TEST REPORT

2019

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Ref.: "Final Report: Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests, Inst. #30821"

Please find attached the final report for the project "Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests". The report includes the following ASTM tests:

EPOXY:

1. ASTM C882 – 13a. Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear. (January 5th, 2019)
2. ASTM D570 – 98 (Reapproved 2018). Standard Test Method for Water Absorption of Plastics. (January 8th, 2019)
3. ASTM D638 – 14. Standard Test Method for Tensile Properties of Plastics. (December 19th, 2018)
4. ASTM D648 – 18. Standard Test Method for Deflection Temperature of Under Flexural Load in the Edgewise Position. (January 6th, 2019)
5. ASTM D695 – 15. Standard Test Method for Compressive Properties of Rigid Plastics. (December 25th, 2018)
6. ASTM D732 – 17. Standard Test Method for Shear Strength of Plastics by Punch Tool. (January 3rd, 2019)
7. ASTM D790 – 17. Standard Test Method for Flexural Properties of Unreinforced Plastics and Electrical Insulating Materials. (December 29th, 2018)

CFRP

1. ASTM D2344/D2344M – 16. Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates. (January 2nd, 2019)

2. ASTM D3039/D3039M – 17. Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials. (December 18th, 2018)

3. ASTM D7264/D7264M – 15. Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials. (December 28, 2018)

Comparing the properties of the epoxies and CFRP composites investigated under this research project, we have found that they are very comparable with those produced in Europe, Japan and North America.

Please review the final reports and let me know by June 15, 2019 if you have any questions. We would like to take this opportunity to thank you for the support of research at Syracuse University.

Best regards,

Riyad Aboutaha, PhD
Associate Dean
College of Engineering and Computer Science
Syracuse University

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Bond Strength of Epoxies According to ASTM C882

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

Syracuse University

May 2019

Bond Strength of Epoxies According to ASTM C882

Introduction

This report provides a summary of the results of test performed as outlined within this document. Bond strength test was conducted following ASTM C882 – 13a. Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear. The specimen configuration was standard according to the standard specified. Bond strength between concrete and eight types of epoxy were tested and reported.

Test Date and Location

The test was conducted on January 5th, 2019 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1 shows information of the tested specimens.

Product name	Manufacturer	Material Type
HM-180	Shanghai Horse Construction	Primer
HM-180C3P	Shanghai Horse Construction	Impregnated adhesive
HM-120ML	Shanghai Horse Construction	Leveling adhesive
HM-120CP	Shanghai Horse Construction	CFRP plate adhesive
HM-500	Shanghai Horse Construction	Anchoring adhesive
HM-120	Shanghai Horse Construction	Steel bonding adhesive
HM-120M	Shanghai Horse Construction	Steel jacketing adhesive
HM-120L	Shanghai Horse Construction	Crack injection adhesive

Table 1. Specimen Description

Specimens were labeled as HM180-# for HM180 materials, as well as the rest.

Two equal sections of a 75 by 150-mm portland-cement mortar cylinder were bonded together with specific epoxy resin, each section of which has a diagonally cast bonding area at a 30° angle from vertical. Mortar with a compressive strength of 60 MPa was used in this test. The mortar sections, and all equipment that will contact the resin to the temperatures specified in Specification C881/C881M.

Apparatus

A 30 kN MTS testing machine was used to conduct this test, load and displacement were recorded by the loading system.

Test Procedure

The bond strength is determined by using the epoxy system to bond together two equal sections of a 75 by 150-mm portland-cement mortar cylinder. After suitable curing of the bonding agent, the test is performed by determining the compressive strength of the composite cylinder. Specimens were tested at 23 °C in compression after capping in accordance with Test Method C39/C39M.

Test Results

The bond strength of the resin bonding system was calculated by dividing the load carried by the specimen at failure by the area of the bonded surface. Reduce the area of the bonded surface by that of any voids found in the bond on inspection after test. The area of the elliptical bonding surface of the test cylinders specified in this test method is 9116 mm^2. Two specimens were tested for each type of product. Test results are summarized in Table 2. Bond strength and position of the fracture of each specimen are shown in Appendix A.

Product name	Bond Strength (MPa)		
	Mean	Standard Deviation	COV (%)
HM-180	21.16	1.09	5.14
HM-180C3P	23.68	2.64	11.15
HM-120ML	27.53	1.69	6.14
HM-120CP	30.82	0.28	0.90
HM-500	26.28	1.12	4.26
HM-120	20.25	1.65	8.13
HM-120M	17.35	0.17	0.99
HM-120L	23.41	1.58	6.76

Table 2. Bond Strength

Appendix A. Test Results of Each Specimen.

Specimen	Bond Strength (MPa)	Position of Fracture
HM180-1	21.92	M
HM180-2	20.39	M
HM180C3P-1	25.55	M
HM180C3P-2	21.82	M
HM120ML-1	26.33	M
HM120ML-2	28.72	M
HM120CP-1	30.62	M
HM120CP-2	31.02	M
HM500-1	25.49	M
HM500-2	27.08	M
HM120-1	21.41	I
HM120-2	19.09	I
HM120M-1	17.23	I
HM120M-2	17.48	I
HM120L-1	24.53	M
HM120L-2	22.29	M

Note: I is in the interface between epoxy and concrete; M is in the mortar.

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Water Absorption of Epoxies According to ASTM D570

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

Syracuse University

May 2019

Water Absorption of Epoxies According to ASTM D570

Introduction

This report provides a summary of the results of test performed as outlined within this document. Bond strength test was conducted following ASTM D570 – 98 (Reapproved 2018). Standard Test Method for Water Absorption of Plastics. The specimen configuration was standard according to the standard specified. Water absorption rate of eight types of epoxy were tested and reported.

Test Date and Location

The test was conducted on January 8th, 2019 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1 shows information of the tested specimens.

Product name	Manufacturer	Material Type
HM-180	Shanghai Horse Construction	Primer
HM-180C3P	Shanghai Horse Construction	Impregnated adhesive
HM-120ML	Shanghai Horse Construction	Leveling adhesive
HM-120CP	Shanghai Horse Construction	CFRP plate adhesive
HM-500	Shanghai Horse Construction	Anchoring adhesive
HM-120	Shanghai Horse Construction	Steel bonding adhesive
HM-120M	Shanghai Horse Construction	Steel jacketing adhesive
HM-120L	Shanghai Horse Construction	Crack injection adhesive

Table 1. Specimen Description

Specimens were labeled as HM180-# for HM180 materials, as well as the rest.

The test specimen for molded plastics shall be in the form of a disk 50.8 mm in diameter and 3.2 mm in thickness.

Apparatus

An analytical balance capable of reading 0.0001 g. An oven capable of maintaining uniform temperatures of 50°C and of 105 to 110°C.

Test Procedure

The conditioned and weighed specimens were placed in a container of distilled water maintained at a temperature of 23°C and rested on edge and be entirely immersed. At the end of 24 h, the specimens were removed from the water one at a time, all surface water wiped off with a dry cloth, and weighed to the nearest 0.001 g immediately. Five specimens were tested for each type of epoxy.

Test Results

Percentage increase in weight during immersion was calculated to the nearest 0.01 % as follows:

$$\text{Percentage increase in weight} = \frac{Wet\ weight - Conditioned\ weight}{Conditioned\ weight} * 100\%$$

Test results are summarized in Table 2. Percentage increase in weight of each specimen are shown in Appendix A.

Product name	Percentage Increase in Weight (%)
HM-180	0.129
HM-180C3P	0.026
HM-120ML	0.074
HM-120CP	0.062
HM-500	0.053
HM-120	0.00
HM-120M	0.077
HM-120L	0.542

Table 2. Percentage Increase in Weight

Appendix A. Dimension and Test Results of Each Specimen.

Specimen	Diameter (mm)	Thickness (mm)	Percentage Increase in Weight (%)
HM180-1	50.11	3.21	0.138
HM180-2	51.12	3.18	0.260
HM180-3	50.74	3.22	0.246
HM180-4	50.69	3.20	0.000
HM180-5	50.94	3.19	0.000
HM180C3P-1	51.11	3.24	0.129
HM180C3P-2	51.06	3.16	0.000
HM180C3P-3	50.94	3.20	0.000
HM180C3P-4	50.77	3.23	0.000
HM180C3P-5	50.93	3.22	0.000
HM120ML-1	50.94	3.20	0.000
HM120ML-2	50.68	3.19	0.000
HM120ML-3	51.06	3.20	0.180
HM120ML-4	51.22	3.23	0.193
HM120ML-5	50.79	3.21	0.000
HM120CP-1	50.83	3.18	0.226
HM120CP-2	50.84	3.23	0.000
HM120CP-3	51.06	3.21	0.000
HM120CP-4	50.94	3.19	0.082
HM120CP-5	50.77	3.24	0.000
HM500-1	50.93	3.29	0.000
HM500-2	50.94	3.23	0.000
HM500-3	50.42	3.21	0.168
HM500-4	50.84	3.16	0.098
HM500-5	51.06	3.21	0.000
HM120-1	50.94	3.19	0.000
HM120-2	50.77	3.27	0.000
HM120-3	50.93	3.21	0.000
HM120-4	50.94	3.23	0.000
HM120-5	50.77	3.25	0.000
HM120M-1	50.93	3.23	0.000
HM120M-2	50.94	3.21	0.000
HM120M-3	50.84	3.16	0.116
HM120M-4	51.06	3.21	0.268
HM120M-5	50.94	3.32	0.000
HM120L-1	50.77	3.15	0.627
HM120L-2	50.74	3.28	0.510
HM120L-3	50.69	3.04	0.504
HM120L-4	50.94	3.09	0.364

HM120L-5	51.11	3.27	0.707

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Tensile Test of Epoxies According to ASTM D638

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

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May 2019

Tensile Test of Epoxies According to ASTM D638

Introduction

This report provides a summary of the results of test performed as outlined within this document. Tensile test was conducted following ASTM D638 – 14. Standard Test Method for Tensile Properties of Plastics. The coupon configuration was standard according to the standard specified.

Test Date and Location

The test was conducted on December 19th, 2018 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1 shows information of the tested specimens.

Product name	Manufacturer	Material Type
HM-180	Shanghai Horse Construction	Primer
HM-180C3P	Shanghai Horse Construction	Impregnated adhesive
HM-120CP	Shanghai Horse Construction	CFRP plate adhesive
HM-500	Shanghai Horse Construction	Anchoring adhesive
HM-120	Shanghai Horse Construction	Steel bonding adhesive
HM-120M	Shanghai Horse Construction	Steel jacketing adhesive
HM-120L	Shanghai Horse Construction	Crack injection adhesive

Table 1. Specimen Description

Specimens were labeled as HM180-# for HM180 materials, as well as the rest.

Typical Type I specimen are used in this test, geometry of tested specimens are summarized in Table 2. Dimension for each specimen is summarized in Appendix A.

Product name	Average Thickness (mm)	Average Width (mm)	Average Length (mm)
HM-180	3.41	13.07	164.76
HM-180C3P	3.48	13.04	164.80
HM-120CP	3.40	13.17	164.70
HM-500	3.23	13.12	164.76
HM-120	3.64	13.07	164.96
HM-120M	3.67	13.06	165.20
HM-120L	3.50	13.07	164.72

Table 2. Specimen dimensions

Apparatus

A 10 kN MTS testing machine (Model: E45) was used to conduct this test.

A 50 mm displacement transducer was used to measure the elongation of the specimen.

Test Procedure

Tests were conducted under a temperature of 23°±3°C.

All specimens were loaded at a rate of crosshead movement of 4.0 mm/min until failure.

Load versus crosshead displacement data throughout the test method, maximum load, final load, and load at any obvious discontinuities in load-displacement data were recorded at a rate of 20 Hz.

Test Results

Five specimens were tested for each type of product. Test results are summarized in Table 3-5.

Product name	Tensile Strength (MPa)		
	Mean	Standard Deviation	COV (%)
HM-180	55.29	0.74	1.34
HM-180C3P	60.96	6.22	10.20
HM-120CP	44.64	2.98	6.67
HM-500	70.18	1.34	1.91
HM-120	52.17	2.13	4.08
HM-120M	58.10	1.27	2.19
HM-120L	47.08	0.63	1.34

Table 3. Tensile Strength

Five specimens were tested for each type of product. Test results are summarized in Table 3.

Product name	Elongation at Break (%)		
	Mean	Standard Deviation	COV (%)
HM-180	6.90	0.72	10.43
HM-180C3P	6.22	0.88	14.14
HM-120CP	2.60	0.47	18.39
HM-500	1.74	0.12	6.80
HM-120	1.56	0.36	23.30
HM-120M	6.90	1.70	24.64
HM-120L	3.96	0.56	14.14

Table 4. Elongation at Break

Product name	Elastic modulus (MPa)		
	Mean	Standard Deviation	COV (%)
HM-180	2764.90	58.11	2.10
HM-180C3P	3025.86	40.49	1.34
HM-120CP	6635.64	393.03	5.9
HM-500	6942.53	164.51	2.37
HM-120	8358.46	342.14	4.09
HM-120M	2879.02	92.22	3.20
HM-120L	2840.23	59.79	2.11

Table 5. Elastic Modulus

Appendix A. Dimension of Each Specimen.

Specimen	Width (mm)	Thickness(mm)	Length (mm)
HM180-1	13.21	3.40	165.1
HM180-2	13.04	3.38	164.8
HM180-3	13.05	3.21	164.3
HM180-4	13.02	3.56	164.2
HM180-5	13.03	3.50	165.4
HM180C3P-1	13.05	3.45	165.1
HM180C3P-2	13.02	3.40	165.1
HM180C3P-3	13.05	3.50	164.9
HM180C3P-4	13.05	3.59	164.3
HM180C3P-5	13.02	3.47	164.6
HM120CP-1	13.16	3.38	164.9
HM120CP-2	13.19	3.4	164.3
HM120CP-3	13.21	3.26	164.6
HM120CP-4	13.12	3.36	164.4
HM120CP-5	13.18	3.62	165.3
HM500-1	13.11	3.47	165.4
HM500-2	13.11	3.44	165.1
HM500-3	13.14	2.88	164.8
HM500-4	13.11	3.12	164.3
HM500-5	13.12	3.23	164.2
HM120-1	13.08	3.60	165.1
HM120-2	13.11	3.58	165.1
HM120-3	13.07	3.74	164.9
HM120-4	13.08	3.53	164.3
HM120-5	13.02	3.73	165.4
HM120M-1	13.05	3.43	165.1
HM120M-2	13.07	3.90	165.1
HM120M-3	13.09	3.55	165.3
HM120M-4	13.05	3.99	165.4
HM120M-5	13.04	3.46	165.1
HM120L-1	13.05	3.63	164.3
HM120L-2	13.11	3.46	164.2
HM120L-3	13.08	3.44	165.1
HM120L-4	13.04	3.56	165.1
HM120L-5	13.07	3.40	164.9

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Deflection Temperature of Epoxies According to ASTM D648

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

Syracuse University

May 2019

Deflection Temperature of Epoxies According to ASTM D648

Introduction

This report provides a summary of the results of test performed as outlined within this document. Deflection temperature test was conducted following ASTM D648 – 18. Standard Test Method for Deflection Temperature of Under Flexural Load in the Edgewise Position. Deflection temperature of eight types of epoxies were tested and reported.

Test Date and Location

The test was conducted on January 6th, 2019 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1. shows information of the tested specimens.

Product name	Manufacturer	Material Type
HM-180	Shanghai Horse Construction	Primer
HM-180C3P	Shanghai Horse Construction	Impregnated adhesive
HM-120ML	Shanghai Horse Construction	Leveling adhesive
HM-120CP	Shanghai Horse Construction	CFRP plate adhesive
HM-500	Shanghai Horse Construction	Anchoring adhesive
HM-120	Shanghai Horse Construction	Steel bonding adhesive
HM-120M	Shanghai Horse Construction	Steel jacketing adhesive
HM-120L	Shanghai Horse Construction	Crack injection adhesive

Table 1. Specimen Description

Specimens were labeled as HM180-# for HM180 materials, as well as the rest.

Rectangular cross-section specimens are selected for this test, specimen dimensions are summarized in Table 2. Dimension for each specimen is summarized in Appendix A.

Product name	Average Thickness (mm)	Average Width (mm)	Average Length (mm)
HM-180	12.83	13.00	134.72
HM-180C3P	13.02	12.75	134.81
HM-120ML	12.71	12.97	134.91
HM-120CP	12.88	12.82	134.89
HM-500	12.88	12.97	134.82
HM-120	12.98	13.00	134.88
HM-120M	13.02	12.71	134.84
HM-120L	12.97	12.98	134.58

Table 2. Specimen dimensions

Apparatus

Temperature was measured during the test by digital thermometers. Deflection at mid span of specimen was measured with electrical deflection measurement devices. Three sets of specimen were tested at the same time.

Test Procedure

Specimens were tested in the edgewise position as a simple beam with load applied at the center to give maximum fiber stress of 0.455 MPa. Specimens were immersed under load in a heat-transfer medium. The temperature started at 23°±3°C, and increased at a rate of 2.0 °C/min until deflection reached 0.25 mm.

Test Results

Three specimens were tested for each type of product. Test results are summarized in Table 3.

Product name	Deflection Temperature (°C)		
	Mean	Standard Deviation	COV (%)
HM-180	68.53	1.10	1.61
HM-180C3P	71.30	063	0.73
HM-120ML	54.27	0.45	0.83
HM-120CP	54.80	0.36	0.66
HM-500	78.00	0.1	0.13
HM-120	63.27	0.15	0.24
HM-120M	62.23	0.40	0.65
HM-120L	50.77	0.46	0.91

Table 3. Deflection Temperature

. Test results of each specimen is shown in Appendix B.

Appendix A. Dimension of Each Specimen.

Specimen	Width (mm)	Thickness(mm)	Length (mm)
HM180-1	12.8	12.96	134.7
HM180-2	12.79	12.99	134.7
HM180-3	12.9	13.04	134.77
HM180C3P-1	13	12.55	134.77
HM180C3P-2	13.1	12.94	134.87
HM180C3P-3	12.95	12.77	134.8
HM120ML-1	12.74	12.99	134.95
HM120ML-2	12.64	12.93	134.88
HM120ML-3	12.76	12.98	134.9
HM120CP-1	12.84	12.99	134.9
HM120CP-2	13.04	12.43	134.88
HM120CP-3	12.76	13.05	134.9
HM500-1	12.97	12.96	134.82
HM500-2	12.81	12.96	134.83
HM500-3	12.86	12.99	134.82
HM120-1	13.01	12.95	134.85
HM120-2	12.98	12.98	134.88
HM120-3	12.95	13.06	134.92
HM120M-1	13.03	12.55	134.85
HM120M-2	12.98	12.78	134.82
HM120M-3	13.06	12.79	134.85
HM120L-1	13.1	12.99	134.49
HM120L-2	12.87	12.91	134.67
HM120L-3	12.76	13.05	134.58

Appendix B. Test Results of Each Specimen.

Specimen	Deflection Temperature (°C)
HM180-1	67.4
HM180-2	68.6
HM180-3	69.6
HM180C3P-1	71.0
HM180C3P-2	71.0
HM180C3P-3	71.9
HM120ML-1	54.7
HM120ML-2	53.8
HM120ML-3	54.3
HM120CP-1	54.5
HM120CP-2	54.7
HM120CP-3	55.2
HM500-1	78.1
HM500-2	77.9
HM500-3	78.0
HM120-1	63.4
HM120-2	63.1
HM120-3	63.3
HM120M-1	62.3
HM120M-2	62.6
HM120M-3	61.8
HM120L-1	50.5
HM120L-2	50.5
HM120L-3	51.3

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Compressive Test of Epoxies According to ASTM D695

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

Syracuse University

May 2019

Compressive Test of Epoxies According to ASTM D695

Introduction

This report provides a summary of the results of test performed as outlined within this document. Compressive test was conducted following ASTM D695 – 15. Standard Test Method for Compressive Properties of Rigid Plastics. Compressive strength of seven types of epoxy was tested and reported.

Test Date and Location

The test was conducted on December 25th, 2018 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1 shows information of the tested specimens.

Product name	Manufacturer	Material Type
HM-180	Shanghai Horse Construction	Primer
HM-180C3P	Shanghai Horse Construction	Impregnated adhesive
HM-120CP	Shanghai Horse Construction	CFRP plate adhesive
HM-500	Shanghai Horse Construction	Anchoring adhesive
HM-120	Shanghai Horse Construction	Steel bonding adhesive
HM-120M	Shanghai Horse Construction	Steel jacketing adhesive
HM-120L	Shanghai Horse Construction	Crack injection adhesive

Table 1. Specimen Description

Specimens were labeled as HM180-# for HM180 materials, as well as the rest.

Cylinder specimen are used in this test, geometry of tested specimens are summarized in Table 2. Dimension for each specimen is summarized in Appendix A.

Product name	Average Height (mm)	Average Diameter (mm)
HM-180	24.97	12.45
HM-180C3P	25.22	12.44
HM-120CP	24.56	12.02
HM-500	23.93	11.97
HM-120	25.22	12.14
HM-120M	25.06	12.59
HM-120L	24.27	11.89

Table 2. Specimen dimensions

Apparatus

A 10 kN MTS testing machine (Model: E45) was used to conduct this test.

Load and displacement were recorded by the MTS loading system automatically.

Test Procedure

Tests were conducted under a temperature of 23°±3°C.

All specimens were loaded at a rate of crosshead movement of 1.3 mm/min until failure.

Test Results

Five specimens were tested for each type of product. Test results are summarized in Table 3.

Product name	Compressive Strength (MPa)		
	Mean	Standard Deviation	COV (%)
HM-180	84.02	2.73	3.25
HM-180C3P	96.62	3.66	3.79
HM-120CP	117.19	0.81	0.69
HM-500	152.65	2.23	1.46
HM-120	113.50	1.36	1.19
HM-120M	87.75	3.90	4.44
HM-120L	76.37	3.84	5.03

Table 3. Compressive Strength

Compressive strength of each specimen are shown in appendix B.

Appendix A. Dimension of Each Specimen.

Name	Height (mm)	Diameter (mm)
HM180-1	25.75	12.64
HM180-2	24.22	12.61
HM180-3	23.74	11.80
HM180-4	25.64	12.60
HM180-5	25.48	12.61
HM180C3P-1	25.75	12.64
HM180C3P-2	25.66	12.58
HM180C3P-3	25.48	12.56
HM180C3P-4	23.74	11.80
HM180C3P-5	25.48	12.61
HM120CP-1	24.80	11.98
HM120CP-2	24.59	12.02
HM120CP-3	24.86	12.17
HM120CP-4	23.91	11.95
HM120CP-5	24.63	11.96
HM500-1	23.31	12.03
HM500-2	24.17	11.87
HM500-3	24.18	11.88
HM500-4	23.26	12.04
HM500-5	24.74	12.01
HM120-1	25.84	12.64
HM120-2	24.86	11.82
HM120-3	25.23	11.82
HM120-4	24.53	11.82
HM120-5	25.66	12.63
HM120M-1	24.99	12.57
HM120M-2	24.13	12.62
HM120M-3	25.81	12.57
HM120M-4	25.44	12.61
HM120M-5	24.93	12.59
HM120L-1	25.07	12.07
HM120L-2	24.85	11.78
HM120L-3	22.95	11.78
HM120L-4	24.94	11.83
HM120L-5	23.52	12.00

Appendix B. Test Results of Each Specimen.

Name	Compressive Strength (MPa)
HM180-1	86.24
HM180-2	81.34
HM180-3	80.92
HM180-4	86.75
HM180-5	84.86
HM180C3P-1	98.71
HM180C3P-2	101.96
HM180C3P-3	95.00
HM180C3P-4	92.91
HM180C3P-5	94.53
HM120CP-1	118.26
HM120CP-2	117.44
HM120CP-3	116.52
HM120CP-4	116.25
HM120CP-5	117.47
HM500-1	153.68
HM500-2	151.70
HM500-3	153.85
HM500-4	149.21
HM500-5	154.82
HM120-1	115.14
HM120-2	113.93
HM120-3	111.57
HM120-4	112.81
HM120-5	114.05
HM120M-1	82.94
HM120M-2	85.20
HM120M-3	87.26
HM120M-4	91.68
HM120M-5	91.68
HM120L-1	80.21
HM120L-2	80.83
HM120L-3	74.41
HM120L-4	73.58
HM120L-5	72.80

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Shear Test of Epoxies According to ASTM D732

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

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May 2019

Shear Test of Epoxies According to ASTM D732

Introduction

This report provides a summary of the results of test performed as outlined within this document. Shear test was conducted following ASTM D732 – 17. Standard Test Method for Shear Strength of Plastics by Punch Tool. Compressive strength of eight types of epoxy was tested and reported.

Test Date and Location

The test was conducted on January 3rd, 2019 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1. shows information of the tested specimens.

Product name	Manufacturer	Material Type
HM-180	Shanghai Horse Construction	Primer
HM-180C3P	Shanghai Horse Construction	Impregnated adhesive
HM-120ML	Shanghai Horse Construction	Leveling adhesive
HM-120CP	Shanghai Horse Construction	CFRP plate adhesive
HM-500	Shanghai Horse Construction	Anchoring adhesive
HM-120	Shanghai Horse Construction	Steel bonding adhesive
HM-120M	Shanghai Horse Construction	Steel jacketing adhesive
HM-120L	Shanghai Horse Construction	Crack injection adhesive

Table 1. Specimen Description

Specimens were labeled as HM180-# for HM180 materials, as well as the rest.

The specimens are molded disks with a 50.8 mm diameter A hole approximately 11 mm in diameter shall was drilled through the specimen at its center. Thickness of tested specimens is summarized in Table 2. Dimension for each specimen is summarized in Appendix A.

Product name	Average Thickness (mm)
HM-180	12.93
HM-180C3P	12.50
HM-120ML	12.84
HM-120CP	12.81
HM-500	12.62
HM-120	12.56
HM-120M	12.37
HM-120L	12.58

Table 2. Specimen dimensions

Apparatus

A 10 kN MTS testing machine (Model: E45) was used to conduct this test.

Load and displacement were recorded by the MTS loading system automatically.

Test Procedure

Tests were conducted under a temperature of 23°±3°C.

All specimens were loaded at a rate of crosshead movement of 1.3 mm/min until failure.

Test Results

Five specimens were tested for each type of product. Shear strength is determined by dividing the load required to shear the specimen by the area of the sheared edge, which shall be taken as the product of the thickness of the specimen by the circumference of the punch. Test results are summarized in Table 3.

Product name	Shear Strength (MPa)		
	Mean	Standard Deviation	COV (%)
HM-180	46.44	0.28	0.59
HM-180C3P	48.41	0.66	1.37
HM-120ML	35.18	3.79	10.77
HM-120CP	55.93	0.78	1.39
HM-500	34.09	4.26	12.49
HM-120	58.73	0.94	1.61
HM-120M	32.66	0.70	2.16
HM-120L	32.12	0.56	1.74

Table 3. Shear Strength

Shear strength of each specimen are shown in appendix B.

Appendix A. Specimen Thickness

Specimen	Thickness (mm)
HM180-1	12.47
HM180-2	13.13
HM180-3	13.15
HM180-4	13.40
HM180-5	12.53
HM180C3P-1	12.76
HM180C3P-2	12.07
HM180C3P-3	12.86
HM180C3P-4	12.59
HM180C3P-5	12.21
HM120ML-1	13.53
HM120ML-2	12.88
HM120ML-3	13.07
HM120ML-4	12.70
HM120ML-5	12.02
HM120CP-1	13.14
HM120CP-2	12.86
HM120CP-3	12.65
HM120CP-4	12.72
HM120CP-5	12.66
HM500-1	12.86
HM500-2	12.43
HM500-3	12.61
HM500-4	12.54
HM500-5	12.65
HM120-1	12.10
HM120-2	12.59
HM120-3	12.53
HM120-4	12.84
HM120-5	12.76
HM120M-1	12.72
HM120M-2	12.24
HM120M-3	12.60
HM120M-4	12.12
HM120M-5	12.18
HM120L-1	12.21
HM120L-2	12.77
HM120L-3	12.67

HM120L-4	12.63
HM120L-5	12.63

Appendix B. Test Results of Each Specimen.

Specimen	Shear Strength (MPa)
HM180-1	46.10
HM180-2	46.85
HM180-3	46.53
HM180-4	46.36
HM180-5	46.35
HM180C3P-1	48.56
HM180C3P-2	48.95
HM180C3P-3	47.49
HM180C3P-4	49.06
HM180C3P-5	47.99
HM120ML-1	32.85
HM120ML-2	36.83
HM120ML-3	40.84
HM120ML-4	34.23
HM120ML-5	31.14
HM120CP-1	57.20
HM120CP-2	55.91
HM120CP-3	55.95
HM120CP-4	55.30
HM120CP-5	55.29
HM500-1	41.70
HM500-2	32.49
HM500-3	32.03
HM500-4	32.03
HM500-5	32.20
HM120-1	59.24
HM120-2	59.46
HM120-3	58.97
HM120-4	58.88
HM120-5	57.09
HM120M-1	31.76
HM120M-2	33.01
HM120M-3	32.05
HM120M-4	33.32
HM120M-5	33.16
HM120L-1	33.08
HM120L-2	31.64

HM120L-3	31.88
HM120L-4	31.99
HM120L-5	31.98

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Flexural Test of Epoxies According to ASTM D790

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

Syracuse University

May 2019

Flexural Test of Epoxies According to ASTM D790

Introduction

This report provides a summary of the results of test performed as outlined within this document. Flexural test was conducted following ASTM D790 – 17. Standard Test Method for Flexural Properties of Unreinforced Plastics and Electrical Insulating Materials. The coupon configuration was standard according to the standard specified. Flexural strength of eight types of epoxies were tested and reported.

Test Date and Location

The test was conducted on December 29th, 2018 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1 shows information of the tested specimens.

Product name	Manufacturer	Material Type
HM-180	Shanghai Horse Construction	Primer
HM-180C3P	Shanghai Horse Construction	Impregnated adhesive
HM-120ML	Shanghai Horse Construction	Leveling adhesive
HM-120CP	Shanghai Horse Construction	CFRP plate adhesive
HM-500	Shanghai Horse Construction	Anchoring adhesive
HM-120	Shanghai Horse Construction	Steel bonding adhesive
HM-120M	Shanghai Horse Construction	Steel jacketing adhesive
HM-120L	Shanghai Horse Construction	Crack injection adhesive

Table 1. Specimen Description

Specimens were labeled as HM180-# for HM180 materials, as well as the rest. Typical Type I specimen are used in this test, geometry of tested specimens are summarized in Table 2. Dimension for each specimen is summarized in Appendix A.

Product name	Average Thickness (mm)	Average Width (mm)	Average Length (mm)
HM-180	2.61	12.80	134.86
HM-180C3P	2.90	12.75	134.82
HM-120ML	2.27	12.81	135.45
HM-120CP	2.62	12.75	135.07
HM-500	2.25	12.78	134.93
HM-120	2.61	12.77	134.93
HM-120M	2.44	12.73	134.87
HM-120L	4.67	12.72	134.83

Table 2. Specimen dimensions

Apparatus

A 10 kN MTS testing machine (Model: E45) was used to conduct this test.

Loading nose and supports with a diameter of 5.0 mm were used in this test.

Test Procedure

Tests were conducted under a temperature of 23°±3°C.

Procedure A, which is a three point bending test was adapted to test the specimens. All specimens were loaded at a rate of 1.07 mm/min until failure. The span length is 40 mm.

Load versus crosshead displacement data throughout the test, maximum load, final load, and load at any obvious discontinuities in load-displacement data were recorded.

Test Results

Five specimens were tested for each type of product. Flexural strength was calculated as equation 1. Test results are summarized in Table 3.

$$\sigma_f = 3PL/2bd^2 \qquad \text{Eq. 1}$$

Where σ_f is flexural strength (MPa); P is the maximum load (N); L is the span length (mm); b is width of the specimen (mm); d is depth of the specimen (mm).

Product name	Flexural Strength (MPa)		
	Mean	Standard Deviation	COV (%)
HM-180	121.60	14.76	12.14
HM-180C3P	118.93	8.33	7.00
HM-120ML	77.45	7.62	9.83
HM-120CP	115.09	11.21	9.74
HM-500	54.65	14.80	27.08
HM-120	113.71	9.90	8.71
HM-120M	115.14	4.59	3.99
HM-120L	100.16	9.60	9.59

Table 3. Flexural Strength

Test results of each specimen are shown in Appendix B.

Appendix A. Dimension of Each Specimen.

Name	Width (mm)	Thickness(mm)	Length (mm)
HM180-1	12.70	2.60	135.06
HM180-2	12.70	2.79	134.76
HM180-3	12.67	2.37	134.8
HM180-4	12.72	2.57	134.87
HM180-5	12.71	2.71	134.8
HM180C3P-1	12.72	3.15	134.81
HM180C3P-2	12.75	2.81	134.89
HM180C3P-3	12.75	2.99	134.8
HM180C3P-4	12.78	2.47	134.81
HM180C3P-5	12.74	3.09	134.81
HM120ML-1	12.77	2.26	135.33
HM120ML-2	12.82	2.22	135.22
HM120ML-3	12.76	2.26	135.44
HM120ML-4	12.93	2.26	135.96
HM120ML-5	12.78	2.35	135.28
HM120CP-1	12.75	2.45	135.15
HM120CP-2	12.75	2.58	135.01
HM120CP-3	12.77	2.83	135.04
HM120CP-4	12.75	2.82	135.11
HM120CP-5	12.73	2.42	135.05
HM500-1	12.82	2.20	134.90
HM500-2	12.80	2.38	134.94
HM500-3	12.74	2.14	134.95
HM500-4	12.75	2.24	134.97
HM500-5	12.78	2.29	134.89
HM120-1	12.75	2.77	134.92
HM120-2	12.73	2.67	134.93
HM120-3	12.82	2.61	134.91
HM120-4	12.76	2.47	135.01
HM120-5	12.81	2.55	134.89
HM120M-1	12.73	2.12	134.87
HM120M-2	12.73	2.88	134.97
HM120M-3	12.74	2.41	134.86
HM120M-4	12.71	2.41	134.85
HM120M-5	12.72	2.36	134.82
HM120L-1	12.73	2.53	134.85
HM120L-2	12.72	12.60	134.82
HM120L-3	12.72	2.78	134.9
HM120L-4	12.66	2.70	134.77

HM120L-5	12.77	2.74	134.8

Appendix B. Test Results of Each Specimen.

Specimen	Flexural Strength (MPa)
HM180-1	111.10
HM180-2	117.51
HM180-3	115.07
HM180-4	116.75
HM180-5	147.64
HM180C3P-1	111.19
HM180C3P-2	119.39
HM180C3P-3	237.86
HM180C3P-4	126.36
HM180C3P-5	109.84
HM120ML-1	70.95
HM120ML-2	87.05
HM120ML-3	84.30
HM120ML-4	71.69
HM120ML-5	73.27
HM120CP-1	126.38
HM120CP-2	118.73
HM120CP-3	122.17
HM120CP-4	109.84
HM120CP-5	98.22
HM500-1	61.54
HM500-2	56.52
HM500-3	73.37
HM500-4	47.83
HM500-5	33.97
HM120-1	107.88
HM120-2	118.58
HM120-3	120.88
HM120-4	122.07
HM120-5	99.11
HM120M-1	119.15
HM120M-2	109.22
HM120M-3	118.68
HM120M-4	111.22
HM120M-5	117.46
HM120L-1	102.77
HM120L-2	104.93
HM120L-3	86.12
HM120L-4	111.24
HM120L-5	95.76

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Short-Beam Strength of CFRP Composites According to ASTM D2344

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

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May 2019

Short-Beam Strength of CFRP Composites According to ASTM D2344

Introduction

This report provides a summary of the results of test performed as outlined within this document. Short-beam test was conducted following ASTM D2344/D2344M – 16. Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates. The coupon configuration was standard according to the standard specified.

Test Date and Location

The test was conducted on January 2nd, 2019 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1. shows information of the tested specimens.

Product name	Manufacturer	Material Type	Fiber Orientation
HM-20 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-20 Grade II	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-30 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-30 Grade II	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-60 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-2.0T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional
HM-3.0T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional

Table 1. Specimen Description

Specimens were labeled as HM20I-# for HM-20 Grade I, HM20II-# for HM-20 Grade II, HM30I-# for HM-30 Grade I, HM30II-# for HM-30 Grade I, HM60I-# for HM-60 Grade I, HM2.0T-# for HM-2.0T and HM3.0T-# for HM-3.0T.

For HM-20 Grade I and HM-20 Grade II sheet specimens, each specimen was made of five layers of dry fiber with HM180C3P impregnated adhesive. For HM-30 Grade I sheet specimens, each specimen was made of three layers of dry fiber with HM180C3P impregnated adhesive. For HM-60 Grade I sheet specimens, each specimen was made of two layer of dry fiber with HM180C3P impregnated adhesive.

Typical flat specimen are used in this test. All CFRP sheet specimens were manufactured with three layers of dry fiber sheets, geometry of tested specimens are summarized in Table 2. Dimension for each specimen is summarized in Appendix A.

Product name	Average Thickness (mm)	Average Width (mm)	Average Length (mm)
HM-20 Grade I	2.03	4.01	12.03
HM-20 Grade II	2.03	4.01	12.02

HM-30 Grade I	2.02	3.99	12.02
HM-30 Grade II	2.08	3.98	12.05
HM-60 Grade I	2.09	4.08	12.04
HM-2.0T	1.99	4.1	12.01
HM-3.0T	3.02	6.02	18.02

Table 2. Specimen dimensions

Apparatus

A 30 kN MTS testing machine (Model: E45) was used to conduct this test.

6.0 mm diameter loading nose and 3.0 mm diameter support was used in this test.

Test Procedure

Tests were conducted under a temperature of 23°±3°C.

The span length was adjusted as 8.0 mm for all specimens except HM-3.0T series. HM-3.0T series were tested with a span length of 12.00 mm.

All specimens were loaded at a rate of crosshead movement of 1.0 mm/min until failure, defined as following:

1. A load drop-off of 30 %,
2. Two-piece specimen failure, or
3. The head travel exceeds the specimen nominal thickness.

Load versus crosshead displacement data throughout the test method, maximum load, final load, and load at any obvious discontinuities in load-displacement data were recorded at a rate of 20 Hz.

Test Results

Five specimens were tested for each type of product. Short beam strength is calculated using Equation 1. Test results are summarized in Table 3.

$$F^{sbs} = 0.75\frac{P_m}{bh} \quad \text{Eq.1}$$

Where F_{sbs} is short beam strength; P_m is the maximum load; b is width of specimens; h is thickness of specimens.

Product name	Short-Beam Strength (MPa)		COV (%)
	Mean	Standard Deviation	
HM-20 Grade I	67.67	2.97	4.40
HM-20 Grade II	63.30	11.98	18.92
HM-30 Grade I	96.23	4.72	4.90
HM-30 Grade II	83.47	6.68	8.00
HM-60 Grade I	104.20	19.27	18.50
HM-2.0T	65.54	5.04	7.69
HM-3.0T	81.88	2.76	3.37

Table 3. Short-Beam Strength

Failure mode and Maximum load for each specimen are summarized in Appendix B. Load-deflection curve for each specimen are summarized in Appendix C.

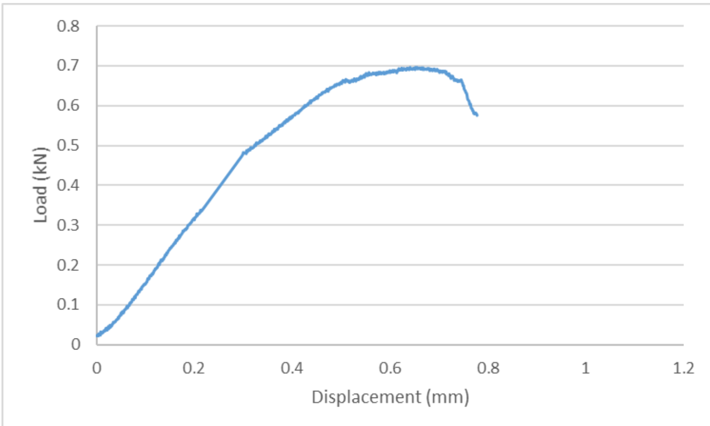
Appendix A. Dimension of Each Specimen.

Name	Width (mm)	Thickness(mm)	Length (mm)
HM20I-1	4.03	1.99	12.02
HM20I-2	4.00	1.99	12.01
HM20I-3	4.03	2.04	12.03
HM20I-4	4.00	2.07	12.04
HM20I-5	4.01	2.05	12.05
HM20II-1	4.01	1.97	12.01
HM20II-2	4.01	2.00	12.00
HM20II-3	4.03	2.07	12.02
HM20II-4	4.00	2.04	12.03
HM20II-5	4.00	2.06	12.04
HM30I-1	3.99	2.05	12.03
HM30I-2	3.99	2.01	12.04
HM30I-3	4.01	1.94	12.02
HM30I-4	3.98	2.05	12.01
HM30I-5	3.98	2.06	12.00
HM30II-1	3.96	2.09	12.06
HM30II-2	4.01	2.08	12.07
HM30II-3	4.01	2.08	12.05
HM30II-4	3.96	2.09	12.04
HM30II-5	3.97	2.06	12.03
HM60I-1	4.10	2.09	12.05
HM60I-2	4.03	2.07	12.06
HM60I-3	4.22	2.10	12.04
HM60I-4	4.04	2.08	12.03
HM60I-5	4.01	2.09	12.02
HM2.0T-1	4.09	1.99	12.02
HM2.0T-2	4.13	1.99	12.03
HM2.0T-3	4.04	1.99	12.01
HM2.0T-4	4.11	1.98	12.00
HM2.0T-5	4.10	1.99	11.99
HM3.0T-1	6.02	3.01	18.03
HM3.0T-2	6.02	3.02	18.04
HM3.0T-3	6.02	3.01	18.02
HM3.0T-4	6.03	3.02	18.01
HM3.0T-5	6.02	3.03	18.00

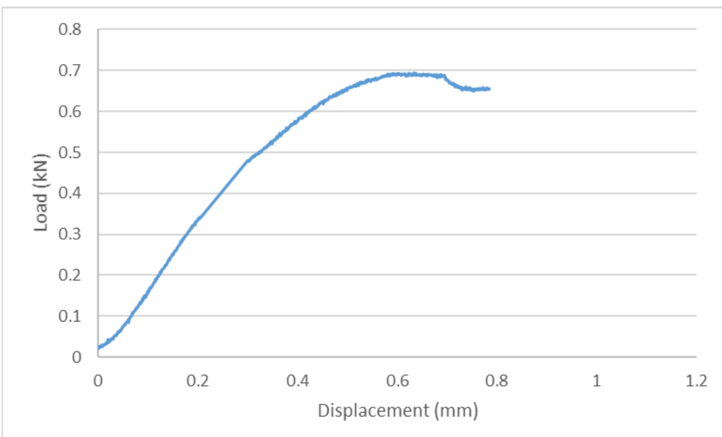
Appendix B. Failure Mode and Maximum Load.

Name	Maximum Load (N)	Failure Mode
HM20I-1	696.41	Flexure
HM20I-2	694.29	Flexure
HM20I-3	787.22	Flexure
HM20I-4	763.34	Flexure
HM20I-5	736.24	Flexure
HM20II-1	487.70	Flexure
HM20II-2	695.87	Flexure
HM20II-3	640.54	Flexure
HM20II-4	757.87	Flexure
HM20II-5	848.00	Flexure
HM30I-1	1138.23	Flexure
HM30I-2	1029.15	Flexure
HM30I-3	983.88	Flexure
HM30I-4	1021.44	Flexure
HM30I-5	1005.29	Flexure
HM30II-1	948.87	Flexure
HM30II-2	810.45	Flexure
HM30II-3	966.80	Flexure
HM30II-4	900.81	Flexure
HM30II-5	984.03	Flexure
HM60I-1	1565.55	Flexure
HM60I-2	1157.92	Flexure
HM60I-3	1176.18	Flexure
HM60I-4	997.25	Flexure
HM60I-5	1020.90	Flexure
HM2.0T-1	745.15	Flexure
HM2.0T-2	728.00	Flexure
HM2.0T-3	690.59	Flexure
HM2.0T-4	630.09	Flexure
HM2.0T-5	771.79	Flexure
HM3.0T-1	2056.17	Flexure
HM3.0T-2	2027.26	Flexure
HM3.0T-3	2002.92	Flexure
HM3.0T-4	1919.56	Flexure
HM3.0T-5	1919.56	Flexure

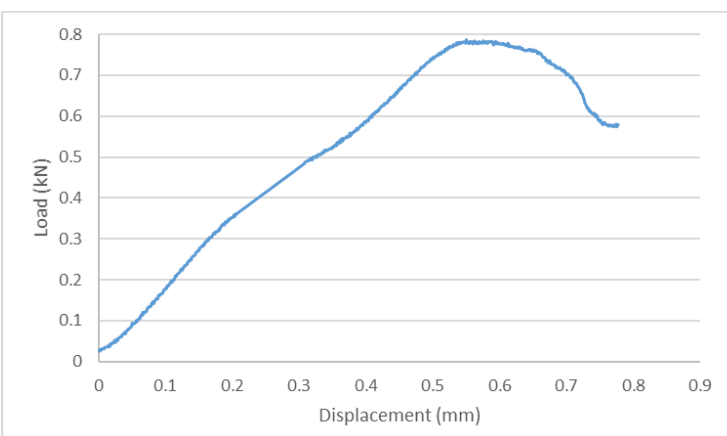
Appendix C. Load-displacement Curves



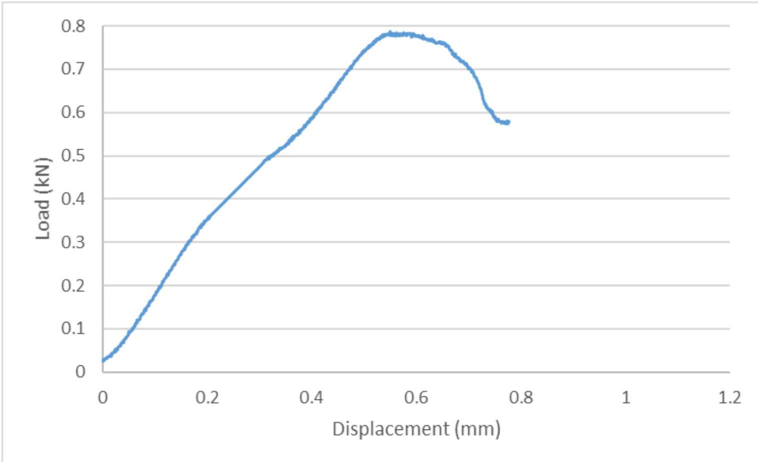
HM20I-1



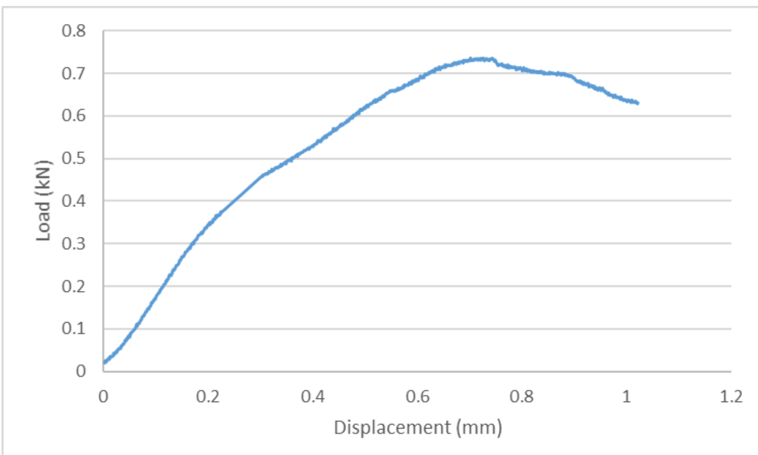
HM20I-2



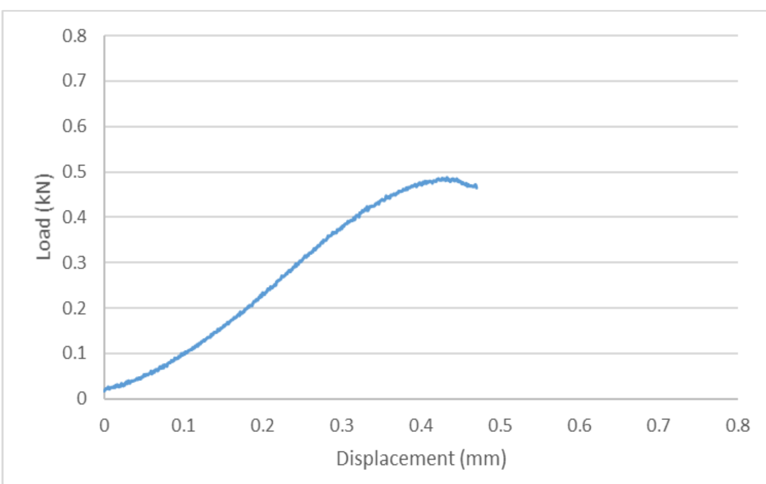
HM20I-3



HM20I-4



HM20I-5



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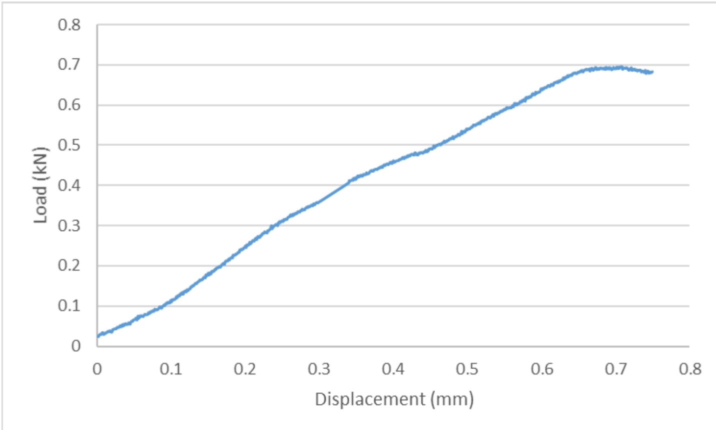

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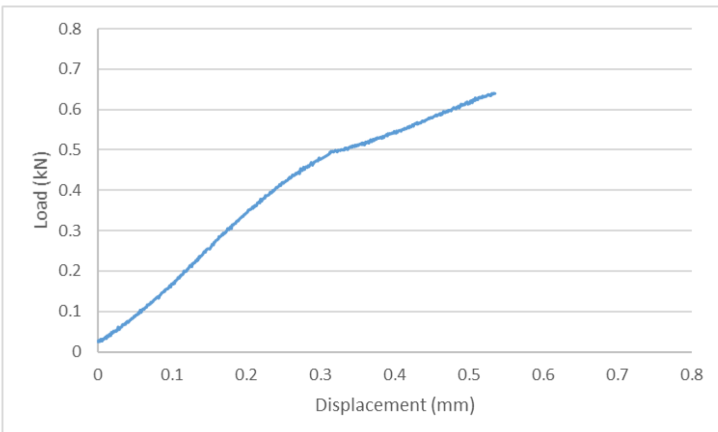

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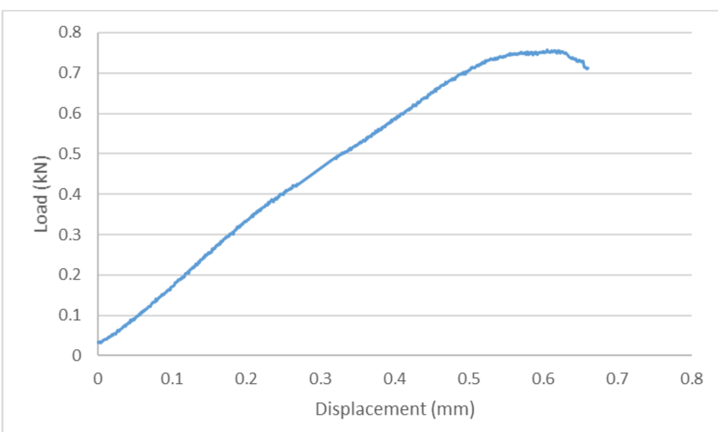

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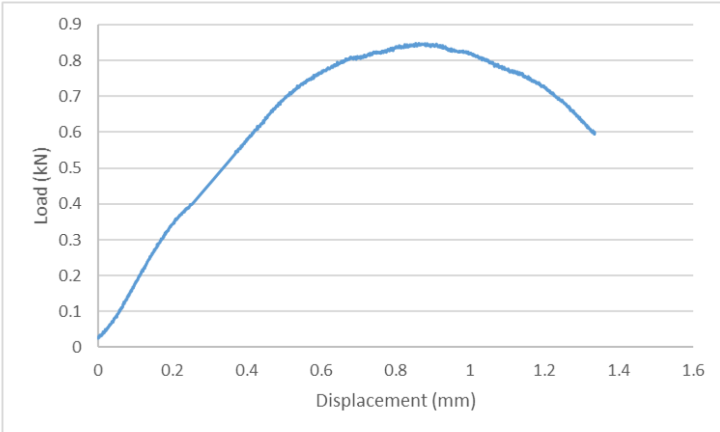

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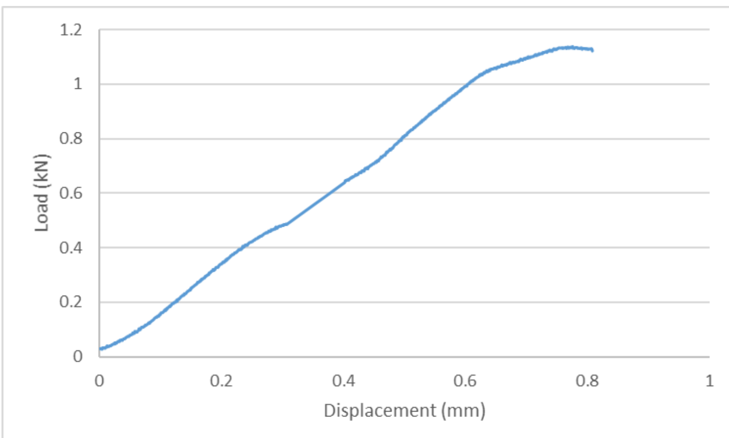

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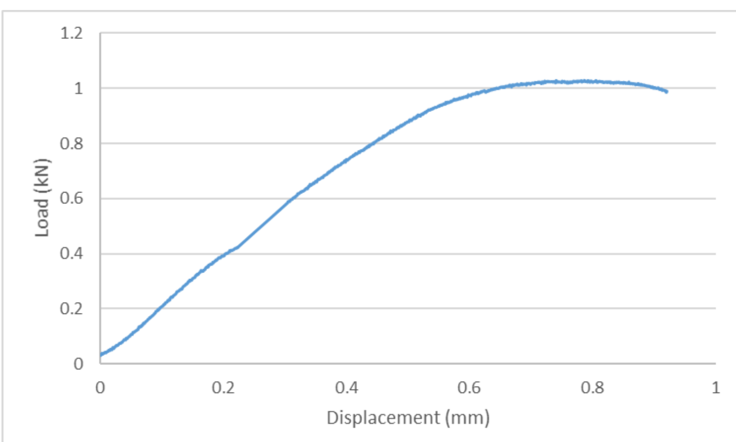

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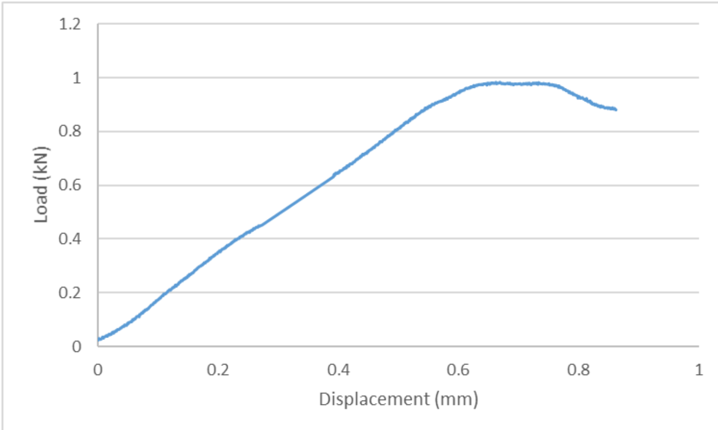

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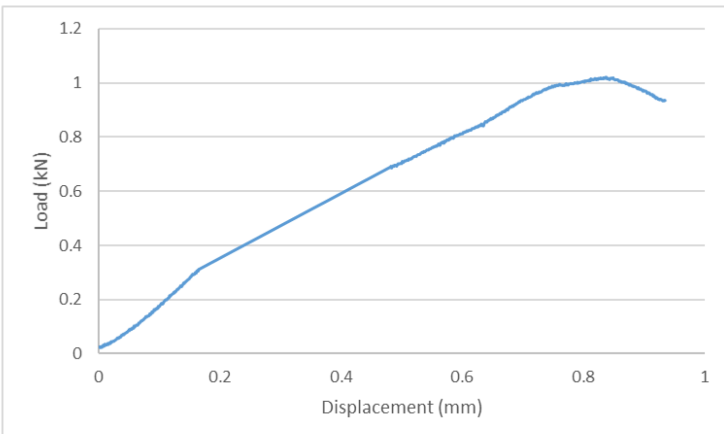

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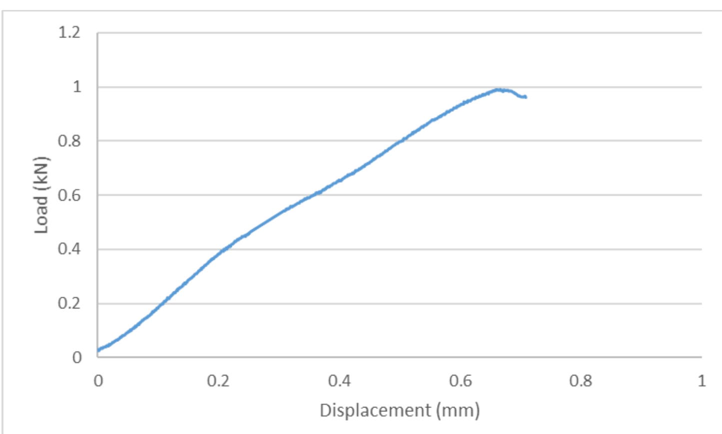

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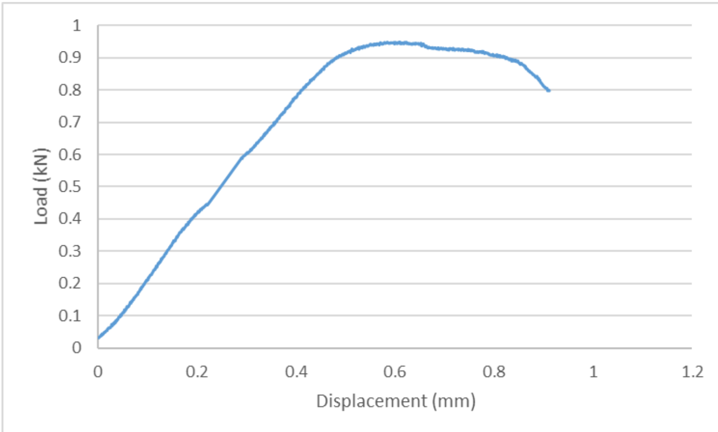

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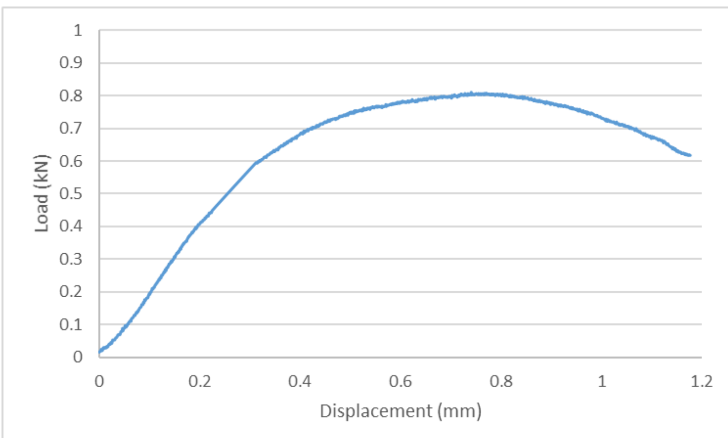

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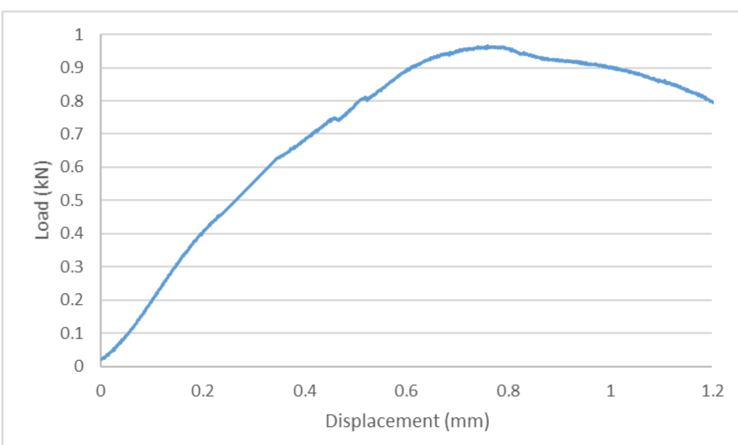

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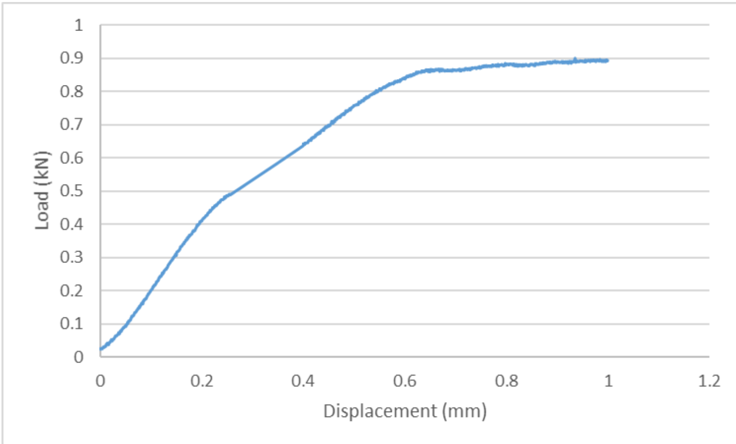

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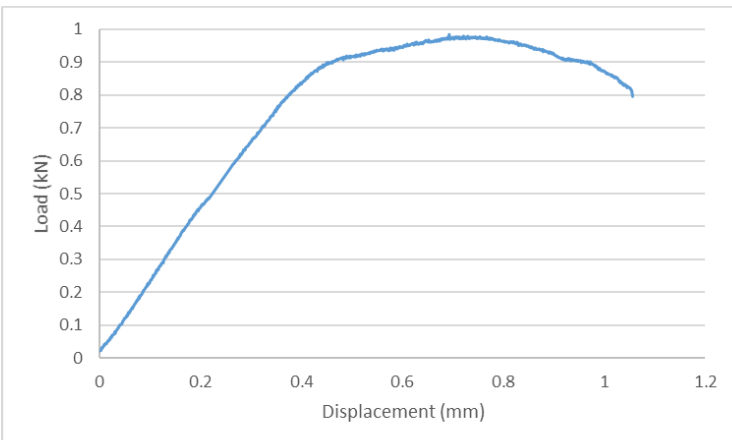

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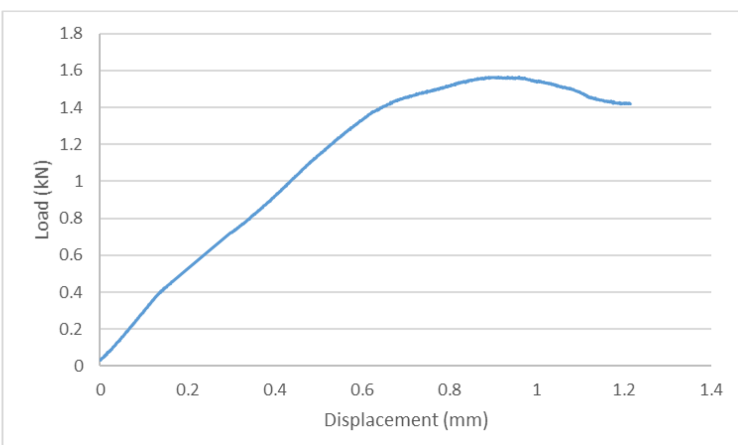

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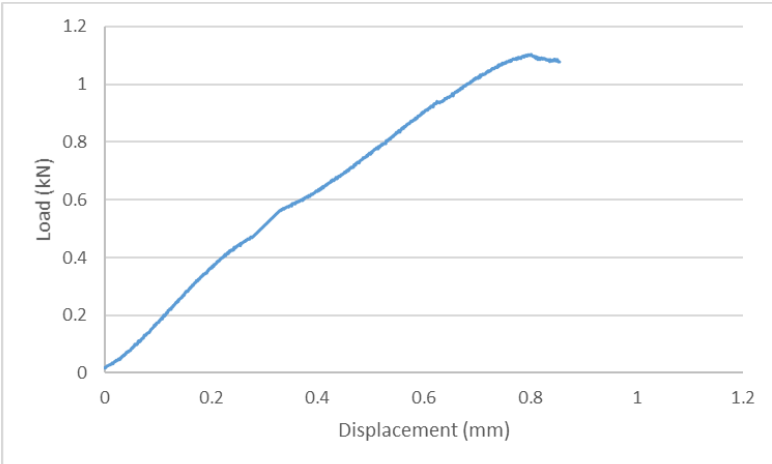

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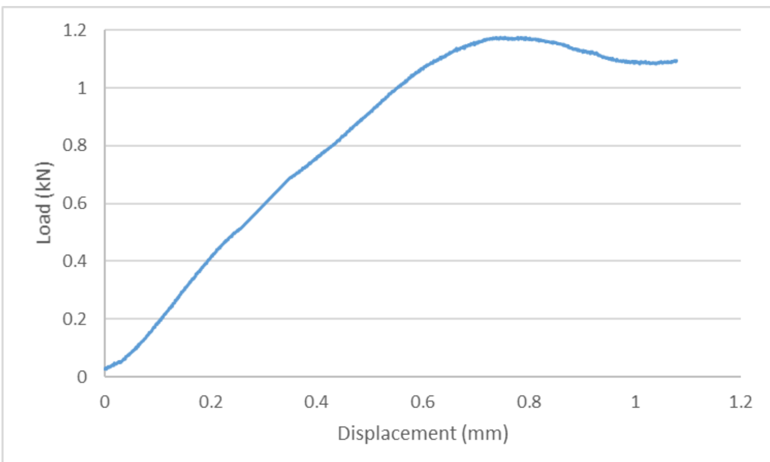

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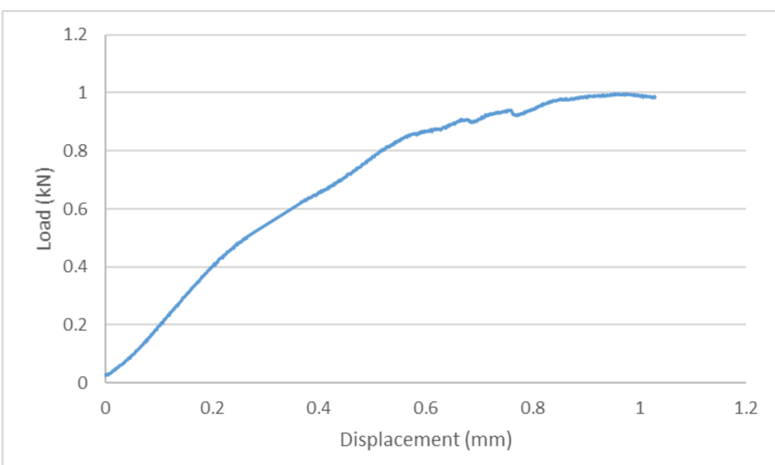

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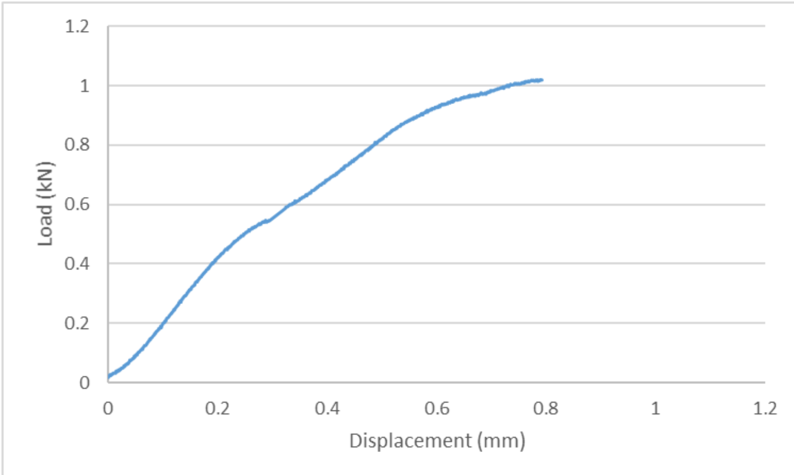

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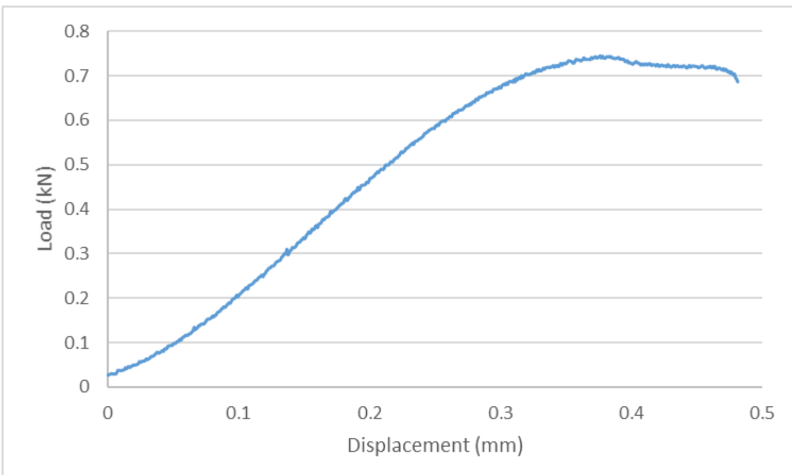

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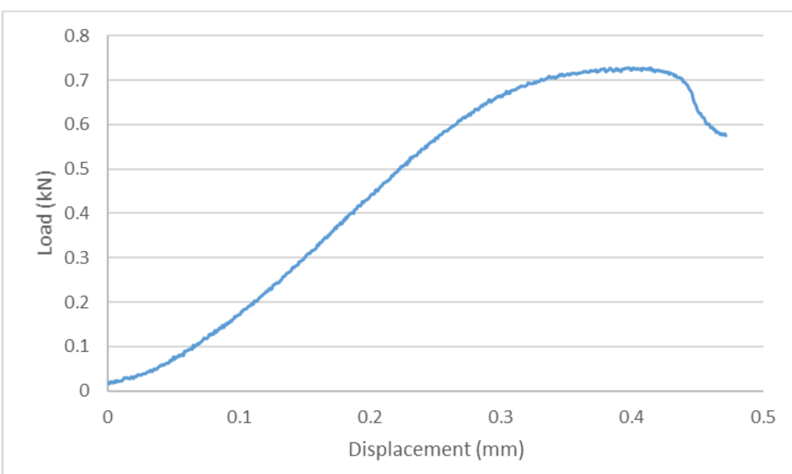

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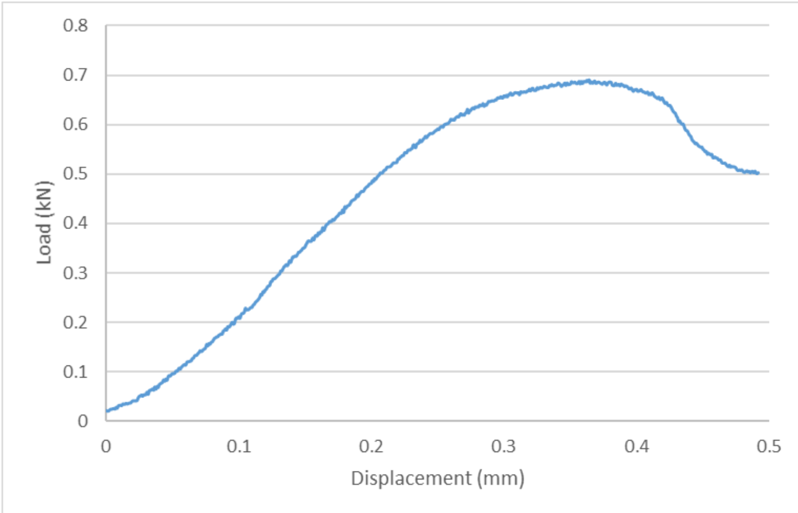

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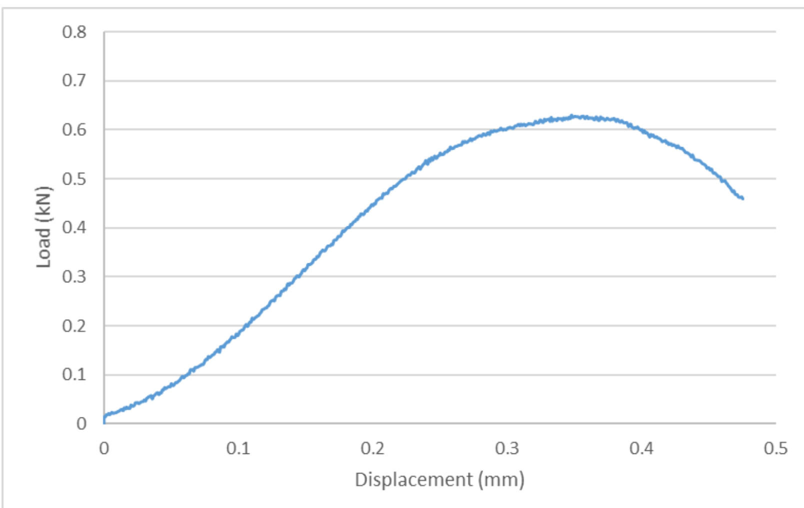

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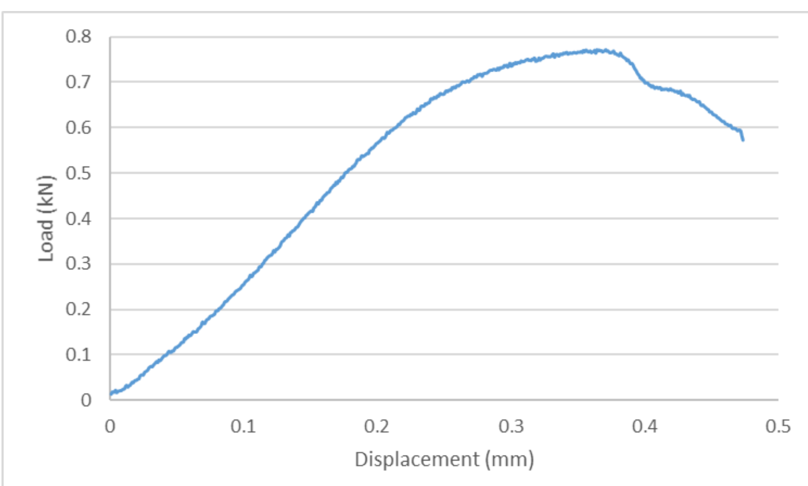

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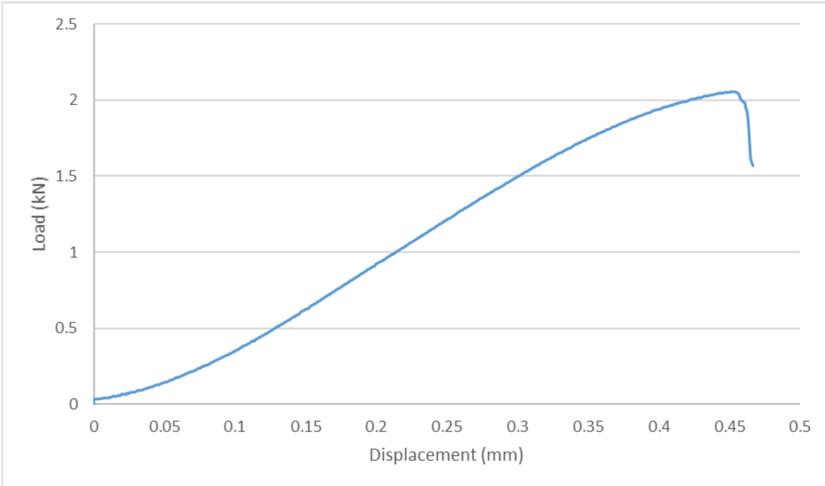

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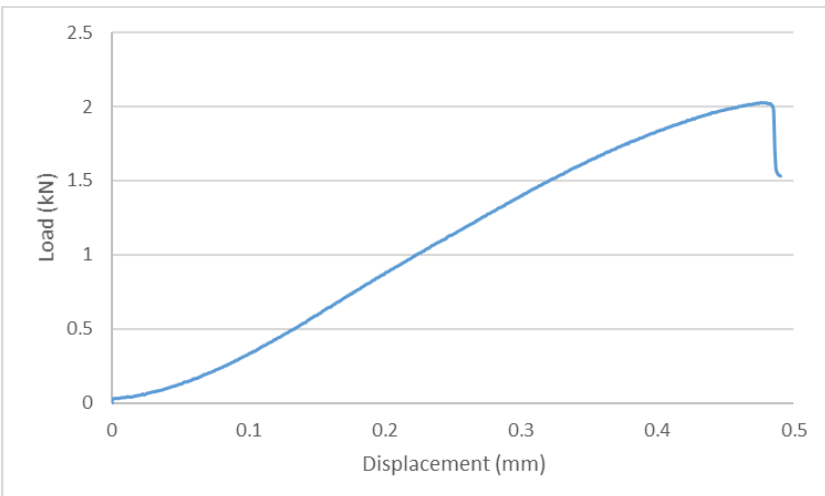

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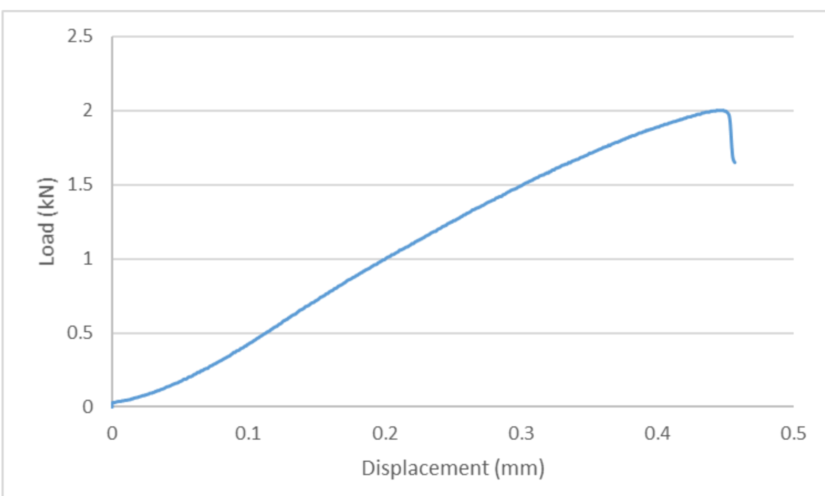

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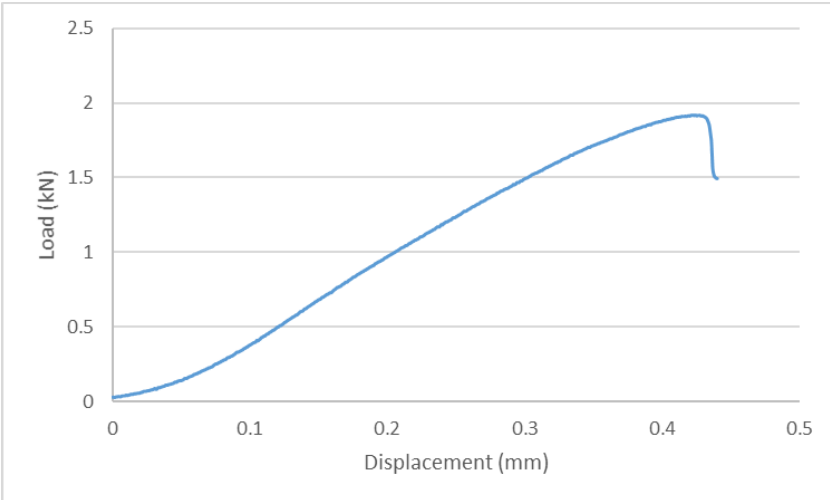

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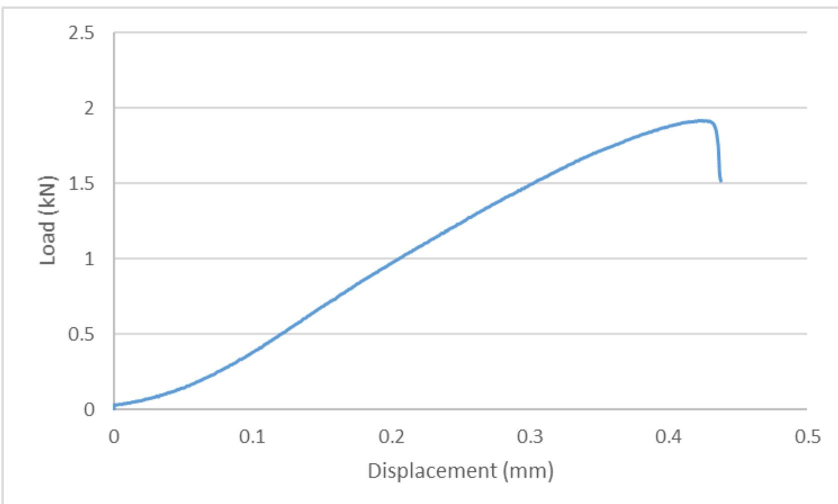


HM3.0T-5

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Tensile Test of CFRP Composites According to ASTM D3039

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

Syracuse University

May 2019

Tensile Test of CFRP Composites According to ASTM D3039

Introduction

This report provides a summary of the results of test performed as outlined within this document. Tensile test was conducted following ASTM D3039/D3039M – 17. Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials. The coupon configuration was standard according to the standard specified.

Test Date and Location

The test was conducted on December 18th, 2018 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1. shows information of the tested specimens.

Product name	Manufacturer	Material Type	Fiber Orientation
HM-20 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-20 Grade II	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-30 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-30 Grade II	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-60 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-1.2T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional
HM-1.4T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional
HM-2.0T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional

Table 1. Specimen Description

Specimens were labeled as HM20I-# for HM-20 Grade I, HM20II-# for HM-20 Grade II, HM30I-# for HM-30 Grade I, HM60I-# for HM-60 Grade I, HM1.2T-# for HM-1.2T and HM1.4T-# for HM-1.4T.

Each CFRP sheet specimens was made of one layer of dry fiber with HM180C3P impregnated adhesive.

Typical flat specimen are used in this test, geometry of tested specimens are summarized in Table 2. Dimension for each specimen is summarized in Appendix A. 56*15*1.5 mm aluminum tabs were used for this test.

Product name	Average Thickness (mm)	Average Width (mm)	Average Length (mm)
HM-20 Grade I	0.70	15.83	56.96
HM-20 Grade II	0.53	15.49	57.08
HM-30 Grade I	0.59	15.65	56.98
HM-30 Grade II	0.76	15.51	57.14
HM-60 Grade I	1.05	15.47	57.00
HM-1.2T	1.20	15.03	57.08
HM-1.4T	1.40	15.01	57.22
HM-2.0T	2.00	15.03	57.06

Table 2. Specimen dimensions

Apparatus

A 30 kN MTS testing machine (Model: E45) was used to conduct this test.

A 50 mm displacement transducer was used to measure the elongation of the specimen.

Test Procedure

Tests were conducted under a temperature of 23°±3°C.

All specimens were loaded at a rate of crosshead movement of 2.0 mm/min until failure.

Load versus crosshead displacement data throughout the test method, maximum load, final load, and load at any obvious discontinuities in load-displacement data were recorded at a rate of 20 Hz.

Test Results

Five specimens were tested for each type of product. Tensile strength is calculated using equation 1.

$$f = \frac{P_{max}}{b*t} \qquad \text{Eq.1.}$$

Where f is the tensile strength; P_{max} is maximum force; b is width of the specimen; t is the theoretical thickness of the CFRP sheet. For HM-20, t = 0.111 mm; For HM-30, t = 0.167 mm; For HM-20, t = 0.333mm.

Five specimens were tested for each type of product. Test results are summarized in Table 3-5.

Product name	Tensile Strength (MPa)		COV (%)
	Mean	Standard Deviation	
HM-20 Grade I	4318.07	90.52	2.10
HM-20 Grade II	3708.16	180.34	4.86
HM-30 Grade I	4840.44	151.47	3.13
HM-30 Grade II	4165.16	116.79	2.80
HM-60 Grade I	4123.43	101.25	2.46
HM-1.2T	2743.26	127.93	4.66
HM-1.4T	3044.36	129.72	4.26
HM-2.0T	2999.75	172.8	5.76

Table 3. Tensile Strength

Product name	Elongation at Break (%)		COV (%)
	Mean	Standard Deviation	
HM-20 Grade I	1.53	0.064	4.25
HM-20 Grade II	1.44	0.035	2.48
HM-30 Grade I	1.95	0.045	2.31
HM-30 Grade II	1.72	0.061	3.52
HM-60 Grade I	1.69	0.039	2.33
HM-1.2T	1.50	0.089	5.91
HM-1.4T	1.77	0.118	6.65
HM-2.0T	1.80	0.083	4.61

Table 4. Elongation at Break

Product name	Elastic Modulus (GPa)		COV (%)
	Mean	Standard Deviation	
HM-20 Grade I	255.53	11.44	4.48
HM-20 Grade II	237.08	5.07	2.12
HM-30 Grade I	230.35	6.66	2.89
HM-30 Grade II	226.70	3.25	1.43
HM-60 Grade I	232.16	3.32	1.43
HM-1.2T	171.32	4.18	2.44
HM-1.4T	158.18	3.56	2.27
HM-2.0T	157.63	5.54	3.44

Table 5. Elastic Modulus

Test results in terms of failure mode, tensile strength, strain at failure and elastic modulus of each specimen are summarized in Appendix B. Load-deflection curve for each specimen are summarized in Appendix C.

Appendix A. Dimension of Each Specimen.

Name	Width (mm)	Thickness(mm)	Length (mm)
HM20I-1	15.83	0.70	57.2
HM20I-2	15.41	0.72	57.3
HM20I-3	15.36	0.55	56.4
HM20I-4	15.22	0.73	56.9
HM20I-5	15.36	0.73	57.0
HM20II-1	15.38	0.58	56.8
HM20II-2	15.64	0.47	57.0
HM20II-3	15.56	0.44	57.3
HM20II-4	15.49	0.62	57.1
HM20II-5	15.39	0.55	57.2
HM30I-1	15.83	0.56	56.9
HM30I-2	15.74	0.66	57.3
HM30I-3	15.45	0.58	56.4
HM30I-4	15.48	0.55	57.3
HM30I-5	15.76	0.60	57.0
HM30II-1	15.54	0.89	56.7
HM30II-2	15.40	0.68	57.6
HM30II-3	15.57	0.85	57.1
HM30II-4	15.48	0.72	57.1
HM30II-5	15.58	0.65	57.2
HM60I-1	15.65	1.01	56.8
HM60I-2	15.39	0.99	56.9
HM60I-3	15.28	1.02	56.6
HM60I-4	15.56	1.10	57.8
HM60I-5	15.46	1.14	56.9
HM1.2T-1	15.06	1.20	57.1
HM1.2T-2	15.03	1.20	57.3
HM1.2T-3	15.05	1.20	57.3
HM1.2T-4	14.99	1.20	57.0
HM1.2T-5	15.04	1.20	56.7
HM1.4T-1	15.01	1.40	57.6
HM1.4T-2	15.00	1.40	57.1
HM1.4T-3	15.01	1.40	57.1
HM1.4T-4	15.02	1.40	57.1
HM1.4T-5	15.00	1.40	57.2
HM2.0T-1	15.03	2.0	57.0
HM2.0T-2	15.05	2.0	57.1
HM2.0T-3	15.04	2.0	57.1

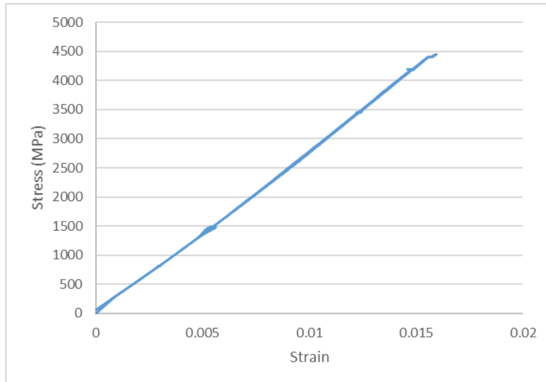
HM2.0T-4	15.01	2.0	57.0
HM2.0T-5	15.00	2.0	57.1

Appendix B. Test Results57.2

Name	Failure Mode	Tensile Strength (MPa)	Strain at Break (%)	Elastic Modulus (GPa)
HM20I-1	LGM	4449.19	1.59	247.29
HM20I-2	LGM	4247.51	1.50	252.29
HM20I-3	LGM	4369.33	1.59	243.34
HM20I-4	LGM	4232.77	1.45	264.59
HM20I-5	LGM	4291.55	1.50	270.16
HM20II-1	LGM	3637.22	1.39	240.54
HM20II-2	LGM	3583.52	1.43	239.37
HM20II-3	LGM	3534.28	1.48	233.25
HM20II-4	LGM	3818.60	1.44	235.70
HM20II-5	LGM	3967.18	1.47	246.52
HM30I-1	LGM	4909.27	1.91	234.66
HM30I-2	LGM	4817.01	1.98	237.91
HM30I-3	LGM	4963.03	2.01	225.52
HM30I-4	LGM	4587.11	1.94	221.66
HM30I-5	LGM	4925.80	1.92	231.98
HM30II-1	LGM	4078.41	1.64	223.24
HM30II-2	LGM	4236.31	1.78	231.50
HM30II-3	LGM	4247.96	1.70	227.57
HM30II-4	LGM	4003.39	1.78	224.17
HM30II-5	LGM	4259.74	1.69	227.04
HM60I-1	LGM	4223.44	1.67	235.03
HM60I-2	LGM	4038.24	1.71	229.81
HM60I-3	LGM	3993.29	1.64	232.41
HM60I-4	LGM	4190.01	1.74	227.91
HM60I-5	LGM	4172.19	1.67	235.64
HM1.2T-1	XGM	2688.32	1.46	167.15
HM1.2T-2	XGM	2894.10	1.62	172.27
HM1.2T-3	XGM	2818.14	1.57	171.42
HM1.2T-4	XGM	2756.63	1.43	177.73
HM1.2T-5	XGM	2559.11	1.42	168.05
HM1.4T-1	XGM	2884.05	1.62	163.58
HM1.4T-2	XGM	2976.99	1.75	153.58
HM1.4T-3	XGM	3133.40	1.81	157.04
HM1.4T-4	XGM	3014.85	1.73	158.18
HM1.4T-5	XGM	3212.50	1.94	158.52
HM2.0T-1	XGM	2827.50	1.80	160.37
HM2.0T-2	XGM	3099.32	1.92	153.00
HM2.0T-3	XGM	2984.79	1.80	150.79

HM2.0T-4	XGM	2848.86	1.69	160.40
HM2.0T-5	XGM	3238.28	1.82	163.34

Appendix C. Load-displacement Curves



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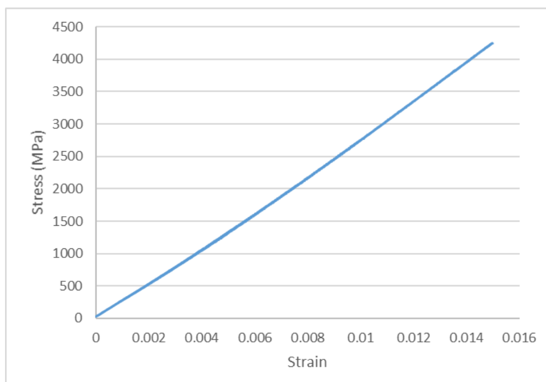

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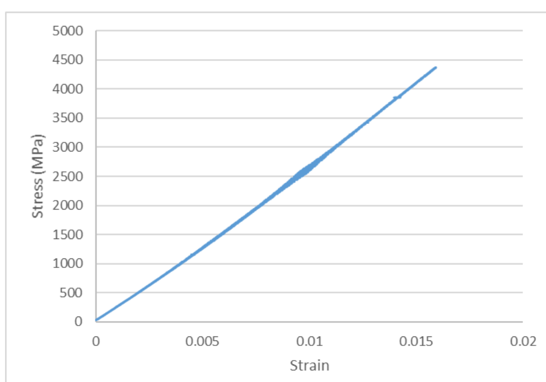

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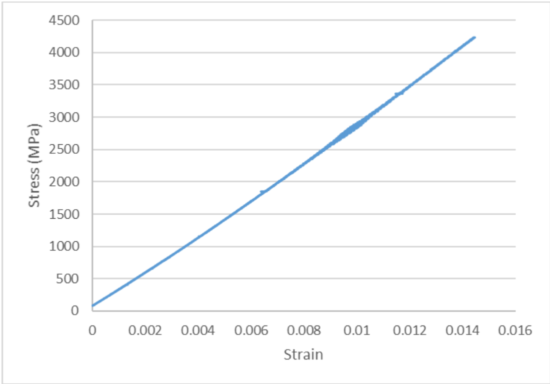

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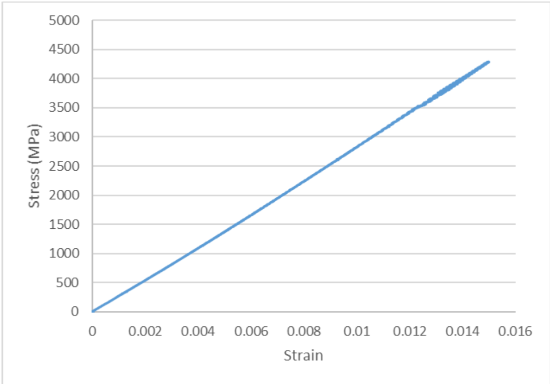

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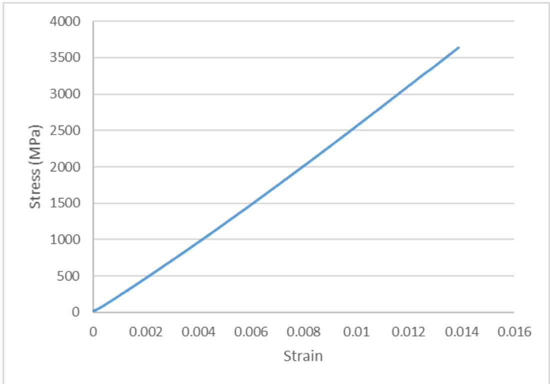

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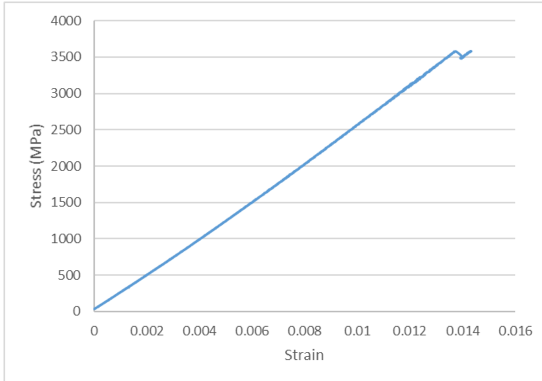

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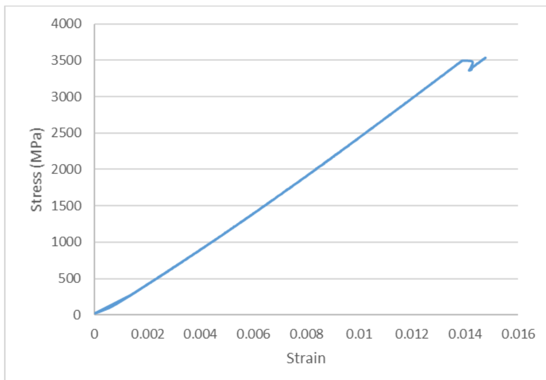

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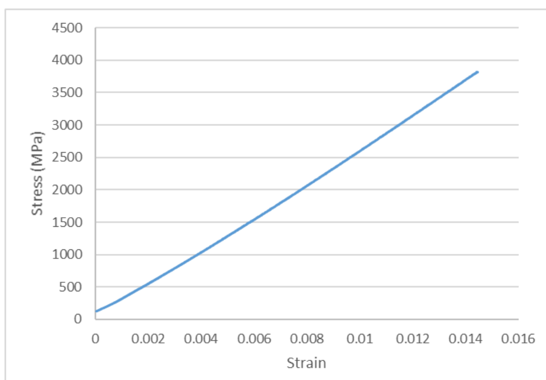

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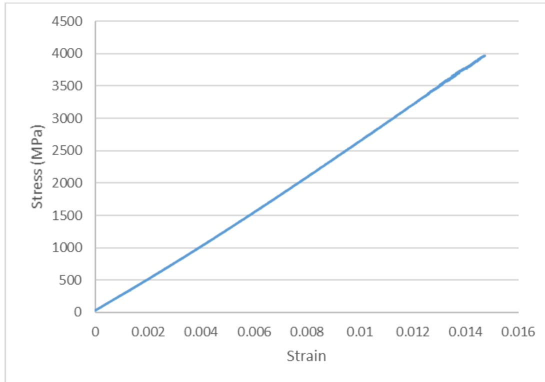

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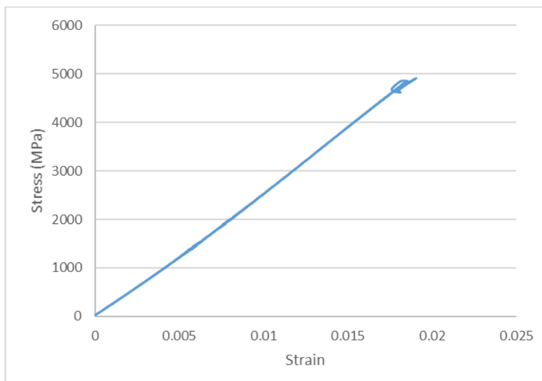

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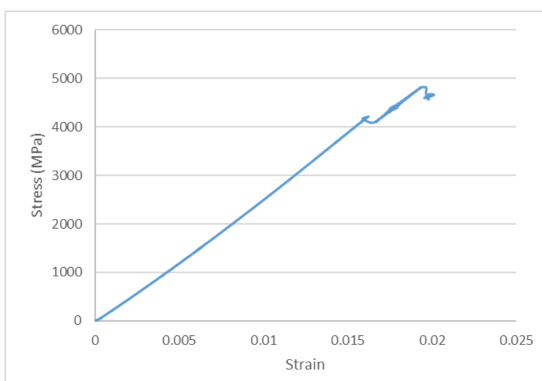

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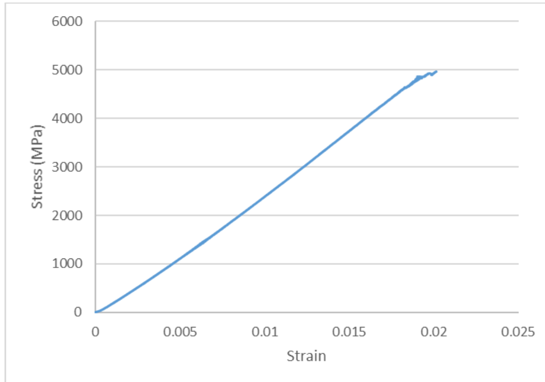

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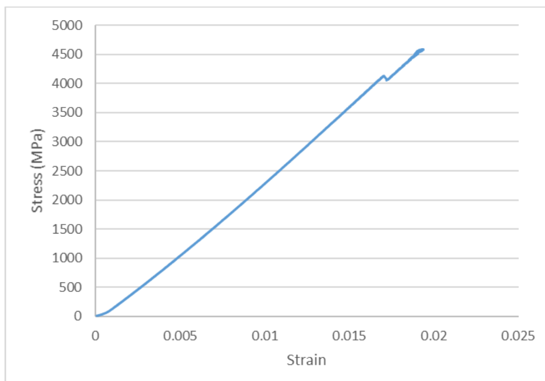

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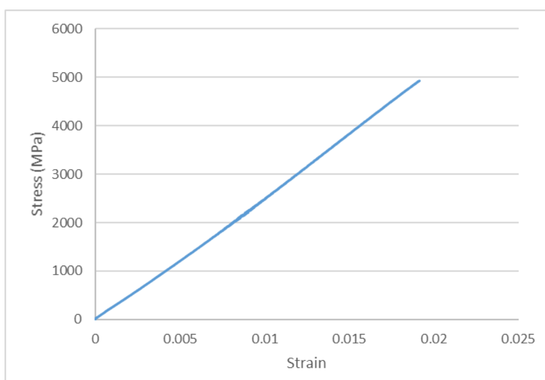

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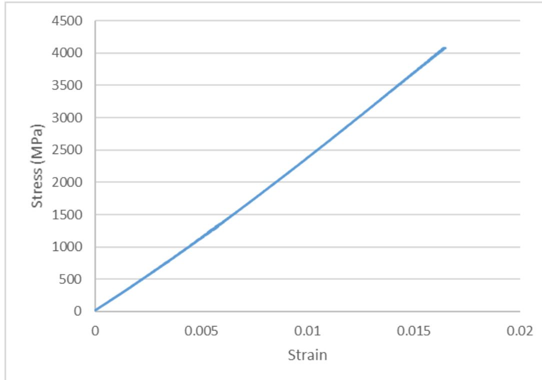

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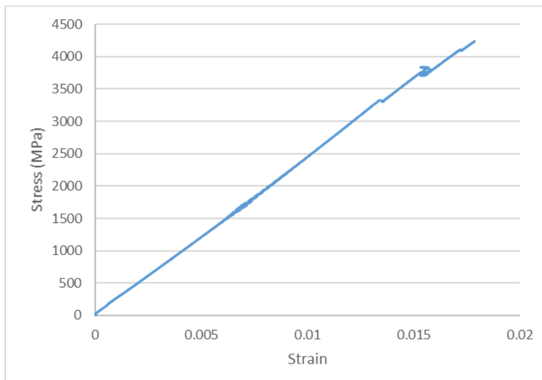

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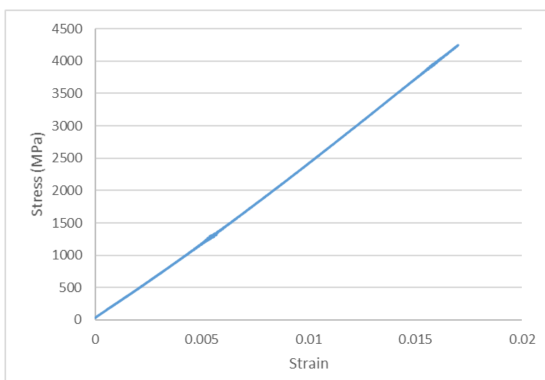

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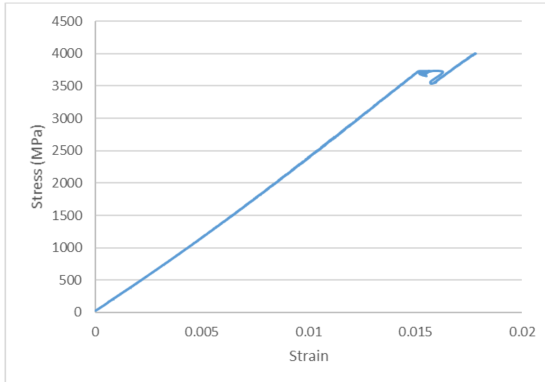

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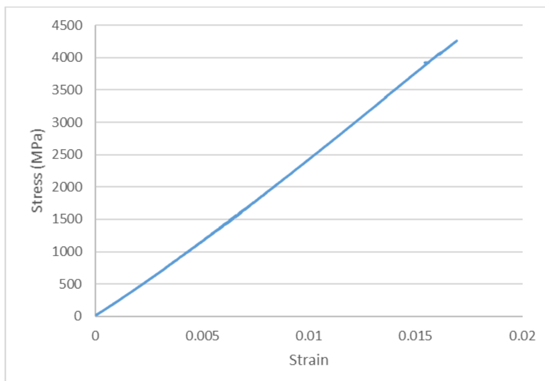

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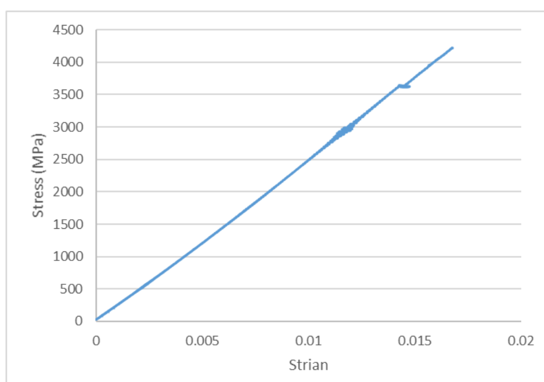

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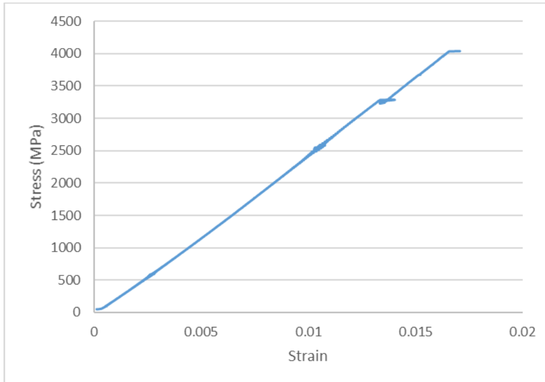

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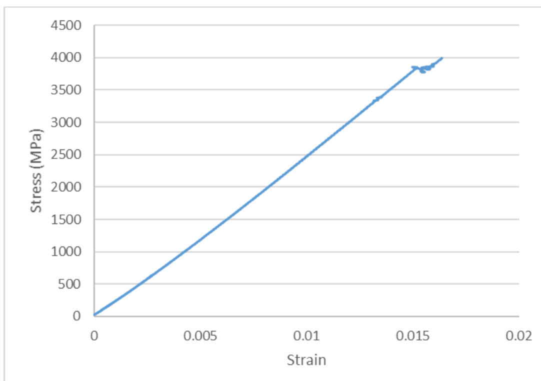

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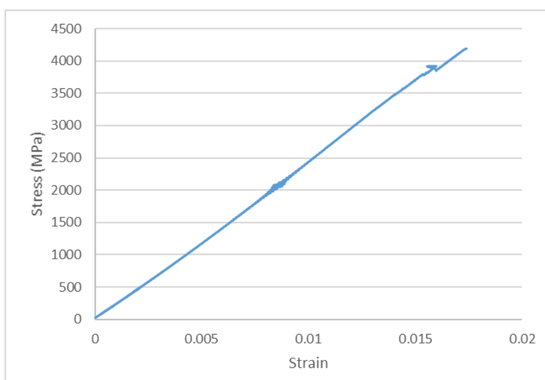

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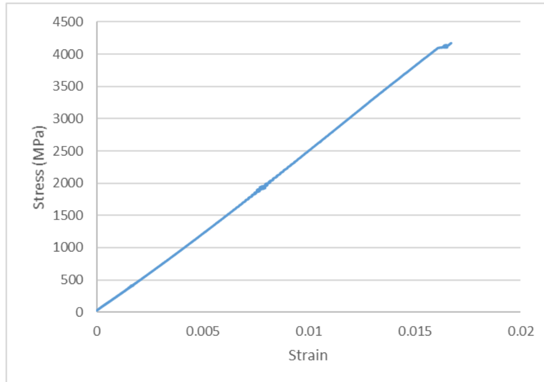

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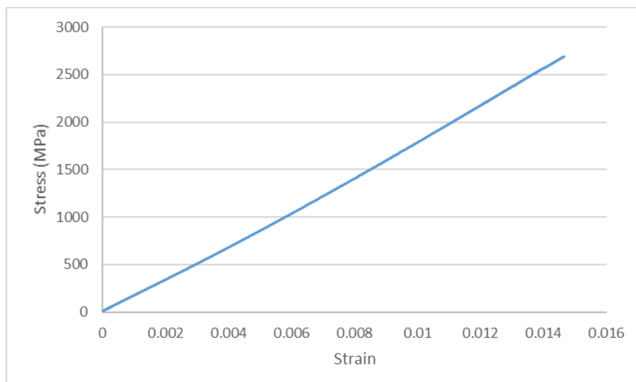

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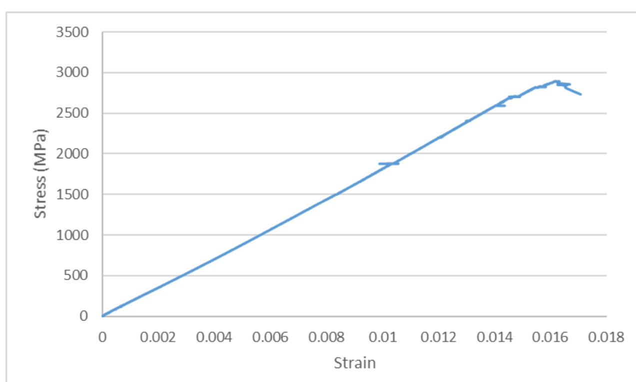

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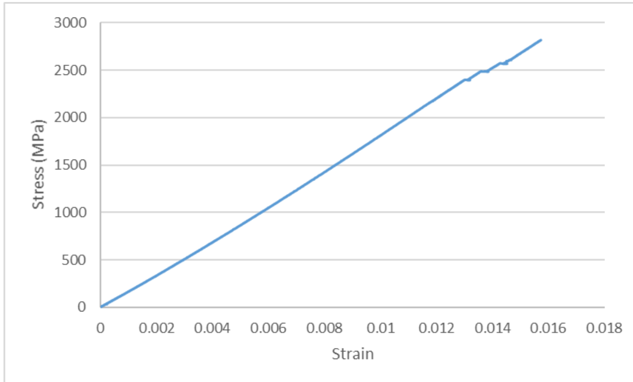

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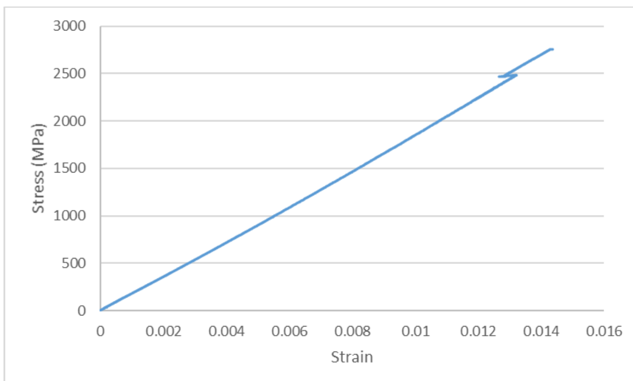

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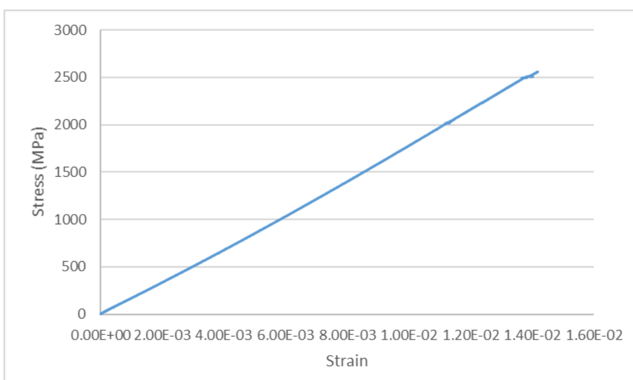

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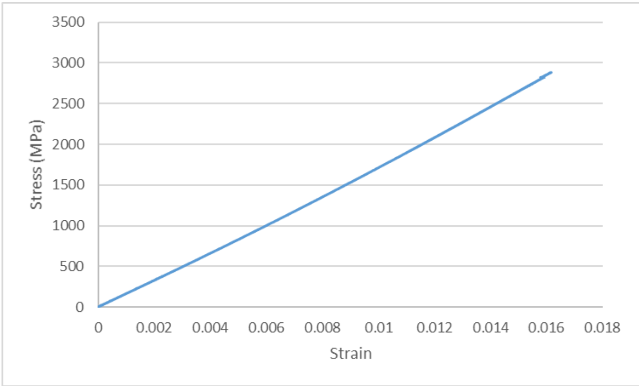

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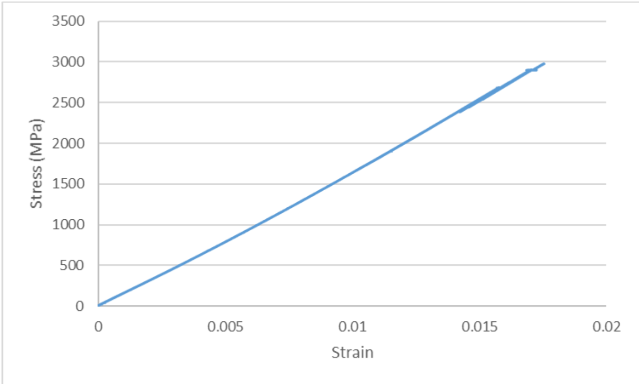

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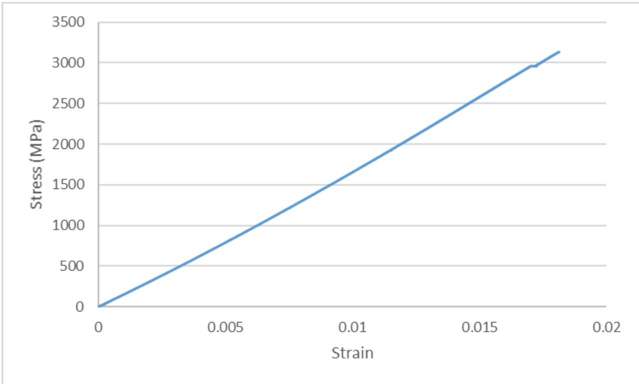

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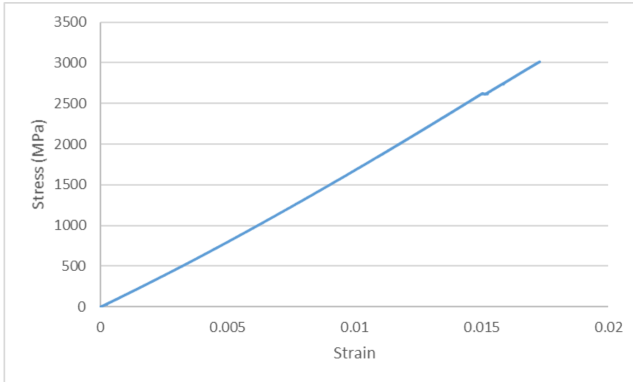

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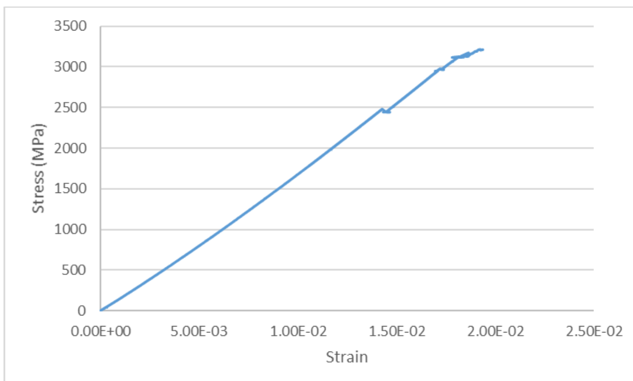

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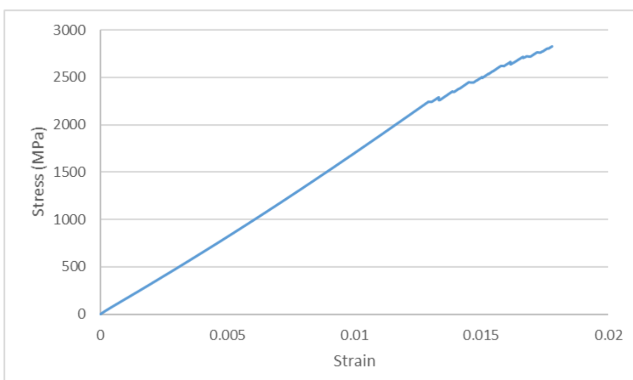

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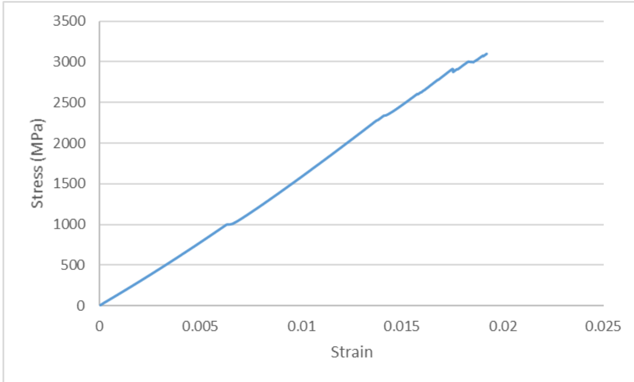

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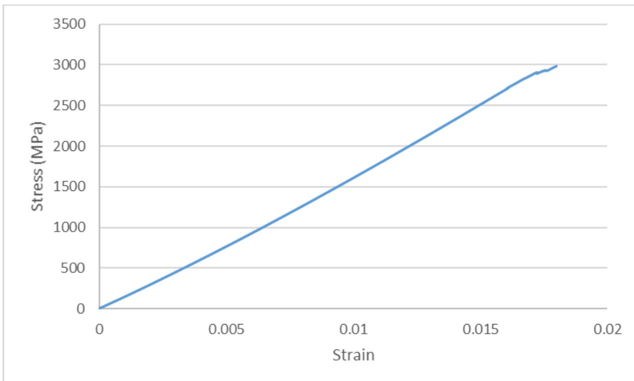

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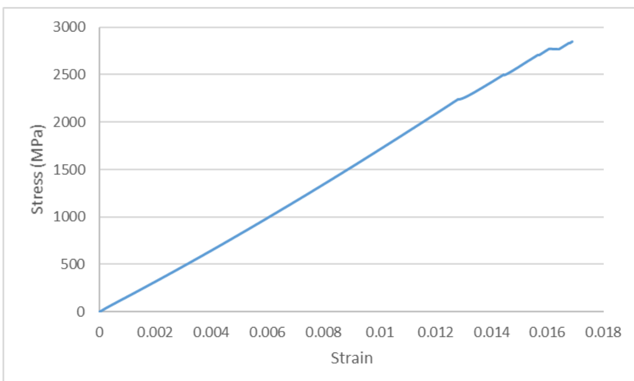

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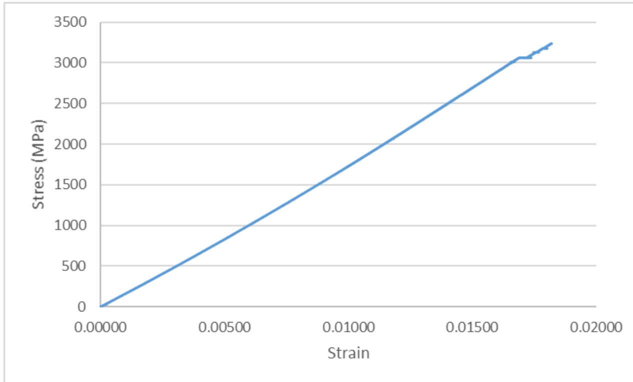

3500
3000
2500
2000
1500
1000
500
0
Stress (MPa)
0.00000
0.00500
0.01000
0.01500
0.02000
Strain

HM2.0T-5

Evaluation of Mechanical Properties of a New CFRP System for Structural Rehabilitation, Based on Experimental Tests

Research Project Number: #30821

Flexural Strength of CFRP Composites According to ASTM D7264

Tested by Cheng Tan

Project Director/Principal Investigator:

Associate Dean Riyad Aboutaha

College of Engineering and Computer Science

Syracuse University

May 2019

Flexural Strength of CFRP Composites According to ASTM D7264

Introduction

This report provides a summary of the results of test performed as outlined within this document. Flexural test was conducted following ASTM D7264/D7264M – 15. Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials. The coupon configuration was standard according to the standard specified.

Test Date and Location

The test was conducted on December 28, 2018 in material laboratory of Shanghai Zhengniu New Material Tech., Ltd., China.

Test Operator

Cheng Tan

Description of Specimens

Specimens in this test were manufactured by Shanghai Horse Construction. Table 1. shows information of the tested specimens.

Product name	Manufacturer	Material Type	Fiber Orientation
HM-20 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-20 Grade II	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-30 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-60 Grade I	Shanghai Horse Construction	CFRP sheet	Unidirectional
HM-1.2T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional
HM-1.4T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional
HM-2.0T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional
HM-3.0T	Shanghai Horse Construction	Pre-cured CFRP plate	Unidirectional

Table 1. Specimen Description

Specimens were labeled as HM20I-# for HM-20 Grade I, HM20II-# for HM-20 Grade II, HM30I-# for HM-30 Grade I, HM60I-# for HM-60 Grade I, HM1.2T-# for HM-1.2T, HM1.4T-# for HM-1.4T, HM2.0T-# for HM-2.0T and HM3.0T-# for HM-3.0T.

For HM-20 Grade I and HM-20 Grade II sheet specimens, each specimen was made of three layers of dry fiber with HM180C3P impregnated adhesive. For HM-30 Grade I sheet specimens, each specimen was made of two layers of dry fiber with HM180C3P impregnated adhesive. For HM-60 Grade I sheet specimens, each specimen was made of one layer of dry fiber with HM180C3P impregnated adhesive.

Typical flat specimen are used in this test. All CFRP sheet specimens were manufactured with three layers of dry fiber sheets, geometry of tested specimens are summarized in Table 2. Dimension for each specimen is summarized in Appendix A.

Product name	Average Width (mm)	Average Thickness (mm)	Average Length (mm)	Test Span (mm)
HM-20 Grade I	12.96	1.09	60.35	32
HM-20 Grade II	12.59	1.09	60.18	32
HM-30 Grade I	12.81	1.13	59.95	32
HM-60 Grade I	12.87	1.09	59.89	32
HM-1.2T	13.06	1.23	72.15	40
HM-1.4T	12.99	1.40	84.12	45
HM-2.0T	13.04	1.99	120.13	64
HM-3.0T	13.00	3.01	180.29	96

Table 2. Specimen dimensions

Apparatus

A 30 kN MTS testing machine (Model: E45) was used to conduct this test.

5.0 mm diameter loading nose and supports was used in this test.

Test Procedure

Tests were conducted under a temperature of 23°±3°C.

The span length was adjusted with a span to depth ratio 32:1 for all specimens as shown in Table 2.

Procedure A, which is a three point bending test was adapted to test the specimens. All specimens were loaded at a rate of crosshead movement of 1.0 mm/min until failure.

Load versus crosshead displacement data throughout the test method, maximum load, final load, and load at any obvious discontinuities in load-displacement data were recorded at a rate of 20 Hz.

Test Results

Five specimens were tested for each type of product. Flexural strength is calculated according to Eq. 1.

$$\sigma_f = \frac{3PL}{2bd^2} \quad \text{Eq.1}$$

Where σ_f is flexural strength; P is the maximum load, L is span length; b is width of specimen; d is the depth of specimen. Test results are summarized in Table 3.

Product name	Flexural Strength (MPa)		Coefficient of variation (%)
	Mean	Standard deviation	
HM-20 Grade I	989.29	46.88	4.74
HM-20 Grade II	824.56	71.12	6.85
HM-30 Grade I	921.94	86.29	9.36
HM-60 Grade I	1044.15	51.15	7.77
HM-1.2T	2164.48	124.13	5.74
HM-1.4T	2122.02	79.30	3.74
HM-2.0T	1764.83	20.84	1.18
HM-3.0T	1572.65	8.43	0.54

Table 3. Flexural Strength

Failure mode and Maximum flexural stress for each specimen are summarized in Appendix B.

Appendix A. Dimension of Each Specimen.

Name	Width (mm)	Thickness(mm)	Length (mm)
HM20I-1	12.94	1.09	60.01
HM20I-2	13.16	1.10	60.02
HM20I-3	13.19	1.09	59.87
HM20I-4	12.87	1.09	61.54
HM20I-5	12.62	1.07	60.30
HM20II-1	12.56	1.07	60.14
HM20II-2	12.86	1.07	59.36
HM20II-3	12.22	1.13	60.51
HM20II-4	12.73	1.10	60.54
HM20II-5	12.57	1.09	60.35
HM30I-1	12.53	1.12	60.54
HM30I-2	12.77	1.13	59.58
HM30I-3	12.80	1.13	58.78
HM30I-4	13.05	1.21	60.55
HM30I-5	12.93	1.05	60.32
HM60I-1	12.97	1.08	60.45
HM60I-2	12.68	1.09	60.33
HM60I-3	12.72	1.11	60.71
HM60I-4	12.84	1.11	58.64
HM60I-5	13.14	1.07	59.32
HM1.2T-1	13.04	1.22	72.56
HM1.2T-2	13.05	1.22	72.14
HM1.2T-3	13.07	1.22	72.36
HM1.2T-4	13.08	1.26	71.68
HM1.2T-5	13.06	1.21	72.00
HM1.4T-1	12.95	1.40	84.33
HM1.4T-2	13.01	1.41	83.65
HM1.4T-3	12.97	1.38	83.97
HM1.4T-4	13.03	1.38	84.56
HM1.4T-5	13.02	1.40	84.11
HM2.0T-1	13.03	1.98	120.14
HM2.0T-2	13.03	1.99	121.31
HM2.0T-3	13.09	1.99	119.65
HM2.0T-4	13.00	1.99	118.97
HM2.0T-5	13.04	1.99	120.60
HM3.0T-1	13.00	3.02	180.56
HM3.0T-2	13.00	3.01	180.33
HM3.0T-3	13.03	3.01	180.54
HM3.0T-4	12.96	3.00	179.88

HM3.0T-5	13.01	3.02	180.16

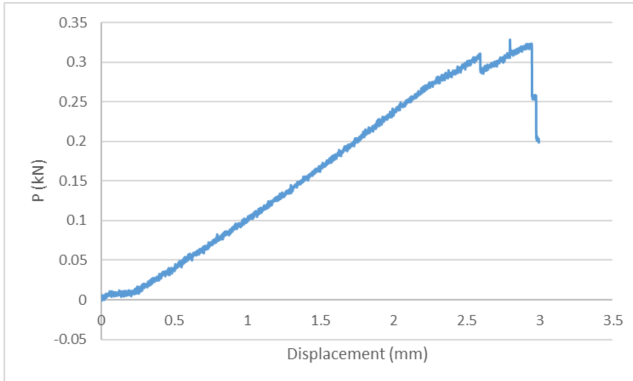
Appendix B. Failure Mode and Maximum Load.

Name	Maximum Flexural Strength (MPa)	Failure Mode	Failure Part	Failure Location
HM20I-1	1019.03	C/B	A	T
HM20I-2	915.88	C/B	A	T
HM20I-3	969.67	C/B	A	T
HM20I-4	1012.24	C/B	A	T
HM20I-5	1029.37	C/B	A	T
HM20II-1	993.40	C/B	A	T
HM20II-2	1097.65	C/B	A	T
HM20II-3	1010.56	C/B	A	T
HM20II-4	960.74	C/B	A	T
HM20II-5	1127.24	C/B	A	T
HM30I-1	993.91	C/B	A	T
HM30I-2	1006.20	C/B	A	T
HM30I-3	901.35	C/B	A	T
HM30I-4	791.36	C/B	A	T
HM30I-5	916.87	C/B	A	T
HM60I-1	1125.59	C/B	A	T
HM60I-2	1109.62	C/B	A	T
HM60I-3	1069.27	C/B	A	T
HM60I-4	958.72	C/B	A	T
HM60I-5	957.57	C/B	A	T
HM1.2T-1	2156.62	C/B	A	T
HM1.2T-2	2310.23	C/B	A	T
HM1.2T-3	2038.51	C/B	A	T
HM1.2T-4	2048.10	C/B	A	T
HM1.2T-5	2268.97	C/B	A	T
HM1.4T-1	2091.79	C/B	A	T
HM1.4T-2	2250.66	C/B	A	T
HM1.4T-3	2090.99	C/B	A	T
HM1.4T-4	2135.57	C/B	A	T
HM1.4T-5	2041.11	C/B	A	T
HM2.0T-1	1754.67	C/B	A	T
HM2.0T-2	1791.80	C/B	A	T
HM2.0T-3	1738.18	C/B	A	T
HM2.0T-4	1761.13	C/B	A	T
HM2.0T-5	1778.37	C/B	A	T
HM3.0T-1	1571.69	C/B	A	T
HM3.0T-2	1566.60	C/B	A	T
HM3.0T-3	1575.14	C/B	A	T
HM3.0T-4	1564.18	C/B	A	T

HM3.0T-5	1585.65	C/B	A	T

Note: C is compression; B is buckling; A is at loading nose; T is top.

Appendix C. Load Deflection Curves.



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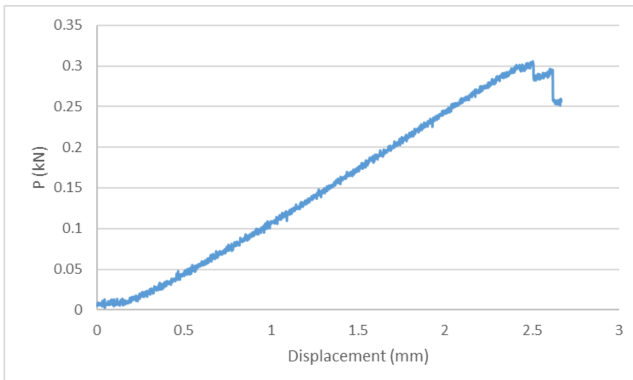

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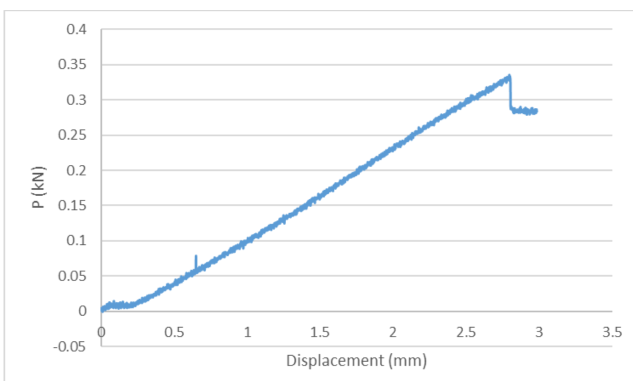

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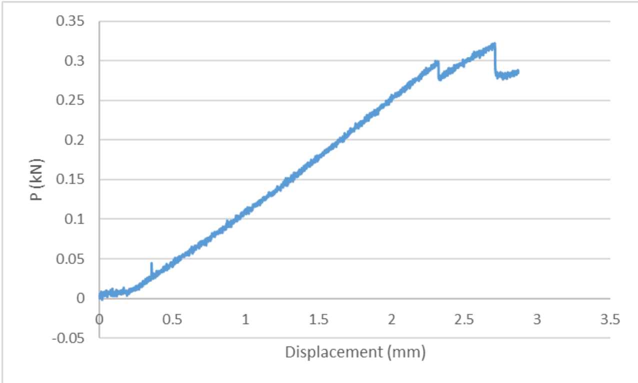

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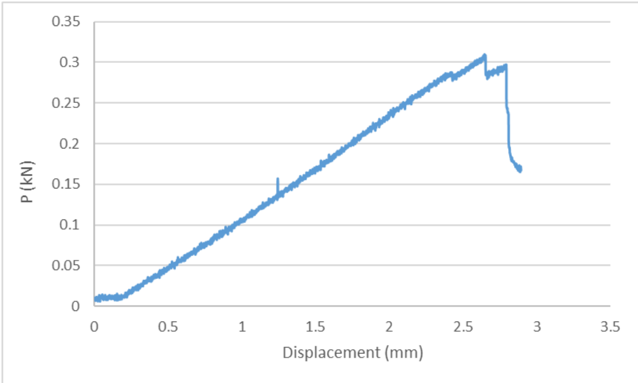

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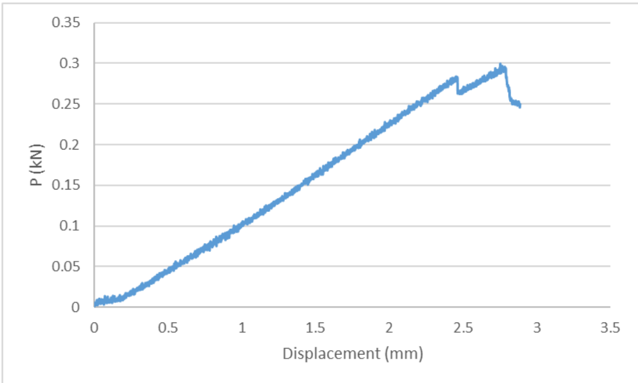

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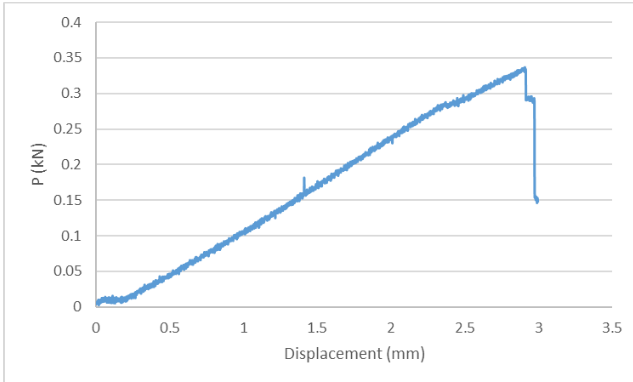

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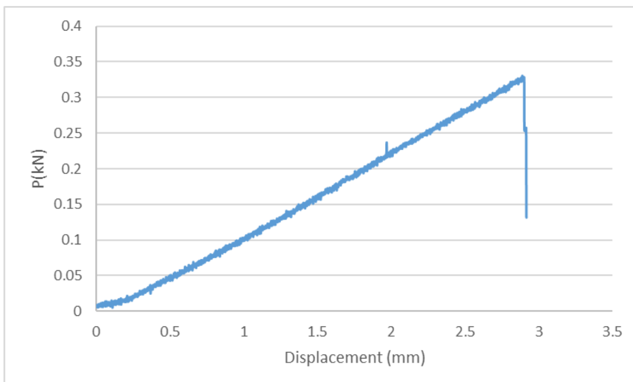

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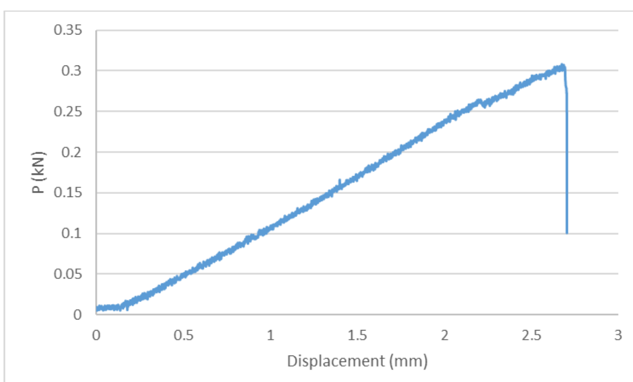

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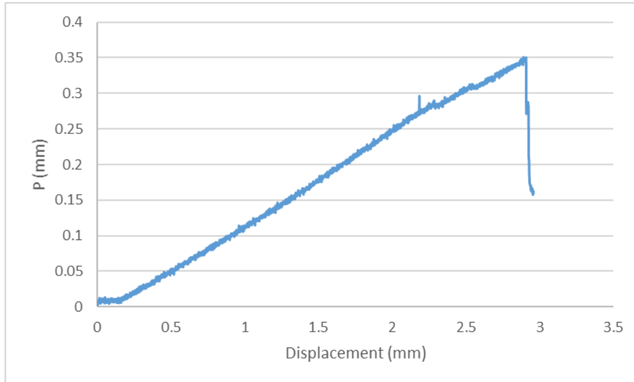

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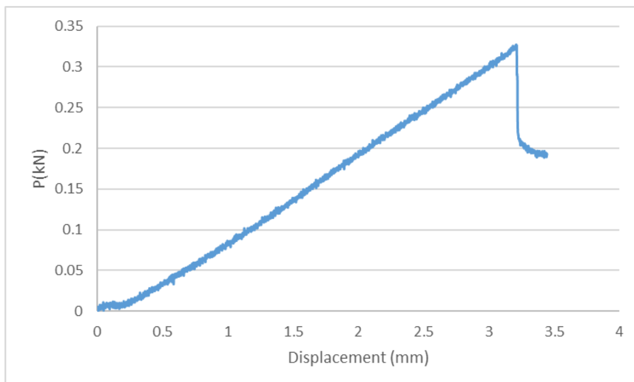

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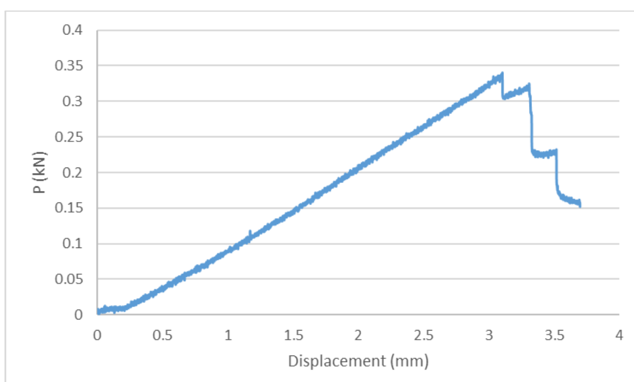

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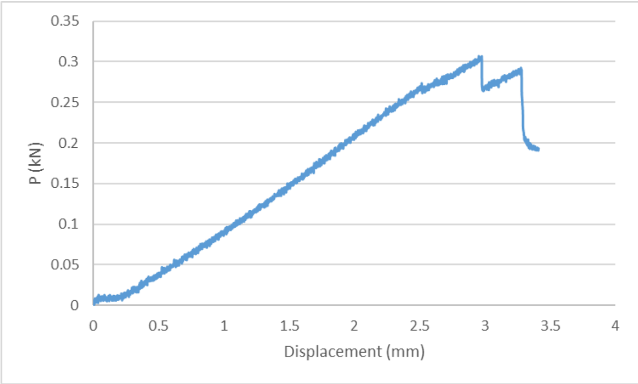

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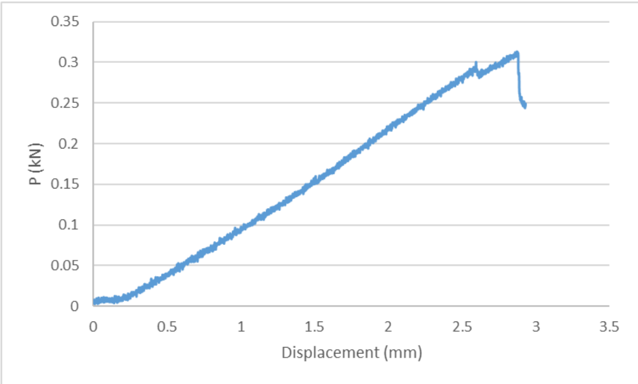

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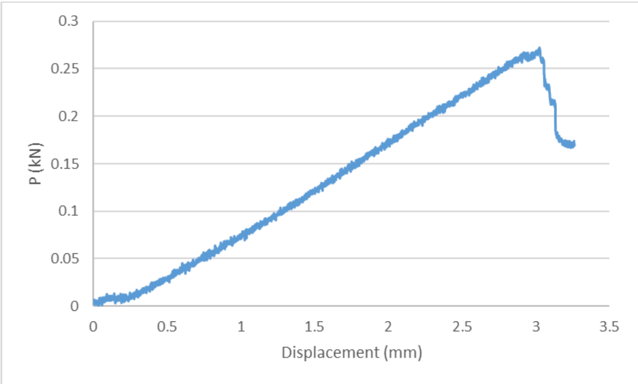

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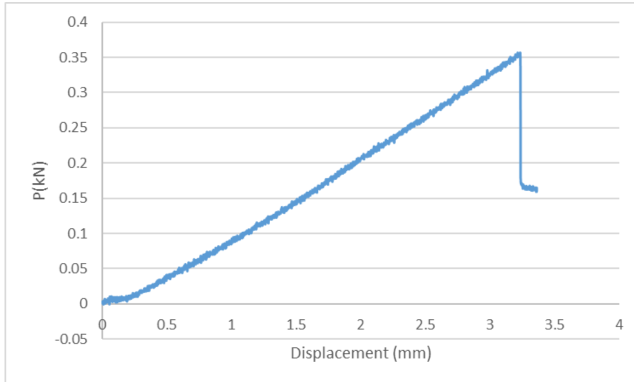

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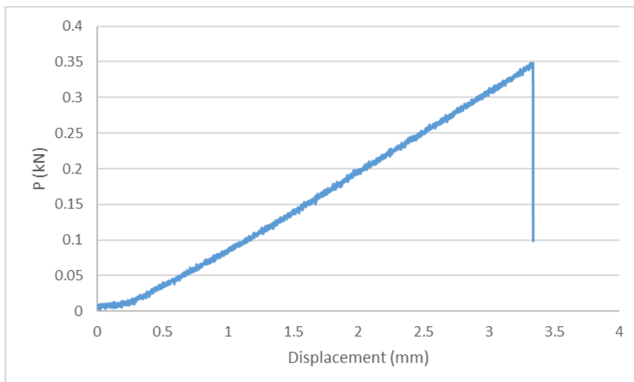

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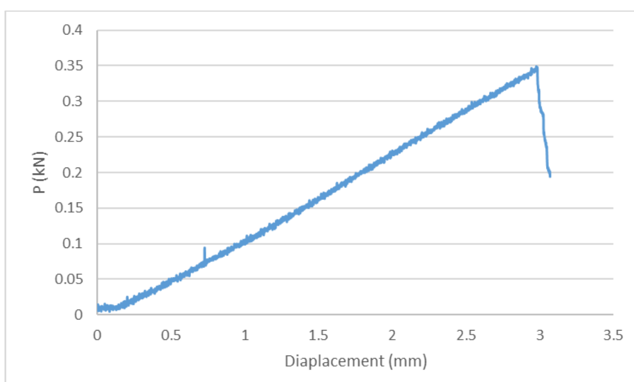

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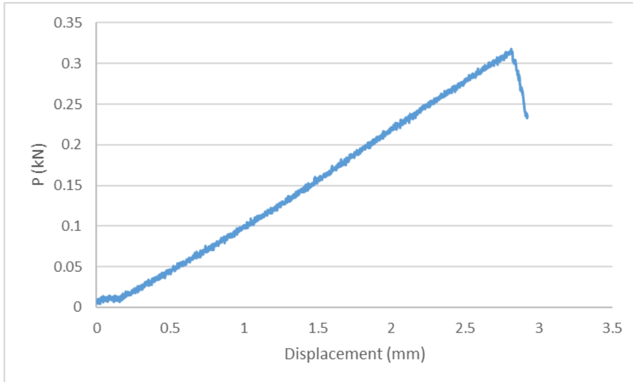

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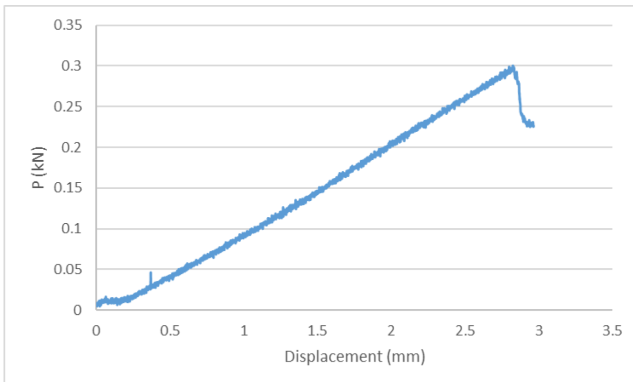

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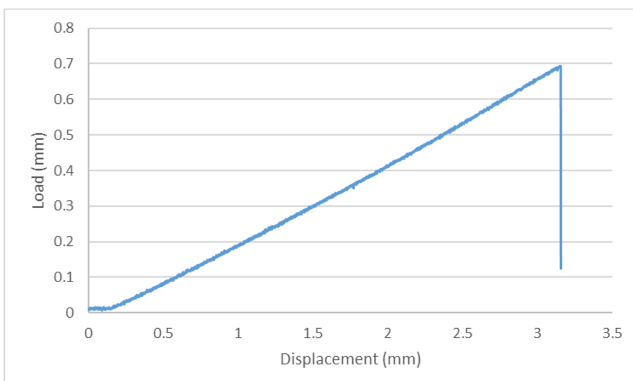

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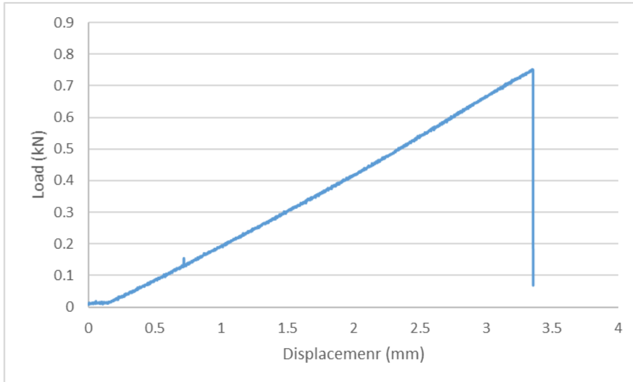

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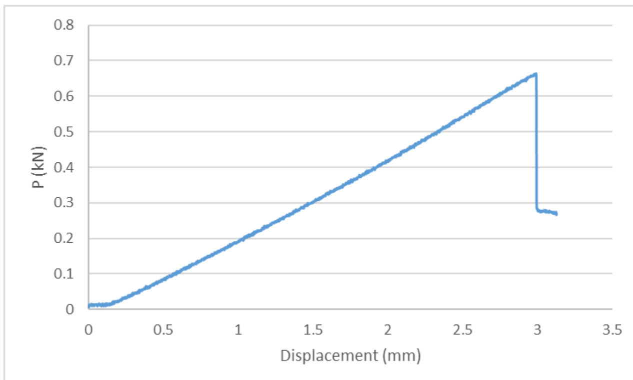

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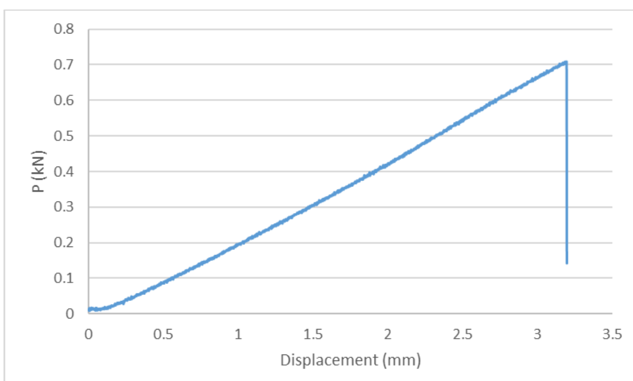

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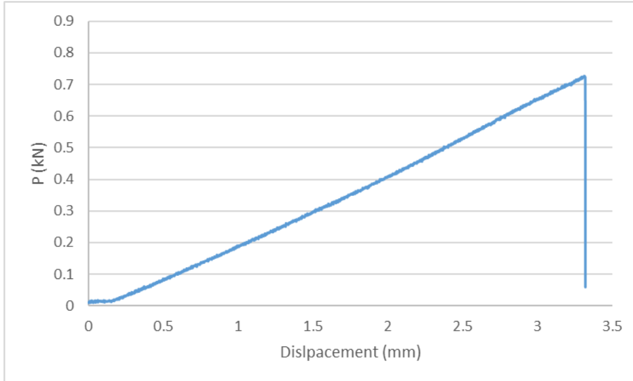

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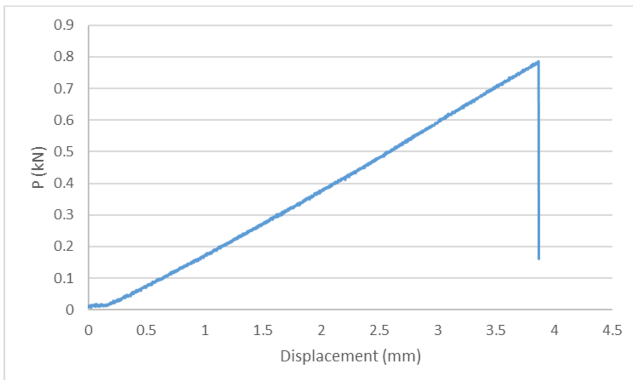

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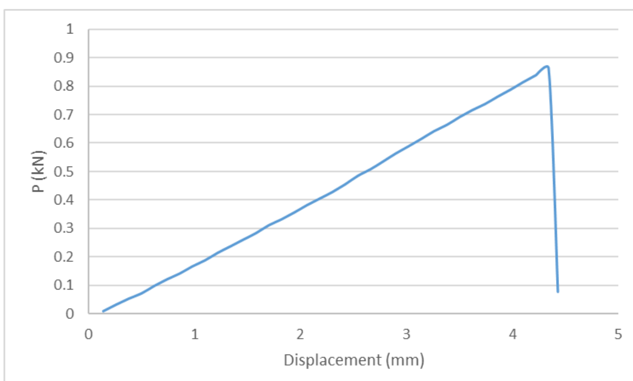

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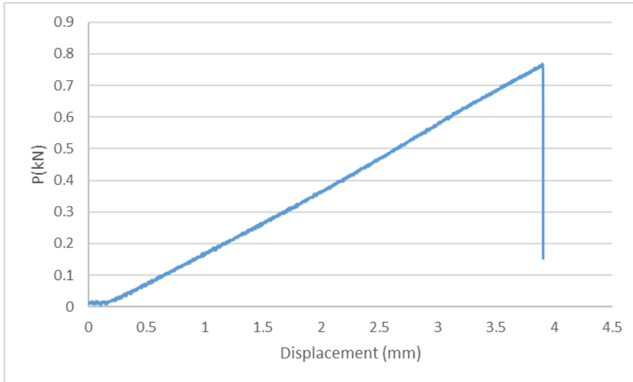

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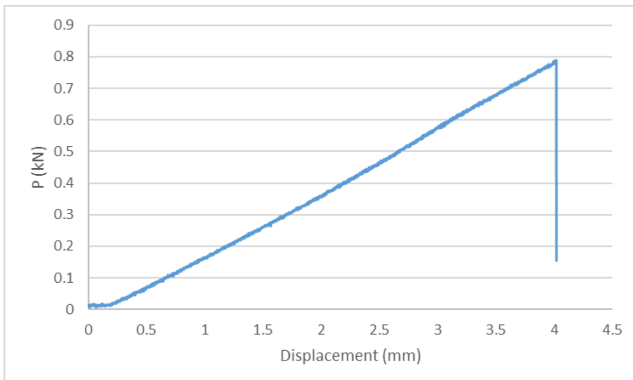

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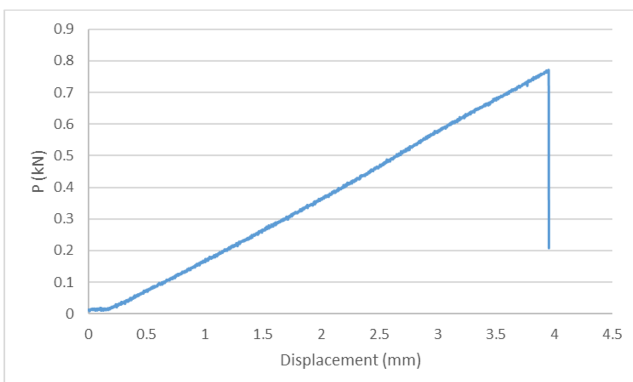

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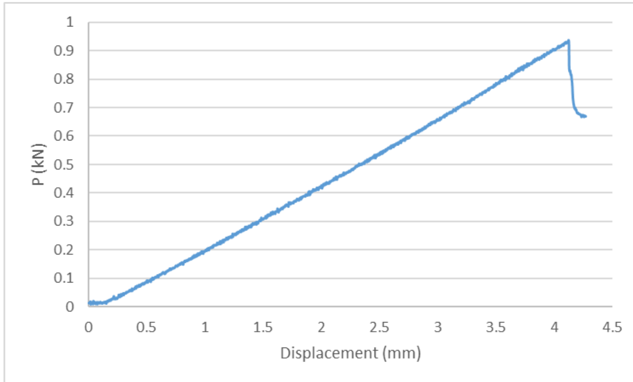

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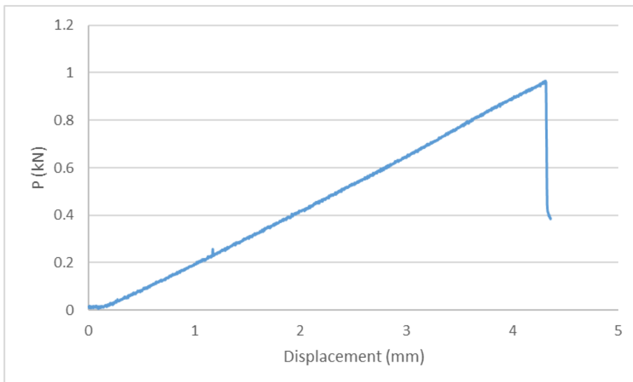

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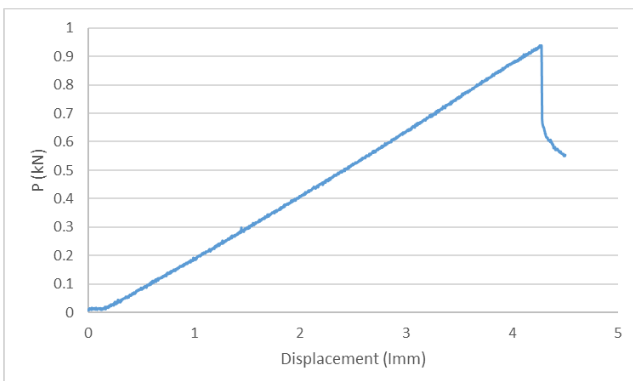

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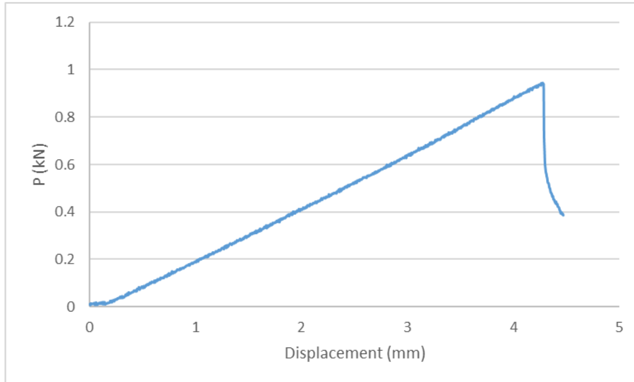

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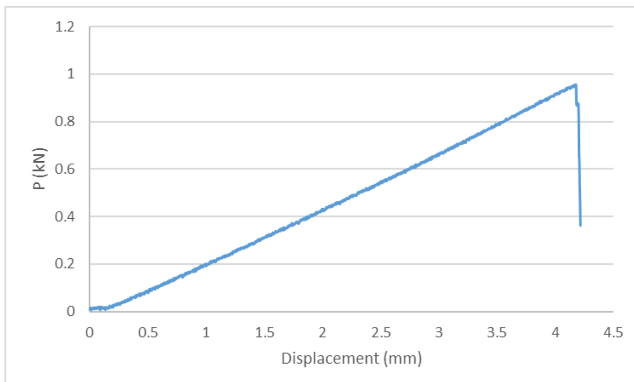

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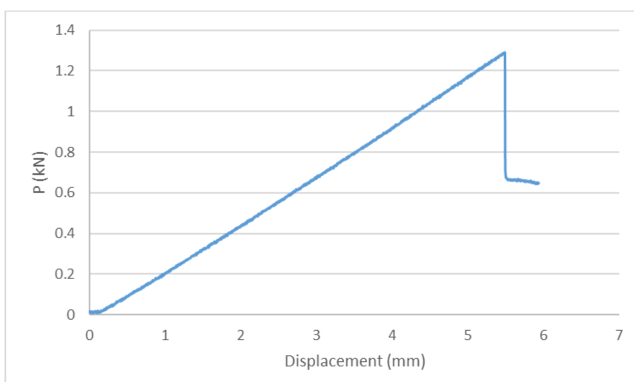

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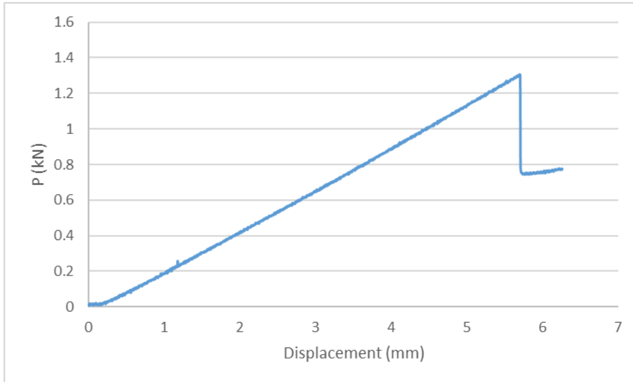

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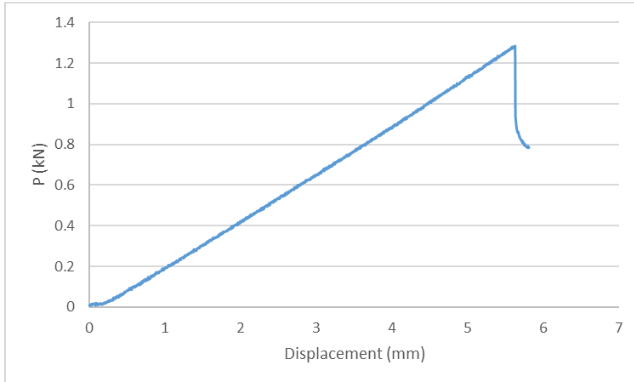

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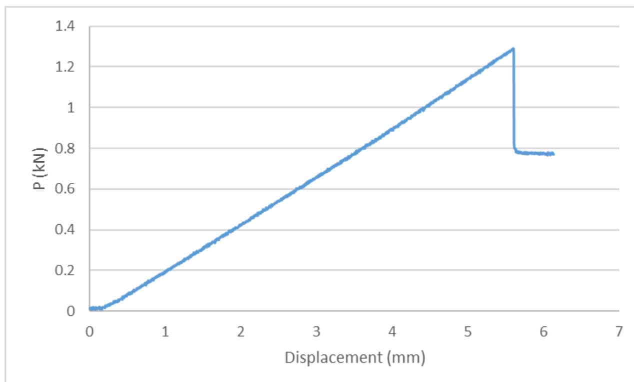

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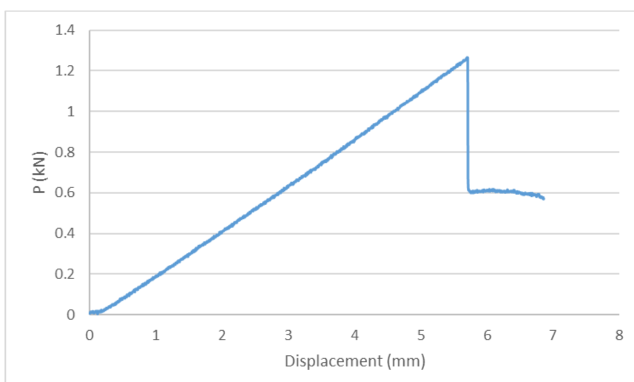

HM3.0T-4

TEST REPORT

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