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Strengthening And Stiffening Of Corroded Steel Beam Using Hybrid Laminates And Posttensioning

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ABSTRACT

The steel beams with crack and corrosion can result in the reduction of stiffness, load carrying capacity and hence it results in the worst performance of the beam. Previous research has looked on flexural rehabilitation of corroded steel beams utilizing Carbon Fibre Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP). However, no research has been done on the use of hybrid laminates and post tensioning to repair corroded steel beams. This study examined the feasibility and effectiveness of using hybrid laminates made with combining CFRP, BFRP and GFRP for rehabilitation of corroded and cracked steel beams. The steel beams examined are of with 10%, 20%, 40%, 50% and 75% corrosion and precrack at flexural and shear zone. These steel beam models compared with control beam model that is, steel beam having no crack and corrosion. Among these models, worst model was rehabilitated using hybrid laminates and post tensioning. Comparison of model retrofitted using CFRP, GFRP and BFRP with model retrofitted with hybrid laminates were also examined. Non-linear finite element models were developed by using ANSYS to assess structural performance of these beams. Three-point bending tests were used to analyses the beams with and without rehabilitation.

Keywords: posttensioning, corrosion, strengthening, laminates, structural analysis, nonlinear analysis

INTRODUCTION

The increased risk of galvanic corrosion when CFRP is used for steel rehabilitation is a major concern. Galvanic corrosion is caused by the electrochemical coupling of two different metals, which results in the creation of an electric current. Because CFRP and steel are different metals, direct contact between the two must be avoided. As a result, the use of an E-glass layer to electrically insulate CFRP and steel was proposed. Basalt FRP (BFRP)

does not suffer from galvanic corrosion since it is not a conductor and so does not require any electrical insulation. Basalt fibre is derived from basalt rock that has been melted. It has no additives throughout the production process, making it harmless and recyclable. As a result, basalt goods offer a greener alternative to carbon and glass fibre textiles. Furthermore, basalt fibre fabric is roughly a fifth of the cost of carbon fibre fabric. When comparing the performance of CFRP, GFRP, and BFRP-rehabilitated concrete beams, the performance of BFRP-

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rehabilitated concrete beams is in the middle of the two. Additionally, concrete beams strengthened with BFRP fabric have higher yield and ultimate load capacities than GFRP-rehabilitated concrete beams.

External prestressed tendons have been utilized to reinforce existing composite steel–concrete beam constructions in addition to these approaches. Welding end anchorages and utilizing high-strength post-tensioning cables are used in this method. The starting force in the tendon, as well as its eccentricity, had a considerable impact on the strength and stiffness of the tested beams, according to the findings. Furthermore, in some situations, this form of strengthening results in a 25% increase in load bearing capability. Applying prestressing in a limited location within a steel beam as an alternative to the above-mentioned procedures for reinforcing existing steel bridges and mending badly damaged steel I-beams. Adding reinforcing steel bars to a segment of the beam enhances the stiffness and load bearing capability of the steel structural component. Prestress is done by employing a manual screw jack to raise the steel bars from the soffit of the steel beam, creating a tensile tension in the steel bars. This technique is also utilized to prestress concrete beams due to its low cost and ease of operation.

CORROSION

Corrosion occurs when a refined metal is naturally changed to a more stable form, such as oxide, hydroxide, or sulphide, causing the substance to deteriorate. Corrosion of structural steel is an electrochemical process that necessitates the presence of moisture and oxygen at the same time. Rust is formed when the iron in steel is oxidised, and it takes up around six times the volume of the original material. Steel is a metal that contains a lot of iron, and if it is continually exposed to environmental elements like water and oxygen, it may rust in as little as 4-5 days.

Causes of Corrosion

- When metal interacts with another material, such as oxygen, hydrogen, electricity, or even dirt and germs, it corrodes. Corrosion may also occur when metals, such as steel, are subjected to excessive tension, which causes the substance to split.
- The following data must be gathered in order to assess the rate of corrosion:
- Loss of weight (the decrease in metal weight during the reference time)
- Density of the population (density of the metal)
- Location (total initial surface area of the metal piece)
- The passage of time (the length of the reference period)

Objectives Of The Study

- To study the flexural performance and strength reduction of corroded beam at various location.
- load carrying capacity of beam.
- Deflection at the time of failure
- Stress distribution
- To strength and improve the performance by single and hybrid laminate concept
- Improve the strength of detorated beam by local post tension method.

GEOMETRY

The steel beam has an overall depth of 150 mm, a flange width of 75 mm, a flange thickness of 7.0 mm, and a web thickness of 5.0 mm, among other geometric characteristics. Tensile coupon testing yielded yield stress, ultimate tensile strength, and Young's modulus of 411.6 MPa, 541.3 MPa, and 207.4 GPa, respectively.

Table 4:1 Material Properties of Steel, Tendon, Hybrid Laminate (BFRP, CFRP, GFRP)

Material Properties	Steel	Tendon	Hybrid Laminate		
			BF RP	CF RP	G FRP

Youngs modulus (Mpa)	2.07×10^5	2.07×10^5	108 000	230 000	71 000
Tensile strength (Mpa)	541.3	541.3	300 0	350 0	20 00
Yield strength (Mpa)	411.6	500	-	-	-

MODELLING OF BUILDING

General

To explain the methodology adopted in the modelling of corroded and non-corroded beam.

Geometric modeling

Figure

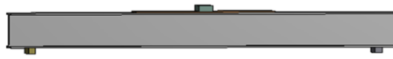


Figure 5.2.1: Front view of geometric modelling.

Model

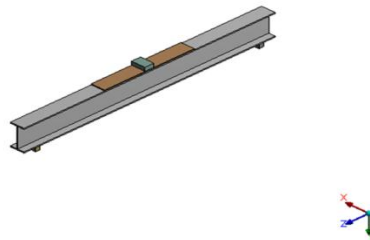


Figure 5.2.2: 3D view of geometric modelling

Finite element model

ELEMENT TYPE: SOLID186

MESH SHAPE: Hexa herdon

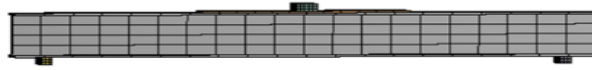


Figure 5.3.1: Plan View

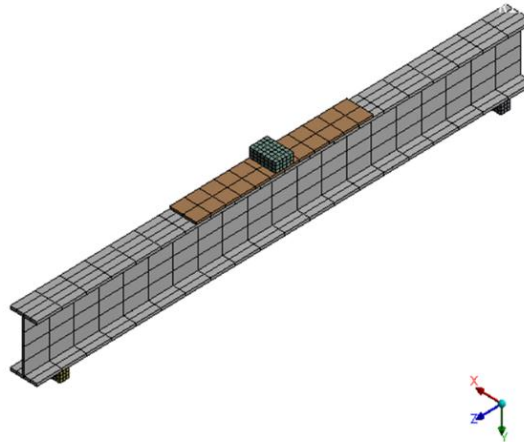


Figure 5.3.2:3D View

Boundry condition

The beam specimen was simply supported on two roller supports with a span of 1250 mm during three-point bending tests with displacement-controlled loading.

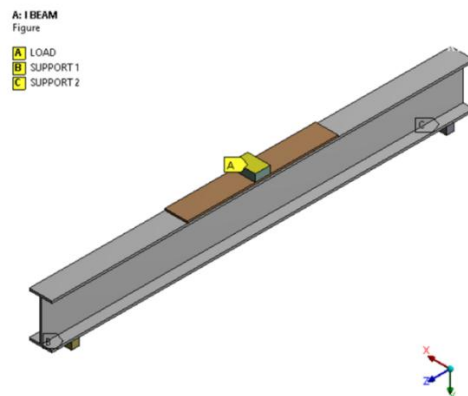
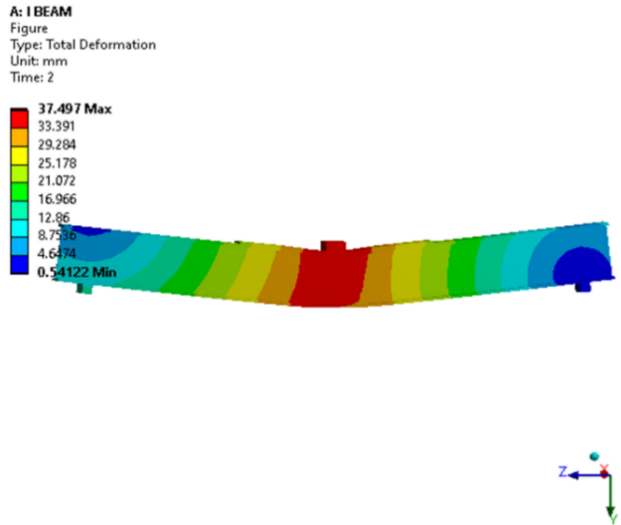
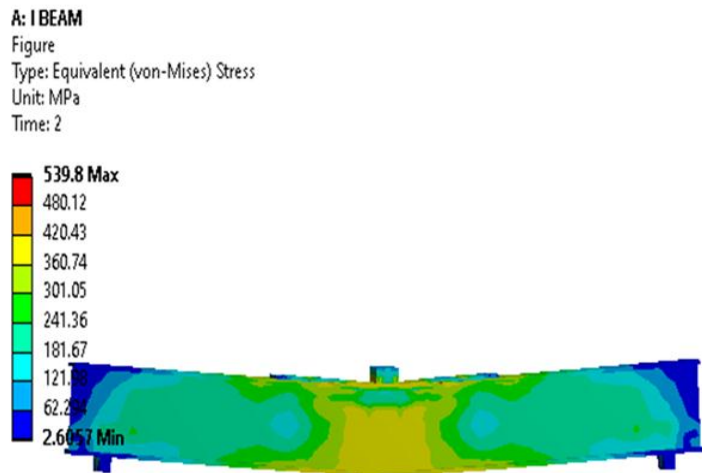


Figure 5.4.1:3D view Boundry condition

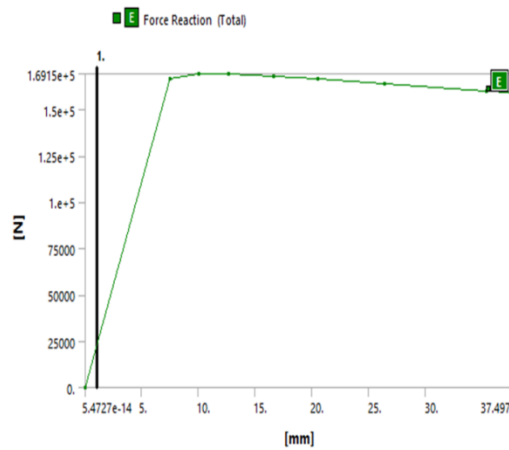
Total deformation



Stress distribution



Load deflection behavior



RESULTS AND DISCUSSIONS

Corrosion damage at flange study table

Strength losses and gain of flange is given in the table.

CONDITION	CASE	MAX.DEFOR MATION	ULTIMATE LOAD	%	
BEAM WITH CRACK AND SURFACE CORROSION	WITHOUT CORROSION DAMAGE	12.63	169.15	1.00	STRENGTH LOSS
	FLANGE C -10 %	12.63	160.05	5.37	
	FLANGE C -25 %	12.63	150.76	10.87	
	FLANGE C -50 %	14.92	131.12	22.40	
	FLANGE C -75 %	14.93	97.16	42.55	
RETROFITTING OF BEAM WITH SINGLE LAYER LAMINATES	FLANGE C -75 % WITH CFRP	14.87	111.75	15.02	STRENGTH GAIN
	FLANGE C -75 % WITH GFRP	22.33	106.91	10.03	
	FLANGE C -75 % WITH BFRP	26.08	127.34	31.06	
	FLANGE C -75 % HYBRID	26.09	151.83	56.27	
RETROFITTING THE WORST CASES WITH HYBRID LAMINATES	FLANGE C -75%+PT	14.84	201.16	107.04	STRENGTH GAIN
RETROFITTING THE WORST CASES WITH POST TENSIONING	FLANGE C -75%+HL+PT	15.06	213.06	119.29	

Total deformation and equivalent stress modelling Flange corrosion 10%

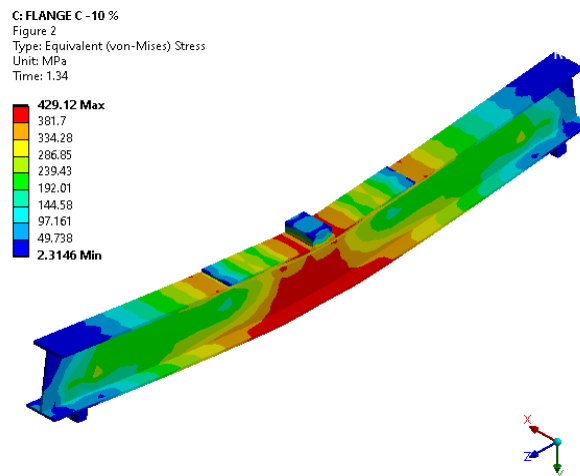


Figure6.2.1.1: Total Deformation

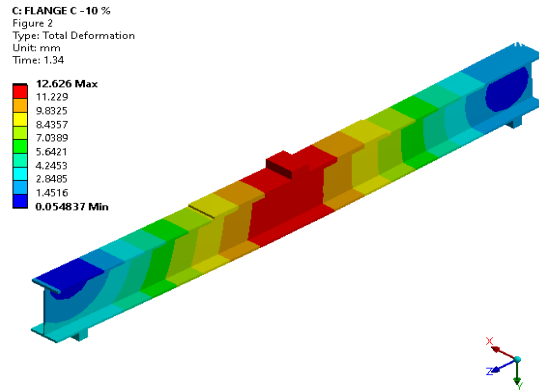


Figure6.2.1.2: Equivalent Stress

Flange corrosion 25%

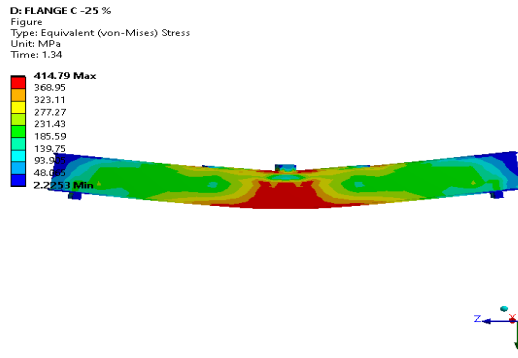


Figure6.2.2.1: Total Deformation

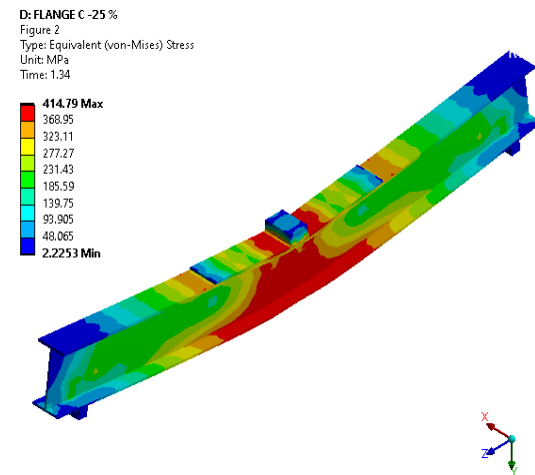


Figure6.2.2.2: Equivalent Stress

Flange corrosion 50%

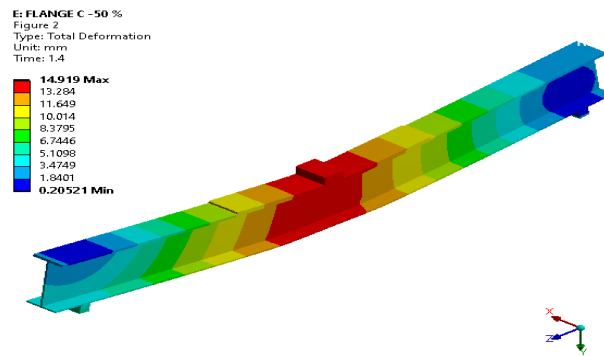


Figure6.2.3.1: Total Deformation

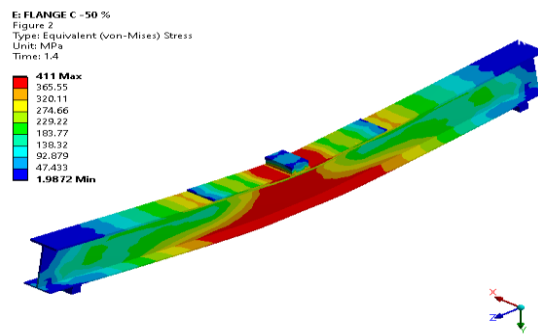


Figure6.2.3.2: Equivalent Stress

Flange corrosion 75% HYBRID

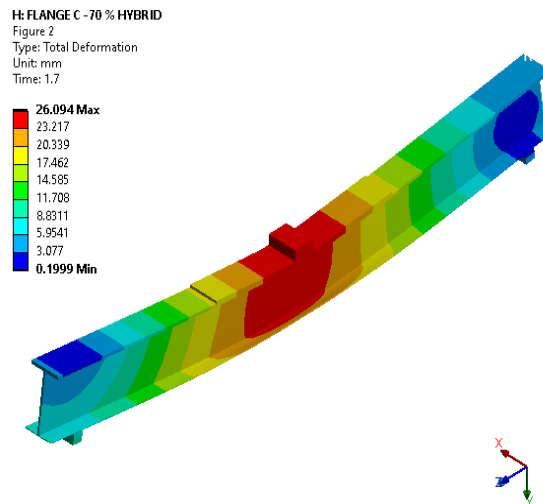


Figure6.2.4.1: Total Deformation

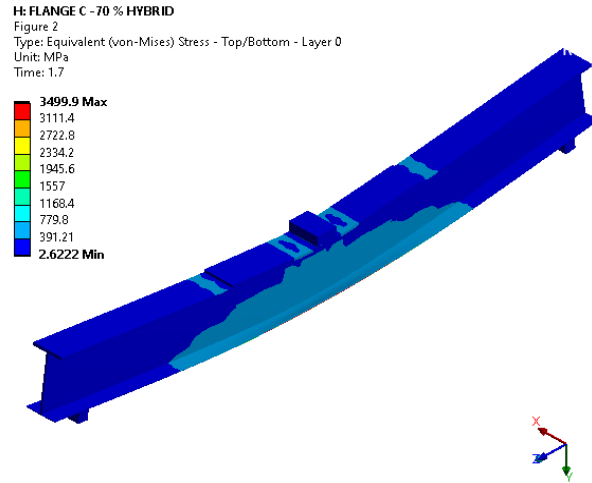


Figure6.2.4.2: Equivalent Stress

Flange corrosion 75% with BFRP

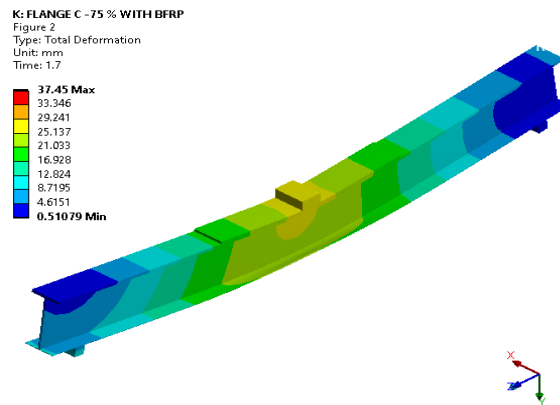


Figure6.2.5.1: Total Deformation

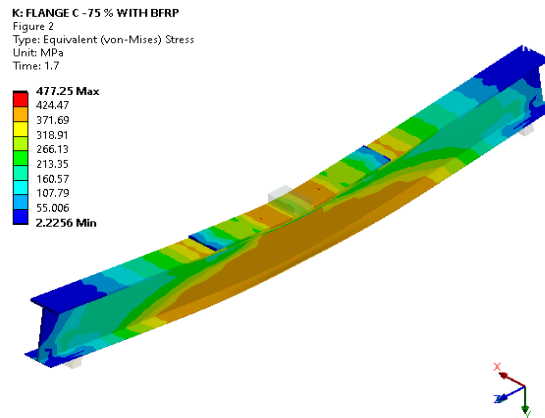


Figure6.2.5.2: Equivalent Stress

Flange corrosion 75% with CFRP

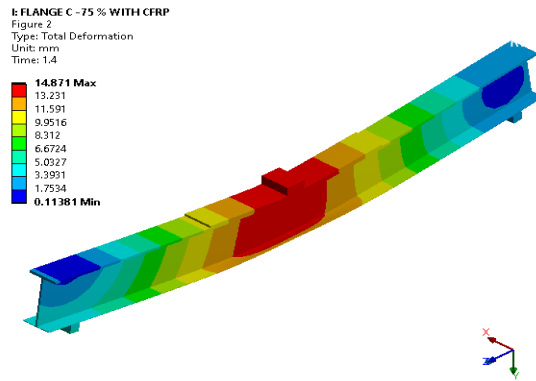


Figure6.2.6.1: Total Deformation

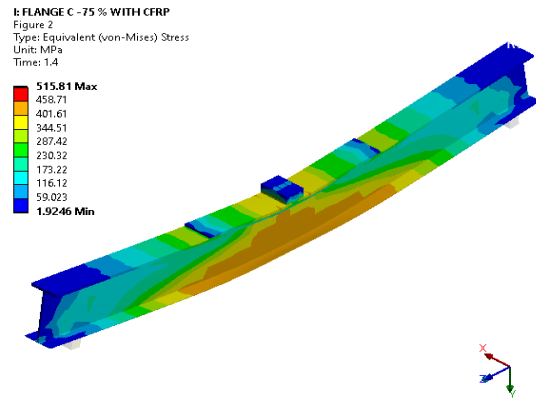


Figure6.2.6.2: Equivalent Stress

Flange corrosion 75% with GFRP

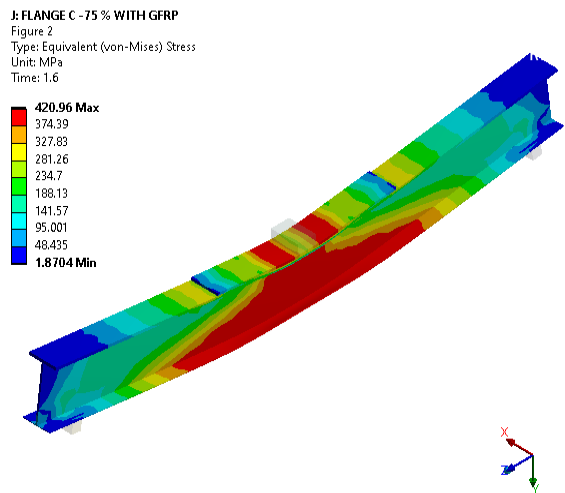


Figure6.2.7.1: Equivalent Stress

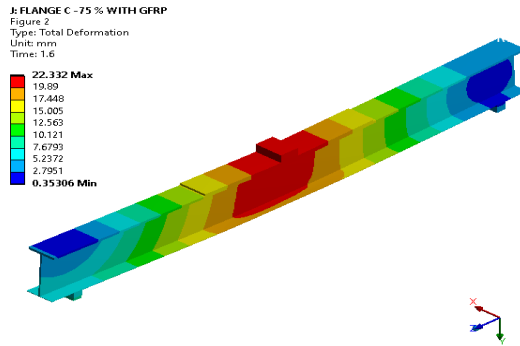


Figure6.2.7.2: Total Deformation

Flange corrosion 75%

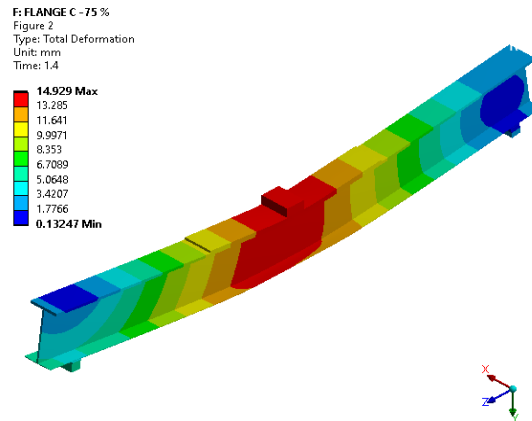


Figure6.2.8.1: Total Deformation

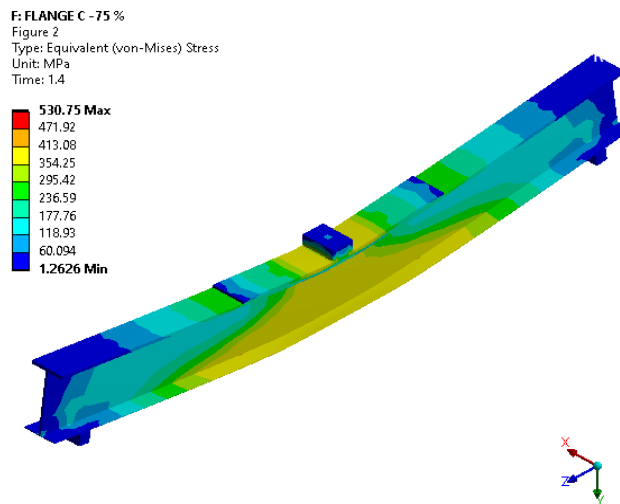


Figure6.2.8.2: Equivalent Stress

Flange corrosion 75%+post tensioning

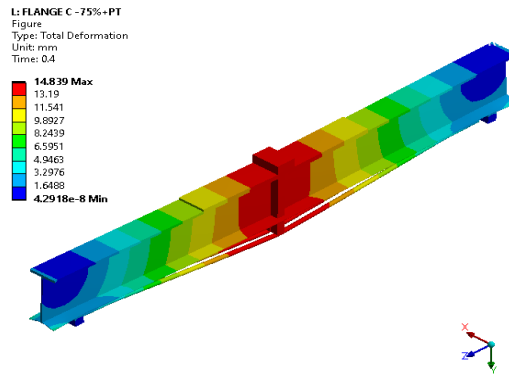


Figure6.2.9.1: Total Deformation

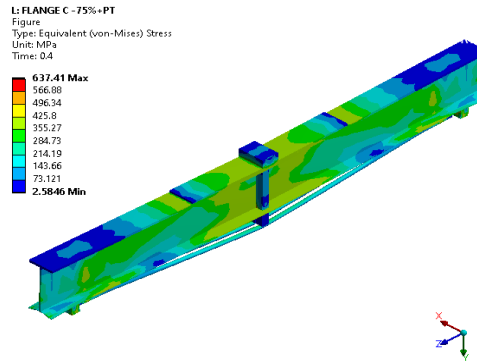


Figure6.2.9.2: Equivalent Stress

Flange corrosion 75%+Hybrid laminates+Posttensioning

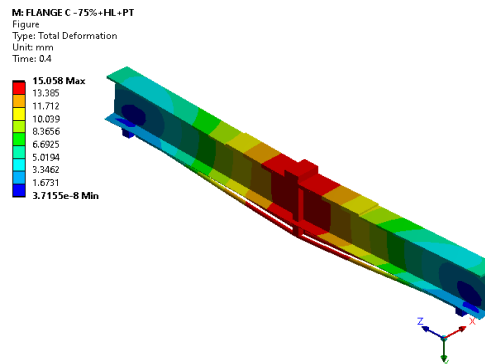


Figure6.2.10.1: Total Deformation

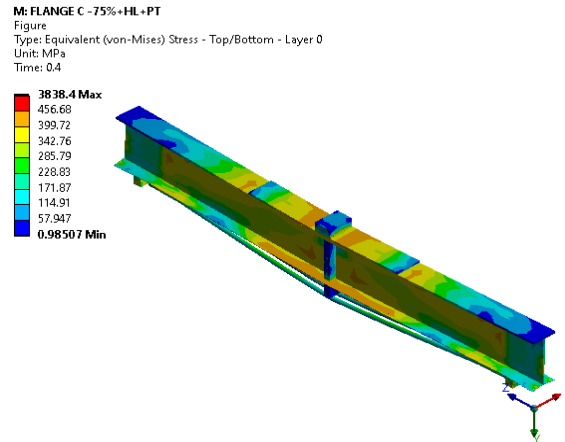


Figure6.210.2: Equivalent Stress

Corrosion damage at web study table

Strength loses and gain of web given in the table.

CONDITION	CASE	MAX. DEFORMATION	ULTIMATE LOAD	%	
BEAM WITH AND SURFACE CORROSION @ WEB	WITH OUT CORROSION DAMAGE	12.63	169.15	1.00	STRENGTH LOSS
	WEB C @ 25	12.89	161.99	5.37	
	WEB C @ 50	16.79	142.93	10.87	
	WEB C @ 75	12.32	83.93	22.40	
RETROFITTING THE WORST CASES WITH PT + HYBRID LAMINATES	WEB C @75+HL+PT	8.79	131.82	57.07	STRENGTH GAIN

Web corrosion 25%

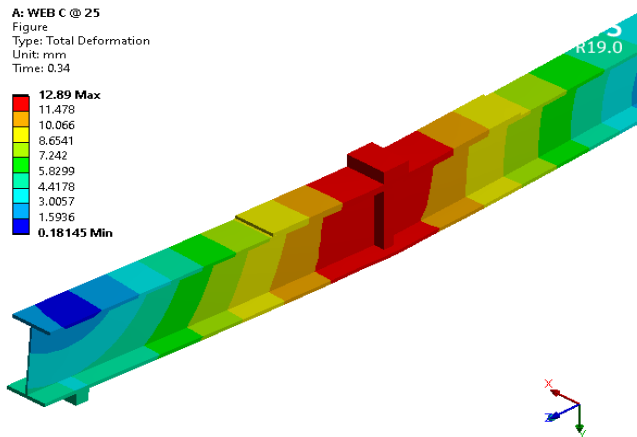


Figure6.3.1.1: Total Deformation

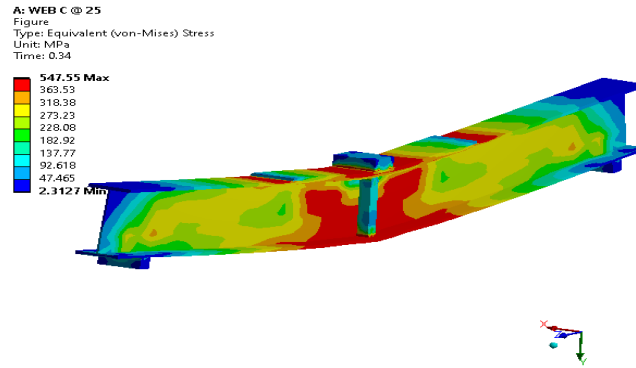


Figure6.2.9.2: Equivalent Stress

Web corrosion 50%

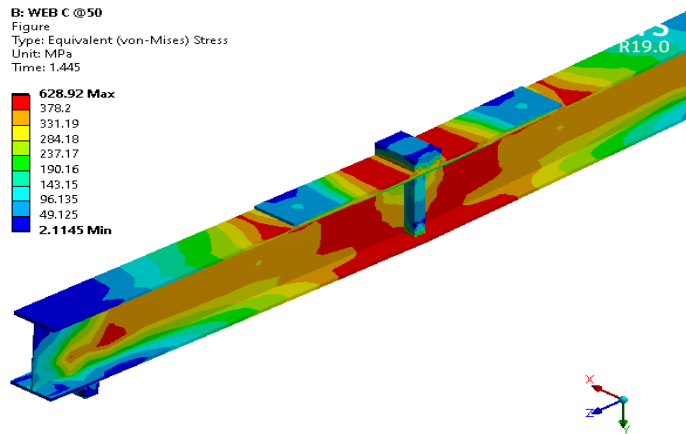


Figure6.3.2: Equivalent Stress

Web corrosion 75%

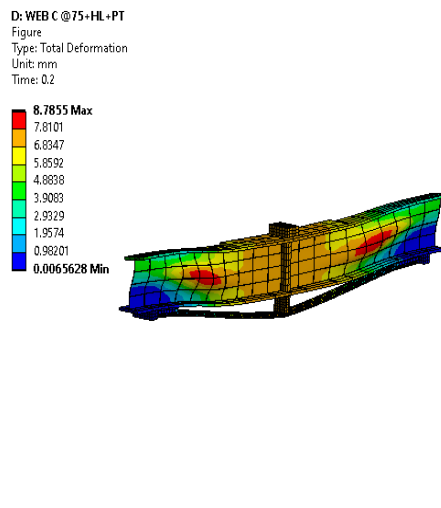


Figure6.3.3: Total Deformation

Web corrosion 75%+hybrid laminates + posttensioning

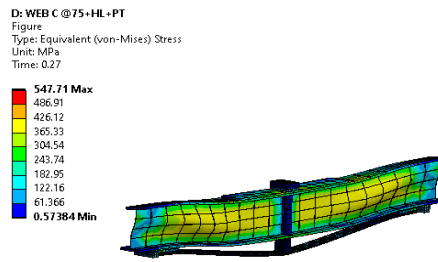


Fig6.3.4: Equivalent stress

Without corrosion damage

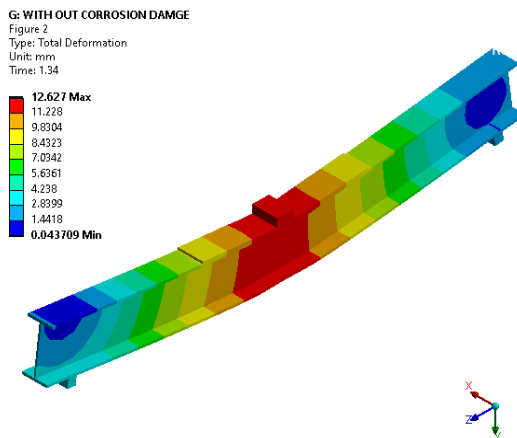


Figure6.3.5.1 Total Deformation

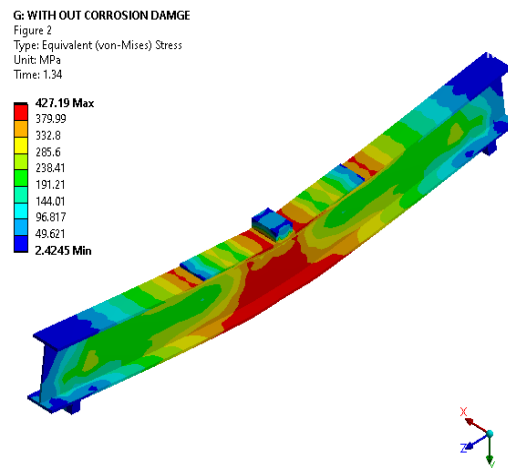
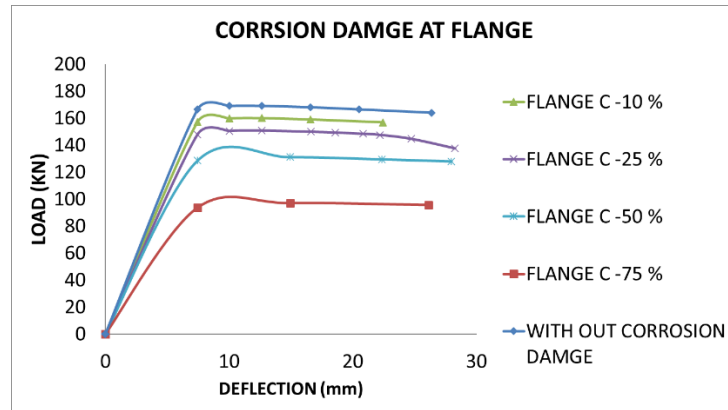
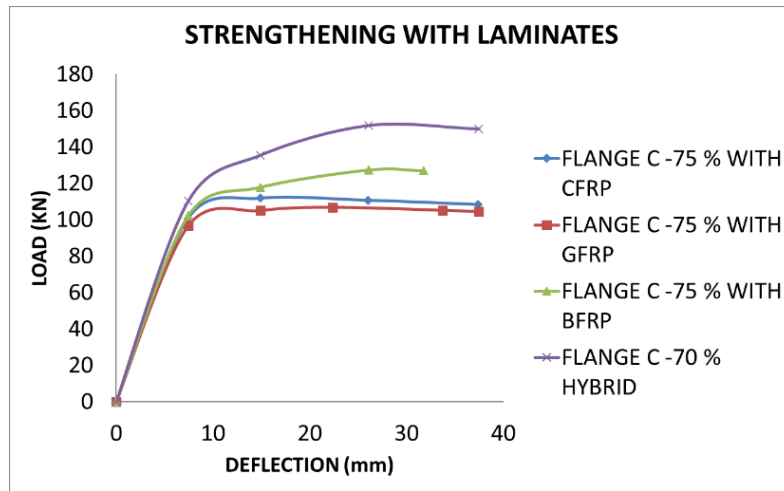


Fig6.3.5.2: Equivalent stress

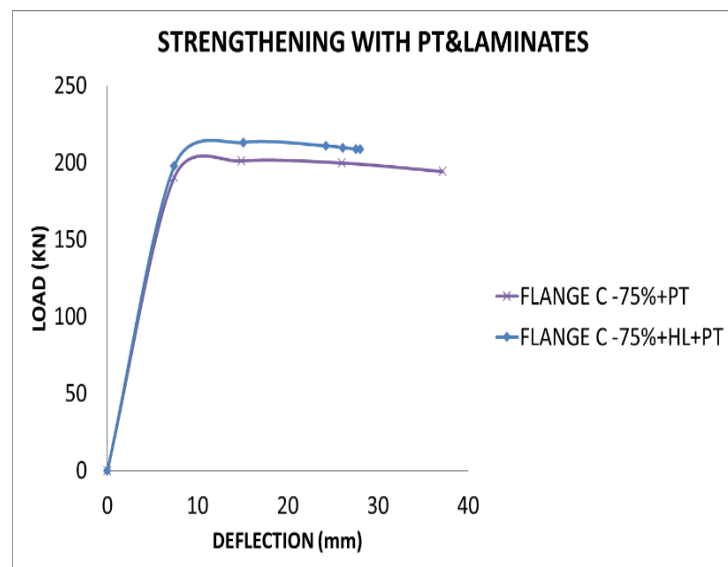
Load deflection graph of flange



Graph 6.4.1:Corrosion damage at flange



Graph 6.4.2:Strengthening with laminates



Graph6.4.3: Strengthening with posttensioning & laminates

Bar diagram of flange

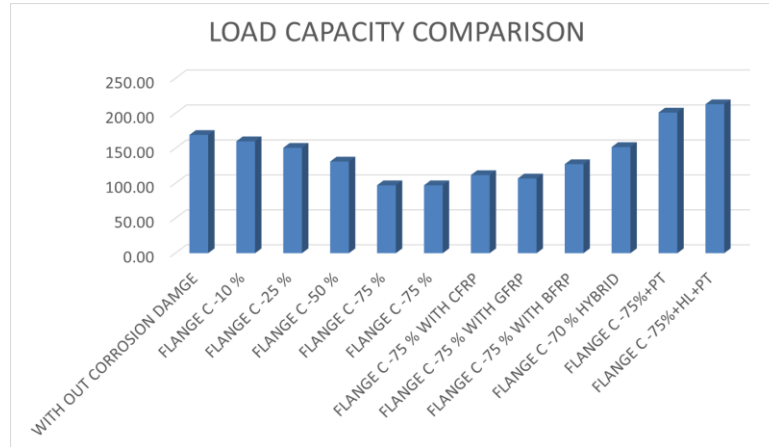


Figure6.5.1: Load capacity comparison

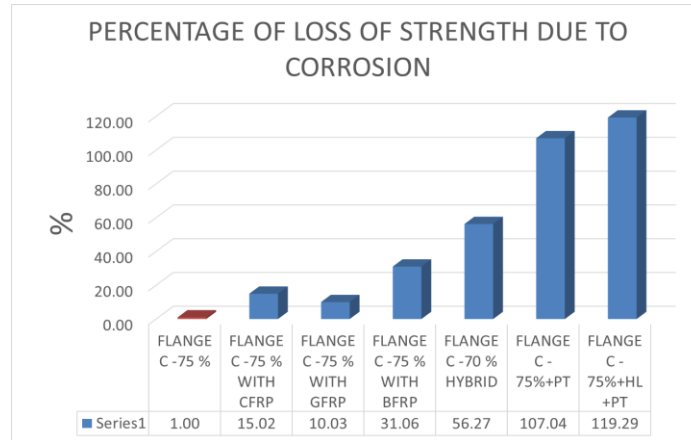


Figure6.5.2:Percentage of loss of strength due to corrosion

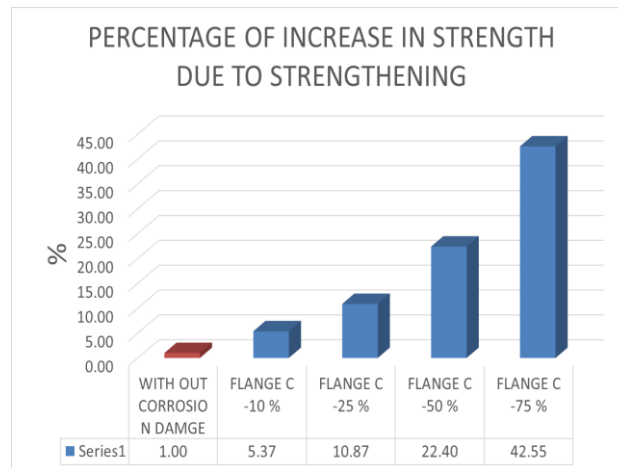
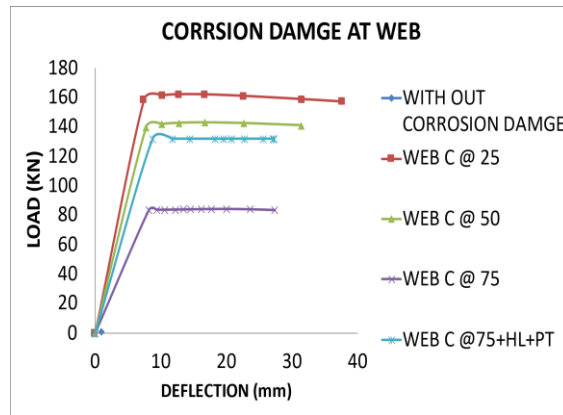


Figure6.5.3:Percentage of increase in strength due to strengthening

Load deflection graph of web



Graph6.6:Corrosion damage at web

Bar diagram of web

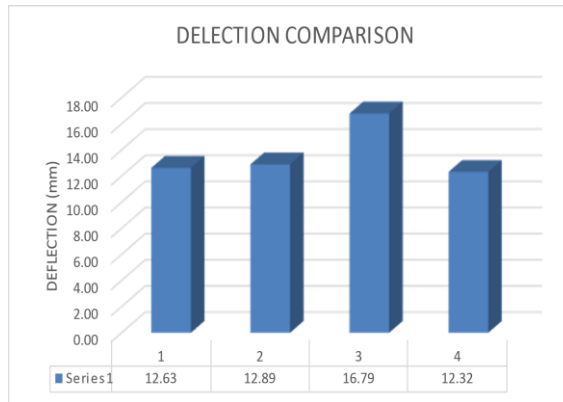


Figure6.8.1:Deflection comparison

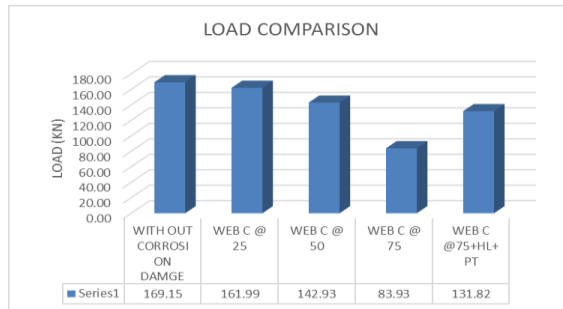


Figure6.8.2: Load comparison

CONCLUSION

Case of flange

Considering the strength loss condition on the flange without corrosion damage case, in beam with crack and surface corrosion we are getting a

maximum strength loss of 42.55% in flange C - 75%.

While some other cases have strength gain, considering the strength gain on flange without corrosion damage there are 4 cases:

1. On all the cases of retrofitting of beam with single layer laminates, i.e., 75 % of

retrofitting with CFRP, GFRP, BFRP .out of these the maximum strength gain is seen in 75 % of retrofitting with BFRP giving value of 31.06.

2. On the case of retrofitting with the hybrid laminates with composition of CFRP, GFRP, BFRP we are getting about 56.27 % of strength gain.

3. On the case of retrofitting with post tensioning effect we are getting about 107.04 % of strength gain.

4. On the case of retrofitting with the hybrid laminates and combination of post tensioning effect we are getting about 119.29 % of strength gain.

Case of web

Considering the strength loss condition on the web without corrosion damage case, in beam with

crack and surface corrosion we are getting a maximum strength loss of 22.40 % in web C -75%.

considering the strength gain on the case of retrofitting with the hybrid laminates and combination of post tensioning effect we are getting about 57.07 % of strength gain.

FUTURE SCOPE

This current work is limited to modelling and analysis of steel beam corroded at different levels. further studies can be made under prepacked condition also and in the case of web corrosion. it can be improved by providing web stiffening method will control the buckling of web and improve the moment capacity.

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