

TENDER DOCUMENTS

SUBSECTION 6.38 STRENGTHENING OF STRUCTURAL COMPONENTS WITH CARBON FIBER REINFORCED POLYMER (CFRP)

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SUBSECTION 6.38 STRENGTHENING OF STRUCTURAL COMPONENTS WITH CARBON FIBER REINFORCED POLYMER (CFRP)

6.38.1 GENERAL

- 6.38.1.1 This subsection describes the requirements relating to the strengthening of structural components with the addition of carbon fiber reinforced polymer (CFRP) work covered by this Contract.
- 6.38.1.2 Any specific requirements pertaining to the strengthening of structural components with carbon fiber reinforced polymer (CFRP) work covered by this Contract are set out on the drawings and in Section 4 *Special Technical Conditions*.
- 6.38.1.3 The requirements relating to demolition work are described in subsection 6.21 *Demolition and Removal*.
- 6.38.1.4 The requirements relating to concreting work are described in subsection 6.33 *Cast-in-Place Concrete*.
- 6.38.1.5 The requirements relating to waterproofing work are described in subsection 6.37 *Miscellaneous Products for Concrete Work*.

6.38.2 MEASUREMENT UNITS

- 6.38.2.1 The measurement units and respective symbols thereof used in this subsection are described as follows:

Measurement Unit	Designation	Symbol
area	square meter	m ²
area	square millimeter	mm ²
length	meter	m
length	millimeter	mm
pressure, stress	megapascal	MPa
temperature	Celsius degree	°C

6.38.3 REFERENCE STANDARDS

- 6.38.3.1 The **Contractor** shall carry out all CFRP strengthening work in accordance with the following standards and documents, to which the provisions of this Contract are added:
- 6.38.3.1.1 (ACI) American Concrete Institute:
- ACI 440.2R *Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures*.

6.38.3.1.2 (CSA) Canadian Standards Association:

- CAN/CSA S6 *Canadian Highway Bridge Design Code.*

6.38.3.1.3 (ASTM) ASTM International:

- ASTM D4541 *Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers.*

6.38.3.1.4 (ISO) International Organization for Standardization:

- ISO 9001 *Quality Management Systems - Requirements.*

6.38.3.1.5 (MTQ) Ministère des Transports du Québec:

- MTQ – *Cahier des charges et devis généraux (CCDG) - Construction et réparation.*

6.38.4 MATERIALS

6.38.4.1 The **Contractor** shall select the products it uses for CFRP strengthening from the following, or an equivalent approved by the Engineer:

Manufacturer Type of Product	BASF Canada Inc.	Mapei Inc.	Sika Canada Inc.	FYFE Co. LLC. (Tyfo Fibrwrap System)
Carbon fiber fabric	MasterBrace FIB 600/50 CFS fabric	MapeWrap C Uni-Ax 600 uni-directional fabric ⁽²⁾	SIKAWRAP 900C uni-directional fabric	Tyfo SCH-41-2X uni-directional fabric, or Tyfo SCH-41 uni-directional fabric
Epoxy resin for the preparation and correction of, and for filling surface cavities	MasterBrace F2000	MapeWrap 11 or MapeWrap 12	Sikadur 300 or Sikadur 330	Tyfo WS
Primer epoxy resin	MasterBrace F3500 ⁽¹⁾	MapeWrap Primer 1	Sikadur 300 or Sikadur 330	Tyfo S ⁽¹⁾
Epoxy impregnating resin	MasterBrace SAT4500 ⁽¹⁾	MapeWrap 21 ⁽¹⁾	Sikadur 300 ⁽¹⁾	Tyfo S ⁽¹⁾

⁽¹⁾ Only the liquid encapsulation technique is allowed

⁽²⁾ Only if the certified detailed technical data sheet is provided to the Engineer

6.38.4.2 All components of the CFRP strengthening system shall come from the same manufacturer.

6.38.4.3 Following a joint inspection of the structural components by the **Contractor's** CFRP specialized engineer and the Engineer, the **Contractor** may, with the prior written authorization of the Engineer, make changes to the materials and construction details it deems necessary.

- 6.38.4.4 All materials shall, at all stages of the work, be new and free from dirt, rust, oil, grease or other deleterious materials.
- 6.38.4.5 The **Contractor** shall carefully handle, proportion and mix the materials used for placing the CFRP strengthening system in accordance with the manufacturer's recommendations.
- 6.38.4.6 The **Contractor** is responsible for the design and implementation of the strengthening works with the CFRP system.
- 6.38.4.7 The **Contractor** shall provide all labour, materials, storage of materials, tools and equipment required for the surface preparation and complete placement of the materials referred to in this subsection.
- 6.38.4.8 The manufacturer of the components of the CFRP strengthening system shall hold a registration certificate issued by an organization accredited by the Standards Council of Canada, attesting that the manufacturer of the specified product has successfully implemented a quality management program in accordance with ISO 9001 standard.
- 6.38.4.9 The manufacturer shall have in place, for a minimum period of ten (10) years, a training, certification and technical support program intended for an organized network of applicators authorized at national level, with a periodical certification of its participants.

6.38.5 INSPECTION PRIOR TO CFRP STRENGTHENING

- 6.38.5.1 Before starting the strengthening work, the applicator of the CFRP strengthening system shall inspect the concrete surfaces and immediately notify the Engineer, in writing, of any unsatisfactory conditions including, without however being limited to, any non-compliance with the requirements of paragraph 6.38.6 *Delivery, Storage and Handling* and any non-compliance with the requirements of paragraph 6.38.8.7 *Surface Preparation*. Any unsatisfactory condition shall be recorded in a site inventory that shall be submitted to the Engineer.
- 6.38.5.2 The CFRP strengthening works cannot begin until the concrete surface is in a condition that is satisfactory to the **Contractor's** CFRP engineer and to the Engineer, and capable of receiving the CFRP strengthening system.
- 6.38.5.3 There shall be no obstacle (walkway grapple or other) present in the location where the CFRP strengthening system will be placed.

6.38.6 DELIVERY, STORAGE AND HANDLING

- 6.38.6.1 The **Contractor's** CFRP engineer shall ensure that all materials constituting the CFRP strengthening system are unloaded and stored with the utmost care and protected against any aggression including, without however being limited to, direct contact with the ground, the weather, and condensation.
- 6.38.6.2 The materials shall be delivered in their original containers, sealed and undamaged, with the name of the manufacturer, the labels, product identification and lot numbers.

- 6.38.6.3 The materials shall be stored in a dry and enclosed area which is protected against moisture. The storage temperature shall be maintained between 20°C and 32°C.
- 6.38.6.4 The Engineer may refuse the use of any material he deems damaged or inappropriate for the purpose for which it is intended.

6.38.7 EQUIPMENT AND TOOLS

- 6.38.7.1 All equipment used for CFRP strengthening shall conform to the technical data sheets of the products used.

6.38.8 EXECUTION OF WORK

- 6.38.8.1 The **Contractor** shall not begin placing the CFRP strengthening system, prior to the reception of the written authorization from the Engineer.
- 6.38.8.2 The **Contractor's** CFRP specialized engineer shall be present throughout the placement of the CFRP strengthening system.
- 6.38.8.3 The placement of the CFRP strengthening system shall be carried out without traffic interruption.
- 6.38.8.4 The instrumentation elements present on the girders shall be removed and, after CFRP strengthening is completed, be reinstalled in the most appropriate location, as directed by the Engineer, without drilling any holes in the CFRP strengthening system, unless the **Contractor's** CFRP specialized engineer and the Engineer authorize another course of action.
- 6.38.8.5 WORK PLANNING
 - 6.38.8.5.1 At least fourteen (14) days prior to the commencement of CFRP work, the **Contractor** shall provide the Engineer with the details of the working method it intends to use for carrying out the work. These details shall include, without however being limited to:
 - 6.38.8.5.1.1 the general description of the method, including surface preparation and other preparatory or related work such as temperature and ambient humidity control and testing;
 - 6.38.8.5.1.2 the equipment and materials to be used;
 - 6.38.8.5.1.3 the number and composition of work teams;
 - 6.38.8.5.1.4 the detailed work procedure and sequences in order to meet the deadlines for applying and coating the successive layers specified by the manufacturer of the CFRP strengthening system.
 - 6.38.8.5.2 At least fourteen (14) days prior to the commencement of CFRP work, the **Contractor** shall also provide to the Engineer, for review, the following:

- 6.38.8.5.2.1 the curriculum vitae of the proposed candidate for the position of CFRP specialized engineer of the **Contractor**. The proposed candidate shall be a member of the *Ordre des ingénieurs du Québec* (OIQ), have a minimum of five (5) years of relevant years of experience in the supervision of CFRP work in the field of bridges and other civil engineering structures whose summation of treated surfaces corresponds to a minimum of 500 m² carried out over the last five (5) years and be recommended by the manufacturer;
- 6.38.8.5.2.2 two (2) representative samples of the CFRP strengthening system, prepared on a rigid and suitable substrate. This procedure shall be completed before the materials required for CFRP strengthening are ordered;
- 6.38.8.5.2.3 when required by the Engineer, placement of one (1) sample on the site in a location determined by the Engineer. Once accepted, this sample may be part of the completed work, and the remaining work under this Contract shall correspond to, or be of higher quality than that of the accepted sample;
- 6.38.8.5.2.4 an example of certificate of conformity to be signed by the **Contractor's** specialized CFRP engineer attesting that the materials supplied meet the specified requirements and that all components of the CFRP strengthening system come from the same manufacturer;
- 6.38.8.5.2.5 two (2) copies of the manufacturer's technical data sheets for all components proposed for the CFRP strengthening system and in accordance to Article 6.38.4 *Materials*;
- 6.38.8.5.2.6 a certificate of authorized applicator issued by the manufacturer of the specified product for the CFRP strengthening system works, in the name of the CFRP strengthening system applicator, certifying the status thereof over the last five (5) years. The applicator shall be an authorized applicator from the manufacturer of the specified product and shall have completed a course on how to place a strengthening system consisting of CFRP reinforcing fabric and two-component primer/epoxy impregnating resin. The **Contractor** shall submit a list of projects demonstrating the experience of the authorized applicator over the last five (5) years in the placement of a CFRP strengthening system and of a two-component primer/epoxy impregnating resin on bridges and other civil engineering structures whose summation of treated surfaces corresponds to a minimum of 500 m² carried out;
- 6.38.8.5.2.7 the curriculum vitae of the proposed candidate for the position of CFRP strengthening design engineer. The proposed candidate shall be a member of the OIQ, have a minimum of five (5) years of relevant experience in the design of CFRP in the field of bridges and other civil engineering structures whose summation of treated surfaces corresponds to a minimum of 500 m² carried out. The candidate shall further have a minimum of ten (10) years of experience in bridge and civil engineering structures design.

- 6.38.8.5.3 At least fourteen (14) days prior to the commencement CFRP work, the **Contractor** shall submit to the Engineer, for review, a design note by the engineer who designed the CFRP strengthening works and the CFRP strengthening systems to be placed in accordance with the drawings and the specifications. This design note shall meet the following design criteria:
- 6.38.8.5.3.1 the CFRP shear strengthening system shall be designed in accordance with standard CAN/CSA S6, Chapter 16, subject to the following:
- 6.38.8.5.3.1.1 in accordance with Article 16.11.3.2 of standard CAN/CSA S6, for sections that are neither rectangular nor “T” shaped, such as girders, a detailed analysis accompanied by a literature review of rigorous tests already conducted shall serve as guide in calculating the strengths of the CFRP shear strengthening system;
- 6.38.8.5.3.1.2 the requirements of Article 8.9.3 in reference to Article 16.11.3.2 of standard CAN/CSA S6 shall not be taken into account by the CFRP manufacturer in calculating the additional shear strength of the CFRP. The CFRP $\Delta V_{r \min}$ and $\Delta V_{r \max}$ shear strengthening values indicated in the tables on the drawings take these effects into account;
- 6.38.8.5.3.1.3 the resistance factor to use ϕ_{frp} shall be obtained in accordance with Article 16.5.3 of standard CAN/CSA S6. The applicable factor shall be the one for CFRP in external links application. Moreover, this factor shall be multiplied by 0.75 for CFRP manufactured by liquid encapsulation. The resistance factor to use is therefore 0.6, or 0.75×0.8 ;
- 6.38.8.5.3.1.4 the formula to be used for calculating k_2 in the case of “U” shaped CFRP strips shall be that of Article 16.11.3.2 of standard CAN/CSA S6. However, in the case of individual CFRP strips, the formula to be used shall be that of formula 11.10 *Two Sides Bonded* of standard ACI 440.2R.
- 6.38.8.5.4 The elongation ratio of all vertical strips of the CFRP strengthening system shall be limited to a maximum of 0.0015.
- 6.38.8.5.5 No CFRP mechanical anchors or CFRP wicks are allowed. Only longitudinal anchoring strips may be used in accordance with the locations and dimensions indicated on the drawings. It is the responsibility of the **Contractor** to guarantee the effectiveness of the longitudinal anchoring strips through test and/or calculations by varying the number of plies, spacing and number of strips in order to guarantee the additional strengths from the vertical CFRP.
- 6.38.8.5.6 All overlaps of longitudinal anchoring strips shall be at least 300 mm and located mainly on a concrete surface. Any deviation from the drawings for overlaps of CFRP's shall be authorized by the **Contractor's** CFRP specialized engineer and by the Engineer.

- 6.38.8.5.7 It is prohibited to drill holes in the CFRP after curing, unless authorized by the **Contractor's** CFRP specialized engineer, by the **Contractor's** CFRP specialized design engineer and the Engineer, if required. Any holes drilled in the CFRP strips shall be planned by the **Contractor**, authorized by the Engineer and done before impregnating the resin to the CFRP fabric as indicated on the drawings.
- 6.38.8.5.8 It is the responsibility of the **Contractor** to ensure that the authorized applicator and the manufacturer of CFRP fill the holes by adding additional plies in the CFRP, if required. No hole may be drilled less than three (3) times the diameter of the hole pierced by any free edge of a CFRP strip, unless otherwise specified by the Contractor's CFRP specialized engineer, and with the required additional reinforcements.
- 6.38.8.5.9 All CFRP strengthening systems shall be make it possible to receive subsequent plies in case of additional strengthening by surface preparation.

6.38.8.6 CONDITIONS OF IMPLEMENTATION

- 6.38.8.6.1 The **Contractor** shall ensure that the substrate temperature is at least 10°C and at most 32°C for a minimum period of twelve (12) consecutive hours prior to placing the CFRP strengthening system. This substrate temperature condition shall be maintained throughout the work period and for a minimum period of twelve (12) consecutive hours following placement and until complete curing of the CFRP strengthening system so as to allow the impregnating resin to achieve the minimum mechanical properties required in accordance with the drawings and specifications.
- 6.38.8.6.2 The **Contractor** shall ensure proper thermal protection for the implementation of the CFRP strengthening work. This protection shall be ensured by means of heated shelters, insulating blankets, or combination of these measures.
- 6.38.8.6.3 The **Contractor** shall ensure that the substrate temperature is more than 3°C above the actual dew point in accordance with Article A16.1.3.5b of Appendix A16.1 of standard CAN/CSA S6.
- 6.38.8.6.4 The cementitious repair mortar shall cure for a minimum period of two (2) weeks or have reached a minimum compressive strength of 40 MPa before the **Contractor** undertakes the placement of the CFRP strengthening system. The maximum acceptable humidity of the concrete substrate and cementitious mortar is 4% when checked by means of procedures authorized by the CFRP strengthening system manufacturer. Furthermore, the relative air humidity shall be below 85% in accordance with Article A16.1.3.5c of Appendix A16.1 of standard CAN/CSA S6.
- 6.38.8.6.5 The **Contractor** shall check the pull-off strength of a CFRP strengthening system from concrete and cementitious mortar through direct tension adhesion testing in accordance with standard ASTM D4541. The minimum tensile strength shall be greater than 1.5 MPa. The manufacturer's laboratory and the personnel responsible for conducting the tests shall be previously authorized by the Engineer.

- 6.38.8.6.5.1 The number of adhesion tests through direct tension that shall be conducted to check the pull-off strength of a strengthening system shall be as follows:
- 6.38.8.6.5.1.1 two (2) tests for a girder web;
 - 6.38.8.6.5.1.2 two (2) tests for the bottom flange of a girder;
 - 6.38.8.6.5.1.3 one (1) test for a diaphragm.
- 6.38.8.6.5.2 The location of the tests shall be determined jointly by the **Contractor's** CFRP specialized engineer and by the Engineer.
- 6.38.8.6.5.3 When strengthening work is completed, a test report shall be submitted to the Engineer.
- 6.38.8.6.5.4 The areas tested shall be filled with epoxy resin to the satisfaction of the **Contractor's** CFRP specialized engineer and of the Engineer.
- 6.38.8.6.6 The **Contractor** shall provide appropriate means to ensure the necessary ventilation during the placement and curing of the CFRP strengthening system.
- 6.38.8.6.7 The placement areas shall be freed from other trades during the placement and curing of the CFRP strengthening system.
- 6.38.8.6.8 All concrete and cementitious mortar surfaces intended to receive the CFRP strengthening system shall be repaired and/or reprofiled in accordance with the CFRP manufacturer's recommendations, approved by the **Contractor's** CFRP specialized engineer and by the Engineer and compliant with the drawings and specifications.
- 6.38.8.7 SURFACE PREPARATION
- 6.38.8.7.1 The surface shall be dry, clean and sound, and free of standing water. The **Contractor** shall remove from the surface all dust, laitance, grease, oil, dirt, curing compounds, impregnation, wax, foreign materials, coating and disintegrated materials.
- 6.38.8.7.2 All dust or loose particles shall, prior to the placement of the CFRP strengthening system, be removed from the substrate surface using an industrial vacuum cleaner or low-pressure water jet.
- 6.38.8.7.3 The prepared concrete or cementitious mortar surface shall correspond to a minimum *Concrete Surface Profile* in accordance with the International Concrete Repair Institute indicated on the technical data sheet of the CFRP to implement. All surface membranes shall be removed prior to the placement of the CFRP strengthening system.

- 6.38.8.7.4 The substrate surface receiving the CFRP strengthening system shall be level and shall not have projections or formwork edges greater than 0.5 mm.
- 6.38.8.7.4.1 The concrete of old surface repairs carried out with added thickness shall be demolished and redone leveled with the surface in accordance with subsections 6.21 *Demolition and Removal* and 6.33 *Cast-in Place Concrete*.
- 6.38.8.7.5 Unevennesses greater than 0.5 mm shall be sealed or reprofiled with epoxy resin for the preparation and correction of, or for filling surface cavities in accordance with the CFRP strengthening system manufacturer's recommendations.
- 6.38.8.7.6 The depressions in the substrate surface over a link length shall comply with the values indicated in Table A16.1.1 of standard CAN/CSA S6.
- 6.38.8.7.7 The correction of the concrete substrate shall be carried out at least twenty-four (24) hours before beginning the placement of the CFRP strengthening system.
- 6.38.8.7.8 The corners of the structure components receiving the CFRP strengthening system shall be rounded to a radius of curvature of at least 35 mm in the locations indicated on the drawings.
- 6.38.8.8 PREPARATION OF THE CARBON FIBER FABRIC
- 6.38.8.8.1 The **Contractor** shall carefully cut the fabric to the dimensions required in order to obtain the capacities indicated on the drawings, while respecting the minimum and/or maximum dimensions and spacing indicated on the drawings.
- 6.38.8.8.1.1 Once cut, the fabric shall remain either flat or rolled up.
- 6.38.8.8.1.2 The fabric shall in no case be folded, so as not to damage the fibers.
- 6.38.8.8.1.3 The **Contractor** shall ensure to keep the fabric away from dust and moisture.
- 6.38.8.9 PREPARATION OF THE EPOXY RESIN
- 6.38.8.9.1 The preparation of the epoxy resin shall be done in accordance with the indications of the technical data sheets of the CFRP strengthening system.
- 6.38.8.10 APPLICATION OF THE RESIN ON THE CONCRETE OR CEMENTITIOUS MORTAR SURFACE
- 6.38.8.10.1 Once the surfaces are clean, the corners are rounded and dust is removed, the **Contractor** shall apply one (1) coat of primer in accordance with the indications of the CFRP strengthening system products.
- 6.38.8.10.2 All cavities, voids or uneven surfaces shall be filled with the resin recommended by the CFRP manufacturer as indicated in Article 6.38.4 *Materials*.

6.38.8.11 IMPREGNATION OF THE EPOXY RESIN INTO THE CARBON FIBER FABRIC

6.38.8.11.1 The CFRP fabric shall be impregnated one (1) ply at a time with the epoxy resin, by means of a roller or manually.

6.38.8.11.2 The impregnated CFRP fabric shall be wrapped around a plastic pipe or around a 25.4 mm x 76.2 mm timber strip and allowed to stand for about thirty (30) to sixty (60) minutes at a temperature of at least 10°C and at most 32°C or any other technique deemed equivalent and authorized by the **Contractor's** CFRP specialized engineer.

6.38.8.12 APPLICATION OF THE EPOXY RESIN-IMPREGNATED FABRIC

6.38.8.12.1 The **Contractor** shall comply with the following requirements, without however being limited thereto:

6.38.8.12.1.1 begin by placing the vertical reinforcing strips on the webs, one (1) ply at a time. If several plies are required, the **Contractor** shall wait after one (1) ply of vertical and longitudinal strips is placed before placing the subsequent ply. In the case where there are both straight and inclined vertical strips, the **Contractor** shall begin by placing all inclined vertical strips and then place the straight vertical strips, one (1) ply at a time;

6.38.8.12.1.2 slightly and carefully stretch the CFRP fabric to unroll it onto the concrete surface to be strengthened. Ensure intimate contact to prevent the formation of folds and entrapment of air pockets. Use rubber gloves, spatulas or suitable rollers to smooth the impregnated CFRP fabric surface;

6.38.8.12.1.3 comply with the instructions and with all the restrictions and warnings relating to the materials used to form the CFRP strengthening system as recommended by the manufacturer;

6.38.8.12.1.4 after having placed one (1) additional ply of CFRP vertical strips, place one (1) ply of CFRP longitudinal anchoring strips in accordance with the dimensions and notes in the placement drawings, within the maximum delays between applications specified by the manufacturer;

6.38.8.12.1.5 subsequently, if required by the manufacturer, place the other plies, one (1) at a time, following the steps prescribed in paragraphs 6.38.8.12.1.1 to 6.38.8.12.1.4, taking care to place one (1) additional ply of vertical strips followed by one (1) additional ply of longitudinal strips in order to create an interlaced effect of the longitudinal and vertical strips;

6.38.8.12.1.6 place one (1) final layer of resin on all areas of strengthening, paying special attention to the edges, corners and ends of the reinforcements;

- 6.38.8.12.1.7 unless otherwise specified by the Engineer and by the **Contractor's** CFRP specialized engineer, the CFRP strengthening system shall not be disturbed for a minimum period of twenty-four (24) hours at a temperature of 23°C and relative humidity of 50%, once all plies are placed;
- 6.38.8.12.1.8 an adequate temporary protection shall be installed during the initial curing of the CFRP strengthening system;
- 6.38.8.12.1.9 with the exception of the anchor blocks for external post-tensioning subsequently added over the existing CFRP, laying any object on the CFRP strengthening system is prohibited. No platform, equipment or grapple shall rest on the girders or diaphragms in the locations where a CFRP strengthening system has been placed.

6.38.8.13 APPLICATION OF UV PROTECTANT

- 6.38.8.13.1 After having been placed, the CFRP strengthening systems shall be protected from UV radiation by a protective layer using a UV protective product authorized by the **Contractor's** CFRP specialized engineer and by the Engineer, unless the CFRP resin in place already includes such protection deemed as adequate by the **Contractor's** CFRP specialized engineer and the Engineer.

6.38.8.14 CLEANING

- 6.38.8.14.1 The **Contractor** shall remove all materials and residues remaining on the worksite and dispose thereof in accordance with subsection 6.13 *Environmental Protection*.
- 6.38.8.14.2 The uncured epoxy resin can be cleaned with a solvent authorized by the **Contractor's** CFRP specialized engineer and by the Engineer. The **Contractor** shall remove the cured epoxy resin that is not affected by solvents or chemical cleaners by mechanical means such as grinding, scaling or scraping.

6.38.9 QUALITY CONTROL

- 6.38.9.1 The **Contractor's** CFRP specialized engineer shall be present throughout the placement to assist and monitor the placement of the CFRP strengthening system, in order to ensure that the authorized applicator follows the manufacturer's recommendations for placement. If anomalies related to the placement are detected, the **Contractor's** CFRP specialized engineer shall immediately notify the Engineer thereof.

6.38.9.2 DELIVERY OF THE REGISTER

- 6.38.9.2.1 Upon completion of CFRP strengthening, the **Contractor** shall produce and submit to the Engineer, for each girder and diaphragm, a register containing all final results of inspections and testing of the CFRP strengthening system materials, including the pull tests in accordance with standard ASTM D-4541. This register shall also include all final repairs made to the CFRP strengthening system. A report of all anomalies identified and measures of correction thereof implemented shall also be submitted to the Engineer no later than five (5) days following the completion of the strengthening works.

6.38.9.3 FINAL INSPECTION

- 6.38.9.3.1 A final inspection of the CFRP strengthening system shall be conducted by the **Contractor's** CFRP specialized engineer, in the presence of the Engineer, after the curing of the epoxy resin is fully completed. The delaminations and all other anomalies detected shall be evaluated on the basis of their importance and number relative to the total area of application as well as of their location relative to the load transfer from the structural point of view. The **Contractor** shall prepare a final inspection which shall be provided to the Engineer for review.
- 6.38.9.3.2 For each girder and diaphragm strengthened, the following inspections shall be conducted by the **Contractor's** CFRP specialized engineer following the completion of CFRP strengthening:
- 6.38.9.3.2.1 echo-sounding, hammer survey of all CFRP strengthening system surfaces;
- 6.38.9.3.2.2 ultrasound of all CFRP strengthening system surfaces;
- 6.38.9.3.2.3 the **Contractor's** CFRP specialized engineer may, with the prior authorization of the Engineer, choose the thermography inspection as an alternative to the two (2) above-mentioned methods.
- 6.38.9.3.3 Any inspection method used shall make it possible to identify delaminations of a minimum surface area of 1500 mm².
- 6.38.9.3.4 The **Contractor** shall remove a delaminated strip when delaminations exceed 1500 mm² or 5% of the total laminated surface area. The removal of this strip shall be followed by the addition of a strip overlapping the patching by 150 mm, with a number of plies which is equivalent to the removed strip. The strip shall then be re-inspected and the results of that inspection shall be compared with those of the initial inspection to check if the repairs were made in accordance with the drawings and the specifications.

END OF SUBSECTION