

**ALBERTA TRANSPORTATION
TECHNICAL STANDARDS BRANCH**

B373 – JULY 2000

**SPECIFICATION FOR THE REPAIR OF BRIDGES
WITH FIBRE-REINFORCED SHOTCRETE**

1.0 GENERAL

1.1 INTRODUCTION

This specification applies to the repair of deteriorated concrete surfaces using pneumatically applied non-fibrous and steel fibre reinforced concrete mortar. The deteriorated concrete shall be removed until a sound substrate is reached, suitable for adequate bond to the new material. The shotcrete work shall use the dry process method with a pre-bagged mix described in Section 2.5. The texture of the surface finish shall be Class A, B, or C as specified in the Special Provisions. The new material shall be properly wet cured prior to sealing.

1.2 WORKERS' QUALIFICATIONS

The work shall be performed by qualified personnel. The crew foreman and nozzleman shall each have a minimum of five years experience in shotcreting. The Contractor shall submit with his Tender, a work history list of the foreman and all nozzle men proposed to be involved in the work. The list shall include the names of past supervisors and employers, with phone numbers, as well as a brief description of the type and amount of the foreman and nozzle men's shotcrete experience. Any related certification or schooling should also be listed. Once the foreman and nozzle men have been approved, they cannot be replaced without the prior written approval of the Engineer.

1.4 PRE-QUALIFICATION OF NOZZLEMEN AND PRE-BAGGED MIX

At least two weeks prior to the commencement of the work, the Contractor shall shoot test slabs of 200 x 200 x 75 mm minimum size on unenclosed plywood forms. The shooting of these test slabs will be witnessed by the Engineer and it is the responsibility of the Contractor to give the Engineer at least 48 hours notice. Test shooting not witnessed by the Engineer will be deemed invalid. One test slab is required for each proposed pre-bagged mix, and an additional slab is required for each nozzleman. These test samples shall be field cured for 24 hours prior to delivery to the laboratory for testing. Cubes shall be cut from the samples and tested for compressive strength according to CSA Standard A179M-1976. The Department will supply the plywood forms, all other costs associated with testing shall be borne by the Contractor. A minimum 7-day compressive strength of 40 MPa is required for the proposed mixes and nozzle men to qualify. No work shall be done if samples do not achieve the required compressive strength or cubes show sand pockets, laminations, and voids.

2.0 MATERIALS

2.1 CEMENT

Only Normal Portland Cement, Type 10, conforming to CSA CAN3-A5-M77, Portland Cements, shall be used in the pre-bagged mix.

2.2 SAND

The maximum allowable aggregate size is 6 mm, and the aggregate shall comply with CSA CAN3-A23.1-M77, "Section 5.3, Fine Aggregate".

2.3 STEEL FIBRE

Only Ribtec fibre or equivalent shall be used. The fibre length shall be 25 mm and shall not contain any trace amounts of aluminum.

2.4 WATER

Mix water shall be of drinking water standards, free of chemical and organic impurities, and shall comply with CSA CAN3-A23.1-M77, "Section 4, Water".

2.5 MIX DESIGN

The mix design of the pre-bagged mix shall be submitted for approval to the Engineer prior to the mix being used on any of the work. The design minimum 28 day compressive strength shall be 40.0 MPa and the flexural strength 10.0 MPa. The pre-bagged mix shall contain a uniform concentration of 60 kg/m³ of an approved steel fibre. The mix may contain dry silica fume in the amount of 5 to 10% by weight of the cement. The mix shall be designed to allow for the addition of water at 3 to 6% by weight of dry mix prior to pumping. No strength accelerating admixtures will be permitted. Other admixtures shall require the approval of the Engineer. The Contractor shall provide written reports, from an independent CSA certified testing laboratory, showing compliance with the following:

(1) a petrographic durability number for the aggregates shall be 115 or less.

(2) compliance with CSA CAN3-A23.1-M77 regarding organic impurities, gradation of particle size, and durability.

The Contractor shall ensure that the pre-bagged mix meets the requirements of the approved mix design

2.6 BEARING PLATE GROUT

The grout mix used below structural bearing plates shall be Sika Grout 212 or an approved non-metallic, non-shrink, non-chloride, Portland Cement based grout conforming to "Specification For Non-Shrink Grout" (B387). The minimum compressive strengths shall be 25 MPa at 1 day and 55 MPa at 28 days.

2.7 JOINT SEALANT

Only Sikaflex 15LM Flexible Joint Sealant or approved equivalent shall be used in this work.

2.8 REINFORCEMENT

All reinforcing steel used to replace damaged or corroded existing bars will be of 400 MPa minimum yield strength, conforming to current CSA specification G30.12-M, Reinforcement.

3.0 **PERFORMANCE**

3.1 CONCRETE REMOVAL

The Contractor shall locate and remove all loose or deteriorated concrete as directed by the Engineer. Surface cracks shall be removed by chipping. Hammer sounding shall be done to locate delaminated areas. Care shall be taken not to damage areas of sound concrete, reinforcing steel, bridgerail or other bridge components. Any such damage will be repaired by qualified personnel at the Contractor's expense.

When corroded reinforcing steel is exposed during concrete removal, the corroded bars shall be further exposed by chipping until clean uncorroded steel has been exposed. Additional chipping shall be done to a depth of 25 mm below the undersides of all exposed and debonded reinforcing. Perimeter of all chip areas shall be sawcut a minimum depth of 40 mm to avoid feather edges.

Removal of deteriorated concrete from the bridge structure shall be done in such a manner as to assure that the structural integrity of the bridge is unaffected. Therefore, all concrete removed shall be replaced as soon as possible. It is the responsibility of the Contractor to design and provide shoring, when it is required, as directed by the Engineer. The shoring shall be designed by a Professional Engineer, the design stamped and signed, and submitted to the Department prior to continuation of the work.

3.2 REINFORCING

Heavily pitted reinforcing steel that is exposed during repairs shall be replaced as directed by the Engineer. In general this is required when the loss of section area at any point on the bar exceeds 20 percent. In cases of isolated pitted areas, the existing pitted reinforcing steel need not be cut out, but reinforced with extra bars added alongside in such a manner that voids will not occur during shotcreting. The minimum lap splice length of all such new reinforcing steel shall be 20 bar diameters. The minimum cover of new shotcrete above the reinforcing steel shall be 25 mm.

3.3 ANCHORS

For the purpose of mechanically anchoring new shotcrete to the substrate material, 10 mm diameter Hilti HKD drop-in anchors or approved equivalent shall be installed where there is no fully exposed reinforcing steel within the repair area. Anchors shall be installed on a 600 mm grid pattern over the repair area and tied with 10 mm reinforcing bars in both directions, spaced 600 mm apart, prior to shotcreting. Anchors and galvanized stucco wire mesh are also required on pier caps, bearing areas, large patches and in other areas where no existing rebar is exposed and as directed by the Engineer.

3.4 FORMING

Repairs to portions of the bridge that are exposed to public view such as curbs, concrete end posts, and substructure elements and girders on grade separations shall be both structurally sound and aesthetically pleasing. Large areas of shotcrete repair to these elements will require forming to provide straight finished lines. Formwork design shall be the responsibility of the Contractor, and shall be done in such a way that the shotcrete material can be adequately compacted during shooting to achieve proper strength and bond. This may involve a form that can be shot into from two different directions. After the initial layer of shotcrete is shot into the form and has set for one day, the form shall be removed and a light sandblasting done to remove the unconsolidated surface material before shooting the second layer to fill any remaining voids. All formwork is subject to approval by the Engineer.

3.5 SHOTCRETE DEPTH CONTROL

In areas of uniform depth on large, uniformly flat surfaces where a jacketing layer is being applied, the Contractor shall install depth gauges to control the depth to which the shotcrete is placed. The depth gauges shall be placed on a 1.2 m using anchors for reinforcement, grid and shall be entirely covered by the shotcrete material. Ready-rod of equivalent diameter shall be installed to serve as depth gauges. The length of depth gauge shall be trimmed 5 mm below the required finished surface in order to prevent future corrosion stains.

3.6 SANDBLASTING

After the deteriorated concrete has been removed, the repair surface and rebar shall be sandblasted to the approval of the Engineer. All loose and fractured material shall be removed. Sandblasting shall be sufficient to uniformly expose the fine aggregate in the substrate concrete.

3.7 PREWETTING

Prior to shotcreting, all bond surfaces shall be continuously prewetted for a 4 to 24 hour period depending on the substrate and patch thicknesses and the porosity of the substrate concrete. Immediately prior to shotcreting, the pre-wetted surfaces shall be allowed to surface dry. The surface shall not be wetted immediately prior to shooting. The Engineer's judgement of the time required for pre-wetting shall be final. If shotcrete is not placed immediately after the pre-wetting period, the rebar shall be sandblasted, substrate concrete pre-wetted again and airblasted prior to shotcreting.

3.8 WEATHER

No shotcrete shall be placed in the event of rain, heavy winds, and temperatures below 8°C or above 28°C, or during other conditions considered unsuitable by the Engineer. The Engineer's judgement of the suitability of weather conditions shall be final.

3.9 APPLICATION

Shotcrete material shall not be placed without prior acceptance of the prepared surfaces by the Engineer. These surfaces shall be kept continuously clean of any loose material such as sand, concrete, and dirt prior to shooting. Application procedures shall conform to requirements of the current ACI 506.2, "Specifications for Materials, Proportioning, and Application of Shotcrete", and ACI 506R, "Guide to Shotcrete".

At any time that shotcreting is done on previously cured shotcrete, the surface shall be sandblasted and washed to remove all non-consolidated surface material to ensure proper bond.

3.10 CASTING

Where the thickness of shotcrete to be placed exceeds 150 mm, and at the option of the Engineer, the Contractor may be required to cast most of the new material rather than shotcreting. Such patches shall be cast to within 25 mm of the finished surface at least one day prior to shooting shotcrete. Any such cast concrete must be properly placed and vibrated to achieve consolidation and compaction of the material. The mix design for cast concrete shall be the same as for pneumatically applied shotcrete.

Payment for cast-in-place patches and grouting of bearings shall be at the reduced rate of 50% of the unit bid price for shotcrete repair.

3.11 PROTECTION FROM OVERSPRAY

The Contractor shall protect bridgerail, bearings, and other adjacent bridge areas as well as the travelling public from overspray and rebound material from shotcreting, painting, and sealing operations. Any damages resulting from these operations shall be the responsibility of the Contractor.

3.12 STRUCTURAL BEARING PLATES

Structural bearings on the piers and abutments are highly stressed elements, transferring the weight of the deck and vehicles to the concrete elements below. The repair of concrete deterioration near bearing plates shall not proceed without the approval of the Engineer. When the deterioration extends below the bearing plates, a non-shrink dry pack grout conforming to the requirements of Section 2.6 is required. Care shall be taken in removing deteriorated concrete, not to weaken or displace the bearing plate. No more than one-quarter of the concrete below any bearing may be removed at any one time unless an approved shoring system is in place so that the bearing is not subject to stress. The procedure for grouting shall be as follows:

1. Provide shoring conforming to requirements of Section 3.1.
2. Remove deteriorated concrete and pre-wet all bond surfaces no less than 15-hours,
3. Sandblast and air dry the bond surfaces immediately prior to grouting, surface to be saturated surface dry,
4. Mix, place and cure the grout in accordance with manufacturer's instructions, using care to consolidate the grout and eliminate voids,
5. Cure until a minimum compressive strength of 30MPa is attained prior to applying load to the grout, removing adjacent deteriorated concrete or removal of shoring.

3.13 FINISHING

The required surface finish of shotcrete repair will be specified in the Special Provisions. In general, Class A finishes will be required for areas of high visibility to the public such as all curbs or on substructure areas of grade separations. Class A and B finishes shall not have any steel fibre exposed at the surface; they will require the top layer of shotcrete to be of non-fibrous mix. Class C finishes may have exposed steel fibre at the surface; these are intended for concrete repair areas not generally visible to the public such as the undersides of short span precast girder bridges in remote locations, and also in areas not exposed to salt or heavy leakage.

<u>Class Finish</u>	<u>Description</u>
A	Smooth finish, similar to wood formed concrete, no fibre at surface, no voids or defects at surface, surface trued by cutting of excess material, hand finishing required. Smoother surface than Class B.
B	No exposed fibre, surface texture similar to wood float finish, surface trued by cutting excess material and hand finishing required.
C	Exposed fibre, gun finish.

3.14 STRAIGHTNESS OF FINISHED SURFACES

In restoring the original lines of curbs and other surfaces exposed to public view, the finished surfaces shall be made straight planes without visible marks from trowelling. Straightness shall be measured by the use of a 2-metre straight-edge or string line placed parallel to the surface to be measured. The maximum tolerance for straightness measured in any direction along the finished surface shall be as shown in the table below for the class of finish specified. Finishing or grinding will be required in the event that surface trueness fails to meet the following requirements.

STRAIGHTNESS OF FINISHED SURFACES

<u>Finish Class</u>	<u>Maximum Deviation From Straight (mm)</u>
A	3
B	5
C	7

3.15 CURING

Beginning no later than four hours after fresh shotcrete has been placed, the Contractor shall begin wet curing procedures. Where possible, as with curbs or pier caps, burlap shall be applied and kept constantly wet on all new surfaces.

Vertical or overhead surfaces not suitable for burlap curing shall nevertheless be kept continuously wet with soaker hoses or manually applied wetting for a period of 24 hours in the case where a sealer will be applied. Where no sealer is to be applied, the shotcrete shall be continuously wet cured for 48 hours.

The Contractor shall supply all hoarding and heating required should the air and bond surface become less than 5° C. The allowable temperature ranges during shooting and wet curing shall be 8° to 28° C. The temperatures and curing conditions shall be maintained for a period of 72 hours after the shooting is completed.

3.16 JOINT SEALING

When specified and as directed by the Engineer, potential reflective cracks or bond lines at the surface between shotcrete and existing concrete or steel shall be properly prepared and sealed with Sikaflex 15LM.

3.17 SURFACE SEALING

Following wet curing procedures, the repaired areas, and adjacent areas as directed by the Engineer, shall be given a light sandblast cleaning and coated with Type 2a clear sealer. Sealers shall be promptly applied to dry surfaces as soon as no free moisture is visible on the surfaces. The application shall be done with airless spray equipment. More than one coat may be required to achieve the total required coverage rate, which varies for each product.

The Department maintains an approved sealer list entitled "Evaluation Procedure for Sealers Used on Concrete Bridge Elements, Type 2a, One Component Clear Coatings for Non-Traffic Bearing Surfaces." Any sealer on the current list may be used. The application rate shall be adjusted such that the material amounts per square metre indicated on the Department's approved list are increased by 40% to compensate for the increased roughness of shotcreted surfaces.

3.18 PAINTING

The Contractor shall paint repaired and adjacent areas when specified and as directed by the Engineer. The application shall be done with airless spray equipment at uniform coverage rates, uniform color, and on a clean dry surface. Colored paints compatible with the natural color of the concrete shall be used. Additional coats may be required to achieve the total required coverage and uniform appearance without runs. This particularly applies to vertical surfaces.

Any sealer on the Department's current approved sealer list, Type 3, Light Grey Colored Coating", may be used except that the published application rate shall be increased by 40% as in the case of Type 2a above. In case of evidence of insufficient hiding power, the application rate shall be further adjusted to provide a solid color, to the satisfaction of the Engineer.

Bridgerail, bearings, and other adjacent bridge areas as well as the travelling public, shall be protected from overspray.

3.19 ENVIRONMENTAL PROTECTION AND SITE CLEAN-UP

No shotcreting will be permitted to commence until adequate environmental protection measures are provided by the Contractor to the satisfaction of the Engineer. When shooting is done above a flowing stream the Contractor shall use tarps, platforms and other enclosures to protect the water from everything except fine dust.

The Contractor shall remove from the site all overspray, rebound and other waste material, so as to leave the repair site and the surrounding area in the same condition it was in prior to his work. The removal shall be done in a manner that no refuse is allowed to enter the stream.

Final payment for the work will not be made until the site clean-up has been done, to the Engineer's approval. In appropriate cases, evidence of adjacent landowners' approval of the clean-up will also be required.

4.0 INSPECTION

4.1 INSPECTOR

The Department will provide an Inspector, to represent the Engineer and to be on site at certain times during the course of these repairs. His attendance shall not relieve the Contractor of the responsibility for quality control.

4.2 COMPRESSIVE STRENGTH TESTING

The Contractor shall shoot test samples, 200 x 200 x 75 mm minimum size, from varying nozzle directions, at the start of each shooting operation and at intervals of 2 m³ of shotcrete repair or at intervals as directed by the Engineer. These test samples shall be field cured for 48 - 72 hours prior to delivery to the laboratory for testing. Cubes will be cut from the samples and tested for compressive strength in accordance with CSA A179M-1976. Cubes will be moist cured at 23 ± 2°C. They will be immersed in water at room temperature for 48 hours just prior to the compression testing.

4.3 BOND TESTING

When required by the Engineer, core samples of finished shotcrete material will be taken and tested for bond strength no less than 7 days after placement. In addition, thickness measurements will be taken to verify volume of shotcrete in place. The bond strength between the shotcrete material and the concrete or between separate passes of shotcrete material shall be no less than 2.5 MPa. Failure to meet this criterion will be cause for rejection and replacement will new shotcrete at the Contractor's expense.

4.4 NOTIFICATION

No shotcreting shall proceed without the Engineer's approval of the surface preparation and volume measurements. The Contractor shall notify the Engineer a minimum of 48 hours in advance of shotcreting to allow for inspection and measurement.

5.0 **PAYMENT**

5.1 MEASUREMENT AND PAYMENT

Prior to shotcreting, measurements of volume for shotcrete repair and surface area to be sealed or painted will be made by the Engineer. The measurement of volumes for shotcrete repair will be made by the average end area method with sections at regular intervals and by depth gauges. All measurements will be made to the nearest millimetre. The shotcrete recording sheets must have the Engineer's verification in order to be honored for payment. It is recommended that the Contractor's Foreman be present during the measurement so that he can confirm the measurements made which will be used to establish payment for the work. No extra payment will be made for material losses incurred by rebound, overspray, or extra material in place beyond gradelines set by the Engineer.

Payment for "Preparation and Shotcrete" will be made on the basis of the unit price per cubic metre bid for the total number of cubic metres of concrete acceptably repaired.

5.2 RIGHT OF REJECTION

The Engineer reserves the right to reject any shotcrete that is debonded, has surface cracks, laminations, voids, sand pockets or trapped rebound, is flawed by incorrect method of encasing reinforcing bars with shotcrete, or does not meet the 40.0 MPa compressive strength specification. The Contractor shall at his expense remove and redo all rejected work.

The Engineer may, however, at his discretion, accept shotcrete with compressive strengths as low as 30.0 MPa. In such cases, payment will be made on the basis of the following schedule.

PARTIAL PAYMENT SCHEDULE

28-Day Compressive Strength Attained	Percentage of Bid Price Per Cubic Metre
40.0 MPa and Over	100%
38.0 MPa up to 39.9 MPa	90%
36.0 MPa up to 37.9 MPa	80%
34.0 MPa up to 35.9 MPa	70%
32.0 MPa up to 33.9 MPa	60%
30.0 MPa up to 31.9 MPa	50%

The percentages shown apply to the amount of shotcrete represented by a single set of test samples. Where the repair volume cannot be evenly divided into 2.0 m³ segments, the last test set will represent a suitable volume not exceeding 2.0 m³, as determined by the Engineer.

5.3 CORING

If any shotcrete tested fails to meet the required 40.0 MPa compressive strength at 28 days, the Contractor may be allowed to remove core samples from the repairs within 7 days (maximum) of the expiry of the original 28 day test period. If the coring is approved by the Engineer, arrangements shall be made by the Contractor, through the Engineer, to employ an independent, qualified testing lab at the expense of the Contractor.

The Engineer will specify the exact location of the coring to assure that the cores represent the same shotcrete as the test samples. The average compressive strength of three adjacent cores taken from a single location shall constitute a test. Cores shall be tested in accordance with CSA CAN3- A23.2-14C-M77. The core test will be considered valid for the shotcrete represented by the original cube tests.

In cases where the shotcrete strength, as indicated by the cores, is higher than the strength based on the cube test results, the core results shall be used as the basis for acceptance of and payment for the shotcrete. If the core strengths are lower than the strength from the cube tests, the core tests shall govern.

In the event the core strengths indicate the shotcrete in question meets the 40.0 MPa strength requirement of this specification, then the Department will assume the cost of the coring and core-testing.

Coring will also be performed at the discretion of the Engineer to verify bond strength, see Section 4.3. If the criterion bond strength of 2.5 MPa is not met, the cost of coring and bond testing shall be borne by the Contractor.

In any event, all core holes shall be patched with an approved 40 MPa concrete patching material and properly cured at the Contractor's expense.

SHOTCRETE EXPERIENCE

Site Foreman (minimum 5 years required)

Name: _____

Summarize and describe total relevant experience: _____

Shotcrete History:

<u>Company Name</u>	<u>Position</u>	<u>Duties</u>	<u>Dates</u>	<u>Supervisor's Name</u>
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Nozzleman (minimum 5 years required)

Name: _____

<u>Company Name</u>	<u>Position</u>	<u>Duties</u>	<u>Dates</u>	<u>Supervisor's Name</u>
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____