# EXPERIMENTAL STUDY ON FLEXURAL STRENGTH OF RCC BEAM BY USING GFRP

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*Abstract : Steel widely used as reinforcement material in construction industry. But, steel fails to perform structurally when it exposed to harsh environment such as bridges, chemical plants and other structures. This has been already tested on GFRP bars many techniques to prevent corrosion of steel reinforcement. When tor steel bars are replaced by GFRP bars to reinforce composite beams, brittle failure of GFRP bars caused due lack of ductility of beam members. Due to lack of ductility of conventional beam both stiffness and ultimate load were reduced significantly. Therefore for overcoming these effects we introduced GFRP I-section beam and C-Channel section in conventional beam.*

*Pultruded GFRP I-section beam and C-Channel section are usually made by pultrusion process. In pultrusion process, materials such as fiberglass & resin are pulling by extrusion process. In this experimental study on flexural behavior, failure pattern and deflection of a composite beam, which is reinforced with longitudinal tensile steel bars as well as glass fibre reinforced polymer (GFRP) pultruded I-section beam and C-Channel section encased in concrete. Six beam specimens, including one Conventional reinforced concrete (RC) beam, GFRP I-beam in center and GFRP I-beam bottom, GFRP C-channel in center and GFRP C-channel bottom and GFRP I-beam is replaced by bottom steel bars, were cast and tested under two-point bending.*

*Result will use to analyze flexural strength of beam. The present project work aims for studying suitability of GFRP as strengthened material for rolled RC beam. So in this paper to flexural strength of RC beam strengthened with glass fiber reinforced polymer I-section beam and C-channel section. Also, check suitable position and pattern of pultruded GFRP member.*

***Keywords – GFRP I-Section, GFRP C-Channel, RCC composite Beams, Flexural strength.***

## I. INTRODUCTION

In previous works done on repair and strengthening of steel and RCC structures by use of FRP materials. An FRP structure generally consist raw materials such as glass roving, glass mad & surface veil, unstructured polyester (UP),Resin applied to mould in combination with steel reinforcement, most commonly glass fiber, to form a part which is rigid, highly durable & lightweight.

Due to low maintenance & lightweight, FRP is used in many applications building & infrastructure projects. To cast synthetic marble & solid surface for kitchens, bathrooms and roof tiles, UP resins can be mixed with glass fiber & fillers. FRP is more suitable option to conventional materials for huge projects like bridges, wind generators because it has advantages like lightweight, low maintenance & easy installation process.

Fiber Reinforced Polymer (FRP) is increasingly used in civil engineering construction in last two decades because of excellent properties of corrosion resistance as well as high strength & lightweight. Wide research has been conducted on to retrofit existing structures by using FRP

Whereas, FRP composites such as FRP bars and FRP pultruded profiles are also exploited as standard construction product for new construction. Due to advantages of convenient installation and customized cross-sections (e.g. I-beam, square tube or circular tube), application of FRP pultruded profiles it has been widely used in recent year). FRP pultruded profiles are suitable for use as all FRP structures such as building floor, cooling towers and offshore platforms. Moreover, it can be used in combination with other materials to develop composite structures. Lot of research were carried out on GFRP I-beam reinforce beam specimen, thus forming a composite structural member.

In order to improve the flexural strength of the composite beam reinforced with I-beam and C-channel, a type of composite beam is proposed in this study. The composite beam created by using I beam & longitudinal tensile steel bars, and those I beam is encased in concrete. The flexural strength and corrosion resistance of conventional beam members are increased by encased of GFRP I-beam or C-channel is contributed to improvement of to achieve enough bending, stiffness and ductility of composite beams use tensile steel bars in this composite beam. The concept of incorporating FRP and steel materials together to enhance ductility of structure has been proven to be effective by both experimental and numerical approaches. Steel stirrups are employed to confine the concrete and enhance the shear strength of beam members.

The advantages of this type of composite beams are apparent when compared with existing conventional beams. Compared with the conventional beam reinforced with composite beam with GFRP I-section, although configurations of both are similar, self-weight of the Pro-posed composite beam is decreased & the corrosion resistance capacity is increased due to existence of I-beam. In comparison of composite beam with GFRP I-beam, there are below advantages of composite beam:

- Due to surroundings concrete of I –beam fire performance can be improved
- Stability of the I-beam can be increased due to encased in concrete; and
- By using tensile steel bar ductility can be improved.

In type of composite beam also have significant advantages in practical applications, such as:

- All materials which are using that is standard which is without special treatment like drilling holes, riveting or welding
- Because of existence if steel bars inside, it is easy for connecting columns.

### 1.1 GFRP as a potential solution

Stainless steel bars are being introduced into newly constructed reinforced concrete bridges to help stop corrosion of newly built structures. Stainless steel is significantly more expensive than regular steel and it is not currently feasible to use it in all bridges that need to be built annually. The cost of stainless steel reinforcing bars can be estimated to be 5 to 6 times greater than a traditional carbon steel bar (Russell, 2004) which can roughly translate into an additional 10-15% of the initial capital costs of bridge. The costs of GFRP on other hand, are competitive depending on manufacturer. Research conducted by National Composites Network in Europe (Halliwell, 2002) has shown that GFRP reinforcing bars cost about half of what stainless steel costs. The cost of GFRP in recent years has been coming down primarily due to a larger market and competition.

The integration of GFRP into infrastructure has generally been delayed because of a lack of any set standards for manufacturing or design. That problem will change with new Canadian Standard CSA S807 which complements current RILEM and ACI standards in Europe and America. With a competitive marketplace, standards in place, pilot project bridges, and significant research and development: GFRP is emerging as a legitimate alternative to steel reinforcing. It is important then to fully evaluate GFRP in context of a primary reinforcing product, by looking at short and long-term structural and durability performance to determine its adequacy as internal reinforcement for concrete structures.

## II. METHODOLOGY

Pultrusion: Pultruded FRP sections are usually made by pultrusion process. By pulling raw material composite through a heated die, this process creates continuous composite profile. In pultrusion process extrusion is pulling of materials such as fibreglass and resin, through a shaping die.

Polyester, polyurethane and vinyl ester epoxy resins etc. are types of resin can be used in pultrusion including Fiber is wetted or impregnated with resin and is organized and then removed of excess resin. After that composite is passed through a heated steel die. Puller clamps also provided for pulling structural profile.

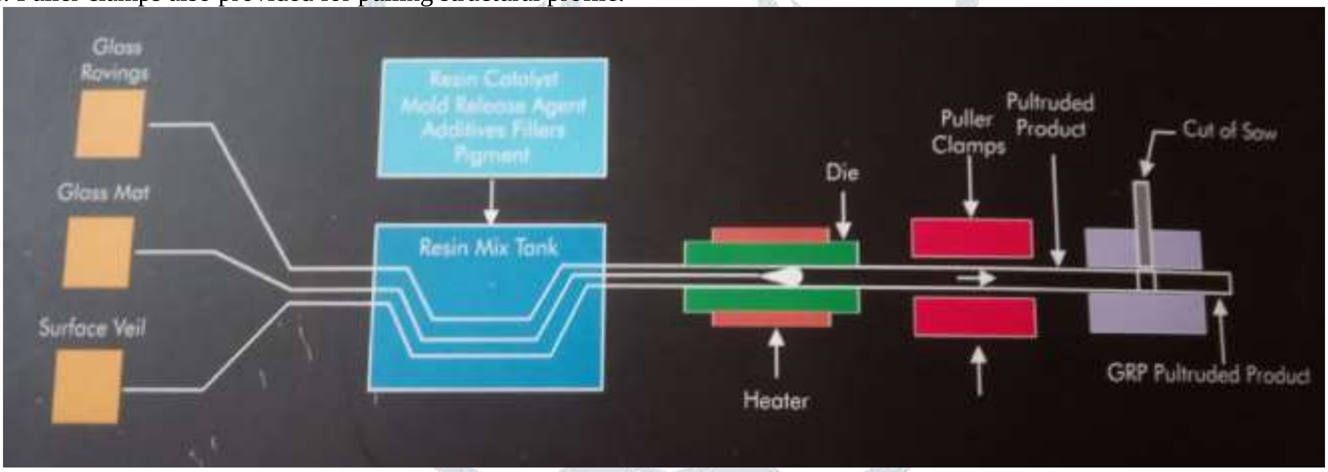


**Fig -1**: Pultrusion Process

Mechanical, physical and electrical properties of GFRP I-section beam and C-channel gives by manufacturer **Atul Electro Formers Ltd., Pune.**

**Table -1:** Mechanical, physical and electrical properties of GFRP I-section beam and C-channel section.

| Description | Code No | Minimum Required | Material value |
|---|---|---|---|
| Density | ASTM D 792 | - | 1.9 |
| Barcol Hardness | ASTM D 2583, | 50-65 | 50 |
| Water Absorption | ASTM D 570, | < 0.25% | 0.24% |
| Ultimate Tensile Strength | ASTM D 638, | 392 Mpa | 403 Mpa |
| Flexural Strength | ASTM D 790, | 245 Mpa | 400 mpa |
| Compressive Strength | ASTM D 638, | 150 | 150 mpa |
| Flammability | UL 94 V0 | - | - |
| Flammability | [ IS : 6746, CLASS 1 ] / PR | - | - |
| Sp. Gravity | IS : 10192 | - | - |
| Fire Retardancy | IS : 11731, | - | - |

| | | | |
|---|---|---|---|
| | PASS | | |
| Surface Burning | ASTM E-84 / IS : 6746, | < 15 | 8 |
| Dielectric Strength (Axial) | ASTM D 149, | 1.2 KV/MM | 4.8 KV/MM |
| Dielectric Strength (Radial) | ASTM D 149, | 10.0 KV/MM | 33.7 KV/MM |
| Arc Resistance | ASTM D 495 | 120s | 122.7s |
| Oxygen Index | ASTM D 2863, | 30 | 41 |
| UV Resistance | RESIN MFR. TC | - | - |

Collection of required material like cement, sand, aggregate, GFRP I-section, GFRP C-channel section, steel etc. is done. The cross section of an elements comprises of beam size is 150 X 150 X 700 mm with 2#8 mm diameter steel bars at top & 2#8 mm diameter steel bars bottom and 6 mm stirrups at spacing 100mm c/c inclusive of GFRP I and C Channel section.
Evaluate flexural strength of reinforced elements of M20 grade and determine corresponding strength after 28 days by applying two points loading. Comparisons of results with conventional beam, composite beam using GFRP I-beam and composite beam using GFRP C-channel.

## III. MODELLING

The reinforcement of beam 2#8mm diameter use for main bar, 2#8 mm Anchor bar and 6 mm@100mm c/c diameter use for stirrups.40mm×25mm×3mm (web × flange × thickness) of GFRP I-section placed at bottom, center, and replacement of main bar for flexural strength of RCC beam. 40mm×25mm×3mm (web × flange × thickness) of GFRP C-channel placed at bottom and center for taking flexural strength of RCC beam.

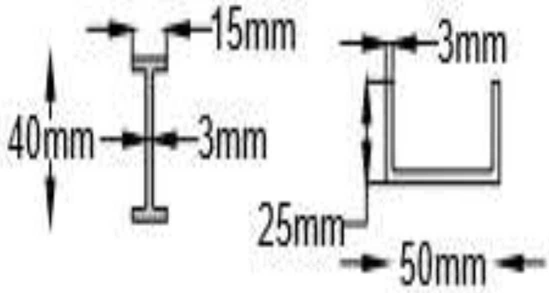


**Fig -2**: Details I-section beam and C-channel of GFRP

### 3.1 Detailing of Specimen

For this investigation Specimen specification was consider as per following specification for RCC beam by using I-section beam and C-channel of GFRP. Total 18 number specimens will be casted then testing of beams on Universal Testing Machine (UTM) by applying two point loads on a beam.

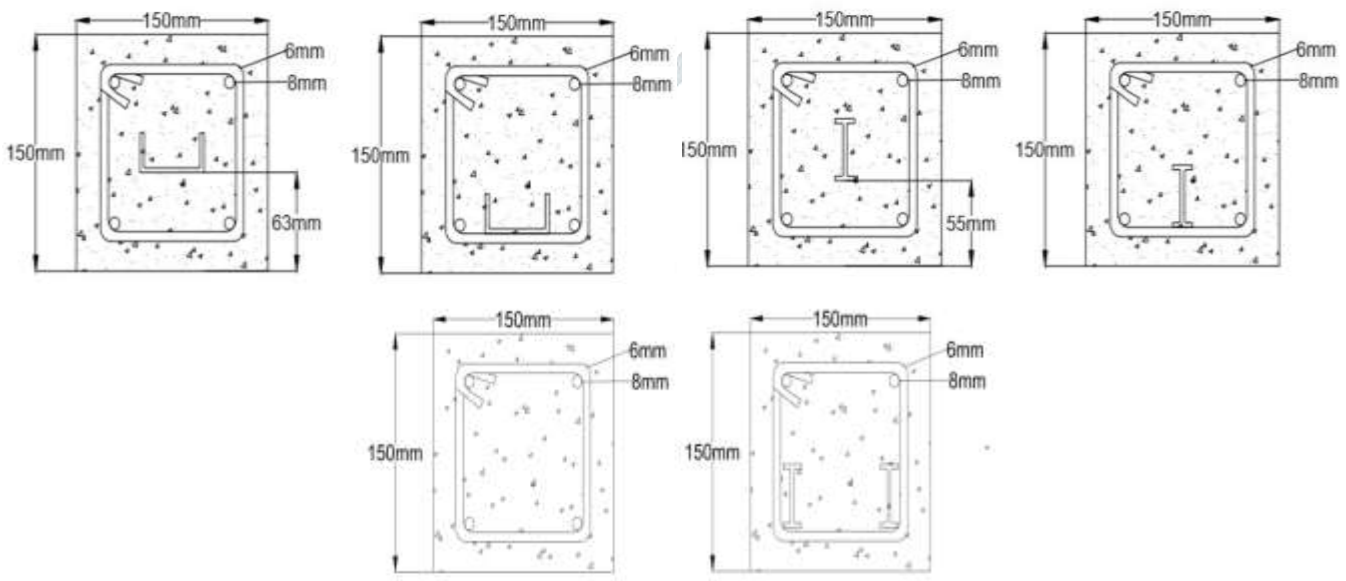

**Fig -3**: Different combination of beams

The beam dimensions selected: 700 mm X 150mm X 150mm (length x width x depth)

GFRP I- beam dimensions: 40 X 15 X 3 mm (web × flange × thickness)

GFRP C-channel dimensions: 50mm X 25 X 3 mm (web × flange × thickness)

**Table -2:** Percentage of material in beams

| Sr. No. | Name of Specimen | % of area of bottom steel | % of area of GFRP |
|---|---|---|---|
| 1. | Conventional beam | 0.44% | 0% |
| 2. | I section beam in bottom or center position | 0.44% | 0.58% |
| 3. | C channel section in bottom or center position | 0.44% | 0.92% |
| 4. | Double I section beam in bottom | 0% | 1.17% |

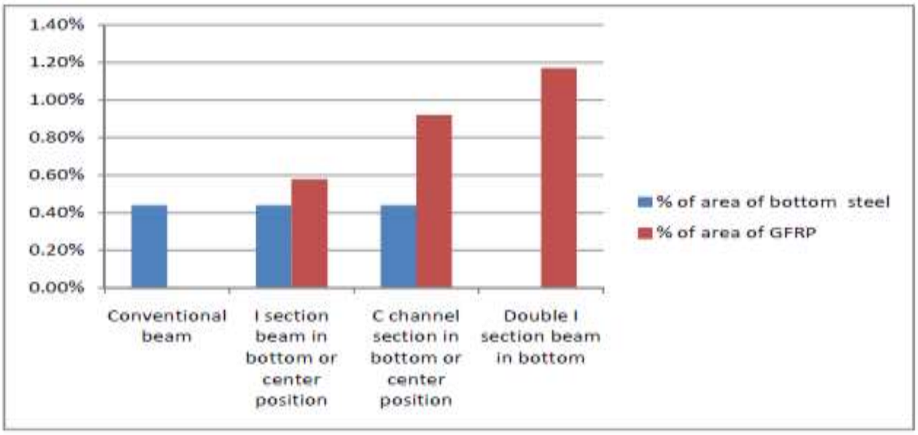


**Chart-1**: Chart of % Percentage of material in beams

**Fig -4**: Casting of I-section GFRP beam

**Fig -5**: Casting of C-Channel GFRP beam

### 3.2 Test Setup

The eighteen specimens were tested with Centre point bending with 700mm effective span. The sample was placed on two supporting pins a set distance apart. Load specimen continuously without shock. The load applied at constant rate to the breaking point. The load applied at the rate of 0.9- 1.2 MPa/min. The specimens' cracks will map and the observations were record during the loading and at the time of failure.

## IV. Result and Discussion

### 4.1 Flexural Strength of Specimen

**Table 1:** Flexural strength

| Specimen | Load | Flexural strength | Average |
|---|---|---|---|
| 1IC | 69 | 12.27 | |
| 2IC | 68 | 12.09 | 12.41 |
| 3IC | 72.4 | 12.87 | |
| 12IB | 72 | 12.80 | |
| 22IB | 70 | 12.44 | 12.86 |
| 32IB | 75 | 13.33 | |
| 1IB | 71 | 12.62 | |
| 2IB | 76 | 13.51 | 12.80 |
| 3IB | 69 | 12.27 | |
| 1CC | 58.6 | 10.42 | 11.37 |
| 2CC | 65 | 11.56 | |

| | | | |
|---|---|---|---|
| 3CC | 68.2 | 12.12 | |
| 1CB | 65.2 | 11.59 | 11.94 |
| 2CB | 66.3 | 11.79 | |
| 3CB | 70 | 12.44 | |
| 1A | 55 | 9.78 | 9.78 |
| 2A | 52 | 9.24 | |
| 3A | 58 | 10.31 | |

Numbers:-Specimen No.
IC:- I-Section GFRP Beam In Center Position
2IB:- Double I-section GFRP Beam in bottom position as main steel
IB:- I Section GFRP Beam in Bottom position
CC:- Channel Section GFRP in center position
CB:-Channel Section GFRP in bottom position
A:- Conventional Beam

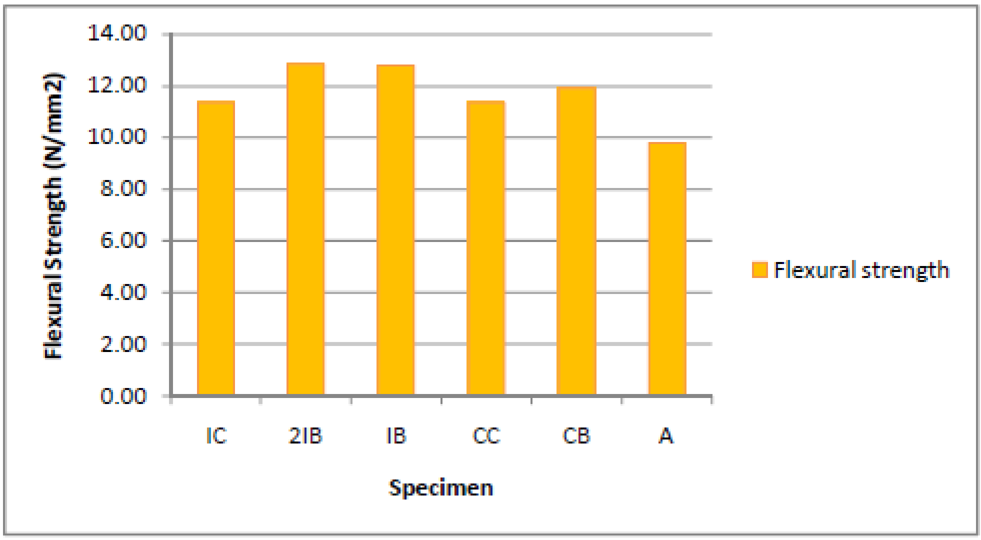


**Chart 2:** Flexural strength of specimen

**Table 2:** Average Load, flexural strength percentage of GFRP and main steel in specimen

| Beam | Load | Flexural strength | % of GFRP | % of Main steel |
|---|---|---|---|---|
| IC | 69.80 | 11.37 | 0.92 | 0.44 |
| 2IB | 72.33 | 12.86 | 1.17 | 0 |
| IB | 72.00 | 12.80 | 0.58 | 0.44 |
| CC | 63.93 | 11.37 | 0.92 | 0.44 |
| CB | 67.17 | 11.94 | 0.58 | 0.44 |
| A | 55.00 | 9.78 | 0.00 | 0.44 |

Flexural strength of various beams by experimentally carried out. Percentage of increased load carrying capacity of conventional beam is compared with GFRP RC beam.

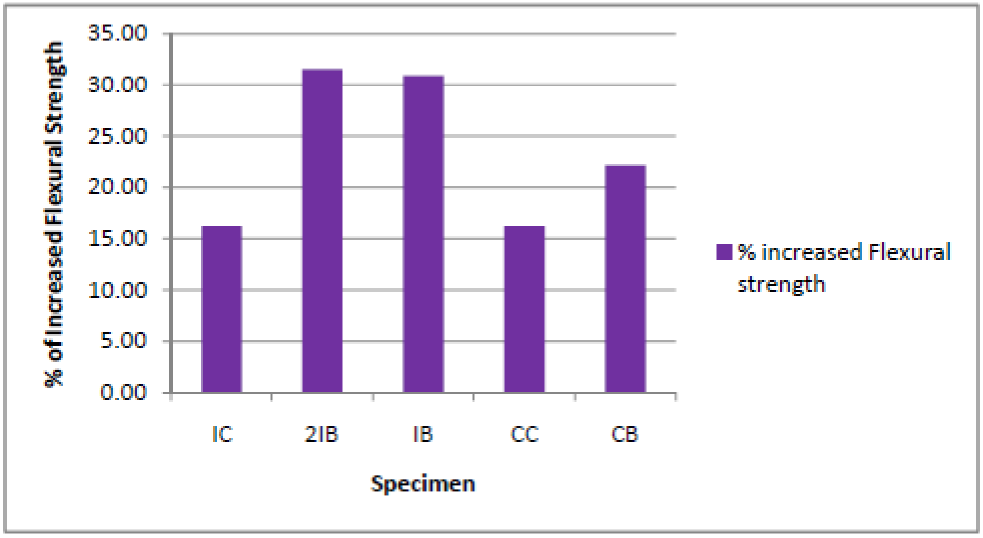


**Chart 3:** Percentage of increased Flexural Strength

Flexural strength of various beams having different section of GFRP, position is carried out. It is observed that load carrying capacity of 2IB is increased i.e., 31.51% than conventional beam. IB is combination of steel and GFRP I-beam having flexural strength increased by 30.90% than conventional beam.

### 4.2 Result of load Vs Deflection

**Table 4 :** Load Vs Deflection

| Load | Deflection (mm) | | | | | |
|---|---|---|---|---|---|---|
| | IC | 2IB | IB | CC | CB | A |
| 0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0.7 | 0.6 | 0.1 | 0.1 | 0.2 | 0.8 |
| 10 | 1.2 | 1 | 0.3 | 0.3 | 0.4 | 1.1 |
| 15 | 1.4 | 1.4 | 0 | 0.5 | 0.6 | 1.5 |
| 20 | 1.7 | 1.6 | 0.5 | 0.8 | 0.9 | 1.8 |
| 25 | 2.1 | 1.9 | 0.5 | 1 | 1.3 | 2 |
| 30 | 2.5 | 2.1 | 0.9 | 1.4 | 1.7 | 2.4 |
| 35 | 2.8 | 2.3 | 1.1 | 1.6 | 2.1 | 2.8 |
| 40 | 3.1 | 2.6 | 1.3 | 1.9 | 2.4 | 3.2 |
| 45 | 3.4 | 2.9 | 1.7 | 2.2 | 2.9 | 3.6 |
| 50 | 3.8 | 3.3 | 2.1 | 2.8 | 3.3 | 4.1 |
| 55 | 4.2 | 3.5 | 2.5 | 3.5 | 3.8 | 5.1 |
| 60 | 4.6 | 3.9 | 3 | 4.3 | 4.4 | 5.4 |
| 65 | 5.1 | 4.3 | 3.7 | 4.5 | 5.3 | |
| 70 | 5.7 | 5 | 4.6 | 4.7 | 6.7 | |
| 75 | | 5.2 | 4.9 | | | |

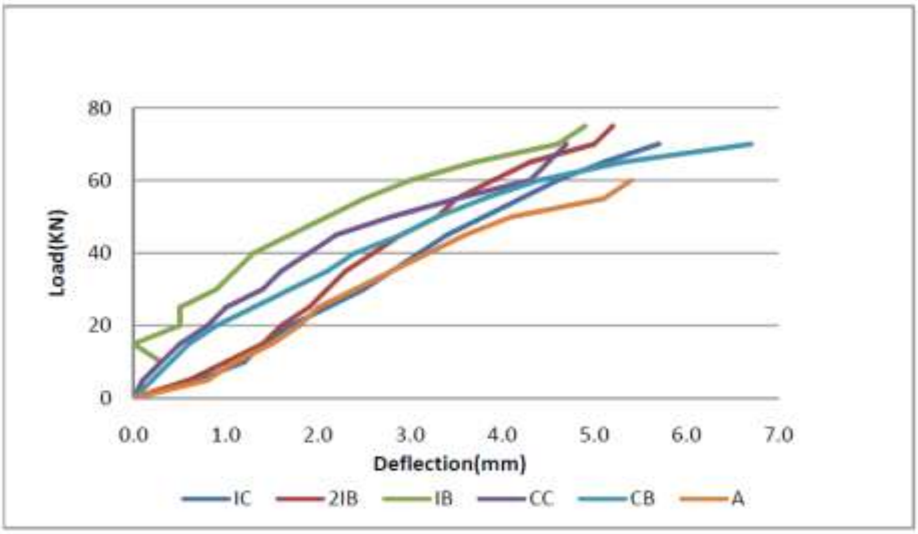


**Chart 4:** Load Vs Deflection

Load carrying capacity Vs Deflection curves of experimental results are plotted. It is observed that load carrying capacity increases deflection also increases that is load carrying capacity is directly proportion to deflection. Load carrying capacity is more GFRP I-section beam in case in RC beam compare to other cases & Deflection is less in GFRP C-Channel in case in RC beam compare to other cases.

## V. Conclusion

It is seen that,

- Flexural Strength of section increases in case of double I section but it is similar to single I section with only 1% increase.
- In case of Center Position of GFRP composite beam deflection is minimum.
- GFRP C-channel section having minimum deflection than I-section GFRP beam.
- With less are I-section GFRP beam carries more load as compare to C-channel section GFRP beam.
- There is no any requirement of special treatment like drilling holes, riveting or welding. It is easy for connection to columns due to presence of the inside steel bars.

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