



Ministry of
Forests

Cast-in-Place Standards

For Cementitious Mixtures



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1.0 Introduction

1.1 Overview

This document provides cementitious mixture cast-in-place (CIP) standards applicable to Forest Service Road (FSR) bridge construction or repair sites. It addresses issues such as design, materials, construction, quality control and quality assurance; and applies to CIP cementitious mixtures such as concrete, grout or mortar. The standards also apply to CIP work for FSR Major Culverts.

This standards document is an appendix to the Ministry of Forests Bridge Standards Manual (BSM).

“Bridge Standards Manual” (BSM) including its appendices:

<https://www2.gov.bc.ca/gov/content?id=B1581B390E7E44B384A67D123EF6145D>.

General Ministry standards for concrete structures and CIP cementitious mixtures are provided in the BSM in Section 8: “Concrete Structures” and in some Standard Bridge Drawings in BSM Section 20: “Standard Drawings”. Additional, and more detailed, CIP standards are provided in this document.

The standards provided in the BSM (including its appendices) are mandatory for FSR bridges. Explanatory non-mandatory information is provided in locations identified as Commentary. The terms “shall” and “must” indicate mandatory requirements; “should” indicates a recommendation; and “may” indicates a permissible option.

Ministry standard CIP cementitious mixes and products for various typical FSR bridge uses are described in Section 4 of this document. Alternatives to standard mixes and products may be proposed to a Ministry Engineer for acceptance consideration.

Some details within this document have been primarily written assuming casting on a horizontal surface (the majority of FSR bridge CIP situations). Users of this document should be aware that some details will not apply for all CIP mixtures that may be used on FSR bridges, for example mixtures using the standard products specified for vertical or overhead surfaces (Section 4- Table 5) and other mixtures not specifically named in this document that may have highly unique characteristics or requirements.

For a specific project, if clarification of any aspect of Ministry standards is required or if deviations from standards are proposed, contact the Ministry Engineer associated with the project.

Commentary

Cast-in-place cementitious mixtures are often critical to the safe performance and structural integrity of Forest Service Road (FSR) bridges. Ministry standards are intended to ensure durable and high-quality CIP results.

Understanding that the underlying principles and best practices related to design, casting, sampling and testing apply equally to both new bridge construction and bridge repairs, this document has combined now obsolete Ministry bridge standards previously presented in the “Structural Field

Grouting, Sampling and Testing Standard” and the “Concrete Repair Guide for Concrete Bridge Components”. Additionally this document addresses entire components composed of CIP concrete such as footings or walls.

Previous Ministry standards (and some current Ministry drawings and references) on this topic used/use the term “grout” to refer to CIP mixtures that are considered by other organizations (e.g. CSA, ASTM) to be mortar or concrete. This document attempts to align its terminology with the terminology used in applicable CSA standards to provide improved clarity relating to the application of CSA standards to FSR bridge CIP work.



Figure 1: Bridge crew starting to place CIP mixtures for the superstructure of a new two lane steel girder composite concrete deck bridge a) in transverse deck panel joints, and b) in shear-stud blockouts for deck to girder connections.

Wires are visible above the deck in the photo. These wires are holding formwork tight against deck panel soffits at transverse deck joints.

1.2 Definitions

If the Ministry has specific/unique meanings for terms used in this document, they are either described within the document or provided in the Definitions section of the BSM. Otherwise, common definitions or explanation of terms may be provided by CSA, ASTM, or others. Ministry provided definitions govern over others.

Cast-in-Place Cementitious Mixture: A Cementitious Mixture (concrete, grout or mortar) that is placed in an unhardened condition in its final location at a bridge site. In this document the term Cast-in-Place or the acronym CIP have the same meaning as Cast-in-Place Cementitious Mixture.

Cementitious Material: Hydraulic cement with or without supplementary cementitious materials.

Cementitious Mixture: A mixture consisting of cementitious materials and liquid (typically water), often with aggregates, resulting in grout, mortar or concrete.

CIP Supervisor: The Contractor's qualified on-site representative directly responsible for Quality Control (QC) of all cast-in-place operations, including surface preparation, formwork, mixing, placement, consolidation, sampling, testing, curing and reporting.

Contractor: In this document, the term Contractor, when used without additional description or clarification, refers to the party directly responsible for physical construction at the bridge site (i.e. bridge installation or repair.)

Engineer: In this document, the term Engineer, when used without additional description or clarification, refers to a General Arrangement Engineer, Structural Design Engineer, Construction Assurance Engineer, Ministry Engineer or other Engineer having the appropriate involvement, responsibility and authority in relation to a specific aspect of a project at a specific stage in a project. The BSM provides definitions for Engineer and for these specific types of Engineers and provides additional explanation in BSM Section 2.

Grout:

(1): (sim. to CSA & other industry standards, and as used in this document) A cementitious material or mixture, without coarse aggregate, that is typically intended for use in a flowable or flowing consistency.

(2): (informal or historical usage of the term in FSR bridge industry, including some older Ministry standard drawings and documents) A cementitious material or mixture with no coarse aggregate or with nominal coarse aggregate diameter ≤ 14 mm, that is typically used during installation of new FSR structures in locations requiring small volumes such as keyways, joints, pockets, beds, and ducts; or for small repairs of concrete components. This definition differs from definitions of grout published by others in that it includes materials/mixtures that contain coarse aggregate and/or are intended for use in a stiffer consistency than flowable or fluid. Many of these materials/mixtures would be considered mortar or concrete by others.

Saturated Surface Dry (SSD): The required moistened condition (having an appearance of being wet but not glistening) of surfaces (e.g. forms and concrete components) that interface with freshly cast CIP mixtures. For SSD concrete, the interior pores shall be filled with water to a depth of several mm.

1.3 Roles & Responsibilities Summary

A summary of roles and responsibilities for FSR bridge CIP activities is provided in Table 1. If this summary contradicts other (typically more detailed) information in the BSM (including other parts of this BSM appendix) this summary shall not govern.

Table 1: Roles and Responsibilities Summary for FSR bridge CIP activities

Role	Responsible Party	Responsibilities
Design	Structural Design Engineer (SDE)	<ul style="list-style-type: none"> Provides specifications, prescriptions and/or designs for CIP work. (Note: A Ministry Engineer specifying structural CIP repairs after reviewing a bridge inspection report is considered the SDE for the repairs unless they specify that another Engineer is required to develop detailed repair specifications.)
Acceptance	Ministry Engineer	<ul style="list-style-type: none"> Acts as “Owner’s Engineer” for a project, making decisions on behalf of the “Owner” (the Ministry); and Accepts designs, specifications, prescriptions and final construction reports including any changes.
Quality Control (QC)	Contractor/ CIP Supervisor	<ul style="list-style-type: none"> Undertakes all CIP operations; and Undertakes QC for all aspects of the operations, including: <ul style="list-style-type: none"> Completion and distribution of a CIP Workplan; Completion and distribution of CIP Field Records; Supply of test moulds to site (if required); CIP sampling and testing (if required); and Distribution of forms, test results and other documents (as required.)
Environmental and Safety Management	Contractor	<ul style="list-style-type: none"> Adheres to requirements of site specific Environmental Management Plan (EMP) as required, and follows construction best practices to avoid negative environmental impacts; and Ensures safe work practices.
Quality Assurance (QA)	Construction Assurance Engineer (CAE)	<ul style="list-style-type: none"> Directs QA field reviews during construction; Reviews, accepts and distributes Contractor’s QC or other documentation as applicable; and Prepares and distributes Quality Assurance documentation. (Note: Non-structural surficial CIP repairs typically don’t require field reviews directed by a CAE.)

2.0 General

2.1 CSA Standards & Manufacturer's Specifications

CSA concrete and cementitious material related standards are applicable, unless otherwise specified by the Ministry.

CIP cementitious mixtures must be designed, mixed, transported, cast, cured, sampled, tested and otherwise supplied in accordance with:

- CSA S6 "The Canadian Highway Bridge Design Code" (CHBDC);
- CSA Standard A23.1/A23.2 "Concrete Materials and Methods of Concrete Construction /Test Methods and Standard Practices for Concrete";
- CSA A283 "Certification of Laboratories for Concrete;" and
- the product manufacturer's specifications.

2.2 Quality Control (QC)

2.2.1 Contractor QC- General

Quality Control (QC) includes all aspects of CIP operations, including the supply, sampling and testing of materials; the methods for producing and handling the materials; the batching, mixing, handling, transporting, placing, consolidating, finishing, curing of the mixture; and all necessary QC and verification testing of the unhardened and hardened mixture. The Contractor is responsible for QC.

2.2.2 Contractor's CIP Supervisor

The Contractor shall provide a qualified on-site representative identified as their CIP Supervisor. The CIP Supervisor shall have experience and qualifications relating to work with cementitious mixtures sufficient to successfully undertake the FSR bridge CIP work specific to the project.

All CIP mixing, placement and sampling shall be documented by the CIP Supervisor using the Ministry's CIP Field Record or an acceptable alternative QC record (refer to Section 9).

The CIP Supervisor shall regularly keep the Construction Assurance Engineer (CAE) informed of the status of CIP activities as they are being undertaken; including curing, form removal and total satisfactory completion of all CIP work.

The CIP Supervisor shall provide QC information to the CAE that confirms standards and specifications have been met.

2.2.3 Contractor's CIP Workplan

Five calendar days prior to the commencement of CIP activities, the Contractor shall provide the Construction Assurance Engineer (CAE) a CIP workplan that includes:

- The name and qualifications of the CIP Supervisor;
- The products/mixes and stiffnesses to be used;
- The locations on the bridge where each product/mix is to be used;
- The schedule/dates for specific CIP activities;
- The anticipated weather conditions;
- Sampling and testing to be undertaken (including names and qualifications of primary individuals and labs involved);
- Curing and protection procedures and timeframes; and
- Cold or hot weather procedures.

The CAE shall review the workplan and advise the Contractor of any concerns with it. If the CAE and Contractor are unable to reach agreement on an acceptable workplan, the Ministry Engineer shall be advised and shall assist in resolution.

2.2.4 QC Responsibility of Others

Notable exceptions to the Contractor being responsible for all CIP QC are when:

- the Ministry provides CIP materials (typically bags of dry mix) to the Contractor; or
- CIP materials are provided to the Contractor by a bridge material supply contractor who is under separate contract to the Ministry or someone else other than the Contractor.

In these notable exceptions, the Contractor shall be responsible to check the materials supplied by others prior to starting CIP operations and as operations proceed, however QC for the provision and, in some cases, proper storage of useable materials will have been the responsibility of the party/parties that supplied the materials.

All parties involved shall consider the complications and risks of purchasing/supplying CIP materials for a project far in advance of construction which may result in materials being unfit for use due to age and/or poor storage conditions.

2.3 Quality Assurance

The Construction Assurance Engineer (CAE) is responsible for Quality Assurance (QA) of CIP work and shall confirm QC information received from the Contractor meets project specifications and Ministry standards and is provided to the Ministry Engineer for documentation in Ministry files.

The CAE shall direct field reviews of the CIP work to confirm that CIP activities have been conducted by the Contractor appropriately and result in an acceptable final product.

2.4 Environmental Protection

The Contractor is responsible for ensuring that construction best practices to avoid negative environmental impacts are implemented.

Construction procedures shall incorporate suitable collection systems that will capture and minimize debris escape and any potential damage or contamination of the surrounding environment during construction. Systems may include laying or hanging geotextile, placing a debris collection box below the area and/or creating barriers to contain debris around the work site.

If an Environmental Management Plan (EMP) exists for a specific FSR project, all EMP mitigation measures required to meet stated regulatory requirements shall be followed.

2.5 Safety

Safe work practices shall be the responsibility of the Contractor.

2.6 Traffic Control

Traffic control shall be considered for all FSR bridge CIP work and, unless otherwise specified by the Ministry, shall be the responsibility of the Contractor.

For rehabilitation/repair projects, the following (and other) traffic control requirements shall be considered and implemented when appropriate:

- Ensure appropriate measures, given the level of traffic, are taken to provide adequate warning and control for approaching vehicles to ensure safety of the vehicles and personnel working on the project.
- If the Engineer determines that rehabilitation/repair activities allow for traffic to continue travelling over the deck, the Engineer may request the Contractor to delineate new CIP mixtures with cones or other approved barriers and may request that specific areas be protected from damage (e.g. with plywood sheeting) to possibly allow for light traffic to continue travelling over the bridge.
- The Engineer may request that all traffic flow ceases for a certain period and until the CIP mixture reaches a certain compressive strength. If necessary, an alternative route should be considered along with detour arrangements and signage.

A bridge shall only be opened or re-opened to traffic with the approval of the Construction Assurance Engineer and any other applicable authorities.

3.0 Design

3.1 CIP Product/Mix & Usage

The Structural Design Engineer (SDE) shall specify products and/or mixes that are to be used, the locations on the structure where they are to be used, and how they are to be used (including the intended consistency of the mixture (e.g. plastic, flowable, fluid) and formwork requirements (if applicable)).

Details are provided throughout this document that shall be considered by the SDE and specified in their drawings, specifications and prescriptions.

The SDE shall specify CIP work to be in accordance with the MOF Bridge Standards Manual (including this appendix) except for specific aspects of a project which may require deviations such as use of alternative products, application of products in a manner that deviates from MOF Standards and/or manufacturer's specifications, etc. When deviations are considered necessary, the SDE shall propose the deviations to the Ministry Engineer for approval consideration.

Commentary

For many projects, the Structural Design Engineer (SDE) may not exclusively specialize in Structural Engineering. For example, a typical General Arrangement Engineer (GA Engineer) may be the SDE for abutments and/or for superstructures when a superstructure is being moved from one site to another.

3.2 Thickness of CIP Beds

Horizontal beds of CIP mixtures are sometimes used in FSR bridge abutments underneath:

- Caps and/or sills; and
- Steel abutment column base plates.

For these situations the Structural Design Drawings shall specify (in addition to other information) the intended CIP bed thickness (or an acceptable range of thicknesses) for each location.

3.3 Required Strengths

The Structural Design Drawings or repair prescription shall specify minimum compressive strengths to be achieved at anticipated critical ages of the cementitious mixture, up to 28 days, relating to anticipated critical construction stages, considering typical FSR bridge installation/repair project requirements (i.e. rapid bridge installation/repair and opening to traffic) unless a specific project does not have typical installation requirements, in which case alternative strengths at various ages shall be proposed to the Ministry Engineer for acceptance consideration.

3.4 Determination of Sampling & Testing Specifications

One of the engineers involved with the design and/or implementation of the design shall determine and communicate appropriate minimum Quality Control CIP Sampling and Testing Specifications for the CIP mixtures specified for the project (refer to Section 10 for details). This information, which may affect potential Contractor's bid pricing, shall be provided in the bridge installation/repair contract documents.

3.5 Special Considerations for Repairs

Repairs using CIP cementitious mixtures shall be undertaken in accordance with a prescription (i.e. site-specific written instructions to repair clearly identified locations) from the Structural Design Engineer (SDE) taking responsibility for design of the repair. The more extensive and critical the repair, the more detailed the engineered prescription shall be. The repair prescription shall address delaminated, deteriorated, contaminated and unsound concrete; and shall describe repair materials, procedures and requirements.

Prior to creating a repair prescription, the SDE (or a qualified bridge inspector) shall carry out a detailed visual inspection of the components which may require repair. Evidence of damaged previous patch repairs, unusual cracking patterns, spalling, delamination, excessive corrosion or other indications of concrete deterioration shall be investigated, noted, measured and photographed. The visual inspection may be enhanced by employing simple non-destructive sounding techniques such as chain-dragging or the use of a rotary percussion device to help identify areas of delaminated concrete.

4.0 Standard CIP Mixes, Products & Uses

4.1 Standard CIP Mix Requirements for Large Volumes

For large CIP volumes (e.g. complete CIP concrete footings or walls) the Ministry does not have standard products (e.g. standard bagged materials) however it does have standard minimum concrete mix design requirements (see Table 2). For large CIP volumes in a specific bridge project, the SDE shall determine the appropriate CIP materials and mixes, considering options such as pre-bagged products mixed on site or ready-mix concrete delivered to site.

Table 2: Standard CIP Concrete Mix Design Requirements for Large Volumes

Bridge Component Type	Typical Component Examples	Exposure Class (As per CSA A23.1 Table 1)	Minimum Compressive Strength @ 28 days (MPa)	Maximum Water to Cementing Materials Ratio (by mass)	Air Content (%)	Maximum Nominal Size of Course Aggregate (mm)
Cast-in-Place Components	Footings, Walls, Abutments, Pipe pile in-fill	F1	30	0.50	4-7	28

The Contractor shall provide the proposed detailed concrete mix design to the Ministry Engineer and the Construction Assurance Engineer for review and acceptance, and to the testing lab for information.

Alternative concrete mix design specifications may be required for bridges that are expected to have substantial chloride exposure. For these bridges, alternative concrete specifications shall be developed on a case-by-case basis by the Ministry Engineer and provided in the contract documents specific to each bridge.

Commentary

The term "Large Volume" in this document refers to entire components composed of CIP concrete (e.g. footings, walls or abutments) or the filling of steel pipe piles with CIP concrete. This is considered "large" only because it is being differentiated from very small volumes frequently used on FSR bridges to fill voids, ducts, shear keys and blockouts or to provide thin beds/levelling courses.

Steel and concrete FSR bridges typically utilize accelerated bridge construction techniques which primarily rely on prefabricated steel and precast concrete components. Very large CIP concrete components are rarely constructed, however use of CIP concrete for construction of complete CIP footings, walls and abutments or filling of steel pipe piles is occasionally undertaken. CIP concrete is also occasionally used for construction of complete footings or headwalls for FSR Major Culverts.

4.2 Standard CIP Products for Small Volumes

4.2.1 General

For small CIP volumes in a specific bridge project, the Structural Design Engineer shall determine the appropriate CIP mixtures, considering use of the standard pre-bagged products described in this section, and shall specify the appropriate mixtures & products for the specific structure on the Structural Design Drawings.

For the uses described in this section (section 4) the standard products described in the section shall be used, unless other products are accepted by a Ministry Engineer for a specific project.

An Engineer and/or Contractor may investigate alternative or equivalent products (e.g. due to product availability, economics, superior product capabilities, unusual project conditions or requirements, etc.) and propose them to the Ministry Engineer for acceptance consideration.

Any proposed equivalent product must be equivalent or superior, in comparison to the standard product it is intended to replace.

Commentary

The standard products specified in this document have been selected by the Ministry for various reasons such as: recommendations from experienced engineers, satisfactory history of use, or specific performance characteristics (such as fiber reinforcement, high early strength gain, high 28-day compressive strength, low shrinkage, etc. related to a specific use.)

In recent decades two different products, Target Traffic Patch (Coarse) and Target Traffic Patch (Fine), have been specified by the Ministry as standard products to be used for many small volume CIP mixtures placed on horizontal surfaces, unless alternative equivalent products were accepted by a Ministry Engineer.

These two products have generally provided satisfactory results when used appropriately, however have failed multiple times when used inappropriately (e.g. excess water added, hot weather procedures not used when required, SSD surface preparation not undertaken, poor placement/consolidation, etc.)

Other products have been relatively infrequently used on FSR bridges.

The Ministry has recently added SikaGrout-212 as an additional standard product for small volume non-shrink CIP mixtures placed on some horizontal surfaces in confined conditions. This product has not frequently been used on FSR bridges but has been frequently and successfully used in other construction projects in British Columbia and has been recommended by numerous experienced FSR bridge engineers.

The products specified as standard for vertical and overhead surfaces have not been frequently used on FSR bridges. They were specified as standard products by the Ministry in previous standards documents and have been carried forward into this document.

4.2.2 Standard Products & Uses- Horizontal Surfaces

This section (section 4.2.2) provides information about standard products for placement on horizontal surfaces (i.e. not vertical or overhead). Table 3 provides information about each product. Table 4 describes standard uses of these products for standard FSR bridge construction.

Table 3: Standard CIP products for small volumes on horizontal surfaces

Product	Misc. Characteristics*. **	Thickness (typ., mm)	Stiffness ***
Target Traffic Patch (Fine)	<ul style="list-style-type: none"> • Example Compressive Strength: <ul style="list-style-type: none"> ○ 21 MPa @ 3 hours; ○ 35 MPa @ 1 day; ○ 52 MPa @ 28 days • Very rapid hardening • Low shrinkage • High abrasion resistance • Polypropylene fibers • Aggregate Size: 100% < 0.5 mm 	12 < t < 25	Plastic (flowable and fluid not allowed)
Target Traffic Patch (Coarse)	<ul style="list-style-type: none"> • Example Compressive Strength: same as Target Traffic Patch (Fine) • Very rapid hardening • Low shrinkage • High abrasion resistance • 30 mm steel fibers • Aggregate Size: 100% < 14 mm dia. 	t > 25	Plastic (flowable and fluid not allowed)
SikaGrout- 212	<ul style="list-style-type: none"> • Example Compressive Strength: <ul style="list-style-type: none"> ○ Fluid: 26 MPa @ 1 day; 56 MPa @ 28 days ○ Flowable: higher than Fluid ○ Plastic: higher than Flowable • Non-shrink • Low heat development • No fibers • Aggregate Size: 100% < 2.5 mm dia. 	25 < t <= 150	Variable stiffnesses: plastic, flowable or fluid

* Example Compressive Strengths provided by manufacturer Product Data Sheets, at ~20-23 degrees C lab conditions. Actual strength (and other characteristics) at a specific bridge site is dependent on site specific procedures and conditions.

** Bonding agents are not compatible with the specified Target Traffic Patch products and shall not be used with them. They are also not required for SikaGrout 212.

*** Formwork to be watertight if CIP mixture is flowable or fluid.

Table 4: Standard small volume uses of standard CIP products on horizontal surfaces

Standard Uses on FSR Bridges*	Standard Products		
	TTP(Fine)	TTP(Coarse)	SG-212
Composite Steel Girder Concrete Deck Superstructures			
Transverse deck joints (if vertical face option)	Yes**	Yes**	No
Transverse deck joints (if angular or reinforced shear key option)	No	Yes	No
Stud pocket blockouts in deck	No	Yes	No
Non-Comp. Steel Girder Concrete Deck Superstructures			
Blockouts (for single bolt deck connection to the steel girder)	Yes	Yes	No
Concrete Slab Girder Superstructures			
Longitudinal shear keys between girders	No	Yes	No
Blockouts in girders for dowel connections to concrete abutments	No	Yes	No
Concrete Caps, Sills & Inv. T-abutments			
blockouts for dowels & threaded anchor rods.	No	Yes	Yes
Interlocking Concrete Blocks			
Drilled holes for dowels	Yes	No	Yes
Steel Column Base Plate on Concrete Footing			
Bed below baseplate	Yes**	Yes**	Yes
All Components			
Blockouts for lifting anchors	Yes	No	No
Other locations where CIP mixture is used in a plastic consistency to fill voids or create CIP beds when $12 \text{ mm} < t < 25 \text{ mm}$.	Yes	No	No
Other locations where CIP mixture is used in a plastic consistency to fill voids or create CIP beds, when $t > 25 \text{ mm}$.	No	Yes	No
Other locations provided all of the following apply: <ul style="list-style-type: none"> ○ Mixture confined (except for small opening for placement and holes for venting); ○ Mixture not used as a patching or overlay mixture; ○ Mixture does not become part of bridge running surface; and ○ $25 \leq t \leq 150$ 	No	No	Yes

* Based on Standard Bridge Drawings and typical projects. Refer to specific project drawings and specifications for actual products to be used for specific projects.

** TTP(Coarse) (> 25 mm thickness) or TTP(Fine) (< 25 mm thickness) in these situations to be appropriate for the the actual thickness of the joint or bed.

4.2.3 Standard Products & Uses- Vertical & Overhead Surfaces

Table 5 (below) provides information about standard products for placement on vertical and overhead surfaces.

Table 5: Standard CIP products for small volumes on vertical and overhead surfaces

Product	Misc. Characteristics*	Thickness (typ., mm)	Stiffness	Standard Uses**
Target V/O Structural Repair Mortar	<ul style="list-style-type: none"> • 16.5 MPa @ 1 day; 34.5 MPa @ 28 days • Polymer-modified • Low shrinkage • No Fibers 	3 < t < 114 (per lift)	Non-sag	<ul style="list-style-type: none"> • Vertical and overhead repairs
SikaTop 123 Plus	<ul style="list-style-type: none"> • 20 MPa @ 1 day; 50 MPa @ 28 days • Polymer-modified • 2-component (no mixing water) • silica fume • No Fibers 	3 < t < 38 (per lift)	Non-sag	<ul style="list-style-type: none"> • Vertical and overhead repairs

* Example Compressive Strengths (1 day and 28 day) provided by manufacturer Product Data Sheets, at ~20-23 degrees C lab conditions. Actual strength at a bridge site is dependent on site specific procedures and conditions.

** Refer to specific project drawings and specifications for actual products to be used for specific projects.

5.0 Surface Preparation

5.1 General Site & Surface Preparation

A preliminary site cleanup shall be undertaken to remove any dirt, dust, organic debris or ponded water from on top or around the areas where CIP work will be done.

The use of any tools or pressure washing techniques shall discontinue if they are causing damage to the host concrete, reinforcing steel, any other part of the structure or to the surrounding environment.

If pressure washing is used, the waste material (including contaminated water) shall always travel away from the CIP area and be captured by a collection system for keeping waste material away from the equipment, preventing the waste material from re-hydrating on the previously cleaned surface, and for disposal in accordance with applicable environmental regulations.

If compressed air blasting is employed, proper line filters and dryers, which remove all oil and water from the air, shall be used. Compressed air shall be periodically tested for presence of these contaminants. A suitable protection system must be employed to contain debris moved by compressed air.

Sandblasting shall never be used.

5.2 Surface Preparation of CIP Interface

Any areas of damage, spalling, delamination, deterioration and/or otherwise unsound concrete shall be removed to expose fresh sound concrete.

The removal of damaged or otherwise unacceptable concrete shall be completed by mechanical and hydraulic methods only.

Any pooled water, dust, oil and debris shall be removed.

Remove any loose sandy material, surface laitance and dusty residue (using a pressure washer if environmentally feasible). If a pressure washer is not available or is not environmentally feasible, use water and brushes followed by compressed air.

For repairs, the final cleaned surface of the concrete shall have a concrete surface profile (CSP) of 6 to 10 (a minimum of 6 mm amplitude) to ensure adequate bonding at the aggregate-cement interface (ICRI 310.2R-2013¹).

New precast components intended to have CIP mixtures placed against them shall have their interface surfaces roughened, typically at the precast plant, as detailed on the applicable Ministry Standard Drawing and as detailed in Chapter 8: "Concrete Structures" of the BSM. If the required roughening has not been done at the precast plant, it shall be done by the Contractor at the bridge site.

¹ 310.2R-2013: *Technical Guidelines for Selecting and Specifying Concrete Surface Preparation*, International Concrete Repair Institute.

The final required phase of surface preparation is to moisten surfaces to a saturated surface dry (SSD) condition (refer to Section 8).

Commentary

Preparation, as described in this section, of the surfaces that will have CIP mixtures placed against them, creates a clean, competent surface for the CIP mixture to adhere to and is essential for CIP success².

5.3 Additional Surface Preparation Details for Repairs

This section provides additional step by step details relating to surface preparation for concrete repairs.

Step 1: Saw Cut Repair Area Boundary

- Mark out the repair boundaries and, for horizontal or vertical repairs, saw cut at 90 degrees to the concrete surface, along the edge to create smooth straight edges.
- Saw cuts shall be measured from the original surface and shall be a minimum of 12 mm deep for shallow repairs up to a maximum of 24 mm for deeper repairs.
- Damage to existing reinforcing steel or rebar that may be within the repair boundary is not permitted. Non-destructive scanning methods to determine rebar locations may be required prior to concrete removal.

Commentary

Attempting to execute an undercut saw cut edge that is shallow may result in a feathered repair edge, due to unintended chipping, which will negatively impact proper adhesion of the CIP repair mixture to the base material.

² Von Fay, Kurt F. (2015): *Guide to Concrete Repair, 2nd Edition*, U.S. Department of the Interior Bureau of Reclamation Technical Services Center.



Figure 2: Site preparation for a repair is in progress. Repairs have been initiated by saw cutting a perimeter area around the repair area. This example depicts a “deck beside ballast wall” configuration of precast bridge components which is no longer used for new FSR bridges.

Step 2: Chip Away Concrete Within Repair Area

- Remove weak, loose or otherwise damaged concrete within the saw cut repair boundaries using a chipping hammer (7 kg or smaller).
- If rebar parallel to the prepared repair face is exposed, the bars must be thoroughly cleaned and fully exposed to allow for adequate surface bonding and encapsulation with the CIP repair mixture. Allow a minimum of 20 mm around the full diameter of the newly exposed rebar to allow adequate space for placing the specified CIP repair mixture.

Step 3: Final Surface Preparation of CIP Interface

- Undertake final surface preparation as described in Section 5.2 above.

Commentary



Figure 3: Mechanical removal of damaged concrete near a guardrail post at the edge of a bridge with a chipping hammer.



Figure 4: An example depicting a typical surface roughness profile of CSP 10. Coarse aggregate surfaces are well exposed and free of loose concrete, sand, dust and debris.



Figure 5: Properly saw cut repair area free of weak, loose or damaged concrete. Surfaces are clean and ready for formwork. The full diameter of the rebar has been exposed, and all areas have been cleaned to remove all traces of loose concrete, dirt, debris and rust.

6.0 Reinforcement & Other Steel

6.1 New Steel Materials

Ministry standards for reinforcing steel are provided in BSM Section 8: “Concrete Structures”. Ministry standards for other steel embedded in concrete are provided in BSM Section 10: “Steel Structures”.

6.2 Concrete Cover

Concrete cover for reinforcement in new CIP components or for repair of CIP components shall be as per CHBDC.

Concrete cover for precast concrete repairs shall be as per Ministry precast concrete cover requirements in BSM Section 8: “Concrete Structures”.

6.3 General Steel Repair Requirements

Steel reinforcing bars and other steel components in a repair area shall be assessed for rust (corrosion), section loss, deformation, fracture and other damage.

Steel damage (including section loss due to rust) shall be considered by the Engineer to determine an appropriate repair prescription.

Rebar is not to be bent or manipulated, spliced or replaced without the direction of an Engineer.

6.4 Rust Removal

Other than slight surficial corrosion, rust shall be removed prior to repairs.

Rust removal shall be undertaken using a drill mounted hand-held steel wire brush wheel. Knotted or partial-knotted wire brushes shall be used for heavy rust removal. A crimped-wire brush may be used for moderate to minor rust removal.

Commentary

Rust on steel reinforcing bars and other steel components in a repair area can negatively impact the longevity of CIP repairs. Removal minimizes the risk of future corrosion and increases bond strength with the CIP mixture.

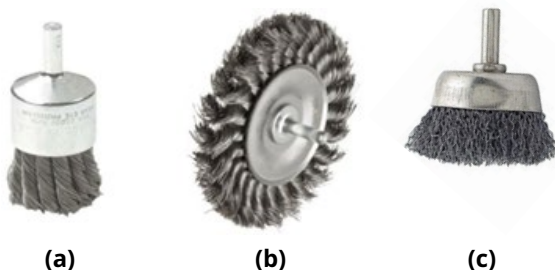


Figure 6: Examples (a) Knotted, (b) Partial-knotted and (c) Crimped wire brushes suitable for use in removing rust from rebar or other steel elements.

7.0 Mixing

The CIP mixture for a specific project shall be prepared and mixed in accordance with these standards, the contract documents, and the mix design or product manufacturer’s technical specifications, including the water to solids ratio.

Increasing water amounts beyond the specifications is generally prohibited, however if it is desired to do so in extraordinary circumstances, it shall be proposed by the Contractor and accepted in advance by the Construction Assurance Engineer and Ministry Engineer.

The Contractor shall monitor cementitious mixture slump/stiffness and ensure that it is maintained at appropriate values such that the mixtures meet required standards and specifications.

Commentary

Excess use of water significantly negatively impacts the bonding, cure time, final strength, amount of segregation, cracking and future durability of a CIP mixture, therefore it is important to always monitor mixing procedures to ensure strict adherence to the manufacturer’s specifications and specific project requirements.



Figure 7: Batch of CIP mixture in a mixer, to be used for shear stud blockouts for deck panel to girder connections on a new steel girder composite concrete deck bridge.



Figure 8: Small batch of CIP mixture being mixed in a bucket to fill ducts for concrete slab girder to abutment dowel connections for a new bridge.

8.0 Formwork, Mixture Placement & Finishing

8.1 Formwork Installation

Place formwork (typically wood or foam backer rod) ensuring the dimensions of the elements being created, joined or repaired are correct. If a flowable or fluid mixture is used, the formwork shall be watertight.

Commentary

See Figure 1 (in Section 1) for example photo of formwork support for new concrete deck panel transverse deck joints.



Figure 9: Formwork placed after removal of damaged concrete and prior to placing CIP mixture for ballast wall and deck panel repair.

8.2 Mixture Placement

Prior to placing the CIP mixture, unless noted otherwise by product manufacturer's specifications, ensure all surfaces and formwork have been moistened sufficiently and for a sufficient length of time so they will be in a saturated surface dry (SSD) condition.

Once the prepared surfaces are SSD, begin placing the mixture as rapidly as possible and adequately consolidate to eliminate voids. Work the mixture into the prepared area, ensuring bonding and complete coverage.

- If the mixture begins to thicken or set before placing, discard the remaining mixture, do not add more water.
- Typical methods of consolidation shall be employed as described in CSA A23.1.
- Tamping and rodding is typically a preferred method of consolidation for mixtures with a plastic consistency. Limited use of an appropriate vibrator may sometimes be helpful however care must be taken to avoid segregation of the mixture.

Commentary

Failure to clean and prepare existing concrete surfaces (including bringing to a SSD condition) is detrimental to the bond between the host concrete and the CIP mixture and can prohibit the mixture from achieving proper hydration and strength development.

The SSD state promotes a durable strong bond to prepared surfaces and reduces potential for grout shrinkage and cracking. This state prevents the form and the concrete from drying too quickly which in turn can result in shrinkage and cracking.



Figure 10: A leaking transverse deck panel CIP joint causing corrosion of a steel bridge girder. Poor Quality Control of surface preparation, mixing, placement and/or curing can be detrimental to FSR bridge durability and longevity.

8.3 Finishing

Once the mixture has partially set, complete the surface finish using a conventional finishing technique (typically broom or trowel) to meet the required surface finish. Ministry standards for concrete finishing are provided in BSM Section 8: “Concrete Structures”.

8.4 Formwork Removal

The CIP mixture must be in place for a minimum of 24 hours prior to removing formwork, unless noted otherwise by the manufacturer’s specifications and/or the Engineer.

Once formwork has been removed, inspect the work for competency. Any areas of “honey combing” or poor consolidation shall be repaired or replaced.

Commentary



(a)

Figure 11: (a) Repair formwork on underside of a “deck beside ballast wall” type of end deck panel has been removed showing a CIP patch inadequately tamped along the edge of the formwork; (b) Additional repair mixture has been placed to fill voids from initial unconsolidated repair work to obtain original deck dimensions.



(b)

9.0 CIP Field Record

9.1 Quality Control Using the CIP Field Record

All FSR bridge CIP work requires CIP activities to be documented by the CIP Supervisor using the Ministry's CIP Field Record.

"CIP Field Record" blank form:

<https://www2.gov.bc.ca/assets/download/878F46BFE7EE453B99C0FBA070ECADBF>

Use of an alternative CIP QC form/checklist in place of the Ministry's CIP Field Record may be acceptable, provided that the proposed blank forms/checklists are submitted to and accepted by the Construction Assurance Engineer (CAE) prior to the commencement of CIP activities. Alternatives must, at minimum, address all aspects of the activities in at least as much detail as the Ministry CIP Field Record.

An individual CIP Field Record shall be completed for each mixture used each day of CIP placement.

The CIP Supervisor shall provide copies of all CIP Field Records to the Construction Assurance Engineer (CAE), any other individual(s) identified in the contract documents or specifications and, if sampling and testing is required, to the testing laboratory.

Commentary

The CIP Field Record contains detailed instructions for its use.

9.2 Quality Assurance Related to the CIP Field Record

The Construction Assurance Engineer (CAE) shall direct field reviews of the bridge project as work progresses. As part of this QA work, field reviews shall be undertaken to confirm the CIP Field Records are reasonably representing the CIP work being undertaken. The CAE shall review the CIP Field Records to confirm project specifications and Ministry standards are being met and shall provide the Records to the Ministry Engineer for documentation in Ministry files for the bridge.

10.0 CIP Sampling & Testing Specifications

10.1 CIP Sampling & Testing Specifications form

The Ministry's CIP Sampling & Testing Specifications shall apply to any FSR bridge installation/repair project that includes CIP work (see Section 10.2 for additional explanation).

If a "Project Specific" version of the Specifications is provided in the contract documents it shall apply.

"CIP Sampling & Testing Specifications (Project Specific)" blank form:

<https://www2.gov.bc.ca/assets/download/50EFD990C05E4524B7DF99C260B312E3>

If a "Project Specific" version is not provided, and if no other information is provided in the contract documents about CIP sampling and testing, the "Default" version of the Specifications shall apply.

"CIP Sampling & Testing Specifications (Default)" completed form:

<https://www2.gov.bc.ca/assets/download/41DA64115A4340A89949AE72FF4EF4E5>

Commentary

An "Example-Project Specific" completed form is available in Section 8 of the Bridge Standards Library to assist Engineers in understanding how the "Project Specific" version may be completed for a project.

"CIP Sampling & Testing Specifications (Example- Project Specific)" completed form:

<https://www2.gov.bc.ca/assets/download/8CDB399D58B54B10BE27E51FDD3120FD>

10.2 Determination of Sampling & Testing Specifications for Contract Documents

One of the Engineers involved with the design and/or implementation of the design shall determine appropriate minimum Quality Control CIP Sampling and Testing Specifications for the CIP mixtures specified for the project and provide direction, as appropriate, for preparation of bridge installation contract documents.

This Engineer may determine that "Default" specifications are appropriate for the project. If the Engineer determines they are not appropriate for the project, they shall prepare "Project Specific" specifications using the CIP Sampling & Testing Specifications (Project Specific) form. The completed "Project Specific" form, which may affect potential Contractor's bid pricing, shall be provided in the bridge installation/repair contract documents.

Prior to determining the appropriate CIP Sampling & Testing Specifications for a project, which will address issues (e.g. types of testing, quantity and curing of test specimens and timing of testing) the Engineer shall consider factors such as:

- remoteness of the site;
- sampling, transportation and testing costs;
- type and amount of CIP work;

- construction phases;
- expected climatic conditions; and
- acceptable risk.

If test specimens are to be field cured at the bridge site, in similar conditions to the CIP mixture used on the bridge, consideration shall be given to how many trips from the bridge site to the testing lab are required for the project so that test specimens can be field cured to various ages (e.g. 20 hours, 7 days, 28 days) bearing in mind that any test specimens delivered to a testing lab and not immediately tested will be placed in typical lab curing conditions which may vary substantially from the conditions of the mixture cast into the bridge.

After these considerations, the Engineer shall determine whether the “Default” specifications are appropriate or whether “Project Specific” Specifications need to be prepared and included in contract documents for the bridge installation/repair project.

10.3 Sampling & Testing Personnel and Lab Qualifications

When lab testing is required, it shall be provided by the Contractor using a testing lab certified to CSA A283 “Certification of Laboratories for Concrete” as described in CSA A23.1 & A23.2.

The individual provided by the Contractor to prepare samples and provide them to a testing lab shall have qualifications as required by CSA A23.1 & CSA A23.2 for preparing cementitious mixture samples for testing (or alternative qualifications acceptable to the Construction Assurance Engineer (CAE) and the Ministry Engineer). This individual may be the CIP Supervisor or they may be working under the direction of the CIP Supervisor.

Commentary

CSA A23.1 cl. 4.4.1.7 specifies that Field sampling and test procedures undertaken to assess concrete quality shall be carried out by personnel certified in accordance with the field testing requirements of CSA A283 under an industry-recognized program.

11.0 Testing Moulds

The Contractor is responsible for supplying testing moulds meeting the requirements in CSA A23.1 & A23.2 unless otherwise stated herein.

The CIP Supervisor shall discuss the CIP mixtures to be used and the anticipated stiffness of the mixtures with the testing lab in advance of mobilizing to site and shall reach agreement with the lab on appropriate mould type(s) for each mixture in order to obtain good quality test specimens that will be suitable for accurate and efficient testing by the lab. The moulds determined in this manner, within the parameters provided in Table 6 (below), shall be used by the CIP Supervisor or other qualified individual for making test specimens at the site.

Table 6: Possible Moulds for CIP Test Specimens

Product Type	Example Product	Possible Moulds (mm)			
		Cube	Cylinder (dia. x ht.)		
		50	50x100	75x150	100x200
Flowable or fluid CIP grout mixture (without coarse aggregate)	SikaGrout-212 *	Yes	Yes	Yes	Yes
Plastic CIP mixture, used in small volumes (with no coarse aggregate or with coarse aggregate nom. dia. \leq 12 mm)	Target Traffic Patch (Fine or Coarse)	Yes	Yes	Yes	Yes
Larger volume, typ. Ready-mix concrete (with coarse aggregate 12 mm < nom. dia \leq 28mm)	Ready-mix concrete for a CIP footing	No	No	Yes (if coarse aggregate dia. < 25 mm)	Yes (if coarse aggregate dia. < 33 mm)

* For SikaGrout-212 the lid must be clamped on the mould due to the expanding characteristics of the product.

Each test specimen shall be labelled with the information shown in the Ministry's CIP Test Specimen Labels template.

"CIP Test Specimen Labels" template:

<https://www2.gov.bc.ca/assets/download/1925BD2F7B814751AE0697A06948E5F8>

Commentary

CSA Standards specify 50 mm x 50 mm cubes for testing of flowable grout without coarse aggregate, and 100 mm dia. x 200 mm (or larger) cylinders for testing of concrete with coarse aggregate.

Based on advice/requests from Contractors, Engineers, product manufacturers and testing labs, the Ministry is allowing more options than described in the CSA standards so that Contractors and testing labs may work as efficiently as possible.

In 2015 the Ministry undertook some research regarding the use of 50 mm x 100 mm cylinders as test

moulds. Details about that research are provided in Section 8 of the Bridge Standards Library.

"Grout Compression Testing, Cubes vs. Cylinders" report and presentation:

<https://www2.gov.bc.ca/gov/content?id=F5EACBC48F294F4C82ABD025C01A4BDB>



Figure 12: Example of damp burlap sacks being used to keep test specimens cool and moist. Periodically re-wetting the mixture placed in the bridge as well as the test specimens is often required.



Figure 13: Example demoulded test specimens.

12.0 Test Results

12.1 Distribution of Test Reports

Copies of test results shall be provided by the CIP Supervisor to the Construction Assurance Engineer (CAE). The CIP Supervisor and the Construction Assurance Engineer (CAE) shall review the compressive strength testing reports and other testing results to confirm project specifications are being met. The CAE shall provide the reports to the Ministry Engineer for documentation in Ministry files.

12.2 Unacceptable Results

If test results are deficient, or if other significant deficiencies become apparent with the CIP work, the Construction Assurance Engineer and Ministry Engineer shall specify the necessary steps to assess and correct the deficiency to establish safe use of the structure. Such assessment may include coring the placed mixture to obtain samples for testing.

13.0 Cold Weather CIP Procedures

Prior to initiating cold weather CIP operations, the Contractor shall provide the Construction Assurance Engineer with written cold weather CIP procedures for review and acceptance.

Where it is anticipated that the temperature will drop below 5°C within 24 hours of placing a mixture, the Contractor shall implement cold weather CIP procedures in accordance with CSA A23.1.

Preheating and continued heating may be required to ensure that curing is adequate and the mixture is kept from freezing.

Cold weather procedures, in addition to typical CIP standard procedures, may include some or all of the following:

- Pre-warm the dry mix materials and components being grouted to above 10°C.
- The ambient temperature of the area surrounding the CIP mixture during the initial 24 hours of cure time shall be maintained above 10°C.
- The temperature of the component being grouted shall be kept above freezing for a minimum of 72 hours subsequent to mixture placement.
- Ensure compliance with the manufacturer's specifications in order to meet the specified compressive strength within the required time frame.
- Use warm water (20°C) in the mixture.
- Prevent heat loss by providing sufficient labour in order to minimize the time required to place and finish the mixture.
- Provide protective wrapping to encapsulate the repair area and drape below the bridge to capture the rising heat. The heated enclosures shall maintain air temperature equal to or above 5°C for a minimum of 24 hours prior to mixture placement and then maintain it above 10°C for the duration of the required curing period.
- Exercise caution to ensure that any heat source is directed away from bridge components to avoid damaging them³.

CIP products specially designed for cold weather may be considered and proposed to the Ministry Engineer for acceptance consideration if considered to be practical, effective and economical.

Commentary

Placement and curing of CIP mixtures during cold weather can affect ultimate strength and durability. Mixtures cure slower in cold temperatures and strength development is delayed. Exposure of fresh mixtures to temperatures below freezing potentially stops the curing process leading to inadequate strength development and an overall loss of durability.

The heat of hydration of a typical CIP mixture is not sufficient to keep the mixture from freezing in sub-zero temperatures.

³ ACI 306R-16: *Guide to Cold Weather Concreting* provides detailed guidance on cold weather preparations for surfaces in contact with fresh cement or mortar.

If cold concrete deck panels or slabs are not pre-heated, they will drain heat out of the CIP mixture and will increase the possibility of the mixture freezing in sub-zero temperatures. If the dry mix materials are not preheated, it will dramatically reduce the temperature of the heated water when mixed. This is particularly true if the concrete deck panels or slabs that the mixture will be placed against are cold. If the mixture freezes, it will likely need to be removed and recast.

Protection practices that have been typically implemented consist of wrapping the structure in tarps and heating from beneath the structure using suitable heaters. Various types of tarps and covers have been used including plastic sheeting, construction tarps, lumber wrap and non-woven geotextile.

The dry mix materials can sometimes be placed on the deck, under the protective wrap to be heated with the deck or slabs. For steel girder bridges, it may be sufficient to have a heat source between the girders to keep the deck sufficiently warm through the CIP placement and initial setting.

Specially designed cold-weather CIP products may sometimes be a more practical and economical solution than using standard products that require more heating and encapsulation.

14.0 Hot Weather CIP Procedures

Hot weather procedures shall be followed when the ambient temperature is at or above 27°C or if there is a probability of the temperature rising above 27°C during the placement period (CSA A23.1).

Hot weather procedures, in addition to typical CIP standard procedures, may include some or all of the following:

- Keep the dry mix materials cool prior to mixing, store in a cool location.
- Use cold water or ice, as part of the mixing water. Ice shall be in a crushed, shaved or chipped form. Mixing shall continue until all of the ice is completely melted. Ice additions shall be considered as part of the mixing water specified in the manufacturer's specifications and will be recorded on the CIP Field Record.
- In extreme conditions consider adjusting the time of CIP placement to take advantage of cooler temperatures in the early morning or nighttime.
- Provide sufficient labour to minimize the time required to place and finish the CIP mixture, as hot weather conditions substantially shorten the times to initial and final set.
- Use a mixture consistency that allows rapid placement and consolidation within acceptable tolerances to achieve the required design strength.
- Maintain moisture for the curing process by covering work with damp burlap as soon as possible after the CIP mixture finishing processes have been completed, then periodically re-wetting to maintain moisture as the mixture sets.

Commentary

Hot weather can have a negative impact on both the plastic and hardened properties of a CIP mixture.

High temperatures cause water to evaporate rapidly from the surface of a mixture. Cement hydration occurs quickly and inadequately causing the mixture to set earlier, lessening workability, increasing the chances of plastic cracking, and reducing the ultimate strength.

Due to the very rapid hardening characteristics of Target Traffic Patch (Fine & Coarse), these products develop high levels of heat from hydration in the initial hours after mixing which makes successful use of these products in hot temperatures particularly challenging.

15.0 Allowing Traffic on the Bridge

The Construction Assurance Engineer shall (among other things) accept all CIP mixture placement and curing that is critical to bridge strength before traffic is allowed to use the bridge.