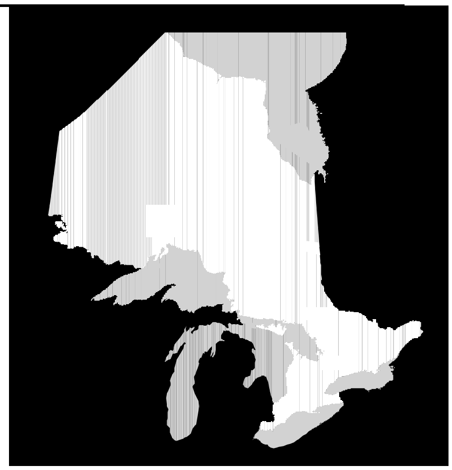
Ontario

Ministry of Transportation
Standards and Contracts Branch
Structures Office Report



Guidelines for Inspection and Field Acceptance of Glass Fibre Reinforced Polymer (GFRP) Reinforcing Bars

STR-00X

Technical Report Documentation

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Abstract	These guidelines have been developed to assist Construction Inspectors, Contract Administrators and Quality Assurance Officers in visually identifying Glass Fibre Reinforced Polymer (GFRP) Reinforcing Bars that are acceptable or not acceptable for use on MTO contracts. Products from all manufacturers of GFRP Reinforcing Bars currently being supplied to MTO projects have been considered in developing this document and figures are representative of the bars available at the time this document was developed. This document is by no means exhaustive with respect to examples of acceptable and not acceptable GFRP Bars.
Key Words	Glass Fibre Reinforced Polymer (GFRP); Reinforcing Bars; Inspection
Distribution	Unrestricted technical audience.

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Guidelines for Inspection and Field Acceptance of Glass Fibre Reinforced Polymer (GFRP) Reinforcing Bars

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Prepared by
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Ontario Ministry of Transportation

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1. Introduction

These guidelines were established for Quality Assurance personnel, Construction Inspectors, and Contract Administrators (CA), to more uniformly, across the Province, visually identify Glass Fibre Reinforced Polymer (GFRP) reinforcing bars that are acceptable for use on Ministry of Transportation Ontario (MTO) contracts. These guidelines show examples of acceptable product as well as deficiencies and inadequacies that have been observed on GFRP bars. However, they do not provide an exhaustive list of all deficiencies that could possibly be encountered and are to be used to supplement Special Provision No. 999S02.

In the event of any inconsistency or conflict between Special Provision No. 999S02 and this Guideline, the special provision shall take precedence.

The guidelines were originally prepared in the year 2011 and updated in the year 2018 by the Materials Engineering Research Office, Concrete Section. This update has been prepared by the Structures Office, Bridge Design and Standards Section which is the custodian office of the MTO Designated Sources for Materials (DSM) lists for GFRP.

With a plan for future improvement, the authors welcome comments and additional photographs of both conforming and non-conforming products for future revisions which should be addressed to:

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2. Statement of Purpose

This document has been prepared to assist the Contract Administrator and the associated inspection staff in making informed decisions on the acceptability of GFRP bars in the administration of construction contracts for the MTO. It will encourage the supply of quality GFRP bars through supporting effective and consistent quality audits by MTO and contract staff.

2.1. Construction Inspection

The objective of construction inspection of GFRP bars is to verify that DSM qualified products have been manufactured and supplied in accordance with the governing specifications. Also, to maximize the safety and reliability of bars by confirming they have been placed and protected according to the contract documents.

2.2. Quality Assurance (QA) Inspection

The objective of quality assurance inspection of GFRP bars includes:

- Monitoring and evaluating material quality and conformance with applicable specifications in the field;
- Assessing conformance with the qualified products on the MTO DSM list;
- Auditing construction inspection and administration of the materials specifications;
- Identifying issues with current specifications; and,
- Providing technical expertise and support to MTO offices.

3. GFRP Bar Types and Manufacturers

3.1. Designated Sources for Materials List #9.65.90

GFRP bars supplied to Ministry Contracts must be manufactured by a supplier from a production facility listed on the Designated Sources for Materials (DSM) list current at the time of the work and be of the grade specified by Ministry contract documents. Therefore, always refer to the DSM and the respective contract documents to identify acceptable suppliers and grade of GFRP bars to be used on an MTO contract. A copy of the current DSM list may be found at The Road Authority or by contacting the Custodial Office: Structures Office (905) 704-2406.

Table 1 provides a list of GFRP reinforcing bars along with their respective suppliers and grades, current as of April 2022.

Table 1 – Glass Fibre Reinforced Polymer – Reinforcing Bar (DSM #9.65.90)

Company	*Product Name*	*Product Grade / Type*	*Description*
MST Rebar Inc. 260 Hanlan Road Woodbridge ON L4L 3P6 Canada Tel: 416-740-0377 Email: info@bandbfrp.com Web: www.MSTBAR.com	MST-BAR	• Grade III straight bar • Grade III bent bar • Grade III straight bar with anchor head	Composed of E-CR glass fibres embedded in a vinyl-ester resin and has a circular cross section with exterior roving to create exterior deformations (grooved bars).
Pulltrall Inc. 700 9th Street North Thetford-Mines QC, G6G 6Z5 Canada Tel: 418-335-3202 Web: www.pultrall.com	V-Rod	• Grade III straight bar • Grade III bent bar • Grade III straight bar with anchor head	Composed of E-CR glass fibres embedded in a vinyl-ester resin and has a circular cross section coated with coarse sand.
Pultron Composites Street S404 Jebel Ali Freezone South South Dubai Tel: 971-4-880-9533 Email:mateen@mateenbar.com Web: www.mateenbar.com	MateenBar	• Grade III straight bar • Grade III bent bar	Composed of E-CR glass fibres embedded in a vinyl-ester resin and has a circular cross section with a continuous machined surface to form the helical spiral deformation.
TUF-BAR Inc. S522 36 St. NW Edmonton AB T6B 3P3 Tel: 1-780-462-8100 Email: info@tuf-bar.com Web: www.tuf-bar.com	TUF-BAR	• Grade III straight bar • Grade III bent bar	Composed of E-CR glass fibres embedded in a vinyl-ester resin and has a circular cross section with helical spirals coated with sand.

3.2. Sample Photos of Products

The following are examples of generally acceptable product sorted by manufacturer. Figure 1 to Figure 14 show samples of each respective bar from each supplier and are examples of bars which have been procured for MTO contracts. However, this document may not be updated as suppliers are added or removed from the DSM list; it is intended that any example below may be used to assess the acceptability of product from any manufacturer.

Products which are no longer listed on the DSM are included in Section 3.2.2. These are examples of acceptable product for the purpose of establishing a general baseline for all products. Note: the reader should make no assumptions about delisting.

3.2.1. DSM #9.65.90 Listed Products

3.2.1.1 MST-BAR

Figure 1 – MST-BAR: straight bar

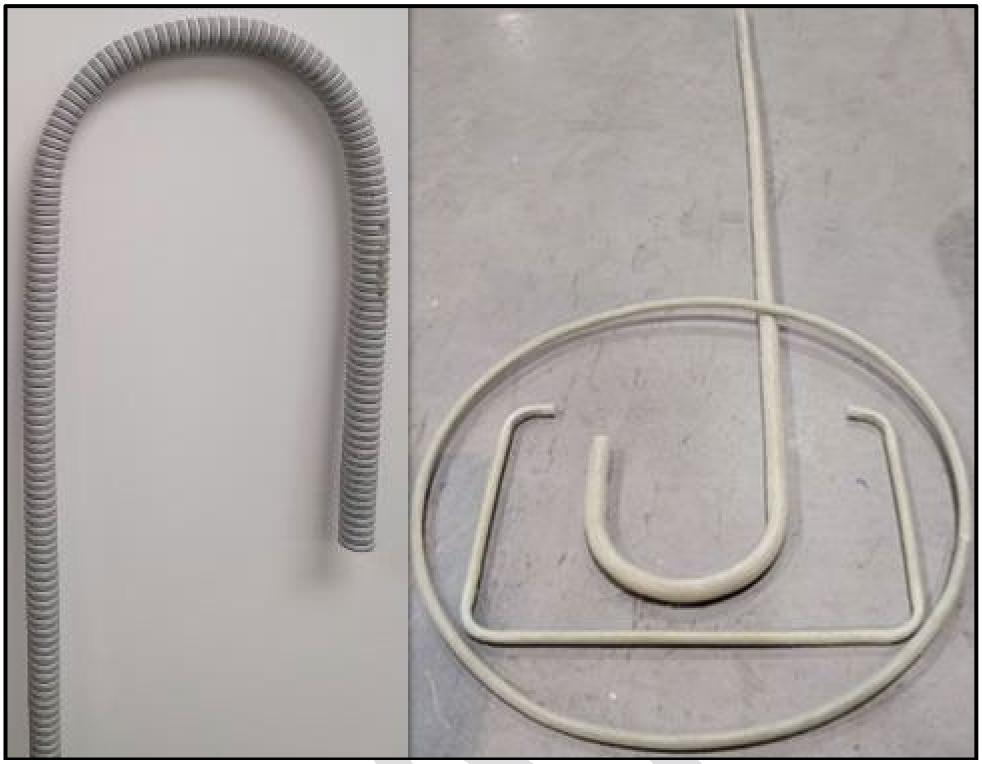

Figure 2 – MST-BAR: bent shapes

The left image in Figure 2 is the approved bar coating that was supplied until November 2020. The right image is the approved bar coating that is being supplied after November 2020.

Figure 3 – MST-BAR: straight bar with anchor head

3.2.1.2 V-Rod

Figure 4 – V-Rod: straight bar

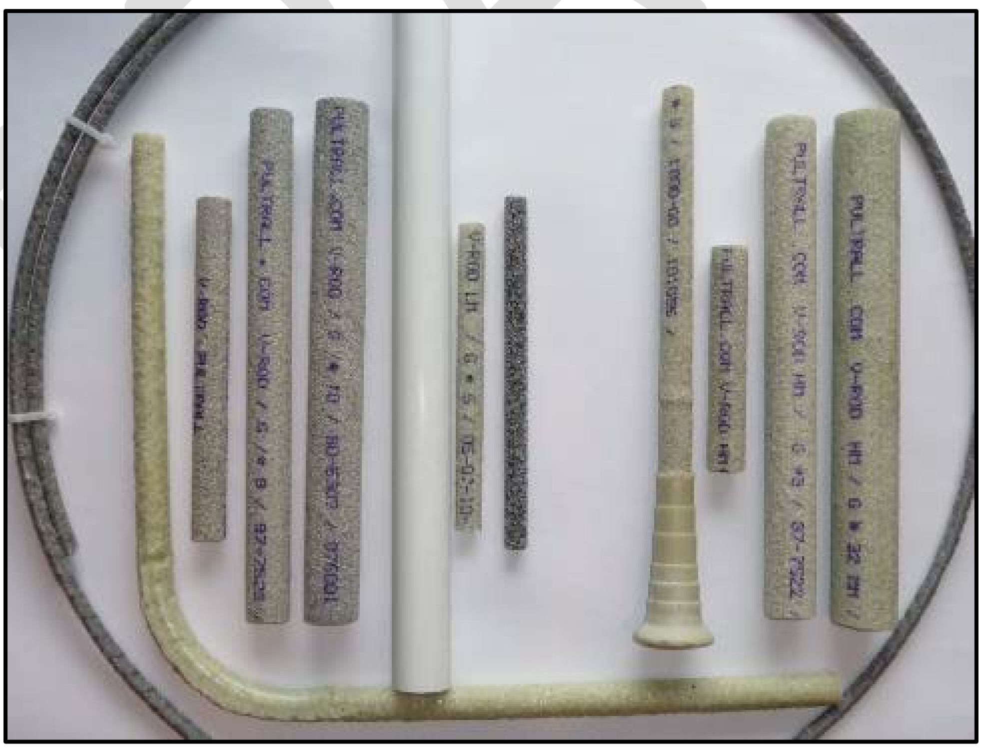

Figure 5 – V-Rod: bent, straight and anchor headed bar shapes

3.2.1.3 Mateenbar

Figure 6 – Mateenbar: straight bar

Figure 7 – Mateenbar: bent bar

3.2.1.4 TUF-BAR

Figure 8 – TUF-BAR: straight bar

Figure 9 – TUF-BAR: straight bar

The small protrusions or bumps on the inside radius of the TUF-BAR bent bars in Figure 10 are an intentional part of the fabrication process. The ribbed profile is consistent and perpendicular to the piece.

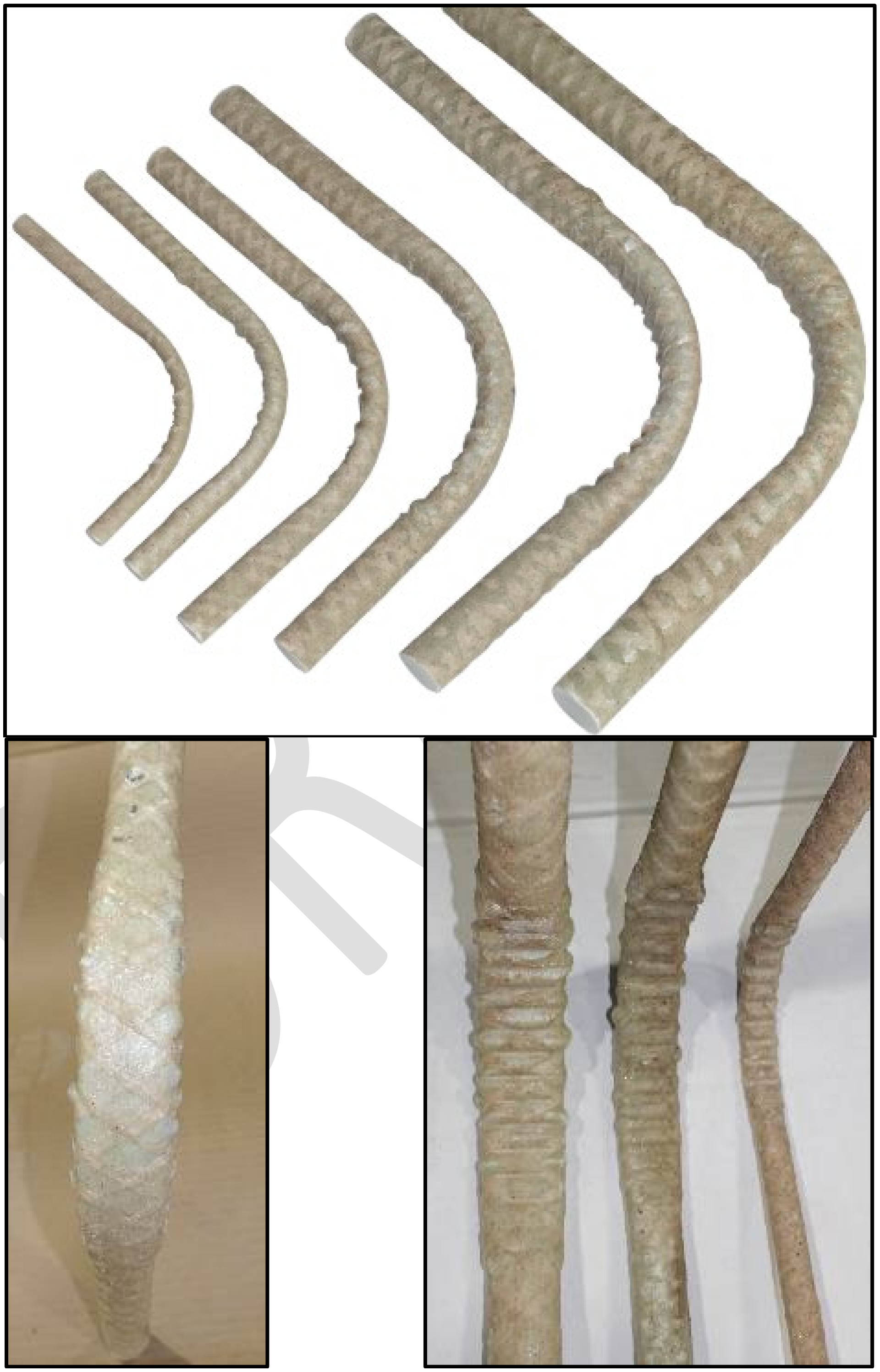

Figure 10 – TUF-BAR: bent bars (Clockwise from top: sizes, inside of bend, outside of bend.)

Figure 11 – TUF-BAR: circular and square spirals

3.2.2. DSM #9.65.90 Delisted Products

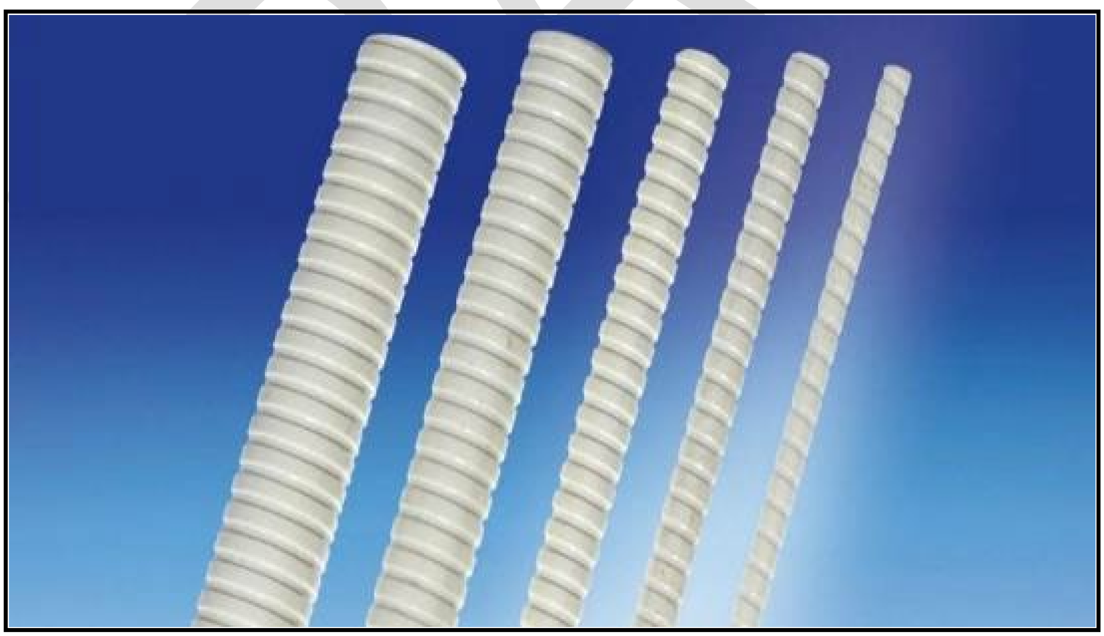

Figure 12 – Schöck ComBAR manufactured by Fiberline Composites Canada Inc. (January 2018)

Figure 13 – Tembar manufactured by TemCorp Industries Ltd. (January 2018)

Figure 14 – Aslan GFRP manufactured by Hughes Brothers, Inc. (June 2016)

4. Examples of Acceptable Bars

There are multiple factors to be considered for GFRP reinforcing bars to be acceptable for use on MTO contracts. As a minimum, GFRP reinforcing bars should:

- Meet the requirements of MTO Special Provision No. 999S02 and CSA S807;
- Be uniform in diameter/size;
- Have a uniform surface finish, free of voids and air pockets;
- Be free of defects that would be detrimental to the mechanical properties and durability;
- Have consistent resin distribution from end to end and through any bend in the material without buildup;
- Be clean of any foreign contaminants;
- Not be bent in an inconsistent manner for bent shapes;
- Not be malformed;
- Be free of obvious signs of damage (e.g., cutting, gouging, splitting, etc.); and,
- The ends of the bars must be cut clean with no chipping, splitting or fraying present.

The bars shown above in Figure 1 to Figure 14 and below in Figure 15 to Figure 30 are examples of acceptable GFRP reinforcing bars.

4.1. Typical Surface Finish of Supplier Bars

4.1.1. Sand Coated Bars

The bars shown in Figure 15 to Figure 25 are typical for sand-coated bars and have a uniform distribution of resin and sand particles. It is acceptable to have a loss of sand coating on the inside surface of the bend, over the arc of the bend as shown in Figure 21. The exterior of the bend must have a uniform sand coating.

Figure 15 – Straight sand coated bar

Figure 16 – Straight bars tied in a grid and ready for concrete placement

Figure 17 – Straight bars tied in a grid and ready for concrete placement

Figure 18 – Straight portion of bent bar

Figure 19 – Straight portion of bent bar

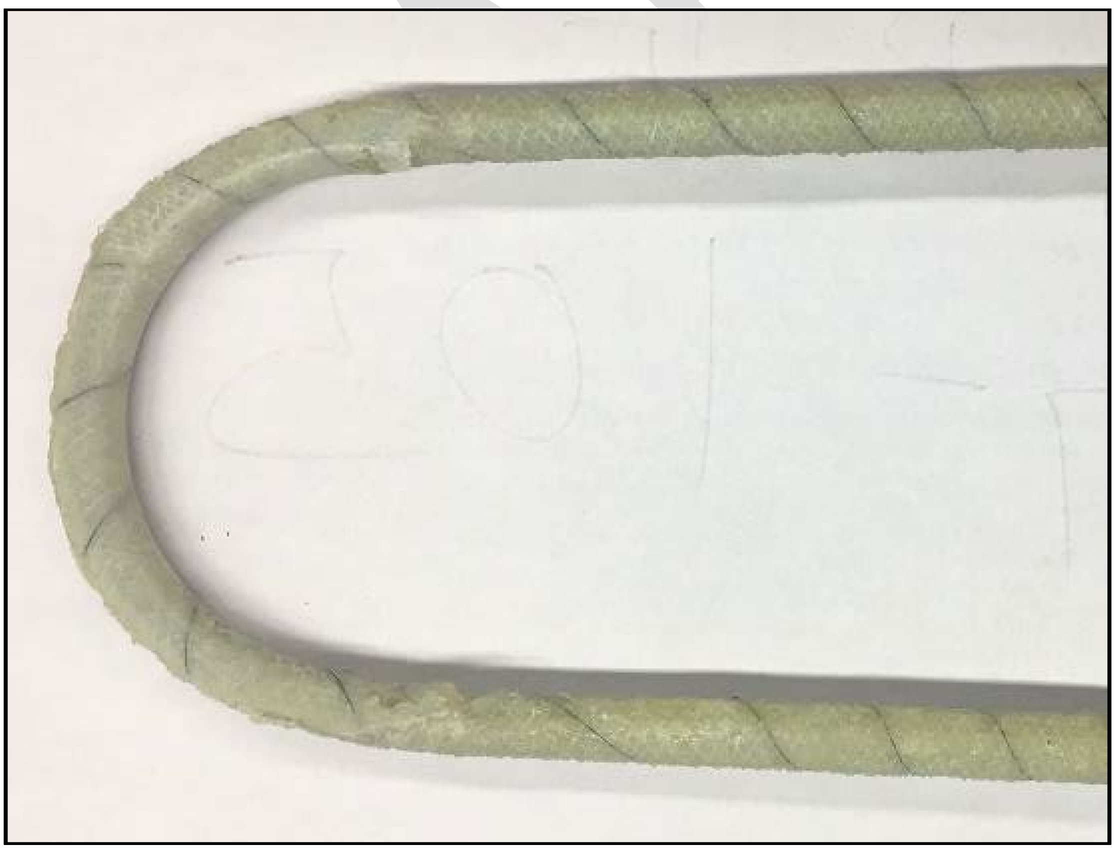

Figure 20 – Bent U-bar

Figure 21 – Inside of bend

Figure 22 – Inside of bend

Figure 23 – Outside of bend

Figure 24 – Outside of bend

Figure 25 – Concave-convex bend sequence

4.1.2. Grooved Bars

Grooved bars may have formed waves or undulations (Figure 26) or cut / ground in shear lugs (Figure 6 and Figure 12), depending on the manufacturer. Like sand coated bars, they should have a uniform finish and distribution of resin.

Figure 26 – Straight bar with formed deformation finish

4.1.3. GFRP Bar Identification

All GFRP bars intended for Ministry contracts shall be stamped by the manufacturer with specific information pertaining to the bar's production. The manufacturers' stamp on each bar must be clear and legible and according to CSA S807. Additionally, this GFRP bar identification stamp must meet the contract requirements as specified in Special Provision No. 999S02.

The following manufacturer's identification markings of straight bars are clear and legible, with proper spacing. The markings indicate the manufacturer's name, fibre type, designated bar diameter, grade designation, designated modulus of elasticity and production lot or batch number.

Figure 27 – Legible bar marking.

The rebar in Figure 28 is an Aslan GFRP rebar, manufactured by Hughes Brothers, Inc. This product is no longer listed on the ministry's DSM.

Figure 28 – Legible bar marking.

Figure 29 – Legible Bar Marking

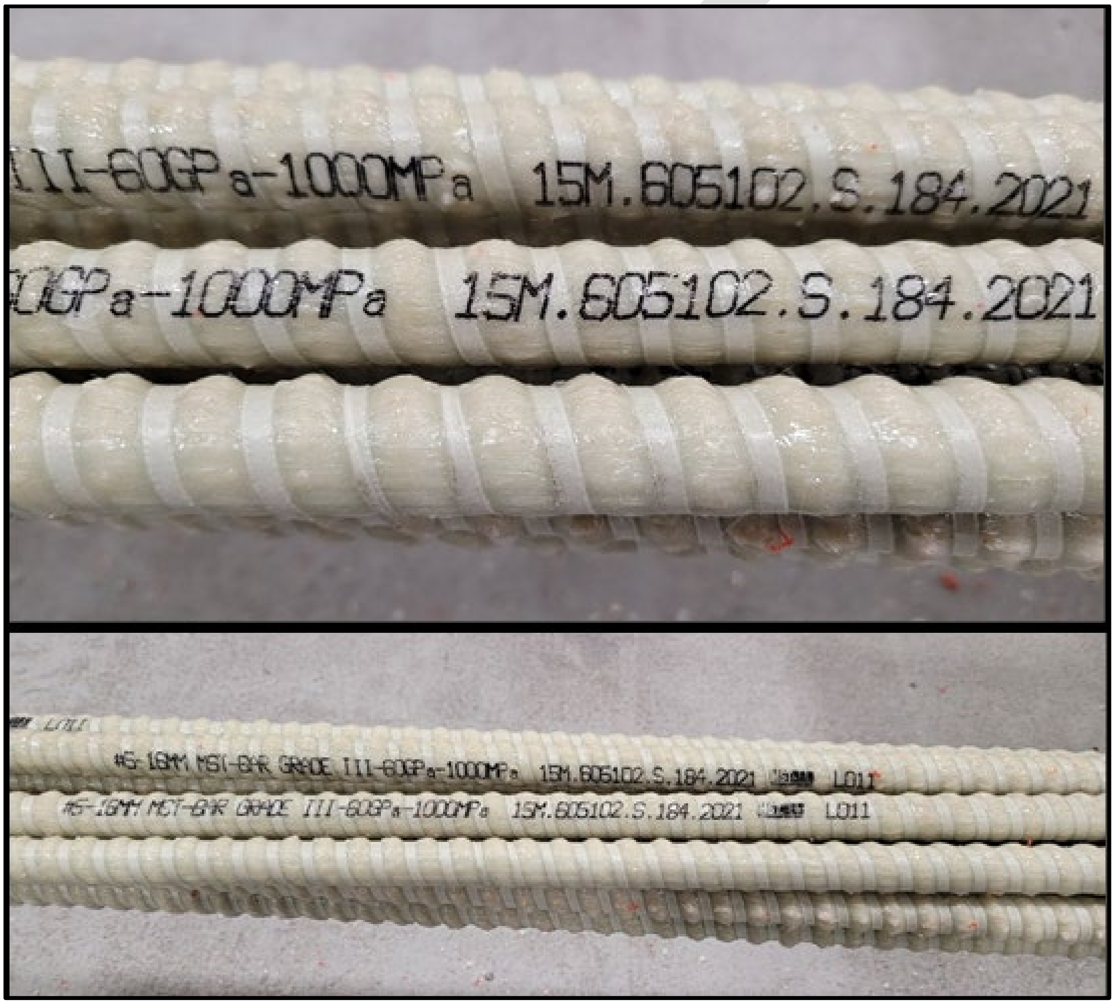

Figure 30 – Legible bar marking.

At publication of this guide, DSM listed suppliers are not printing bar identification marking on bent bar shapes due to technical limitations. Until a solution is found, bent bar identification may be a combination of coloured paint markings, bar tags, and information from the submitted quality control (QC) reports. Examples of paint marking, and bar tags were not available for publication. In this system, bar ends, and bar tags will be marked with a paint colour, and that colour will be identified in the QC report. A unique colour shall be provided for each sublot and be readily distinguishable from other sublots.

4.2. Acceptable Visual Defects/Contamination

The following examples are acceptable bars which involve visual defects and contamination. The defects/contamination are within the limits provided in the specification or may be considered to have a minor impact.

4.2.1. Non-Uniform Sand Coating

Over the arc of the bend of bent bars, it is acceptable to have a loss of sand coating on the inside surface of the bend such as in Figure 31. The exterior of the bend should still have a uniform sand coating.

Figure 31 – Inside of bend loss of sand coating

4.2.2. Bulging

The October 2021 publication of SSP 999S02, Requirements for Glass Fibre Reinforced Polymer (GFRP) Reinforcing Bar includes a new tolerance on the size of bulges in bent bars. Bulging of the cross-section on the inside of the bend or along the start of bend shall be less than 4 mm or 25% of the bar diameter, whichever is smaller. A photo of an acceptable form of this defect is not available at the time of publication.

4.2.3. Flatness / Non-uniform Finish

It is acceptable for the inside surface of bent bars to be flat through the bend provided the flatness is uniform through the bend and there is no loss in cross sectional area of the bar.

Figure 32 – Typical spiral with uniform, flat surface on inside of bend

The examples in Figure 33 to Figure 37 include small accumulations and runs of excess resin which are smaller than 4mm. These defects are within the permissible size limits of other defects in the specification and may be considered acceptable.

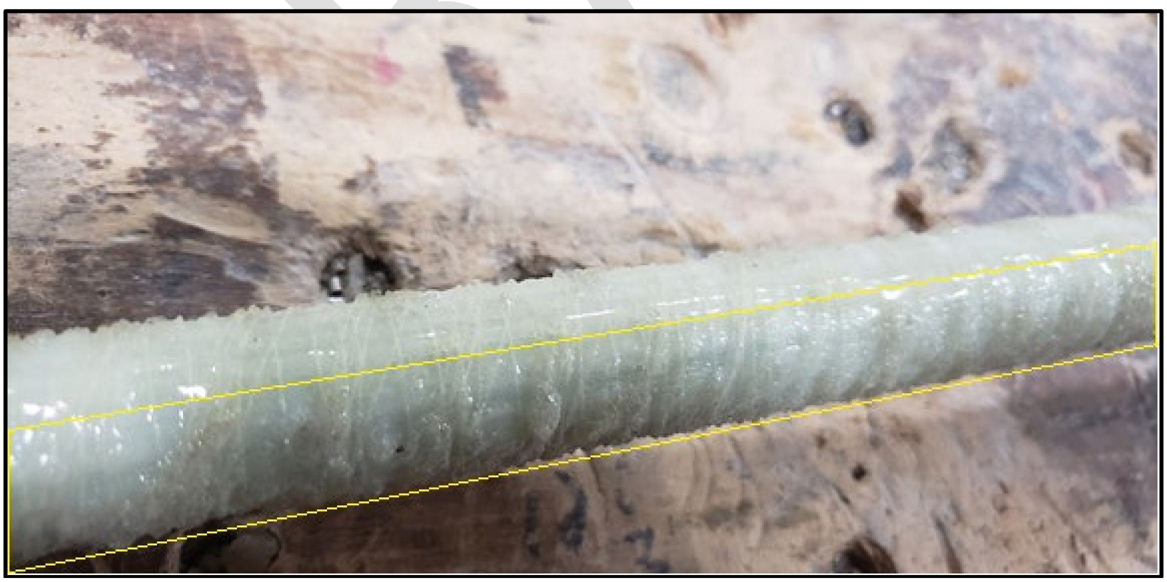

Figure 33 – Resin run along straight portion of bent bar (usually smooth and shiny)

Figure 34 – 4mm resin accumulation

Figure 35 – 3mm resin accumulation

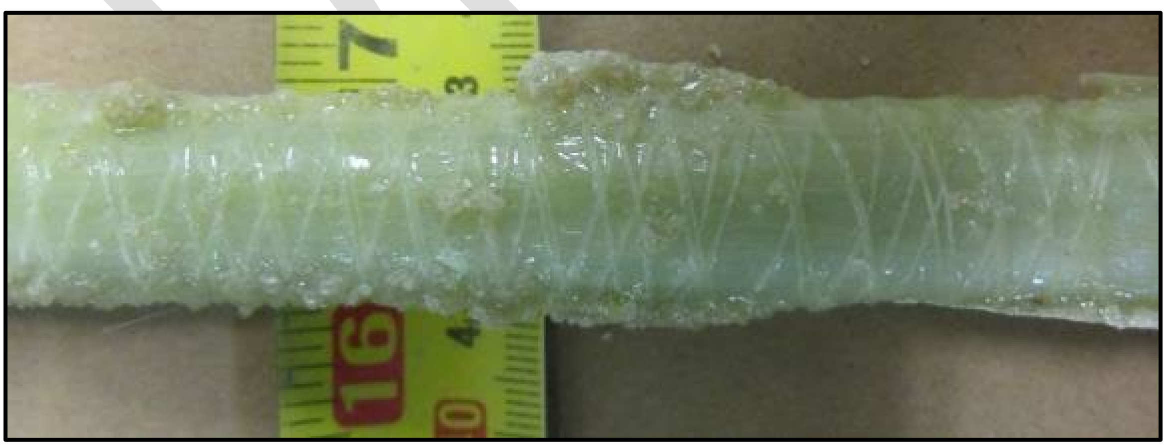

Figure 36 – 4mm resin accumulation

Figure 37 – Random resin accumulations

4.2.4. Cuts/ Damage / Visible Fibres

Figure 38 shows dry, visible fibres in a straight bar. A small quantity of visible surface fibres such as the defect circled in red may be acceptable. The visible fibres shall be surface fibres and the defect shall not penetrate the bar more than 0.7 mm deep. A larger quantity of visible fibres or runs are unacceptable; reference Figure 66.

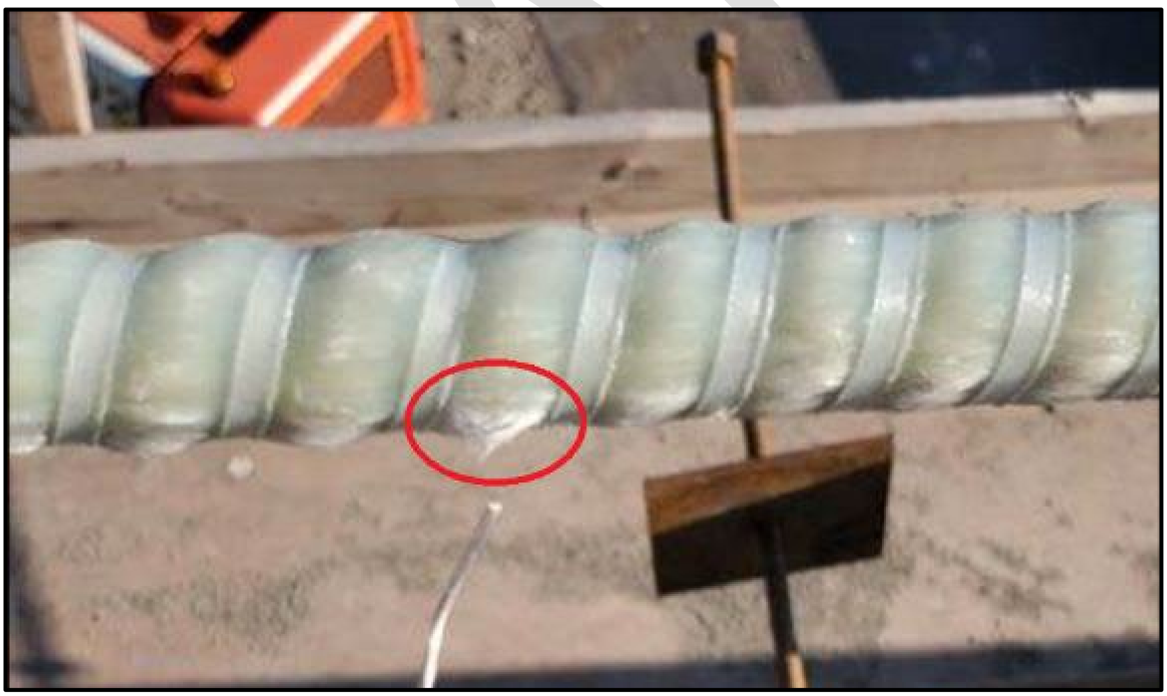

Figure 38 – Dry, visible fibres

Figure 39 shows a nylon strand detached from the bar exterior, but this does not constitute a core fibre of the reinforcement contributing to tensile properties. There may be multiple detached exterior strands, but they should not appear frayed and should not involve any core fibres.

Figure 39 – Detached nylon strand

Figure 40 is an irregular cut, however it is at the end of a bar. Ends of bars may have irregular or non-uniform cuts. Shallow cuts not at ends, less than 0.7 mm deep for bars of size 15 or less, and less than 1.0 mm deep for larger bars are also acceptable (Figure 41).

Figure 40 – Irregularly cut bar end

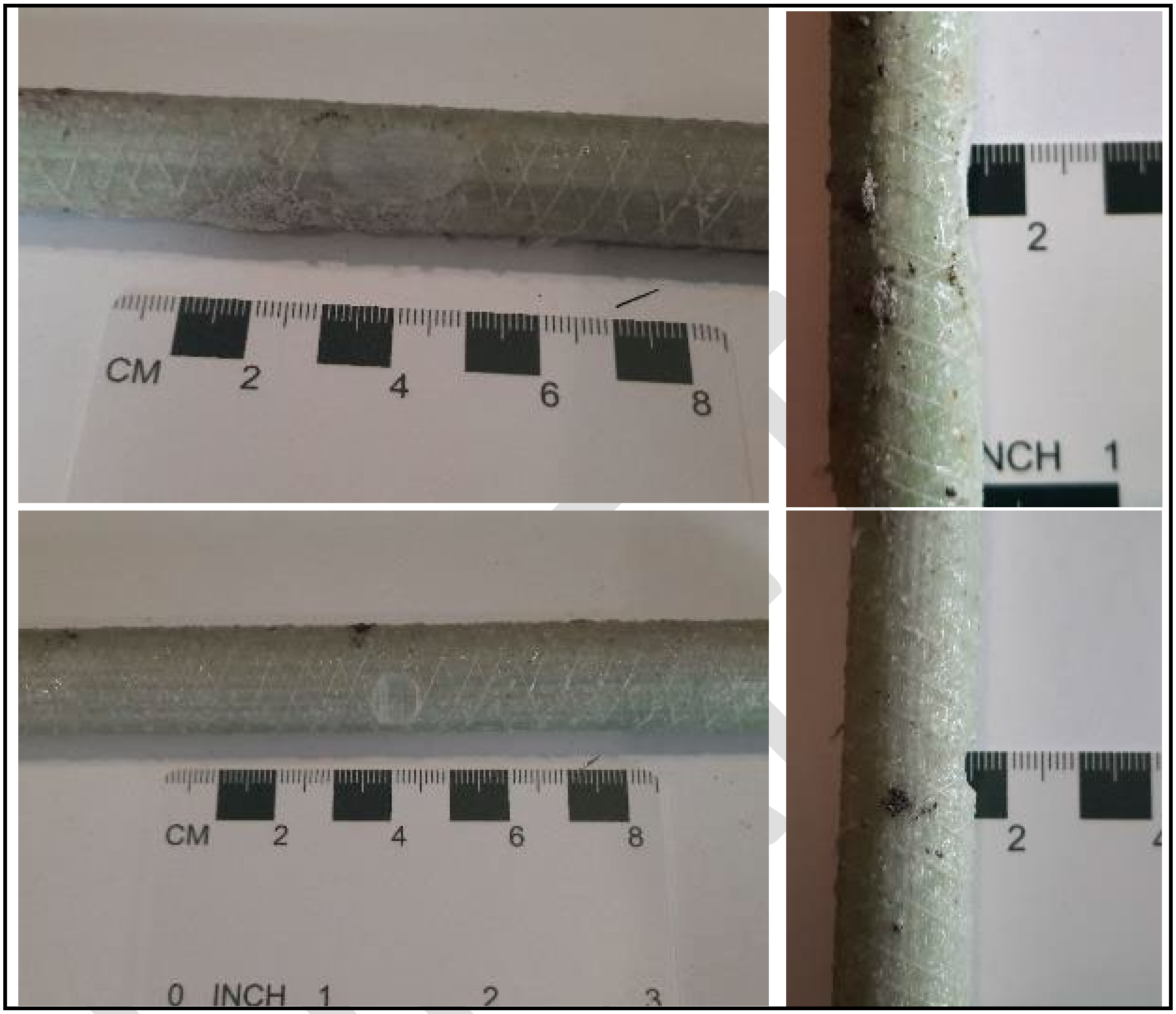

Figure 41 – Shallow cuts

4.2.5. Concrete Contamination (Splatter)

Concrete splatter is a contaminant in SSP 999S02 and any quantity of concrete contamination on the GFRP bars should be considered non-conforming work. Concrete paste can act as a bond breaker between the GFRP bars and newly placed concrete. Where there are large chunks of spatter and aggregates, there is an increased probability that voids will be introduced into the component. This workmanship defect has the potential to decrease both the structural adequacy and durability of the component.

Where the contractor has proposed to leave concrete contaminated bars in the work, the Contract Administrator will need to make a subjective evaluation of the contamination. The quantity of contamination should be small; the appearance should be uniform and not include voids. GFRP bars are brittle, but they are not fragile. Where possible, concrete contamination may be removed by hand and light manipulation, but bars shall not be struck by tools such as hammers to remove concrete. Figure 42 is an example of concrete contamination that was incorporated in the work of a construction contract.

The fins should be broken off by hand and the remaining concrete should be checked to ensure it is comprised of solid, well bonded pieces.

It is preferable to provide a system to protect bars from any contamination to avoid this situation. Examples of protection used on MTO construction contracts has included draped plastic and/or burlap over bars (Figure 43), and plywood sheets between concrete discharge and adjacent bars. The bottom of the barrier GFRP in Figure 43 should also be covered to at least the bottom of the screed rail during concrete placement.

It is suggested that white polyethylene sheeting is a cost-effective way of protecting installed bars from both element exposure and concrete contamination.

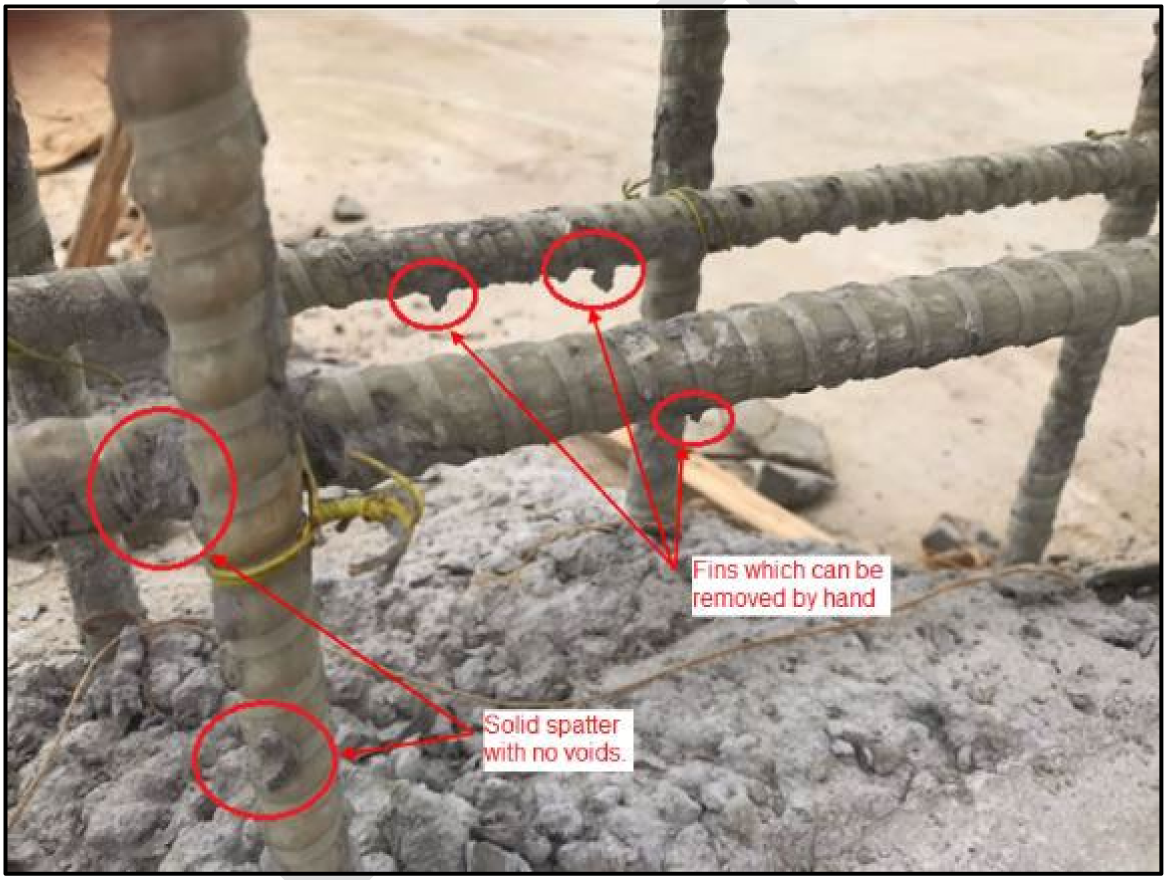

Figure 42 – Example of incorporated concrete contamination

Figure 43 – Barrier GFRP covered with burlap

4.2.6. Discolouration

Bars are expected to be encased in concrete for the entirety of their life so there is no MTO requirement for UV resistant additives. Bars may or may not include UV resistant additives in the blended polymer matrix, depending on the manufacturer. Inspectors should assume the bars are not UV protected until given documentation stating otherwise and as such, bars should be protected from sun exposure as much as possible.

Unacceptable discolouration from UV exposure or manufacturing processes can typically be identified from non-uniform colouration. The sun exposed side of the bar would be discoloured compared to the non-exposed side or compared to bars deeper in the bundle.

Figure 44 shows different coloured anchor-headed bars from the same production lot. The colours are uniform and are likely related to typical batch-to-batch variations in colourants (additives) during manufacture. This may be considered acceptable.

Figure 44 – Different coloured headed bars from the same production lot

4.2.7. Storage

Figure 45 is an example of good storage cribbing for GFRP on site and keeps bars away from direct contact with the ground. When there is not ongoing work to place bars, they shall be covered, protected from sunlight and rain exposure.

Figure 45 – Good storage cribbing

4.2.8. Loose Wrapping

The loose wrapping in Figure 46 does not contribute to the strength of the bar. The wrapping helps maintain bar shape during fabrication but has no structural function in the cured bar. These bars are acceptable.

Figure 46 – Loose wrapping

4.2.9. Burn Marks

It is expected that factory produced bar cuts will have clean faces with no damage. Where there is field cutting of GFRP bars, there may be some minor burn marks at the cut ends depending on the tools used. The photos in Figure 47 show some slight burn marks which may be considered acceptable. The leftmost photo shows some light streaking at the cut end with a thin burn around the circumference of bar which was imparted by a grinding wheel. The second two photos are burn marks from a high-speed cutter.

Figure 47 – Various acceptable burn marks

4.3. Acceptable Surface Finish of Delisted Supplier Bars

The following images (Figure 48 to Figure 55) exhibit straight and bent bars with acceptable surface finish. Schöck ComBAR and Aslan were previously listed as products on MTO DSM list #9.65.90 but are no longer listed suppliers. These images are only current to January 2018 and are provided as additional examples of uniform GFRP bars and acceptable resin about bends.

Figure 48 – Acceptable straight bar (Schöck ComBAR - Fiberline Composites Inc.)

Figure 49 – Acceptable anchor-headed straight bar (Schöck ComBAR - Fiberline Composites Inc.)

Figure 50 – Acceptable straight bar (Schöck ComBAR - Fiberline Composites Inc.)

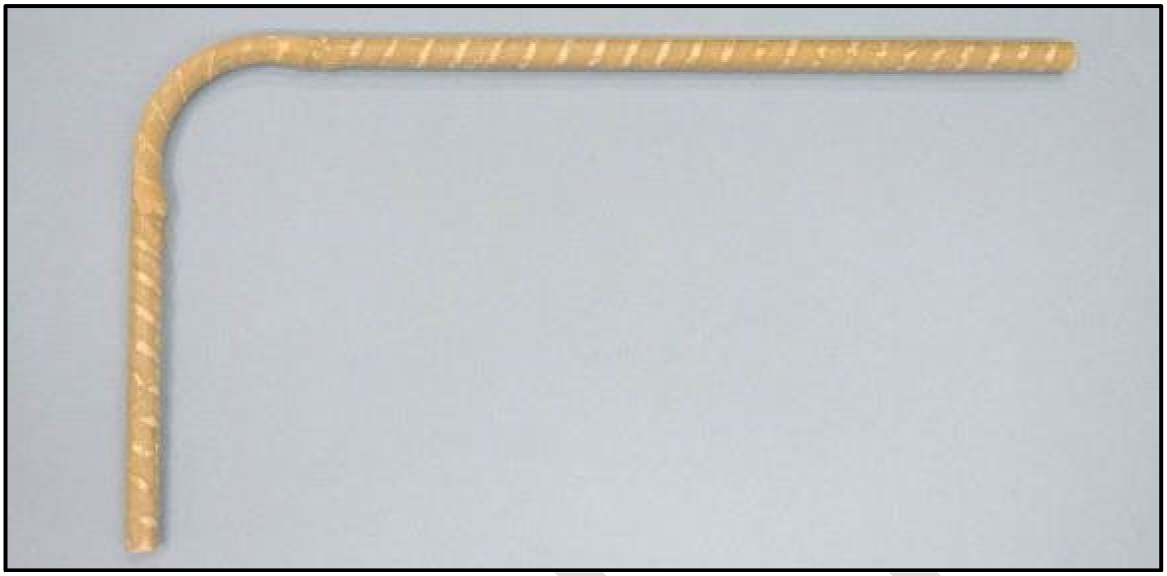

Figure 51 – Acceptable L bar. (Aslan - Hughes Brothers Inc.)

Figure 52 – Acceptable L bar with resin bulge. (Aslan - Hughes Brothers Inc.)

Figure 53 – Acceptable straight bar. (Aslan - Hughes Brothers Inc.)

Figure 54 – Acceptable bent U bar. (Aslan - Hughes Brothers Inc.)

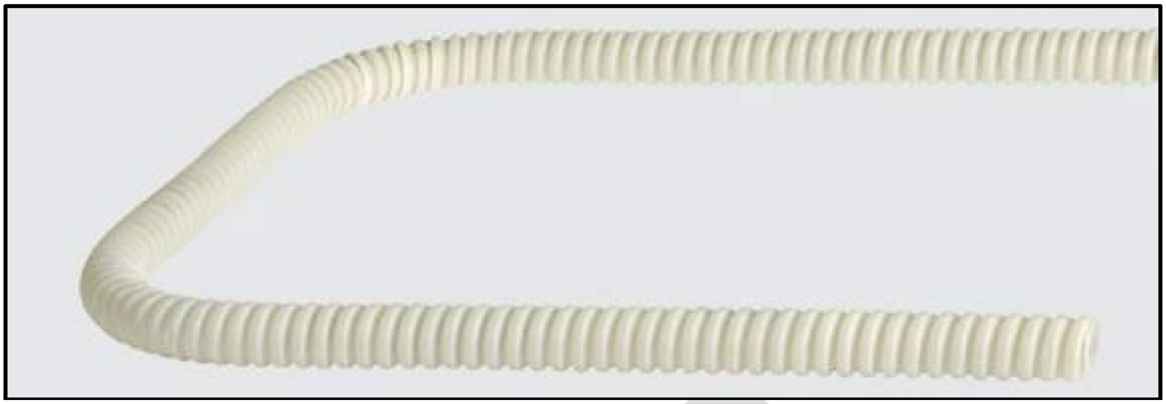

Figure 55 – Acceptable bent bar. (Schöck ComBAR - Fiberline Composites Inc.)

Figure 56 – Acceptable straight bars in formwork (Schöck ComBAR - Fiberline Composites Inc.)

5. Examples of Unacceptable Bar Defects

Deficiencies in bars may originate at the time of manufacturing and go undetected by the suppliers' quality control processes, they may occur during transportation of the bars to the construction site, or they may be the result of damage during construction.

The bars shall be uniform in diameter/size and be free of defects that are detrimental to their mechanical properties and durability. The surface finish shall be uniform and free of voids, air pockets, exposed fibres, cracks, kinks, surface pitting and uneven or patchy discoloration. The bars shall be free of obvious signs of damage (e.g., cuts, gouges, splitting, etc.). Some tolerances on bulging, cuts, visible fibres, and other defects can be found in the specification.

The following examples show rejectable bars with unacceptable defects. Where photos were not available for the type of defect, descriptions have been provided.

5.1. Unacceptable Visual Defects / Contamination

5.1.1. Not Legible Bar Marking

Below is an example of an unacceptable bar identification as the bar marking is not legible or clearly displayed.

Figure 57 – Illegible bar marking

5.1.2. Non-uniform Sand Coating

For sand coated bars, the sand is the main bonding mechanism between the FRP reinforcing bar and concrete. The bar in Figure 58 does not have enough sand coating for acceptable bond and is rejectable. Bars may have multiple defects, Figure 71 and Figure 72 also includes an unacceptable loss of sand coating.

Figure 58 – Non-uniform sand coating

5.1.3. Bulging

The following examples involve bars with bulges exceeding the bulging limit of 4mm or 25% of the bar diameter, whichever is smaller. These bulging bars cannot be repaired and are rejectable.

Figure 59 – Out-of-plane bulging larger than 4mm

Figure 60 – Bulging fibres and inconsistent resin coating

5.1.4. Excessive Flattening / Non-uniform Finish

The bends of the bent bars shown in Figure 61 exhibit excessive flattening about the curves. This condition cannot be repaired, and the bars must be rejected.

Figure 61 – Excessive flattening

The bar shown in Figure 62 has non-homogeneous resin coverage and is therefore an unacceptable GFRP reinforcing bar. This defect is also greater than the maximum allowable area of the nominal cross-sectional area for bar diameters 13 mm to 20 mm. The defect cannot be repaired, and the bar must be rejected.

Figure 62 – Non-homogeneous resin distribution

5.1.5. Voids / Air Pockets / Surface Pitting

The bar in Figure 63 has multiple voids or air pockets along the surface. There is also a resin run along the ribs of the middle bar.

Figure 63 – Straight bar with voids/air pockets

5.1.6. Exposed Fibres / Dry Fibres

Half of the surface area of the bars in Figure 64 has exposed fibres with no resin. The dryness of the surface fibres is excessive, and the bars are rejectable.

Figure 64 – Exposed and dry fibres

Figure 65 is an example of an unacceptable GFRP reinforcing bar. There is a noticeable inconsistency with resin embedment and coating of the glass fibres that make up the bar, which may negatively affect the performance of this GFRP reinforced bar. This bar cannot be repaired and must be rejected.

Figure 65 – Exposed glass fibres and inconsistent resin

Figure 66 includes exposed and dry fibres. A single rib was used as an example in Figure 38 from the same photo as acceptable exposed fibres. However, there is a run on this bar resulting in a consistent defect. The quantity of bar defect is more than 50 mm or two consecutive ribs per 300mm length of bar, can be considered too high, and the bar is rejectable.

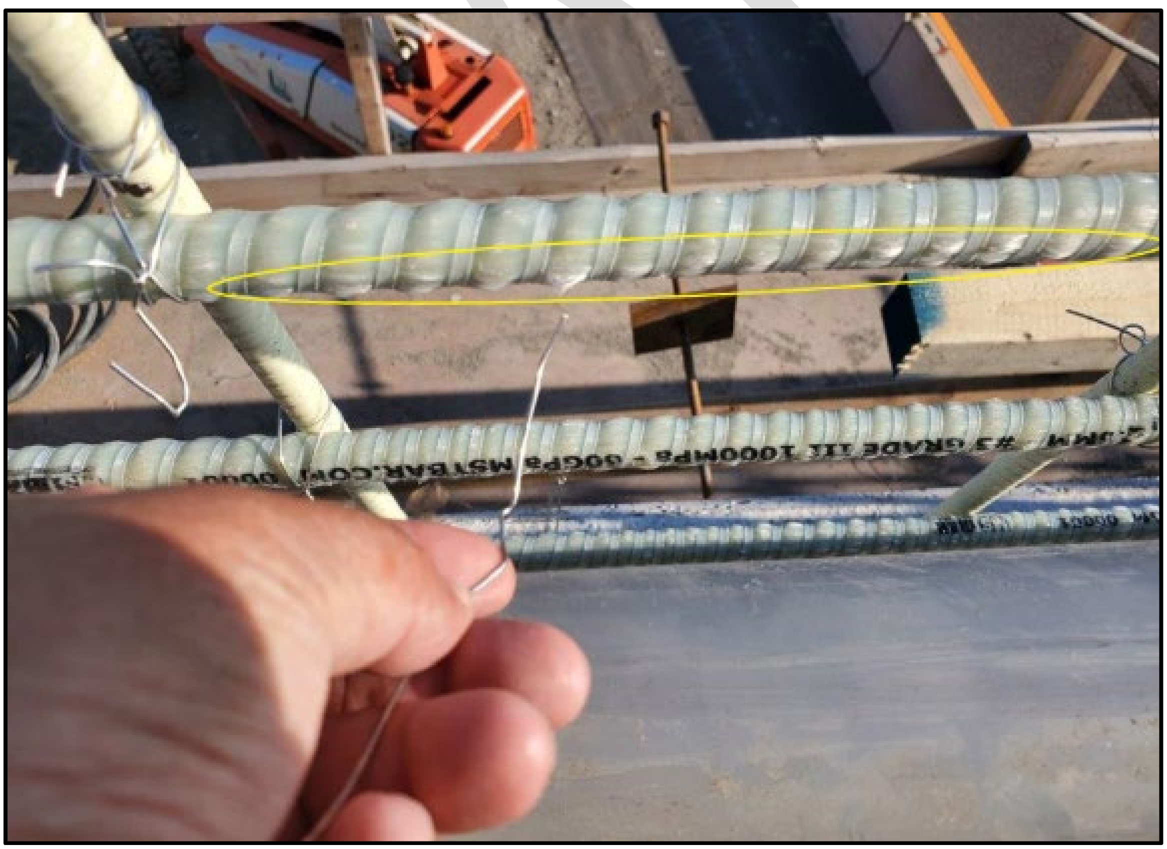

Figure 66 – Exposed, dry fibres

Figure 67 also shows exposed core fibers and is rejectable.

Figure 67 – Repairable exposed fibres

Figure 68 shows an unacceptable GFRP reinforcing bar with frayed, loose fibres and inconsistent resin coverage. Surface finishes are required to be uniform, and without exposed fibres. This bar cannot be repaired and must be rejected.

Figure 68 – Loose fibres

Figure 69 is a bar with inconsistent and insufficient resin coverage, resulting in exposed glass fibres, and is therefore an unacceptable GFRP reinforcing bar. This bar cannot be repaired and must be rejected.

Figure 69 – Inconsistent resin coating and exposed fibres

Figure 70 shows a bar with frayed, exposed fibres. The exposed fibres include core fibres, and the bar is therefore an unacceptable GFRP reinforcing bar. This bar cannot be repaired and must be rejected.

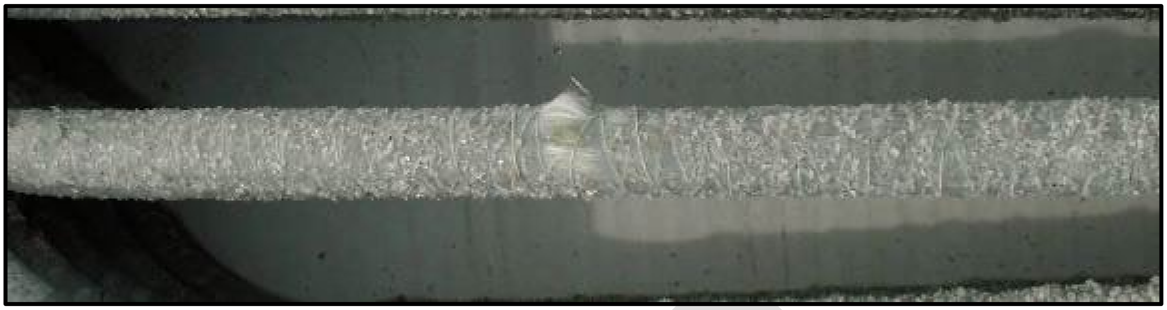

Figure 70 – Exposed and frayed glass fibres

The bars shown in Figure 71 and Figure 72 have a noticeable loss of sand coating and lack of resin on the exposed glass fibres and are examples of unacceptable GFRP reinforcing bars. These bars cannot be repaired and must be rejected for use on MTO contracts.

Figure 71 – Sand and resin loss and exposed fibres

Figure 72 – Sand and resin loss and exposed fibres

5.1.7. Cracks

Splits and cracks cannot be repaired, and these bars are always rejectable. The length and depth of splits may vary. The ripped off nylon strands in Figure 73 are not considered an issue.

Figure 73 – Rejectable split bar

5.1.8. Kinks

Kinks cannot be repaired, and these bars are always rejectable. Figure 74 is an example of a kinked bar.

Figure 74 – Kinked bar

5.1.9. Frayed Cuts / Burn Marks

The bar in Figure 75 and Figure 76 has not been cut properly and the end is frayed. The manufacturer could repair this type of defect if sufficient bar length is available. This particular bar cannot be repaired because of other defects.

Figure 75 – Cut bar with frayed ends

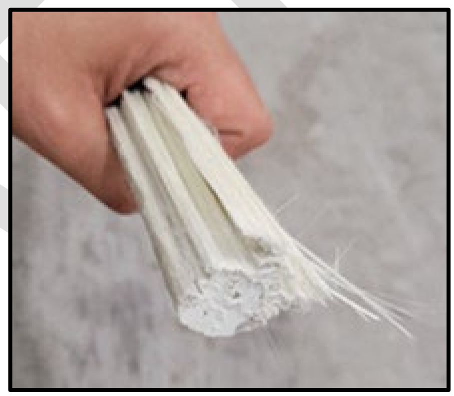

Figure 76 – Cut bar with frayed ends

The bar in Figure 77 has a cut with a depth that exceeds the specification limits and is rejectable.

Figure 77 – Deep cut in rejectable bar

Figure 78 – Deep cut in rejectable bar

Various burn marks to GFRP bars are shown clockwise in Figure 79 with increasing severity. The first two photos have heat damage to the resin and nylon strands. The last three photos have experienced flame damage with blistered resin and dry/burned fibres.

Figure 79 – Various unacceptable burn marks

5.1.10. Concrete Splatter

Concrete contamination is not acceptable and all of the bars in Figure 80 and Figure 81 should be rejected. Contaminating bars and then cleaning them is also not acceptable or 'preventative'. The examples shown here are particularly egregious with large quantities of paste and voided clumps of aggregate.

Figure 80 – Concrete contamination

Figure 81 – Concrete contamination

Visible damage can be seen in Figure 82 where contaminated longitudinal bars rubbed against vertical bars as they were removed from the cage and replaced with new ones. These bars must now also be replaced.

Figure 82 – Damage from bar rubbing

Figure 83 and Figure 84 show damage to bars which were 'cleaned' of concrete contamination. There is still visible concrete contamination; concrete paste may act as a bond breaker between the bars and the concrete placed for the rest of the component.

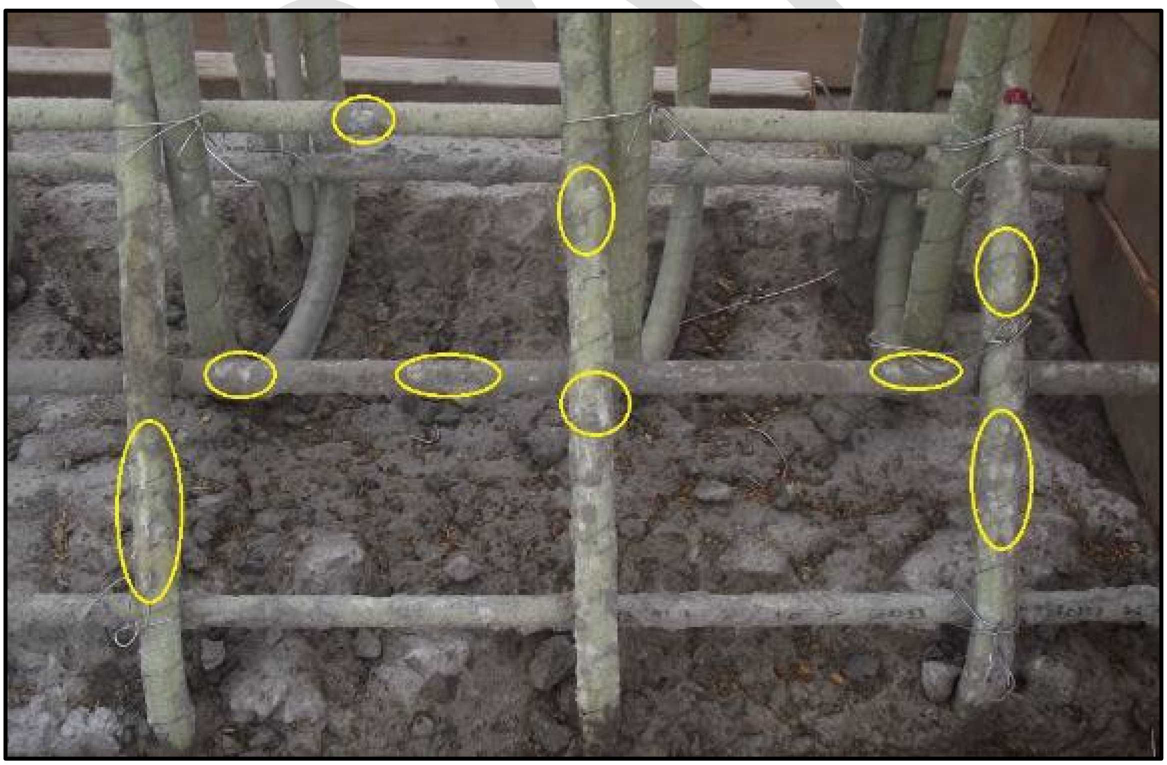

Figure 83 – Contamination and hammer strike damage

There is also visible damage to the bars from removal of concrete using a hammer. These bars are easily rejectable because of the visible damage on the exterior of the bar. However, GFRP bars are brittle and hammer strikes can cause internal damage to the bar which may not be visible. Any bars struck with hammers shall be rejected and replaced.

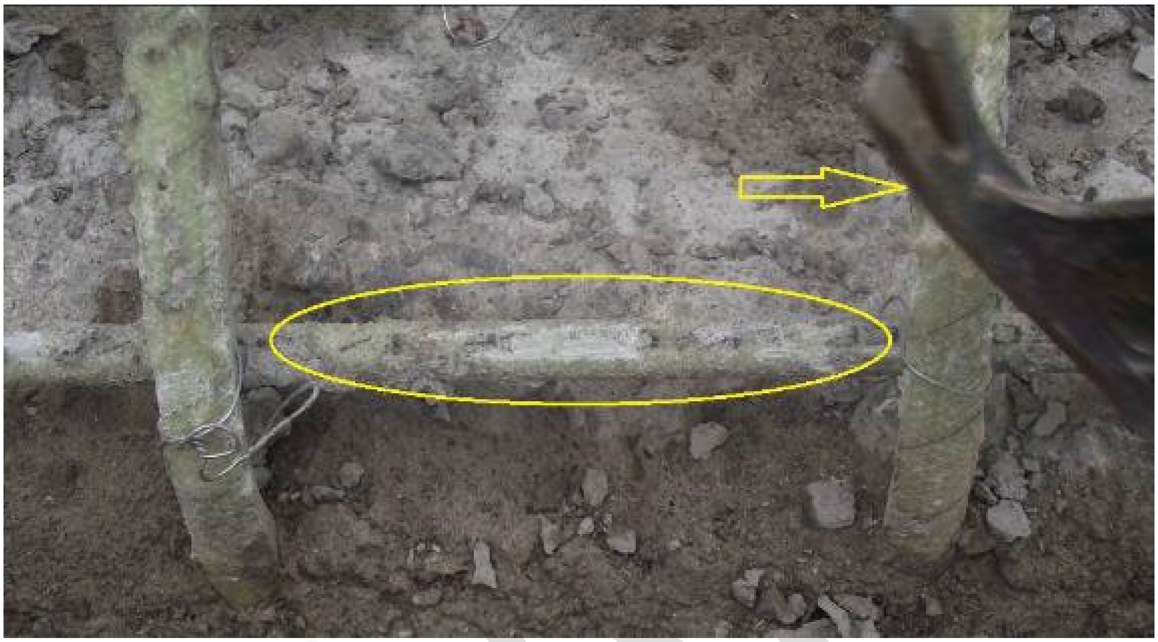

Figure 84 – Hammer strike damage to bars (arrow pointing to hammer)

5.1.11. Discolouration

Examples of what could be considered detrimental discolouration from UV exposure can be seen in Figure 85 and Figure 86. There is an obvious discolouration of the exterior bars that were exposed to the sun when compared to bars that did not experience the same exposure from the same bundle.

Figure 85 – UV exposure discolouration

Figure 86 – UV exposure discolouration

Figure 87 is another example with a colour change in the same bar where one side is darker than the other and there is a more well-defined contrast line. This defect only applies to a few of the bars on the top of the skid.

Figure 87 – UV exposure discolouration

5.1.12. Storage

Bars, including bars installed in components, shall be covered with opaque, white polyethylene sheeting, or equivalent protective material during storage. The bars in Figure 89 and Figure 90 are stored well on acceptable cribbing but are not covered with sheeting. This may be considered acceptable if there is active work to lay bars. If bars are not being installed, or there are no plans to install more bars that day, they should be covered. The bars in Figure 88 have been left on the ground, this is not acceptable storage.

Figure 88 – Not acceptable storage of bars

Figure 89 – Bars not covered with polyethylene

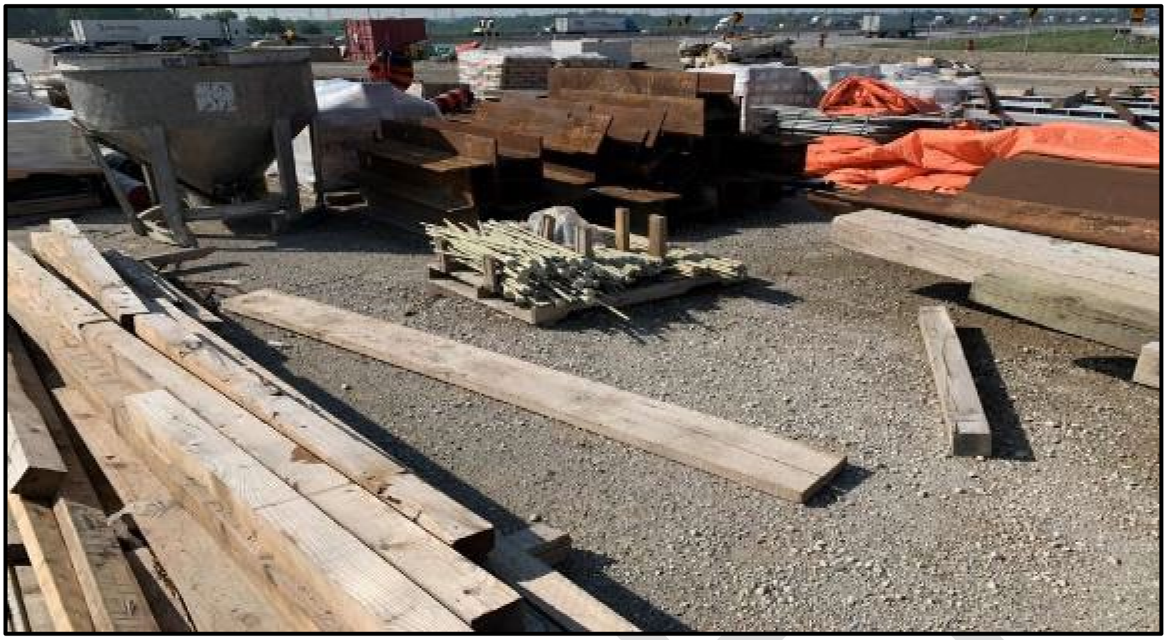

Figure 90 – Bars not covered with polyethylene

The bars in Figure 91 are covered with burlap, but they are not completely covered, and burlap permits sunlight transmission. This is not considered acceptable for 'storage' until concrete placement and they should be covered with polyethylene sheeting. However, it is better than the Figure 92 condition.

Figure 91 – Installed bars with improper and incomplete coverage

Figure 92 does not have any protection for installed bars. This condition is not acceptable.

Figure 92 – Installed bars not covered with polyethylene

5.2. Bent Bars Defects

Bent bars have the same categories of defects as straight bars, but they may appear differently due to the bending process. The most common defect as a result of the bending process is a build-up of resin at the start of bend. All the figures in this section are rejectable, but many may be repaired by the manufacturer prior to shipping from the plant. Defects that might be repaired are noted in the figure captions.

Figure 93 – Visible fibres (may be repaired by the manufacturer)

Figure 94 – Dry and exposed fibres

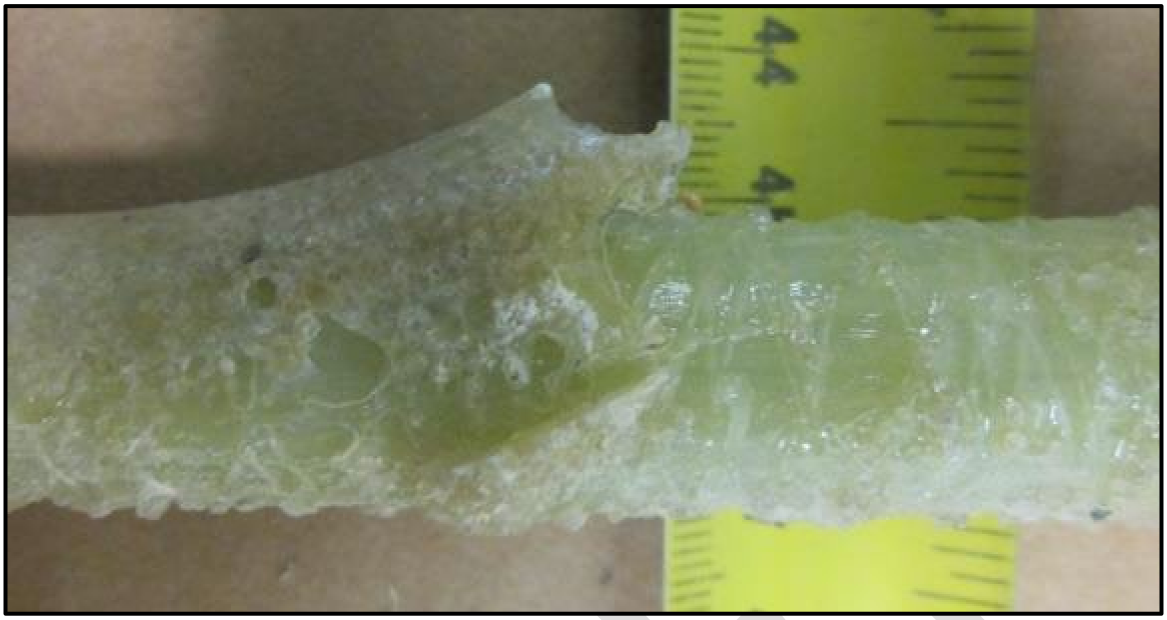

Figure 95 – Resin accumulation at the start/end of bend larger than 4mm (may be repaired by the manufacturer)

Figure 96 – Resin accumulation at the start/end of bend larger than 4mm (may be repaired by the manufacturer)

Figure 97 – Resin accumulation at the start/end of bend larger than 4mm (may be repaired by the manufacturer)

The defects in Figure 98 and Figure 99 are from mis-aligned tooling coming into contact with the bend. This defect is usually accompanied with a large bulging defect, not shown here.

Figure 98 – Mis-aligned tooling print into the bend

Figure 99 – Mis-aligned tooling print into the bend

Figure 100 – Bend bulge more than the lesser of 4mm or 25% of diameter (17mm bar shown)

There is an excess of resin built up in multiple locations on the bars in Figure 101 to Figure 103. This inconsistent resin distribution causes the bar not to be homogeneous throughout its cross-section. The guideline for acceptability of excess resin or bulging of fibres on the inside of the bend is 4mm, or 25% of the bar diameter, whichever is smaller, beyond which the bar becomes unacceptable. This only applies to bulging or bumps, not flattening of the cross-section at the bend.

Figure 101 – Resin build-up and inconsistencies

Figure 102 – Resin inconsistency (drips and runs)

Figure 103 – Resin build-up on outer circumference of bend

Figure 104 – Deformity at the start/end of bend

Figure 105 – Resin build-up at bend

The same bar is shown in Figure 106 and Figure 107 which has loose and exposed fibres protruding on the outside of the bend. Also, the end of the bar has not been cleanly cut and shows excessive and frayed loose fibres as seen in Figure 107. This bar cannot be repaired and must be rejected because of the exposed fibres on the outside of the bend. For a similar bar with no loose fibres on the bend, and if it was long enough, it might be made acceptable by the manufacturer cutting the end properly before leaving the plant.

Figure 106 – Exposed fibres at bend

Figure 107 – Loose / frayed fibres at bar end

Figure 108 – Exposed fibres at bend

The bar in Figure 109 has excessive voids and cracks in the resin at the bend. This bar cannot be repaired and must be rejected.

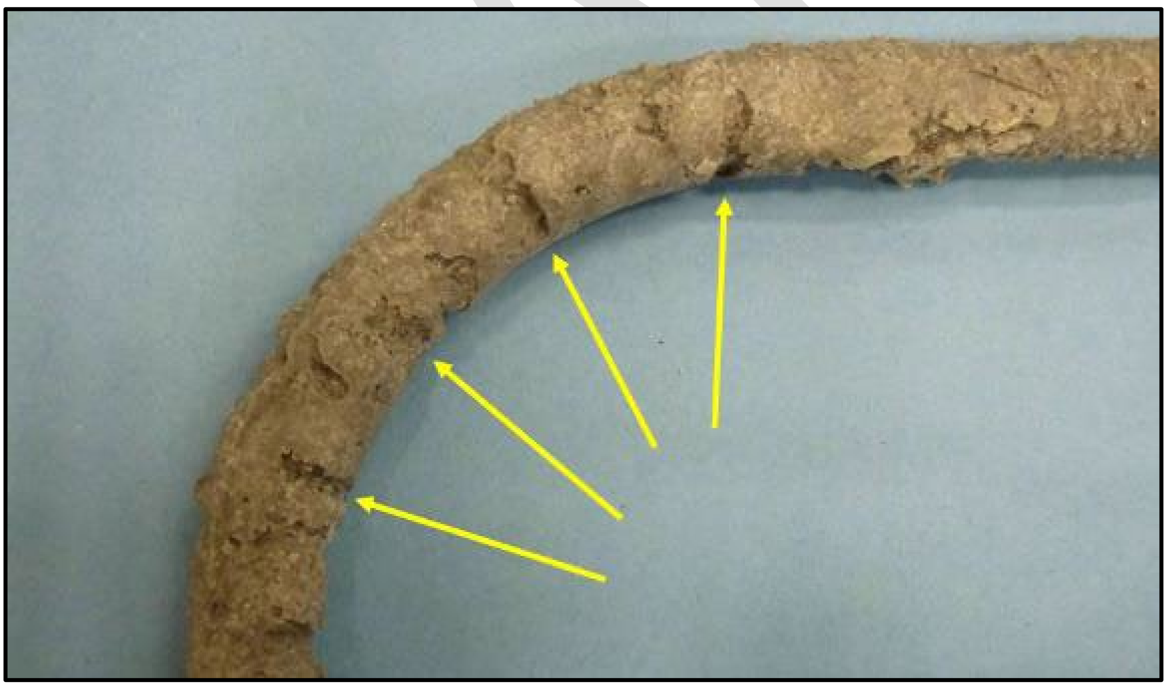

Figure 109 – Rejectable bar, with arrows pointing to surface voids

The group of bars in Figure 110 show cross-section inconsistencies and bulges on the inside of their bends. The guideline for acceptability of excess resin or bulging of fibres on the inside of the bend is 4mm, or 25% of the bar diameter, whichever is smaller. The bulges are too large and there is a non-homogeneous cross-section, making the bars unacceptable for use. These bars cannot be repaired and must be rejected.

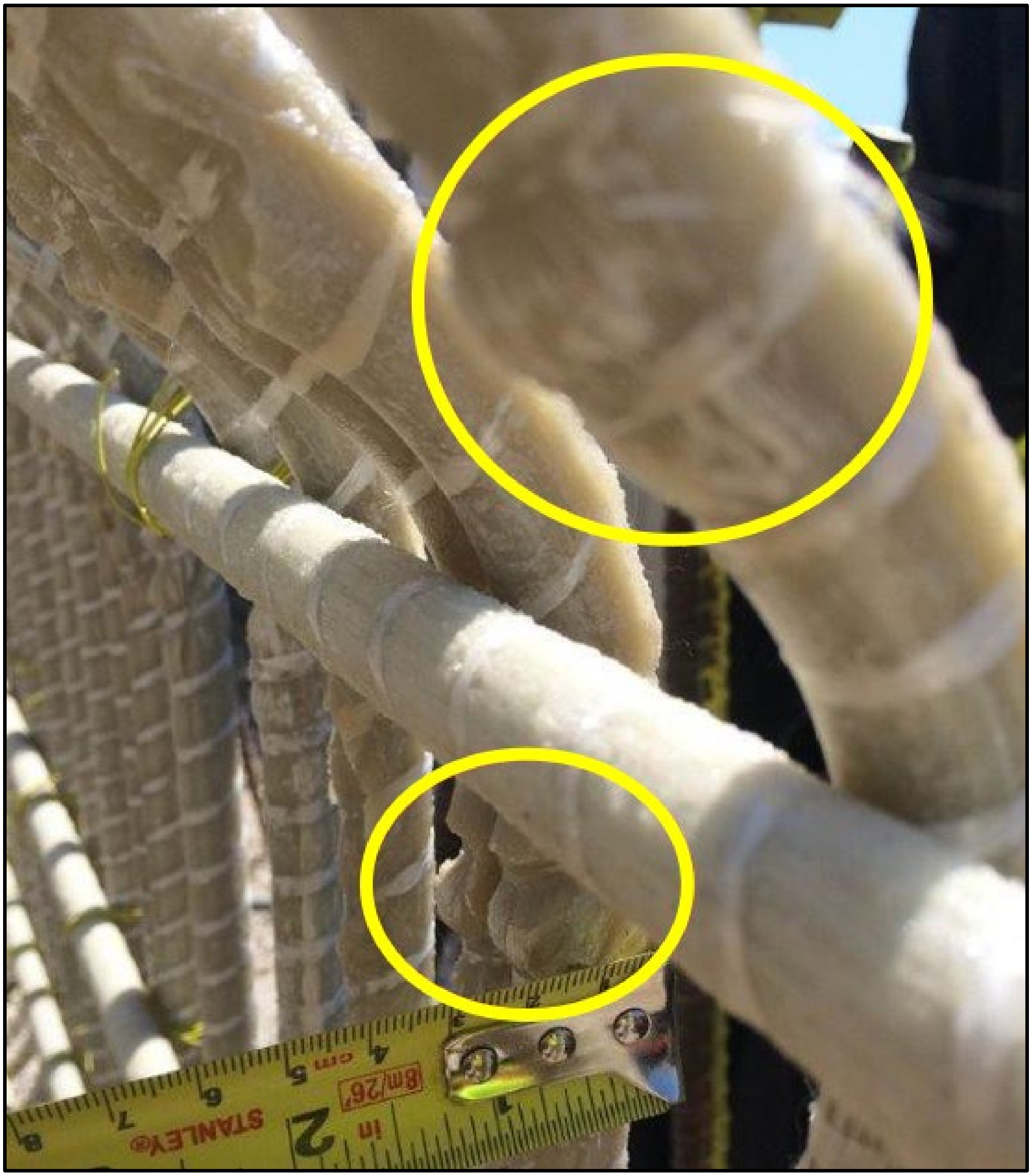

Figure 110 – Unacceptable bar, showing bulges on the inside of their bends

The bar in Figure 111 has crevices and a deformed section at the bend, which creates a non-uniform longitudinal cross section along the bar. Surface finishes are required to be free of voids and air pockets. As a result, this bar is unacceptable for use on MTO contracts. This deficiency was noticed after the bars were delivered to the construction site; therefore, this bar can no longer be repaired and must be rejected.

Figure 111 – Unacceptable bar with crevices and section loss at bend

6. Reporting Requirements

The MTO expects all GFRP reinforcing bars to be of consistently acceptable quality. This guideline functions as a support to assessing quality of products listed on the MTO's DSM lists. As custodian of the GFRP DSM list, the detection of frequently unacceptable bars must be documented and reported to:

Lead Bridge Standards Engineer, Structures Office
Ministry of Transportation
Transportation Infrastructure Management Division
Standards and Contracts Branch
Structures Office
2nd Floor, 301 St. Paul Street
St. Catharines, Ontario
L2R 7R4

Email: StructuresOffice@ontario.ca
Phone: 905-704-2406

This guideline was updated by the Structures Office Bridge Design and Standards Section, where questions regarding this document should be directed.

7. Acknowledgements

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