CHAPTER 8 - CONCRETE

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8.1 SCOPE

This chapter covers the manufacture and use of concrete in structures.

Site monitoring staff should read and obtain a sound understanding of the relevant section of the Standard Specification and the Project Specifications before applying this section of the manual. This chapter contains a substantial amount of information and requirements which are contained in the specifications. This is provided to assist monitoring staff in understanding “normal requirements”: note that this does not take precedence over the specifications.

Other useful references include:

- Fulton’s Concrete Technology: This deals in some depth in all aspects of concrete. (See www.cnci.org.za/booklets1.htm)
- Cement and Concrete Institute’s courses (See www.cnci.org.za). The following course is particularly recommended for monitoring staff who do not already possess a sound understanding of concrete technology: SCT 30 Concrete Technology (5 days)

The chapter is laid out to follow the concreting process encountered on a construction site, and then deals with specific issues:

(a) Mix Design: Reviewing and approving the contractor’s mix design.
(b) Storing of materials: Storing of cement, stone and sand on site.
(c) Pre-concreting inspection: Inspections of the works to ensure that it is ready for concreting.
(d) Batching concrete: The measuring and mixing process.
(e) Placing and compacting: Transporting, placing and vibrating the concrete.
(f) Construction joints: Approvals, positions, preparation, construction.
(g) Curing and protecting concrete;
(h) Adverse weather conditions: Cold and hot weather concreting;
(i) Loading concrete;
(j) Monitoring concrete strength and durability;
(k) Specialist forms of concreting;
(l) Concrete cubes

This chapter should be read in conjunction with the other chapters, specifically formwork, reinforcement and, where applicable, prestressing.

Note that various standard specifications refer to SABS documents which may now be out-dated or superseded. COLTO Standard Specifications is an example of this. In Table 8.1 below some typical superseded SABS documents along with the replacement document is given.
Table 8.1: Superseded SABS documents along with the replacement documents

<table>
<thead>
<tr>
<th>Description</th>
<th>Superseded code</th>
<th>New code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement: OPC, RHC</td>
<td>SABS 471</td>
<td>SANS 50197-1</td>
</tr>
<tr>
<td>Cement: PBFC</td>
<td>SABS 626</td>
<td>SANS 50197-1</td>
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<tr>
<td>Cement: PC15, RHPC15</td>
<td>SABS 831</td>
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</tr>
<tr>
<td>Cement: GBFS</td>
<td>SABS 1491 Part 1</td>
<td>SANS 50197-1</td>
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<tr>
<td>Aggregate</td>
<td>SABS 1083</td>
<td>SANS 1083</td>
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<tr>
<td>Drying shrinkage of aggregates</td>
<td>SABS method 836</td>
<td>SANS 5836</td>
</tr>
<tr>
<td>Drying shrinkage of concrete</td>
<td>SABS method 1085</td>
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<tr>
<td>Aggregate size</td>
<td>SABS 1083</td>
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<tr>
<td>Sulphate content: Aggregates</td>
<td>SABS 850</td>
<td>SANS 5850-1</td>
</tr>
<tr>
<td>Drilling cores</td>
<td>SABS 865</td>
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<td>Evaluate cores</td>
<td>SABS 0100 Part II</td>
<td>SANS 10100 Part 2</td>
</tr>
<tr>
<td>Load tests</td>
<td>SABS 0100 Part II</td>
<td>SANS 10100 Part 2</td>
</tr>
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</table>

8.2 MIX DESIGN

The contractor is responsible for the design of the mix and the constituent materials producing concrete with the specified properties. The design should be submitted on the standard form prescribed by the employer for concrete mix designs.

The contractor should submit samples of the constituent materials of the concrete and a statement of the mix proportions which he proposes to use for each class of concrete.

The contractor’s mix designs and materials samples must be received early enough for the engineer and monitoring staff to review them and have independent tests done if this is considered necessary.

Generally the contractor should show that the mix design complies with the specifications by producing a statement of test results from an approved laboratory or, if acceptable to the engineer and employer, a report on previous use. Where relevant, product data sheets must also be supplied.

The following should be reviewed in the contractor’s mix design:

8.2.1 Cement

Cement must comply with the new standard SANS 50197-1:2000 code for cements: (refer to CNCI website www.cnci.org.za).

The application of cement types must comply with the specifications.

Blending of cements must comply with the specifications.

8.2.2 Aggregates

Source of sand or stone: Where these are not from recognized sources and records of compliance with the relevant specifications are not available, additional tests must be done by an approved laboratory.

Both stone and sand must comply with SABS 1083.

COMMENT

In some areas the geological source may be specified due to its superior properties with regard to for example, low shrinkage properties for prestressed concrete elements.
Drying shrinkage testing must comply with SABS Methods 1085 and 836 and the relevant clauses of the Standard Specification. Drying shrinkage should not exceed:

- 0.040% when testing the concrete mix design, and
- 130% of that of the reference aggregate for both sand and stone for prestressed concrete, or
- 175% of that of the reference aggregate for sand in reinforced concrete and
- 150% of that of the reference aggregate for stone in reinforced concrete.

The flakiness index using TMH 1 Method B3 should not exceed 35.

Aggregates should not contain any detrimental amounts of organic materials such as grass, timber or similar.

Alkali-Aggregate Reaction: Where there is a possibility of this occurring, test the mix design in accordance with the standard specifications. Total alkaline content (Na₂O-equivalent) should be limited as specified in the specifications (for example COLTO 8105(f) ). Non-conforming mix designs should not be accepted.

The fineness modulus of the fine aggregates should not vary by more than +/- 0.2 from the approved modulus.

### 8.2.3 Water

Water must be free of detrimental amounts of:

- Chlorides (For reinforced and prestressed concrete the chloride content should not exceed 500 mg/l to SABS method 202),
- Acids,
- Alkalis,
- Salts,
- Sugar, and
- Other organic or chemical substances that may adversely affect the concrete.

Where appropriate, the water must be tested in an approved laboratory.

### 8.2.4 Admixtures

Admixtures must comply with the following requirements:

- Must be of an approved brand and type,
- Must have a proven track record,
- Must be in liquid form,
- Must be mixed in with the water to an accuracy of +/- 5%,
- Must comply with ASTM C494 or AASHTO M194 and
- Must not contain chlorides.
8.2.5 Curing agents

Only approved curing agents should be used.

Test curing agents in accordance with ASTM C156.

Curing agents should comply with ASTM C309, except that the loss of water within 72 hours should not exceed 0.40 kg/m3.

Resin-based curing compounds should be avoided as they generally stain the concrete and reduce adhesion should future coating be required.

8.2.6 Mix proportions

Generally all concrete in current bridge design practice is strength concrete.

The following must comply with drawings, bills of quantity and specifications:

- Concrete cube strength
- Nominal size of course aggregate
- Maximum water:cement ratio (if specified)
- Minimum cementitious content (if specified).

Aggregate sizes must comply with SABS 1083.

Cement content should not exceed 500 kg/m3 of concrete.

Sulphate content should fall within the limits specified in the Standard Specifications.

8.2.7 “W” prefix durability concrete

Where durability concrete with a prefix “W” e.g. W40/19 is specified, it should comply with the project specifications.

The process associated with durability concrete includes:

- The contractor uses an approved laboratory to determine the mix proportions.
- Before any durability concrete is cast, the laboratory should test concrete specimens taken from trial panels using the concrete mix, for the relevant durability parameters as described in the specifications.
- When durability concrete is cast, further test panels are cast as described in the specifications. These panels will have concrete specimens cored out of them after 28 days. These specimens are then tested for durability.

NOTE

The process of getting the mix design for concrete approved can take up to two months or more. This applies to all concrete mix designs, including “W” concrete. The contractor needs to submit his sample materials and mix design as

COMMENT

Certain specified durability criteria such as the use of PFA or GGCS, max water-cement ratio and min cement content will invariably result in a higher cube strength than what is specified for strength concrete. The target strength as determined from the trial mix is therefore an important criteria for monitoring compliance with the W-specification. Whilst cube strengths below the target value may still meet the strength requirement (e.g. 40 MPa), the durability properties of the concrete will become suspect.
- If the specimens do not meet the relevant acceptance criteria, then cores are taken from the concrete component and tested.

Achieving “W” concrete is not a complex operation and is not high in risk. It is actually simple and has three components.

- Concrete mix design: This is easy to achieve and because of its high cement content makes up for a few shortcomings in the aggregates. Accurate batching and water dosing will achieve the requirements;

- Placing and curing: If the concrete is placed without delay after mixing and is properly vibrated and cured, the requirements for W Concrete will easily be achieved; and

- Formwork: If good quality well maintained formwork is used and left in place for the required curing period then the requirements will easily be achieved. Contractors that have commercial pressures to strip early will increase the risk of not achieving the W specification.

8.2.8 Trial mixes

Slump measurements in accordance with TMH1 Method D3 should fall within the ranges specified in the Standard Specifications.

Bleeding should not be excessive. Limits to the amount of bleeding is given in the specifications.

In the above Photo 8.1 of the bottom flange of a precast beam, the concrete has bled excessively due to very poor grading of the sands in the mix. The bleed water has collected on the sloping face of the shutter. This has significantly reduced the durability as the bleed paths have reduced the effectiveness of the concrete cover resulting in porous cover concrete.
The concrete in the above photo 8.2 has very high shrinkage due to a very poor stone combined with a high cement content. High bleeding contributed to the problem.

8.3 STORING OF MATERIALS

8.3.1 Cement

• Cement must be stored under cover. Cement must not get damp or wet.

• Cement bags must not be stacked higher than 12 bags and must not be in contact with the floor or walls. Doors must be opened as infrequently as possible and windows must be kept closed.

• Cement should not be kept in storage for longer than 8 weeks.

• Bulk cement must be stored in weather-proof silos. Bulk cement should also not be kept in storage for longer than 8 weeks.

8.3.2 Aggregates

• Aggregates of different sizes should be stored separately.

• Aggregates must not become contaminated by foreign matter e.g. the ground below the stockpile.

• Aggregates should be stored on a concrete apron slab at least 150 mm thick or similar approved.

• Aggregates exposed to sea air should be covered to prevent salt contamination.

• Sufficient material should be stored on site to ensure that no unintended construction joints are required in the structure.

NOTE

It is the responsibility of the contractor to ensure that he complies with the contract specifications and good practice. The Monitoring Staff must conduct the inspection in such a way that he does not perform the contractor’s quality control duties. This can be done by ensuring that the contractor produces his own signed-off quality documents. When a component is found to be clearly not ready for an inspection, it is advisable to declare it not ready for inspection without giving specific lists of outstanding items, making it quite clear that this is the contractor’s responsibility.
8.4 PRE-CONCRETING INSPECTION

Prior to batching and casting concrete, the works must be inspected to ensure that they are ready for concreting (Refer to the other sections of this manual and to the specifications.).

This inspection should include checking of the following.

8.4.1 Falsework
   (a) Falsework design approved;
   (b) Temporary foundations and supports adequate;
   (c) Falsework in place and adequately braced;
   (d) Falsework components adequate tightened;

8.4.2 Formwork
   (a) Correct formwork in place;
   (b) Correct quantity of shutter release agent applied (too much can retard and stain concrete);
   (c) Ferule ties etc in place and adequately tightened. Note that cones should be used – refer to Chapter 7;
   (d) Formwork adequately secured – will not kick or move;
   (e) Sloping formwork will be able to withstand concrete hydrostatic pressure which may try to lift it up;
   (f) Deck void formers etc adequately tied down and internally braced – must not move or collapse under concrete hydrostatic pressure;
   (g) Dimensions and alignment correct and within tolerance;
   (h) Chamfers in place and adequately secured;
   (i) Drip grooves in place;
   (j) Filled expansion joints properly prepared;
   (k) Formwork clean, especially of debris and reinforcement tie wires;
   (l) Existing concrete and construction joints properly prepared and pre-wetted.

8.4.3 Reinforcement
   (a) Reinforcement in place according to the drawings;
   (b) Reinforcement clean and only lightly corroded – no shutter oil or compressor oil etc;
   (c) Reinforcement adequately tied – if you can easily kick or twist a bar out of place, it will move during concreting;
   (d) Correct cover blocks in place and strong enough to support concreting loads – Refer to Chapter 7.

8.4.4 Ferrule ties and other pipes and conduits installed for the contractor’s use
   (a) Check that these have been approved by the engineer; [see the relevant clauses in the specification]
(b) Minimum clear gaps of 40 mm to ensure good concreting;
(c) Minimum concrete cover of 25 mm to ferrules and other pipes;
(d) Ends of the plastic ferrule tubes should be cut back to at least 50 mm (removable cups are preferred).

### 8.4.5 Additional components to be concreted in

All of the drawings need to be studied to ensure that any additional component is correctly fixed in place. These components can include:

(a) Starter bars for subsequent concreting in correct position;
(b) Drainage and electrical ducts and components;
(c) Bolt groups and fixtures for railways components;
(d) Bolt groups and fixtures for lampposts, pedestrian rails, guardrails, etc.

### 8.4.6 Concrete

(a) Materials and mix design approved;
(b) Batching procedure approved and equipment and operators ready;
(c) Testing procedure approved and equipment and operators ready;
(d) Placing procedure approved and equipment and operators ready;
(e) Compaction procedure approved and equipment and operators ready;
(f) Curing procedure approved and equipment and operators ready.

### 8.4.7 Testing equipment ready

(a) Slump cone testing equipment;
(b) Concrete cubes – enough cubes, correct compacting rod, etc;

### NOTE 1

The Monitoring Staff should not only rely on the methodical use of check-lists for the inspection, but should also apply their intelligence, judgement and experience to the work to be performed. The Monitoring Staff should stand back after the inspection and go through the whole process in his mind to ensure that nothing has been overlooked. This applies especially to anything that is unusual about the particular component being constructed.

### NOTE 2

It is not always necessary to do all of these inspections at the same time. For instance, for a bridge deck, all the procedures and mix designs etc should be reviewed and accepted early in the project, the falsework and formwork can be inspected at the next stage, the reinforcement later and the concreting process prior to concreting, etc.

### 8.5 BATCHING CONCRETE

#### 8.5.1 Measuring materials

(a) Cement, stone and sand should be measured by mass. Accuracy to be within 3%. A standard bag of cement should be assumed to contain 50 kg.
(b) Water should be measured either by mass or by volume. The quantity of water should be adjusted to make allowance for the moisture content in the aggregates.

#### 8.5.2 Mixing materials

(a) A mechanical mass-batch mixer of an approved type should be used.
(b) The operator should be experienced.

(c) The same procedure of charging the materials should be used throughout the construction.

(d) The mixing time should be 90 seconds unless otherwise approved. A suitable timing device should be used.

(e) When discharging, no segregation should occur. The mixer should be fully discharged before recharging the next batch.

8.5.3 Maintaining and cleaning the mixer

(a) If the mixer is stopped for more than 30 minutes, it should be thoroughly cleaned out. All hardened concrete should be removed.

(b) Worn or bent blades and paddles should be replaced.

8.5.4 Standby mixer [refer to the relevant clause in the Standard Specifications]

When sections are cast where it is important to continue without interruption, a standby mixer should be available to run on 15 minutes notice should the main mixer break down. This applies especially to large concrete foundations and bridge decks.

NOTE
Not all ready-mix suppliers are prepared to guarantee this compliance. The contractor therefore has to carry the risk of non-compliance. The Monitoring Staff need to discuss this with contractor and supplier during the mix-design approval process to ensure that the final product complies with the specifications.

8.5.5 Ready-mixed Concrete

This should comply with SABS 878.

8.6 PLACING AND COMPACTING OF CONCRETE

Before concrete is placed, the slump should be checked in terms of the specifications using the slump-cone test. For Ready-mixed concrete, the slump of each truck should be checked. This is important as each truck is batched separately and there has been known to be substantial variation in slump from one truck to another. With experience, it is possible to estimate the slump by eye. This is done by looking at the way the concrete slumps over the mixing blades in the mixer or Ready-mix truck. One can also see it in the way concrete “flows” in the formwork or around reinforcement. This check by eye is not a substitute for the slump test but is very useful to pick up problems early such as flash setting where the slump starts decreasing rapidly. Additional slump tests can then be called for to confirm the estimate by eye.

The methods used for transporting, placing and compacting of concrete should be such that segregation does not occur. The mix must remain homogeneous without the stone and paste separating.

Working at night time should be avoided. Where it cannot be avoided, adequate lighting needs to be supplied in advance. Workmen should not work double shifts.

Concreting should be under the direct supervision of an experienced concrete supervisor.

Concreting should be a continuous process between construction joints with no interruptions. Concrete should be placed within 50 minutes of mixing. Where retarders are used, this may be extended.
All absorbent surfaces such as concrete, timber, earth, etc, should be pre-wetted but should have no standing water.

8.6.1 Placing concrete:

The placing sequence, rate and layer thickness must be controlled to ensure that consolidation is effective and complete. Most surface defects are related to incorrect placement, and the inability of the poker to expel air and effectively consolidate. The poker vibrator cannot rectify what poor placement has done.

Where chutes are used to place concrete, they should not cause segregation. Baffles and spouts should be used to minimize segregation.

This also applies to tremie-pipes or “elephant trunks” where segregation can occur if the discharge at the bottom is not controlled. Photo 8.3 is an example of segregation caused by an “elephant trunk” that was incorrectly operated.

Moving concrete sideways with vibration should not be done without the engineer’s approval. This will cause segregation.

When casting thick components such as bridge decks or large bases, the concreting procedure should be such that fresh concrete should not be placed against concrete which has been in position for more than 30 minutes. Where retarders are used, the time can be extended.

Photo 8.3: Segregation of concrete

Placing underwater should only be allowed in exceptional circumstances. Refer to specialist literature.
8.6.2 Compacting concrete

(a) Concrete should be fully compacted by vibration. Where other methods of compaction are used, refer to specialist literature.

(b) Internal vibrators (pokers) should operate at more than 10 000 rpm while external vibrators attached to the formwork should operate at more than 3 000 rpm.

(c) External vibrators should ensure efficient compaction and should not cause surface blemishes.

(d) Vibrators should be operated by experienced workmen.

(e) There should be sufficient vibrators on site to allow for breakdown.

Good practice in operating a vibrator includes the following:

(f) The vibrator is lowered into fresh concrete until it just penetrates the previous placed and compacted concrete;

(g) It is slowly removed while the air bubbles come to the surface;

(h) Once all the air bubbles are out of the concrete, the sound emitted by the vibrator changes. The concrete is now compacted;

(i) The vibrator is pulled out slowly so as not to leave a hole behind;

(j) The vibrator is placed again into the concrete not more than 400 mm from the previous position for large vibrators (75 mm and larger). For small vibrators, this distance should be reduced. The necessary spacing can be determined by looking at the zone where the air comes to the surface and ensuring that there is overlap of these zones.

Where there are high areas of reinforcement congestion such as in prestressing anchorage zones or where multiple layers of reinforcement are used in a reinforced concrete beam, special attention should be given to compaction to ensure that no “honeycombing” occurs. Where necessary, a mix containing a smaller stone should be used.

Concrete is properly compacted when:

- It is worked around reinforcement, prestressing, embedded fittings, etc, with no voids;
- There is no honeycombing; and
- There are no planes of weakness between successive layers.

Concrete should not be disturbed for 4 to 24 hours after compaction. Any vibration or movement will weaken the bond that is forming between the concrete and reinforcement. Sources of vibration to be avoided include heavy machinery, generators, traffic, etc.

8.7 CONSTRUCTION JOINTS

All construction joint positions should be as marked on the drawings or as approved by the engineer. No other construction joints should be allowed.

All construction joints, especially horizontal joints, should be formed with straight edges, usually by fixing a strip of timber to the formwork.
Where concreting needs to be stopped due to unforeseen circumstances such as a change in the weather, a construction joint should be formed at the place of stoppage such that it will have the least impact on the structural design, durability, appearance and proper functioning of the concrete. The design engineer must first be consulted to check if this is acceptable.

Stub columns, stub walls, stays on footings and kickers should be cast integrally with the footings and not afterwards.

Kickers, typically 75 mm high, will generally be in the areas of highest stress and therefore need to be constructed properly as mentioned above. Their purpose is to:

- Prevent honeycombing by ensuring that the following column or wall does not leak cement paste at the bottom;
- Prevent the formwork from kicking by supplying a face against which the formwork can be tied or braced; and
- Assist in assuring that starter bars are in the correct position.

**8.7.1 Preparing construction joint surfaces:**

Where the concrete is still green, the concrete laitance should be removed to expose the stone without disturbing the stone using a water jet and light brushing.

Where the concrete has hardened, suitable hand held mechanical means should be used.

The method of preparation should not disturb the stone or cause internal and surface cracking and damage. The prepared surface should be sound and roughened. The surface should be washed with clean water to remove dirt and loose particles.

**8.7.2 Placing fresh concrete at construction joints:**

If the existing concrete at a construction joint is more than a day old, it will absorb water from the fresh concrete, forming a plane of weakness. The following good concreting techniques must be followed to avoid this:

- Keep the construction joint constantly wet for at least 6 hours before concreting restarts. If the concrete is more than a month old, this period should be increased to 24 hours. There must be no free surface water when concreting restarts.
- The construction joint should be washed to remove all dirt and loose particles. On no account must shutter release oil or other contaminates be applied to the construction joint.
- The first batch of fresh concrete cast against a horizontal construction joint should have 25% less stone than the normal mix to ensure a paste-rich high slump concrete. This should form a 25 mm thick layer of fluid concrete.

**NOTE**

Generally, the use of epoxy resins is NOT recommended for bonding new concrete to old concrete owing to the high incidence of failure of this system. Where it is used, it is essential that the manufacturer’s recommendations be strictly adhered to. If the epoxy is left too long before concreting, it will not serve its intended purpose and will form a weak layer. If concrete cannot be cast within the allowable time, the epoxy must be completely removed and reapplied.
Curing is the process of limiting early loss of water from concrete. The best form of curing is to keep a component immersed under water for at least 7 days. Losing too much water too early in the life of a concrete component causes high creep and shrinkage, and may even cause a significant loss of strength. Most importantly, poor curing is detrimental to the durability of the concrete, particularly the outer concrete which is required to provide protection to the embedded reinforcement.

In general, the longer the period of curing, the better will be the quality of the concrete. This applies not only to its compressive strength, but also to its durability, impermeability, its resistance to wear, weathering and chemical attack, and to its freedom from crazing and shrinkage cracking. Concrete therefore needs to be kept moist, both by the prevention of loss of moisture due to evaporation, and by the provision of extra water from outside the concrete. Concrete also needs to be maintained at a suitable temperature for the hydration process to continue.

There are two general forms of curing:

- Keeping all concrete surfaces wet to prevent moisture loss; and
- Creating a barrier to prevent moisture loss.

One or more of the following techniques should be used to prevent loss of moisture, subject to compliance with the requirements of the standard and project specifications:

(a) Retaining formwork in place;
(b) Ponding exposed surfaces with water. This must not be done when air temperatures are below 5°C;
(c) Covering with sand or moisture-retaining material and then keeping constantly wet;
(d) Constantly spraying with water;
(e) Using a curing compound applied according to the manufacturer’s instructions. Note that where a surface will subsequently be waterproofed, coated or gunited, curing compound should not be used as it will be highly detrimental to bond. Curing compounds are generally not as effective as other forms of curing;
(f) Steam-curing. This is usually only applied to precast units; and
(g) Wrap in plastic. This method is very effective for slender elements such as columns.

The curing period should be continuous for at least 7 days for normal concrete. Concretes which gain early strength slowly should be cured for at least 10 days. This includes cements containing blast-furnace slag.

When the air-temperature falls below 10°C, the concrete reaction slows appreciably. The curing period should be extended by the period that the temperature falls below this limit.

For sliding formwork and other specialist forms of concreting, refer to appropriate literature.

If permeable curing membranes are to be used as a curing method, they should be installed at the same time as formwork is removed and no portion of a concrete surface may be left unprotected for a period in excess of 2 hours. If the surface is an unformed finish e.g. top of deck slab, then the surface should be protected immediately by appropriate methods approved by the engineer after it is finished.

NOTE
Deck surfaces and other large exposed surfaces are especially prone to moisture loss and special care needs to be taken to ensure good curing. Wind can speed up the loss of moisture significantly. Often two systems are used, such as wetting and covering in plastic in addition to applying a curing compound.
without damage to that surface, since it is vulnerable to plastic shrinkage cracking due to high rates of evaporation while the concrete is still in a plastic state. Plastic shrinkage and settlement should not be permitted on any of the structural elements since it compromises the durability of the concrete. In order to prevent early settlement and shrinkage of the concrete, the concrete placed should be re-vibrated after initial compaction while the concrete is still in a plastic state. Any remedial measures shall be as approved in writing by the engineer.

On bridge decks, the top surface should be cured by constantly spraying the entire area of exposed surfaces with water.

All durability concrete prefixed ‘W’, should be cured in the same manner as the test panel.

Note that sometimes the concrete needs protection against moisture loss before the concrete has set. This applies especially to deck slabs during strong wind or high temperature when evaporation is particularly high. Protection can take the form of water sprays or covering the concrete before it has set.

8.9 ADVERSE WEATHER CONDITIONS

Refer to the standard and project specifications for manufacture and placement of concrete in adverse weather conditions. Additional information and guidelines are provided in 8.9.1 and 8.9.2 below.

8.9.1 Cold weather concreting:

When concrete falls below 10°C, the chemical reaction and rate of gain in strength slows considerably.

When fresh or green concrete freezes, the water within the mix expands and severely fractures the concrete. This concrete must be removed and replaced.

Special measures are therefore required for cold weather concreting and specialist literature should be consulted. However, the following guidelines can be given:

- Where the concrete temperature may fall below 10°C, heating or thermal protection is required;
- Concrete temperature when placed must be above 10°C and preferably above 15°C to ensure that the chemical reaction takes place. The chemical reaction will also generate additional heat;
- Water, stone or sand may be pre-heated to a maximum of 30°C to raise the mix temperature; and
- Heat loss from concrete can be reduced by insulating the member with timber formwork, polystyrene sheeting, or other suitable materials.

8.9.2 Hot weather concreting:

Where the air temperature is above 30°C, the temperature of the placed concrete should not exceed 30°C.

This can be achieved by using a combination of the following techniques:

- Shading the aggregates;
- Spraying the aggregates to cause evaporative cooling;
- Adding ice to the mix water.
Curing should receive special attention and should start as soon as possible during hot weather.

8.10  LOADING CONCRETE

No loading should be applied to concrete until it has attained sufficient strength. Any loading that needs to be applied before the 28 day concrete cube strengths have been approved, should first be approved by the engineer.

Refer to paragraph 8.13 below regarding additional cubes.

8.11  MONITORING CONCRETE STRENGTH AND DURABILITY

Refer to the relevant sections of the Standard Specifications

With regard to the 28 day cube strength, the concrete should satisfy the relevant requirements in the Standard Specifications for:

- Full acceptance; and
- Conditional acceptance.

The concrete should also comply with the relevant specifications regarding durability.

8.12  SPECIALIST FORMS OF CONCRETING

Where the form of concreting is highly specialized, refer to specialist literature.

These forms include:

- Concreting using sliding formwork;
- Concreting using climbing formwork;
- Low temperature concreting;
- High temperature concreting.

8.13  CONCRETE CUBES

The COLTO Standard Specification specifies that test cubes should be made in accordance with TMH1 method D1. It furthermore specifies the number of concrete samples that has to be taken and requires that samples be taken in a stratified random pattern as per TMH 5, Sampling for Road Construction Materials. According to TMH 1 a sample consists of 3 cubes and these have to be taken from the same batch of concrete, that is, from the same wheelbarrow or bucket.

The lot size for sampling should be determined by the engineer, but normally a lot will be equal to the volume of concrete of a given mix design cast in a day e.g. see COLTO Table 8206/2 for lot size. The method of random sampling as described below is recommended.

(a) Determine the volume of concrete of a given mix design to be cast on a specific day
(b) Use the volume to determine the number of batches that will be cast, e.g.:

- If a ready mix truck contains 6 m³; and
- Volume of concrete to be cast = 40 m³,
- Therefore 40/6 = 7 batches or trucks will be cast, so \( x = 7 \).

(c) The Standard Specifications require 6 samples of 3 cubes each for a lot size of 40 m³, therefore \( n = 6 \).

(d) Start at the top of the list of random numbers in TMH 5 and multiply the first \( n \) numbers by \( x \).

(e) Round the answer up to the nearest whole number.

(f) Note down these \( n \) numbers for these are the trucks to be sampled.

(g) If a number occurs more than once, a truck could be sampled twice, or the next random number in the list could be multiplied by \( x \) and this number used as the next truck to be sampled.

(h) Continue with the list of random numbers the following casting day.

Where an early indication of concrete strength is required (such as early loading or prestressing), additional cubes should be made. Cubes tested at 7 days would typically be 70% of the 28 day strength, depending on the type of cement and temperature.

Cubes should be made, cured, stored and transported in accordance with the latest version of TMH1. Cubes should be made by a trained workman. The cubes should be made in a sheltered location to prevent rain or wind or site operations from causing damage. The cubes should be stored in a temperature-controlled bath.

Since a cube crushing machine is not always available on site it is sometimes necessary to transport cubes to a nearby laboratory. Cubes should not be transported before the age of three days, but if this cannot be prevented, the cubes need to be placed securely in sandbags to prevent them from knocking against each other or being damaged during transportation. Cubes older than three days should be placed on and covered with wet hessian bags before being transported.

Each cube should be marked with the date, cube number and concrete element, in permanent ink, before being placed in the curing bath. It is recommended that the cubes be numbered consecutively from the start to the end of the contract to prevent confusion. All the relevant information regarding the cubes e.g. the number, date of casting, concrete element, approximate position in the element, slump, truck number, site arrival and departure time, date of testing, mass, compressive strength and any irregularities that occurred, should be recorded in a cube book kept on site. This information is useful when cube failures occur to assess the extent of the damage.

Cube results should be analyzed in accordance with the relevant section of the Standard Specification.
INDEX TO APPENDICES

APPENDIX 8A: MIX DESIGN CHECK LIST

APPENDIX 8B: PRE-CONCRETING CHECK LIST

APPENDIX 8C: CONCRETING CHECK LIST
## CONSTRUCTION MONITORING CHECKLIST

**PROJECT NO. / NAME:**  

**INSPECTOR’S NAME(S):**  

**STRUCTURE:**  

**ELEMENT:**  

<table>
<thead>
<tr>
<th>ACTIVITY AND DETAILS</th>
<th>APPROVAL</th>
<th>SIGNED</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mix design and materials received</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Cement complies</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Stone, including durability, complies</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Sand complies</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 No Alkali-aggregate reaction</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Water complies</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Additives comply</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Mix proportions comply</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 For “W” concrete, trial panel test results comply</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Cube strength and slump measurements comply</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Bleeding complies</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Independent laboratory confirms concrete mix design</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## CONSTRUCTION MONITORING CHECKLIST

**PROJECT NO./NAME:** ..........................................................................................................................

**INSPECTOR’S NAME(S):** ..........................................................................................................................

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<th>APPROVAL</th>
<th>SIGNED</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dimensions, positions, levels and precamber comply</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Falsework and formwork comply</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Reinforcement and concrete cover complies</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Additional components correctly installed (Drip grooves, drainage pipes, kickers, bolt groups, etc)</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Concrete mix design approved</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Method of curing approved</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Position and details of construction joints approved</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Kicker formwork in place</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Construction joints have been correctly prepared</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sketch
## CONSTRUCTION MONITORING CHECKLIST

### 1. Pre-concreting check list approved

### 2. Enough concrete cement, sand, stone, additives etc available

### 3. Concrete batching plant/Ready mix trucks fully operational and capable of delivering required concrete quantity

### 4. Enough concrete cube moulds and slump cones available

### 5. Enough time to complete the pour or suitable lighting for night-work

### 6. “W” concrete site requirements comply

### 7. Enough staff and equipment to place and compact the concrete

### 8. Chutes, conveyor belts, wheelbarrows, etc required to place concrete fully operational

### 9. Materials for curing ready for application

### 10. Construction joints have been correctly prepared and pre-wetted as required

### 11. If adverse weather conditions is expected, are the necessary measures in place

---

### Activity and Details | Approval | Signed | Date

| 1 | Pre-concreting check list approved | | |
| 2 | Enough concrete cement, sand, stone, additives etc available | | |
| 3 | Concrete batching plant/Ready mix trucks fully operational and capable of delivering required concrete quantity | | |
| 4 | Enough concrete cube moulds and slump cones available | | |
| 5 | Enough time to complete the pour or suitable lighting for night-work | | |
| 6 | “W” concrete site requirements comply | | |
| 7 | Enough staff and equipment to place and compact the concrete | | |
| 8 | Chutes, conveyor belts, wheelbarrows, etc required to place concrete fully operational | | |
| 9 | Materials for curing ready for application | | |
| 10 | Construction joints have been correctly prepared and pre-wetted as required | | |
| 11 | If adverse weather conditions is expected, are the necessary measures in place | | |