EVALUATION OF EXPERIMANTAL AND ANALYTICAL TEST ON FAILURE CONCRETE BEAM RETROFITTED USING COLD-FORMED STEEL PLATE

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Abstract - *Structures all over the world are susceptible to increasing load demands due to up-gradation of existing codes or unplanned increase in the number of storeys. So that retrofitting enhancement techniques are used in order to increase life time and serviceability of the structure. Although structures were safe under their pre-revision loading, they might become unsafe under post-revision loading. These structures are required to maintain a certain performance level, which includes load carrying capacity from strength and serviceability considerations in addition to durability and aesthetic appearance. Structural failure occurs when a structure, or a part of it, loses the ability to support the load acting upon it. In view of the existing design deficiencies and the performance of faulty construction, there is an urgent need to look for appropriate strengthening measures to ensure safety of structures. Maintaining the desired performance levels in these structures becomes a challenge. Such structures can be kept in service either by demolition of the capacity deficient structural members and replacing them with adequately strong new members, or by restricting the maximum load on such members. Since replacement of such capacity deficient members incurs huge amount capital and time, thus, retrofitting becomes the adoptable way of improving their load carrying capacity and extend their service life. In addition, retrofitting will ensure sustainability of materials. Here we retrofit a simply supported beam with 2mm and 3mm Cold Formed Steel plate. The finite element model had been developed by using ANSYS WORKBENCH software and the results has been found satisfactory.*

Keywords **:** Ansys analysis, Cold Formed Steel, Maintenance, Retrofitting.

1.INTRODUCTION

Concrete is the most widely used construction material in India with annual consumption exceeding 100 million cubic metres. Concrete is a mixture of cement, water and aggregates with or without admixtures. The cement and water will form a paste that hardens as a result of a chemical reaction between the cement and water. The paste acts as glue, binding the aggregates (sand and gravel or crushed stone) into a solid rock-like mass. The quality of the paste and the aggregates dictate the engineering properties of the construction material. During hydration and hardening, concrete will develop certain physical and chemical properties, low permeability, chemical and volume stability. Concrete has relatively high compressive strength, but significantly lower tensile strength. It is well known that conventional concrete designed on the basis of compressive strength does not meet many functional requirements such as impermeability, resistance to frost, thermal cracking adequately. Conventional Portland cement concrete is found deficient in respect of: durability in severe environs (shorter service life and require maintenance), time of construction (longer release time of forms and slower gain of strength), energy absorption capacity (for earthquake-resistant structures) and repair and retrofitting jobs. This study examined experimentally the flexural and the shear behaviours of RC-beams retrofitted or strengthened with Cold formed steel.

2.REVIEW OF ALL LITERATURES

By observation from more literatures we assess few procedures to proceed. During the planning stage of structural strengthening, the most crucial decision is of the choice of an appropriate strengthening material which should result in convenient strengthening as well as its durability, at minimum cost (**Vasudeva and Kaur 2016**). Hot rolled steel flats have been conventionally adopted for the strengthening of capacity deficit beams. They may be attached to the beams by bolts grouted in the soffit of the beam or by the application of epoxy resins (**Alam et al. 2016**). They improve the load carrying capacity of the beam viz., improves its ductility and stiffness. Cold-formed steel (CFS) sections are becoming more and more popular since through the continuous research on CFS, highly efficient profiles have been developed to obtain desired properties. They also result in reduction in thickness of the CFS sections as well as cost while ensuring the desired properties in the structure (**Anbarasu and Sukumar 2013, 2014, Dar et al. 2019a, b, c, d, e, 2018a, b, c, d, Valse et al., 2013). Wehbe et al. (2011**) developed concrete-CFS composite flexural members through experimental and analytical studies in order to assess their structural performance and failure modes, and to develop optimum beam configurations for the use in light-gauge steel (LGS) construction. The flexural and shear strengths, flexural stiffness, and interface shear transfer were investigated. In their research, only the flexural strength/stiffness characteristics was reported. The results showed that concrete-CFS composite beams can be designed for ductile flexural failure and that the degree of composite action is dependent upon the stand-off screws rather than the configuration.

2.1 ADVANTAGES OF USING COLD FORMED STEEL

a. High strength to weight ratio

b. Resistance against fire

c. More efficient manufacturing process

d. Economic

e. High ductile preferred in high seismic zones

3.MATERIALS USED

Cement: Ordinary Portland Cement, 53 Grade conforming to IS 12269 – 1987.
Fine aggregate: Locally available river sand conforming to Grading zone II of IS 383 –1970.
Coarse aggregate: Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS 383 – 1970.
Cold Formed Steel plates: Locally available plates of thickness 3mm and 2mm is used.
Bolts and nuts for connection:8mm anchor bolts of required numbers.
Water: Potable water.

Table 1 Properties of Coarse Aggregate

S. No.	Properties	Values
1	Specific Gravity	2.77
2	Size of Aggregates	Passing Through 12.5 mm Sieve
3	Fineness Modulus	5.96

Cold formed steel

The manufacturing of cold-formed steel products occurs at room temperature using rolling or pressing. Designs of cold formed steel sections are dealt with in IS: 801-1975 which is currently due under revision. In the absence of a suitable Limit State Code in India, the Code of Practice for Cold Formed Sections in use in the U.K. Generally material thicknesses for such thin-walled steel members usually range from 0.0147 in. (0.373 mm) to about 1 in. (6.35 mm). Steel plates and bars as thick as 1 in. (25.4 mm) can also be cold-formed successfully into structural shapes (AISI, 2007b).
Here we use 2mm and 3mm CFS plate for retrofitting purpose at soffit of the Reinforced concrete beam.

A.TEST DATA FOR MATERIALS

Test	Results
Specific gravity of cement	3.15
Specific gravity of Fine aggregate	2.624
Specific gravity of Coarse aggregate	2.695
Water Absorption of Fine aggregate	0.8%
Water Absorption of Coarse aggregate	0.4%
Sieve analysis of Fine aggregate	Sand conforming to Zone III of IS 383:1970
Sieve analysis of Coarse aggregate	Aggregate conforming to IS 383:1970

B.MIX CALCULATIONS

The ratio becomes in terms of per cubic metre of concrete is 1: 1.38: 2.65: 0.45

Table 2 Weight of materials per m^3 (M30)

W (kg/m^3)	C (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)
197.2	438.2	608	1160
0.45	1	1.38	2.65

4.EXPERIMENTAL INVESTIGATION

A.FRESH CONCRETE PROPERTIES

4.1 GENERAL

Fresh concrete or plastic concrete is a freshly mixed material which can be moulded into any shape. The relative quantities of cement, aggregates and water mixed together, control the properties of concrete in the wet state as well as in the hardened state. The following tests are conducted to evaluate the degree of work-ability.

4.2 SLUMP VALUE

Slump test is used to determine the work-ability of fresh concrete. Slump test as per IS 1199: 1959 is followed.

Fig.1 Slump cone test

Slump value has been observed to be 85mm ,for M30 concrete 75-100mm slump is found to be satisfactory as per IS 1199-1959.

B.HARDENED CONCRETE PROPERTIES

Table 3 Specimen Details

S.No.	Shape of the Specimen	No. of Specimens	Size of Specimen
1	Cube	2	150x150x150 mm
2	Cylinder	2	150mm diameter, 300mm high

The controlled concrete is cast and cured for 28 days and the tests for hardened concrete such as compressive strength, split tensile strength are done.

4.3 COMPRESSIVE STRENGTH

Compression test on cubes before loading and after loading.

Table 4 TEST RESULTS:

No. of curing days	Compressive strength (N/mm^2)
7	23.8
28	28.8

On 28^{th} day the compressive strength has of cube to be observed as 28.8 N/mm. That is 96% of its Design strength.

4.4 SPLIT TENSILE STRENGTH TEST ON CONCRETE

A concrete cylinder of size 150mm diameter×200mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner. The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress.

To find horizontal tensile stress following formulae is used:

Horizontal tensile stress=2P/πDL

Where,

P = the compressive load on the cylinder.

L = length of the cylinder

D = diameter of cylinder

Fig .2 Split tensile test on Cylinder before and after loading

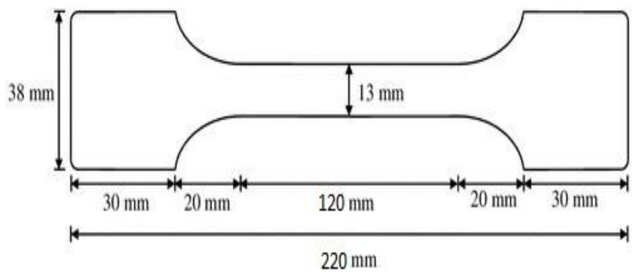
Table 5 Split tensile test results:

No. of curing days	Split tensile strength
7 days	1.27
28 days	1.41

4.5 COUPON TEST ON COLD FORMED STEEL

A coupon is a small sample of the material under test that has been prepared in such a way that it's failure mechanism will be representative of the larger production pieces. Tensile testing, is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. The following properties can also be determined:

modulus, Poisson's, yield strength, and strain-hardening characteristics.



Schematic diagram

Fig.3 Cold form steel before coupon test

Fig.4 Cold formed steel after coupon test

Table 6 Coupon test Results

Thickness of CFS plate (mm)	Ultimate Tensile strength (kN)
2	11.765
3	31.204

5.BEHAVIOUR OF BEAMS AND SELECTION OF SUITABLE RETROFITTING

As per the failure pattern Cold formed steel plate has to be fitted with help of bolted connections.

5.1 COMPARING THE BENEFITS CFS OVER FRP RETROFITTING

In most researches CFRP has proven to be higher strengthening retrofitting material. In **Yasmeen et al.** the beam which retrofitted with CFRP laminate of higher length has given value up to 351 kN whereas the beam which retrofitted with Cold formed steel section has given 321.6 kN . It is found that these two are best retrofitting methods in comparing with other retrofitting materials like Natural fibre, Bolted Hot rolled flat etc., FRP Laminates has its own disadvantages of High cost and for fixing it with beam we have incorporate chemical substances like Epoxy.

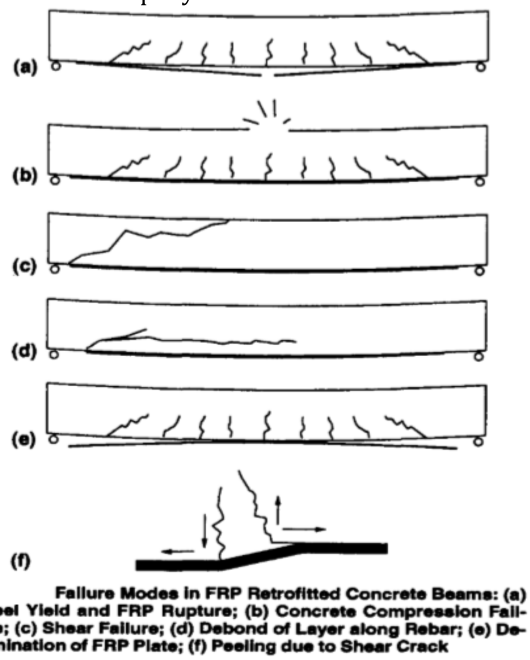


Fig.5 FRP Failure Modes

5.2 RETROFITTING PATTERN

Material	Particulars
Concrete	Grade of concrete=75 MPa Modulus of Elasticity E = $5000\sqrt{f_{ck}}$ (according to replacements of additives added)
Steel	Young's Modulus E=2*10^5 MPa Poisson's ratio= 0.3, Yield strength= 415 MPa

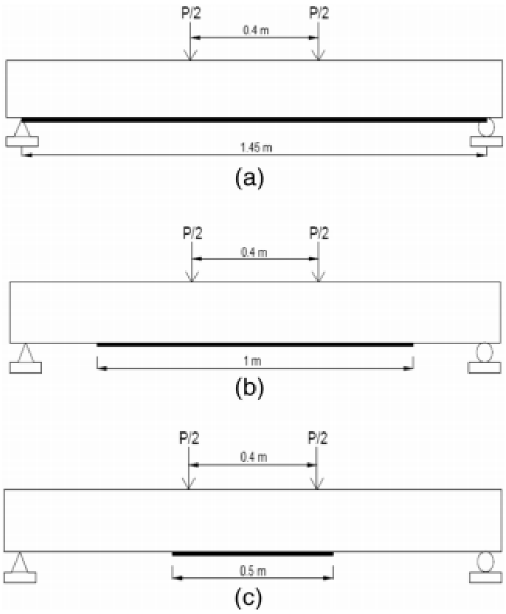


Fig.6 Retrofitting Pattern

a) Fully retrofitting
b) Partial retrofitting in shear and max bending zone
c) Partial retrofitting in maximum deflection zone

In this project we are going to follow (b) Partial retrofitting in shear and max bending zone

Considering these cases, we are switching to Cold formed steel in which sections are susceptible to debonding failure as the thickness is large **(M. Adil Dar et al)**. Hence we can go for Cold formed steel plates with lesser thickness.

Yasmeen et al. has also stated that larger the length of the retrofitting plate larger load bearing capacity.

Two important things to remember while retrofitting is:

I. Debonding occurs due to high shear stress occurring near the ends of plates.

II. A lower stiffness & higher fracture energy will probably weaken the tendency of debonding

Hence we use Cold formed steel plate of thickness 2mm and 3mm.

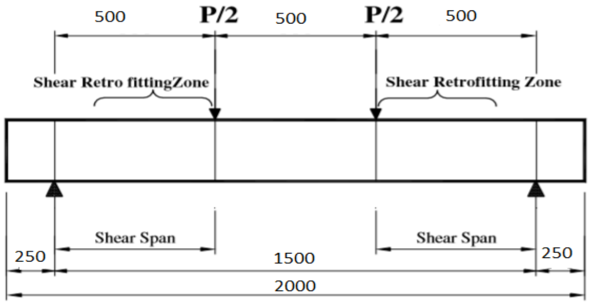


Fig.7 Shear Retrofitting Zone

6.ANALYTICAL INVESTIGATION IN ANSYS

Table 7 Material Properties

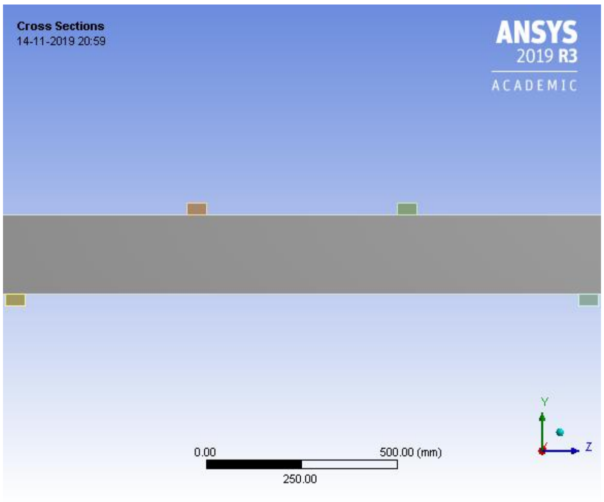


Figure.8 Geometric Model of Beam

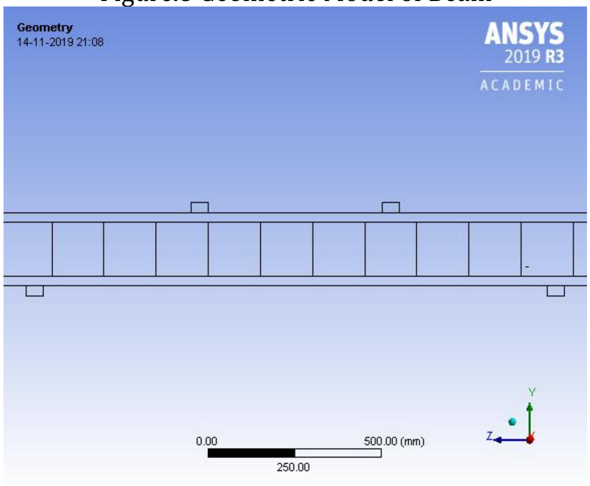


Figure.9 Reinforcement

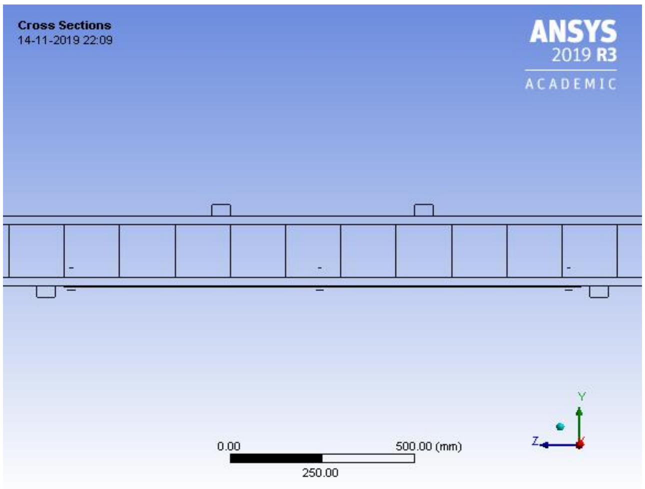


Figure.10 Reinforcement with the plate bolted in soffit of the beam

6.1 RESULTS FROM ANSYS

BEAM WITHOUT RETROFITTING

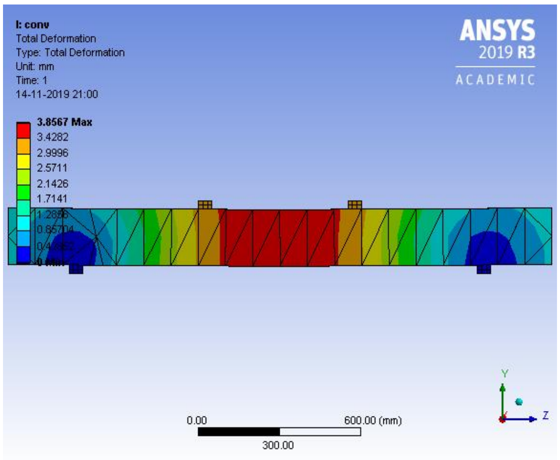


Figure.11 Total Deformation

FOR ULTIMATE FAILURE LOADING:

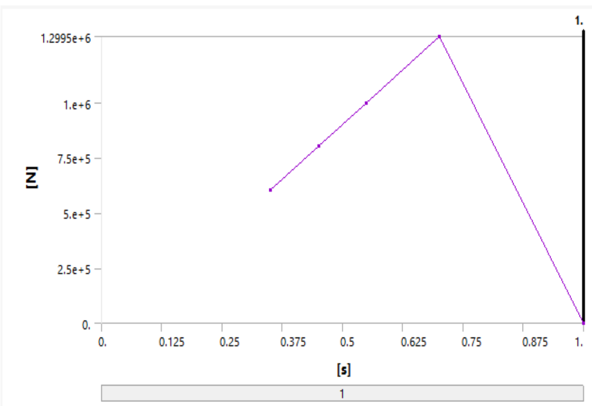


Figure 12 Graph of force reaction

Table .8 Ultimate load on beam without retrofitting

S.no	Time (s)	Force Reaction Total (kN)
1	0.35	60.5
2	0.45	80.3
3	0.55	100
4	0.7	129.5

BEAM RETROFITTED WITH 2MM CFS PLATE

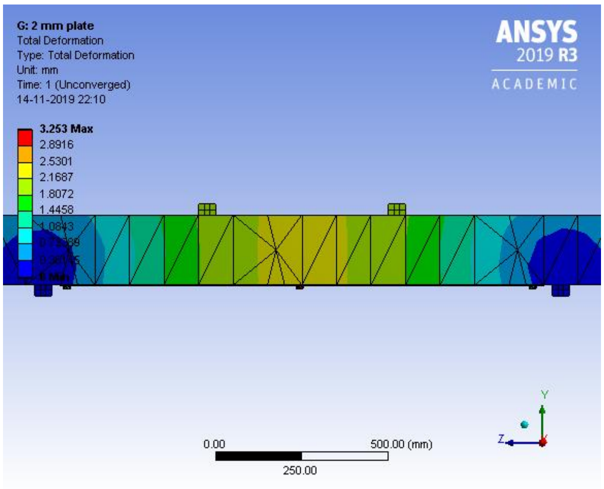


Figure.13 Total Deformation

FOR ULTIMATE FAILURE LOADING:

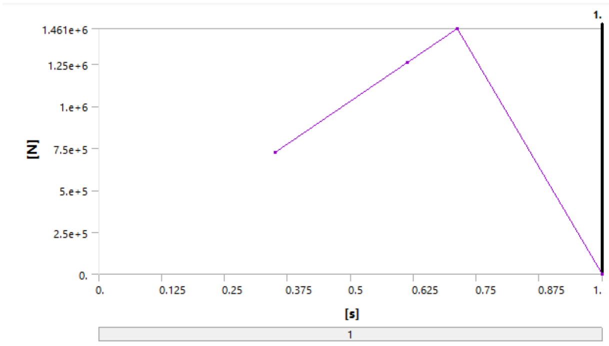


Figure 14 Graph of force reaction

Table.9 Ultimate load on beam with retrofitting of 2mm CFS plate

BEAM RETROFITTED WITH 3MM CFS PLATE:

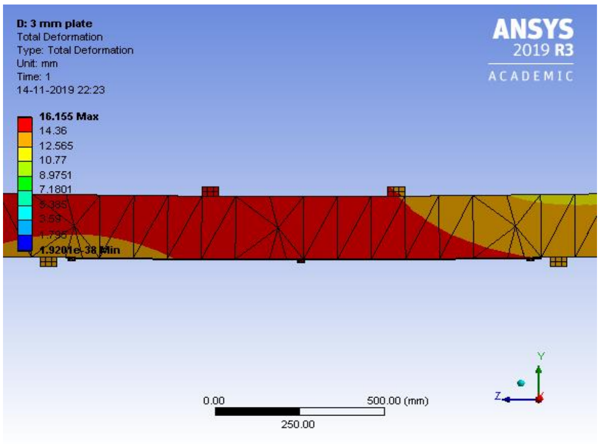


Figure.15 Total Deformation

FOR ULTIMATE FAILURE LOADING:

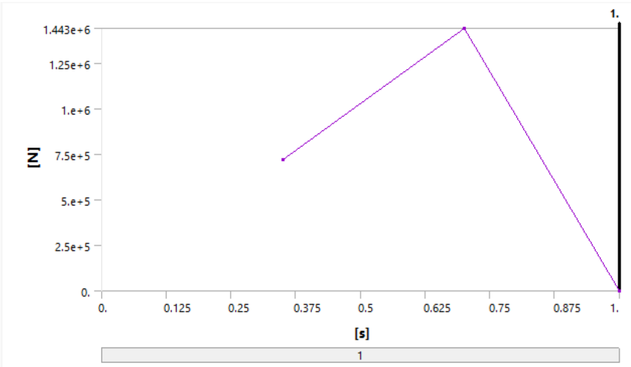


Figure.16 Graph for force reaction on beam retrofitted with 3mm plate

Table.10 Ultimate load on beam retrofitted with 3mm CFS plate

S.no	Time (s)	Total Force Reaction (kN)
1	0.35	72.3
2	0.7	144

Table.11 Details of Specimens and Test Results

S.no	**Specimen**	**Ultimate load(kN)**	**Deflection (mm)**
1	Conventional beam	**129.5**	**3.867**
2	Beam retrofitted with 2mm CFS plate	**146**	**3.263**
3	Beam retrofitted with 3mm CFS plate	**144.3**	**16.15**

S.no	Time (s)	Total Force reaction (kN)
1	0.35	72.2
2	0.6125	125
3	0.7125	146

7.EXPERIMENTAL INVESTIGATION

This chapter presents the procedure and results of the experimental program carried out on reinforced concrete beams and after retrofitting the same beams with 2mm and 3mm Cold formed steel plate. Reinforced Concrete Beams of standard size 150mm x 200 mm x 2000 mm conforming to IS: 516-1959 were cast for studying flexural strength of concrete. Three specimens were casted of M30 grade. These specimens were tested for deflection in the Universal testing machine of capacity 1000 KN. The beams were designed as under reinforced sections.

Use 2 nos of 12 mm dia rods @Bottom

Use 2 nos of 10mm dia rods @Top

Use 8 mm dia 2 legged stirrups at 150 mm c/c.

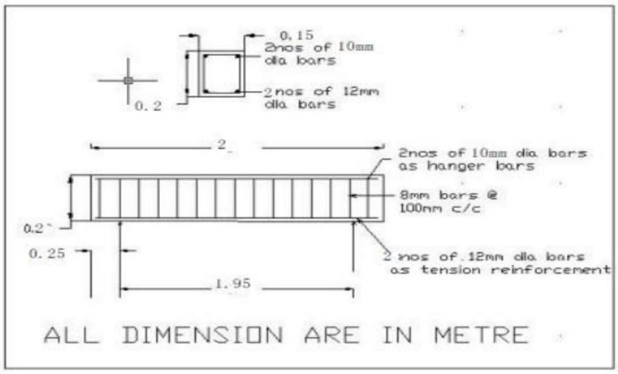


Fig.17 Reinforcement of beam

Fig.18 Testing of beam on Two-point loading frame

Fig.19 Fixing of Plates

The beam is bolted with 8mm anchor bolts

From observation of noted values, it is seen that beam which retrofitted with 2mm CFS plate has shown maximum progress than beam retrofitted with 3mm CFS plate.It also shows 30% more strength than conventional reinforced concrete beam.

CFS Retrofitted beam Crack pattern

Fig.20 Crack pattern of Retrofitted beam

From study it is observed as flexure crack failure. The retrofitting plate was bending and hogging away due to the failure of beam.

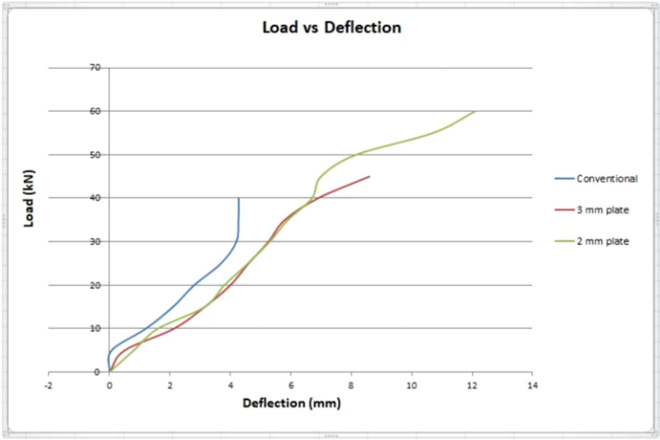


Chart-1 Load vs Deflection graph until Ultimate loading

Table.12 Test results of specimens

S.no	Specimen	Ultimate load(kN)	Deflection (mm)
1	Conventional beam	43	4.28
2	Beam retrofitted with 2mm CFS plate	56	12.1
3	Beam retrofitted with 3mm CFS plate	45	8.6

8.CONCLUSION

In this project, the Concrete Mix M30 has been designed as 1: 1.38: 2.65: 0.45. Using ANSYS concrete beam has been retrofitted and the results has been obtained as per Indian standard codes were examined.

The following conclusions are arrived from this study,

From ANSYS,

- **Maximum Ultimate load (146kN)** is taken by Beam retrofitted with **2mm CFS plate.**
- **Least Deflection (3.26mm)** is formed by Beam retrofitted with **2mm CFS plate.**
- The Beam retrofitted with 3mm CFS plate has comparatively lesser Ultimate load(144.3kN) but also the Deformation is Maximum.
- The Conventional beam has 129.5kN Ultimate load which is when compared to Beam retrofitted with 2mm plate. **12% increase in strength** has been noted**.**
- Thus it will provide serviceability strength and increase the life span of the structure if the beam is properly retrofitted.
- It is also learnt that **lesser thickness has higher load carrying capacity** as it **reduces the debonding effects**.

From Experimental Investigation,

- It is seen that beam which retrofitted with 2mm CFS plate has shown maximum progress than beam retrofitted with 3mm CFS plate.
- It also shows 30% more strength than conventional reinforced concrete beam.
- So, it is also proven in experimental method that beam with 2mm CFS plate provides serviceability strength and increase the life span of the structure if the beam is properly retrofitted.
- Here the plate is fixed with 8mm anchor bolts thus provided greater bond strength and at the same time it prove to be better advantage for environment as it neglects epoxy or any chemical usage.

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