crew and the crew supervisor in conformance with this Specifications;
- Type, quality, and brand of materials used in grouting including all required certifications;
- Type of equipment furnished, including capacity in relation to demand and working condition, as well as back-up equipment and spare parts;
- General grouting procedure;
- Duct pressure test and repair procedures;
- Method to be used to control the rate of flow within ducts;
- Theoretical grout volume calculations;
- Mixing and pumping procedures;
- Direction of grouting;
- Sequence of use of the inlets and outlet pipes;
- Procedures for handling blockages and for possible post grouting repair;

Before grouting operations begin, a joint meeting of the Contractor, grouting crew, and the Engineer or MOC Project Managers shall be conducted. At the meeting, the grouting operation plan, required testing, corrective procedure, and any other relevant issues shall be discussed.

9.2 Preparation of Ducts

Each duct shall be air-pressure tested prior to the installation of the prestressing steel into the ducts. If leaks are indicated during the test, the duct shall be repaired to eliminate the leakage or minimize the consequences of the leakage.

All ducts shall be clean and free of deleterious materials that would impair bonding or interfere with grouting procedures.

Metal ducts shall be flushed if necessary, to remove deleterious material.

After flushing, all water shall be blown out of the duct with oil-free compressed air.

9.3 Equipment

The pump shall be a positive displacement type and be able to produce an outlet pressure of at least 1.04 N/mm^2. The pump should have seals adequate to prevent introduction of oil, air, or other foreign substance into the grout, and to prevent loss of grout or water.

A pressure gauge having a full-scale reading of no greater than 2.07N/mm^2 shall be placed at some point in the grout line between the pump outlet and the duct inlet.

The grouting equipment shall contain a screen having clear openings of 0.32cm maximum size to screen the grout prior to its introduction into the grout pump. If a grout with a thixotropic additive is used, and a screen opening of 0.48cm is satisfactory. This screen shall be easily accessible for inspection and cleaning.

Under normal conditions, the grouting equipment shall be capable of continuously grouting the largest tendon on the project in no more than 20 minutes.

9.4 Mixing of Grout

Water shall be added to the mixer first, followed by cement grout.

Grout shall be mixed in accordance with the Manufacturer's instructions using a colloidal mixer to obtain homogeneous mixture. A fluidity test shall be performed on the mixed grout prior to beginning the injection process. Target flow rates as a function of mixer type used and ambient temperatures shall be obtained from the grout Manufacturer. The grouting process shall not be started until the proper grout properties have been obtained.

Mixing shall be of such duration as to obtain a uniform, thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixture. The grout shall be continuously agitated until it is pumped.

Water shall not be added to increase grout flowability which has been decreased by delayed use of the grout.

The mixing time for grout should be in accordance with the qualification trials and generally not more than 4 minutes for a vane mixer or 3 minutes for a high-speed shear mixer.

According to the pilot project mentioned in Appendix-C, high-speed mixer is better to keep the quality.

In Japan, generally high-speed mixer (over 1000rmp) is used.

Figure 9.4-1 Example of Mixing Grout in Myanmar

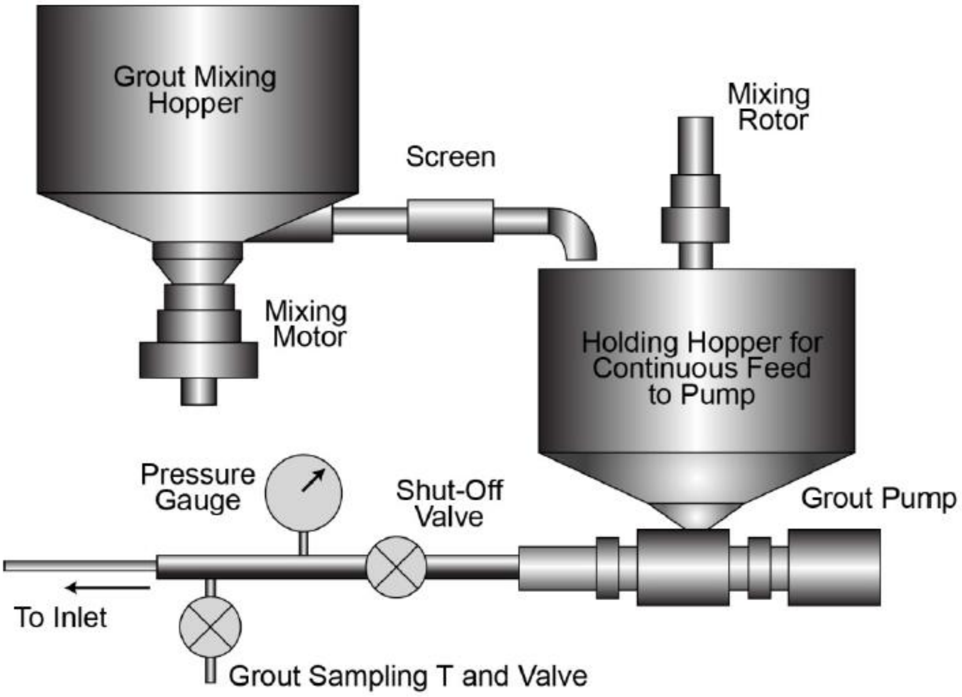


Figure 9.4-2 Example of Grout Mixing and Pumping Equipment

9.5 Injection Grout

All grout vents shall be opened before grouting starts. Injection and ejection vents with positive shut-offs shall be provided. Grout shall be allowed to flow from the first injection vent until any residual flushing water or entrapped air has been removed prior to closing that same manner. A continuous flow of grout at a rate between 10.7m and 15.3m of duct per minute shall be maintained.

The pumping pressure at the injection vent should not exceed 1.04N/mm^2. Normal operations shall be performed at approximately 0.52N/mm^2. If the actual grouting pressure exceeds the maximum allowed, the injection vent shall be closed and the grout shall be injected at the next vent that has been, or is ready to be closed, as long as one-way flow is maintained. Grout shall not be injected into a succeeding vent from which grout has not yet flowed.

Grout shall be pumped through the duct and continuously wasted at the ejection vent until no visible slugs of water or air are ejected. A fluidity test shall be performed on each tendon in accordance with Article 7.3, "Grout Physical Properties," measuring the grout fluidity from the discharge outlet. The measured grout efflux time shall not be faster than the efflux time measured at the inlet or the minimum efflux time established in CHAPTER7. If the grout efflux time is not acceptable, additional grout shall be discharged from the discharge outlet. Grout efflux time shall be tested. This cycle shall be continued until acceptable grout fluidity is achieved. To ensure that the tendon remains filled with grout, the ejection and injection vents shall be closed in sequence, respectively, under pressure when the tendon duct is completely filled with grout. The positive shut-offs at the injection and ejection vents shall not be removed or vents opened until the grout has set.

Figure 9.5-1, Figure 9.5-2 and Figure 9.5-3 shall be used as a reference.

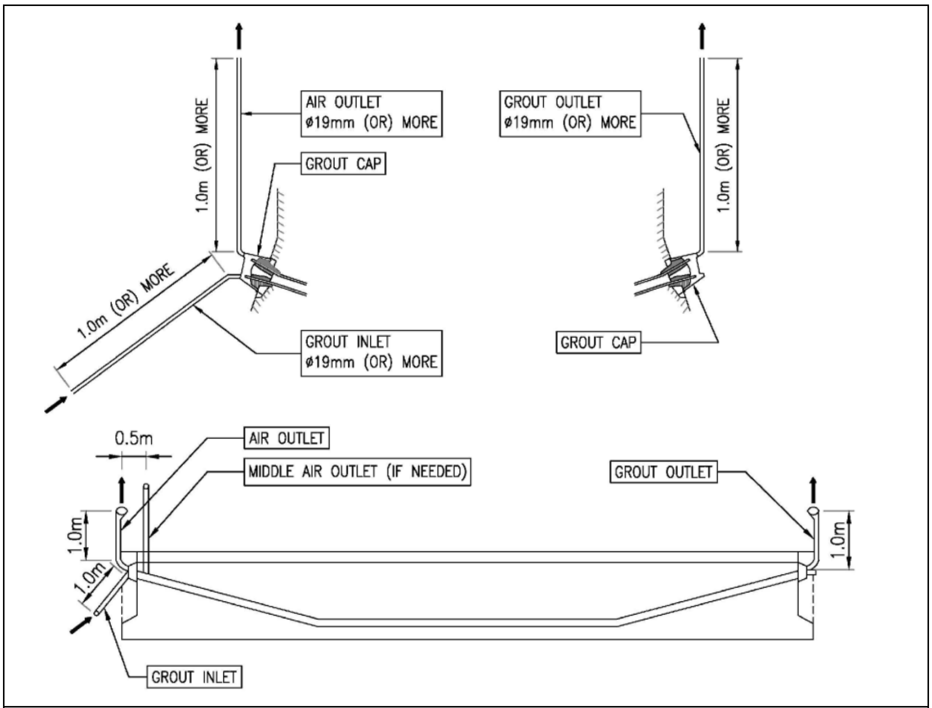
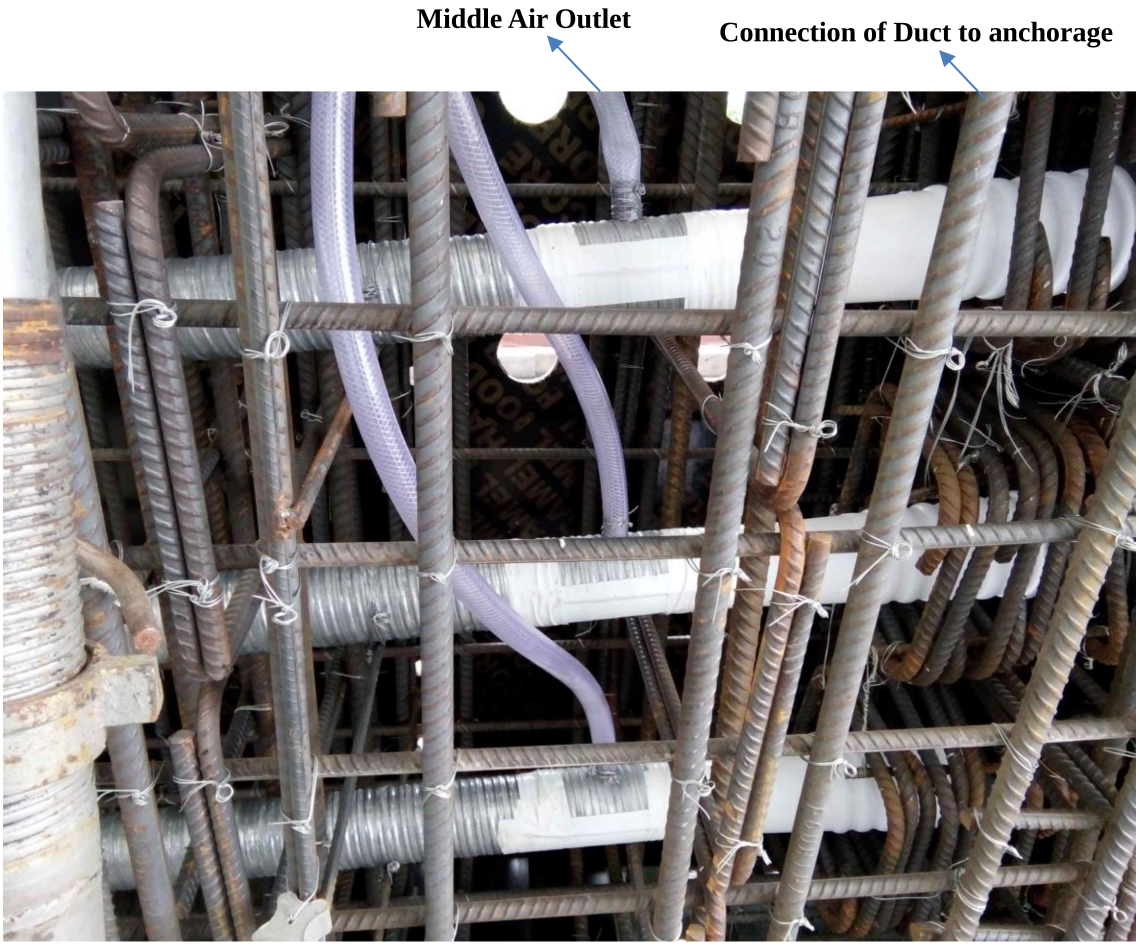


Figure 9.5-1 Example of Setting of Grout Inlet and Outlet, and Air Outlet



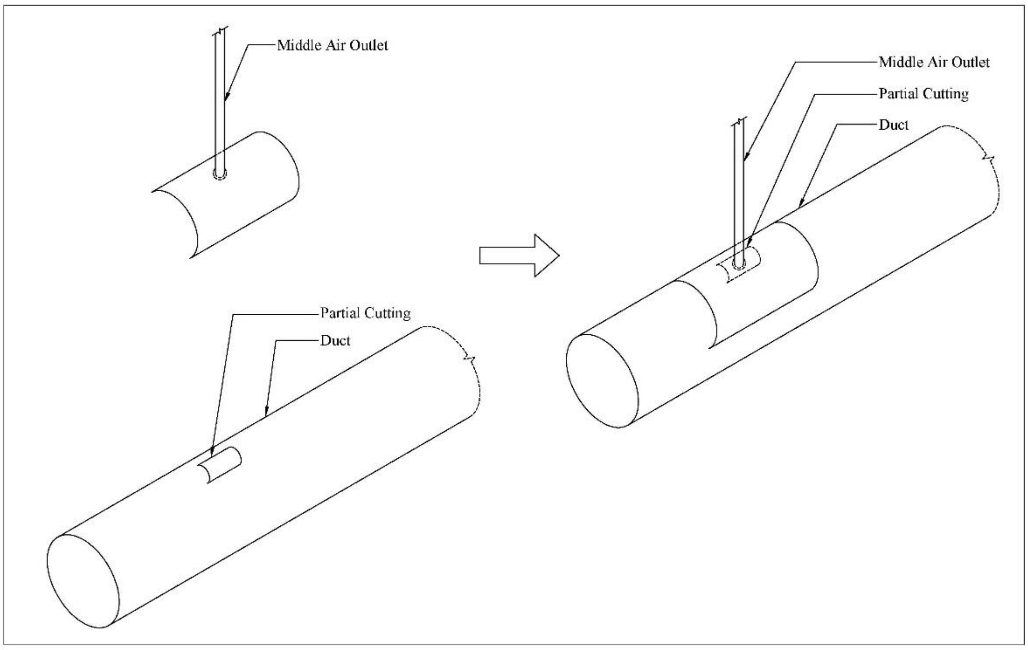


Figure 9.5-2 Example of Air Outlet

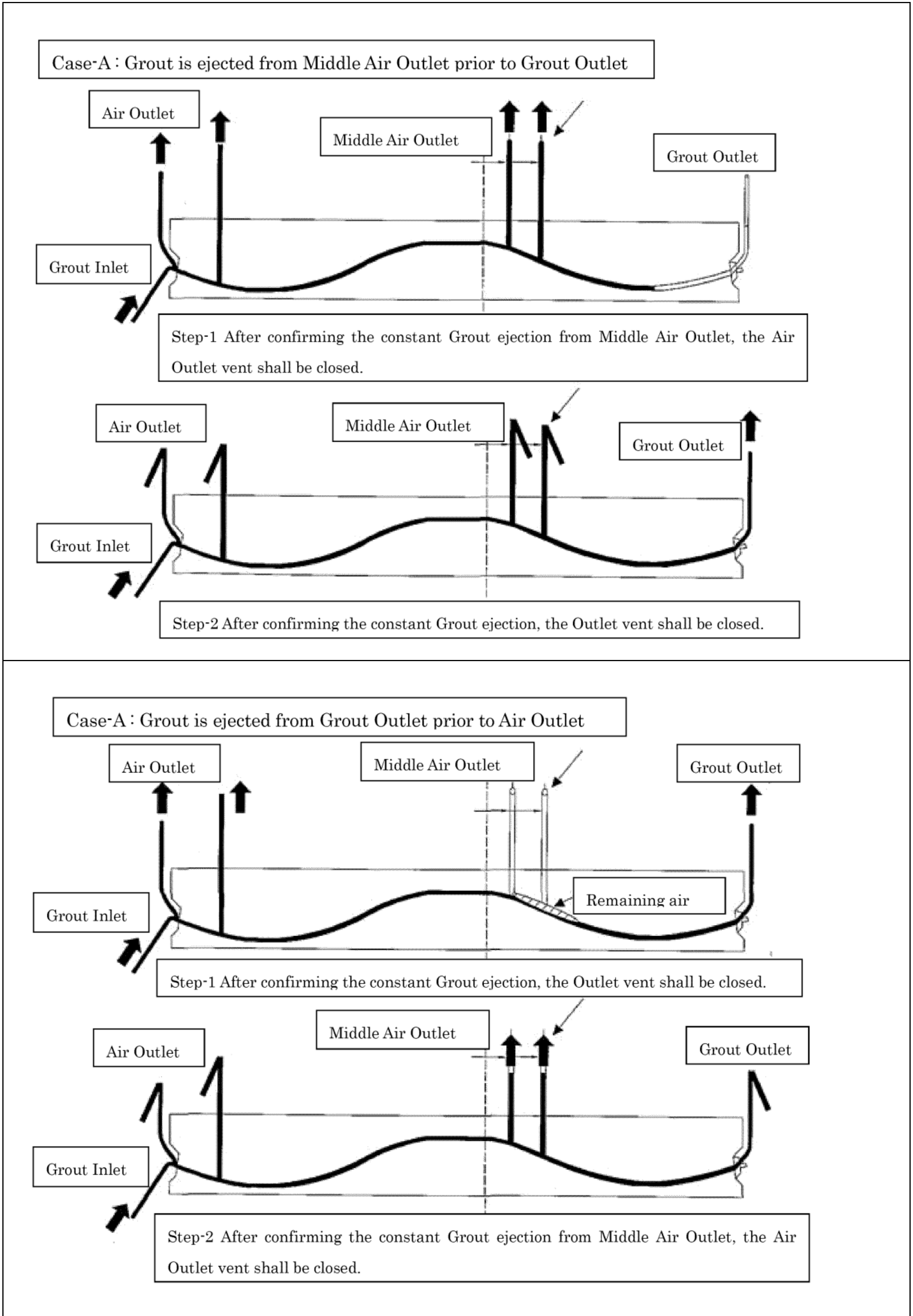


Figure 9.5-3 Example of Treatment of Injection Grout

9.6 Temperature Consideration

In temperatures below 0℃, ducts shall be kept free of water to avoid damage due to freezing. The temperature of the concrete shall be 1.7℃ or higher from the time of grouting until job cured 51mm cubes of grout, reaching a minimum compressive strength of 5.5N/mm^2. Grout shall not be above 32℃ during mixing or pumping. If necessary, cool the mixing water.

9.7 Post-Grouting Inspection

In AASHTO, Post-Grouting Inspection shall be implemented as specified below. Another method for Post-Grouting Inspection is shown in Article 9.10.

Where possible, all anchorages and high-point vents shall be drilled and probed 48 hours after grouting, until the Engineer or MOC Project Manager is assured that no bleed water or subsidence (settlement) voids exist. After the Engineer or MOC Project Manager is assured that voids do not exist, only one or two anchorages per span shall be drilled and probed to ensure quality grouting. Any voids discovered should be filled immediately with the approved grout.

9.8 Finishing

The following requirements apply.

- Valves, caps, and vent pipes shall not be removed or opened until grout has set.
- The ends of vents shall be removed at least 25mm below the concrete surface after the grout has set.
- The void shall be filled with epoxy grout. All miscellaneous materials used for sealing grout caps shall be removed before carrying out further work to protect end anchorages.

9.9 Protection of End Anchorages

In Myanmar, the surrounding of anchorages is usually filled by cast-concrete directory.

Figure 9.9-1 Protection of End Anchorage in Myanmar

In AASHTO, protection of end anchorages is specified as follows:

	
Figure 9.9-2 Anchorage with permanent grout cap, grout inlet, and cap vent (Steel)	**Figure 9.9-3 Permanent Plastic Grout Cap (Courtesy of VSL)**

Permanent grout caps constructed from either stainless steel or polymer shall be specified. The following requirements apply:

- The correct grout is properly installed to completely fill the tendon and anchor.
- The permanent grout cap is fully filled with grout.
- Surfaces of pour-back substrates are thoroughly cleaned and roughened prior to casting pour backs.
- Anchors and grout caps are encased in pour back of an approved, high-strength, high-bond, low-shrink, sand-filled epoxy grout.
- Pour back provides a minimum cover over cap and edges of anchor plate of 2.54cm – 1.27cm.

  Ends of precast beam-type members are encased in a diaphragm that provides additional (reinforced) concrete over the end of the beam and that at expansion joints, reinforced diaphragms are properly formed and cast. (Only approved joint spacer forming materials should be used between continuous units where one diaphragm is cast against the other.)

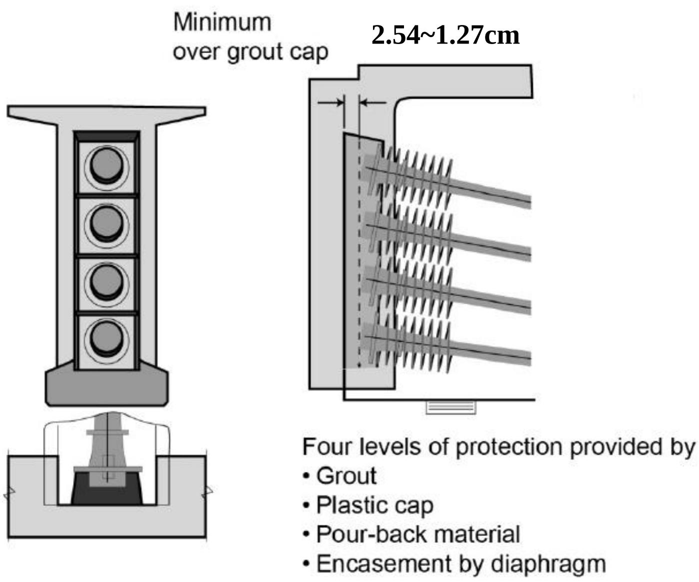


Figure 9.9-4 Example of Anchor Protection Detail at End Anchorage

9.10 Confirming of Grouting

The following shall be used as reference for confirming of grouting.

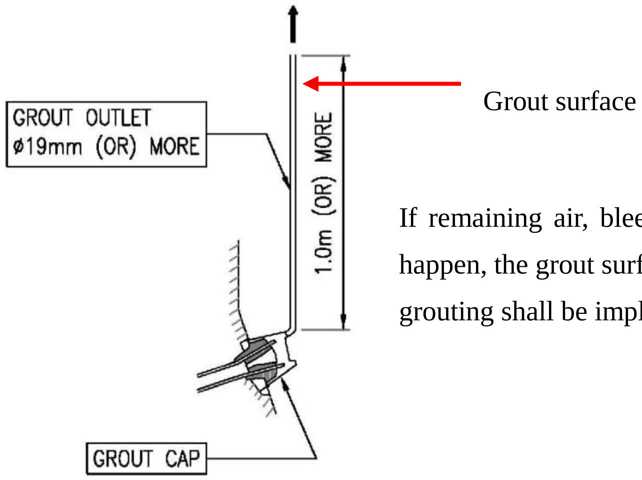
An appropriate probe method shall be selected and the probe shall be carried out adequately. Any voids discovered should be filled immediately with the approved grout.

9.10.1 Visual Inspection of Outlet and Calculation of Grout Volume

Visual inspection of grout outlet and estimated calculation of grout volume shall be implemented at least.

Total grout volume is calculated by measuring the material volume and water volume. Estimated grout volume shall be obtained as follows:

Total Grout Volume – Remained Grout Volume



If remaining air, bleeding water, or shortage of grout happen, the grout surface will be down. In that case, re-grouting shall be implemented.

Figure 9.10-1 Visual Inspection of Grout Outlet

9.10.2 Checking of Grout Volume by Digital Volumeter

Actual volume of grout shall be calculated using a digital volumeter.

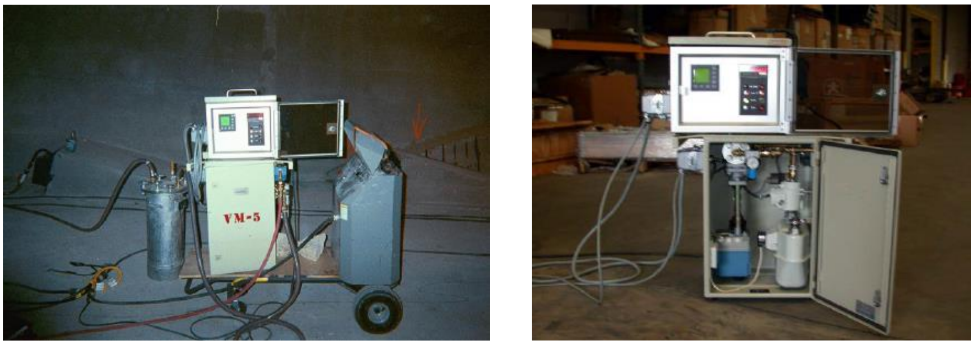


Figure 9.10-2 Digital Volumeter

9.10.3 Method for Confirming of Grouting in Japan

(1) During and after grouting

A. Vibration device sensor

Setting the vibration device sensor at the target spot. The remaining air will be searched by the difference in vibration characteristics.

Figure 9.10-3 Vibration device sensor

B. Thermocouple heat radiation sensor (MS sensor)

Setting the sensor on the surface inside the duct. The remaining air will be detected by the difference of ratio of heat radiation.

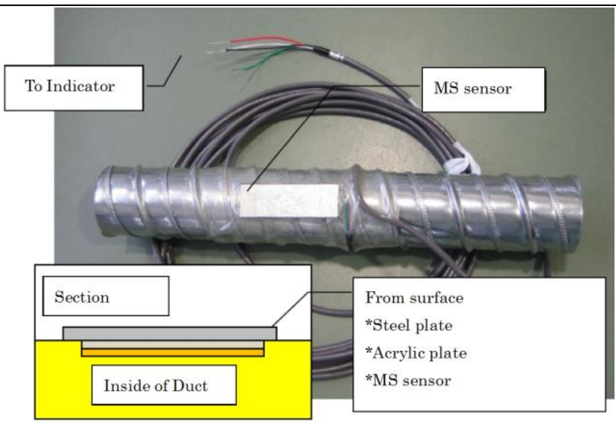


Figure 9.10-4 MS sensor system

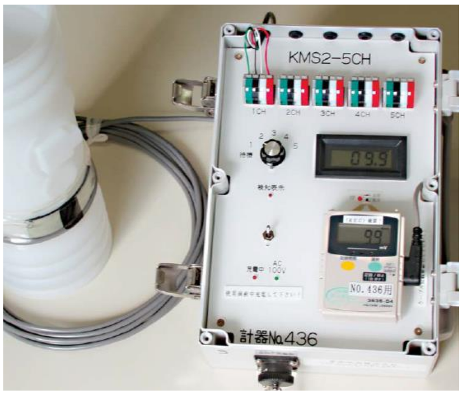


Figure 9.10-5 Indicator

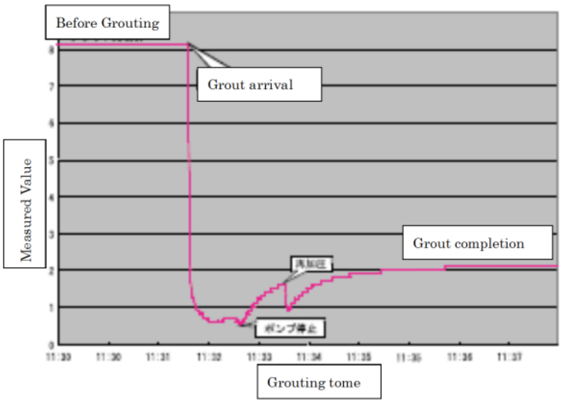


Figure 9.10-6 Result of Measuring

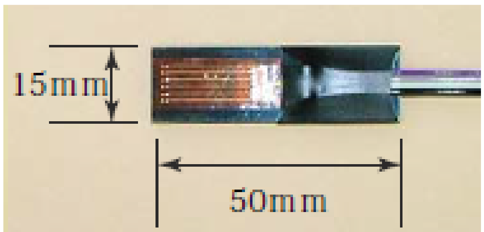
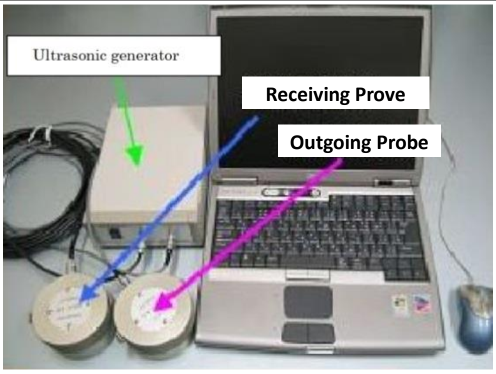


Figure 9.10-7 MS Sensor

(2) After hardening (non-destructive inspection)

A. Broadband ultrasonic wave method

The remaining air will be detected by the difference of characteristics of electric waves.



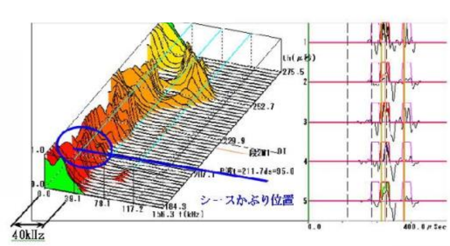


Figure 9.10-8 Normal Result

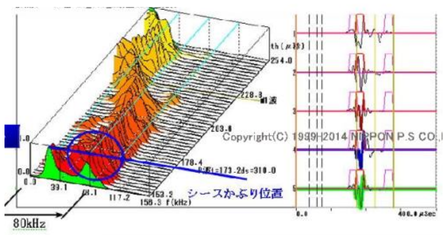


Figure 9.10-9 Air-Remaining Area

B. Multipath array electromagnetic wave method

The remaining air will be detected by the difference of electric characteristics.

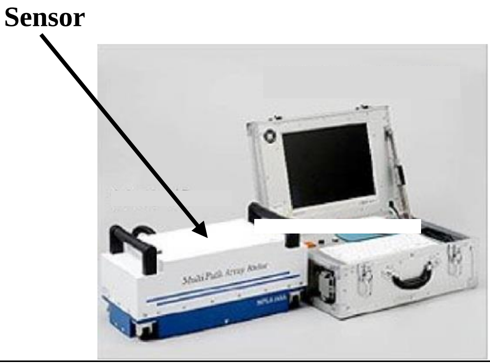


Figure 9.10-10 Indicator

Figure 9.10-11 Checking by Multipath Array Electromagnetic Wave Method

9.11 Grouting Problems and Solutions

9.11.1 Interruption of Grout Flow

If there is a breakdown, then use the available standby equipment. Standby equipment should be periodically checked to make sure it is in working order. Standby equipment may be a second set of production grouting equipment in operation nearby. In any event, standby equipment should be mobilized as soon as possible.

Standby equipment should be brought into operation within 15 to 30 minutes or else grout may be begin to solidify and it will be too difficult to mobilize the grout, especially on long tendons.

If standby equipment cannot be brought into operation, then the grouting should be terminated.

9.11.2 Too High Grouting Pressure

If it requires an excessive pressure to inject the grout, there may be a blockage. Excessive pressure would be any pressure about 50% more than the limiting pressure in Article 9.5. In any circumstances no attempt should be made to force the grout through. Excessive pressure can lead to failure of ducts or cracking of concrete, depending upon circumstances and details.

If grout cannot be injected at an intermediate outlet from which it has already flowed, grouting should cease.

9.11.3 Production Grout Fluidity Interruption of Grout Flow

Prior to grouting, if the flow-cone time exceeds the allowable limits, perform another test. If the flow time still exceeds allowable limits, check the source, date, storage, and mixing of grout materials. Abandon the batch and begin again with new material.

Do not add water or any high-range water reducer to improve fluidity. If necessary, abandon the batch and begin again with new material.

9.11.4 Vacuum Grouting

Vacuum grouting is used for more reliable grouting; it is normally used in the U.S.

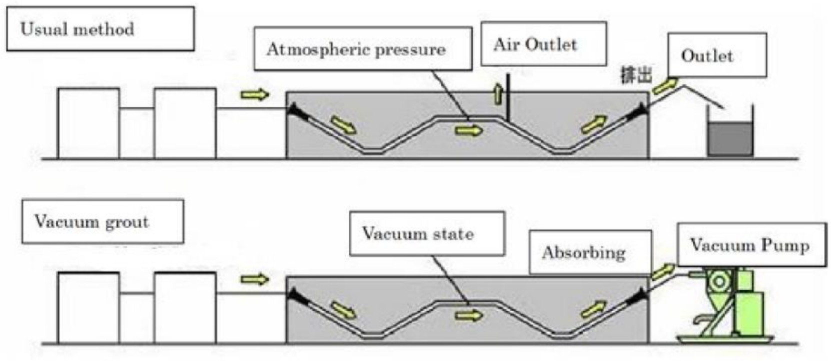


Figure 9.11-1 Vacuum Grout System

Figure 9.11-2 Grout Pump

Figure 9.11-3 Vacuum Grout Injection

CHAPTER10. INSTRUCTIONS FOR INSPECTION

Outline for PC girder inspection is shown as follows.

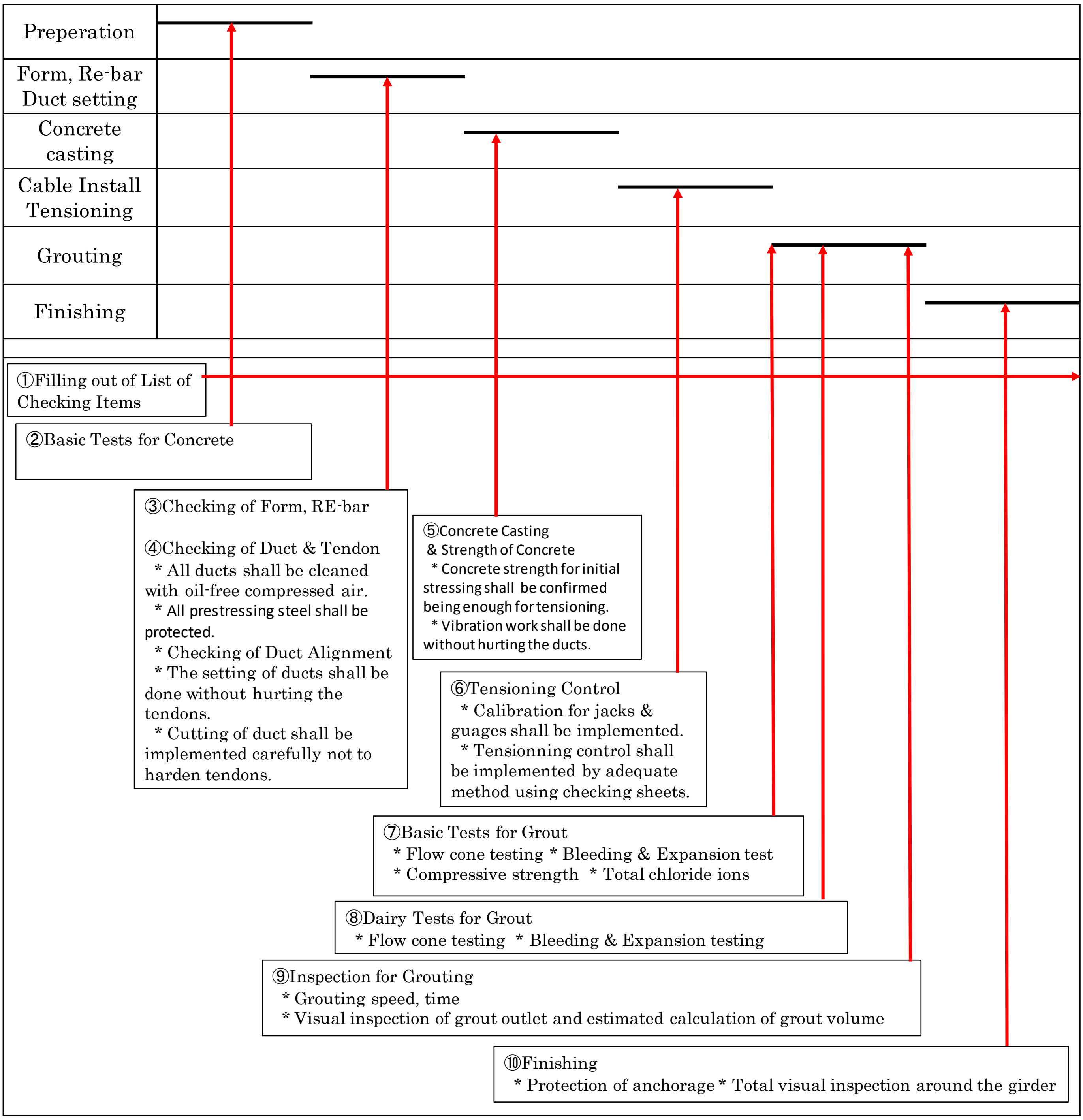


Figure 10-1 Inspection Outline for PC girder

10.1 Recording to the List of Checking Items

The Supervisor shall record “Yes” or “No” in the checking sheet (Appendix B-1) to indicate whether the inspection has been done or not throughout the whole process of PC girder construction.

Materials shall be stored under good condition; especially, prestressed steel shall be stored so as to avoid the occurrence of corrosion.

List of checking items that should be implemented				
			Checking	
Concrete	Concrete Strength	Test piece (At Transfer)	yes	no
		Test piece (28 days)	yes	no
		Schmidt hammer (At Transfer)	yes	no
	Requred tests shall be in accordance with "2 Concrete Structure"			
Prestressing Steel	Checking of Manufacturer's certificate & a test		yes	no
	Implementation of Protection of Prostressing Steel		yes	no
Grout	Basic Test	Compressive Strength	yes	no
		Content of Chloride	yes	no
		Fluidity	yes	no
		Ratio of Bleeding	yes	no
		Rate variability of volume	yes	no
	Daily Test	Compressive Strength	yes	no
		Content of Chloride	yes	no
		Fluidity	yes	no
		Ratio of Bleeding	yes	no
		Rate variability of volume	yes	no
Anchorage	Yield & ultimate strength, Modulus of elasticity		yes	no
Duct	Thickness (By Manual)	Steel	yes	no
		Plastic	yes	no
Duct setting	Checking of Duct Position		yes	no
Cable Tension Strength Control	Checking of Pressure & Elongation		yes	no
Grouting	Visual Inspection		yes	no
	Volume of grouting		yes	no
	Mechanical checking (MS sensor etc.)		yes	no

Figure 10.1-1 Checking Sheet Sample

10.2 Basic Tests for Concrete

Basic required tests shall be implemented in accordance with “Concrete Structure Manual”.

10.3 Checking of Form and Re-bar Arrangement

Checking of form and re-bar arrangement shall be implemented in accordance with “2 Concrete Structure”.

10.4 Checking of Duct and Prestressing Steel Arrangement

All ducts shall be cleaned with oil-free compressed air.

Alignment of duct shall be checked in accordance with drawings.

In case when the prestressing steel materials are already inserted in the duct, the setting of duct shall be done without hurting the prestressing steel.

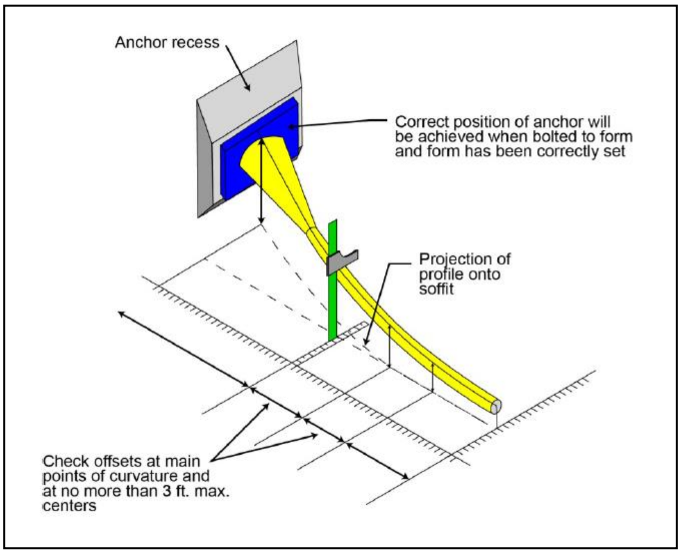


Figure 10.4-1 Checking of Duct Alignment

From manufacture to grouting, all prestressing steel shall be protected against physical damage and rust or other results of corrosion at all times.

Cutting of duct shall be implemented carefully so as not to harden the tendons.

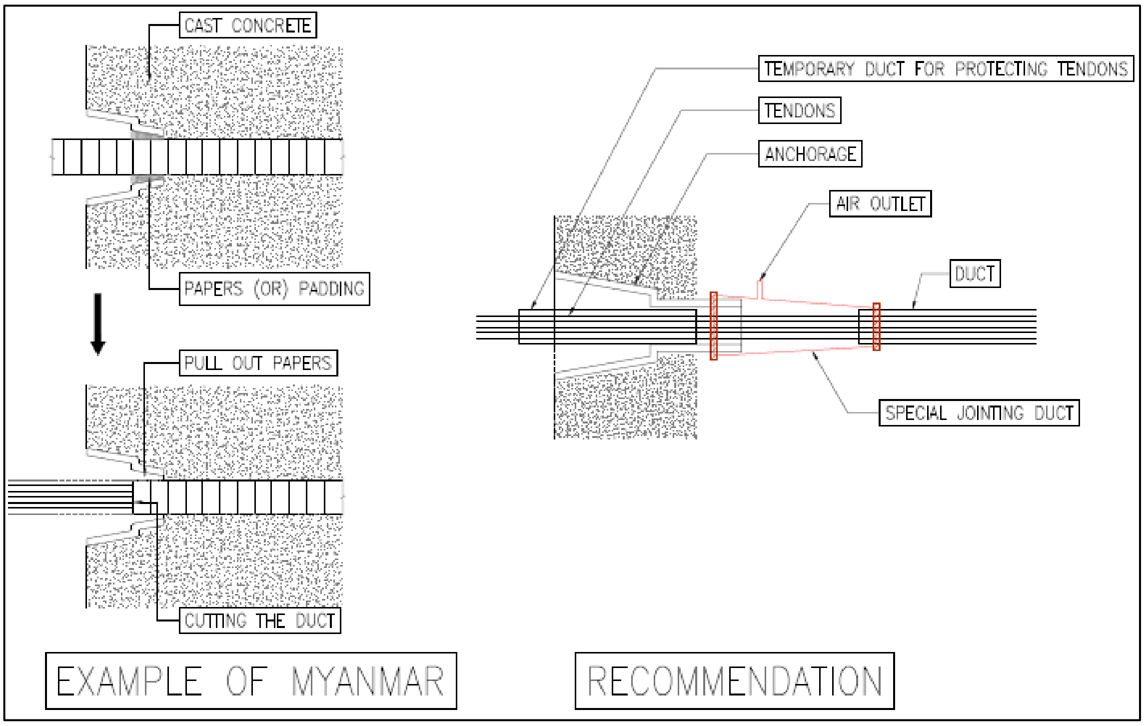


Figure 10.4-2 Detailed of Duct at Anchorage

Setting of Air Outlet: It is better to set the air outlet in the grout inlet side.

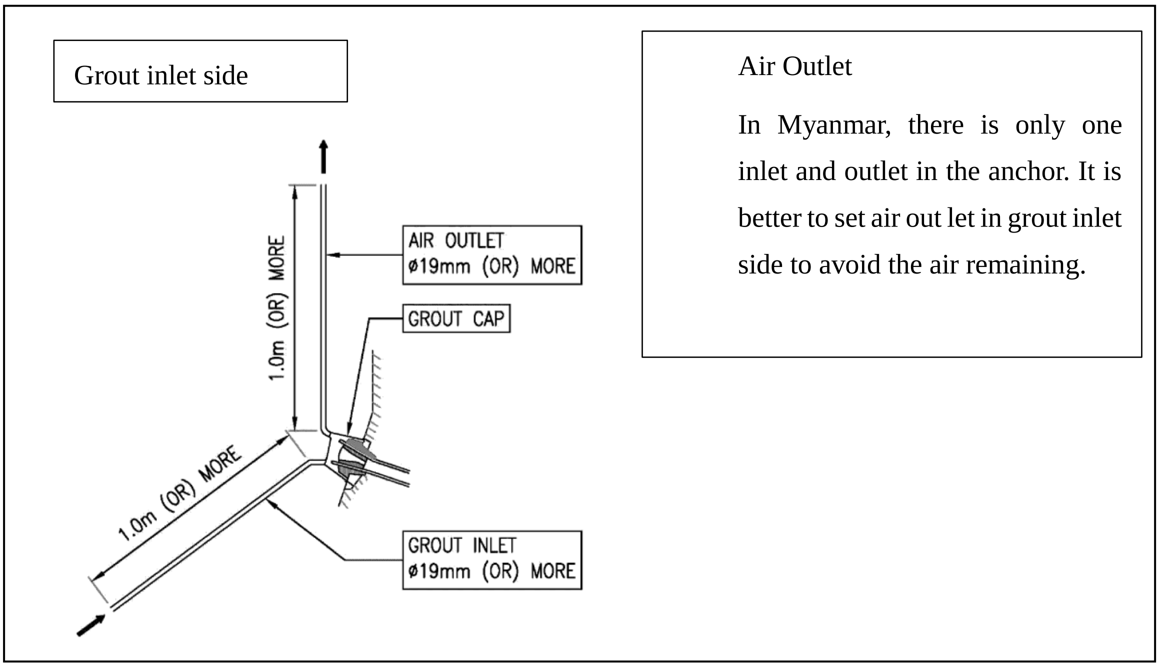


Figure 10.4-3 Setting of air outlet

10.5 Checking of the Casting of Concrete and Concrete Strength

Basic required tests shall be implemented in accordance with “2 Concrete Structure”.

Concrete strength for initial stressing shall be confirmed as being enough for tensioning (Manual 8.1.1).

Casting work shall be implemented according to “Concrete Structure Manual”, especially the vibration work shall be done without hurting the ducts.

10.6 Tensioning Control

Calibration for jacks and gauges shall be implemented as follows:

- Just before the initial prestressing of first tendons
- After prestressing about 50 tendons
- After repair of jacks or pumps, etc.

Tensioning is especially important for PC bridge because tensioning will affect the safety of the girder. Tensioning control shall be implemented by adequate method using the checking sheet as follows (Manual: Appendix B-2):

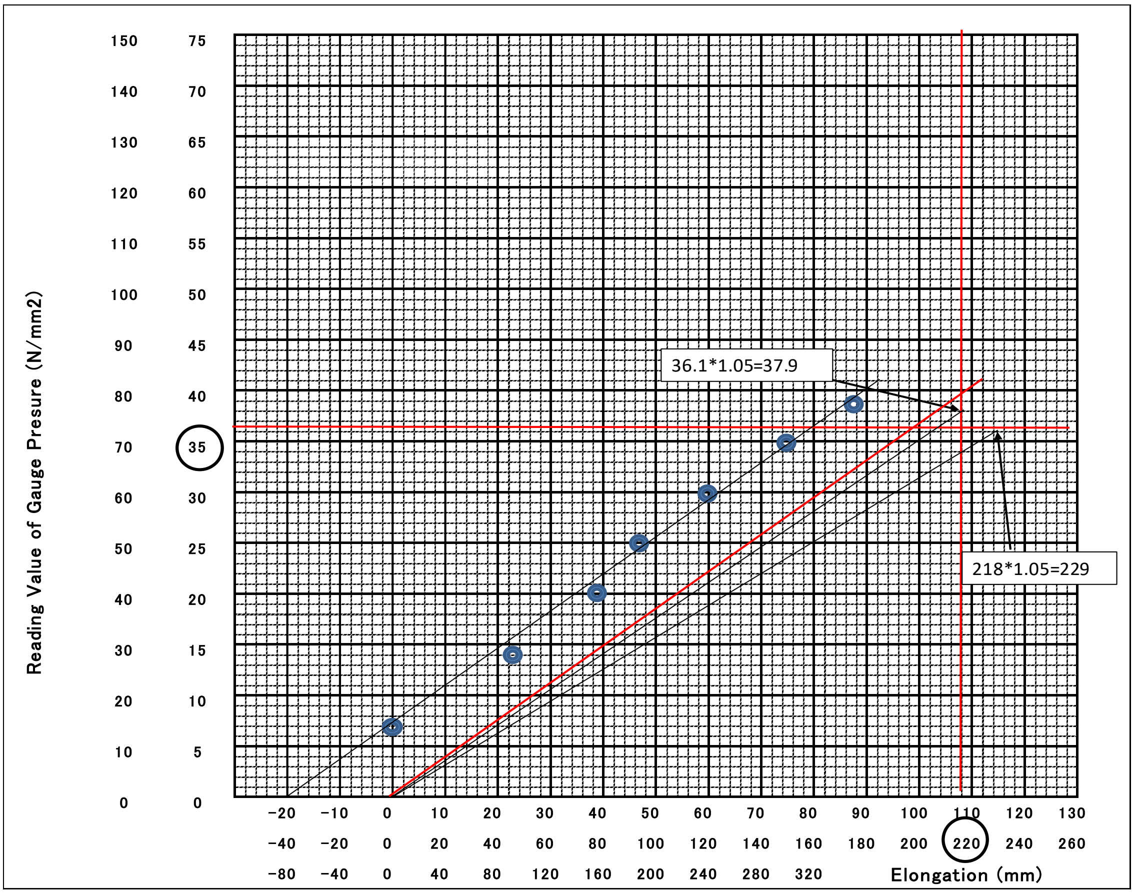


Figure 10.6-1 Example of Cable Tension Strength Control

10.7 Basic Tests for Grout

For basic field testing of grout, referring to “Appendix B-3, 1/3 & 2/3” shall be required.

	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time(sec.)	Test value	Flow time(sec.)	Test value
Flow cone Testing		0			9~20		
		15					
		30			<30		
		45			(Remixing 30s)		
		60					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Hight of Grout (mm)	Hight of Bleed water (mm)	Bleeding (%)		Test value
Bleeding Test		0.0					
		0.5					ASTM C940
		1.0					0.0%(At 3hr)
		2.0					
		3.0					JSCE-F535
		5.0					0.0%(Final)
		10.0					
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Hight of Grout (mm)	Amout of change (mm)	Expansion (%)		Test value
Expansion Test		0.0					
		0.5					ASTM C940
		1.0					<2.0%(up to 3hr)
		2.0					
		3.0					JSCE-F535
		5.0					±0.5%
		10.0					
		24.0					

	No.	Compressive strength (N/mm^2)				Dimnsionsof mortar cube
		24 hrs.	3 days	7 days	28 days	
Compressive Strength (28 days)	1					Diameter (mm)
	2					
	3					Hight (mm)

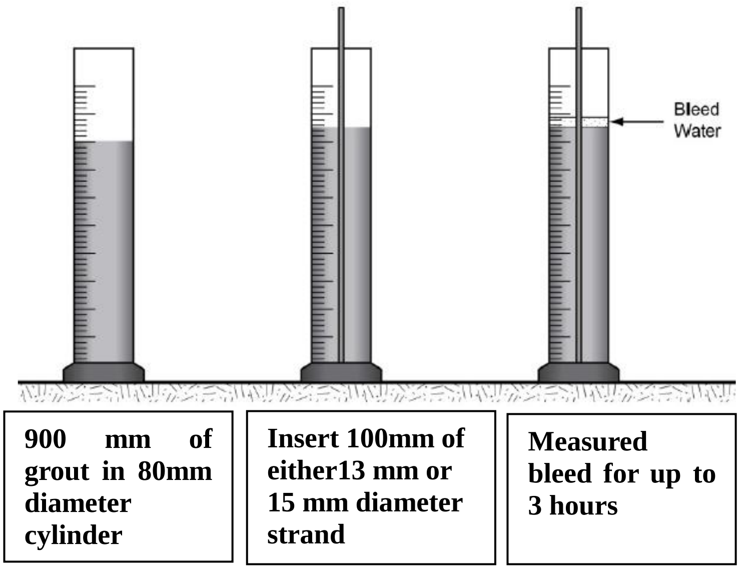
	No.	Unit value on the numbered scale	Chloride Ions getting from the chart(mg/L)	Chloride Ions(%)			Test value
Total Chloride Ions (In case of using "Quantab")	1						< 0.08%
	2						
	3						

Figure 10.7-1 Inspection Sheets for Grouting

10.8 Daily Tests for Grout

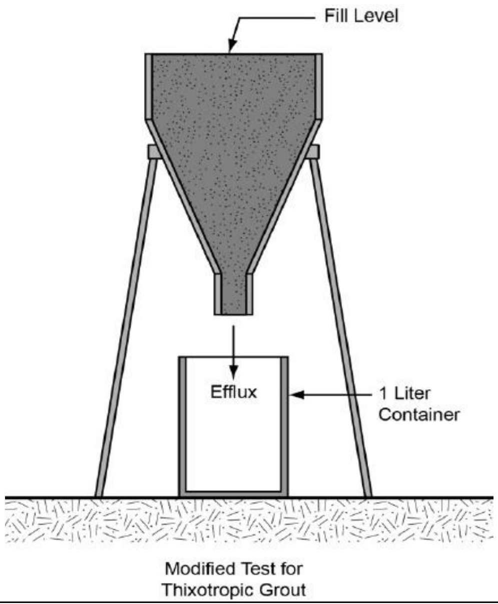
Daily field testing of the grout at least for the following properties shall be required:

- Fluidity,
- Bleed at 3 h, and
- Expansion (volume changing)



Seven wire strands in a cylinder with a height of 1,000 mm and diameter of 80 mm, filled with 900 mm of carefully prepared grout and record the bleed water above the grout. A bleed of 0.0% after 3 hours at normal ambient room temperature of 20ºC is acceptable.

Figure 10.8-1 Wick-Induced Bleed Test



The efflux time should be between 9 to 20 seconds immediately after mixing. After allowing the grout to stand for 30 minutes without agitation and then remixing for 30 seconds, the efflux time should be less than 30 seconds.

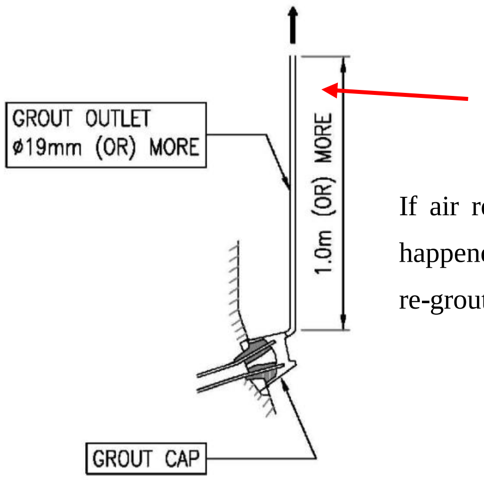
Figure 10.8-2 Flow Cone Testing (Modified ASTM C939)

10.9 Inspection for Grouting

Grout shall be mixed in accordance with the Manufacturer's instructions using a colloidal mixer to obtain homogeneous mixture.

Water shall not be added to increase grout flowability which has been decreased by delayed use of the grout.

Visual inspection of grout outlet and estimated calculation of grout volume at least shall be implemented.



Grout surface

If air remained, bleeding water, or shortage of grout happened, the grout surface will be down. In that case, re-grouting shall be implemented.

Figure 10.9-1 Visual Inspection of Grout Outlet

10.10 Finishing

Before casting of concrete, the anchorages shall be cleaned. Concrete shall be casted fully around the anchorages. Finally, inspector shall check visually all around the girder carefully.

Appendices

Appendix A: Method for Tensioning Operation

A-1: Using record of gauge pressure and elongation of Tendon

(1) Procedure of the revision correction for operation line

- Tendons shall be tensioned to a preliminary force (about 20% of final jacking force). In this example, a preliminary force is 100 N/mm^2.
- Before final jacking force, gauge pressure and elongation shall be plotted step-by-step (Line A).
- Then slide the Line A to revision correction line (Operation Line B).
- Tendons shall be tensioned to a final jacking force, and a final elongation shall be measured.

(2) Allowable error

Operation Line B shall be inside between upper allowable error line and lower allowable error line. The following shows an example of allowable error.

Number of Tendons for 1 set	1	2	3	4	5	6	7	8	9	Over 10
Allowable error (%)	10	7.1	5.8	5.0	4.5	4.1	3.8	3.5	3.3	3.2

Source: Construction Manual for Concrete Road Bridge (Japan Road Association)

(3) Elongation

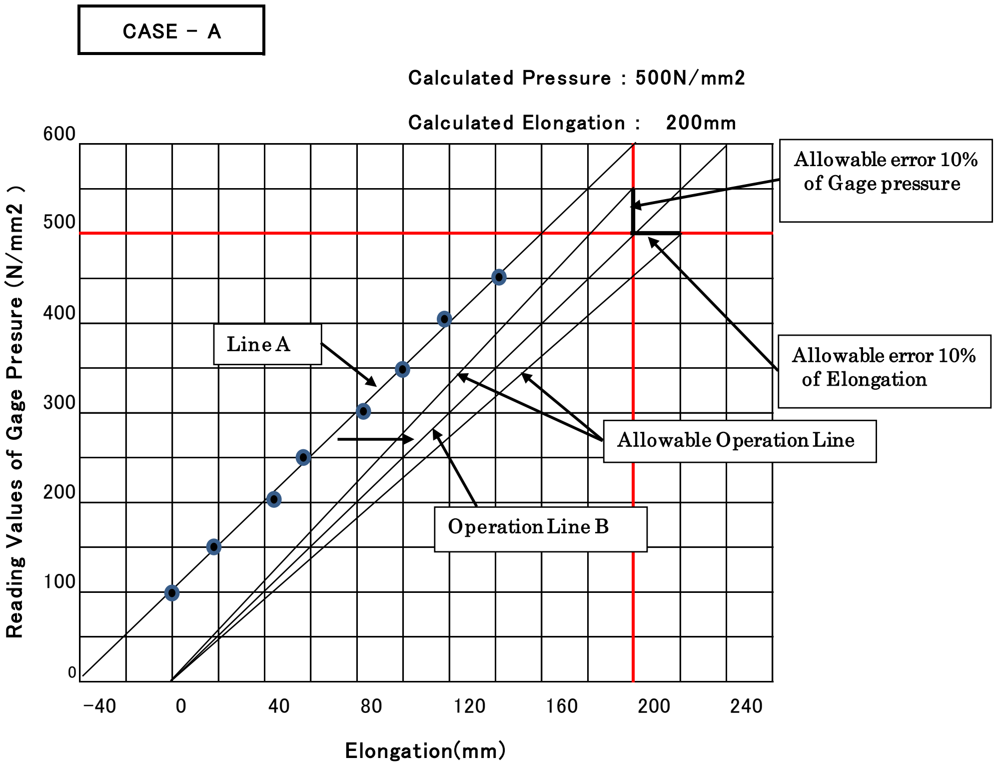
Total Elongation is as follows:

- Single pulling: Total Elongation = "Elongation of Stressing" - "Pull in at Fix Side Tendon Grip"
- Double pulling: Total Elongation = "Elongation of Stressing A" + "Elongation of Stressing B"

(4) Treatment for various cases

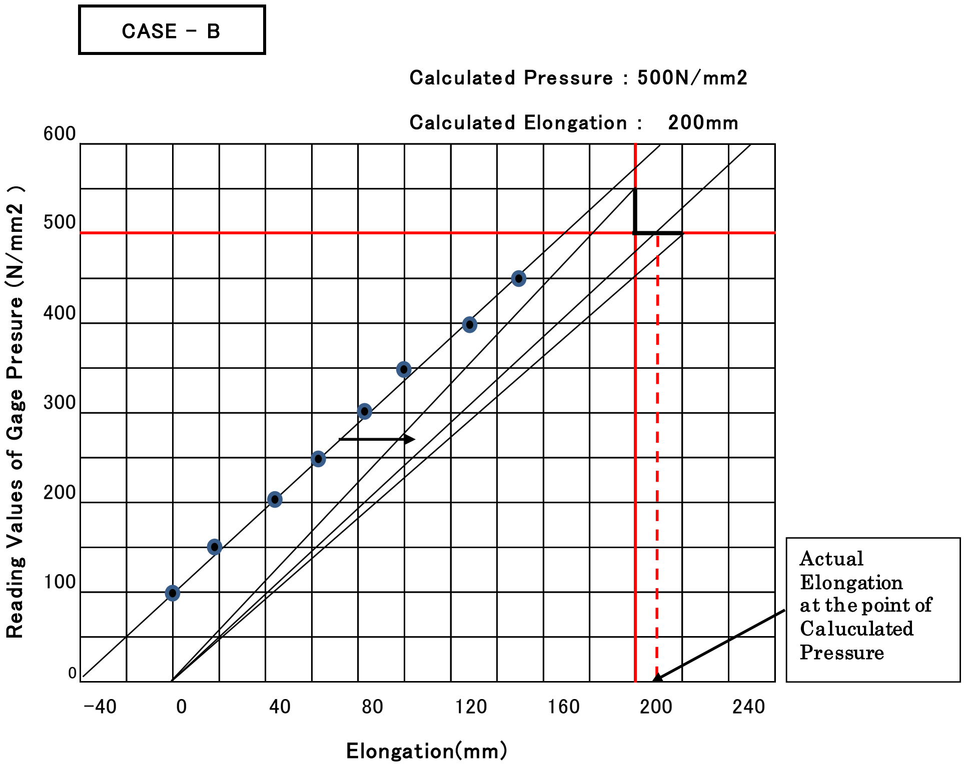
1) CASE A: Actual Elongation is almost the same as Calculated Elongation

Operation of prestressing is acceptable.



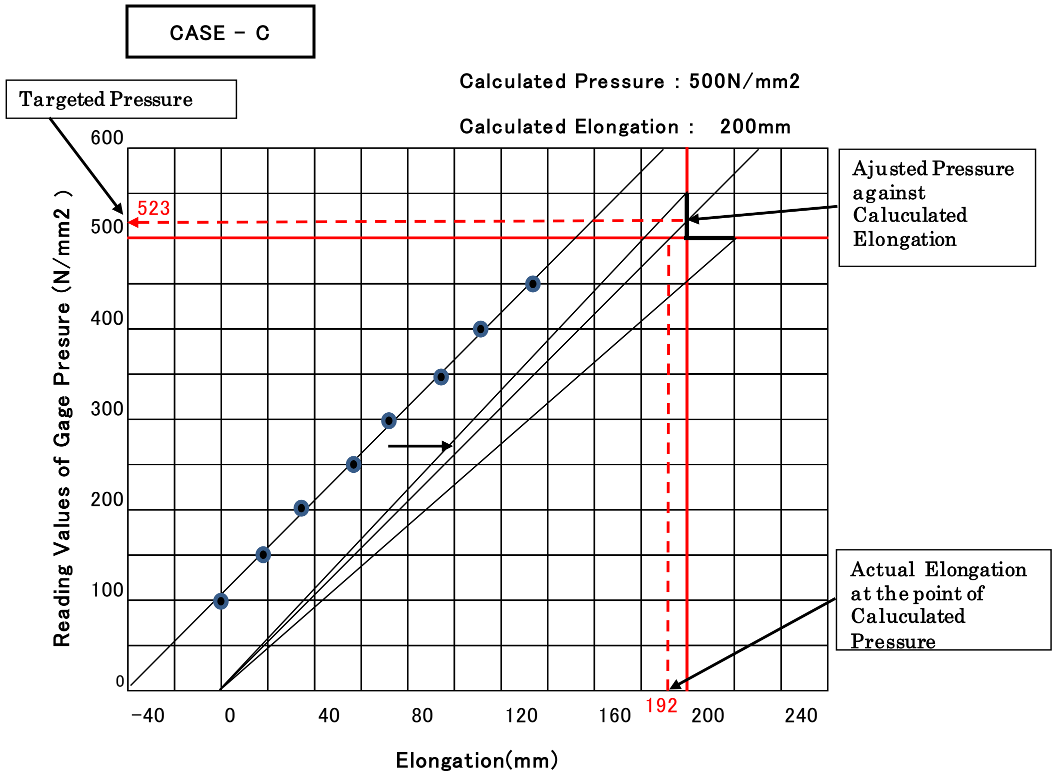
2) CASE B: Actual Elongation is bigger than Calculated Elongation, but inside of allowable error Line.

Operation of prestressing is acceptable.



3) CASE C: Actual Elongation is smaller than Calculated Elongation, but inside of allowable error line.

Tendons shall be re-tensioned to the Pressure (523 N/mm^2 in this example) where the elongation will be to a calculated elongation.



4) CASE D: Actual Elongation is outside of allowable error line.

The reason shall be investigated immediately, and the countermeasure shall be discussed.

Appendix B Inspection Sheet

B-1 List of Checking Items

				PC 01
Checking items that should be implemented				
			Checking	
Concrete	Concrete Strength	Test piece (At Transfer)	yes	no
		Test piece (28 days)	yes	no
		Schmidt hammer (At	yes	no
	Requred tests shall be in accordance with			
	"2 Concrete Structure"			
Prestressing Steel	Checking of Manufacturer's certificate & a		yes	no
	Implementation of Protection of Prostressing		yes	no
Grout	Basic Test	Compressive Strength	yes	no
		Content of Chloride	yes	no
		Fluidity	yes	no
		Ratio of Bleeding	yes	no
		Rate variability of volume	yes	no
	Daily Test	Compressive Strength	yes	no
		Content of Chloride	yes	no
		Fluidity	yes	no
		Ratio of Bleeding	yes	no
		Rate variability of volume	yes	no
Anchorage	Yield & ultimate strength, Modulus of		yes	no
Duct	Thickness (By Manual)	Steel	yes	no
		Plastic	yes	no
Duct setting	Checking of Duct Position		yes	no
Cable Tension Strength Control	Checking of Pressure & Elongation		yes	no
Grouting	Visual Inspection		yes	no
	Volume of grouting		yes	no
	Mechanical checking (MS sensor etc.)		yes	no

B-2 Stressing Record

B-2-1 Example 1 (MOC Inspection Sheets)

PRE TENSION RECORD

Project Name	Bridge Name/ No	Inspecter Name	Designation
Span No.	Girder No.	Concrete Compressive Strength Design	Foreman skill
Concreting Date	Tensioning Date	Concrete Compressive Strength at Transfer	Contract.

	R	R	R	R	R	R	R	R	Fm	Fm	PTc	Fc	PTc	Fc	
									A	B	C	D	E	F	
Strand No.	Reel No.	Jack Serial No.	Gauge Serial No.	Jack Location Side	Total Req'd Jack Force (ksi)	Req'd JackForce Per Wire (psi)	Gauge @ 20% Jacking Force (psi)	Gauge @ Req'd Jacking Force (psi)	Measured Elong. @ 20% Gauge (in)	Measured Elong. @100% Gauge (in)	Calc. 100% Elong. (in)	(B-A) = Measured 80% Elong. (in)	Calc. 80% Elong. (in)	% Elong. Per Tendom	Remarks

R Recorded info. From Plant, Shop Dwg; ,PT Suppliers, Equipment.

PTc PT Supplier Calculations from Shop Dwg;

Fm Field Measured Values

Fc Field Calculation

Camber Checking________________

Note: % Elong. Per Tendom (F) = Col: (D) divided by Co:. E x 100

% Elong. Per Tendom shall be between 95% minimum and 105% maximum

Recorded By Inspected By Checked By Approved By

POST TENSION RECORD

Project Name	Bridge Name/ No	Inspecter Name	Designation
Span No.	Girder No.	Concrete Compressive Strength Design	Foreman skill
Concreting Date	Tensioning Date	Concrete Compressive Strength at Transfer	Contract.

	R	R	R	R	R	R	R	R	Fm	Fm	PTc	Fc	PTc	Fc	
									A	B	C	D	E	F	
Tendom No.	Reel No.	Jack Serial No.	Gauge Serial No.	Jack Location Side	Req'd Jack Force per Tendom (ksi)	Strands Per Tendom	Gauge @ 20% Jacking Force (psi)	Gauge @ Req'd Jacking Force (psi)	Measured Elong. @ 20% Gauge (in)	Measured Elong. @100% Gauge (in)	Calc. 100% Elong. (in)	(B-A) = Measured 80% Elong. (in)	Calc. 80% Elong. (in)	% Elong. Per Tendom	Remarks

R Recorded info. From Plans, Shop Dwg; ,PT Suppliers, Equipment.
PTc PT Supplier Calculations from Shop Dwg;
Fm Field Measured Values
Fc Field Calculation

Note: % Elong. Per Tendom (F) = Col: (D) divided by Co:. E x 100
% Elong. Per Tendom shall be between 95% minimum and 105% maximum

Camber Checking________________

Recorded By Inspected By Checked By Approved By

B-2-2 Example 2 (Federal Highway Administration: Post-Tensioning Tendon Installation and Grouting Manual)

STRESSING REPORT

Page 1 of 2

Project name:	Job No.
Contractor:	Stressing Sub-Contractor:
Tendon Location:	Tendon Number:
Tendon Size:	PT Steel Supplier:
Assumed for Calculations	Actual Values Delivered per Pack or Reel of Strand
	Strands from Reel No:
Number of Strands, Ns:	Number of Strands per Reel, Nr:
Assumed Strand Area, As:	Actual Strand Area per Reel, Ar:
Assumed Modulus, Es:	Actual Modulus per Reel, Er:
Product, Ns*As*Es =	Product, Nr*Ar*Er =
	Sum of Products: Sum(Nr*Ar*Er) =

Adjusted Elongation Expected = [Nr*Ar*Er / (Sum(Nr*Ar*Er))]

First Stage Stressing from End A

	Jack Force (kip)	Gauge (psi)
Required force before wedge set:		

Theoretial elongation, ΔA, (ins) =

Theo ΔA+ΔB =

Adjusted elongation, ΔA, (ins) =

Adj ΔA+ΔB =

Expected Wedge Set, End A, Wa:

Second Stage Stressing from End B

	Jack Force (kip)	Gauge (psi)
Required force before wedge set:		
Anticipated pick-up force:		

Theoretical elongation, ΔB, (ins) =

Adjusted elongation, ΔB, (ins) =

Expected Final Wedge Set, End B, Wb:

	Jack	Gauge
Equipment Identifiers End A:		
Equipment Identifiers End B:		

Stressing Mode:

One End only: ______ Both A then B: ______ Both Simultaneous (A and B with 2 sets of equipment): ______

Target Gauge Pressures and Elongations

	End A Pressure	End A Elongation per increment	End A Wedge Set	End B Pressure	End B Elongation	End B Wedge Set

Elong before set at A = ΔA = (Sum) =

Elong before set at B = ΔB = (Sum) =

Net Elong after wedge set at A=

Net at B after set =

Overall anticipated elongation =

STRESSING REPORT

Elongation Measurement:

First Stage Stressing	End A Pressure	Elongation	Wedge Set at A, Wa	End B Pressure	Elongation	Wedge Set at B, Wb	Increment of Elong per 20% of Load	Average per 20%
Initial 20%								
40%								
60%								
80%								I
Final 100% at A								V
Second Stage Stressing Pick-up at B								I
Final 100% at B								V

Elongation at A from 20 to 100% =								V
Add for initial 20% load =		<-----------------<	---------------------------<	-----------------------------<	---------------------<-------			--------<--
Elongation at A before set =			Elongation at B before set =					
Total Elongation before set =								
Total Wedge Set =								
Deduct for elongation inside jack =								
Final Elongation =								
Expected Elongation =			Ratio of (Final / Expected) =		% under or over =			< 7% O.K. (AASHTO LRFD Construction or Project Specs.)
Approved:			Not Approved:					

Observations: *No popping noises of broken wires O.K. Over elongation is within tolerance, O.K.*

Signed - Stressing Foreman: ______________________________ Date: ______________

Signed - Inspector: ______________________________ Date: ______________

B-2-3 Example 33 (Recommended Format)

Project Name	
Bridge Name	
Span Number	
Girder Number	
Cable Number	

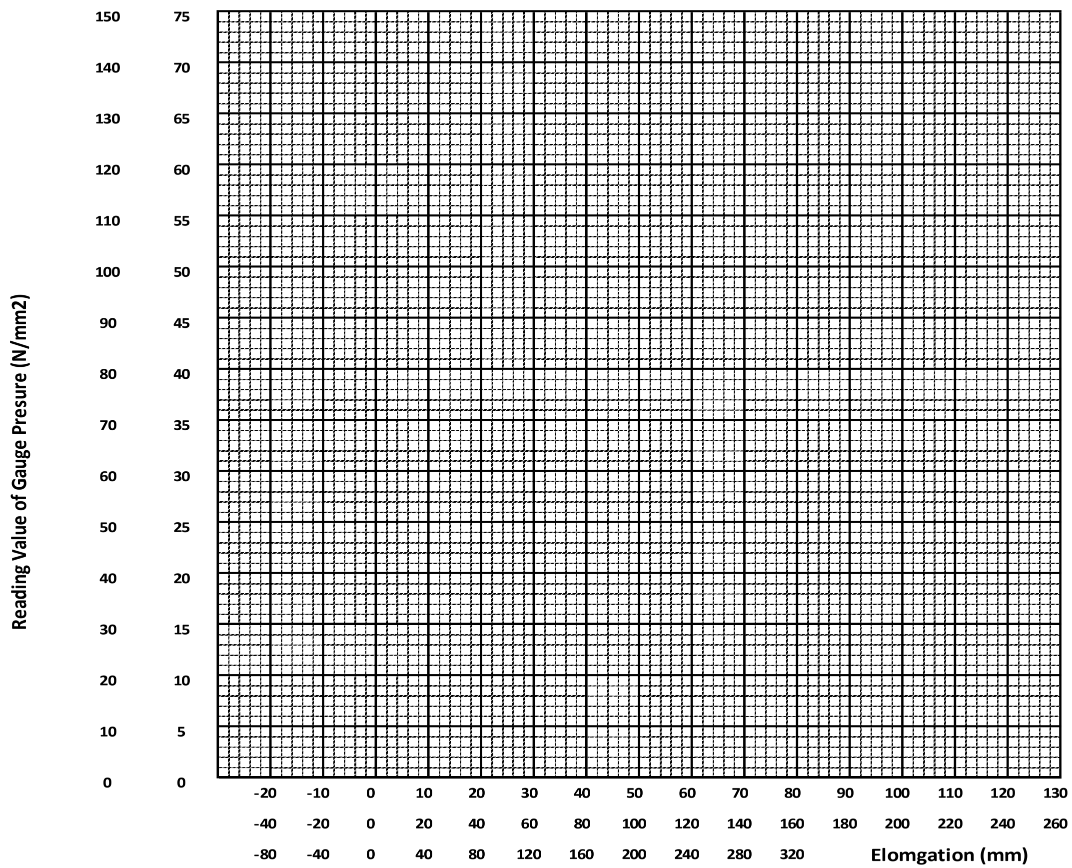
Cable Tension Strength Control Chart

PC 02

(A)Calculated Tension Strength(N/mm2)		Concrete Strength σc(N/mm2)	
Jack Plate Area Aj(cm2)		σc(N/mm2) at Transfer (N/mm2)	
Total Cable Area/tendon At(cm2)			
(B).Calculated Gauge Pressure(N/mm2)		Final Gauge Pressure(N/mm2)	
B=(A*At/Aj)			
Calculated Elongation (mm)		Adjustment Total Elongation (mm)	

Name of Inspector

Gauge Pressure (N/mm2)	Elongation (mm)		
	Stressing side A	Stressing side B(or Pulling at Fix side)	Total
"0"Adjustment			
Adjustment Total Elongation			



Project Name	
Bridge Name	Saing Du Bridge
Span Number	6
Girder Number	5
Cable Number	4
Tendon Numer	T2

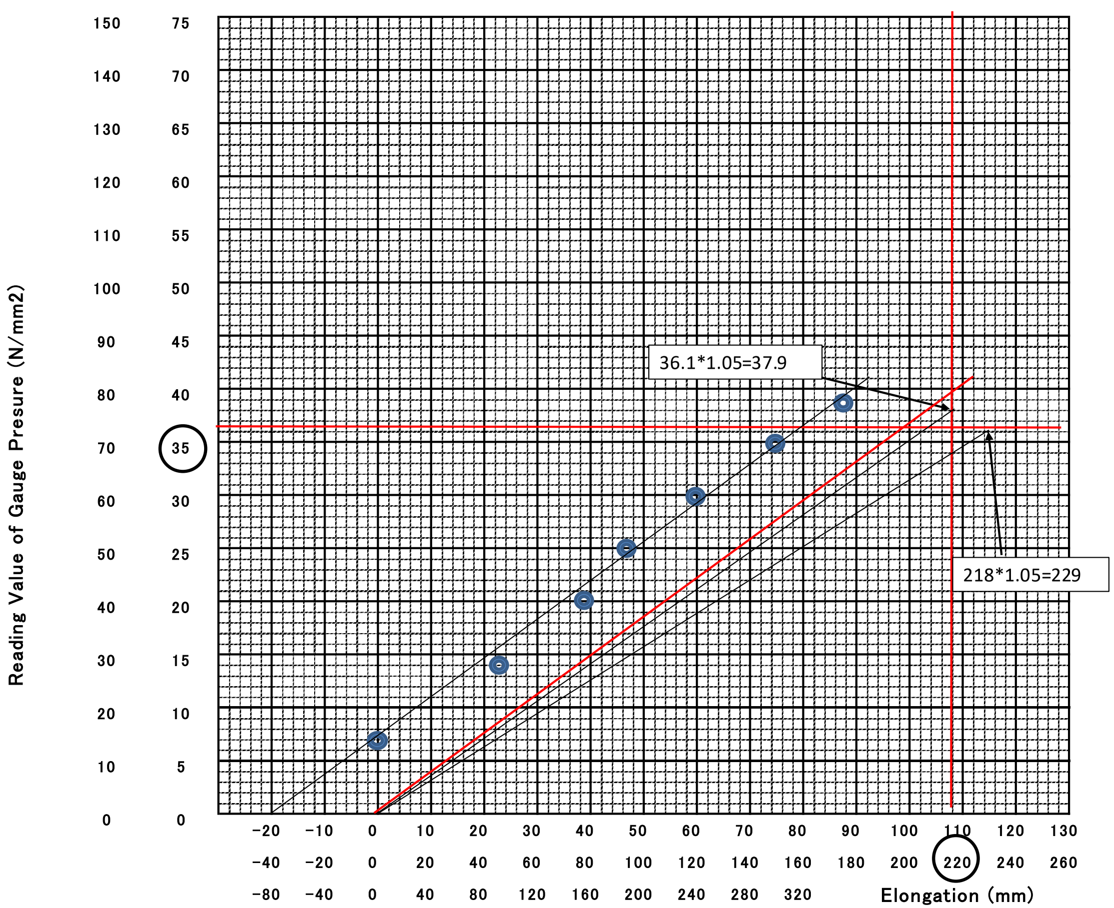
Cable Tension Strength Control Chart

PC 02

(A)Calculated Tension Strength(N/mm2)	1397	Concrete Strength σc(N/mm2)	
Jack Plate Area Aj(cm2)	459.4	σc(N/mm2) at Transfer (N/mm2)	
Total Cable Area/tendon At(cm2)	98.8＊12		
(B).Calculated Gauge Pressure(N/mm2)	36.1	Final Gauge Pressure(N/mm2)	38.5
B=(A*At/Aj)			
Calculated Elongation (mm)	218.0	Adjustment Total Elongation (mm)	215

Name of Inspector

Gauge Pressure (N/mm2)	Elongation (mm)		
	Stressing side A	Stressing side B(or Pulling at Fix side)	Total
38.5	189	14	175
38	182	14	168
37	177	13	164
36	170	13	157
35	162	12	150
30	130	10	120
25	102	8	94
20	85	6	79
14	49	3	46
7	0	0	0
"0"Adjustment			
Adjustment Total Elongation			



B-3 Testing for Grout

PC 03

Testing Report for Grout 1/3 (Basic Physical Properties)

Report No.				Date			
Project Name				Name of Project Manager			
Bridge Name				Name of Contructor or Unit No.			
Span No.				Name of Grout Operator			
Place of Test				Batch No.			
Basic data of materials	Name of materials	Type & Bland name		Manufacturer		Date Sheet No by supplier	
	Cement					No.	
	Admixture					No.	
	Premixed One					No.	
	Water					No.	
Combination	Watet/Cementitious Material ratio (%)	Water (kg)	Cementitious material (kg)		Admixture (kg)		Date
			Cement	Premixed One			
1 m^3							
Mixing	Volume (m^3)	Capacity & form of Mixer		Number of Revolutions (rpm)	Mixing time (min)	Number of Revolutions is required over 1000rpm. The mix time should be generally not more than 4 minutes for a vane mixer.	
Compressive Strength (28 days)	No.	Compressive strength (N/mm^2)				Dimnsionsof mortar cube	
		24 hrs.	3 days	7 days	28 days		
	Giredr No1					Diameter (mm) (Cylinder)	
	Giredr No2						
	Giredr No3					Hight (mm)	
	Giredr No4						
	Giredr No5						
Total Chloride Ions (In case of using "Quantab")	No.	Unit value on the numbered	Chloride Ions getting from the chart(%)	Chloride Ions(%) Ave		Chloride Ions(kg/m^3)	Test value
							< 0.08% or < 0.30kg/m^3
	Ave of 3						
					:Water		

Testing Report for Grout 2/3 (Fluidity, Bleeding, Expansion)

Report No.		Date	
Project Name		Name of Project Manager	
Bridge Name		Name of Contructor or Unit No.	
Span No.		Name of Grout Operator	
Place of Test		Batch No.	

	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time(sec)	Test value	Flow time(sec)	Test value
Flow cone Testing		0			9~20		
		15					
		30			<30		
		45		(Remixing 30s)			
		60					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Height of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
Bleeding Test (Measure by 100ml)		0.0	A0				
		0.5					ASTM C940
		1.0					0.0%(At 3hr)
		2.0					
		3.0					JSCE-F535
		5.0					0.0%(Final)
		10.0					
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Amout of change C=Ai-A0	Expansion C/A0 (%)		Test value
Expansion Test (Measure by 100ml)		0.0	A0				
		0.5					ASTM C940
		1.0					<2.0%(up to 3hr)
		2.0					
		3.0	Ai				JSCE-F535
		5.0					±0.5%
		10.0					
		24.0					

Testing Report for Grout 3/3 (Checking of Grouting Volume & Grouting Pressure)

Report No.		Date	
Project Name		Name of Project Manager	
Bridge Name		Name of Contractor or Unit No.	
Span No.		Name of Grout Operator	
Place of Test		Batch No.	

Designed Grouting Pressure	Conversion to Grouting Pump Meter Pressure :	< 2.0 Mp	
	Conversion to Grouting Hose Pressure :	< 0.6 Mp	
	Target Re-pressurize : over Final Grouting Pressure	< 2.0 Mp	
Factor of Tendon	Inner sectional area of Duct (B)	Sectional area of Tendon (C)	(B-C)
			mm^2
Design Grouting Volume (Gd)/1-girder	Gd = ΣLi * (B - C) : liter		
	Li : length of Duct (m)	B-C : Empty Area (mm^2)	
	Gd=		litter
Actual Grouting Volume (Ga)	Ga = B/ρ + W (litre) - R : liter		
	B : Weight of Cementitious materials (kg)	ρ: Density of Cementitious materials (kg/liter)	
	W : Volume of water (liter)	R : Volume of remained mixed grout (liter)	

No. of Duct	Remainning Volume (Liter)				Actual Grouting Volume (Ga) (liter)	Actual Grouting Volume (Liter)
					Ga = B/ρ + W (litre) - R	
					B= (kg)	
	Outle: (liter)	1 Girder				
					ρ= (kg/liter)	
	In hopper	Pump & hose	For testing	Total R		B/ρ+W-R
Girder No1					B/ρ= (liter)	
Girder No2						
Girder No3					W= % =158or135 (liter)	
Girder No4						
					R= Remainning (liter)	
Total					**Ga= B/ρ+W - R(liter)**	

Appendix C Inspection Example on the Pilot Project

1. Pretesting of Grout Materials

1.1 Outline

Pretesting of grout for Taung Bway Bridge was implemented at Unit 9 on 27th February and 7th March 2018.

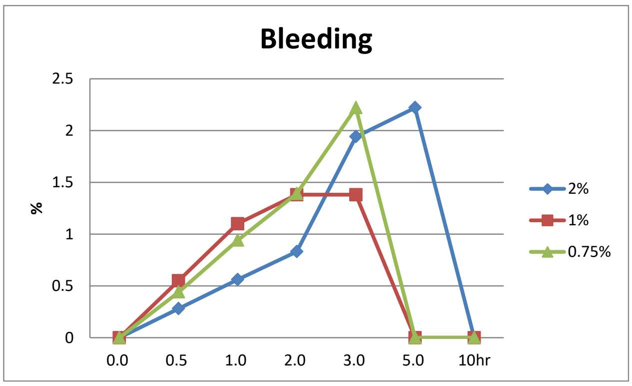
		(A-1) Sika ZX (1%)	(A-2) Sika ZX (2%)	(A-3) Sika ZX (1%)	(A-4) Sika ZX (0.75%)	Test Value
Flow Cone Test Flow time (sec)	Elapsed T(min)					AASHTO
	0	38	21	59	56	9～20
	30	**91**	**24**	**43**	**43**	<30
Bleeding Test Bleed ratio(%)	Elapsed T(min)					AASHTO
	3.0	0.83&1.09(with steel)	1.94&2.78(with steel)	1.38	2.22	0.00%
	10.0		0	0	0	
Expansion Test Expand Ratio(%)	Elapsed T(min)					AASHTO
	3.0	5.83&5.43(with steel)	8.06&7.78(with steel)	3.88	1.94	2.00%
	10.0		8.89&7.78(With steel)	3.88	1.94	
Compressive Strength (N/m^2)	Elapsed T(day)					AASHTO
	7	10.53	10.58	16.18	4.05	
	28	9.04	10.80			41Mpa
Chloride ions（%）						
	Average	0.29				0.30kg/m^3
Comment		Mixed by hand only Some water flowed out from buck et				over 32degree

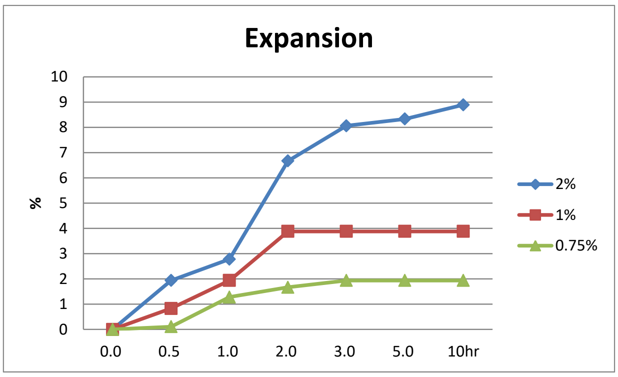
Regarding workability, Sika 2% shall be selected.

But bleeding and expansion did not satisfy the standard value of AASHTO, so more suitable admixture shall be studied.

APT admixture cannot be tested because of its stiffness.

MAPEI admixture cannot be tested because that material was not imported.





1.1-1 Mixing by hand

1.1-2 Mixing by hand-mixer

1.1-3 Slow mixing hopper to pump

1.1-4 Bad mixing of APT (not available for testing)

1.1-5 Flow cone testing

1.1-6 Bleeding and expansion testing

	
1.1-7 Chloride ion testing	**1.1-8 Compressive strength testing**

1.2 Design of grout

1000(l=m^3) = C/W*C + (1/3.16)(l/kg)*C

= C/W*C + 0.316*C

C : Cement(kg) W : Water(kg=l) 3.16 : Unit weight of Cement(kg/l)

	(A-1) Sika ZX (1%)	**(A-2) Sika ZX (2%)**	**(A-3) Sika ZX (1%)**	**(A-4) Sika ZX (0.75%)**
Cement (kg)	50kg	50kg	50kg	50kg
Admixture(%, kg)	(1%) 0.5kg	(2%) 1.0kg	(1%) 0.5kg	(0.75%) 0.375
W/C	42.5%	45%	45%	45%
Water (kg)	21.25kg	22.5kg	22.5kg	22.5kg
Cement C(kg/m^3)	1000=0.425C+ 0.316C C=1350kg/m^3	1000=0.45C+ 0.316C C=1305kg/m^3	1000=0.45C+ 0.316C C=1305kg/m^3	1000=0.45C+ 0.316C C=1305kg/m^3
Water W(kg/m^3)	W=574kg/m^3	W=587kg/m^3	W=587kg/m^3	W=587kg/m^3
Comment				

1.3 Basic date and chloride ions test

Testing Report for Grout 1/3 (Basic Physical Properties) PC 03

Report No.		Date	
Project Name		Name of Project Manager	
Bridge Name		Name of Contructor or Unit No.	
Span No.		Name of Grout Operator	
Place of Test		Batch No.	

	Name of materials	Type & Bland name	Manufacturer	Date Sheet No by supplier
Basic data of materials	Cement			No.
	Admixture			No.
	Premixed One			No.
	Water			No.

Combination	Watet/Cementitious Material ratio (%)	Water (kg)	Cementitious material (kg)		Admixture (kg)		Date
			Cement	Premixed One			
1 m^3	42.5	574	1350		13.5	**Sika ZX(1%)**	27.02.2018
1 m^3	45	587	1305		26.1	**Sika ZX(2%)**	27.02.2018
1 m^3	45	587	1305		13.1	**Sika ZX(1%)**	08.03.2018
1 m^3	45	587	1305		9.79	**Sika ZX(0.75%)**	08.03.2018

Mixing	Volume (m^3)	Capacity & form of Mixer	Number of Revolutions (rpm)	Mixing time (min)	Number of Revolutions is required over 1000rpm. The mix time should be generally not more than 4 minutes for a vane mixer.

Compressive Strength (28 days)	No.	Compressive strength (N/mm^2)				Dimnsionsof mortar cube
		24 hrs.	3 days	7 days	28 days	
	Sika ZX(1%)		8.52	10.53		Diameter (mm) (Cylinder) 50
	Sika ZX(2%)		9.06	10.58		
	Sika ZX(1%)		13.1	16.18		Hight (mm)
	Sika ZX(0.75%)		13.7	4.05		

Total Chloride Ions (In case of using "Quantab")	No.	Unit value on the numbered	Chloride Ions getting from the chart(%)	Chloride Ions(%) Ave		Chloride Ions(kg/m^3)	Test value
	1	2.7	0.048				< 0.08% < 0.30kg/m^3
	2	2.8	0.052	0.052	(0.052/100)* 574=	0.0298	
	3	2.9	0.056		574:Water		

1.4 Flow Cone Testing

Report No.		Sika ZX(1%)		Date		27.02.2018	
Project Name				Name of Project Manager			
Bridge Name				Name of Contructor or Unit No.			
Span No.				Name of Grout Operator			
Place of Test				Batch No.			
	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time (sec.)	Test value	Flow time (sec.)	Test value
	9:42	0		38	9~20		
	9:57	15		74			
	10:12	30		91	<30		
Flow cone Testing		45		(Remixing 30s)			
		60					

Report No.		Sika ZX(2%)		Date		27.02.2018	
Project Name				Name of Project Manager			
Bridge Name				Name of Contructor or Unit No.			
Span No.				Name of Grout Operator			
Place of Test				Batch No.			
	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time (sec.)	Test value	Flow time (sec.)	Test value
	11:15	0		21	9~20		
	11:30	15		25			
	11:45	30		24	<30		
Flow cone Testing		45		(Remixing 30s)			
		60					

Report No.		Sika ZX(1%)		Date		08.03.2018	
Project Name				Name of Project Manager			
Bridge Name				Name of Contructor or Unit No.			
Span No.				Name of Grout Operator			
Place of Test				Batch No.			
Flow cone Testing	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time (sec.)	Test value	Flow time (sec.)	Test value
	11:15	0		21	9~20		
	11:30	15		25			
	11:45	30		24	<30		
		45		(Remixing 30s)			
		60					

Report No.		Sika ZX(0.75%)		Date		08.03.2018	
Project Name				Name of Project Manager			
Bridge Name				Name of Contructor or Unit No.			
Span No.				Name of Grout Operator			
Place of Test				Batch No.			
Flow cone Testing	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time (sec.)	Test value	Flow time (sec.)	Test value
	11:15	0		21	9~20		
	11:30	15		25			
	11:45	30		24	<30		
		45		(Remixing 30s)			
		60					

1.5 Bleeding and expansion test

(A-1) Sika ZX (1%) without steel

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Height of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
Bleeding Test (Measure by 100ml)	9:45	0.0	A0 1800				
	10:15	0.5	1820	1825	5	0.28	ASTM C940
	10:45	1.0	1860	1865	5	0.28	0.0%(At 3hr)
	11:45	2.0	1905	1930	25	1.39	
	12:45	3.0	1905	1920	15	0.83	JSCE-F535
		5.0					0.0%(Final)
		10.0					
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Amout of change C=Ai-A0	Expansion C/A0 (%)		Test value
Expansion Test (Measure by 100ml)	9:45	0.0	A0 1800				
	10:15	0.5	↑ 1820	20	1.11		ASTM C940
	10:45	1.0	1860	60	3.33		<2.0%(up to 3hr)
	11:45	2.0	1905	105	5.83		
	12:45	3.0	1905	105	5.83		JSCE-F535
		5.0					±0.5%
		10.0					
		24.0	↓				

(A-1) Sika ZX (1%) with steel

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Height of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
Bleeding Test (Measure by 100ml)	9:45	0.0	A0 1840				
	10:15	0.5	1855	1860	5	0.27	ASTM C940
	10:45	1.0	1880	1900	20	1.09	0.0%(At 3hr)
	11:45	2.0	1930	1960	30	1.63	
	12:45	3.0	1940	1960	20	1.09	JSCE-F535
		5.0					0.0%(Final)
		10.0					
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Amout of change C=Ai-A0	Expansion C/A0 (%)		Test value
Expansion Test (Measure by 100ml)	9:45	0.0	A0 1840				
	10:15	0.5	↑ 1855	15	0.82		ASTM C940
	10:45	1.0	1880	40	2.17		<2.0%(up to 3hr)
	11:45	2.0	1930	90	4.89		
	12:45	3.0	1940	100	5.43		JSCE-F535
		5.0					±0.5%
		10.0					
		24.0	↓				

(A-2) Sika ZX (2%) without steel

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Height of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
	11:15	0.0	A0 1800				
	11:45	0.5	1835	1840	5	0.28	ASTM C940
	12:15	1.0	1850	1860	10	0.56	0.0%(At 3hr)
Bleeding Test (Measure by 100ml)	1:15	2.0	1920	1935	15	0.83	
	2:15	3.0	1945	1980	35	1.94	JSCE-F535
		5.0	1950	1990	40	2.22	0.0%(Final)
		10.0	1960	1960	0	0	
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Amout of change C=Ai-A0	Expansion C/A0 (%)		Test value
	11:15	0.0	A0 1800				
	11:45	0.5	1835	35	1.94		ASTM C940
	12:15	1.0	1850	50	2.78		<2.0%(up to 3hr)
Expansion Test (Measure by 100ml)	1:15	2.0	1920	120	6.67		
	2:15	3.0	1945	145	8.06		JSCE-F535
		5.0	1950	150	8.33		±0.5%
		10.0	1960	160	8.89		
		24.0					

(A-2) Sika ZX (2%) with steel

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Height of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
	11:15	0.0	A0 1800				
	11:45	0.5	1830	1840	10	0.56	ASTM C940
	12:15	1.0	1850	1870	20	1.11	0.0%(At 3hr)
Bleeding Test (Measure by 100ml)	1:15	2.0	1910	1945	35	1.94	
	2:15	3.0	1940	1990	50	2.78	JSCE-F535
		5.0	1940	2000	60	3.33	0.0%(Final)
		10.0	1940	1940	0	0	
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Amout of change C=Ai-A0	Expansion C/A0 (%)		Test value
	11:15	0.0	A0 1800				
	11:45	0.5	1830	30	1.67		ASTM C940
	12:15	1.0	1850	50	2.78		<2.0%(up to 3hr)
Expansion Test (Measure by 100ml)	1:15	2.0	1910	110	5.56		
	2:15	3.0	1940	140	7.78		JSCE-F535
		5.0	1940	140	7.78		±0.5%
		10.0	1940	140	7.78		
		24.0					

(A-3) Sika ZX (1%)

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Height of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
Bleeding Test (Measure by 100ml)	11:44	0.0	A0 1805				
	12:11	0.5	1820	1840	10	0.55	ASTM C940
	12:44	1.0	1840	1870	20	1.10	0.0%(At 3hr)
	1:44	2.0	1875	1945	25	1.38	
	2:44	3.0	1875	1990	25	1.38	JSCE-F535
	4:44	5.0	1875	1875	0	0	0.0%(Final)
	9:44	10.0	1875	1875	0	0	
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Amout of change C=Ai-A0	Expansion C/A0 (%)		Test value
Expansion Test (Measure by 100ml)	11:15	0.0	A0 1805				
	11:45	0.5	1820	15	0.83		ASTM C940
	12:15	1.0	1840	35	1.94		<2.0%(up to 3hr)
	1:15	2.0	1875	70	3.88		
	2:15	3.0	1875	70	3.88		JSCE-F535
		5.0	1875	70	3.88		±0.5%
		10.0	1875	70	3.88		
		24.0					

(A-4) Sika ZX (0.75%)

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Height of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
Bleeding Test (Measure by 100ml)	12:40	0.0	A0 1800				
	1:10	0.5	1802	1810	8	0.44	ASTM C940
	1:40	1.0	1823	1840	17	0.94	0.0%(At 3hr)
	2:40	2.0	1830	1855	25	1.39	
	3:40	3.0	1835	1875	40	2.22	JSCE-F535
	5:40	5.0	1835	1835	0	0	0.0%(Final)
	10:40	10.0	1835	1835	0	0	
		24.0					

	Observed Time (hr.min.)	Elapsed Time (hr.)	Height of Grout A (ml)	Amout of change C=Ai-A0	Expansion C/A0 (%)		Test value
Expansion Test (Measure by 100ml)	12:40	0.0	A0 1800				
	1:10	0.5	1802	2	0.11		ASTM C940
	1:40	1.0	1823	23	1.28		<2.0%(up to 3hr)
	2:40	2.0	1830	30	1.67		
	3:40	3.0	1835	35	1.94		JSCE-F535
	5:40	5.0	1835	35	1.94		±0.5%
	10:40	10.0	1835	35	1.94		
		24.0					

2 Inspection at the Site

2.1 Basic Inspection

The PC Manual team conducted an inspection in the pilot project Taung Bway Bridge (Unit 9) in 2018.

C/T and JICA engineer visited the site for inspection of forms, rebars, ducts, and PC steel (6^{th}, 7^{th} March 2018).

2.1-1 Tendons and duct

Tendons were installed in the duct before setting, and the ducts with tendons were kept on the ground until setting time. Setting the duct with tendons was implemented manually. So, the hurting of tendons may not be a cause of worry. But in the tendons, some rusts are happened, so it is better to keep the tendons in good condition until the installing to the ducts that are set in the girder position without tendons.

Connection part of ducts was not sufficient to protect the tendons. It is better to use the connection duct mentioned in the Manual.

2.1-2 Anchorage

Sealing around the duct at the anchorage was some kind of rubber pad, a material not good for grouting work. It is better to use the special connecting duct mentioned in the Manual between the anchorage and standard part duct.

Reinforcing by rebars around the anchorage was not sufficient.

2.1-3 Rein forcing bars and concrete casting of concrete

Mixing work was not uniform and insufficient, so the results of slump testing for each batch were so different.

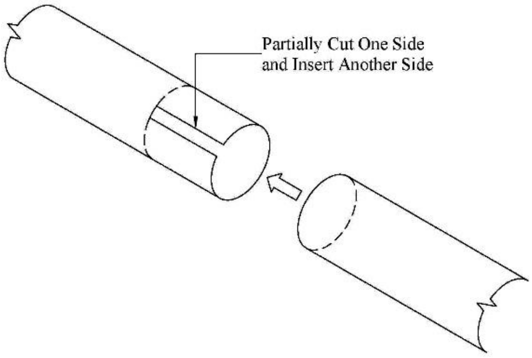
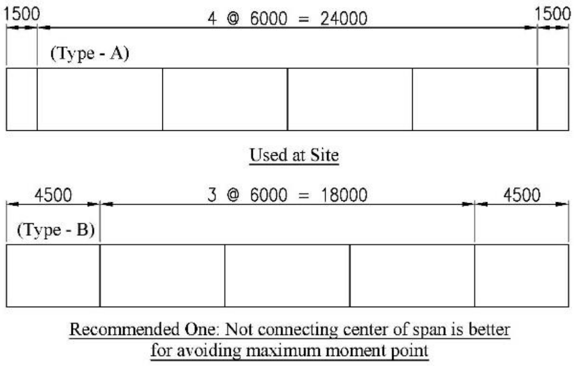
The strength of PC concrete was almost sufficient for design strength.

The setting of rebars for the crossbeam is bad. The connection of rebars for the crossbeam was done by spot welding, and that was the problem.

2.1-4 Others

Scaffolding and stationary were not sufficient with regards to work safety.

	 Figure shows placing of PC ducts on the ground that are already installed with PC steel. This situation should be avoided in order to prevent corrosion.
2.1-1 View of the work site	**2.1-2 Storage of ducts and PC steel**
	
2.1-3 Setting of rebar and ducts	**2.1-4 Setting of duct**

	
2.1-5 Connection part of ducts	**2.1-6 Connection part of ducts**
	
2.1-7 Division number of ducts shall be odd number	**2.1-8 Checking of duct setting**
	 Reinforced bars are not enough around the anchorage. (See in photo).
2.1-9 Spacer for rebar	**2.1-10 Duct and anchorage**

2.1-11 Sealing between duct and anchorage

2.1-12 End duct at anchorage (after casting concrete)

2.1-13 End duct at anchorage (before casting concrete)

2.1-14 Concrete casting (1): Vibration work for bottom of girder was not enough

2.1-15 Concrete casting (2)

2.1-16 Curing of concrete

2.2 Inspection for Tensioning

C/T and JICA engineer visited the site for inspection of tensioning (24th, 25th March 2018).

Prestressing work was controlled by the skilled engineer at the site. There were no severe problems observed, but the following aspects should be improved:

- Design final pressure and elongation were not checked by the site engineer, so feedbacks on some errors on design were not provided.
- Final elongation was calculated using only preliminary force stage and final prestressing stage figures. It will be better to use the plotting method, or μ-method, mentioned in the Manual. Also, the fix side pulling shall be considered.
- Checking of the final pressure and elongation were not clear. Checking of allowable error shall be set and implemented.

2.2-1 Pressure gauge

2.2-2 Anchor head before prestressing

2.2-3 Setting of grips (wedge)

2.2-4 Prestressing

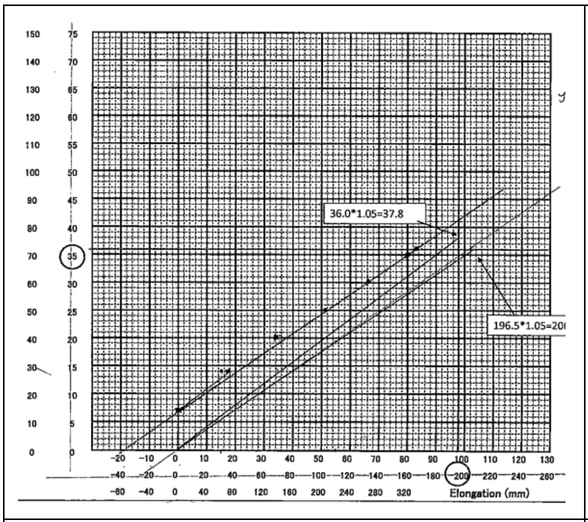
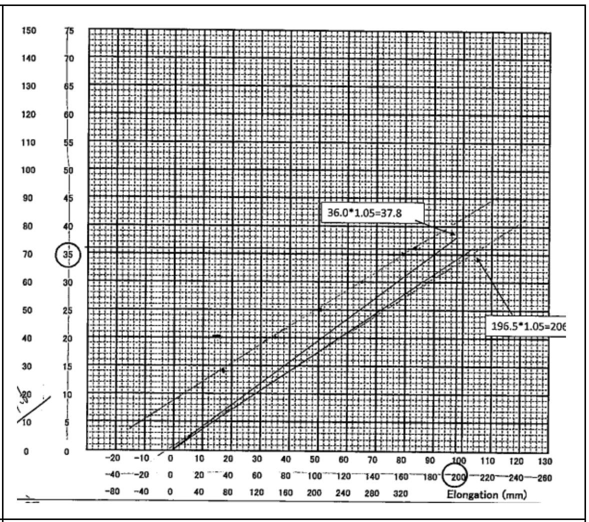
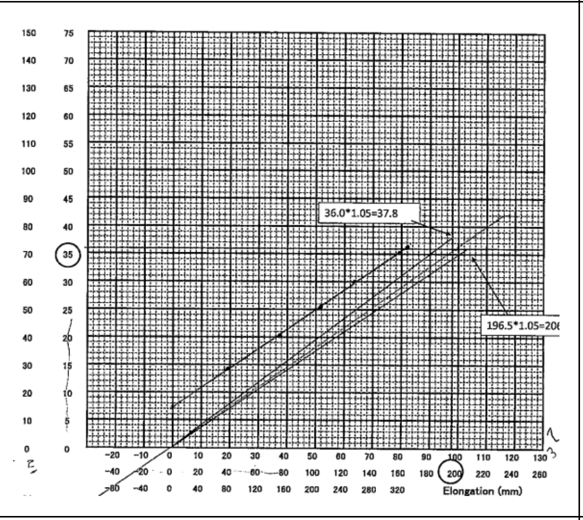
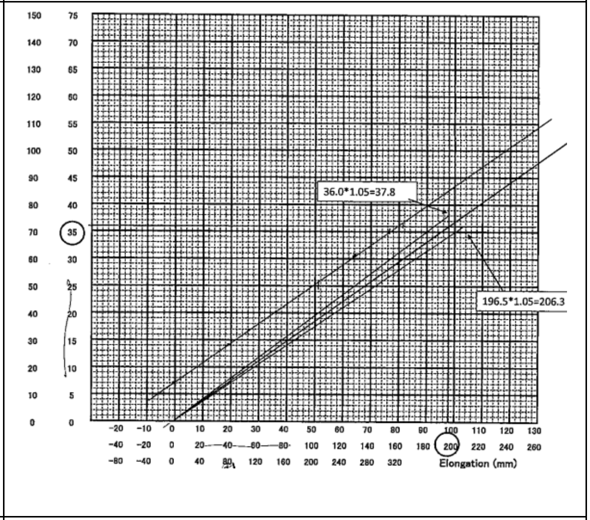
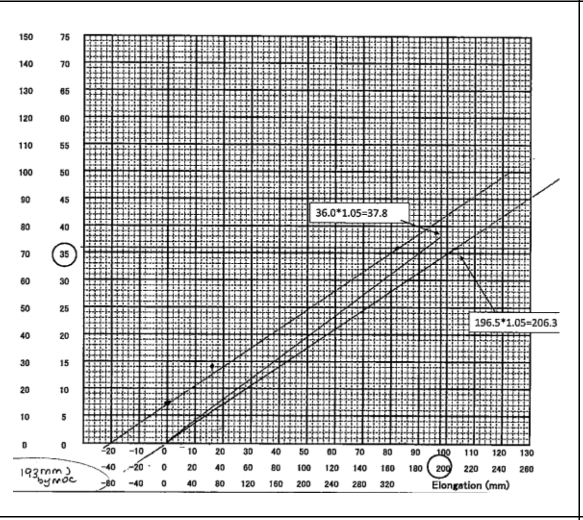
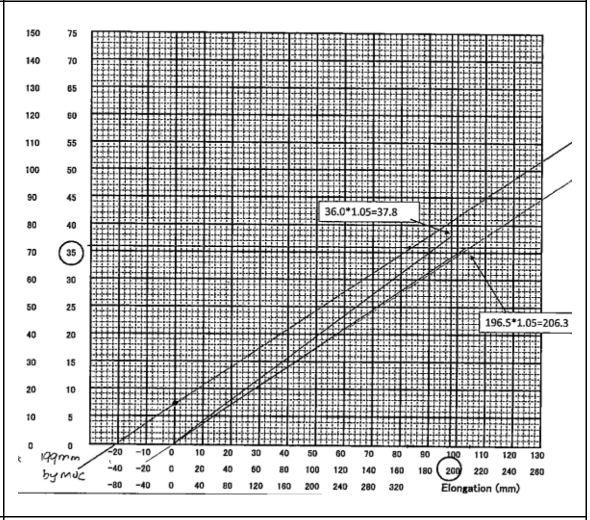
Difference between final elongation values calculated by C/T and the site engineer was 3.0% on the average and 7.5% at maximum.

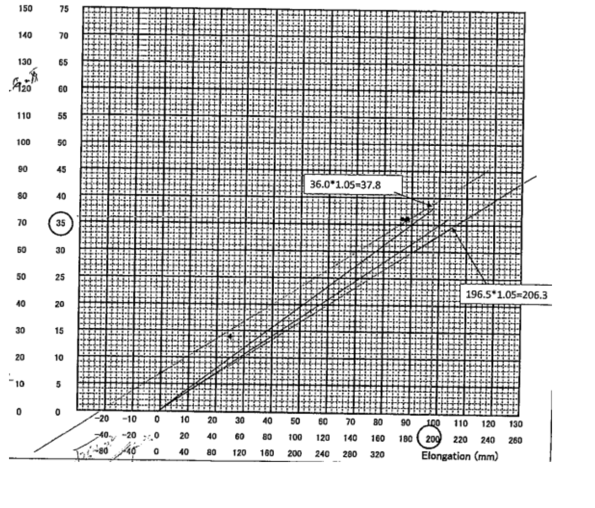
Final elongation value was over the designed elongation value in most cases, and only “Girder 5-Tendon 3” is under the designed elongation. This shall be checked.

7 tendons were sufficient for the allowable error of 5%; 8 tendons were not sufficient for allowable error.

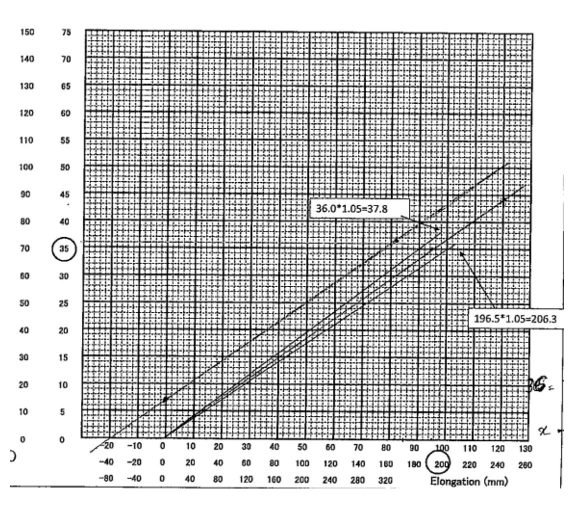
Calculated Gauge Pressure (N/mm2)	**36.0**	**Calculated Elongation (mm)**	**196.5**

	Actual Final Pressure(N/mm2)	**Final Elongation (by C/T)**	**Final Elongation (by Site Engineer)**
Girder 1-Tendon 1	36.5	207	211
Girder 1-Tendon 2	36.5	212	205
Girder 1-Tendon 3	36.5	200	205
Girder 2-Tendon 1	36.0	200	195
Girder 2-Tendon 2	36.0	205	193
Girder 2-Tendon 3	36.0	208	199
Girder 3-Tendon 1	36.0	216	213
Girder 3-Tendon 2	36.5	198	200
Girder 3-Tendon 3	36.5	201	201
Girder 4-Tendon 1	36.0	210	204
Girder 4-Tendon 2	35.0	206	205
Girder 4-Tendon 3	35.5	213	200
Girder 5-Tendon 1	36.0	202	203
Girder 5-Tendon 2	35.5	214	199
Girder 5-Tendon 3	36.5	182	189

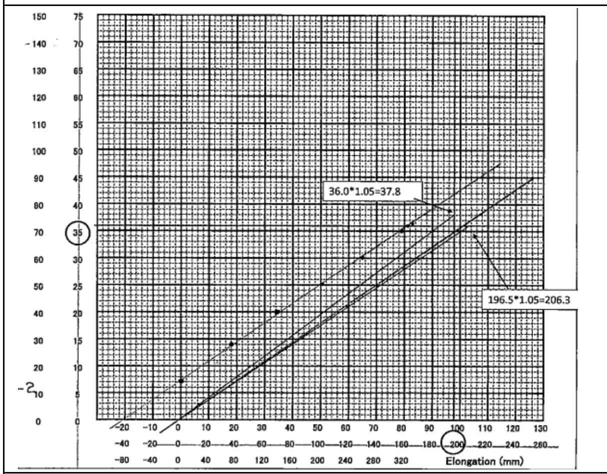
	
Girder 1-Tendon1	**Girder 1-Tendon2**
	
Girder 1-Tendon3	**Girder 2-Tendon1**
	
Girder 2-Tendon2	**Girder 2-Tendon3**



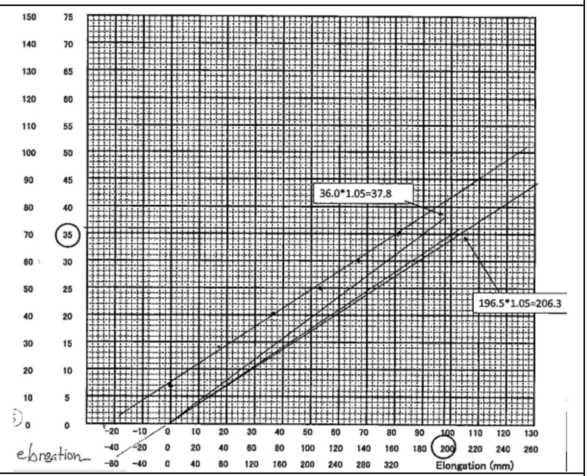
Girder 3-Tendon1



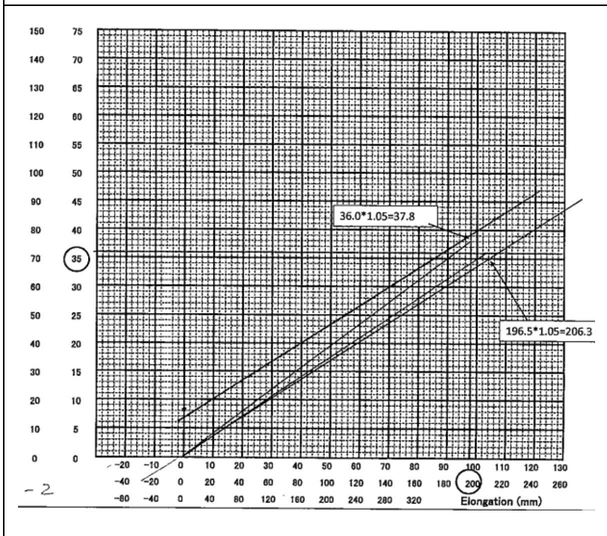
Girder 3-Tendon2



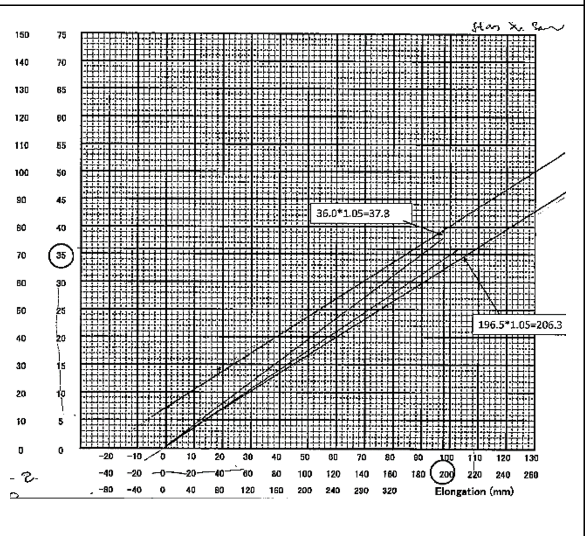
Girder 3-Tendon3



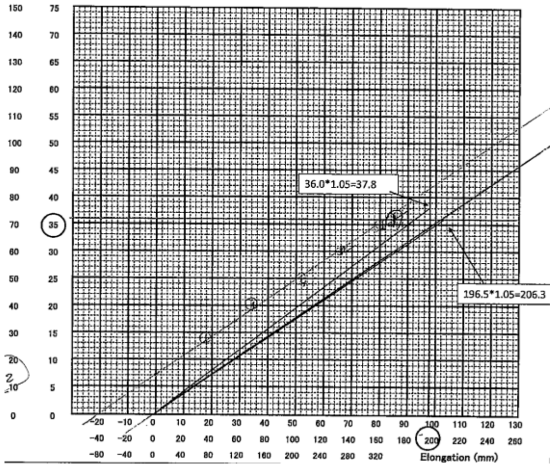
Girder 4-Tendon1



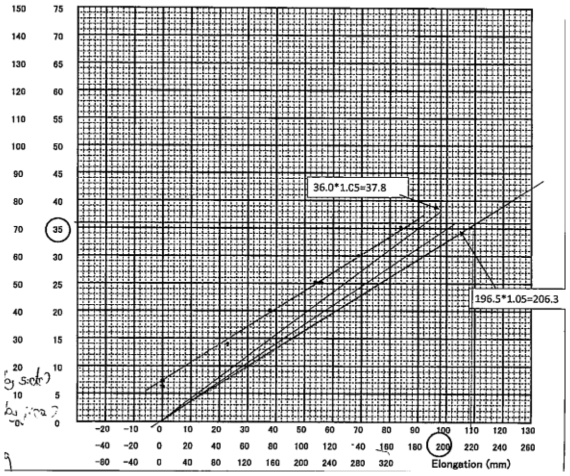
Girder 4-Tendon2



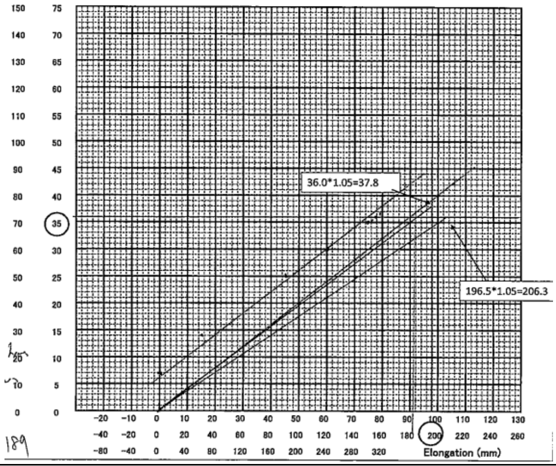
Girder 4-Tendon3



Girder 5-Tendon1



Girder 5-Tendon2



Girder 5-Tendon3

2.3 Inspection for Grouting

C/T and JICA engineer visited the site for inspection of tensioning (26th, 27th March 2018).

In this pilot project, MOC selected Sika Intraplast ZX as grouting admixture based on the result of pretesting. Main targets for the quality control test for grouting are listed below. All of these test items were not sufficient against AASHTO.

- Flow Cone Testing
- Bleed Testing
- Expansion Testing
- Compressive Strength

According to the Sika company test report, each test result was sufficient for AASHTO. But the test result at the site was so different. MOC shall test and study the grouting materials, including those from another company.

		Girder-1	Girder-3	Girder-2 & 4	Girder-5	Test Value
Flow Cone Test Flow time (sec)	Elapsed T(min)					AASHTO
	0	33	34	40	65	9～20
	30	40	37	49	91	<30
Bleeding Test Bleed ratio(%)	Elapsed T(min)					AASHTO
	3.0	0.8	–	–	0.8	0.00%
	10.0					
Expansion Test Expand Ratio(%)	Elapsed T(min)					AASHTO
	3.0	9.2	–	–	8.9	2.00%
	10.0				8.9	
Compressive Strength (N/m^2)	Elapsed T(day)					AASHTO
	7					
	28				4.6~33.7	41Mpa
Chloride ions (%)						
	Average	0.38				0.30kg/m^3

	
Mixing by hand mixer	**Grout pressing pump (strong type)**
	
Grouting work	**Outlet of grouting mortal**

2.3-1 Basic physical testing

1. Compressive strength

All results of testing were not sufficient against AASHTO, especially the result on cylinder strength which was so small. These results shall be checked by BRL and Sika company.

2. Total chloride ions

The result was not sufficient for test value.

River water was used for concrete and grout concrete in this site, in which case total chloride ions test shall be implemented before construction in every project.

Testing Report for Grout 1/3 (Basic Physical Properties)

PC 03

Report No.		Date	
Project Name		Name of Project Manager	
Bridge Name		Name of Contructor or Unit No.	
Span No.		Name of Grout Operator	
Place of Test		Batch No.	

Basic data of materials	Name of materials	Type & Bland name	Manufacturer	Date Sheet No by supplier
	Cement			No.
	Admixture			No.
	Premixed One			No.
	Water			No.

Combination	Watet/Cementitious Material ratio (%)	Water (kg)	Cementitious material (kg)		Admixture (kg)		Date
			Cement	Premixed One			
1 m^3	45	587	1305		26.1	**Sika ZX(2%)**	27.02.2018

Mixing	Volume (m^3)	Capacity & form of Mixer	Number of Revolutions (rpm)	Mixing time (min)	Number of Revolutions is required over 1000rpm. The mix time should be generally not more than 4 minutes for a vane mixer.

Compressive Strength (28 days)	No.	Compressive strength (N/mm^2)				Dimnsionsof mortar cube
		24 hrs.	3 days	7 days	28 days	
	Giredr No1	See Another sheet				Diameter (mm) (Cylinder) 50
	Giredr No2					
	Giredr No3					Hight (mm)
	Giredr No4					
	Giredr No5					

Total Chloride Ions (In case of using "Quantab")	No.	Unit value on the numbered scale	Chloride Ions getting from the chart(%)	Chloride Ions(%) Ave		Chloride Ions(kg/m^3)	Test value
							< 0.08% < 0.30kg/m^3
	Ave of 3			0.065	(0.065/100)* 587=	0.38	
					587:Water		

Cube Strength

Sr No	Date (Moulded)	Date (Tested)	Age	Specimen Size			Compressive Strength
				Length	Width	Height	
			(Days)	(mm)	(mm)	(mm)	(MPa)
1	25.3.2018	28.3.2018	3	52	50	52	16.325
				52	51	52	20.399
2	25.3.2018	2.4.2018	7	50	50	50	24.151
				50	50	50	20.566
3	25.3.2018	22.4.2018	28	51	51	51	21.325
				51	51	51	33.659

Cylinder Strength

Sr No	Date (Moulded)	Date (Tested)	Age	Specimen Size		Compressive Strength	Remark
				Length	Height		
			(Days)	(mm)	(mm)	(MPa)	
1	25.3.2018	28.3.2018	3	50	105	6.731	
				50	105	6.638	
2	25.3.2018	2.4.2018	7	50	100	6.676	Capping
				50	100	6.558	
3	25.3.2018	22.4.2018	28	50	100	9.68	Capping
				50	100	4.558	Capping

Allowable Compressive strength (28 days) is over 41MPa (cube strength) in AASHTO.

2.3-2 Flow cone Testing

Report No.				Date		25.03.2018	
Project Name				Name of Project Manager		U Kyaw Myo(DD)	
Bridge Name	Taung Bway Bridge			Name of Contructor or Unit No.		9	
Span No.	Girder 1			Name of Grout Operator		U Zaw Myo Thant(SAE)	
Place of Test				Admixture		Sika ZX(2%)	
Flow cone Testing	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time(sec.)	Test value	Flow time(sec.)	Test value
	8:40	0		33	9~20		
	13:12	15		38			
	9:10	30		40	<30		
	9:25	45			(Remixing 30s)		
		60					

Report No.				Date		25.03.2018	
Project Name				Name of Project Manager		U Kyaw Myo(DD)	
Bridge Name	Taung Bway Bridge			Name of Contructor or Unit No.		9	
Span No.	Girder 3			Name of Grout Operator		U Zaw Myo Thant(SAE)	
Place of Test				Admixture		Sika ZX(2%)	
Flow cone Testing	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time(sec.)	Test value	Flow time(sec.)	Test value
	7:47	0		34	9~20		
	8:02	15		36			
	8:32	30		37	<30		
		45			(Remixing 30s)		
		60					

Report No.				Date		24.03.2018	
Project Name				Name of Project Manager		U Kyaw Myo(DD)	
Bridge Name	Taung Bway Bridge			Name of Contructor or Unit No.		9	
Span No.	Girder 2 & 4			Name of Grout Operator		U Zaw Myo Thant(SAE)	
Place of Test				Admixture		Sika ZX(2%)	
	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time(sec.)	Test value	Flow time(sec.)	Test value
Flow cone Testing	9:50	0		40	9~20		
	10:05	15		47			
	10:20	30		49	<30		
		45			(Remixing 30s)		
		60					

Report No.				Date		24.03.2018	
Project Name				Name of Project Manager		U Kyaw Myo(DD)	
Bridge Name	Taung Bway Bridge			Name of Contructor or Unit No.		9	
Span No.	Girder 5			Name of Grout Operator		U Zaw Myo Thant(SAE)	
Place of Test				Admixture		Sika ZX(2%)	
	Observed Time (hr.min.)	Elapsed Time (min.)		ASTM C939		JSCE-F531	
				Flow time(sec.)	Test value	Flow time(sec.)	Test value
Flow cone Testing	7:44	0		65	9~20		
	7:59	15					
	8:14	30		91	<30		
		45			(Remixing 30s)		
		60					

2.3-3 Bleeding Test

Girder-1

	Observed Time (hr.min.)	Elapsed Time (hr.)	Hight of Grout A (ml)	Hight of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
Bleeding Test (Measure by 100ml)	8:45	0.0	A0 1780				
	9:15	0.5	1820	1825	5	0.3	ASTM C940
	9:45	1.0	1865	1880	25	1.4	0.0%(At 3hr)
	10:45	2.0	1950	1965	15	0.8	
	11:45	3.0	1960	1975	15	0.8	JSCE-F535
		5.0					0.0%(Final)
		10.0					
		24.0					

Girder-5

	Observed Time (hr.min.)	Elapsed Time (hr.)	Hight of Grout A (ml)	Hight of Surface B (ml)	Bleeding water B-A (ml	Bleeding (B-A)/A0 (%)	Test value
Bleeding Test (Measure by 100ml)	7:44	0.0	A0 1800				
	8:14	0.5	1840	1845	5	0.3	ASTM C940
	9:45	1.0	1880	1900	20	1.4	0.0%(At 3hr)
	10:45	2.0	1960	1975	15	0.8	
	11:45	3.0	1960	1960	0	0.8	JSCE-F535
		5.0	1960	1960	0		0.0%(Final)
		10.0	1960				
		24.0					

2.3-4 Expansion Test

Girder-1

	Observed Time (hr.min.)	Elapsed Time (hr.)	Hight of Grout A (ml)	Amout of change C=Ai-A0 (ml)	Expansion C/A0 (%)		Test value
Expansion Test (Measure by 100ml)	8:45	0.0	A0 1780				
	9:15	0.5	1820	40	2.2		ASTM C940
	9:45	1.0	1865	85	4.8		<2.0%(up to 3hr)
	10:45	2.0	1950	170	8.7		
	11:45	3.0	1960	180	9.2		JSCE-F535
		5.0					±0.5%
		10.0					
		24.0					

Girder-5

	Observed Time (hr.min.)	Elapsed Time (hr.)	Hight of Grout A (ml)	Amout of change C=Ai-A0 (ml)	Expansion C/A0 (%)		Test value
Expansion Test (Measure by 100ml)	8:45	0.0	A0 1800				
	9:15	0.5	1840	40	2.2		ASTM C940
	9:45	1.0	1880	80	4.4		<2.0%(up to 3hr)
	10:45	2.0	1960	160	8.9		
	11:45	3.0	1960	160	8.9		JSCE-F535
		5.0	1960	160	8.9		±0.5%
		10.0	1960	160	8.9		
		24.0					

2.3-5 Volume Checking

Some of the dates were a bit doubtful, but checking of volume by this method is useful for evaluating the grouting work.

Testing Report for Grout 3/3 (Checking of Grouting Volume & Grouting Pressure) PC 05

Report No.		Date	
Project Name		Name of Project Manager	
Bridge Name		Name of Contractor or Unit No.	
Span No.		Name of Grout Operator	
Place of Test		Batch No.	

Designed Grouting Pressure	Conversion to Grouting Pump Meter Pressure : < 2.0 Mp		
	Conversion to Grouting Hose Pressure : < 0.6 Mp		
	Target Re-pressurize : over Final Grouting Pressure < 2.0 Mp		
Factor of Tendon	Inner sectional area of Duct (B)	Sectional area of Tendon (C)	(B-C)
	(66~68)*((66~68)*3.1416/4=(3419~3632) mm^2	98.7*12=1184mm^2	(2236~2448)mm^2
Design Grouting Volume (Gd)/1-girder	Gd = ΣLi * (B - C) : liter		
	Li : length of Duct (m) B-C : Empty Area (mm^2)		
	Gd= 27.38*3*(2236~2448)*(10^-6)*(10^3) =**(183.7~201.1) litter**		
Actual Grouting Volume (Ga)	Ga = B/ρ + W (litre) - R : liter		
	B : Weight of Cementitious materials (kg) ρ: Density of Cementitious materials (kg/liter)		
	W : Volume of water (liter) R : Volume of remained mixed grout (liter)		

No. of Duct	Remainning Volume (Liter)				Actual Grouting Volume (Ga) (liter)	Actual Grouting Volume (Liter)
					Ga = B/ρ + W (litre) - R	
					B= 350or 300 (kg) 350:N03 300:Others	
	Outle:12(liter)	1 Gierder				
					ρ= 3.16 (kg/liter)	
	In hopper	Pump & hose	For testing	Total		
Girder No3	16		8	36	B/ρ= 110.8 or 94.9 (liter)	268-36=232
Girder No1	2		8	22		230-22=208
Girder No2&4	3	13		40(20:1Girder)	W= 45% 350or300*0.45=158or135 (liter)	230-20=210
Girder No5	11	13	8	44		230-44=186
					R= Remainning (liter)	
Total					**Ga= 268or230 − R(liter)**	