Technical Report on the Detailed Testing and Quality Determination of GFRP Rebars

Based on ASTM D7957/D7957M – 22, ASTM D8505-23 & CSA S807:19

Prepared by: Dr. Ahmed Elbady of SFTec, Inc. & Université de Sherbrooke
Presented by: RayBelle Infratrade Corp.

1. Introduction

Glass Fiber Reinforced Polymer (GFRP) rebars are non-metallic, corrosion-resistant reinforcements engineered as a high-performance alternative to traditional steel reinforcement in concrete structures. Their excellent resistance to corrosion, high tensile strength-to-weight ratio, and electromagnetic neutrality make them particularly suitable for infrastructure exposed to aggressive or sensitive environments.

This report presents a comprehensive overview of the testing methodologies, physical and mechanical property evaluations, and durability performance assessments necessary to determine the quality of GFRP rebars in accordance with international standards. The principal references are **ASTM D7957/D7957M – 22**, **ASTM D8505-23**, & **CSA S807:19** which defines the specification for solid, round GFRP bars with surface enhancements, including **12 required tests** covering key mechanical, physical, and long-term durability properties.

In the **Philippines and ASIA**, the capacity to conduct a **complete ASTM D7957**, **D8505-23** & **CSA S807:19 testing** remains limited. While some local laboratories may perform **basic mechanical tests and geometrical inspections**, such as **tensile strength**, **concrete bond** (**pullout**) **testing**, and **diameter inspection**, more advanced evaluations, particularly those related to **durability** are generally **not available regionally** under a single, fully accredited facility.

Currently, only two internationally recognized institutions are fully equipped to carry out the **entire suite of 12 tests** under ASTM D7957, D8505-23 & CSA S807:19:

1. **Université de Sherbrooke**, Quebec, Canada
2. **University of Miami**, Florida, USA

These institutions are widely acknowledged by the **International Code Council (ICC)** and recognized by standards bodies such as **ACI, ASTM, CSA, and AASHTO**. They are also recommended by the **Florida Department of Transportation (FDOT)** for GFRP rebar compliance testing based on ASTM standards.

This technical report consolidates the test procedures and quality verification framework based on these globally accepted standards and highlights the current state of GFRP testing infrastructure both locally and in the broader Asian region.

2. Scope of ASTM D7957/D7957M – 22

The standard covers solid round GFRP bars for concrete reinforcement, applies to both straight and bent bars, and defines requirements for geometric dimensions, mechanical properties, physical properties, and durability. It applies only to bars made exclusively from glass fibers and vinyl ester thermoset resin systems.

3. Key Definitions for Quality Assessment

Term	Definition
Guaranteed Property	The minimum value of a characteristic, calculated as the mean minus three standard deviations.
Mean Property	The average value is based on sample testing.
Production Lot	A batch of GFRP bars produced under uniform conditions and materials.
Surface Enhancement	Mechanisms (e.g., sand coating, lugs) to improve bond with concrete.

4. Quality Determination of GFRP Rebars

4.1 Product Qualification (Initial Validation)

For each GFRP bar size, eight specimens per lot shall be submitted, taken from a minimum of three separate production lots—totaling 24 samples. This is to ensure statistical validity, as required by the standard. All specimens must satisfy both the mean and guaranteed values specified in Table 1.

4.2 Quality Control and Certification (Production Monitoring)

Five random samples per production lot must be tested. Each must independently pass the test limits in Table 2. These are used for continual process verification and customer certification.

5. Specimen Requirements, Facilities, Certification, and Testing Timeline

5.1 Specimen Requirements

The number of test specimens required varies by test type and is defined in the individual ASTM methods referenced within ASTM D7957. A general overview is as follows:

Test Type	Minimum No. of Specimens	Notes
Tensile Strength & Modulus	5 per bar size	Tested per ASTM D7205
Transverse Shear Strength	5 per bar size	ASTM D7617
Alkali Resistance (per exposure)	5 specimens per time point	At 30, 60, and 90 days
Fiber Content / Density	3–5 specimens	ASTM D2584 / ISO 1172
Moisture Absorption / Tg / Cure	3–5 specimens	ASTM D570 / E1356 / E2160
Bent Bar Performance	5 specimens	ASTM D7913 or D7914

Total Specimen Count: Can range from 30 to 50 bars depending on bar sizes and exposure durations. All specimens must be manufactured from the same production batch to ensure representative results.

5.2 Testing Facilities and Their Capabilities

University of Sherbrooke (Canada)

Renowned for its advanced FRP research and home to one of North America's most sophisticated composite material testing laboratories, the university conducts the full suite of ASTM D7957/D7957M, ASTM D8505-23 & CSA S807:19 tests, along with an additional in-house quality control test developed in collaboration with the Florida Department of Transportation (FDOT) to further enhance production validation.

In addition, more than six additional tests were also performed in accordance with **CAN/CSA S807-19**, providing a comprehensive evaluation of the physical, mechanical, and durability properties of the GFRP bars. To further support manufacturers in enhancing product performance, **advanced material characterization techniques** such as **Fourier Transform Infrared Spectroscopy (FTIR)** and **Scanning Electron Microscopy (SEM)** were also conducted. These analyses offer deeper insight into the chemical structure and surface morphology of the composites, enabling continuous improvement in quality and long-term structural reliability.

This research facility operates under the leadership of ***Prof. Brahim Benmokrane, Ph.D., P.Eng.***, a world-renowned expert in FRP reinforcement technologies. *Prof. Benmokrane* has been instrumental in the development of international standards for GFRP bars and continues to contribute significantly to the advancement of composite materials in infrastructure.

University of Miami – Infrastructure Materials Lab (USA)

Led by ***Prof. Antonio Nanni***, a globally recognized authority in FRP technologies and the founding chair of **ACI 440 Committee**, which governs the use of fiber-reinforced polymer (FRP) materials in concrete construction. The Infrastructure Materials Lab at the

University of Miami is one of the leading research and testing centers for composite materials. The lab is fully accredited to perform the entire ASTM D7957 & ASTM D8505-23 test group and supports ICC-ES evaluation processes.

The lab also benefits from the expertise of ***Prof. Francisco De Caso***, the **Lead Principal Scientist** at the University of Miami within the Department of Civil and Architectural Engineering. Prof. De Caso plays a key role in the development and execution of testing protocols for GFRP materials.

All three, Prof. Antonio Nanni, Prof. Francisco De Caso, and Prof. Brahim Benmokrane are members of **ACI 440.11-22 Committee**, which focus on the use of glass fiber-reinforced polymer (GFRP) bar materials in concrete construction and structural concrete, respectively.

Both Prof. Nanni and Prof. De Caso are instrumental in the ongoing research and development of FRP composites, particularly GFRP bars. Prof. Nanni has published extensively on FRP applications in concrete infrastructure and has been recognized globally for his leadership in composite construction. Prof. De Caso, as a principal investigator and technical expert, has authored and co-authored numerous scientific papers focused on material performance and FRP testing methodologies. Their academic and professional contributions have significantly shaped the current practices and standards used in the FRP industry. Their collaboration with international organizations such as ACI, ASTM, and ICC-ES, as well as state Departments of Transportation (DOTs), positions the University of Miami as a cornerstone in global FRP validation and certification efforts.

Similarly, Prof. Brahim Benmokrane of the University of Sherbrooke has been a pivotal figure in the advancement of GFRP bar technologies. He leads one of the most sophisticated composite testing facilities in North America and has published numerous research papers and design guides that have contributed to international GFRP standards. His work, in partnership with global regulatory and academic institutions, has made the University of Sherbrooke a leading authority and reference hub for FRP research and infrastructure applications.

5.3 ICC-ES Evaluation and Certification

The **ICC-ES (International Code Council Evaluation Service)** certification verifies that a GFRP product not only meets ASTM D7957, D8505-23 & CSA S807:19 performance criteria but also adheres to strict manufacturing quality standards. A certifying or notifying body like ICC-ES is essential because it provides an impartial, third-party validation that ensures consistency, reliability, and compliance of the product and production processes with internationally accepted codes and standards. This is particularly important for regulatory approval, public infrastructure funding, and international acceptance of GFRP materials in structural applications.

For structural materials like GFRP rebars, certification by a body such as ICC-ES is crucial because it confirms that the product can safely and reliably perform in load bearing and durability-critical applications. Structural materials must meet strict codes and undergo regular monitoring to protect public safety. ICC-ES certification establishes trust across design professionals, contractors, and regulators, ensuring that the product has undergone extensive and standardized validation. It also supports procurement transparency and is often a requirement in major infrastructure and government-funded projects. The certification process includes:

- Complete mechanical, physical, and durability verification per ASTM D7957, D8505-23 & CSA S807:19
- Routine inspections and audits of the production facility and quality control systems
- Continuous production traceability and code compliance

An **ICC-ES Evaluation Report (ESR)** affirms a product's acceptability under international building codes, supporting approval by engineers, contractors, and regulatory bodies worldwide. It is often the preferred benchmark among leading structural practitioners including design engineers, academic researchers, infrastructure consultants, construction professionals, and government institutions because it provides a unified, internationally accepted reference for product compliance and performance. ICC-ES certification simplifies material selection, improves design confidence, supports public procurement criteria, and reinforces the accountability of suppliers and manufacturers.

5.4 Estimated Timeline for Testing

Activity	**Time Required**
Sample Preparation & Shipping	1–2 weeks
Mechanical & Physical Testing	2–3 weeks
Durability (Alkali) Testing	Up to 90 days
Data Review & Reporting	1–2 weeks post-testing
ICC Plant Audit & ESR Processing	2–4 weeks
Total Duration	**3.5 to 4 months**

6. Testing Procedures

6.1 Mechanical Properties

6.1.1 Ultimate Tensile Force

Conducted using ASTM D7205/D7205M. A straight section of GFRP bar is subjected to uniaxial tensile loading in a testing machine until rupture. The bar is gripped with specialized fixtures to prevent slippage. The maximum load recorded before failure is the Ultimate Tensile Force.

6.1.2 Tensile Modulus of Elasticity

Also, per ASTM D7205/D7205M. Determined by measuring the slope of the linear portion of the stress-strain curve during the tensile test. A high-precision extensometer is used to measure strain.

6.1.3 Ultimate Tensile Strain

Calculated by dividing the measured elongation at rupture by the original gauge length of the specimen. It is derived from data collected during ASTM D7205/D7205M testing.

6.1.4 Transverse Shear Strength

Tested as per ASTM D7617/D7617M. A short cylindrical section of the GFRP bar is loaded transversely between two shear fixtures until failure. The shear strength is calculated based on the peak load and cross-sectional area.

6.1.5 Bond Strength to Concrete

Performed following ASTM D7913/D7913M. GFRP bars are embedded in concrete cylinders and subjected to direct pullout. The bond strength is the peak force divided by the embedded surface area of the bar.

6.1.6 Tensile Strength of Bent Portions

ASTM D7914/D7914M specifies testing bent sections of GFRP bars. The bend must be formed in uncured state. After curing, the specimen is tested in a tensile machine to assess the strength at the bend.

Property	**Limit**	**Test Method**
Ultimate Tensile Force	Per Table 3	ASTM D7205/D7205M
Tensile Modulus of Elasticity	≥ 44,800 MPa	ASTM D7205/D7205M
Ultimate Tensile Strain	≥ 1.1%	ASTM D7205/D7205M
Transverse Shear Strength	≥ 131 MPa	ASTM D7617/D7617M
Bond Strength to Concrete	≥ 7.6 MPa	ASTM D7913/D7913M
Tensile Strength of Bent Portion	≥ 60% of straight bar	ASTM D7914/D7914M

6.2 Physical and Thermal Properties

6.2.1 Fiber Mass Content

Tested by ASTM D2584 (burn-off) or D3171 (acid digestion). A known mass of GFRP bar is burned or dissolved to remove the resin, and the remaining fiber mass is measured. The percentage is calculated accordingly.

6.2.2 Glass Transition Temperature (Tg)

Determined via ASTM E1356 using Differential Scanning Calorimetry (DSC). A small sample is heated at a controlled rate and the midpoint temperature of the shift in heat flow is recorded as the glass transition temperature.

6.2.3 Degree of Cure

Tested under ASTM E2160. It quantifies the extent of polymerization in the thermoset resin system by comparing the measured heat-of-reaction of cured samples to uncured references using DSC.

6.2.4 Moisture Absorption (24 hours)

ASTM D570, Section 7.4. GFRP specimens are submerged in water at 50°C for 24 hours, then weighed to determine water uptake by mass gain.

6.2.5 Moisture Absorption to Saturation

Also, per ASTM D570. Samples are soaked until no further increase in weight is recorded. The percentage increase from dry weight to saturated weight is the moisture absorption capacity.

Property	Limit	Test Method
Fiber Mass Content	≥ 70%	ASTM D2584 / D3171
Degree of Cure	≥ 95%	ASTM E2160
Glass Transition Temperature	≥ 100°C	ASTM E1356
Moisture Absorption (24hr)	≤ 0.25%	ASTM D570
Moisture Absorption to Saturation	≤ 1.0%	ASTM D570

6.3 Durability Performance

6.3.1 Alkaline Resistance

According to ASTM D7705/D7705M, GFRP bars are immersed in an alkaline solution at 60°C for 90 days. Post-exposure, the tensile strength is measured and must be ≥80% of the initial value.

Property	Limit	Test Method
Alkaline Resistance	≥ 80% of original tensile force after 90 days at 60°C	ASTM D7705/D7705M

7. Bar Geometry and Dimensional Standards

7.1 Cross-Sectional Area

- Measured using ASTM D7205/D7205M.
- Must fall within the **minimum and maximum tolerance limits** listed in Table 3.

7.1.1 Measured Cross-Sectional Area

Measured using ASTM D7205/D7205M and D792. This involves calculating the average cross-sectional area of the bar, including any surface deformations, via immersion or caliper-based displacement methods.

7.2 Bar Sizes and Minimum Ultimate Tensile Force

- Bar sizes range from **M6 to M32**.
- Each size has defined:
  - Nominal diameter
  - Cross-sectional area
  - Minimum ultimate tensile force

7.3 Minimum Inside Bend Diameters

- Defined for sizes up to M25.
- Bends must be formed during the uncured state of the resin.

7.3.1 Minimum Inside Bend Diameter (Bent Bars)

Referenced in ASTM D7957 Section 9 and Table 4. It is a geometric specification: the inside bend radius of bent bars must conform to minimum values (e.g., 3× to 6× bar diameter). This is a dimensional inspection.

8. Manufacturing and Traceability Requirements

- **Resin**: Must be vinyl ester-based; no polyester allowed.
- **Fibers**: Continuous unidirectional glass roving's.
- **Traceability**: Every bar must include:
  - ASTM standard reference
  - Manufacturer's mark
  - Bar size
  - Production lot number
- **Bends**: May be tagged with shape and lot info.

9. Certification and Compliance

9.1 Quality Control Documentation

- Manufacturer must provide test reports upon request.
- Reports include test results, lot number, bar designation, and production date.

9.2 Rejection Criteria

- Any non-compliance with Table 2 limits results in lot rejection.
- Rehearing or re-sampling may be requested if disagreement arises.

10. Ensuring the Quality of GFRP Rebars in Practice

To evaluate and verify the quality of GFRP rebars in project procurement and use:

A. Check Product Certification

- Confirm certification per ASTM D7957/D7957M.
- Review test data: tensile strength, modulus, alkaline resistance, etc.

B. Verify Physical Characteristics

- Ensure correct bar sizes, markings, and geometry.
- Confirm bond-enhancing surfaces are intact and uniform.

C. Request Quality Control Records

- Ask for recent quality control test results.
- Compare against Table 2 thresholds.

D. Inspect Storage and Handling

- Ensure bars are protected from UV, excessive heat, and mechanical damage.
- Avoid improper bending after curing.

11. Special Design Considerations & Applications

GFRP rebars are particularly beneficial in:

- **Marine and coastal infrastructure**
- **Wastewater treatment facilities**
- **Bridges and tunnels (chloride-prone zones)**
- **MRI rooms and electromagnetic-sensitive structures**
- **Corrosion-critical transportation projects**

Engineers must consider:

- **Lower modulus of elasticity** compared to steel
- **Higher strain capacity**
- **Different anchorage and lap splice design**
- **Temperature-dependent mechanical behavior**

12. Conclusion

The ASTM D7957/D7957M – 22, ASTM D8505-23 & CSA S807:19 standard provides a comprehensive and rigorous framework for the qualification and quality control of Glass Fiber Reinforced Polymer (GFRP) rebars used in structural applications. Through standardized testing of mechanical, physical, and durability properties, along with strict production oversight, this specification ensures that GFRP bars deliver reliable performance in corrosive and demanding environments.

Compliance with this standard is not only essential for engineering integrity and long-term structural durability but also serves as a critical foundation for third-party certification. In addition to meeting ASTM criteria, GFRP rebars are also required to conform to related provisions under **ACI (American Concrete Institute), AASHTO (American Association of State Highway and Transportation Officials), and CSA (Canadian**

Standards Association) for use in infrastructure and building projects across different jurisdictions.

Furthermore, adherence to ASTM D7957/D7957M – 22 is a requirement by the **International Code Council Evaluation Service (ICC-ES)** as part of its evaluation and certification process for both the rebar product and the manufacturing facility. Full compliance with these protocols is necessary for obtaining an **ICC-ES Evaluation Report (ESR)**, which facilitates code acceptance and broad market approval. For more information on the ICC-ES certification process, visit: https://icc-es.org.

SFTec, Inc., the manufacturer of SFT-Bar®, is globally recognized for its engineering excellence and testing integrity. It is the **only GFRP rebar manufacturer with four bar sizes ICC-ES certified**, setting it apart as an industry benchmark. These certifications confirm that SFT-Bar® meets or exceeds all requirements of ASTM D7957/D7957M – 22, ASTM D8505-23 & CSA S807:19 across multiple critical sizes, backed by full-scale testing in internationally accredited laboratories. With proven performance in tensile strength, bond properties, alkali resistance, and dimensional tolerance, SFT-Bar® has earned its place as one of the most trusted and advanced GFRP rebar solutions in the world today.

ASTM D7957/D7957M – 22 Tables:

TABLE 1 Property Limits and Test Methods for Qualification[A]

Property	Limit	Test Method
Mean Glass Transition Temperature	Midpoint temperature ≥100 °C [212 °F]	ASTM E1356
Mean Degree of Cure	≥95 %	ASTM E2160
Mean Measured Cross-Sectional Area	Table 3	ASTM D7205/D7205M, subsection 11.2.5.1
Guaranteed[B] Ultimate Tensile Force	Table 3	ASTM D7205/D7205M
Mean Tensile Modulus of Elasticity	≥44,800 MPa [6 500 000 psi]	ASTM D7205/D7205M
Mean Ultimate Tensile Strain	≥1.1 %	ASTM D7205/D7205M
Guaranteed[B] Transverse Shear Strength	≥131 MPa [19 000 psi]	ASTM D7617/D7617M
Guaranteed[B] Bond Strength	≥7.6 MPa [1100 psi]	ASTM D7913/D7913M
Mean Moisture Absorption to Saturation	≤1.0 % to saturation at 50 °C [122 °F]	ASTM D570, subsection 7.4
Mean Alkaline Resistance	≥80 % of initial mean ultimate tensile force following 90 days at 60 °C [140 °F]	ASTM D7705/D7705M, Procedure A
Guaranteed[B] Ultimate Tensile Force of Bent Portion of Bar	≥60 % of the values in Table 3	ASTM D7914/D7914M

[A]For the determination of the mean and guaranteed properties, at least 24 samples shall be obtained in groups of eight or more from three or more different production lots. The mean and guaranteed properties shall satisfy the limits.
[B]Guaranteed property is defined in 3.2.4.

TABLE 2 Property Limits and Test Methods for Quality Control and Certification[A,B]

Property	Limit	Test Method
Fiber Mass Content	≥70 %	ASTM D2584 or ASTM D3171
Glass Transition Temperature	Midpoint temperature ≥100 °C [212 °F]	ASTM E1356
Degree of Cure	≥95 %	ASTM E2160
Measured Cross-Sectional Area	Table 3	ASTM D7205/D7205M, subsection 11.2.5.1
Ultimate Tensile Force	Table 3	ASTM D7205/D7205M
Tensile Modulus of Elasticity	≥44 800 MPa [6 500 000 psi]	ASTM D7205/D7205M
Ultimate Tensile Strain	≥1.1 %	ASTM D7205/D7205M
Moisture Absorption in 24 h	≤0.25 % in 24 h at 50 °C [122 °F]	ASTM D570, subsection 7.4

[A]For the determination of each of the property limits, five random samples shall be obtained from each production lot. Each individual sample shall satisfy the property limits.
[B]For bent bars, the tests are performed on the straight portion of the bars.

TABLE 3 Geometric and Mechanical Property Requirements

Bar Designation No.	Nominal Dimensions		Measured Cross-Sectional Area Limits mm^2 [$in.^2$]		Minimum Guaranteed Ultimate Tensile Force kN [kip]
	Diameter mm [in.]	Cross-Sectional Area mm^2 [$in.^2$]	Minimum	Maximum	
M6 [2]	6.3 [0.250]	32 [0.049]	30 [0.046]	55 [0.085]	27 [6.1]
M10 [3]	9.5 [0.375]	71 [0.11]	67 [0.104]	104 [0.161]	59 [13.2]
M13 [4]	12.7 [0.500]	129 [0.20]	119 [0.185]	169 [0.263]	96 [21.6]
M16 [5]	15.9 [0.625]	199 [0.31]	186 [0.288]	251 [0.388]	130 [29.1]
M19 [6]	19.1 [0.750]	284 [0.44]	268 [0.415]	347 [0.539]	182 [40.9]
M22 [7]	22.2 [0.875]	387 [0.60]	365 [0.565]	460 [0.713]	241 [54.1]
M25 [8]	25.4 [1.000]	510 [0.79]	476 [0.738]	589 [0.913]	297 [66.8]
M29 [9]	28.7 [1.128]	645 [1.00]	603 [0.934]	733 [1.137]	365 [82.0]
M32 [10]	32.3 [1.270]	819 [1.27]	744 [1.154]	894 [1.385]	437 [98.2]

TABLE 4 Minimum Inside Bend Diameter of Bent Bars[A]

Bar Designation, mm [U.S. Standard]	Minimum Bend Diameter mm [in.]
M6 [2]	38 [1.50]
M10 [3]	58 [2.25]
M13 [4]	76 [3.00]
M16 [5]	96 [3.75]
M19 [6]	114 [4.50]
M22 [7]	134 [5.25]
M25 [8]	152 [6.00]

[A] Bent bars of designation M29 [9] and M32 [10] are not included in this specification.