# IMPROVING AXIAL LOAD CARRYING CAPACITY OF COMPOSITE I-BEAM SECTION

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***Abstract*: Rusting of *Polyurethane (PU) coated steel sample which is used in most of the chemical industries has become a problem requiring necessary attention and corrective prevention method. Composite materials are looked at as the alternatives to address this issue. As these composites are not attacked by the chemicals in the industries, acids in present problem. However, composites have complex manufacturing processes and need high cost. The glass fibre plates, composites, cut in to the necessary lengths and dimensions. Then joined at Web Flange Joint (WFJ) with the help of adhesives to reduce the process complexity and cost. It is observed that Huntsman Araldite gives better results as adhesive to be used at WFJ. This is validated using Finite Element Analysis (FEA) with ANSYS tool. The Hundsman Araldite failure strength is much better at the WFJ area. In addition to this, cleats are used with 4 mm, 12 mm for increasing the WFJ area and improve the load carrying capacity of the composite I- Beam. The results of experiments have clearly shown that the glass fibre immersed in the acidic bath solution for certain period has no reaction as such. Hence shown much improved resistance to acidic attack and no rusting as such. Appreciable correlation between experimental and analytical results indicated improved performance of Composite Beam in given chemical (acidic) environment. It is recommended to use the composite I – Beams in acidic environments in place of steel beams to have improved rusting behaviour and lonf life of the beams.***

***Keywords: Acidic environment, Composite I-Beam, FEA with ANSYS, Glass fiber composite, Hundsman Araldite Adhesive.***

## I. INTRODUCTION

TheI-beamismadebytwodifferentsectionhorizontalelementiscalledasflangeandtheverticalelementiscalledasweb. I – beam is known by variety of commercial names in the application industries, withanHorIshapecrosssection.Theflangesresist the bending moment and the webresistsshearforcesexperienced bythebeam.As suggested by the beam theories, the I beams are very efficient in case of shear forces and bending moments. However, the cross section of these beams is inefficient in case of torsional stresses or twisting moments. Hence hollow sections are suggested in such loading conditions for these beams to get improved strengths.

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There are two different processes used to make the I-beam sections. 1. Plate girder made by welding plates. 2. Rolled I-beam, made by extrusion,coldrolling,hotrolling.The major application areas of these beams are construction work in civil engineering work,mechanicalindustry,chemical,and automobile. In the present proposed work, I-beam which isused in chemical factory for stirrer mounting mechanism, is subjected to study.Fig.1showsthatthegeometryofI-beamistakenfromISMB80standardforusingthesampleofstirrermountingmechanism. Height of the I-beam is 80 mm, flange width 50mmand Web and Flangethicknessis 5 mm.

Construction work, chemical industry, aircraft industry, automobile bodies are the major application areas where I beam are the structural members. In larger sections this I-beam is made up of steel withPU coating Web-flange junction of that beam is joining bywelding or nut bolt joint. This I beam is completely immersedintotheacid, named benzoinicacid. After certain duration, the PU coating shows rusting, as a result of reaction of the acidic environment with the base steel. This affected beam loses its utility and becomes a waste, cannot be used for any other application in future. Hence, as an alternative to this, the I-Beamwithcompositebeam, made upofepoxyglass fiber material. However, the failure is mostly observed at the Web Flange Joint.

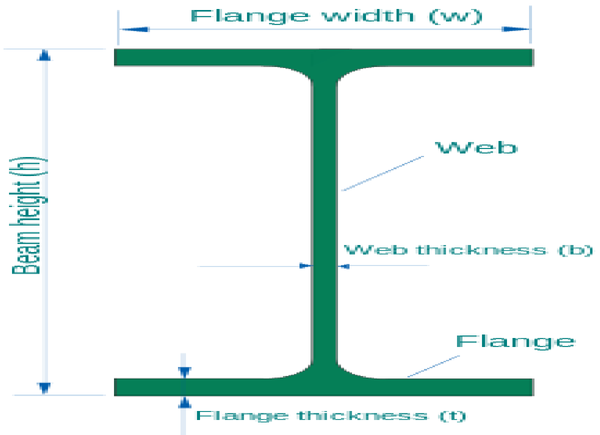


Fig.1.GeometryofIBeammodel

Adhesives are used to prevent this problem occurrence.Therearetwotypeadhesivesused1^st isAraldite2015and2^nd isHuntsmanaraldite. A choice is made between these two adhesives. The stirrer and it's motor are mounted on

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that beamandstirreris rotated at5-6rpm. The beam observed to be failing after some time at WFJ, the complete structure is immersed is inside the acidic solution. The area at the joint is less and causing more stress concentration, which leads to failure. Hence it is suggested to use cleats of 4 mm, 12 mm, 16 mm at the joint to increase the area and cause more strengthening.

## II. METHODOLOGY

The main object of this research work is to obtain thestructuralthe design of Ibeam, usingreinforcedepoxyglassfibercompositematerials. This will address theproblemofchemicalreaction with steel. This will eliminate the WFJ failure with application of theadhesive.The mathematical calculations are carried out,usingthe empirical relations and conventional design formulae. A model is constructed to simulate the geometry and material properties of composite I Beam. This model is adapted as Finite element model in ANSYS workbench. Finemesh with higher order element is generated to achieve themeshconvergence.This epoxy glass fiber composite I beammodelisanalysed usingANSYSworkbench.

## III. PROBLEMSTATEMENT

It is observed in normal practice, that, the I beam is completely immersed into the acid. This acid is benzoinic acid and after some time the PU coating isshowing rust on its surface.Thisis effect of reaction of the acid with I beam material i.e. steel.

As we know in I beam structure, shear resistance is provided by the web while the bending moments are resisted by theflanges. Most of the times failure occurs at joint section of web and flange, known as web – flange joint (WFJ). Hence, this WFJ is an essential part of analysis in identifying the failure cause and its remedial action.

Hence this paper attempts to findoutthedesign of structuralIbeam,using reinforced epoxy glass fiber composite materials. As epoxy glass fiber is resistant to the acidic attack. This will address the issue of chemical reaction between the acid and the steel. TocalculatethestressandforceofcompositeIbeamatweb-flangejunctionusingFEanalysis.The failure strength of WFJ is improved by using Huntsman araldite.

## IV. NUMERICALFORMULATION

The type of the composite I-beam in simply supportedtype. I-beam is taken from ISMB 80 standard to be used assample of stirrer mounting mechanism. Height of the I-beamis80mm,flangewidth50mmandWebandFlangethickness5 mm. These dimensions are used for calculating the cross sectional area andthe stressgenerated at Web – Flange - Joint.

**Table-1:DimensionofcompositeI-beam**

| **BeamType** | **Height ofbeam(mm)** | **Widthofflange(mm)** | **ThicknessoWeb(mm)** | **FlangeThickness(mm)** |
|---|---|---|---|---|
| ISMB80 | 80 | 50 | 5.0 | 5.0 |

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As shown in above Table 1 the dimension of compositeI-beam.ThisdimensionofI-BeamisselectedfromtheIndianstandard medium weight beam chart. This beam is ISMB 80&thisdimensionisstandard.

1) **Area of flange and web**=b*d

Where,

b = breadth

d =depth

2) **Totalareaofbeam**=$A_1$+$A_2$+$A_3$Where,

$A_1$&$A_3$=area of flange$A_2$=areaofweb

3) **Total area of beam (A) = 850mm^2**

**Momentofinertia (I)**=$I_1$ +$I_2$+ $I_3$

$I_1$=bd^3/12+$A_1$($Y_{max}$–$Y_1$)Where,

$Y_{max}$ = Distance from bottom to N.A$Y_1$=distance from flange bottom to

flange N.A**Momentofinertia(I)=7.646E6mm^4**

Stress=P/A

Where,P=force

A=Areaofbeam

## V. FINITEELEMENTANALYSIS(FEA)

The finite element model of compositeI-beam is analysed using ANSYS. The finite element analysis techniques applied inthisworkwereexplainedinatypicalFEA.Consequently 80%-90% of the time is spent to find the best parametersettings.Finally,athreedimensional,compatibleFEAmodelwascreatedinANSYSworkbench,andtheresultswerecomparedwith thephysicaltestresults. The geometry and material properties were same during eithr analyses to verify the accuracy of the FEA model.

### Material Properties

**Table-2:PropertiesofglassFiber-ReinforcementMaterials**

| FiberProperty | GlassFibers |
|---|---|
| Diameter(µm) | 8-14 |
| Density(kg/m3) | 2560 |
| ModulusofElasticity(GPa) | 76 |
| Tensilestrength(GPa) | 1.4-2.5 |
| Elongation at fracture(%) | 1.8-3.3 |

AsshowninaboveTable2showsthatthematerialpropertiesof material of glass fiber which is used as reinforcementmaterial.

**Table-3: Properties of Epoxy matrix Materials**

| MatrixProperty | Epoxy |
|---|---|
| Density(kg/m3) | 1100-1400 |
| ModulusofElasticity(GPa) | 03-Jun |
| TensileStrength(GPa) | 0.035-0.10 |
| CompressiveStrength(GPa) | 0.1-0.2 |
| ElongationatFracture(%) | 01-Jun |

As shown in above Table 3 the material properties of Epoxyand which is used as matrix material for producing the glassfiber epoxyresinmaterial.

FEmodelinformation:

The geometric model is built to simulate the actual stirrer mounting mechanism, as part under study.The boundary conditions also resemble to the actual loading conditions.Hence,a non-linear FEA has been carried out to to achieve the high level of accuracy. Multi-dimensionalstress - straincurve,frictionalcontactbetweenthe matingpartsandgeometricnon- linearityhasbeendefinedin FE model. ANSYS workbench is used to carry out this non-linear analysis. Firstly, finite element analysis has beencarriedoutoncurrentdesign(baselinemodel).Thefinemeshisused so asto increase the accuracy of results.

2DModeling ofI-Beam:

CAD software like CREO which is used for generate 2Dmodel of the project .We can use CREO for generate theI-beam model and which is converted into IGES format.Fig2 showsthattheCreomodeloftheI-beam.

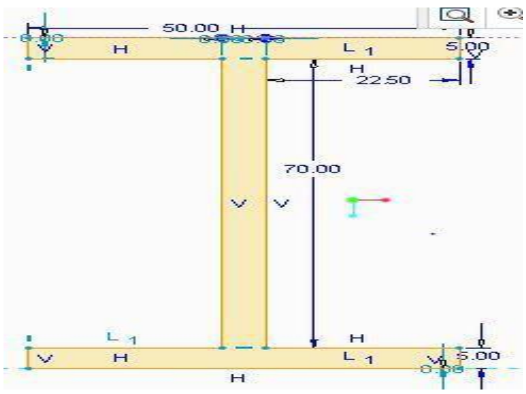


Fig.2.Creo design of I beamLoadsandBoundary conditions

This I-beam is used in acid chemical factory for stirrermounting mechanism in these flanges are connected at thetank&theloadbearingismountedatthewebinthisoneendofbeamisfixedandloadisappliedatanotherendthisloadisthe tensile. This load is the motor and stirrer weight which ismountedattheI-beam.Loadandboundaryconditionisshowninthe Fig.3.

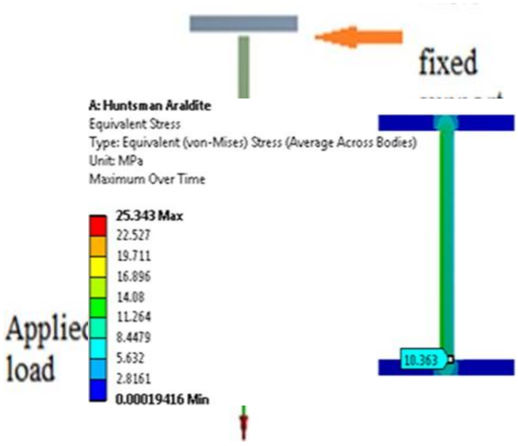


Fig. 3. Loads and Boundary conditionsAnalysisresultsof I-beammodel:

TheconventionalmodelisdevelopedintotheCREOsoftwareandthismodelconvertedintoIGE Sformatwhichisimported into the ANSYS software for the analysis purpose.There are two adhesive used for joining the WFJ 1st one isAraldite2015and2ndoneisHundsmanaralditeandthenfindoutwhichbetter forjoiningWFJ ofcompositeI-beam.

I-BeamwithAraldite 2015 Adhesive:

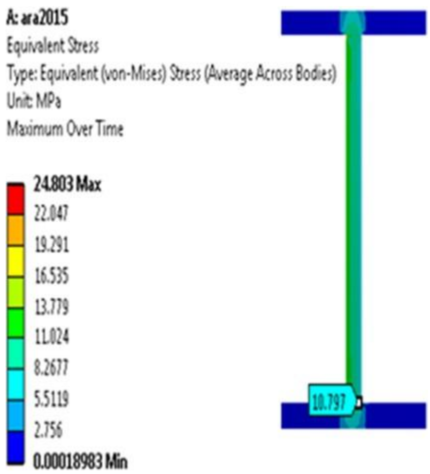


Fig.4.VonmissesstresswithAraldite2015

The above Fig.4 shows the Von Mise stress plot. The maxVon mise stress occurred on WFJ is 10.79 MPa and loadcarryingcapacityis14945N.

I-Beam with Huntsman Araldite Adhesive

FollowingFig.5showstheVonMisestressplotandmaxloadcarring capacity plot. The max Von mise stress occurred onWFJ is10.363 MPaandload carryingcapacityis15269 N.

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Fig.5VonmissesstresswithHundsmanaralditeAnalysisresultsof nonlinearmodel

Now in this step, FE model is solved by considering thetwodifferentadhesivewithcompositeI-beam.Table.4showsthat the maxi stress concentration at WFJ of the I-beam withAraldite2015and Hundsmanaraldite.

Table-4:StressconcentrationatWFJ of I-Beam

| Sr. No | I-Beamwith adhesive | Stress (MPa) |
|---|---|---|
| 1 | Araldite2015 | 10.79 |
| 2 | Hundsmanarad ite | 10.36 |

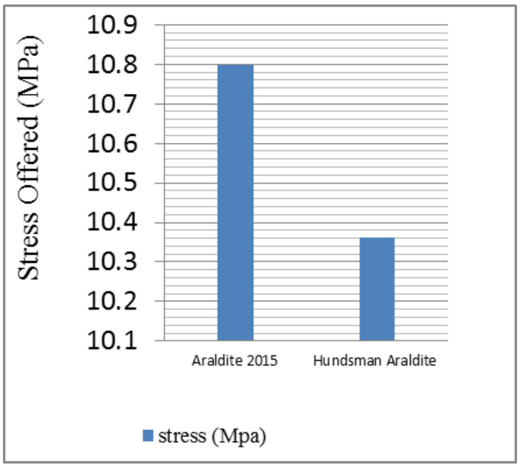


**Fig.6. Stress concentration of I-beam at WFJ withadhesive**

AsshowninaboveFig.6thegraphicalrepresentationofstressconcentrationofI-beamat WFJ withadhesive.

From above Table 4 and Fig.6 shows that thehundsmanaraldite is better adhesive material as compare to the araldite2015 because its stress concentration at WFJ is less and loadcarryingcapacityismore.StressconcentrationAtWFJoftheHundsman araldite is 10.36 MPa and Araldite 2015 is 10.79MPa and force capacity of Hundsman araldite 15269 N andAraldite2015is14945.

In this I-beam structure there is less area ofjoining at WFJthen the beam is failure at the junction to avoid this problemwe can use the extra cleat which dimension is 4mm and 16mmwhich is available in the market for incresing the area ofjioning which is increas the load carrying capacity of thebeam.

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## I-BeamwithHundsmanAralditeand4mmCleat

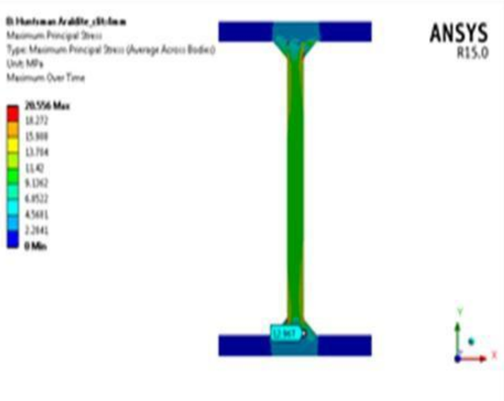


**Fig.7StressofI-beamHundsmanaralditewith 4mmcleat**

As shown in above Fig.7the Von Mise stress plot. The maxVon misestress occured on WFJ is 12.96 MPa and loadcarringcapacityis17018N.

I-BeamHundsmanAralditeAdhesivewith12mmCleat

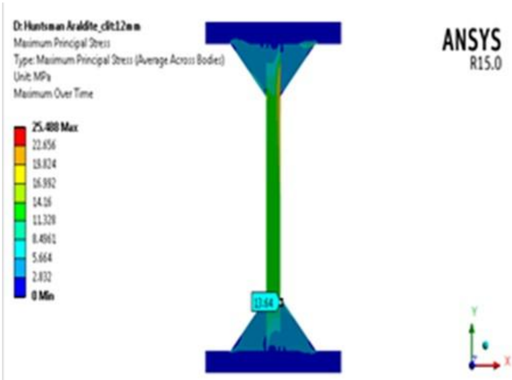


**Fig.8StressI-beamHundsmanaralditewith12mmcleat**

AsshowninaboveFig.8theVonMisestressplot.ThemaxVon misestress occurred on WFJ is 13.64MPa and loadcarryingcapacityis18602N.

**Table-5: Stress carrying capacity of composite I-beam with Huntsman araldite**

| Sr.No | I-Beamspecimen withdifferent sizecleat | Stress (MPa) |
|---|---|---|
| 1 | I-Beam WithHundsmanAraldite,4mmCleat | 12.96 |

| | | |
|---|---|---|
| 2 | I-Beam WithHundsmanAraldite,12mmCleat | 13.64 |

As shown in above Table.5 the maximum stress carrying capacityofcompositeI-beamhuntsmanaralditewith4mmand12mmcleat.

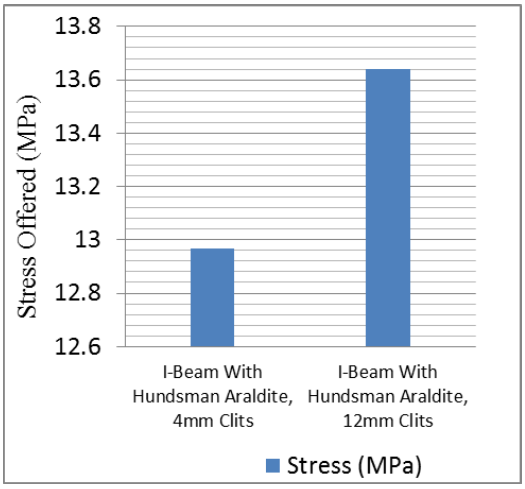


**Fig.9.StresssustainedbyI-BeamHundsmanaralditewith4mmand12 mmcleat**

AsshowninaboveFig.9thegraphicalrepresentationofstresscarryingcapacityofI-beamwith4mmand 12mmcleat.FromtheTable.5andFig.9showsthatwhenweincreasethesizeofcleat then the stress and load carrying capacity of beamincreases.

## I. PHYSICALTESTING:

As shown in Fig.10 the Universal Testing Machines (UTM):InthisprojectwearechooseUTMforphysicaltestingofthespecimen. UTM is used for taking four type of material testandmyprojecttestistensiletest.UniversalTestingMachinesarenamedBecausetheycanperformmanydifferentvarietiesof test on the material. Another name UTM is materialtesting machine and machine can used to test tensile andcompressive properties of materials.Theycan perform thevariousoperationonsamemachinesuchastension,compression, bending etc to examine mechanical propertiesof the material this type of machine is called as UTM. Thereare two type of machines available in market like singlecolumn and two column in our project using two columnmachine.Digitaldisplayandextensometersareusedformeasuringtheforceanddeformationwhichcanalsopresentedingraphicalformincomputeroperated machine.These machines are widely used in industry and allmaterialtestinglaboratory.

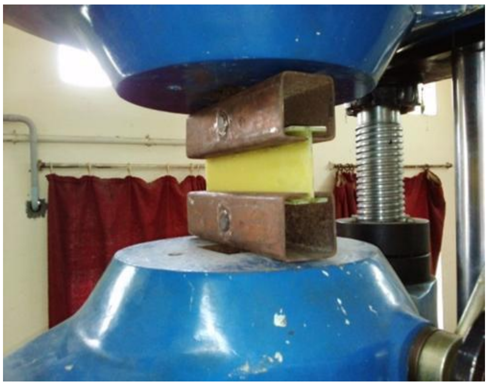

**Fig.10. Experimental set up for tensile test of I-Beam UTM Fig.11 Manufactured sample of I-Beam**

As shown in aboveFig.11 the actual manufactured specimenofI-beamand whichisusedforthetesting.

**1st Sample I-beam with adhesive araldite 2015**

As shown in below Fig.12 and Fig 13 the composite I-beamwith araldite 2015 before and after testing. Test is a tensiletesttheloadisapplied tohydraulicpressure

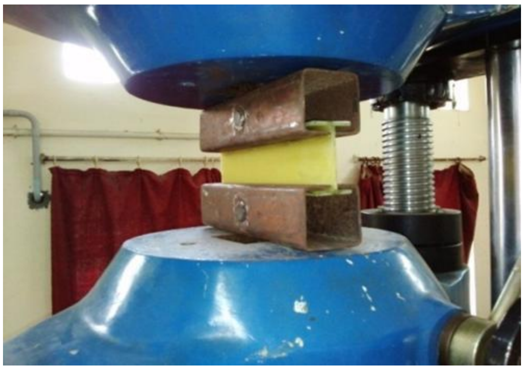

**Fig.12. I-beam with adhesive araldite 2015 before test**

**Fig.13.I-beam with adhesivearaldite 2015 after test2nd SampleI-beamwithadhesiveHuntsmanaraldite**

AsshowninbelowFig.14andFig15thecompositeI-beamwithHuntsmanaralditebeforeand aftertesting.

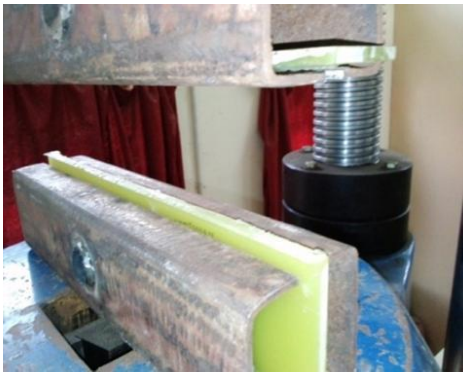

**Fig 14.I-beam with adhesive Huntsman araldite before test**

**Table-6:Experimental stress of I-beam**

| Sr. No | I-Beamwithadhesive | Stress (MPa) |
|---|---|---|
| 1 | Araldite2015 | 9.54 |
| 2 | HudsmanAraldite | 9.83 |

AsshowninaboveTable6thestressgeneratedofmanufacturedI-beamwitharaldite2015andHuntsmanaraldite.

**TensileTestingof3rdI-Beamspecimenwith4mmcleat**

**Fig.16.I-beamwith4mmcleatbeforeTest**

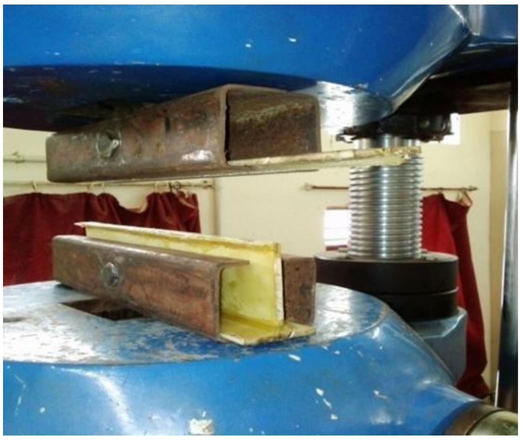

**Fig17.I-beamwith4mmcleatAfterTest**

As shown in above Fig.16 and Fig.17 the composite I-beamHundsmanaralditewith4mmcleatbeforeandaftertesting.

**Tensile testing of 4th I-Beam specimen with 12mm cleat**

**Fig.18.CompositeI-Beamwith12mmcleatbeforeTest**

**Fig.19. Composite I-Beam with 12 mm cleat After Test**

AsshowninaboveFig.18andFig.19thecompositeI-beamHuntsmanaralditewith12mmcleatbeforeandaftertesting.

**Table-7:Max stress of I-beam with cleat**

| Sr. No | I-Beam specimen with different sizecleat | Stress (MPa) |
|---|---|---|
| 1 | I-Beam with hundsman Araldite, 4mmcleat | 12.06 |
| 2 | I-Beam with hundsman Araldite, 12mmcleat | 12.46 |

As shown in above Table 7 the maximum stress sustained byI-beamHundsmanaralditewith4mmand12mmcleat.

## I. RESULTANDDISCUSSION

In this study an attempt ismade to calculate the stressconcentration at WFJ ofjoint. Then numerical formulationhasbeenestablishedwiththehelpofempiricalformulaeandanalyticallystressiscalculated.Thestressconcentrationcalculated byanalytical method is10.36 MPa.

**Table.8:Maximum Stress concentration of I-Beam at WFJ**

| Sr. No | I-Beam Specimens withAdhesive | ANSYS stress( MPa) | Analyticalstress (MPa) |
|---|---|---|---|
| 1 | I-beam with araldite 2015 | 10.78 | 9.5 4 |
| 2 | I-beam with Hundsmanaraldite | 10.36 | 9.8 3 |

Table 8 shows that the Ansys and Experimental stresssustainedby theI-beam with adhesive araldite 2015 andHundsmanaraldite .

AsshowninFig.20thegraphicalrepresentationofI-beam Ansys and Experimental stress value of I-Beam withadhesivearaldite2015and Hundsmanaraldite

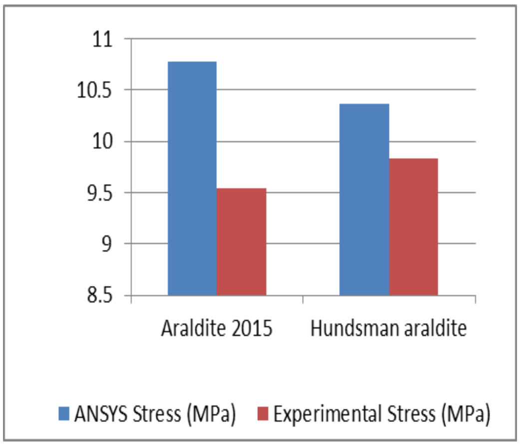


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**Fig.20 Maximum Stress concentration of I-Beam at WFJ**

From Table 8 and Fig 20shows that the Hundsmanaralditeisbetteradhesiveforjoiningthe WFJbecausethereislessstressconcentratinnas comparetoaraldite2015.

In next step to increase the stress and load carrayingcapacityofcompositeI-beamhundsmanaralditewiththehelpofcleat.Table9showsthattheAnsysandExperimentalstresss ustainedby I-beam with the different size of cleat. Size ofcleatis4mmand 12mm.

**Table-9:MaximumStressSustainedByI-Beamwithcleat**

| **Sr.No** | **I-BeamHundsmanaralditewithcleats** | **ANSYS Stress(MPa)** | **AnalyticalStress(MPa)** |
|---|---|---|---|
| 1 | I-beamwith4mmcleat | 12.96 | 12.067 |
| 2 | I-beamwith12mmcleat | 13.64 | 12.46 |

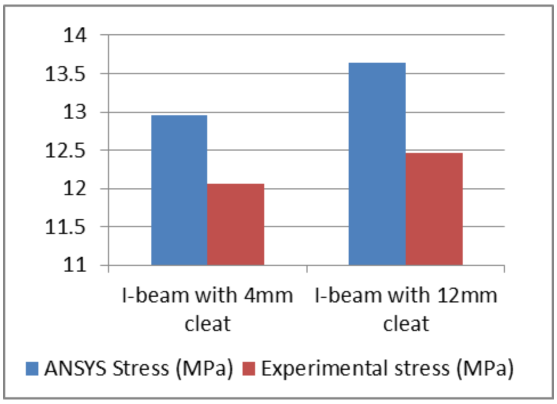


**Fig.21MaximumStressSustainedBy I-Beamwithcleats**

Fig.21 shows that the graphical representation of Ansysand Experimental stress sustained by I-beam. Table 9showsthatthewhenweincreasethesizeofcleat thenthestressandload carryingcapacityof beam.

The physical testing is carried out to verify the resultsobtained from finite element analysis. From physical testingtheobservedstressatWFJofI-beamwithhundsmanaralditeis9.83MPaandandwithcleat4mmis12.06and12mmis12.46MPa.

All the results obtained in this study are tabulated infollowingTable

**Table-10: Result summary**

| I-beamwith | Stress MPa | |
|---|---|---|
| | FEA | Exp |
| Araldite2015 | 10.78 | 9.54 |
| Hundsman Araldite | 10.363 | 9.83 |
| Hundsman Araldite with 4mm | 12.96 | 12.06 |
| Hundsman Araldite with 12mm | 13.64 | 12.46 |

Physical testing results of baseline model it is observed thatthere is only 1.43% difference with FEA results. For themodel confirmation testing is to be carried out FE analysisresultsand physical testingresults.

## II. CONCLUSION

Thepresentworkhassuccessfullydemonstratedtheapplication of Design of experiment. The final conclusionsarrived,attheend ofthisworkare asfollows:

CompositeI-Beamwillbebestoptioninchemicalfactorybecausethereisnoreactionwithacid.Also,itsmainadvantageislowweightascomparedto steel.

The composite I-beam with Hundsman Araldite is betterthan I-beam with araldite 2015 because there is less stressconcentrationatWFJ andloadcarryingcapacityismore.

Thestressandloadcarrayingcapacityofcompositel-beam with hundsman araldite can be increased by attachingdifferentsizecleatsto web-flangejunction.

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