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Analysis of GFRP Composite I-Beam Subjected to Pulling Load

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Abstract: *This paper presents a Finite Element Analysis of Adhesively bonded GFRP I-Beam in Pulling load which changes damage occurs, due to alterations in Adhesives used. The use of adhesive bonding in advanced composite structures has potential to reduce weight as compared to mechanical fasteners. Three tests were carried out for each composite I-beams with three Adhesives. The three adhesives used have different properties and they are used as per their data sheet and processing given by their respective companies.*
The result of the analysis work of these three beams are presented and next step of this work is experimental which will validate FEA result.

Key words*:* *GFRP, I-Beam, Adhesives, FEA.*

INTRODUCTION

An I-beam, also known as H-beam-beam, Universal Beam, Rolled Steel Joist, or double-T with an I- or H-shaped cross-section. The horizontal elements of the I beam are known as flanges, while the vertical element is termed the web. I-beams are usually made of structural steel and are used in construction and civil engineering. I-beams are widely used in the construction industry and are available in a variety of standard sizes. I-beams may be used both as beams and as columns. It has been observed that when a column or a strut is subjected to a compressive load and the load is gradually increased, a stage will reach when the column will be subjected to ultimate load. Beyond this, the column will fail by crushing and the load will be known as crushing load. It has also been experienced, that sometimes, a compression member does not fail entirely by crushing, but also by bending i.e. buckling. This happens in the case of long columns. K. D. Potter et. al. [1] have studied the use of adhesive bonding in advanced composite structures which offers the potential for considerable weight and cost saving compared to the use of mechanical fasteners. Y.A. Khalid et.al. [2] Made an experimental and finite-element analyses for glass/epoxy composite I- beams have been carried out. Four, six, eight and ten layers of woven fabric glass/epoxy composite I-beams were fabricated by a hand lay-up (molding) process. G. Vasdravellis et.al. [3] Investigated the ultimate strength of composite beams under the combined effects of axial tension and negative (hogging) bending moment. Ultimate failure modes were identified and the resulting interaction diagrams were compared to the results of sectional rigid

plastic analysis. N.S. Trahairt [4] The resistances of steel I-section monorail beams to lateral buckling are difficult to assess because monorails are often not well restrained against twisting. R. Morishima et.al. [5] Presented the failure mechanism and alternative design of composite sandwich T-joints subjected to pulling load. Luciano Feo et.al. [6] presented experimental and numerical results of the first phase of a multi-phase comprehensive joint research program between University of Salerno, Italy, and the University of California, Irvine, USA, on investigating one of the major structural issues that defines the strength limit-state of pultruded fiber-reinforced polymer (PFRP) profiles.

Table – 1: Selected Dimensions Of I-Beam For The FEA.

Type	Beam Height (mm)	Flange Width (mm)	Web thickness (mm)	Flange Thickness (mm)
ISMB 80	80	50	5.0	5.0

2. FACTORS TO CONSIDER WHEN SELECTING THE OPTIMUM MATERIAL FOR I-BEAM PROJECT

Elastic Deformation, Tensile Strength, Operating Temperature, Operating Environment, Corrosion Resistance, Electric Conductivity & Cost.

Table – 2: Properties of Typical Fiber-Reinforcement Materials.

Fiber Property	Glass Fibers
Diameter (μm)	8-14
Density (kg/m3)	2560
Longitudinal Modulus of Elasticity (GPa)	76
Transverse Modulus of Elasticity (GPa)	76
Tensile Strength (GPa)	1.4-2.5
Elongation at Fracture (%)	1.8-3.3

Table – 3: Mechanical Properties of Typical Matrix Materials.

Matrix Property	Epoxy
Density (kg/m3)	1100-1400
Modulus of Elasticity (GPa)	3-6
Tensile Strength (GPa)	0.035-0.10
Compressive Strength (GPa)	0.1-0.2
Elongation at Fracture (%)	1-6

3. MATRIX (ADHESIVE) USED FOR FEA WORK.

Three different adhesives are used to prepare three different I-Beam components, these three adhesives and their properties are given below.

1) Araldite Instant
2) Araldite 2015
3) 3M Fastbond Contact Adhesive 30-NF, Neutral

Table – 4: Product data of Araldite Instant.

Property	Araldite Instant /Resin	Araldite Instant / Hardener	Araldite Instant /mixed
Colour (visual)	transparent	pale yellow	pale yellow
Specific gravity	1.15 – 1.2	1.1 – 1.2	ca. 1.2
Viscosity at 25°C	50 – 75	10 - 20	30 - 50

Table - 5: Processing of Araldite Instant.

Mix ratio	Parts by weight	Parts by volume
Araldite Instant / Resin	100	100
Araldite Instant / Hardener	100	100

3.1 Typical cured properties For Araldite 2015

Cured for 16 hours at 40°C and tested at 23°C. Pre-treatment: plastics abraded and degreased, metals sandblasted and degreased.

Table – 5: Product Data of Araldite 2015

Property	2015 A	2015 B	Mixed Adhesive
Colour (Visual)	Neutral Paste	Neutral Paste	Neutral Paste
Specific Gravity	1.4	1.4	1.4
Viscosity At 25°C	Thixotropic	Thixotropic	Thixotropic

Table – 6: Processing of Araldite 2015.

Mix ratio	Parts by weight	Parts by volume
Araldite 2015/A	100	100
Araldite 2015/B	100	100

3.2 Typical cured properties For 3M Fastbond Contact Adhesiv

Cured for 16 hours at 40°C and tested at 23°c.

Table -7: Product Data of 3M Fastbond Contact Adhesive

Boiling point	>=64 ºC
Density	1.1 g/ml
Vapour Density	1.1 [Ref Std: AIR=1]
Vapour Pressure	<=38 mmHg [at 68 ºF]
Specific Gravity	1.1 [Ref Std: WATER=1]
pH	10 - 11
Solubility in Water	Complete
Evaporation rate	1.0 [Ref Std: ETHER=1]
Hazardous Air Pollutants	<=4.7 % weight
Volatile Organic Compounds	37 g/l
Percent volatile	45 - 55 % weight
VOC Less H2O & Exempt Solvents	37 g/l
VOC Less H2O & Exempt Solvents	0.31 lb/gal
VOC Less H2O & Exempt Solvents	3.4 %
Viscosity	200 - 750 centipoise [at 73.4 ºF]

4. FEA OF COMPOSITE I-BEAM WITH DIFFERENT ADHESIVES

4.1 FEA of 1st I-Beam Specimen with 3M Fastbond Contact Adhesive

By using this adhesive when we done FEA of 1st I-Beam component we got following graph of time Vs force capacity shown in Chart-1. In the graph time is taken on x-axis and force capacity is taken on y-axis. This component have taken max force of 75.002 N.

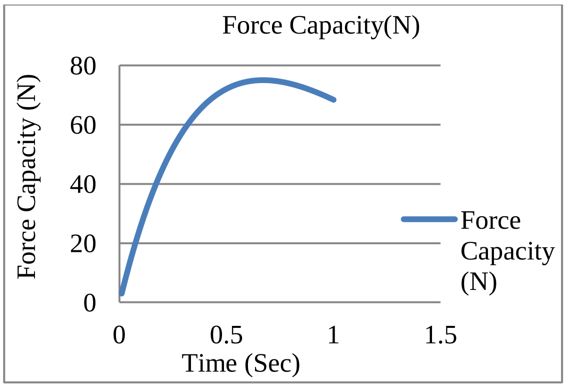

Chart -1: Force capacity of I-Beam with 3M Fastbond Adhesive.

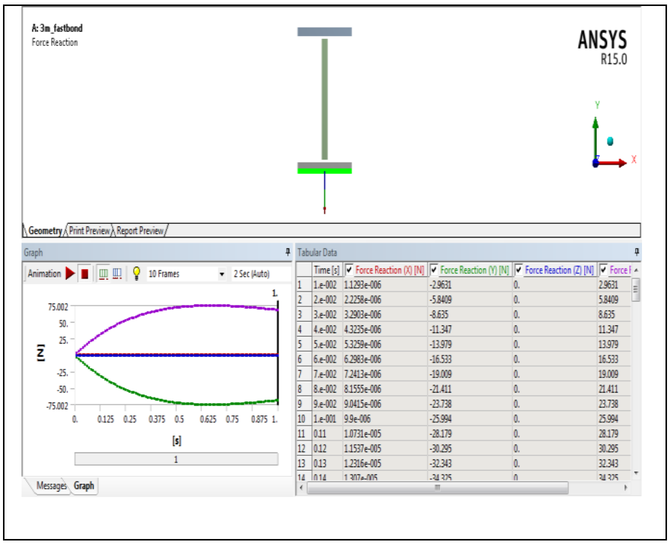

Fig – 1: Force Reaction of I-Beam with 3M Fast bond Adhesive.

Above fig.1 Shows force reaction, Upper flange of beam is fixed and pulling load is applied on lower flange, as load increases with time one step reached where the beam taken 75.002 N load and failed.

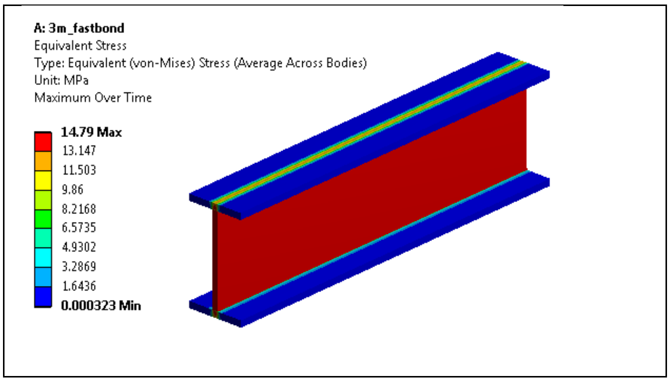

Fig - 2: Equivalent Stress of I-Beam with 3M Fastbond Adhesive.

In above fig.2, It is clear that maximum equivalent stress across the body of this beam is 14.79 MPa.

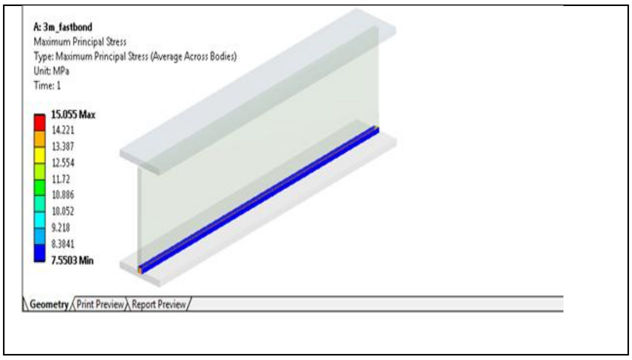

Fig – 3: Max Principal Stress of I-Beam with 3M fast bond Adhesive.

Maximum principal stress at the bonding area of flange and web junction is 15.005 MPa and it can be seen in above fig.3.

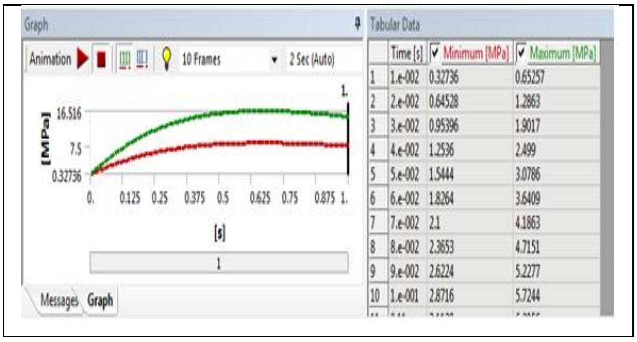

Chart – 2: Time Vs Stress for 3M Fastbond Adhesive.

The graph of Time Vs Stress for 1st I-Beam specimen is shown above Chart -2 which clearly indicates as time increases stress on junction point increases and it takes 15.055 Mpa stress and this specimen fails.

4.2 FEA of 2nd I-Beam Specimen With Araldite Instant Adhesive

By using this adhesive when we done FEA of 2nd I-Beam component we got following graph of time Vs force capacity shown in Chart -3. In the graph time is taken on x-axis and force capacity is taken on y-axis. This component have taken maximum force of 82.437 N

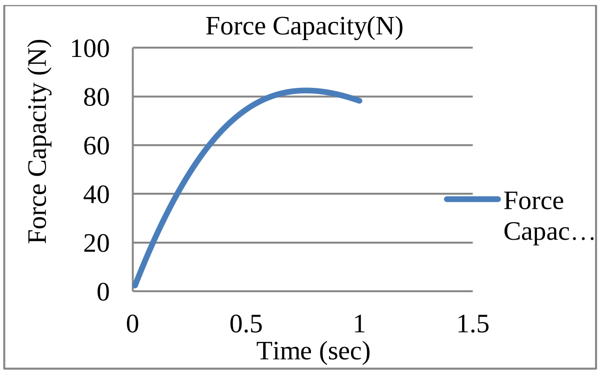

Chart – 3: Force capacity of I-Beam with Araldite Instant Adhesive.

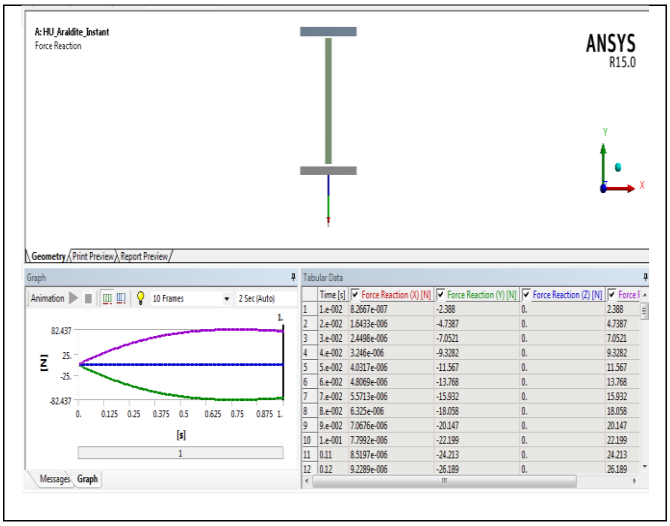

Fig – 4: Force Reaction of I-Beam with Araldite Instant Adhesive

Above fig – 4: Shows force reaction, Upper flange of beam is fixed and pulling load is applied on lower flange, as load increases with time one step reached where the beam taken 82.437 N load and failed.

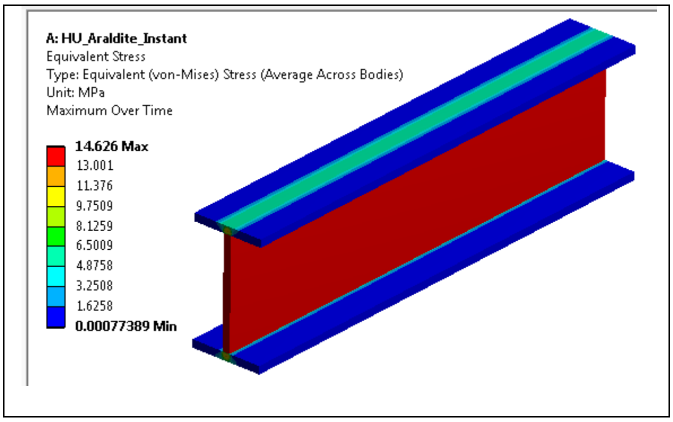

Fig – 5: Equivalent Stress of I-Beam with Araldite Instant Adhesive.

In above fig -5 It is clear that max equivalent stress across the body of this beam is 14.626 Mpa.

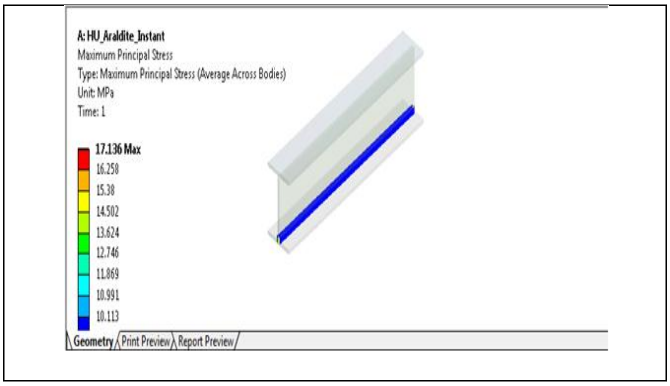

Fig -6: Max Principal Stress of I-Beam with Araldite Instant Adhesive.

Max principal stress at the bonding area of flange and web junction is 17.136 MPa and it can be seen in above fig – 6.

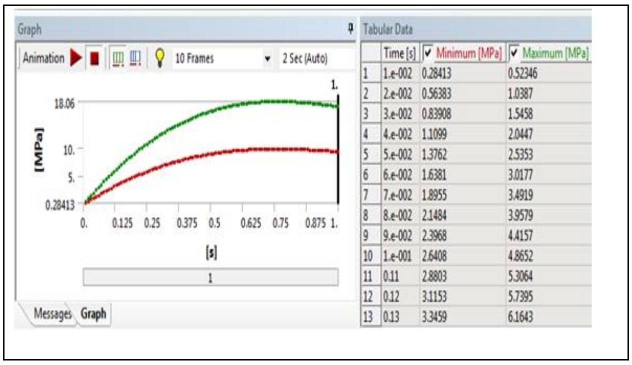

Chart – 3 Time Vs Stress for Araldite Instant Adhesive.

The graph of Time Vs Stress for 2nd I-Beam specimen is shown above chart -3 which clearly indicates as time increases stress on junction point increases and it takes 17.136 Mpa stress and fails.

4.3 FEA of 3rd I-Beam Specimen with Araldite 2015 Adhesive

By using this adhesive when we solved FEA of 3rd I-Beam component we got following graph of time Vs force capacity shown in Chart-4 In the graph time is taken on x-axis and force capacity is taken on y-axis. This component have taken max force of 90.005 N.

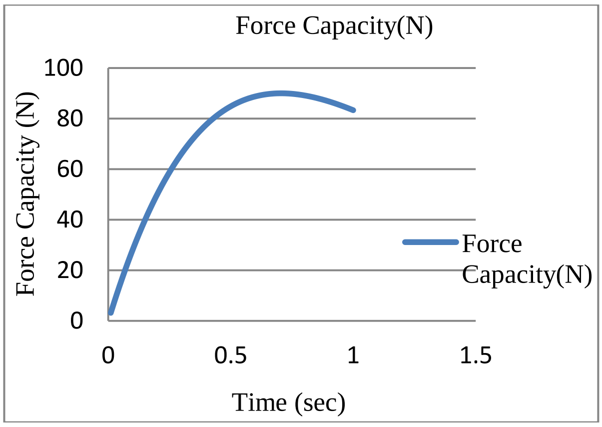

Chart – 4: Force capacity of I-Beam with Araldite 2015 Adhesive.

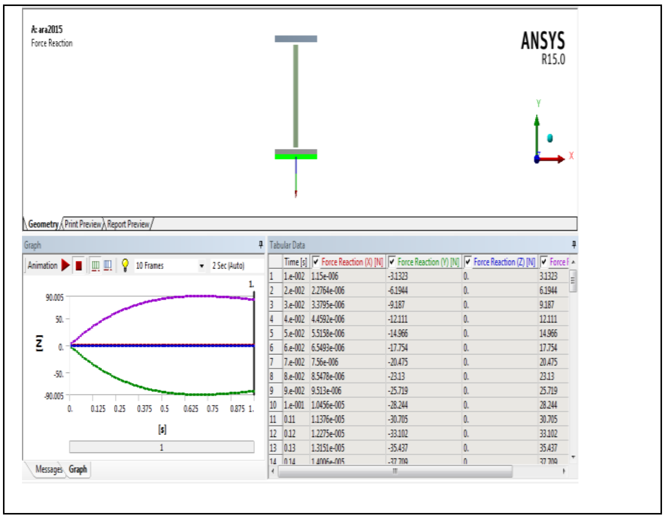

Fig – 7: Force Reaction of I-Beam with Araldite 2015 Adhesive.

Above fig -7 Shows force reaction, Upper flange of beam is fixed and pulling load is applied on lower flange, as load increases with time one step reached where the beam taken 90.005 N load and failed.

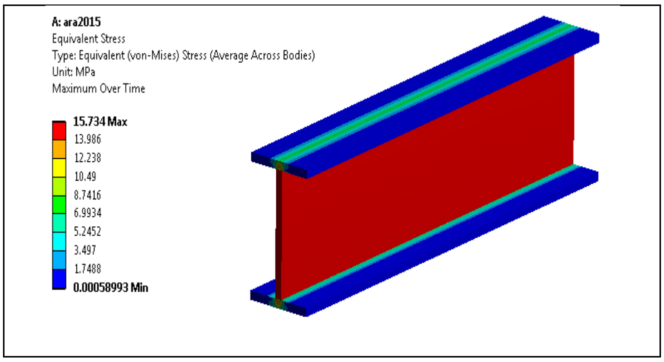

Fig – 8: Equivalent Stress of I-Beam with Araldite 2015 Adhesive.

In above fig.-8 It is clear that max equivalent stress across the body of this beam is 15.734 Mpa.

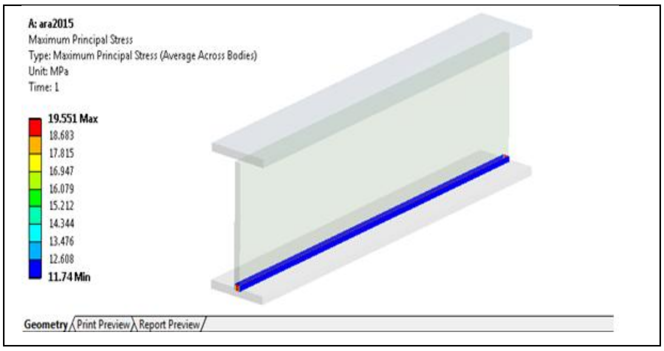

Fig – 9: Max Principal Stress of I-Beam with Araldite 2015 Adhesive.

Max principal stress at the bonding area of flange and web junction of 3rd specimen is 19.551 MPa and it can be seen in above fig-9.

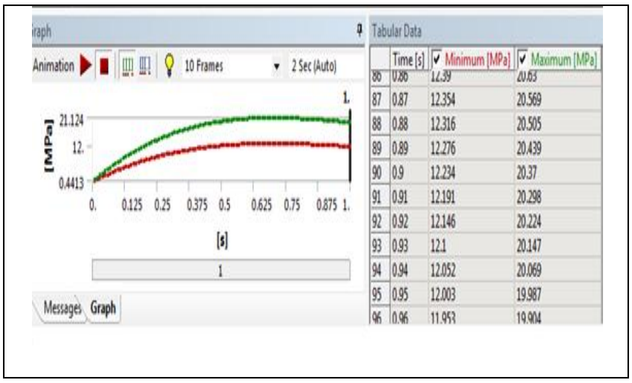

Chart – 5: Time Vs Stress For Araldite 2015.

The graph of Time Vs Stress for 3rd I-Beam specimen is shown above in Chart-5 which clearly indicate as time increases stress on junction point increases and it takes 19.551 Mpa stress and fails.

5. RESULT AND DISCUSSION

Table -8: Max Principal Stress Sustained by I-Beams

Sr.No.	I-Beam With Adhesive	Time(S)	Stress (Mpa)
1	3M fastbond	0.67	15.055
2	Araldite Instant	0.77	17.136
3	Araldite 2015	0.71	19.551

From above result table-8 it is observed that, I-Beam with Araldite 2015 has taken max stress as compared to 3M Fastbond and Araldite Instant.

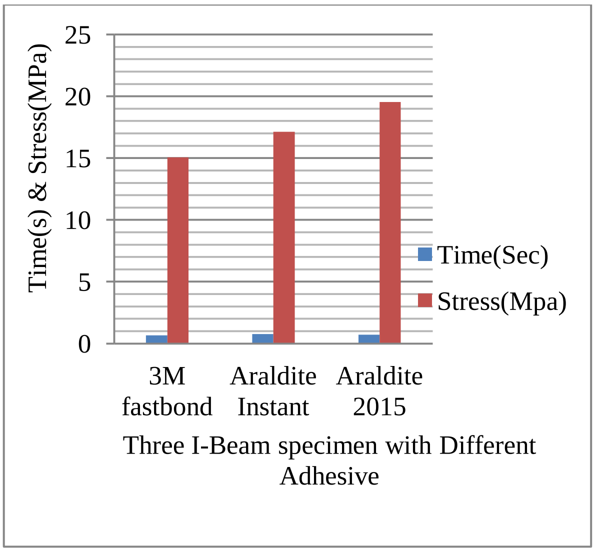

Chart 6- Graph of Adhesives Vs Time & Stress.

In above plotted Chart - 6, Three I-Beam specimen are taken on x-axis, time and stress are taken on y-axis, it is clear that 3rd I-Beam specimen with Araldite 2015 adhesive has taken maximum stress 19.551 MPa.

Table – 9: Maximum Force carrying capacity of I-Beams Specimens.

Sr.No.	I-Beam With Adhesive	Time(S)	Force (N)
1	3M Fastbond	0.67	75.002
2	Araldite Instant	0.77	82.437
3	Araldite 2015	0.71	90.005

It is observed from above result table - 9, I-Beam with Araldite 2015 has maximum force carrying capacity as compared to 3M Fastbond and Araldite Instant specimen

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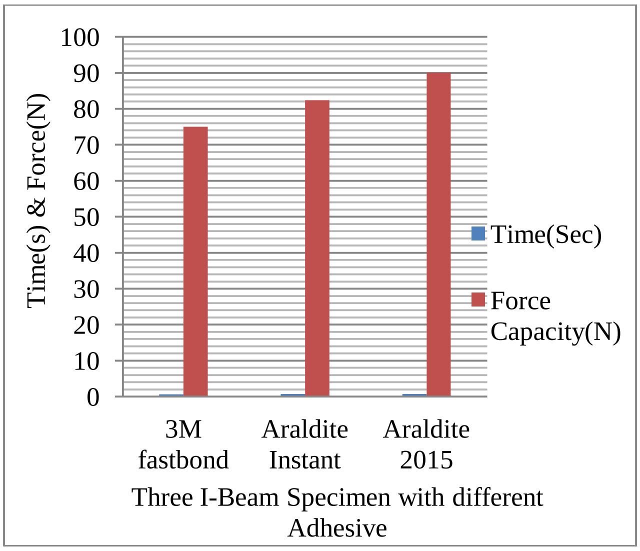

Chart 7- Graph of Adhesives Vs Time & Force.

In above plotted Chart -7, Three I-Beam specimen are taken on x-axis, time and force capacity are taken on y-axis, it is clear that 3rd I-Beam specimen with Araldite 2015 adhesive has taken maximum force as compared to 3M Fastbond and Araldite Instant specimen.

6. CONCLUSION

It is seen from the FEA, GFRP I-Beam with 3M Fastbond adhesive have less force carrying capacity i.e 75.002 N, but GFRP I-Beam with Araldite Instant as a adhesive has taken force of 82.437 N which is more than 3M Fastbond and GFRP I-Beam with Araldite 2015 have highest force carrying capacity of 90.005 N as compared to 3M Fastbond and Araldite Instant.

The maximum principal stress for 1st specimen is 15.005 MPa, 2nd specimen has offered, maximum principal stress 17.136 MPa, but 3rd specimen has offered maximum principal stress of 19.551 MPa. The next step of present work is to validate FEA result with experimental work.

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