QUALITY CONTROL
BRIDGE CONSTRUCTION

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- The following quote is very appropriate for bridge engineering:

“Quality is never an accident. It is always the result of high intention, sincere effort, intelligent direction, and skillful execution. It represents the wise choice of many alternatives.”

Quality Control At Construction Site

- Quality Control at the construction site is defined in the Set of Technical Conditions (specifications), which is an integral part in every project.
- It is divided into: -
  - Control of material receipt.
  - Control of project units execution
- It is a normal provision that the control is effectively accomplished by laboratories or independent accredited laboratories.

Quality Control At Construction Site

- The set must define for each of the materials or construction items, the inspection, the number of samples to be taken, tests to be accomplished & actions in case of rejection.
- Construction quality control involves control specifications, certification of suppliers, surveillance by the Construction Management, rejection or acceptance of materials or products.

1. CONCRETE

1. CONCRETE

- Concrete mix for the construction of bridge must be designed mix.
- Concrete trial mixes were carried out after the proposed ready-mixed supplier; sources of their materials & the design mix were approved.
- There upon, the mixing process & the quality of every batch of concrete supplied to the site were monitored for the whole duration of concreting works.
- Ready mixed concrete delivered to the site must be accompanied by delivery ticket.

1. CONCRETE

- Ensure the information provided in the delivery tickets contains date, time, vehicle registration number, complies with the designed mix & its corresponding designed workability before discharging the concrete.
- Slump tests were performed on each truck load of fresh concrete delivery to check on concrete workability.
- Rejected concrete must be removed from the Site. The delivery ticket must be marked “REJECTED”.
- Standard sample cubes were prepared on site for every concreting operation & tests were carried out on the cube samples to establish the strength achieved at 7 days & 28 days age to check on compliance of actual strength with the designed characteristic strengths specified.

1. CONCRETE

- Each batch of concrete must be placed & compacted within 2 hours of adding the cement to the dry aggregates & within 45 minutes of adding water to the cement & aggregate.
- Concrete must not be placed in any part of the structure until the approval of the S.O. has been obtained.
- All formwork & reinforcement contained in it shall be clean & free from standing water before placing of concrete.
- Concreting must be carried out continuously up to predetermined construction joints in one sequence of operation.

1. CONCRETE

- Concrete must be thoroughly compacted by mechanical vibration thoroughly worked into the corners.
- The internal vibrators must be inserted & withdrawn slowly at a uniform pace of approximately 100 mm per second.
- Compaction must be completed when cement mortar appears in an annulus around the vibrator.
- Over vibration leading to segregation of the mix must be avoided.
- The internal vibrators must not be allowed to come into contact with the formwork or the reinforcement & shall be inserted at a distance of not less than 75 mm from the formwork.

1. CONCRETE

Honeycomb of concrete due to inadequate vibration

1. CONCRETE

- Concrete in slabs with no formwork on its upper surface should be compacted either by vibrators of the pan type or by a vibrating screen.
- Concrete must not be subjected to any disturbance within 24 hours after compaction.
- No standing or flowing water is allowed to come into contact with exposed concrete surfaces during the first 2 hours after placing & compaction of the concrete.
- Fresh concrete must not be placed against in-situ concrete which has been in position for more than 45 minutes unless a construction joint is formed

1. CONCRETE

- When in-situ concrete has been in place for 4 hours, no further concrete must be placed against it for a further 20 hours.
- Concrete must be deposited in horizontal layers to a compacted depth not exceeding 450 mm when internal vibrators are used or 300 mm in all other cases.
- Concrete must not be dropped into place from a height exceeding 1.5 meters.
- However, higher drops by using trunking or chutes may be allowed provided the mix has been well designed & proportioned.

1. CONCRETE

- All concrete work must be cured for the full period of curing which must not be less than 5 days for F1, F2, F3 and F4 surfaces.
- When the concrete has attained its final set, one of the following curing methods must be adopted:

  i. Keeping the surface of the concrete continuously wet by ponding with water.

  ii. Sealing in the water as specified above by covering with an approved plastic sheeting laid with airtight joints. It must be securely positioned to prevent displacement by wind and protected from tearing or other injury.

1. CONCRETE

- When concrete is subjected to high internal thermal gradient or with large exposed surface area, the use of other methods of curing may be necessary.
- The Contractor must submit a method statement to the approval of the S.O.
- The rise in temperature within any period of 30 minutes must not exceed 10°C.
- Maximum temperature attained must not exceed 70°C.

CURRING OF CONCRETE

CURRING OF CONCRETE

- The strength of concrete gives an overall picture of the quality of hardened concrete (A.M. Neville, 1995)
- In order to obtain good concrete (quality), the placing of an appropriate mix must be followed by curing in a suitable environment during the early stages of hardening (A.M. Neville, 1995)
- One of the main factors influencing the strength of concrete is curing or the presence of adequate quantity of moisture for full hydration.
- It has been reported in many literatures that shrinkage cracking resulted from improper curing.

CURRING OF CONCRETE

- To minimize shrinkage cracks, it is important to provide proper curing to hold moisture in the concrete long enough for the concrete to gain tensile strength.
- Curing is a method used for promoting the hydration of cement & ensuring the concrete is continuously in moist condition (preventing evaporation) over a period of time.
- Curing involves control of temperature & moisture movement from & into the concrete.

CURING = KEEP CONCRETE SATURATED

&

PREVENT EVAPORATION

CURRING OF CONCRETE

Benefits of Curing •

- Many literatures have discussed that curing will:-

  i. increase concrete strength

  ii. increase concrete abrasion resistance

  iii.increase durability to chemical attack

  iv. increase concrete resistance to traffic wear

  v. increase concrete water tightness

  vi. lessen the chance of concrete cracking

CURRING OF CONCRETE

Methods of Curing

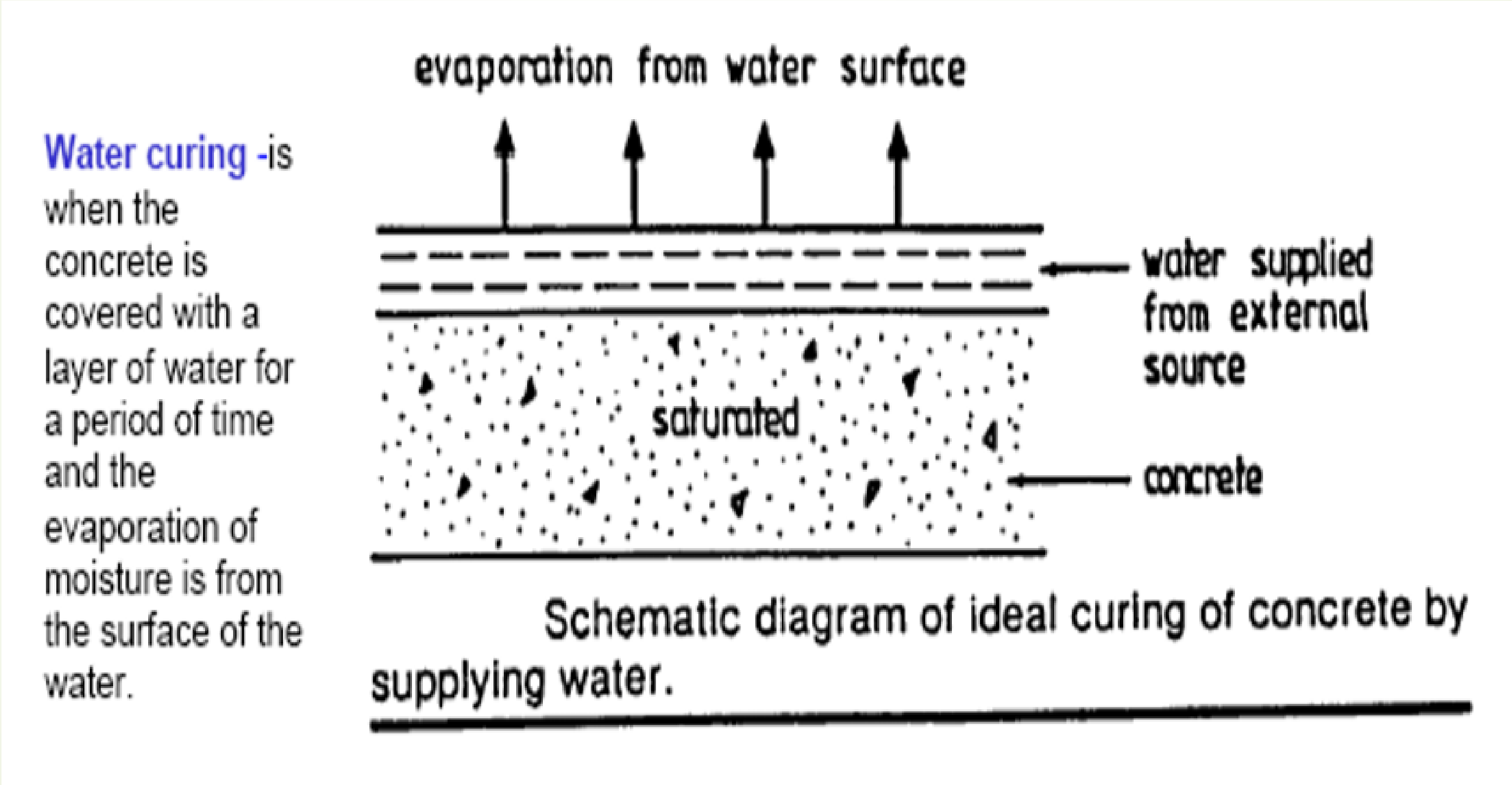
- There are two categories of curing, namely:-

i. wet curing (or water curing)

a) providing water which can be imbibed by the concrete i.e. concrete is continuously in contact with water for a specified time.

b) This is done by spraying, flooding or by covering with wet sand or earth.

CURRING OF CONCRETE



The most ideal way of curing concrete.
Take note that the concrete need to stay wet, continuously, for at lease 7 days or preferably 14 days.

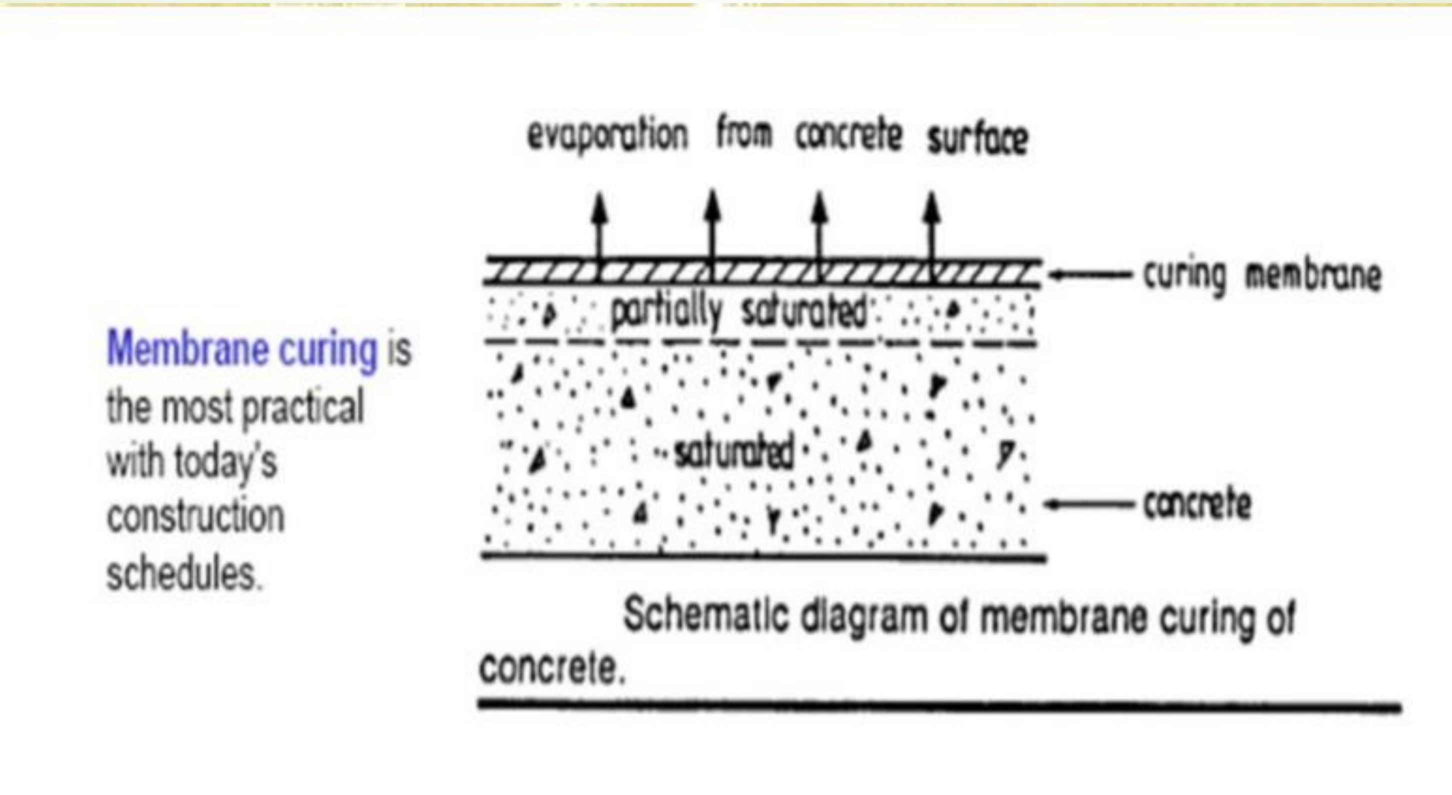
CURRING OF CONCRETE

ii. membrane curing (water-barrier method)

a) this method is focusing on the prevention of moisture loss from the surface of the concrete without the possibility of external water ingress into it.

b) this is done by covering the surface of the concrete with overlapping polyethylene sheeting or using reinforced paper

CURRING OF CONCRETE



The success of curing is dependent on the quality of the membrane, its thickness and the uniformity of membrane when applied to the concrete.

CURRING OF CONCRETE

JKR Specification – Curing and Protection

- Length of Curing

  All concrete works shall be cured for the full period of curing which shall not be less than:

  (a) 5 days for F1, F2, F3 & F4 surfaces

  (b) 3 days for F11, F12, F13, F14 & F15 surfaces

CURRING OF CONCRETE

- Curing and protection shall start immediately after compaction to protect it from:

  i. impact damage such as shock, overloading or fallen earth

  ii. Premature drying out from direct sunlight & wind

  iii. leaching out by rain and flowing water

  iv. high internal thermal gradient

CURRING OF CONCRETE

- Curing and protection shall be accomplished by covering exposed concrete surface with impermeable material e.g. polyethylene sheet
- Curing methods for concrete that has attained its final set:

  i. water curing - keep the surface of the concrete continuously wet by ponding with water.

  ii. Curing by sealing in water by means of waterproofing curing paper or plastic sheeting laid with airtight joints.

  iii. Accelerated curing (Elevated Temperature Curing)

CURRING OF CONCRETE

Hot Weather Concreting

- Some problems involved in Hot Weather Concreting arising from higher temperature of the concrete and increased rate of evaporation from fresh mix.
- This poses challenges to the processes of

  i. mixing

  ii. Placing

  iii. Curing

CURRING OF CONCRETE

Effect of Hot Weather on Fresh and Hardened Concrete

- Fresh Concrete
  1. loss of workability
  2. accelerated rate of stiffening
  3. poor compactibility
  4. increased water demand
  5. difficulty in achieving good surface finish
  6. Plastic shrinkage and plastic settlement cracking

CURRING OF CONCRETE

Plastic shrinkage

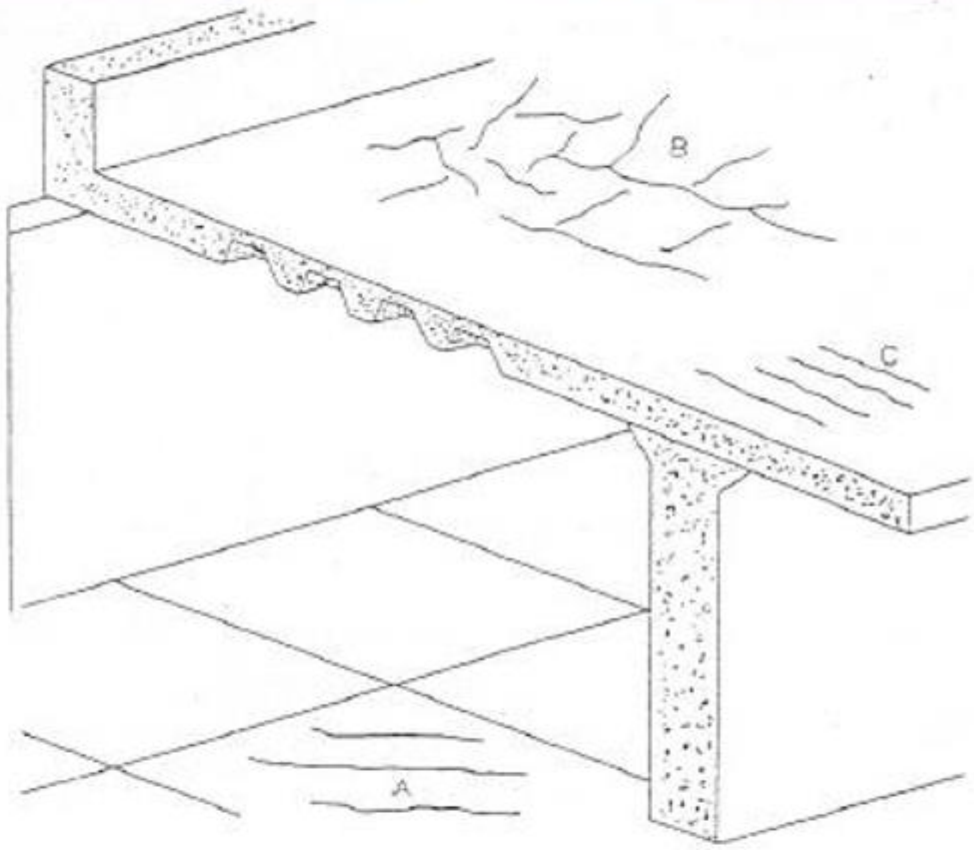


Figure 3.4

Typical plastic shrinkage crack patterns

(A=Diagonal, B=Random, C=Over Reinforcement).

CURRING OF CONCRETE

Plastic settlement cracking

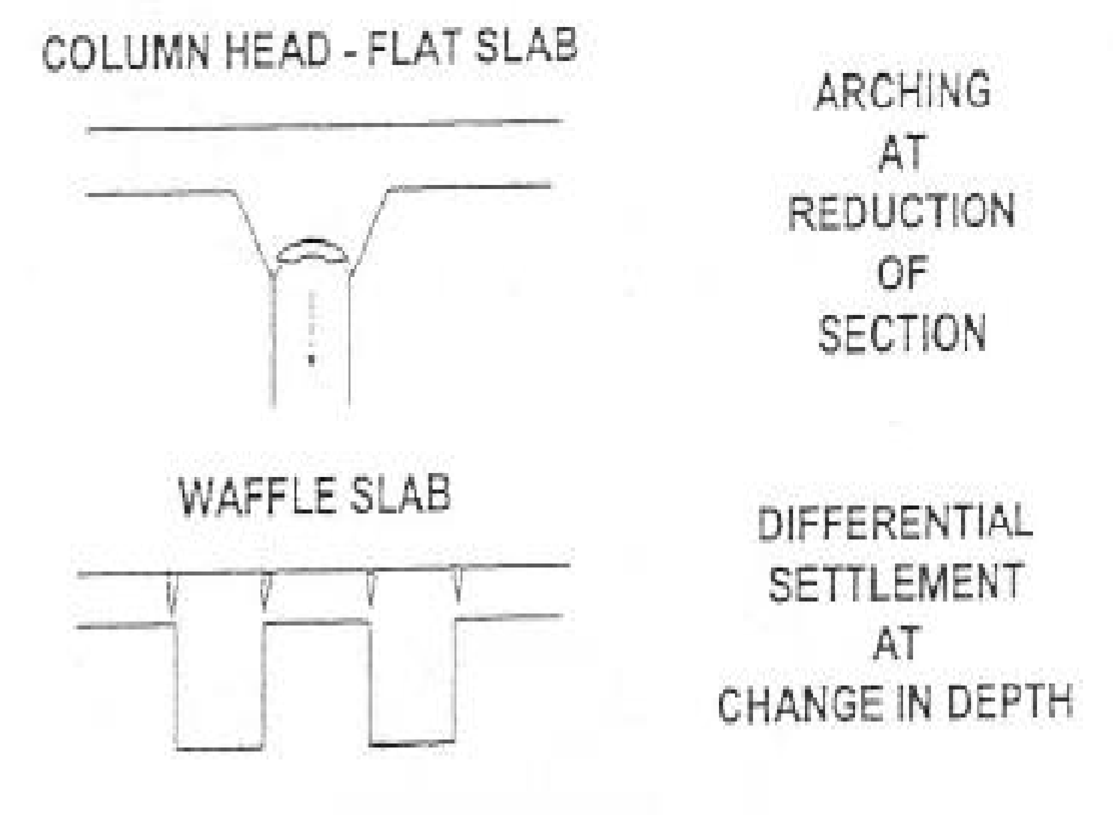


Figure 3.3

Typical Examples of Plastic Settlement Cracking.

CURRING OF CONCRETE

Hardened Concrete

i. inadequate hydration
ii. possible reduction in strength
iii. reduced bond with reinforcement
iv. more cold joints
v. increased permeability
vi. reduced durability
vii. non-uniform surface appearance
viii. increased thermal cracking

CURRING OF CONCRETE

- Hot weather concreting is taking recognised measures to minimise or control the effects of:

  i. high ambient temperature – causes higher water demand of concrete and rapid evaporation that can lead to plastic shrinkage cracking and crazing

  ii. high temperature of concrete

  iii. low relative humidity

  iv. high wind velocity

  v. high solar radiation

CURRING OF CONCRETE

How to minimise shrinkage cracking ?

1. During mixing - mixing water can be chilled - coarse aggregate can be cooled by spraying with chilled water
2. Before placing - formwork can be cooled
3. After placing - concrete should be protected from direct exposure to the sun - proper provision of moist curing

CURRING OF CONCRETE

Large Pour Concrete Construction

- In Malaysia, large pour concrete construction has been adopted for bridge structures, culverts, retaining walls, pile caps, abutments and piers, box girder etc. •
- Large pour concrete construction in hot weather condition presents substantial problems due to high temperature which can cause excessive concrete bleeding, plastic settlement cracks, plastic shrinkage cracks and early thermal crack

CURRING OF CONCRETE

- The main problem of placing concrete in large continuous pour is the heat developed in the large mass of concrete due to the hydration of the cement
- Cracking in large pours of concrete may be due to the internal temperature gradients in the concrete, also due to overall thermal contraction when the concrete cools down

CURRING OF CONCRETE

- **Cracking can be overcome by FitzGibbon technique:**

  i. temperature differential between the coolest and the hottest part of the hydrating concrete is not allowed to be more than 20°C

  ii. To monitor these temperatures, place thermocouple about 25mm from the most exposed face and at mid-depth of the pour

  iii. If it is found that the 20°C temperature differential is being exceeded, it becomes necessary to raise the temperature of the cool part by a suitable method of thermal curing

  iv. Some examples of thermal curing are covering by a layer of sand over and under polythene sheeting; using insulating boards e.g. soft board; using insulating blanket or quilts; tenting and ponding with about 75mm of water

CURRING OF CONCRETE

Fresh Concrete

- produce concrete at lower temperature and take necessary precautions
- Retarding admixture may be employed to delay stiffening of concrete
- Control bleeding rate by:

  i. using lowest optimum water content

  ii. choosing suitable retarder

  iii. shading of newly placed concrete from direct sunlight by covering and other means

  iv. Using optimum polypropylene fibres to increase concrete tensile strain capacity at early age of concrete setting

Example :Projek Membina Jalan Penyambung Subang – Kelana Construction of Pilecap at Pier P16

Features of Pilecap Pier P16

i. combined pilecap for two pier columns

ii. pilecap founded on 31 nos. of 1500mm dia. Bored piles

iii. pilecap is in the shape of elongated octagon of

size 25.5 m (L) x 20.1 m (W) x 3.75 m (D)

iv. Construction using G40/20 concrete

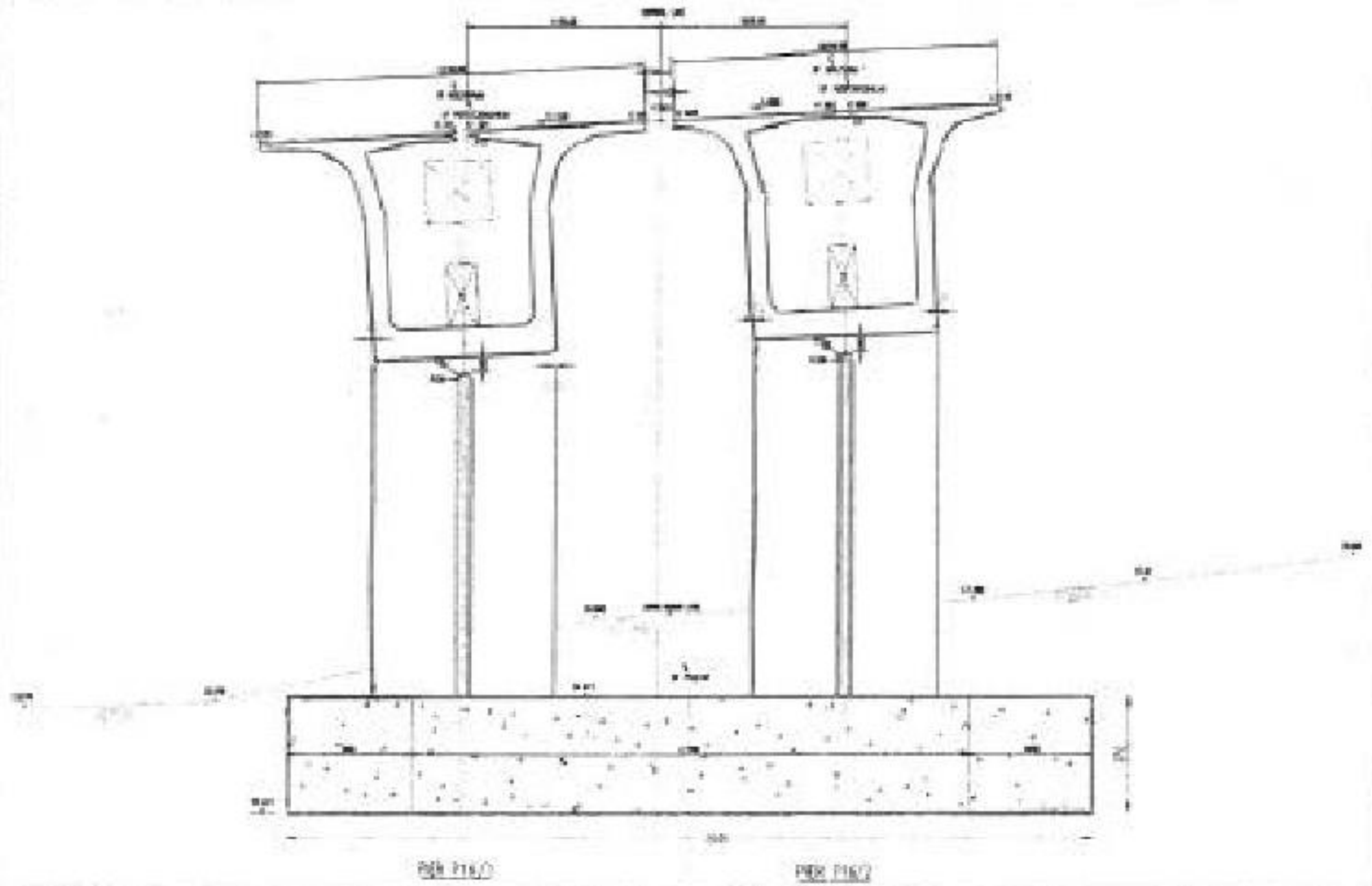


Figure 1: Elevation of Pier 16

Thermal Control Plan (proposed by the contractor)

- Concreting in single lift (1,856 m3 in a single pour)
- The temperature control exercised

  i. placing temperature > 33°C (MS 523 allows maximum temperature of 36°C

     - ice added to water tank at the batching plant to reduce placement temperature to about 30°C

  ii. Maximum temperature after placing >70°C (to avoid possibility of DEF)

     - use low heat cement e.g. mascrete or GGBS (slag cement) and superplasticising admixture to increase slump)

Thermal Control Plan (proposed by the contractor)

iii. Rise and fall in temperature (temperature differential) > 10°C within curing period of 30 minutes interval

- cover concrete with plastic sheeting after concreting and against rainstorm

Proposal for Thermal Control

"Sandwich Approach" (See Figure 4)

- to reduce temperature between the middle section of structure and its outer layers

  i. 3.75 m thick pilecap divided into 3 main layers of 1.25 m thick and sublayers of 300mm to 350mm

  ii. 1st layer -initial placement temperature of 32°C to 36°C were used

  iii. 2nd layer – lower placement temperature of 30°C adopted

  iv. Final top layer (3rd layer) with normal placement temperature of concrete. The top most sublayer utilised concrete of low retardation time to minimise plastic settlement and shrinkage

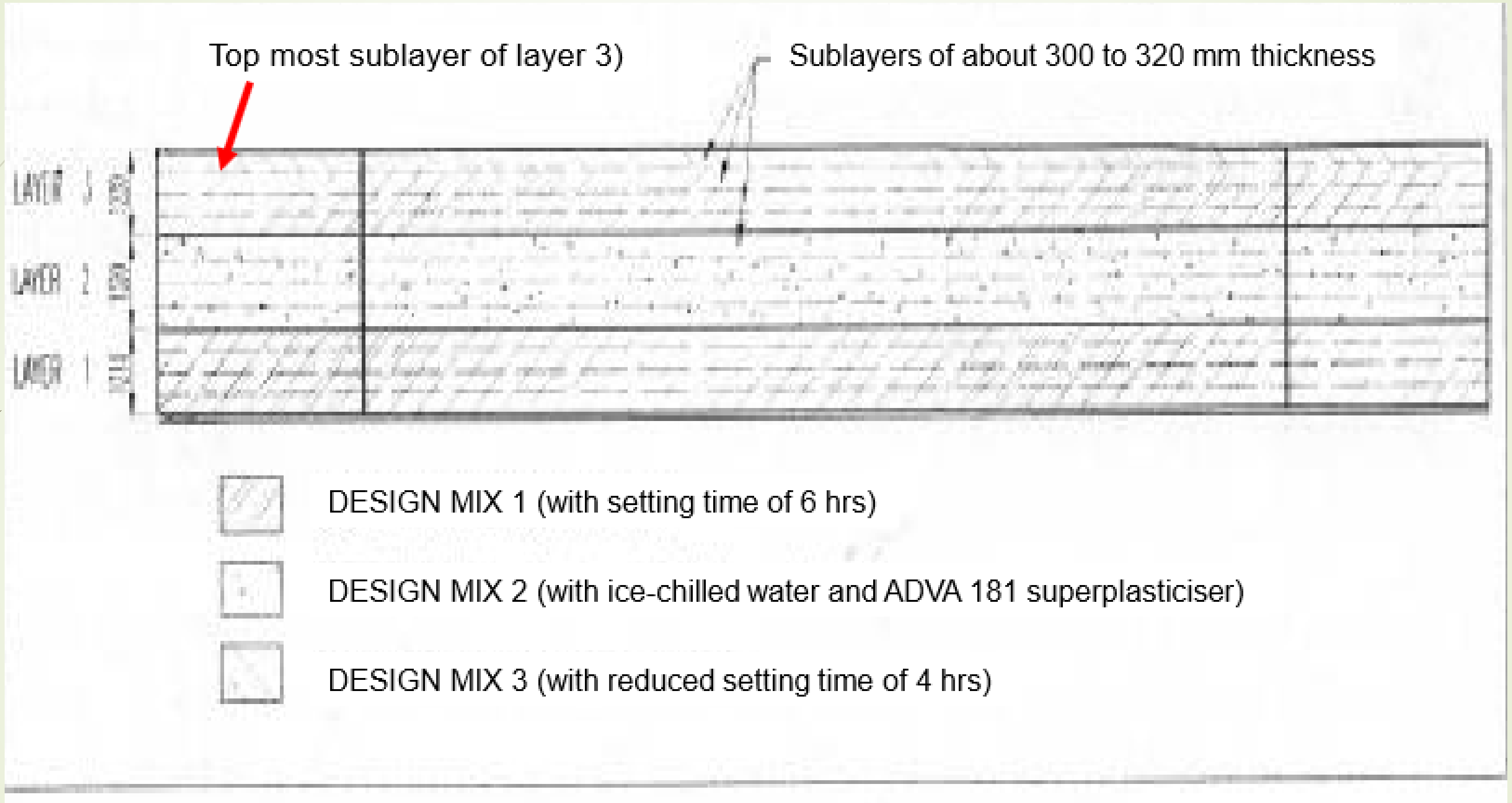


Figure 4: Proposed "Sandwich" Layers

Concrete Mix

- **With the Sandwich Approach, each layer has different concrete mix design:**

  i. Lower and upper sandwich layer (except for top most sublayer of layer 3) used grade 40 low heat cement (Mascrete-LH). Cement content was 415 kg

  ii. Middle sandwich layer adopted ice- chilled concrete with low cement content of 375 kg. Superplasticiser ADVA 181 was added to ensure same strength and workability in concrete

  iii. Top most sublayer adopted a mix with low setting time of 4 hours

Concrete Mix

- concreting duration = 38 hours (pouring rate of 50 m3 / hour)
- Upon completion of concreting, a layer of 50mm thick polystyrene foam was laid over the exposed top surface. A layer of plastic sheeting was placed on top of the foam (over the next 2 days)
- The side form was not removed for 4 to 5 days.

Temperature Monitoring

- A total of 12 nos. of thermocouple were installed as shown in Figure 5 to monitor concrete temperature during and after concreting
- Thermocouple installation was done after reinforcement works are completed
- Thermocouple wires were attached to a rebar but insulated from the bar and tied using nylon string and lowered to the designated positions from the top of the pilecap
- Thermocouple monitoring started after one half of the pilecap was concreted – temperature readings taken on an hourly basis for a duration of 2 to 3 days

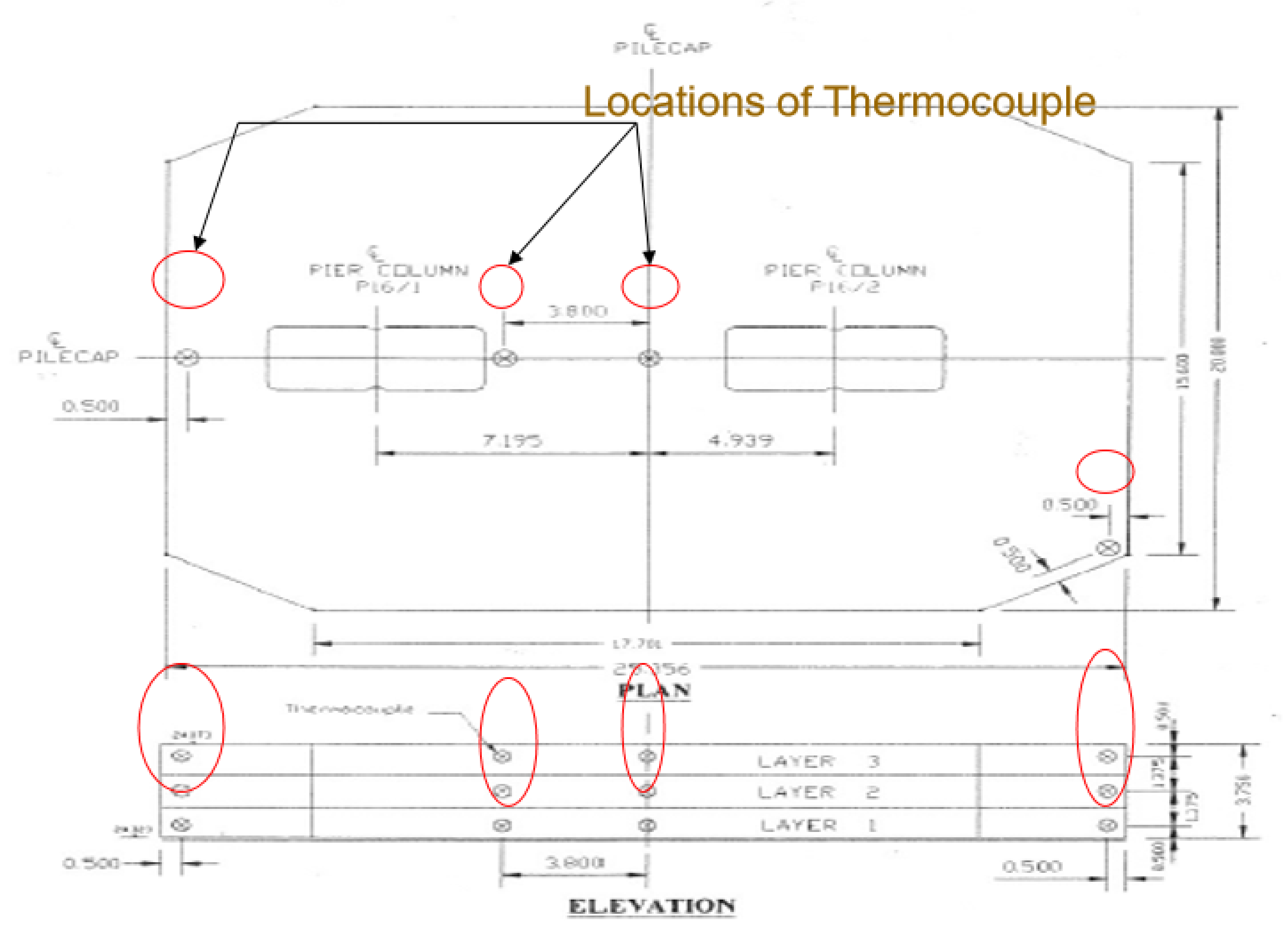


Figure 5: Position of Proposed Thermocouple

Temperature Monitoring

- The rate of evaporation increases rapid with higher:
  i. Air temperature
  ii. Relative humidity
  iii. Concrete temperature
  iv. Wind speed
- Rate of evaporation should be kept below 1.0 kg/m2, ideally below 0.5 kg/m2 to prevent plastic shrinkage cracking

Hardened Concrete

- Concrete placed and cured at elevated temperature may develop a high initial strength but ultimate strength may be reduced
- At 70°C, this reaction may occur:

gypsum + C3A (Tricalcium Aluminate)

$$\downarrow$$

Ettringite (but may decompose releasing sulfate ions)

Thermal Control

THERMAL CONTROL REQUIREMENTS

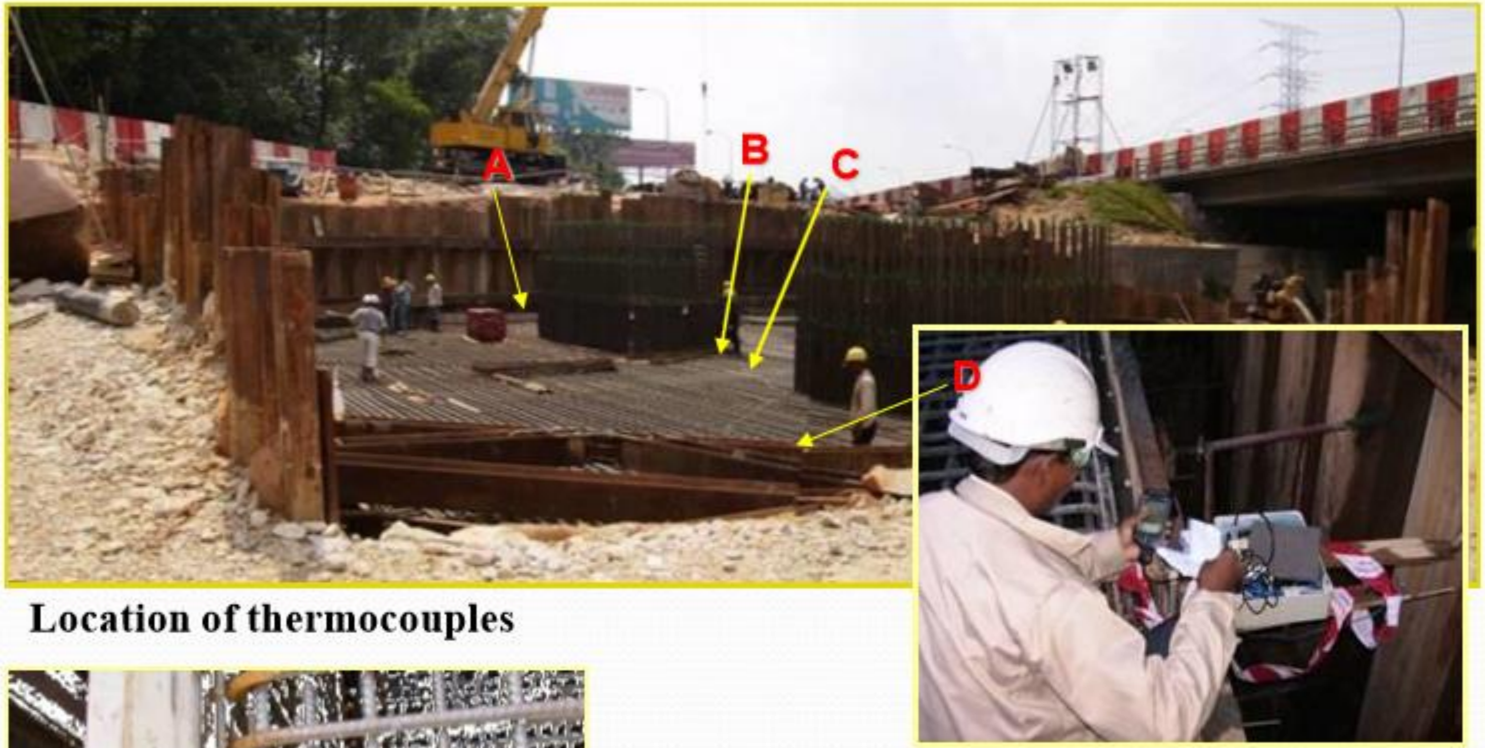
Specification Requirements:

- ***Placing temperature for concrete shall not exceed 33 °C;***
- ***Maximum temperature after placing shall not exceed 70 °C;***
- ***Rise and fall in temperature shall not exceed 10 °C within any period of 30 min. interval;***

There is apparently no mention about maximum temperature differential between centre section of pilecap and concrete surface (i.e. spatial temperature difference)

- **Placement Temperature:**
  - *Temperature of fresh concrete for G40 is about 2 – 3 °C above ambient temperature;*
  - *MS 523 allows for max. placement temperature of 36 °C while CP 65 (1999) Singapore code allows up to 37 °C;*
  - *To reduce placement temperature add ice to concrete mix. 1/3 water replacement with ice able to cool down water from 28 °C to 0 °C;*
  - *However even with H20 at 0 °C, fresh concrete temperature would still be about 28.5 °C when ambient temperature is 30 °C;*
- **Maximum Temperature:**
  - *Depends on structure thickness, quantity and type of cement used;*
  - *Temperature rise is 12 °C per 100 kg of cement used;*
  - *To reduce max. temperature rise:*
    - ✓ *Use low heat cement such as mascrete or GGBS (slag cement).*
      - ➢ *Temperature rise is 9.7 °C per 100 kg of low heat cement;*
      - ➢ *So if 400 kg of low heat cement used, there would be a drop of 8 °C as compared to OPC;*
      - ➢ *However low strength gain;*
    - ✓ *Minimise amount of cement used in the mix.*
      - ➢ *Reducing cement would mean lower concrete strength unless amount of water is also proportionately reduced;*
      - ➢ *Problem with workability;*
      - ➢ *Use superplasticising admixture.*
- **Maximum Temperature Differential:**
  - *2 temperature differential to be considered*
    - *Spatial*
    - *Time*
  - *Time-related rate of temperature change happens when there is a rainfall on the exposed concrete surface. Solution is to provide plastic sheeting cover.*
  - *Spatial temperature differential:*
    - *BS 8110: Part 2: 1985 provide guidelines on early thermal cracking and this can happen through 2 different mechanisms*
      - *Internal temperature gradients*
      - *External restraint during cooling*
    - *For our pilecap the restraint factor, R=0.1 to 0.2. Hence limiting temperature differential allowed for by Code is 50 °C, where aggregate type used is granite.*

TEMPERATURE MONITORING INSTRUMENTS



Location of thermocouples

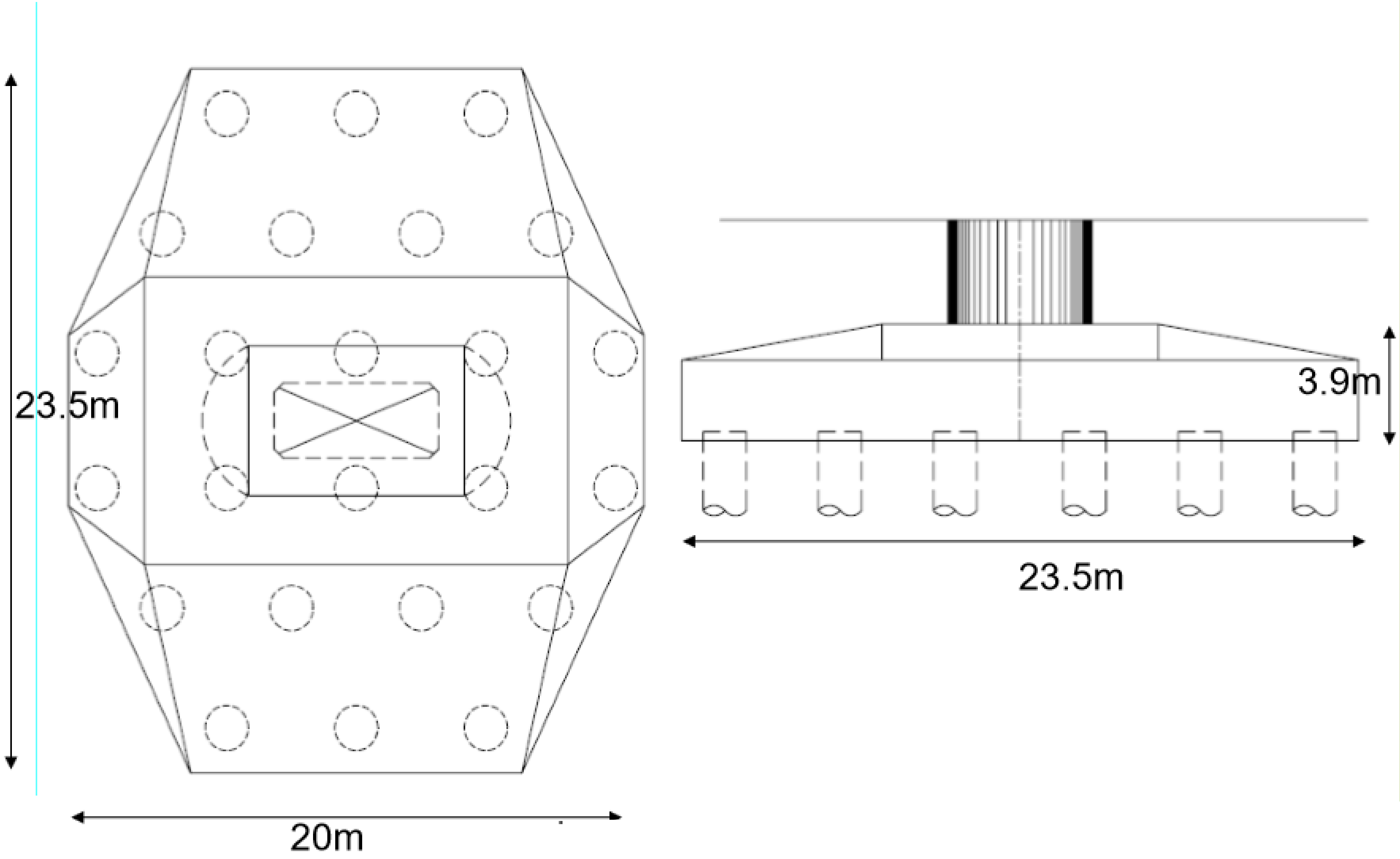
Thermocouple wires and ducting

Transferring Data from Data logger to Read-out Unit

INSULATION

- Insulation with 50 mm polyfoam with another layer of plastic sheeting;
- Side form only removed 6 days after completion of concreting;
- Insulation kept in place for more than 14 days after completion of concreting

FOUNDATION CONSTRUCTION – GENERAL PRECAUTION / ISSUES (PILE CAP – MAIN PIER)



FOUNDATION CONSTRUCTION – GENERAL PRECAUTION / ISSUES (PILE CAP – MAIN PIER)

- Pilecap size = 23.5m x 20m x 3.9m thk
- Concrete Volume required for pilecap=1833 cu.m
- Concrete mixture shall be designed using low heat emission and low setting time.
- Stage of pouring shall be design to reduce the heat release on the inner layer.
- Thermo couple must be installed , at least 9 nos, 3 nos at each layer (1.0m thk each layer)
- Concreting shall be in one continuous process.
- The cofferdam shall be free from any water intrusion or rise in water table before concreting takes place. Contractor to produce shop drawing incorporating the rebar and stump for temporary prop or tie-down.

FOUNDATION CONSTRUCTION - THERMAL CONTROL REQUIREMENTS

Specification Requirements:

- Placing temperature for concrete shall not exceed 36 °C;
- Maximum temperature after placing shall not exceed 70 °C;
- Rise and fall in temperature shall not exceed 10 °C within any period of 30 min. interval;
- Concrete shall not be placed in forms or around reinforcement whose temperature exceeds 36oC. This can be achieved by providing shading or other means to protect from direct sunlight.
- No concrete shall be placed when the air temperature at the point of deposition exceeds 36oC

FOUNDATION CONSTRUCTION - THERMAL CONTROL REQUIREMENTS

To reduce max. temperature rise:

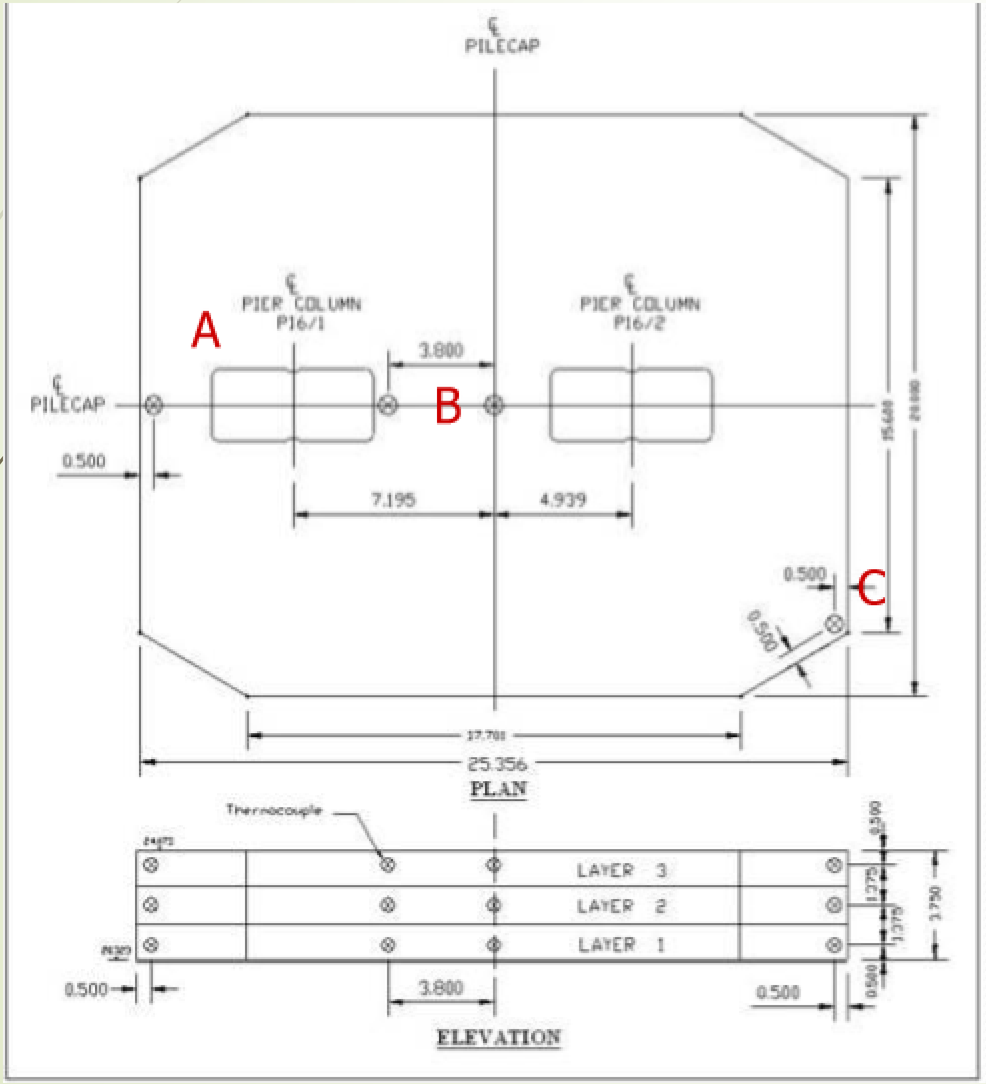
- Use low heat cement such as mascrete or GGBS (slag cement).
  - ✓ Temperature rise is 9.7 °C per 100 kg of low heat cement;
  - ✓ So if 400 kg of low heat cement used, there would be a drop of 8 °C as compared to OPC;
  - ✓ However low strength gain;
- Minimise amount of cement used in the mix.
  - ✓ Reducing cement would mean lower concrete strength unless amount of water is also proportionately reduced;
  - ✓ Problem with workability;
  - ✓ Use superplasticising admixture.

FOUNDATION CONSTRUCTION - THERMAL CONTROL REQUIREMENTS

Curing and Insulation

- 50 mm thick polystyrene foam laid over top exposed surface;
- Plastic sheeting laid over polystyrene foam to protect against unforeseen rain storm;
- Maintain side form until peak temperature has dropped to below 60 °C.

FOUNDATION CONSTRUCTION – TEMPERATURE MONITORING



- **Aim – to determine**
  - *Max. temperature and period it occurred;*
  - *Temperature differential at different locations.*
- **Installation**
  - *Thermocouple wire placed in 15 mm PVC pipe for protection;*
  - *At appropriate levels, PVC pipe will have holes for thermocouple tips to protrude out into the concrete;*
  - *PVC pipe tied to vertical rebar;*
- **Monitoring**
  - *Hourly interval;*
  - *Expected to take about 14 days.*
  - *Temperature readings must be taken and plot accordingly*

High Performance Concrete

- Permeability should be the controlling requirement if the concrete will be placed in an environment subjected to concentrations of chloride ions.
- The designer should understand that permeability will decrease with concrete age. With that, permeability values can be established at 28 days with an understanding that by the time the element is placed into service it will be considerably lower than when tested at 28 days.
- It can be shown that the permeability of plain cement concrete with no fly ash can decrease significantly up to about 60 days after placement.

High Performance Concrete

- However no significant decrease in permeability will occur after 60 days.
- On the other hand, concrete containing fly ash continues to decrease in permeability for 100 to 200 days after casting.
- High Performance Concrete (HPC) technology in an effort to extend the service life of pavements and bridges.
- The term HPC is used to describe concretes that are made with carefully selected high quality ingredients, optimized mixture designs, and which are batched, mixed, placed, consolidated and cured to the highest industry standards.

High Performance Concrete

- Typically, HPC will have a water-cementitious materials ratio (w/cm) of 0.4 or less.
- Achievement of these low w/cm concretes often depends on the effective use of admixtures to achieve high workability, another common characteristic of HPC mixes.
- A definition for HPC as, "…concrete that attains mechanical, durability or constructability properties exceeding those of normal concrete."
- Different characteristics of concrete in the fresh and hardened states affect performance.
- In the fresh state, flowability is an important characteristic.

High Performance Concrete

- It describes the ease or difficulty of placing the concrete depending on the equipment available.
- The adequacy of flow for a specific job will affect the quality of the finished product.
- Concrete with high flowability is easy to place and facilitates the removal of undesirable air voids in concrete.
- In fact, self-consolidating concrete (SCC) is available that flows through heavily reinforced areas or demanding places and consolidates under its own mass.

High Performance Concrete

- Well-consolidated concretes (either through mechanical vibration or mix design, as in SCC) are essential in achieving low permeability for long-lasting structures.
- The important characteristics of concrete in the hardened state mainly relate to durability and structural design.
- The performance characteristics related to durability include freeze-thaw resistance, scaling resistance, abrasion resistance, chloride ion penetration, alkalisilica reactivity, and sulfate resistance.
- The four structural design characteristics are compressive strength, modulus of elasticity, shrinkage, and creep.

High Performance Concrete

- The characteristics are determined using standard test procedures, and grades of performance are suggested for each characteristic.
- Durability is of utmost importance for structures exposed to the environment and concrete for each structure may need one or more of these characteristics.
- The material characteristics and grades should be selected in accordance with the intended application and the concrete's environment.
- For example, a bridge deck supported on girders needs a specified compressive strength but is unlikely to require specified values for modulus of elasticity and creep.

High Performance Concrete

- It is not necessary to require all performance characteristics for a given application.
- Other important features of HPC are uniformity and consistency. With high variability, the concrete has a high potential for not meeting the specifications.

Permeability Requirements

Permeability Requirement

- Durability of concrete identifies the ability of the concrete to resist degradation due to environmental exposure conditions.
- There are many factors that indicate the durability of concrete, one being permeability.
- Permeability is the ability of a concrete to pass pore water through the hardened matrix.
- In reality, a durable concrete should resist this passage of pore water, or in other words, the concrete should be impermeable.

Permeability Requirement

- This important factor is affected by water to cementitious materials ratio, mineral admixtures and high range water reducers.
- In cases where severe exposure of the concrete is expected, such as in splash zones, marine environments and climates where deicing salts are applied, silica fume is another mineral admixture that can be added to the mix to increase density and significantly reduce the permeability of the concrete.

Permeability Requirement

Initial Surface Absorption Test (ISAT)

- ISAT are to be carried out on samples of different components of the bridge structures (e.g. bridge deck, pier, pylon, abutment, parapet) before the mix designs are approved.
- The samples size are 150mm x 150mm x 600mm for precast elements and in-situ members.
- The tests are to be carried out on 4 samples of size 150mm x 150mm x 150mm cubes cut from the sample in accordance with BS 1881:1970 at 28 days after casting and water cured of the samples.
- The maximum values must not exceed the following limits at 10 minutes after starting the test: - In-situ constructions: less than 0.10ml/m2/s - Precast concrete elements: less than 0.10ml/m2/s

Permeability Requirement

- During construction, the ISAT test shall be similarly carried our on test samples and will form one of the basis for rejecting/accepting concrete elements.
- The maximum values must not exceed the following limits at 10 minutes after starting the test: - In-situ constructions: less than 0.10ml/m2/s - Precast concrete elements: less than 0.10ml/m2/s
- During construction, the ISAT test must be similarly carried our on test samples and will form one of the basis for rejecting/accepting concrete elements.

Permeability Requirement

Chloride Permeability Test

- Rapid Chloride Permeability Test (RCPT) shall be carried out using cores taken from the 150mm x 150mm x 600mm samples cast, in accordance with AASHTO T277 'Rapid Determinations of the Chloride Permeability of Concrete.
- The following limits shall not be exceeded: - In-situ construction : 1000 coulombs - Precast concrete elements : 1000 coulombs
- During construction, the RCPT test must be similarly carried out on test samples and will form the basis for rejecting/accepting concrete elements.
- Test shall be carried out at 28 days after the date of casting.

Permeability Requirement

- Based on the past experience of the specialist ready mixed concrete supplier however, the required permeability limits could not be achieved reliably with Grade 40 concrete.
- Hence to be able to satisfy this requirements, the Contractor had on their own initiative and at their own costs, upgraded the originally specified Grade 40 concrete members such cross-beams and deck slab to Grade 50 concrete, in addition to the silica fume compound added to the concrete mix.
- The outcome of the tests carried out on concrete samples revealed that the specified permeability limits were consistently satisfied with the upgrading of Grade 40 to Grade 50 concrete amid higher strength advantage to the concrete members.
- A sample of Initial Surface Absorption and Rapid Chloride Permeability test results are given below.

INITIAL SURFACE ABSORPTION TEST

Client : Pioneer Sun-mix Concrete Sdn Bhd

Project : Kuala Kurau bridge .

Structure : Trial Mix .

Area of cap used : 5432 mm²

Length of capillary : 350 mm

Tested by : ABD Halim

Date of Testing : 25/11/02

Method of testing : BS 1881 : Part 208 : 1996

Reference	Initial Testing Time	Temp °C	Capillary water movement at mm (in 1 min)									Corrected Initial surface absorption ml / (m².s)		
			10 min			30 min			1 hour			10 min	30 min	1 hour
			bfr	aft	dif	bfr	aft	dif	bfr	aft	dif			
TM2 RAB 50x45	15.08	28°C	95.5	89.0	6.5	95.5	82.1	13.4	95.5	76.6	18.9	0.03	0.07	0.09
TM1 BAB 50x45	15.11	28°C	100	94.4	5.6	100	94.1	5.9	100	91.4	8.6	0.03	0.05	0.04

Note : 1. 1division equivalent to 0.01 ml/(m².s)

2. Correction factors to convert readings to an equivalent value at 20°C

29°C multiply by 0.82

Lab Ref : T19/03

REPORT NO : RCPT 137/03/P0223
REPORT DATE : 20th March 2003

RAPID CHLORIDE PERMEABILITY TEST RESULT

Client	:	Latimer Corporation Sdn Bhd
Project	:	Membina Jambatan Baru Kuala Kurau, Daerah Kerian, Perak Darul Ridzuan (Fasa 1)
Structure	:	**Pile Cap - Pier 1**
Tested By	:	Mohd Khairol Anuar

Concrete Mix Code : BAB50XH5

Test Method : ASTM C1202

Category of Testing : Laboratory Testing

Core Reference	:	A	
Diameter of specimen	:	101	mm
Length of specimen	:	50.3	mm
Date of casting	:	13-Jan-03	
Date of testing	:	19-Mar-03	
Density of specimen	:	2410	kg/m^3
Resistor, R	:	1	Ohms

Time	Elapse Time (Hours)	Voltage, V (millivolt)	Current, I (milliamps)
9:05 AM	0:00	19.7	19.7
9:35 AM	0:30	20.5	20.5
10:05 AM	1:00	21.0	21.0
10:35 AM	1:30	21.3	21.3
11:05 AM	2:00	21.9	21.9
11:35 AM	2:30	22.2	22.2
12:05 PM	3:00	22.3	22.3
12:35 PM	3:30	22.5	22.5
1:05 PM	4:00	22.8	22.8
1:35 PM	4:30	23.0	23.0
2:05 PM	5:00	23.2	23.2
2:35 PM	5:30	23.3	23.3
3:05 PM	6:00	23.4	23.4

Maximum current recorded	mA	23.4
Measured Charge passed	Coulombs	478.0
Corrected Charge passed	Coulombs	425.1
* Relative Chloride Permeability		Very Low

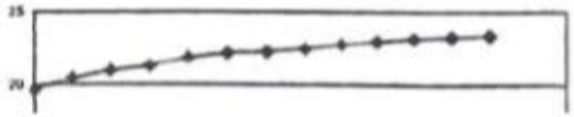
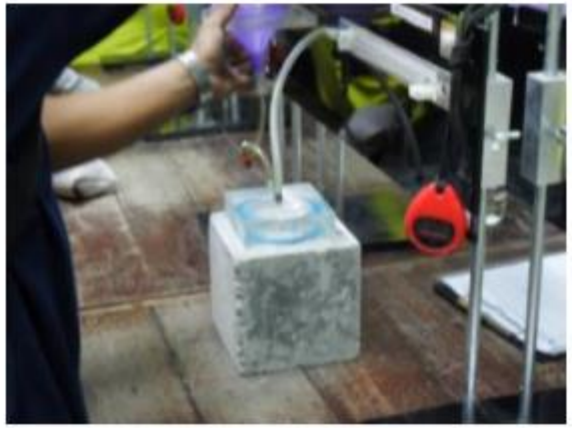


Table 1 : ASTM C1202 : Chloride ion penetrability base on charge passed.

Charge passed (coulombs)	Chloride Ion Penetrabity
[illegible]	[illegible]



Initial Surface Absorption Test (ISAT)




Rapid Chloride Permeability Test (RCPT)

2. Steel Reinforcement

- Before any reinforcement steel is brought to Site, contractor must furnish the mill certificates of tests.
- Tensile tests must be conducted at accredited laboratory for any batch of bars.
- Steel reinforcement must be stored in clean & dry conditions.
- When placed in the work it must be clean & free from loose rust, mill scale, oil, grease, paint, dirt or anything which may reduce its bond with concrete.
- Steel bars must be brushed or otherwise cleaned before use.

2. Steel Reinforcement

- Cold worked & hot rolled bars must not be straightened or bent again once having been bent.
- Where it is necessary to bend the free end of mild steel reinforcement already cast in the concrete, the internal radius of the bend must not be less than twice the diameter of the bar.
- Reinforcements must be secured against displacement.
- The actual concrete cover must be taken as the distance between face of concrete & the nearest steel surface.
- All intersecting bars must be tied together with binding wire & the ends of the wire shall be turned into the main body of the concrete.

2. Steel Reinforcement

- Particular care must be taken that the reinforcement is laid out correctly in every aspect & temporarily suspended by annealed wire or supported on concrete blocks or other approved spacers in the forms to prevent displacement during the placing & compacting of concrete.
- Links must tightly embrace the longitudinal reinforcement to which they shall be securely wired or spot welded.
- The top reinforcement in slabs must be rigidly supported on mild steel "chairs" or equivalent spaced in each direction to prevent sagging during concreting.

2. Steel Reinforcement

- Joints to reinforcement bars must be affected by lapping of bars at positions shown in the drawings.
- All connections should away from points of high stress & should be staggered.
- Supporting & spacer blocks required for ensuring that the reinforcement is correctly positioned must be as small as possible.
- The nominal size of aggregates used must be 10mm. The concrete spacers must be of at least the same strength & material's source as the concrete to be poured.

3. Formworks

- Formwork must include all temporary or permanent forms required for forming the concrete, together with all temporary construction required for their support.
- When the use of proprietary type of formwork is proposed by contractor, the design must be certified by a Professional Engineer.
- The formwork must be sufficiently rigid & tight to prevent any loss of grout or mortar from the concrete at all stages of construction & must be appropriate for the methods of placing & compacting.
- Before concreting, all forms must be thoroughly cleaned out, free from sawdust, dust, mud or other debris.

3. Formworks

- The minimum periods between concreting & the removal of forms are given as below :

TABLE 9.10 - MINIMUM PERIODS BETWEEN CONCRETING AND REMOVAL OF FORMS

Vertical faces of beams, wall, columns, piles, foundation plinths and precast components	3 days
Slabs (props left under)	4 days
Removal of props to slab	10 days
Beam soffits (props left under)	8 days
Removal of props to beams	21 days

Note: **This table is applicable only for Ordinary Portland Cement.** Where other types of cement, admixtures or additional material are to be used, the minimum periods between concreting and removal of forms shall be as approved by the S.O.

- For prestressed in-situ components, temporary supports must not be removed until the components is stressed.

4. Prestressing Materials

Prestressing tendons

- Prestressing tendons must be clean & free from pitting, loose rust & loose scale at the time of incorporation in the Work.
- Test on prestressing strands :
  - i. relaxation tests
  - ii. Tensile test
- Manufacture's mill certificates for parcel of steel must be obtained.

4. Prestressing Material

Grout For Ducts

- The grout must :-

  i. Consist only of Ordinary Portland Cement & water;

  ii. Water: cement ratio as low as possible consistent with the necessary workability & under no circumstances shall the water: cement ratio exceed 0.45;

  iii. Not subject to bleeding in excess of 2% after 3 hours or 4% maximum when measured at 27°C in a covered glass cylinder approximately 100mm diameter with a height of grout approximately 100mm and must be re-absorbed after 24 hours.

4. Prestressing Material

- The compressive strength of 100mm cubes made of the grout must exceed 17N/sq.mm at 7 days.
- Cubes must be cured in a moist atmosphere for the first 24 hours & subsequently in water.

5. Bearings

Rubber Bearings

- Bearings must made up of good quality natural rubber comply with the requirements of MS 297.
- The physical properties of the vulcanized rubber when tested according to appropriate standard must conform to the requirements of Table below :

PHYSICAL PROPERTIES OF ELASTOMER

	Type A	Type B	Type C	Methods of Tests
1. Nominal Hardness (IRHD)	46 to 55	56 to 65	66 to 75	ISO 48
1. Tensile strength (N/sq.mm), min	21	17	14	ISO 37
1. Elongation at Break (%), min	550	450	300	ISO 37
1. Compression set after 24 hours at 70°C and 25% compression (%), max	30	30	30	ISO 815
1. Ozone resistance test after 96 hours at 25pphm ozone, 40°C 20% strain	No visible cracks	No visible cracks	No visible cracks	ISO 1431 Part I
1. Accelerated ageing for 168 hours at 70°C				
6.1) Change in tensile strength, (%)				ISO 188 (air oven)
6.2) Change in elongation at break, (%)	± 15	± 15	± 15	ISO 37
	- 20	- 20	- 20	ISO 48

Bearings whose nominal hardness falls within the ranges of 46 – 55, 56 – 65 & 66 – 75 are classified as types A, B & C respectively

5. Bearings

Sampling

- For acceptance purposes, a lot must consists of bearing of a single size and design.
- A lot must not exceed one hundred bearings.
- From each lot, a minimum of two bearings must be selected at random by the S.O. for testing in accordance with the requirements of the specification.
- Testing must be carried out at the Rubber Research Institute of Malaysia.

5. Bearings

- Performance tests must be conducted in accordance with the test methods :-
  - i. Stiffness in direct compression
  - ii. Stiffness in shear - must be in accordance with Appendix B of MS 671.
- For bearings which fails to meet any of the material tests, specimens must be taken from another bearings sampled earlier.
- If the bearings fail performance tests, two further bearings must be sampled from the same lot.
- The bearings must meet all the requirements or the lot shall be rejected.

5. Bearings

Test Certificates

- Test certificate for at least two samples of each type of bearings must submitted for the approval.
- The following bearing properties must satisfy the requirements of :

  i. Hardness

  ii. Tensile Strength and Elongation at Break

  iii. Compression Set

  iv. Ozone Resistance

  v. Accelerated Ageing

  vi. Chemical Composition

  vii.Stiffness in Shear

- The minimum thickness of the steel plates must be 3 mm for the outermost planes & 2 mm for innermost plates.

5. Bearings

Epoxy Mortar Bedding & Dowel Bars

- Epoxy mortar for the bearing pads bedding must have a comprehensive strength of at least 48N/sq.mm at 7 days.
- All aggregates must be of dried quality & no damps or wet aggregate be permitted in the epoxy mortar.
- Dowel bars must be of galvanized in accordance with BS 443, ‘Testing Zinc Coatings on Steel Wire and for Quality Requirements’.

5. Bearings

- Prior to placing the epoxy mortar bedding, a trial mix of epoxy mortar mixture must be prepared.
- The equipment used to make the trial mix must be the equipment to be used during the Work.
- 3 standard 100mm test cubes must be cast and compression tested in accordance with BS 1881 ‘Method of Testing Concrete’ and cured for 7 days.
- The 3 cubes must be tested for compression strength at 7 days and each cube must have a compressive strength of at least 48N/sq.mm.

6. Expansion Joints

- End welded studs must conform to the specification.
- Anchors must be fabricated from hot rolled mild steel deformed bars conforming to BS 4449 & must be of weldable quality.
- Steel plates, bars & shapes must be fabricated from high strength low alloy steel conforming to the requirements of BS 4360 grade 50B, with the additional requirements that the steel shall contain 0.33/0.50 copper.
- Bolts, nuts and washers must be high strength conforming to the requirements of BS 4395: Part 1 General Grade or ASTM 4325, Type 3.
- The metal surfaces in direct contact with the neoprene seal elements, must be sand blasted & treated as recommended by the manufacturer so as to provide a high strength bond between the neoprene seal & the mating metal surfaces.

6. Expansion Joints

- Epoxy for bonding the neoprene seals in place must be one-point moisture curing, polyurethane & hydrocarbon solvent mixture equal to Bon-Lastic Adhesive & meeting the following properties:

  i. Average Weight Per litre1.2 kgs +10%

  ii. Solids Contents by Weight 65%

  iii. Material to be fluid from -15°C to 49°C

  iv. Film Strength N/sq.mm min 14

  v. Elongation 250%

  vi. Low temperature - 60oC Tensile – OK

  Elongation -Not Brittle

6. Expansion Joints

- Epoxy for use in coating concrete surfaces & for filling the joint blockout in the concrete after installing & adjusting the expansion joints must be a two-components epoxy resin adhesive meeting the requirement of AASHTO M235.
- Neat epoxy adhesive or epoxy grout must be used in filling the gap below bottom of the expansion joint dam.

6. Expansion Joints

Joint Filler

- Non extruding and resilient type filler must conform to the ASTM D1752; Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction AASHTO 13.
- Bituminous type filler must conform to the ASTM D1751; Specification for Preformed Expansion Joint fillers for concrete Paving and Structural Construction AASHTO M213.
- Preformed joint filler must conform to the ASTM D994; Specification for Preformed Joint Fillers and concrete Paving and Structural Construction AASHTO M33.
- Preformed elastomeric compression joint seals must conform to the Specification for Preformed Elastomeric Compression Joint Seals for concrete AASHTO M220.

6. Expansion Joints

Joint Sealing Compound

- Rubber bitumen sealant must consist of hot poured material complying with the requirements of BS 2499.
- Cold poured compound material must comply with the requirements of ASTM D1850-74.

7. Protective Coating

- Coating to deck soffit, diaphragms, capping beams, etc.
- The material employed for the coating must comply with the following requirement or equivalent :-

a) Wet film thickness 150 microns per coat

b) Dry film thickness 75 microns per coat

c) Reduction in water 80% minimum @ 28 days absorption (ASTM C642)

d) Carbon Dioxide diffusion A minimum equivalent to resistance 250 metres of air (Research Laboratories Taywood Engineering Ltd)

e) Water vapour transmission Shall be more than 13g/m2/day (Research Laboratories Taywood Engineering Ltd)

f) Reduction in chloride ion 90% minimum @ 28 days

g) Penetration - Freeze/Thaw salt scaling Unaffected by 50 exposure (ASTM C672) cycles

7. Protective Coating

Coating Materials To All Abutments And Piers

- The solvent free based epoxy resin coating must comply to the following properties:-

a) Specify gravity : 1.67 (approx.)

b) Volume Solids : 100%

- Recommended thickness per coat:dry film thickness (dft) 200 um. wet film thickness 200 mm.
- Theoretical coverage : 5m2/litre (3m2/kg) for a dft of 200 um.
- Practical coverage : Theoretical coverages are quoted for guidance. Practical coverages may be lower, depending on substate and application method.

7. Protective Coating

Number of coats : 2

Pot Life :	at 20°C	at 35°C
	30-40 mins	12-20 mins
Drying Time :	at 20°C	at 35°C
Touch dry	6 hours	3 hours
Fully dry	7 days	7 days
Recoatable	6-24 hours	3-12 hours

Application temperature : Minimum 5°C

Single span steel plate bridge failed due to scouring of abutment

Severe cracking at asphaltic plug joint

Cracks on piles due to rotation of abutment

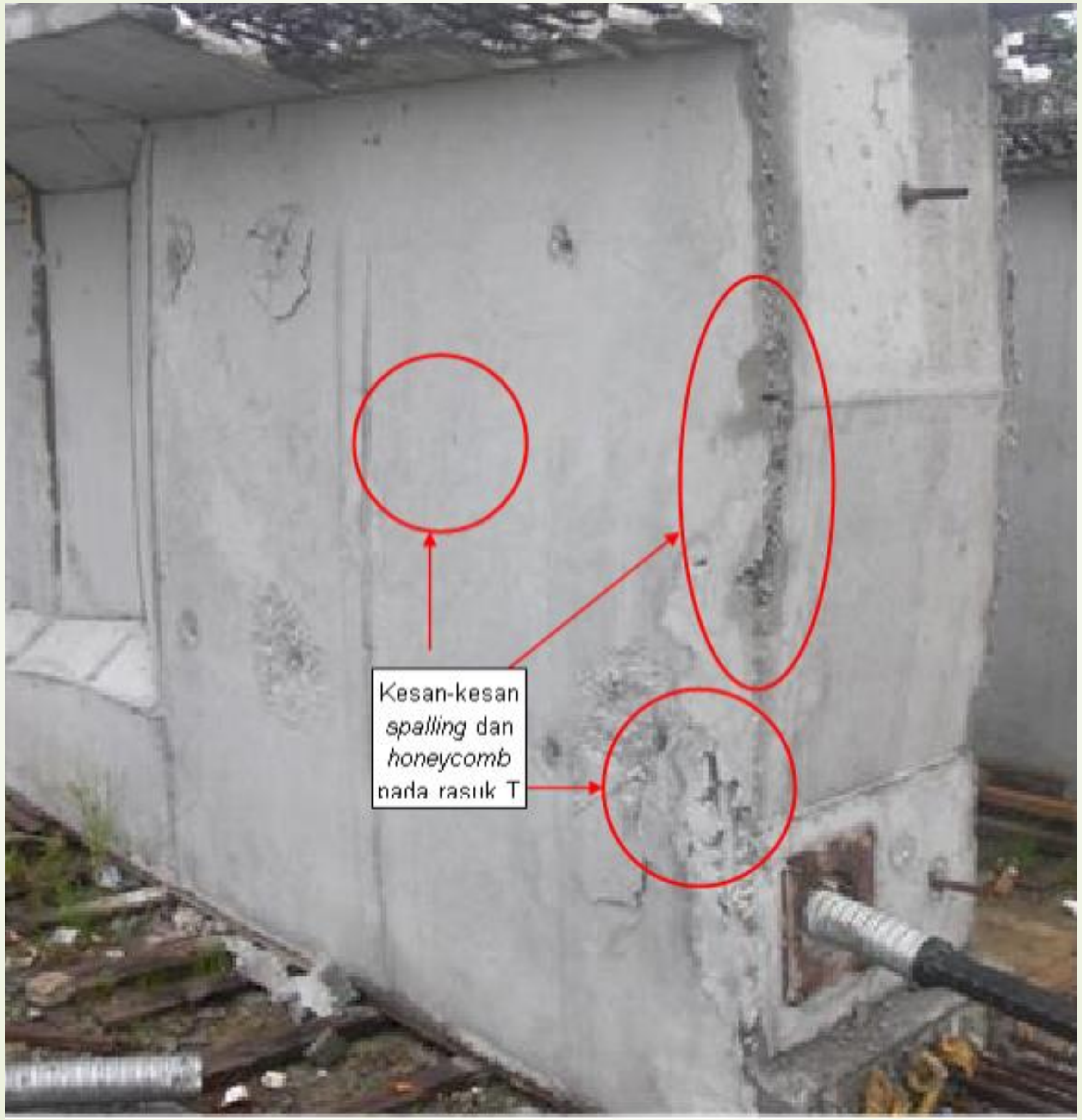
Plastic settlement cracks on a bridge deck follows the line reinforcement

Plastic shrinkage cracks on top of the deck slab

Early thermal
contraction
cracks at
underside of
cantilever slab

Cracking at the abutment due to the presence of alkali silica reaction (ASR)


16
15
14
13
12
11
10


Kesan-kesan *spalling* dan *honeycomb* pada rasuk T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Thank You for
Your Attention
Questions??