



JOHN ELIAS BALDACCI  
GOVERNOR

STATE OF MAINE  
DEPARTMENT OF TRANSPORTATION  
16 STATE HOUSE STATION  
AUGUSTA, MAINE  
04333-0016

DAVID A. COLE  
COMMISSIONER

May 25, 2010  
Subject: **T5 R9 (Ebeemee)**  
State Project No: 017088.00  
**Amendment No. 1**

Dear Sir/Ms:

Make the following changes to the Bid Documents:

NOTE: MaineDOT is adding a fiber reinforced plastic (FRP) lining as a liner option within the existing culvert. Please refer to the revised and additional specifications mentioned below.

In the Bid Book (pages 39 and 40), **REMOVE** "SPECIAL PROVISION, SECTION 502, STRUCTURAL CONCRETE CULVERT INVERT LINING" 2 pages dated January 2, 2003 and **REPLACE** with the attached new "SPECIAL PROVISION, SECTION 502, STRUCTURAL CONCRETE CULVERT INVERT LINING" 2 pages dated May 12, 2010.

In the Bid Book, after page 47, **ADD** the attached "SPECIAL PROVISION, SECTION 509.73, COMPOSITE INVERT LINING OPTION", 12 pages dated May 12, 2010.

Consider this change and information prior to submitting your bid on June 2, 2010.

Sincerely,

Scott Bickford  
Contracts & Specifications Engineer



PRINTED ON RECYCLED PAPER

**SPECIAL PROVISION**  
**SECTION 502**  
**STRUCTURAL CONCRETE CULVERT INVERT LINING**

Description The work shall include preparation of existing surfaces, installation of machine bolts or studs, spot painting of corroded areas, placement of concrete, and the application of emulsified asphalt.

The Contractor has the following options for the culvert invert lining:

1. Cast in place concrete.
2. Shotcrete with cast in place concrete for any fish weirs. If the Contractor chooses this method, the shotcrete special provision must be followed.
3. Glass fiber reinforced plastic liner. If the Contractor chooses this method, the composite invert lining special provision must be followed.

Materials Concrete for the culvert repair shall be modified Class LP Concrete. The concrete mix shall include a chemical accelerator and shall be submitted to the Resident for prior approval.

Construction Requirements All work shall be in conformity with applicable requirements of Section 502.

Stud welded shear connectors or machine bolts shall be installed in accordance with Section 505 of the Standard Specifications, except that Section 505.04 shall be ignored.

All reinforcement shall be secured in place to prevent displacement during the concrete placement.

The upstream and downstream ends of the invert slab shall taper down from 5 in to 2 in minimum (measured from the top of the corrugations inside the pipe) at each end of the culvert. The taper will be approximately 8 in long.

Finish the entire length of the concrete invert with a rough broom surface, 3 ft wide.

All horizontal edges of exposed concrete shall be sealed with an asphalt emulsion which extends onto the culvert at least 1 in.

All areas of section loss above the concrete shall be sandblasted and painted with an MC Zinc Primer with MC Urethane with a Mox Tar Topcoat.

The Contractor shall sandblast all areas from 1 in below the top of concrete lining to 6 in below lowest row of shear connectors. The Contractor shall remove all loose materials, rust,

scale, oil and deleterious material from all remaining receiving surfaces to receive concrete by methods acceptable to the Resident. In areas where the metal is non-existent, a preliminary concrete placement shall be made utilizing forms where required, to fill voids and establish the former extremity lines of the metal. The final placement is to be made over this preliminary placement. No concrete shall be placed on frozen surfaces.

An approved curing cover (or compound) shall be applied within 18 hours after finishing. Finished concrete shall be cured for a minimum of 48 hours before flushed with water, unless otherwise directed by the Resident, and flush water must be collected as per Section 656.

Method of Measurement The structural concrete for the culvert invert lining, satisfactorily placed and accepted in accordance with the dimensions shown on the plans, will be measured as one lump sum unit.

Basis of Payment The accepted structural concrete for the culvert invert lining will be paid for at the contract lump sum price for Structural Concrete Culvert Invert Lining. The contract lump sum price shall be full compensation for preparing surfaces, filling large voids with concrete installing machine bolts or studs, spot painting of corroded areas with an MC Zinc Primer with MC Urethane with a Mox Tar Topcoat, placing concrete, applying of asphalt emulsion and furnishing all materials, equipment, labor and incidentals necessary to complete the work.

If the FRP composite lining option is selected, the lump sum price shall include preparing surfaces, filling large voids with concrete, spot painting of corroded areas, design, fabrication, and delivery of the liner segments; installation of the liner including fasteners, placement of grout and furnishing all materials, equipment, labor and incidentals necessary to complete the work.

Concrete admixtures including silica fume will not be paid for directly, but shall be incidental to the related contract item.

Any fish weirs located inside the culvert shall be paid for under item 502.326.

The containment and disposal of pollutants during surface preparation will not be paid for directly, but shall be incidental to the related contract item and included in the Contractor's SEWPCP.

Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
502.325      Structural Concrete Culvert Invert Lining	Lump Sum

**SPECIAL PROVISION**  
**SECTION 509.73**  
**COMPOSITE INVERT LINING OPTION**  
(FURNISHING AND INSTALLING COMPOSITE INVERT LINER)

**DESCRIPTION**

The work is the repair of a corroded invert of a corrugated steel culvert within the limits of the existing culvert or as directed by the Resident. The work shall include preparation of existing surfaces, spot painting of corroded areas as directed by the resident, concrete placement to fill large void(s), installation of the glass fiber reinforced polymer (FRP) liner, placement of grout as indicated on the plans, and in accordance with this specification; and as directed by the Resident.

**DEFINITIONS**

For the purpose of this specification, the following definitions apply:

<b>E-glass</b>	Alumo-borosilicate glass with an alkali content of maximum one weight percent, when expressed as sodium oxide (Na <sub>2</sub> O)
<b>Effective length of unit</b>	The distance between planes normal to the unit axis and passing through the end points of the lining unit
<b>Liner segment</b>	A discrete length of culvert lining which may be either a single pipe lining unit or a combined pair of segmental lining units
<b>Vinyl ester resin</b>	A resin produced by the esterification of an epoxy resin with an unsaturated monocarboxylic acid – the reaction product is then dissolved in a reactive solvent, such as styrene, to a 35 - 45 percent content by weight

**MATERIALS****GLASS MAT**

A layer of E-glass fiber constructed as either chopped strand mat (CSM) or continuous filament mat (CFM) that provides a resin rich FRP layer near the corrosion/erosion exposed surface. All glass fiber reinforcement shall have a surface treatment (binder) compatible with the lining manufacturing process and the matrix resins. A stitched material laminate is also acceptable.

## GLASS FIBER REINFORCEMENT

All glass fiber reinforcement shall be E-glass or better and have a surface treatment compatible with the lining manufacturing process and the matrix resins. Unidirectional (UD) reinforcement areal weight shall not exceed 55 oz/yd<sup>2</sup> in any single ply. A layer of CSM or CFM shall separate layers of UD fabric where applicable to maintain laminar shear strength. The E-glass material shall not contain more than 0.2% moisture by weight as supplied; it shall be uncontaminated and protected to the point of use.

## GROUT

Grout having a 28-day compressive strength of at least 5,000 psi at the desired water content for optimum placement shall be used. The permissible mixing and placement temperature range per the manufacturer's recommendations shall not be lower than 40°F or higher than 90°F. The non-shrink grout shall have a Hardened Height Change per ASTM C1090 of 0.0 to 0.3%.

## RESIN

Vinyl ester corrosion resistant resin shall be used with a catalyzation process applied in accordance with the resin manufacturer's instructions. The resin shall have a viscosity suitable for vacuum infusion. The gel time shall be adequate for the given environmental conditions present during the manufacturing process. The gel time must allow for the elimination of wedging within the part. Resin promotion should allow for adequate cure during manufacture. Resin must achieve 80+% of manufacturer's Barcol value without post curing.

Cured resins, as cast singly without reinforcement, shall have an elongation at break greater than 5% when tested in accordance with ASTM D790. In addition, the Barcol Hardness as determined by ASTM D2503 shall be at least 30. Resins "flexibilised" by the addition of plasticisers shall not be used.

## COATING

Dyes, pigments, or additives shall be introduced as necessary in the resin to provide resistance to ultra-violet light degradation and a uniform, muted appearance.

## FASTENERS

Carbon steel fasteners and washers with a minimum 0.2 mil zinc coating shall be used. Fasteners shall have a minimum shank diameter of 0.138 inches and washers shall have a diameter of between ¾ to 1 inch.

## **DESIGN**

The FRP liner shall have a minimum total thickness of 0.25 inches. A minimum of 2 rows of fasteners shall be used.

The Contractor shall design the FRP liner in accordance with the AASHTO LRFD Bridge Design Specifications, current edition. The design live load shall be as follows: \*modified HL-93 Strength I for LRFD method. \*(modify HL-93 by increasing all wheel loads by a factor of 1.25). Any part of the design of the FPR not covered or supported by AASHTO shall be noted in the design computations. The designer shall also document in the design computations any part of the design of the FPR liner that is based on physical testing or research results.

A composites engineer shall determine the appropriate reinforcing ply thickness to satisfy all strength, stiffness, and seam strength requirements assuming the corroded invert does not provide any residual strength to the system. Mechanical testing performed by a certified (ISO 9000 or equivalent) testing laboratory shall be conducted to verify predicted material properties for final design and provide quality control data.

The Contractor shall submit design calculations and shop drawings for the FRP liner to the Department for approval. A Registered Professional Engineer, licensed in accordance with State of Maine laws, shall sign and seal all design calculations and drawings. Drawings shall conform with Section 105.7 - Working Drawings.

## **CONSTRUCTION**

### **GENERAL**

All culvert linings shall be manufactured with the following elements:

- a. a corrosion and abrasion resistant barrier layer
- b. a reinforcement layer comprised of double bias and unidirectional fabric
- c. a rough backing to provide a bond between the lining and annulus grout
- d. a nailing flange that is offset from the general liner radius

The manufacturing facility shall have an American Composites Manufactures Association Certified Composites Technician (CCT) certified in the Vacuum Infusion Process (VIP) on staff to supervise or perform the layup and infusion of all composite components.

#### BARRIER LAYER (BL)

The BL shall be manufactured from a vinyl ester resin system reinforced with E-glass CSM or CFM between 40-50% content by weight. The BL shall be a minimum of 0.12 inches thick.

#### GLASS REINFORCEMENT

The structural layer shall be made up of vinyl ester resin impregnated layers of E-glass fiber. The two outer plies shall be double bias ( $\pm 45$ ) stitched or woven fabric having an areal weight of at least 24 oz/yd<sup>2</sup>. The inner plies shall be made up of unidirectional (UD) E-glass with the fiber direction oriented in the circumferential (hoop) direction of the liner. The areal weight of the UD plies shall be selected by analysis and test to satisfy strength and stiffness requirements. The structural layer shall have a fiber content of between 55%-65% by weight.

#### LINER FABRICATION

Each fabric layer comprising the FRP liner shall be placed in a mold having the same nominal inner radius as the culvert minus 1 inch to avoid contact with the culvert bolts. A nailing flange shall transition outward to the nominal inner radius of the culvert extending a minimum of 2 times the number of fastener rows plus 1 inch. A gradual transition shall exist between the two liner radii extending between 3 to 6 inches depending on liner radius. The extent of the liner in the circumferential dimension shall be such that the bottom row of fasteners is at least 6 inches above the limit of the rust line. The dimensions of the liner shall be approved by the Resident before fabrication begins. A sample design is presented in Figure 1.

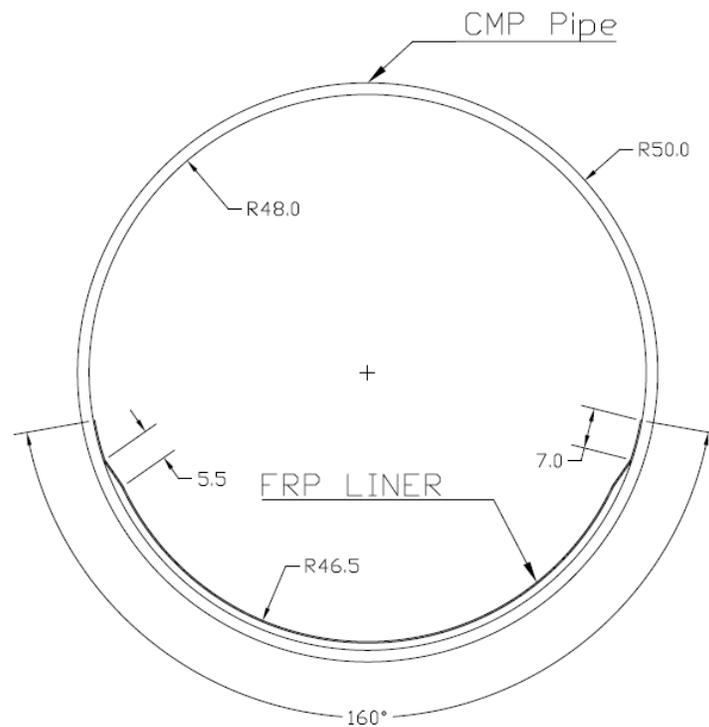


Figure 1 – Sample Liner Dimensions

### ROUGH BACKING

A clean, dry aggregate shall be bonded to the back of the FRP liner to promote a mechanical bond between the liner and grout filler. It shall consist of an angular, inert material, such as crushed granite, nominally 1/8 to 1/4 inch in size uniformly distributed over the external surface. A CSM layer with an areal weight at least 1.5 oz/ft<sup>2</sup> shall be hand laid on to the back of the liner using vinyl ester resin and rollers to provide a resin-rich embedment layer for the aggregate. Once the resin has cured, a stiff broom shall be passed over the surface to remove any loose or poorly bonded aggregate. The aggregate must uniformly cover 50% or more of the total surface area of the back of the panel.

### FISH WEIR FABRICATION

Weirs shall be fabricated from E-glass fabric and vinyl ester resin using the materials described above. The size, shape, and elevation of the weir features shall be approved by Resident. Wall thickness shall be at least 1/2 inch. Wall thickness may need to increase based on panel radius. Allowable stresses as per RTP1-2007.

### EDGES AND ENDS

The edges and ends of all trimmed lining segments and sections shall be sealed with a vinyl ester resin to prevent the exposure of glass fibers. The resin shall be pigmented to match the color and performance of the laminating resin.

## **Grouting**

Performance Requirements Prior to any work the Contractor shall furnish an acceptable plan for performing and testing the grouting. The Contractor shall submit the proposed grout mix, methods, plans and criteria of the grouting operations. The grouting system shall have sufficient gauges, monitoring devices and tests to determine the effectiveness of the grouting operation and to ensure compliance with the liner specifications and design parameters.

(c) Mix Designs One or more mixes shall be developed to completely fill the annular space based on the following requirements:

- (1) Size of annular void
- (2) Void (size) of the surrounding soil
- (3) Absence or presence of groundwater
- (4) Sufficient strength and durability to prevent movement of the liner
- (5) Provide adequate retardation.

Qualifications The Contractor shall demonstrate to the Resident its worker's capabilities of filling the annular space and performing their work in conformance with the Plans and the Specifications.

Grouting Equipment The materials shall be mixed in equipment of sufficient size and capacity to provide the desired amount of grout material for each stage in a single operation. The equipment shall be capable of mixing the grout at densities required for the approved procedure and shall also be capable of changing density as dictated by field conditions any time during the grouting operation.

Injection Procedure and Pressure The Contractor shall use a low pump pressure and have no delays in placing the grout

Submittals and Required Calculations The Contractor shall submit the following to the Resident for his review and approval at least 30 working days prior to the start of the grouting operation:

- 1) The proposed grouting mix
- 2) The proposed densities and viscosities
- 3) Initial set time of the grout
- 4) The proposed grouting method
- 5) The maximum of injection pressures
- 6) The 24-hour and 28 day compressive strengths
- 7) Proposed grout stage volumes
- 8) Flow control

- 9) Provisions for service connections
- 10) Pressure gauge certification

Certification that grouting plan conforms with all provisions, cautions and restrictions of the liner manufacturer

### **Quality Control Plan**

The Contractor shall develop, submit and implement a Quality Control Plan (QCP) for the glass fiber reinforced polymer (FRP) liner segments. The quality control plan shall be in general accordance with section 106.4 of the standard specifications. Requirement of section 106.7 shall not apply.

Section 106.4.4 is replaced in its entirety with the following:

The Contractor's QC inspector shall have a minimum of 5 year experience in FRP fabrication.

## **INSTALLATION**

### **GENERAL**

#### **Flow Diversion**

Flow shall be rerouted or dammed prior to culvert cleaning and until after the liner, grout, and weirs have been installed. The presence of some groundwater is acceptable as long as flow is prevented along the length of the culvert. Any water propagating through the corroded invert of the culvert must be contained prior to panel installation. No grout dilution is allowable.

#### **Cleaning and Preparation**

Debris shall be removed from the culvert and disposed of in accordance with state and local environmental requirements. The invert shall be pressure washed to remove soil and loose, corroded material from the culvert. All debris should be removed by mechanical means. Any holes in the steel culvert shall be sealed with hydraulic cement. Bolts that protrude more than 1 inch above the crest of corrugations shall be trimmed prior to placing the FRP liner. Bolts shall be cut off flush with the top of the nut.

## LINERS

### Attachment

The exact position of the first liner segment placed at one end of the culvert shall be determined based on the segment length and the overall length of the culvert such that the first and last liner segments shall be at least 5 feet long.

Liner segments shall be secured to sound steel using powder-actuated galvanized steel fasteners. The frequency and spacing of the fasteners shall be determined by engineering analysis of the seam strength requirements. Fasteners shall be driven with enough energy to ensure the head and washer are seated tight against the FRP liner and that contact is maintained between the FRP liner and steel culvert while avoiding excess force that may cause cupping of the washer or damage to the FRP. Jacking poles may be used to hold the FRP against the steel in places where sudden geometry changes prevent contact under dead weight. The allowance of any gap between the FRP liner and the steel culvert is at the discretion of the Resident and shall be minimized.

### Trimming

Liner segments placed at the culvert ends shall be trimmed to match the taper of the existing steel culvert. The ends shall be sealed with a mixture of resin and fiber to contain the annular grout. All trimmed edges shall be treated in accordance with the "Edges and Ends" section of this document.

### Joining

All joining of panels shall be designed as per RTP1-2007 standards and specifications. Reference sections 3A-800 Secondary Bond Shear Stress and subpart 3B Design by Stress Analysis sections 3B-100 through 3B-700 to determine proper joint design. Refer to RTP1-2007 Mandatory Appendix M-5 Qualification of Laminators and Secondary Bonders for the required standards and practices. See section M-5 for required procedures to properly manufacture and test shear bond strength specimens.

## FISH WEIRS

### Size and Location

The number, size, geometry, and location of FRP fish weirs, unless noted otherwise on the plans shall be determined by the Department.

### Fitting

Each fish weir shall be fabricated oversized and trimmed to fit in the field in the required location. All trimmed edges shall be treated in accordance with section 4.6. The final weir channel elevation of the trimmed part shall be verified prior to attachment.

### Attachment

The internal fish weirs shall be attached to the liner through the use of a methacrylate adhesive capable of bridging a gap of at least 0.250". The weir must be 100% edge sealed with the adhesive. The adhesive must be allowed to completely cure prior to installing the final weld kit. The final weld kit shall be installed on the upstream side of the weir and across the top seams on both sides. The weld kit shall be in accordance with ASME RTP-1 specifications. Glass used shall be E-glass and consist of a combination of 1.5 oz CSM and 24 oz Woven Roving. All weld kits must be final coated and leave no exposed areas.

### QUALITY ASSURANCE

As part of the quality assurance procedures, the manufacturer shall keep records of the following against each batch of output product:

- raw material batch details, including source, acceptance test records, purchase dates and shelf-life at time of use
- resin mixing records
- initiator level
- mold pressure at commencement of infusion
- mold temperature
- resin temperature
- ambient temperature of the shop
- infusion start and stop time
- visual inspection results of the cured part
- final Barcol readings
- technician names and date of manufacture

### APPEARANCE AND SURFACE CONDITION

The surface of the lining material shall be free from tackiness and defects such as protruding fibers, air voids, crazes, cracks, blisters or foreign matter that might impair the performance in service. The internal surface of the lining shall be smooth. The surface of the panels shall be finished with a pigmented UV resistant final coat. Pigment must be compatible with the resin system.

### JOINTS

The liner and joint shall be designed so that the resulting lap joint is flush with the interior surface of the liner segments. The flexible or rigid joints are required to provide a permanent seal between liner segments to protect the integrity of the

grout and prevent water ingress. Rigid setting or flexible compounds used to caulk or seal the gap between liner segments shall be resistant to the environment for which they are intended, and shall be suitable for installation within a confined space taking safety aspects into consideration. Upon complete cure of the sealing compound the joint should be finished with a weld kit designed in accordance with ASME RTP-1 specifications and final coated.

#### TYPE TESTS

Coupon tests to verify predicted mechanical properties used during preliminary design shall be performed before completing the detail design. These tests shall include flexural strength and modulus per ASTM D7264 and compressive strength and modulus per ASTM D6641. Component level tests shall be performed to verify the predicted buckling strength of the FRP/grout system and the shear capacity of the connection. The acceptable design value for strength is the mean minus two standard deviations. The acceptable design value for modulus is the mean.

#### QUALITY CONTROL TESTS

##### General

The following test requirements are necessary in order to demonstrate a continuing satisfactory level of production quality in day to day production. The manufacturer shall establish a quality system to meet the requirements of ISO 9001 or ASME RTP-1. Witness panels fabricated at the same time using the same materials as the liner or cut-outs from the liner segment shall be used to conduct verification tests for every tenth panel fabricated. A minimum of 2 witness panels shall be used for testing on each individual culvert to be lined.

##### Dimensions

Wall thickness and resin rich layer thickness shall be determined at a minimum of three locations in each test sample using a method of measurement accurate to the nearest 0.005 inches by measuring cut surfaces through the lining wall. The cut surfaces shall be smoothed sufficiently for the different layers to be delineated. Generally the locations of cores shall include:

- (i) a point towards the center of the test sample and
- (ii) points near each end of the test sample, but not at a joint.

##### Resin cure

The surfaces shall not be tacky to the touch. Each test specimen shall be tested in accordance with the method described in ASTM D2583 at a minimum of three points and shall have a hardness not less than the minimum declared in the "Resin" subsection of the "Materials" section of this document. Post curing is permissible if necessary to achieve the desired results.

#### Analysis of construction

The disposition of the laminates or layers and the constituents within them shall correspond to those of the type tested liners. The percentage by weight of the constituents and the weight of glass per unit area shall not deviate from the declared control values by more than  $\pm 10\%$  (of each numerical value).

#### Appearance

The internal and external surfaces of each lining unit shall be examined visually and be free from defects. Where practicable this shall occur prior to application of any bed mat backing or pigmented, UV resistant final surface coating.

#### Mechanical Properties

The coupon tests described in 6.4 shall be conducted on test samples. The Quality Control Test results are acceptable if the calculated design values (as described in 6.4) are not less than 95% of the Type Test values.

#### CONTROL OF TEST CONDITIONS

##### Test conditions

Unless otherwise required by this specification the test measurements shall be conducted at a temperature of  $72 \pm 10^\circ\text{F}$  and relative humidity of  $50 \pm 10\%$ .

##### Specimen conditioning

For Type Testing, specimens shall be kept in air  $72 \pm 10^\circ\text{F}$  and  $50 \pm 10\%$  RH for not less than 72 hours prior to testing.

For Quality Control Testing, specimens shall be kept in air at  $72 \pm 10^\circ\text{F}$  and  $50 \pm 10\%$  RH for not less than 24 hours after they are considered to be cured.

##### Test specimen preparation

Test specimens shall be prepared in accordance with the applicable ASTM standards.

#### WORKMANSHIP, INSPECTION AND CERTIFICATION

##### Manufacturing Process

FRP liners shall be manufactured using vacuum assisted resin transfer molding (VARTM) to ensure the production of high quality components and repeatability of physical and mechanical properties.

All layers of the FRP liner shall be produced in a single-injection process whereby barrier elements and reinforcing layers are formed in a singular resin infusion step.

All raw materials shall be tested at a frequency sufficient to ensure consistency and compliance with this specification. The manufacturer shall adequately supervise all stages of production and keep records of the raw material batches used and products made each work shift or day. Manufacture shall be under environmental conditions compatible with producing satisfactory liners and raw materials shall be stored and used in compliance with the recommendations of their manufacturers.

Reinforcement materials shall be stored in dry conditions. The liner manufacturer shall be familiar with the changes in viscosity, gel times, etc., which may occur during storage of the resin, and make appropriate allowances in the lining manufacturing process. Resin stored in original unopened containers shall not be used after the resin manufacturer's stated expiration date.

#### Inspection

In addition to the manufacturer's own inspection and supervision, the Department shall have access at all reasonable times to inspect parts and all relevant test records.

#### Certification

The manufacturer shall, on request, furnish the purchaser or purchaser's representative, with copies of a signed certificate for each size of liner stating that the construction and testing of liner segments supplied comply with the requirements of this specification and given details of minimum performance parameters agreed with the purchaser. If required by the purchaser, the quality control test results or a suitable summary shall be provided with the certificate.

#### PROTECTION OF LINING UNITS

Liner segments shall be handled, stored and transported in such a way as to prevent damage. Steel chains or steel straps shall not be used.