EXPERIMENTAL INVESTIGATION ON E-TYPE GLASS FIBER REINFORCED LOW CARBON STEEL- EPOXY COMPOSITE

[1]Mr. Masood Vali, [2]Mr.L Lokesh, [3]Prof. S L V Prasad
[1]M.Tech (Advanced Manufacturing systems) JNTUA , [2] M.Tech (Advanced Manufacturing systems) JNTUA,
[3]Head of Mechanical Engineering Department, GATES Institute of Technology
[1]Mechanical Engineering Department,
[1]JNTU, Anantapur, India - 9642776296

Abstract **:** Fiber metal laminates are good candidates for advanced aerospace structural applications due to their high specific mechanical properties especially fatigue resistance. The most important factor in manufacturing of these laminates is the adhesive bonding between steel and FRP layers. In this study several glass-fiber reinforced steel laminates with different bonding adhesion were manufactured. Mechanical Tests like Tensile, Compression and Impact tests were carried out based on ASTM standard were then conducted to study the effects of interfacial adhesive bonding on impact behavior of these laminates. It is observed that the damage size is greater in laminates with poor interfacial adhesion compared to that of laminates with strong adhesion between steel and glass layers. In addition, FMLs of with good adhesion bonding shows better resistance under low velocity impact and their corresponding contact forces are about 50% higher than that of specimens with a weak bonding. Moreover, maximum central deflections in laminates with strong bonding are about 30% lower than that of FMLs with poor adhesion.

Key words –Glass Fiber, Hand layup, Steel, Epoxy.

I. INTRODUCTION

Over the past ten decades, application of composite materials are continuously increasing from traditional application areas such as military aircraft, commercial aircraft to various engineering fields including automobiles, robotic arms and even architecture. Due to its superior properties, composites have been one of the materials used for repairing the existing structures. In such applications and also for joining various composite parts together, they are fastened together either using adhesives or mechanical fasteners. Nowadays, a novel method called hybrid joint is also being employed, where a combination of both adhesive and mechanical fasteners is used.

II. AIM & OBJECTIVES

To investigate the mechanical characterization of glass fiber epoxy composite laminates and glass reinforced with steel powder. To achieve this, laminate plate will prepared and then make specimen as per the ASTM standards. This specimen will undergo for testing with data acquisition system.

III. METHODOLOGY

The specimens were prepared with the glass fiber epoxy laminates with steel powder according to the ASTM standard. The specimens were undergoing for mechanical testing by Universal testing machine and Impact testing machine. These results were compared with and without orientation.

IV. EXPERIMENTAL

MATERIALS

In the present investigation E-Type glass fiber & steel are used for fabricating the composite specimen. Glass fiber is obtained from Sri Lakshmi group of exports and imports, Mangalagiri, Guntur, A.P,India. Epoxy resin, catalyst and accelerator is obtained from

Suntech fiber private limited, Bangalore, Karnataka, India. steel powder is obtained from J.J groups, Bangalore, Karnataka, India. The GFRP used for the fabrication is of bidirectional matt having 500gr/sq.mtr.

GLASS

Glass is one of the oldest known man-made materials; the practical strength of glass, however, has always been a limiting and puzzling factor. Still today the mechanical properties of glass fibers are twofold a) a special quality is the high strength b) the brittle fracture is limiting its application. An understanding of the structure of glass in relation to how and why it breaks is crucial in both improving existing applications of glasses and in new functionalities and application of all kinds of glasses, not only fiber glass.

GLASS FIBER REINFORCED POLYMER

Glass fiber reinforced plastic is also called as glass fiber reinforced polymer, it is also called as fiber glass. Fiber glass is light in weight, extremely strong and robust material. These glass fibers are preferred in most of the industrial applications due to high chemical resistance good insulating properties, high tensile strength at low cost. However carbon fibers may show superior front in properties than glass fiber but carbon fibers are more costly than glass fibers and they offer a marginal improvement in properties. Glass fibers exhibit bulk strength and weight properties ahead with respect to the metals. Molding is the suitable process for the development of glass fiber Matts. Glass fibers are developed in two common types. i. E-glass and ii. S-glass. C-glass is also developed, which is suitable for the application where a corrosion resistance is required. C-glass fibers show a good corrosion resistance in acidic medium. Glass fibers can be produced in various diameters and it is very easy to produce a super fine fibers with very small diameter. The fineness quality is a key parameter in allowing the flexibility for the fibers. Home furnishing tables, toys, apparels, tire, automobiles, bath-wares, water tanks, stir cases, bottles, containers, carriers, hot tubs door skins etc. are produced from glass fiber manufactured.

PROPERTIES OF STEEL

Steel has a unique and unbeatable combination of properties that make it into a versatile, highly usable and attractive construction material.

WEIGHT

Steel is light with a density one third that of steel, 2.700 kg/m3.

STRENGTH

Steel is strong with a tensile strength of 70 to 700 MPa depending on the alloy and manufacturing process. Extrusions of the right alloy and design are as strong as structural steel.

ELASTICITY

The Young's modulus for steel is a third that of steel (E = 70,000 MPa). This means that the moment of inertia has to be three times as great for an steel extrusion to achieve the same deflection as a steel profile.

FORMABILITY

Steel has a good formability, a characteristic that is used to the full in extruding. Steel can also be cast, drawn and milled.

MACHINING

Steel is very easy to machine. Ordinary machining equipment can be used such as saws and drills. Steel is also suitable for forming in both the hot and the cold condition.

JOINING

Steel can be joined using all the normal methods available such as welding, soldering, adhesive bonding and riveting.

CORROSION RESISTANCE

A thin layer of oxide is formed in contact with air, which provides very good protection against corrosion even in corrosive environments. This layer can be further strengthened by surface treatments such as anodising or powder coating.

CONDUCTIVITY

The thermal and electrical conductivities are very good even when compared with copper. Furthermore, an steel conductor has only half the weight of an equivalent copper conductor.

LINEAR EXPANSION

Steel has a relatively high coefficient of linear expansion compared to other metals. This should be taken into account at the design stage to compensate for differences in expansion.

NON-TOXIC

Steel is not poisonous and is therefore highly suitable for the preparation and storage of food.

REFLECTIVITY

Steel is a good reflector of both light and heat.

LIGHT WEIGHT

Steel is a very light metal with a specific weight of 2.7 g/cm3, about a third that of steel. For example, the use of steel in vehicles reduces dead-weight and energy consumption while increasing load capacity. Its strength can be adapted to the application required by modifying the composition of its alloys.

CORROSION RESISTANCE

Steel naturally generates a protective oxide coating and is highly corrosion resistant. Different types of surface treatment such as anodising, painting or lacquering can further improve this property. It is particularly useful for applications where protection and conservation are required.

ELECTRICAL AND THERMAL CONDUCTIVITY

Steel is an excellent heat and electricity conductor and in relation to its weight is almost twice as good a conductor as copper. This has made steel the most commonly used material in major power transmission lines.

REFLECTIVITY

Steel is a good reflector of visible light as well as heat, and that together with its low weight, makes it an ideal material for reflectors in, for example, light fittings or rescue blankets.

DUCTILITY

Steel is ductile and has a low melting point and density. In a molten condition it can be processed in a number of ways. Its ductility allows products of steel to be basically formed close to the end of the product's design.

IMPERMEABLE AND ODOURLESS

Steel foil, even when it is rolled to only 0.007 mm thickness, is still completely impermeable and lets neither light aroma nor taste substances out. Moreover, the metal itself is non-toxic and releases no aroma or taste substances which makes it ideal for packaging sensitive products such as food or pharmaceuticals.

RECYCLABILITY

Steel is 100 percent recyclable with no downgrading of its qualities. The re-melting of steel requires little energy: only about 5 percent of the energy required to produce the primary metal initially is needed in the recycling process.

STEEL POWDER

Steel powder is light in weight and it is good conductor of electricity. Steel powder is extensively used in the manufacturing of automobiles. Steel powder finds more applications in the development of marine bodies, aerospace and cooking utensils etc.

EPOXIES

Epoxies are polymer materials, which begin life as liquid and are converted to the solid polymer by a chemical reaction. An epoxy based polymer is mechanically strong, chemically resistant to degradation in the solid form and highly adhesive during conversion from liquid to solid. These properties, together with the wide range of basic epoxy chemicals from which an epoxy system can be formulated, make them very versatile.

Epoxy systems physically comprise two essential components, a resin and a hardener. Sometimes there is a third component, an accelerator, but this is not so common. The resin component is the ‘epoxy’ part and the hardener is the part it reacts with chemically and is usually a type of ‘amine’. Whereas the resin component is usually light, sometimes almost clear coloured and near odourfree, hardeners are usually dark and have a characteristic ‘ammonia-like’ odour. When these two components are brought together and mixed intimately in a prescribed way, they will react chemically and link together irreversibly, and when the full reaction has been completed they will form a rigid plastic polymer material.

This polymer is called a ‘thermoset’ plastic because, when cured, it is irreversibly rigid and relatively unaffected by heat. Epoxy polymers have many uses: as industrial adhesives, or as coatings, or as matrices in which to embed reinforcement fibres to form advanced reinforced plastics, and also as encapsulation media.

The uses for epoxies span many markets including aerospace, transport, marine, civil engineering and general industry, and such is the versatility of epoxy’s chemistry that chemists are able to fine tune the formulations for a wide variety of specific tasks. Some epoxies, which are used as coatings, are dispersed in solvents, but the majority used for structural applications are solvent-free, and these are the types which require more care in their use and which are featured here.

PREPARATION OF COMPOSITE SPECIMEN

In the present investigation the specimen are fabricated with a hand layup technique. The fabricated specimen consists six layers. steel powder mixed with epoxy is sprayed between the layers. The purpose of adding steel powder is to increase hardness of the specimen. Here an attempt is made to verify the composite behavior when steel powder is included as an important ingredient epoxy resin is employed for binding. Dura wax is applied on the surface of the polythene sheet; Dura wax on the sheet surface will help in taking out the fabricated pieces with-out sticking to the matt very easily. A roller is used to remove air gaps between each a pair of successive layers. After the addition of layers the matt is kept under press for 24 hours, any excess amount of air /air gaps are removed under hydraulic press. Once the hardness is accomplished the composites are taken out and trimmed to required dimensions.

MECHANICAL TESTING

TENSILE TEST

Tensile test is performed by using ASTM D638 method. ASTM D638 is a standard test for evaluating behavior of both reinforced and unreinforced plastics under tensile loading. Conditions such as machine operating speed input humidity and some other pretreatment conditions should be defined before doing the test, the maximum thickness of the specimen in ASTMD638 should not exceed 14 mm, thin sheets and very thin films having 1mm thickness are less than that can be also tested through this standard tests. UTM (universal testing machine) is performing required tensile test in the present work, two different specimens are prepared 1. GFRP 2.GFRP with steel. The hybrid composites are trimmed in to required dimensions and smooth finishing by using emery paper the gauge length dimensions and cross head speeds are followed as per ASTM D638 manual fig.1 shows specimen for tensile test once the specimen are conformed to dimensions, each specimen is mounted in to the machine for conducting the tensile test . The load is gradually applied till the specimen is failed the results are recorded as a function of gauge length and applied force in each variety three specimen are made to the encounter the test.

Fig.1 Tensile test specimen

FLEXURAL TEST

Flexural test can is performed by using ASTM D790.Three point flexural test as per ASTM D790 stanadrad is conducted on the specimen the specimen deflection is the out put of the flexural test and it is measured with cross head position, the results of the test are displacement corresponded to flexural strength to conduct flexural test the test specimen is placed in the UTM and the force is applied till there is a fracture/break the specimen for flexural test are shown in fig.2 .The flexural test is conducted at the room temperature is 24 deg centigarde with an average relative humidity of 50%.

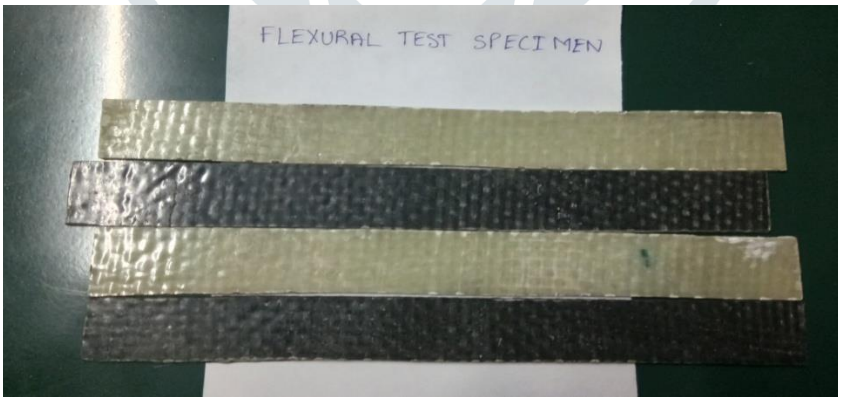


Fig.2 Flexural test specimen

IMPACT TEST

Impact test is performed by using ASTM A370 procedures are suitable for composite specimen and cast steel products during the test, the specimen is loaded in to the machine the pendulum is made to hit the specimen through impact test the specimen is braked and the amount of energy needed to break the specimen is measured. Toughness, Yield strength also can be measured. It is possible to analyses the ductility and strain rate on fracture through impact test, the specimens for impact test are shown in fig.3

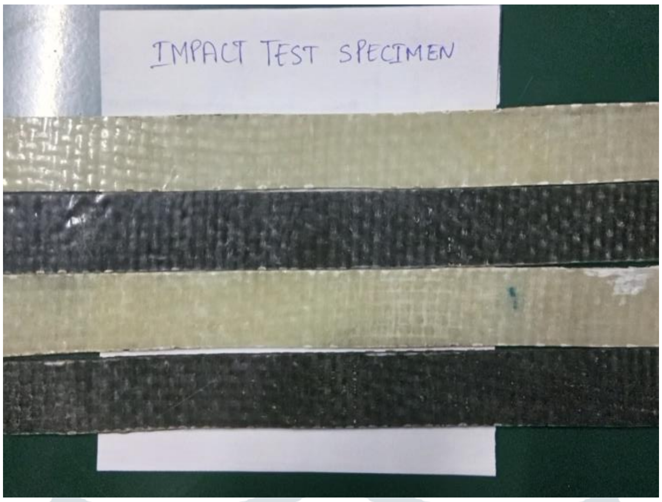


Fig.3 Impact test specimen

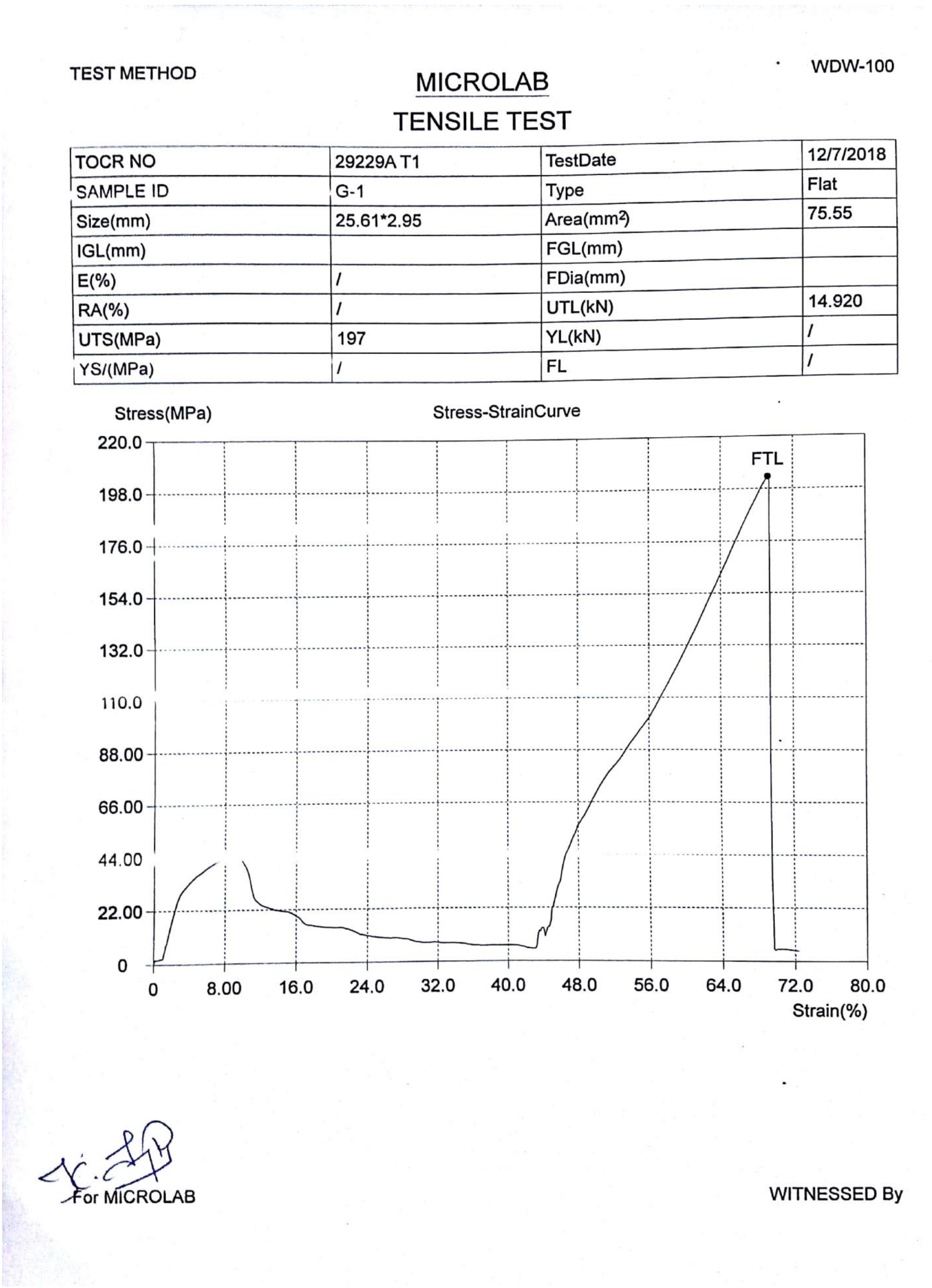
V. RESULTS AND DISCUSSION

MECHANICAL PROPERTIES OF COMPOSITES

The hybrid composites are prepared with a combination of glass fibers with steel powder. steel powder is added as an important ingredient in the specimen preparation mechanical testing's such as tensile test (ASTM D638), impact test(ASTM-A370) and flexural (ASTMD790) are conducted on two different specimen in each variety four specimen are fabricated .Totally 14 specimen are fabricated and tested for the evaluation of mechanical properties.

TENSILE PROPERTIES

The hybrid composite samples are tested in UTM till the samples are left to break till the ultimate tensile strength occurs. The ultimate tensile strength, elastic modulus are determined. Determined stress strain curve is directly generated as a sample graph by the machine for GFRP in fig.4 & fig.5 GFRP with steel powder is as shown in fig.6 & fig.7



TEST METHOD

WDW-100

MICROLAB

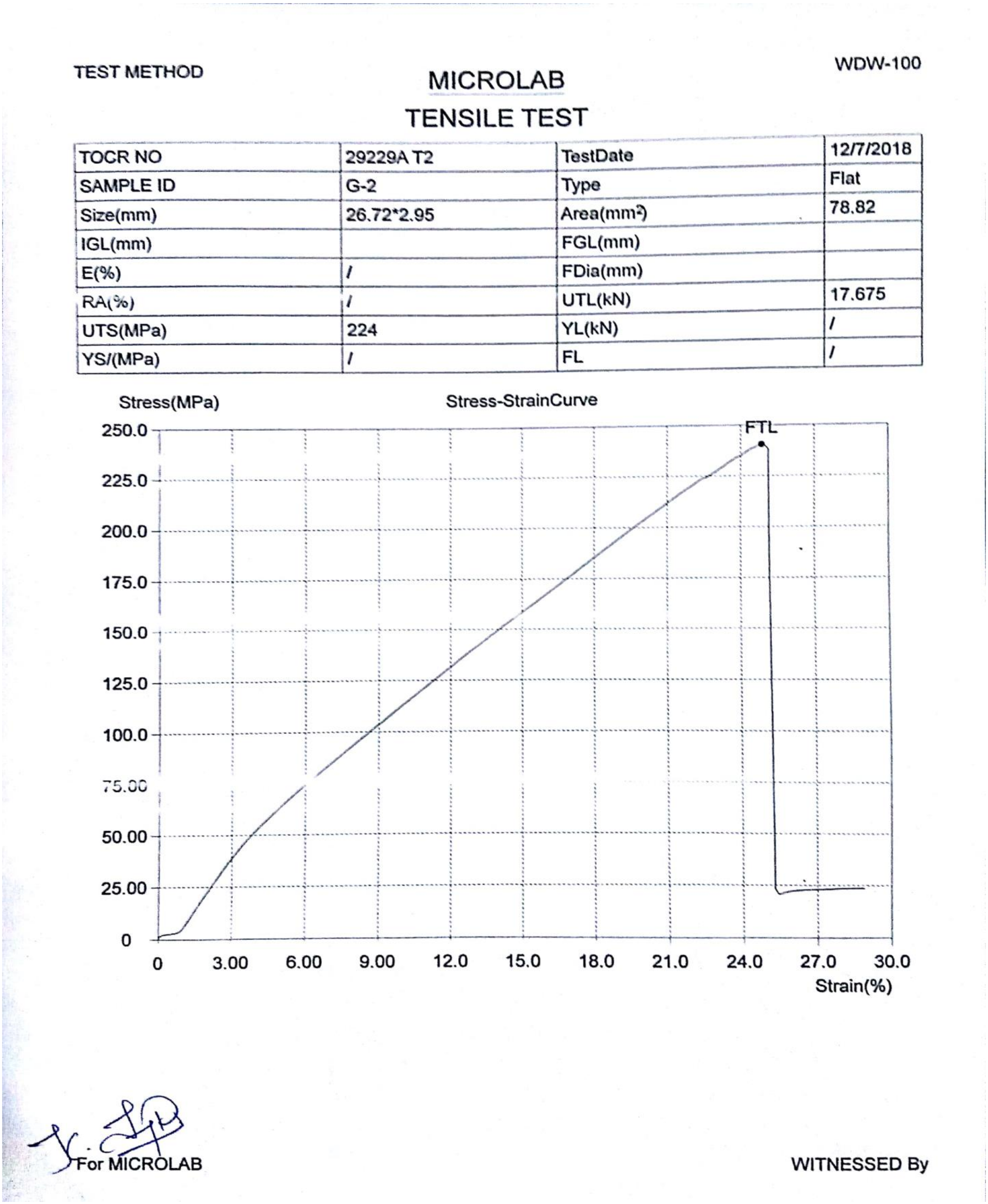
TENSILE TEST

TOCR NO	29229A T1	TestDate	12/7/2018
SAMPLE ID	G-1	Type	Flat
Size(mm)	25.61*2.95	Area(mm2)	75.55
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	14.920
UTS(MPa)	197	YL(kN)	/
YS/(MPa)	/	FL	/

For MICROLAB

WITNESSED By

Fig.4 stress Vs strain-Tensile test GFRP-1



TEST METHOD

WDW-100

MICROLAB

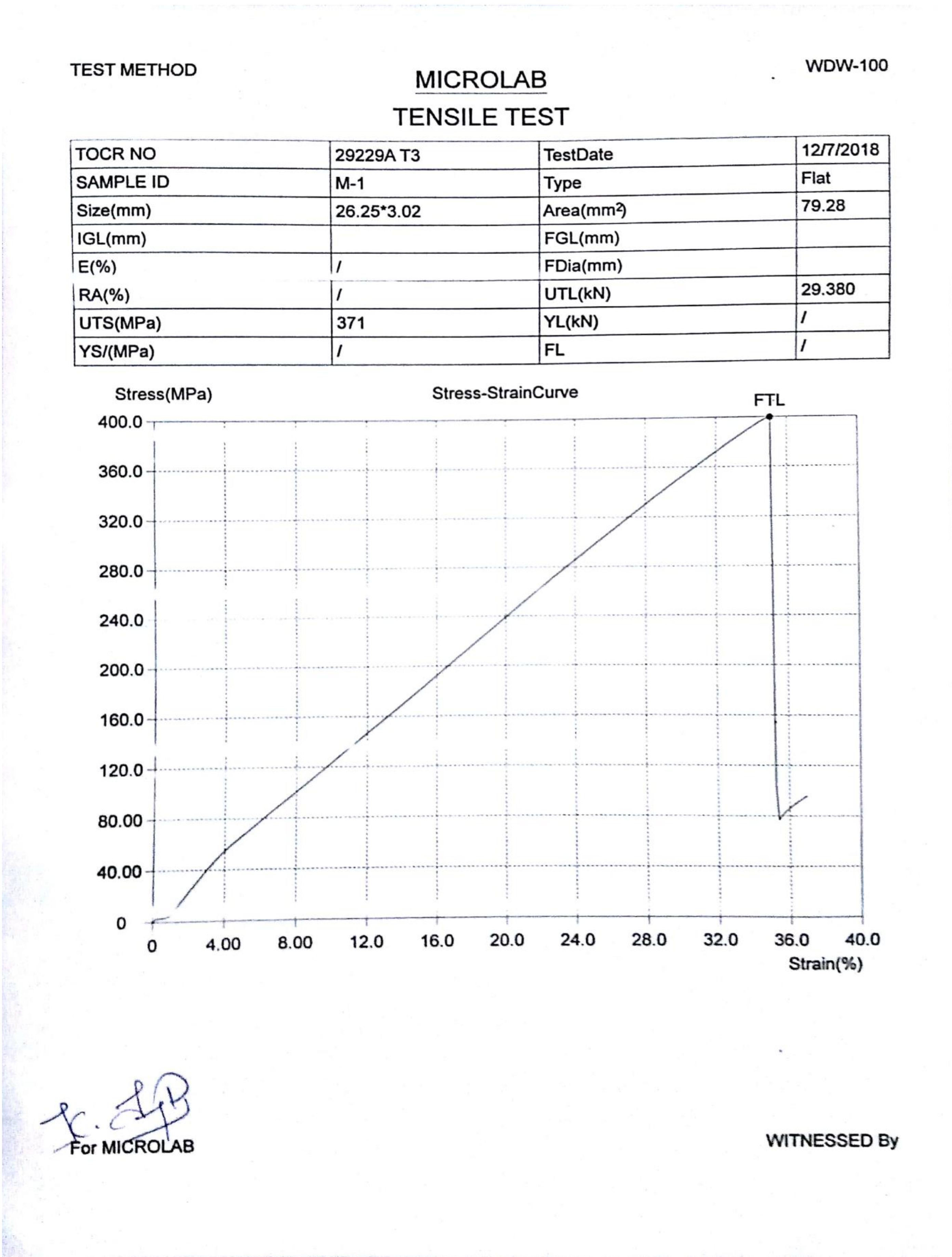
TENSILE TEST

TOCR NO	29229A T2	TestDate	12/7/2018
SAMPLE ID	G-2	Type	Flat
Size(mm)	26.72*2.95	Area(mm²)	78.82
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	17.675
UTS(MPa)	224	YL(kN)	/
YS/(MPa)	/	FL	/

For MICROLAB

WITNESSED By

Fig.5 stress Vs strain-tensile test GFRP-2



TEST METHOD

WDW-100

MICROLAB

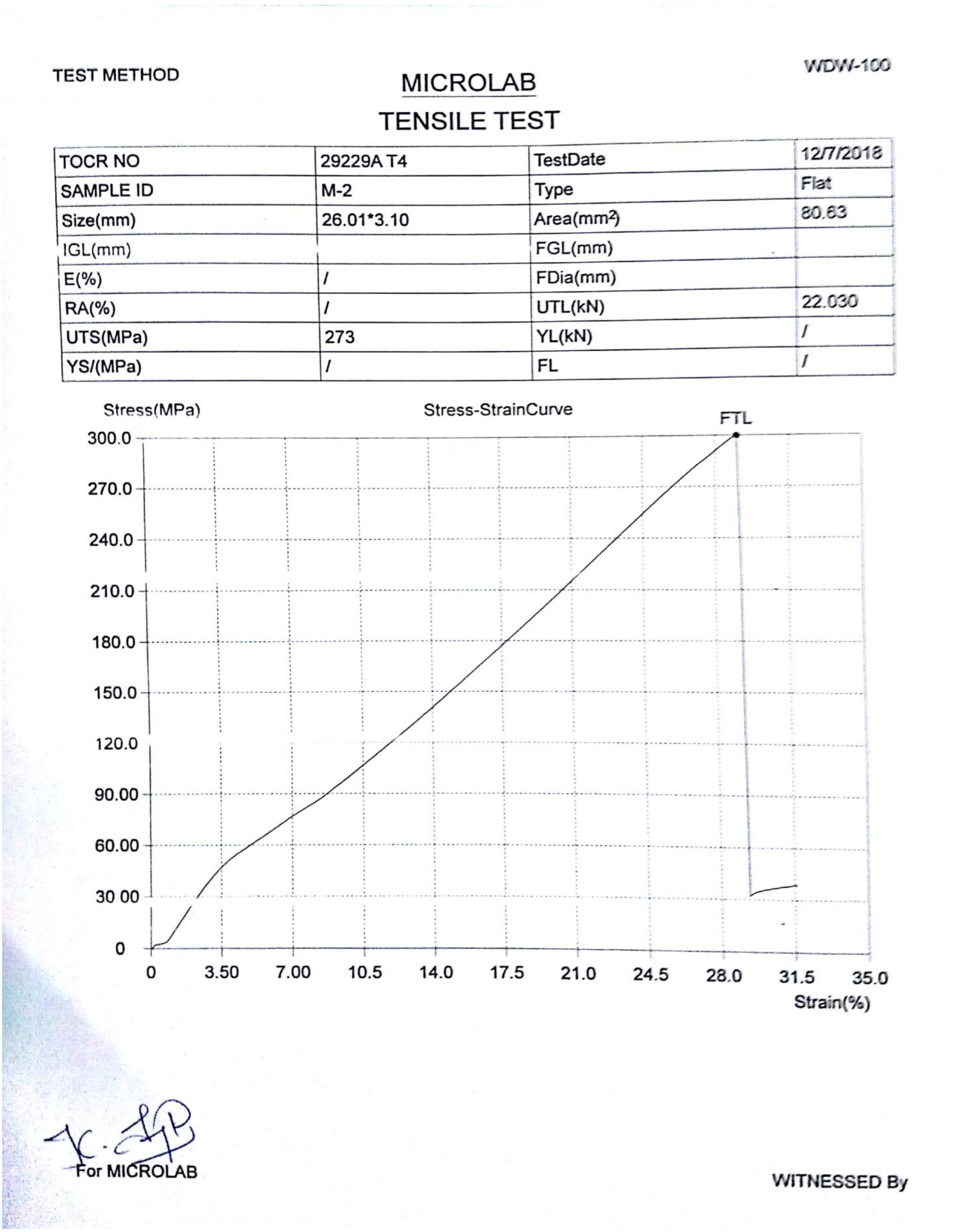
TENSILE TEST

TOCR NO	29229A T3	TestDate	12/7/2018
SAMPLE ID	M-1	Type	Flat
Size(mm)	26.25*3.02	Area(mm2)	79.28
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	29.380
UTS(MPa)	371	YL(kN)	/
YS/(MPa)	/	FL	/

For MICROLAB

WITNESSED By

Fig.6 stress Vs strain-tensile test – GFRP with steel powder-1



TEST METHOD

MICROLAB

TENSILE TEST

WDW-100

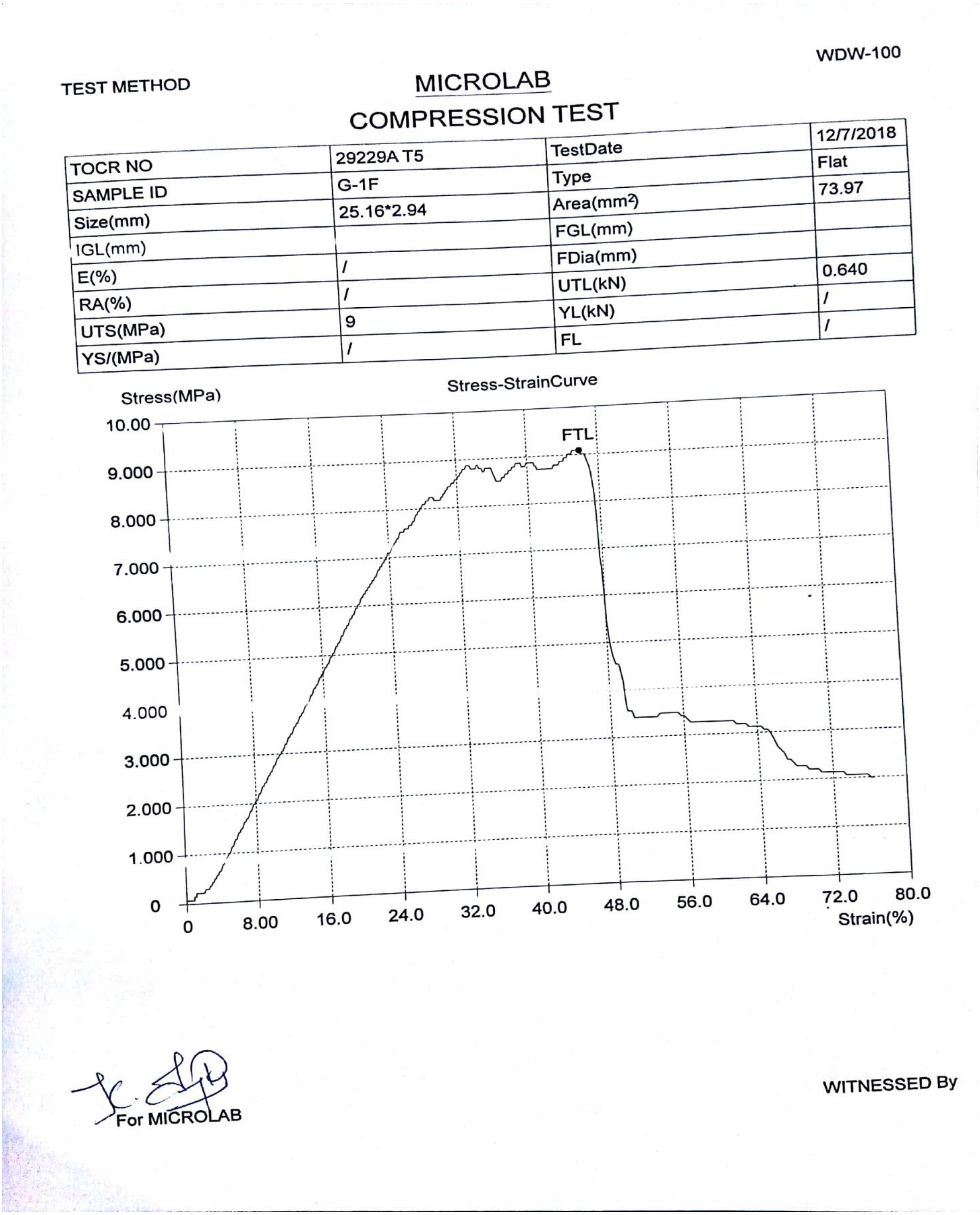
TOCR NO	29229A T4	TestDate	12/7/2018
SAMPLE ID	M-2	Type	Flat
Size(mm)	26.01*3.10	Area(mm2)	80.63
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	22.030
UTS(MPa)	273	YL(kN)	/
YS/(MPa)	/	FL	/

For MICROLAB

WITNESSED By

Fig.7 stress Vs strain-tensile test – GFRP with steel powder-2

FLEXURAL PROPERTIES



WDW-100

TEST METHOD

MICROLAB

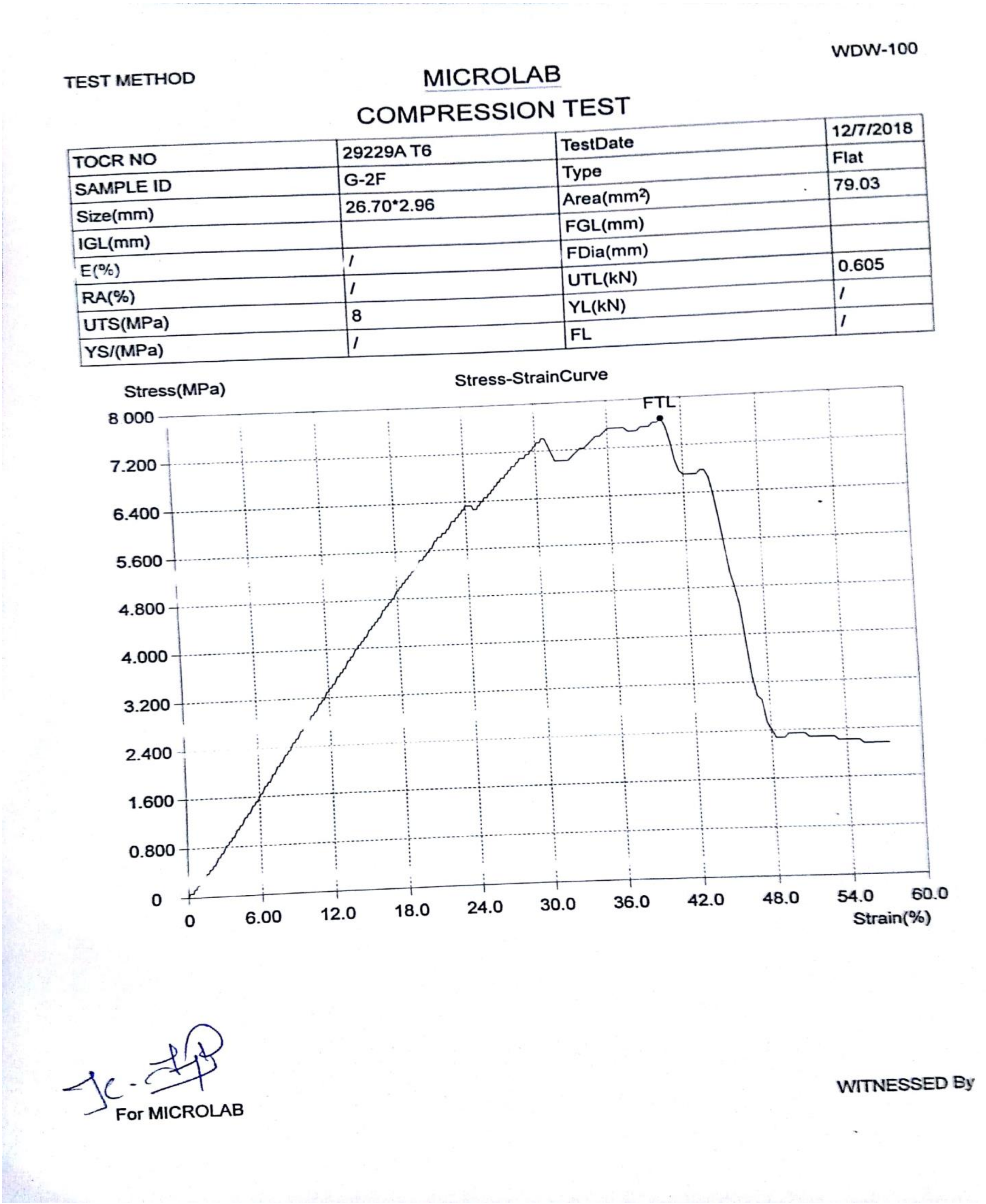
COMPRESSION TEST

TOCR NO	29229A T5	TestDate	12/7/2018
SAMPLE ID	G-1F	Type	Flat
Size(mm)	25.16*2.94	Area(mm2)	73.97
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	0.640
UTS(MPa)	9	YL(kN)	/
YS/(MPa)	/	FL	/

For MICROLAB

WITNESSED By

Fig.8 stress Vs strain-flexural test –GFRP-1



WDW-100

TEST METHOD

MICROLAB

COMPRESSION TEST

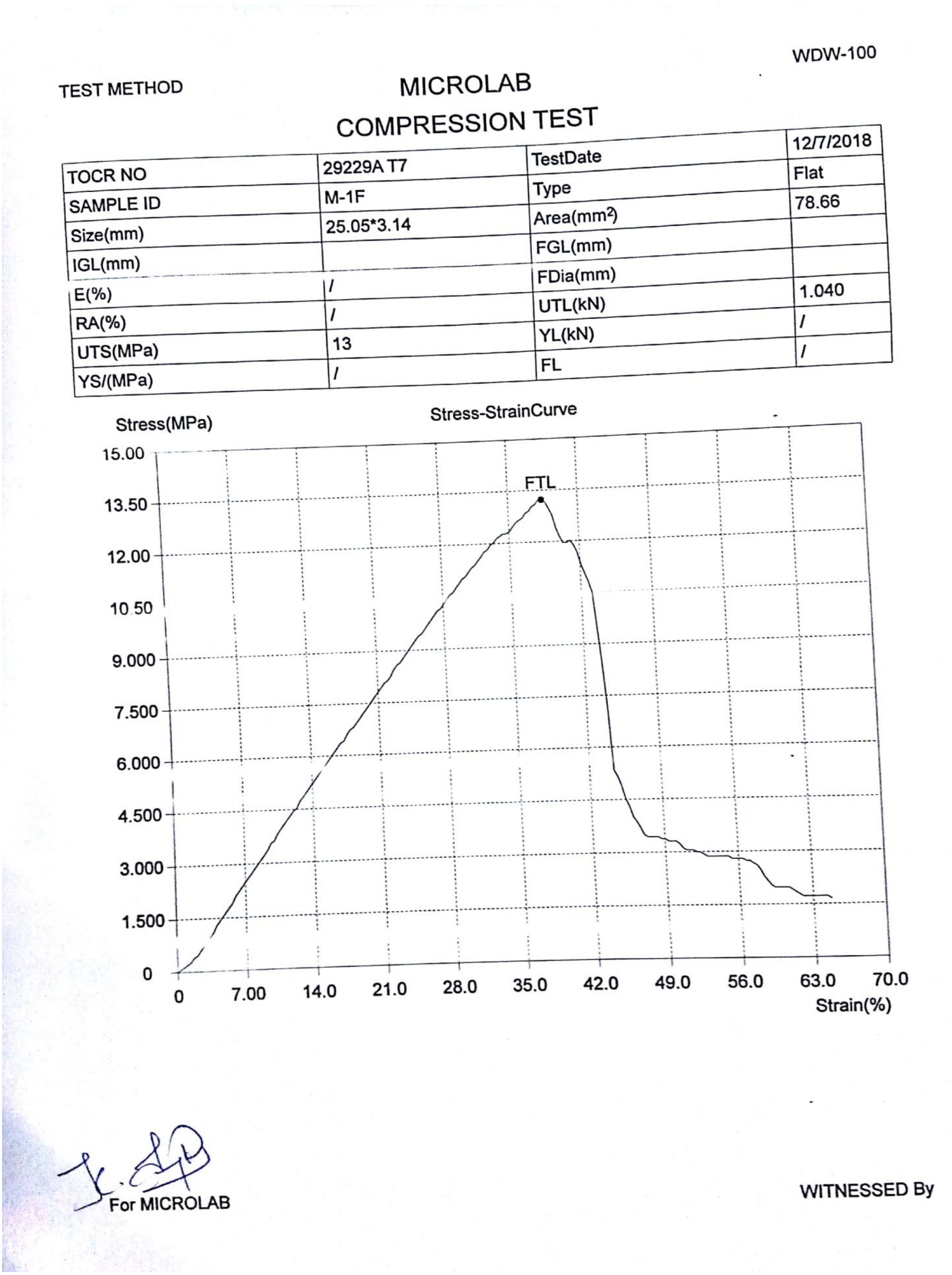
TOCR NO	29229A T6	TestDate	12/7/2018
SAMPLE ID	G-2F	Type	Flat
Size(mm)	26.70*2.96	Area(mm²)	79.03
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	0.605
UTS(MPa)	8	YL(kN)	/
YS/(MPa)	/	FL	/

Stress-StrainCurve

For MICROLAB

WITNESSED By

Fig.9 stress Vs strain-flexural test –GFRP-2



WDW-100

TEST METHOD

MICROLAB

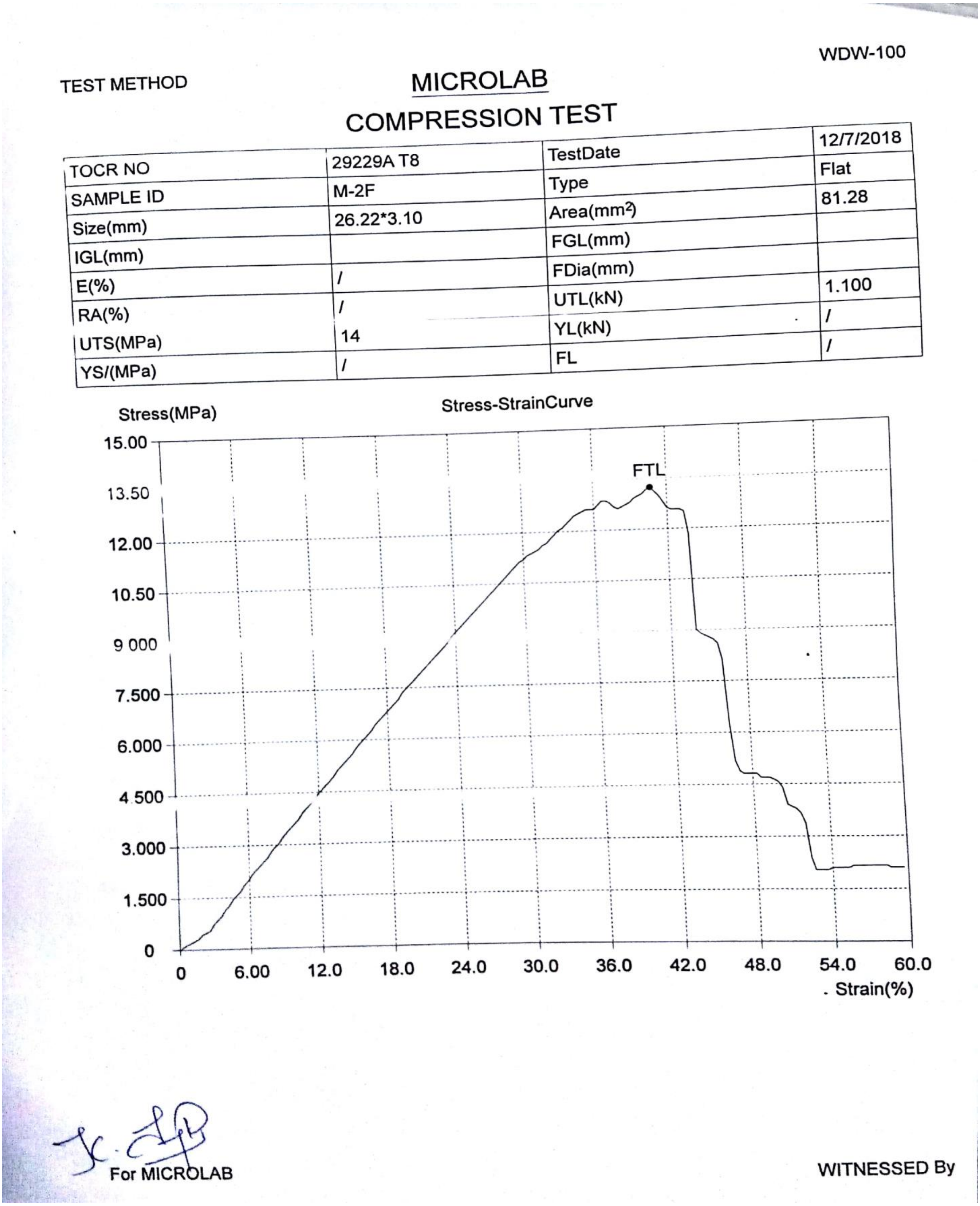
COMPRESSION TEST

TOCR NO	29229A T7	TestDate	12/7/2018
SAMPLE ID	M-1F	Type	Flat
Size(mm)	25.05*3.14	Area(mm2)	78.66
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	1.040
UTS(MPa)	13	YL(kN)	/
YS/(MPa)	/	FL	/

For MICROLAB

WITNESSED By

Fig.10 stress Vs strain-flexural test –GFRP with steel powder-1



WDW-100

TEST METHOD

MICROLAB

COMPRESSION TEST

TOCR NO	29229A T8	TestDate	12/7/2018
SAMPLE ID	M-2F	Type	Flat
Size(mm)	26.22*3.10	Area(mm^2)	81.28
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(kN)	1.100
UTS(MPa)	14	YL(kN)	/
YS/(MPa)	/	FL	/

For MICROLAB

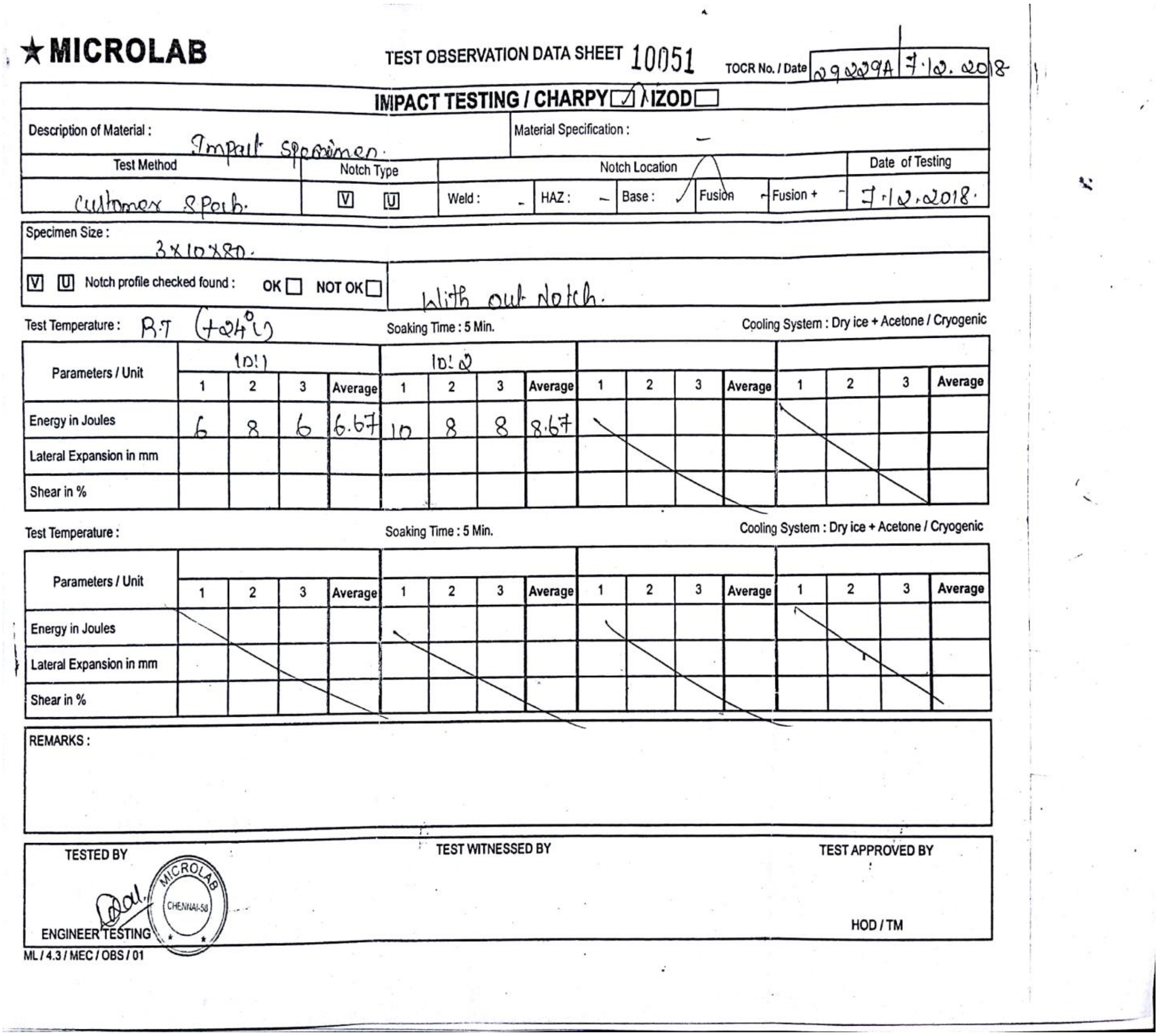
WITNESSED By

Fig.11 stress Vs strain- flexural test –GFRP with steel powder-2

IMPACT PROPERTIES

For analyzing impact capability of the prepared specimen the impact test is conducted the investigations of the impact test is carried out by using charpy impact test the energy loss is found out as a reading delivered by charpy impact test setup the impact response reflecting a failure process with crack initiation and growth , fiber breakage and pullout delaminating and disbanding the impact test results are tabulated in table .The charpy impact test was conducted without notch at 24 degree centigrade room temp the results indicated that GFRP-Steel powder has shown a maximum of 8.67 joules absorbed energy.

The impact load comparison for different hybrid composite specimen is shown in fig .12.



★MICROLAB

TEST OBSERVATION DATA SHEET 10051 TOCR No. / Date 29229A 7.12.2018

IMPACT TESTING / CHARPY ☑ IZOD ☐

Description of Material : Impact specimen.

Material Specification : -

Test Method	Notch Type	Notch Location					Date of Testing
Customer Spch.	V U	Weld : -	HAZ : -	Base : ✓	Fusion -	Fusion + -	7.12.2018.

Specimen Size : 3x10x80.

V U Notch profile checked found : OK ☐ NOT OK ☐ With out Notch.

Test Temperature : R.T (+24°C) Soaking Time : 5 Min. Cooling System : Dry ice + Acetone / Cryogenic

Parameters / Unit	10!1				10!2											
	1	2	3	Average	1	2	3	Average	1	2	3	Average	1	2	3	Average
Energy in Joules	6	8	6	6.67	10	8	8	8.67								
Lateral Expansion in mm																
Shear in %																

Test Temperature : Soaking Time : 5 Min. Cooling System : Dry ice + Acetone / Cryogenic

Parameters / Unit																
	1	2	3	Average	1	2	3	Average	1	2	3	Average	1	2	3	Average
Energy in Joules																
Lateral Expansion in mm																
Shear in %																

REMARKS :

TESTED BY

MICROLAB CHENNAI-58

ENGINEER TESTING

TEST WITNESSED BY

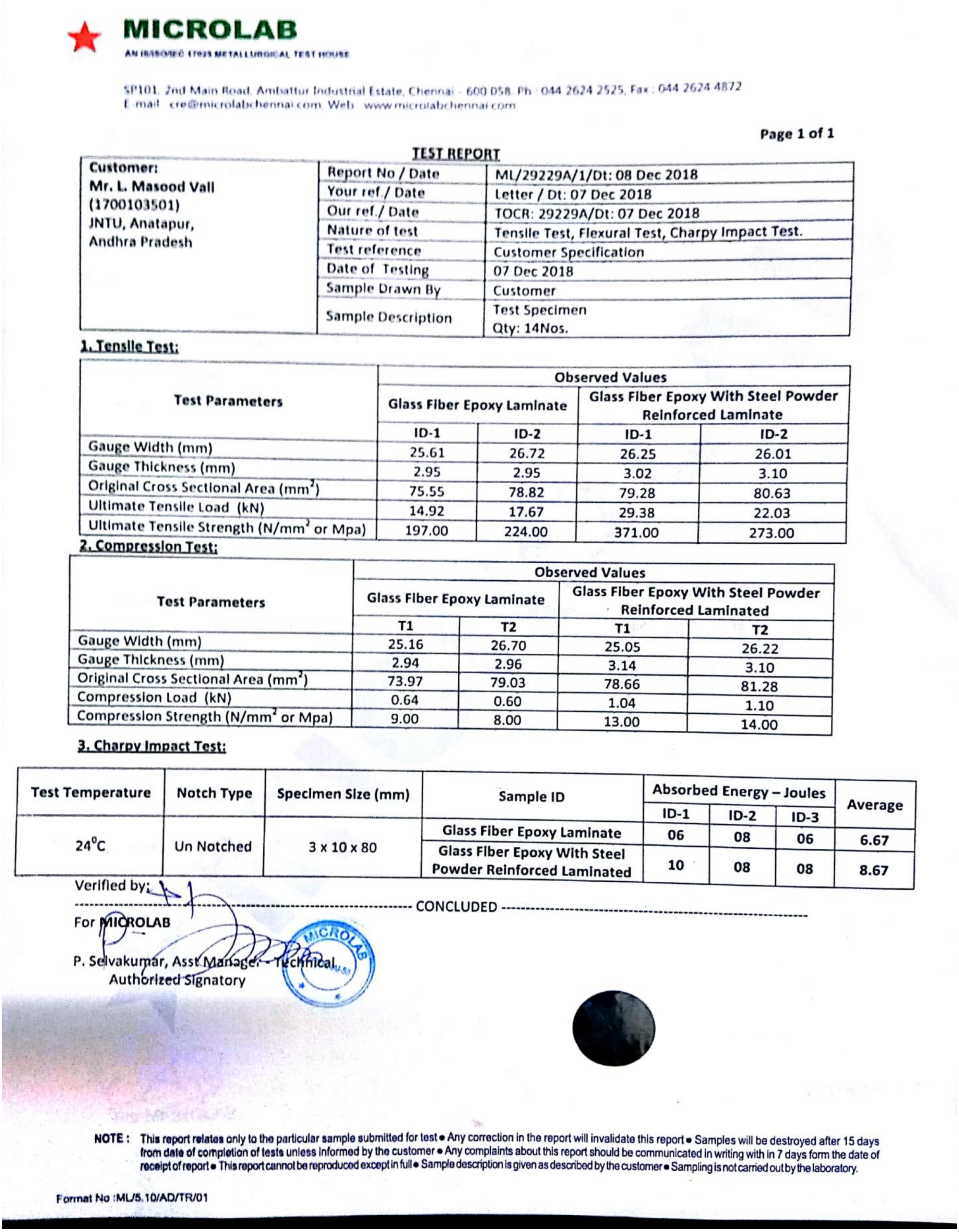
TEST APPROVED BY

HOD / TM

ML / 4.3 / MEC / OBS / 01

Fig.12 Impact test results

CONCLUSION:



MICROLAB

AN ISO/IEC 17025 METALLURGICAL TEST HOUSE

SP101, 2nd Main Road, Ambattur Industrial Estate, Chennai - 600 058. Ph : 044 2624 2525, Fax : 044 2624 4872
E-mail : cre@microlabchennai.com, Web : www.microlabchennai.com

Page 1 of 1

TEST REPORT

Customer: **Mr. L. Masood Vali** (1700103501) JNTU, Anatapur, Andhra Pradesh	Report No / Date	ML/29229A/1/Dt: 08 Dec 2018
	Your ref./ Date	Letter / Dt: 07 Dec 2018
	Our ref./ Date	TOCR: 29229A/Dt: 07 Dec 2018
	Nature of test	Tensile Test, Flexural Test, Charpy Impact Test.
	Test reference	Customer Specification
	Date of Testing	07 Dec 2018
	Sample Drawn By	Customer
	Sample Description	Test Specimen Qty: 14Nos.

1. Tensile Test:

Test Parameters	Observed Values			
	Glass Fiber Epoxy Laminate		Glass Fiber Epoxy With Steel Powder Reinforced Laminate	
	ID-1	ID-2	ID-1	ID-2
Gauge Width (mm)	25.61	26.72	26.25	26.01
Gauge Thickness (mm)	2.95	2.95	3.02	3.10
Original Cross Sectional Area (mm^2)	75.55	78.82	79.28	80.63
Ultimate Tensile Load (kN)	14.92	17.67	29.38	22.03
Ultimate Tensile Strength (N/mm^2 or Mpa)	197.00	224.00	371.00	273.00

2. Compression Test:

Test Parameters	Observed Values			
	Glass Fiber Epoxy Laminate		Glass Fiber Epoxy With Steel Powder Reinforced Laminated	
	T1	T2	T1	T2
Gauge Width (mm)	25.16	26.70	25.05	26.22
Gauge Thickness (mm)	2.94	2.96	3.14	3.10
Original Cross Sectional Area (mm^2)	73.97	79.03	78.66	81.28
Compression Load (kN)	0.64	0.60	1.04	1.10
Compression Strength (N/mm^2 or Mpa)	9.00	8.00	13.00	14.00

3. Charpy Impact Test:

Test Temperature	Notch Type	Specimen Size (mm)	Sample ID	Absorbed Energy – Joules			Average
				ID-1	ID-2	ID-3	
24^0C	Un Notched	3 x 10 x 80	Glass Fiber Epoxy Laminate	06	08	06	6.67
			Glass Fiber Epoxy With Steel Powder Reinforced Laminated	10	08	08	8.67

Verified by:

-- CONCLUDED --

For MICROLAB

P. Selvakumar, Asst.Manager - Technical
Authorized Signatory

NOTE : This report relates only to the particular sample submitted for test • Any correction in the report will invalidate this report • Samples will be destroyed after 15 days from date of completion of tests unless informed by the customer • Any complaints about this report should be communicated in writing with in 7 days form the date of receipt of report • This report cannot be reproduced except in full • Sample description is given as described by the customer • Sampling is not carried out by the laboratory.

Format No :ML/5.10/AD/TR/01

Fig.13 Test Report

REFERENCES

[1]. N. Venkateshwaran, A. Elayaperumal, G.K Sathiya, Prediction of tensile properties of hybrid natural fiber composites, CompoaitepartB; 2012; 43:793-796

[2]. M. Jawid, H.P.S Abdul Khalil, Azman Hassan, Rudi Dungani, A. Hadiyanne, effect of jute fiber loading on tensile and dynamic mechanical properties of oil/palm epoxy compoaites, Composite: Part B;2012;xx:xxx-xxx. Article in press.

[3]. M. Jawid , H.P.S. Abdul Khalil,A. Abu Bakar, P. Noorunnisakhanam, Chemical resistance, void content and tensile of oil palm/jute fiber reinforced polymer hybrid composites, Materials and design ; 2011;12:1014-1019.

[4]. Goulart S.A.S., Olivera T.A, Teixeira A., Mileo P.C., Mulinari D.R., Mechanical behavior of polypropylene reinforced palm fibers composites, Procedia engineering; 2011;10:2034-2039

[5]. Silva Flavio de Andrade, FilhoRomildo Dias Toledo, Filho Joao de Almeida Melo, Fairbairn Eduardo de Moraesrego. Physical and mechanical properties of durable sisal fiber- cement composites. Construct Build Mater 2010; 24: 777-85.

[6]. KasamaJarukmjorn, NitinatSuppakam, Effect of glass fiber hybridization on properties of sisal fiber polypropylene composites, Composite: Part B; 2009; 40: 623-627

[7]. Cicala G, Cristaldi G, Recca G, Ziegmann G, EL-Sabbagh A, Dickert M, et.al. Properties and performance of various hybrid glass/ natural fiber composite for curved pipes. Mater Des 2009; 30:2538-42.

[8]. JarukumjornKasama, SuppakamNitinat. Effect of glass fiber hybridization on properties of sisal fiber polypropylene composites. Compos: Part B 2009; 40: 623-7.