Design and Analysis of Sandwich Structure of Single Girder Electric Overhead Travelling Crane Girder for Weight Reduction

K. H. Kuber [#1], V. L. Bhanavase [#2], F. B. Sayyad [#3], V. G. Patil[#4]

Department of Mechanical Engineering, Paravatibai Genba Moze College of Engineering,
Pune, India.

***Abstract*-A structural sandwich consists of two thin face sheets made from stiff and strong relatively dense material such as metal or fiber composite bonded to a thick light weight material called core. This construction has often used in lightweight applications such as aircrafts, marine applications and wind turbine blades. Sandwich structure is used in heavy weight applications such as electric overhead crane for reduction of weight, reduction of deformation, increasing of strength. In this paper the structural analysis of X core, Vf core with stainless steel (C40) face sheets and core (C40) is done using ANSYS work bench. compressive strength, deflection, is compared with theoretical value. The model of the I sec, X core, and Vf core sandwich structures are done in CATIA and the weight, equivalent stress, deformation are analysed of sandwich structure and this values compare to I section beam.**

Key Word: Sandwich structure, Universal Testing Machine, Electronic Overhead Transfer Machine

I. INTRODUCTION

Bijlaard studied sandwich optimization for the case of a given ratio between core depth and face thickness as well as for a given thickness[1] Various analyses on sandwich structure are Kevin J. Doherty investigate sandwich panels of metallic face sheets and a pyramidal truss core subjected to panel bending and in plane compression testing to explore the effects of relative core density and process analysis of honeycomb structures to develop an equivalent orthotropic material model that is substitute for the actual honeycomb core.[3] . Jukka Saynajakangas make a review in design and manufacturing of stainless steel sandwich panels and conclude an efficient sandwich is obtained when the weight of the core is close to the combined weight of the both faces[4]. Tomas Nordstrand made an analysis on corrugated board in three-point bending and evaluation of the bending stiffness and the transverse shear stiffness[5]. Pentti Kujala discussed that steel sandwich panels that are welded by laser can save 30-50% weight compared to conventional steel structures[6]. Jani Romanoff presents a theory of bending of laser welded web core sandwich panels by considering factors that effect the total bending response of laser welded web core sandwich plates[7]. Pentti Kujala made analysis on metallic sandwich panels which are laser welded have excellent properties with light weight having more applications[8]. Narayan Pokharel determined local buckling behavior of fully profiled sandwich panels which are based on polyurstyrene foam and thinner and high strength steels[9]. Pentti kujala determined ultimate strength of all steel sandwich panels and numerical FEM analysis and development of design formulations for these panels.[10] A.Gopichand Analyzed corrugated sand which panel with stainless steel faces sheets and mild steel as core is done using ANSYS work bench and compressive strength is compared with experimental value For given length and height of the structure increasing the number of curved waves (3 waves to 4 waves) the strength increases effectively. For increase of 4% weight, the strength is increase to 66%[11]

NOMENCLATURE			
σ_c	Permissible stress (N/mm^2)	L	Length of span (mm)
F	Force on each wheel (N)	Mb_{max}	Maximum bending moment (Nm)
l	Contact length(mm)	b	Width of flange(mm)
v_1	Poisons ratio of wheel material	t_w	Thickness of web (mm)
v_2	Poisons ratio of rail material	t_{f1}	Thickness of upper flange (mm)
E_1	Young's modulus of wheel (N/mm^2)	t_{f2}	Thickness of lower flange (mm)
E_2	Young's modulus of rail (N/mm^2)	σ_b	Bending stress (N/mm^2)
r_w	Radius of wheel (mm)	μ	Poissons ratio
ρ	Weight density (Kg/mm^3)	S_{yt}	Yield stress Mpa (N/mm^2)
W	Weight (N)	E	Modulus of elasticity (N/mm^2)
V	Volume (mm^3)	G	Modulus of rigidity (N/mm^2)
I_{xx}	Mass moment of inertia(mm^4)	S_{ut}	Ultimate tensile strength (N/mm^2)
Y_{max}	Maximum height (mm)	$\propto$	Co-efficient of linear expansion (μm/mk^0)
Z_{xx}	Section modulus(mm^3)		

X core and Vf core sandwich structures have been investigated for the overhead crane weight, stress and deflection analyzed. In this paper structural analysis of I section beam and sandwich structures analysed and selected the optimum sandwich structure replace of I section beam. The different sandwich structures investigated are X core, Vf core. Theoretical and analytical (ANSYS) representative cases are discussed in this paper.

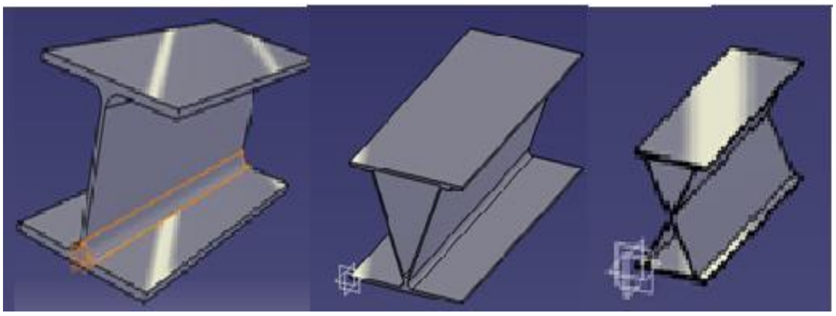

Fig. 1. various sandwich structures studied in this work: I section, Vf core sandwich structure, X core sandwich structure

II. MATHEMATICAL FORMULATION

The self weight, Equivalent stress, and deflection equations are expressed as:

$$\text{Mass density} = \frac{\text{Weight}}{\text{Volume}} = \frac{W}{V} \quad (1)$$

$$\text{Bending stress} = 6_b = \frac{M}{Z} \quad (2)$$

$$\text{Maximum deflection} = Y = \frac{5WL^3}{384EI} \quad (3)$$

The above equations 1, 2, and 3 used for theoretical result of sandwich structure.By using this equation calculated the self weight, bending stress and maximum deflection of sandwich structure.

TABLE I: Theoretical values with I section beam :Equivalent stress, deflection, self weight of sandwich structure

sandwich structure	Load (KN)	Theoretical		Self Weight (kg)
		Deflection (mm)	Stress$\left(N/_{mm^2}\right)$	
I section	22.612	1.6595	50.948	253.00
X core	22.612	1.011	47.948	230.57
Vf core	22.612	1.4195	52.76	240.33

III. ANALYSIS OF SANDWICH STRUCTURE

I section beam is modeled in CATIA. Then the geometry is saved in STP format and imported to ANSYS workbench. In ANSYS Workbench the STP format is imported and geometry will show three contact pairs. Materials properties are given to the geometry. Now mesh the geometry as optimum meshing size, convergence study optimum mesh size selected and optimum mesh size 20 mm. The structural analysis is done by fixing the geometry at both end part of the span of the beam and force 22612 N is applied at top face of the plate. Now by solving the structure the deflection and Equivalent stress are noted.

A. Deflection of sandwich structure:

After meshing solution is solve. The solution took about 30-40mins and after a successful solution, there could be retrieved a multitude of results for the crane static structural response.

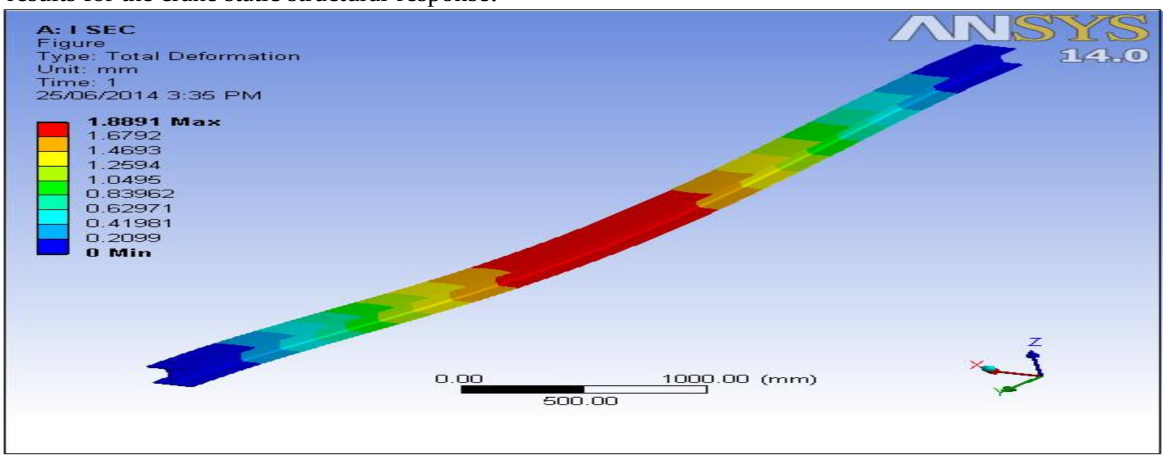

Fig. 5 Deflection of I section

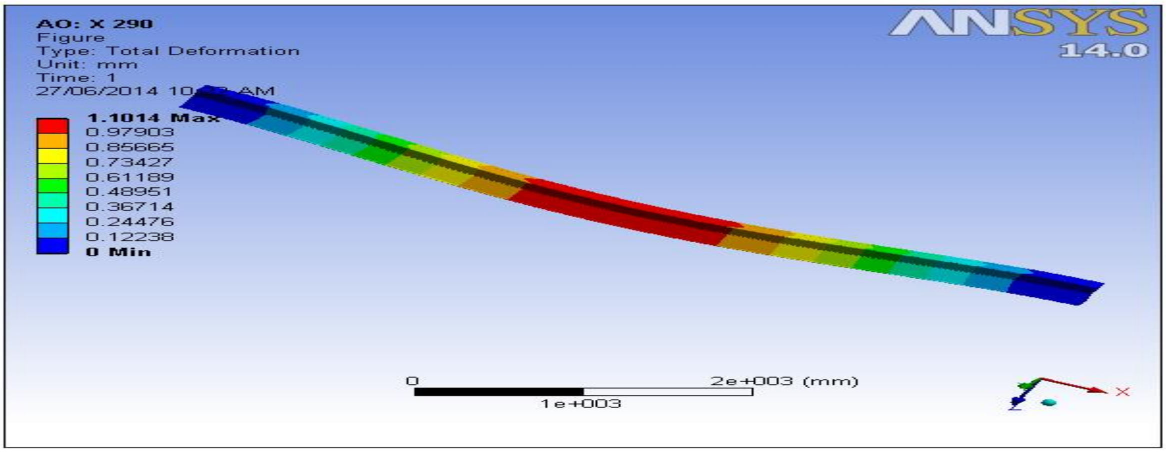

Fig. 6 Deflection of X core sandwich structure

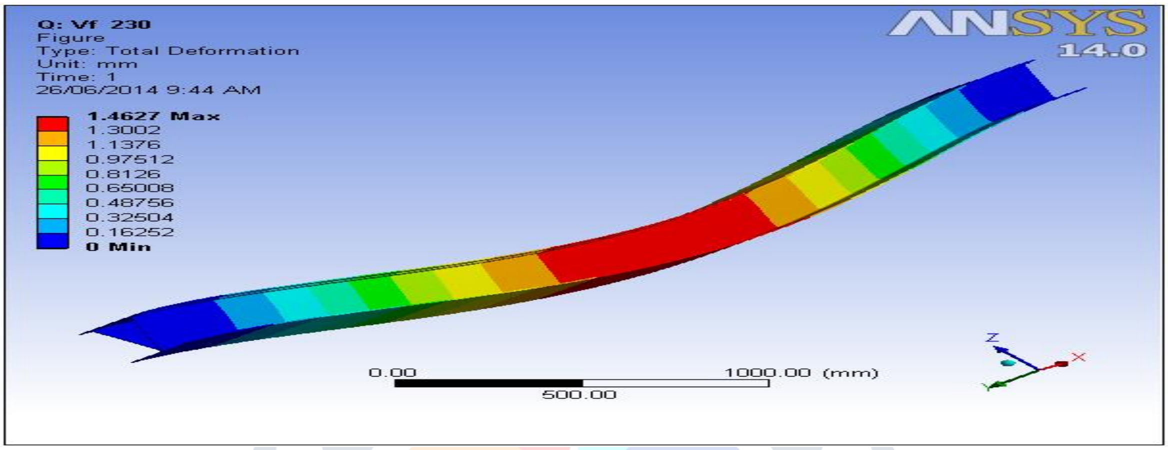

Fig. 7 deflection of Vf core sandwich structure

B. ***Equivalent stress of sandwich structure***

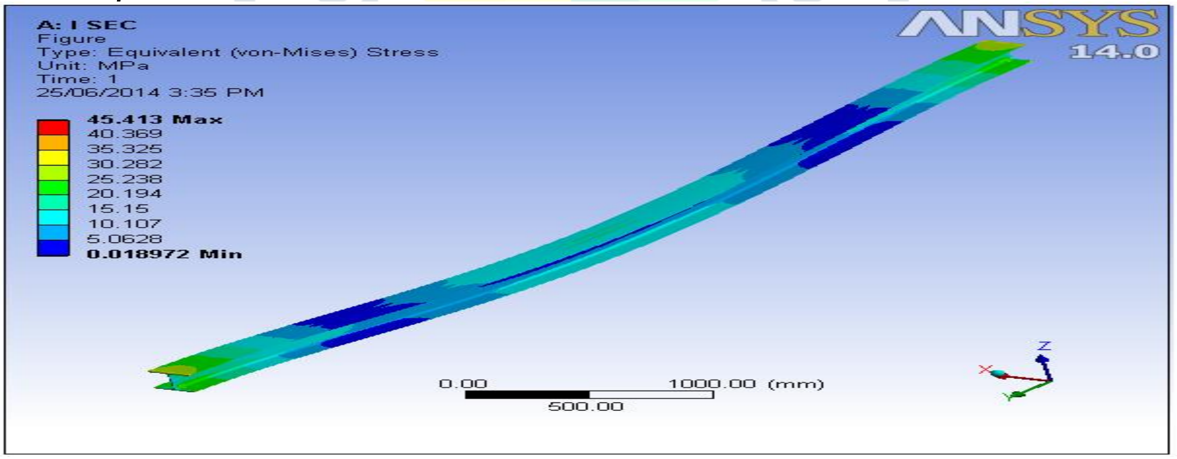

Fig. 8 Equivalent stress of I section

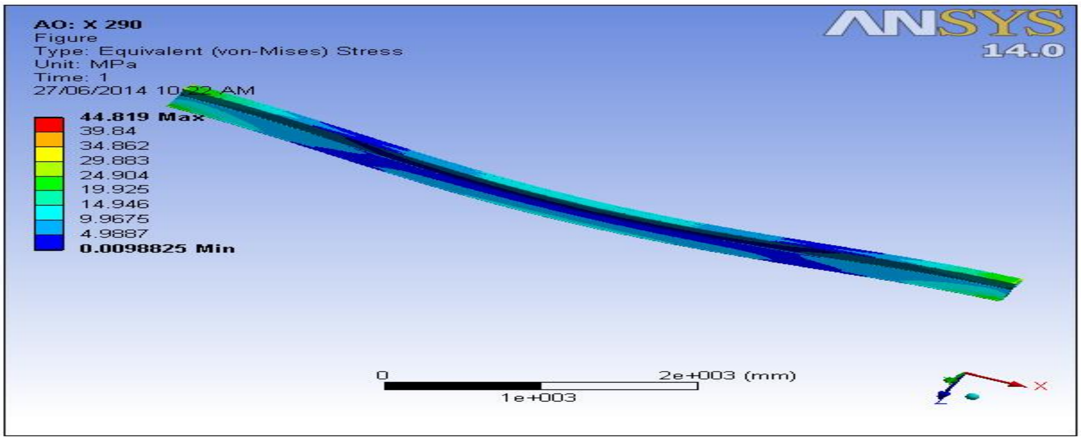

Fig. 9 Equivalent stress of X core sandwich structure

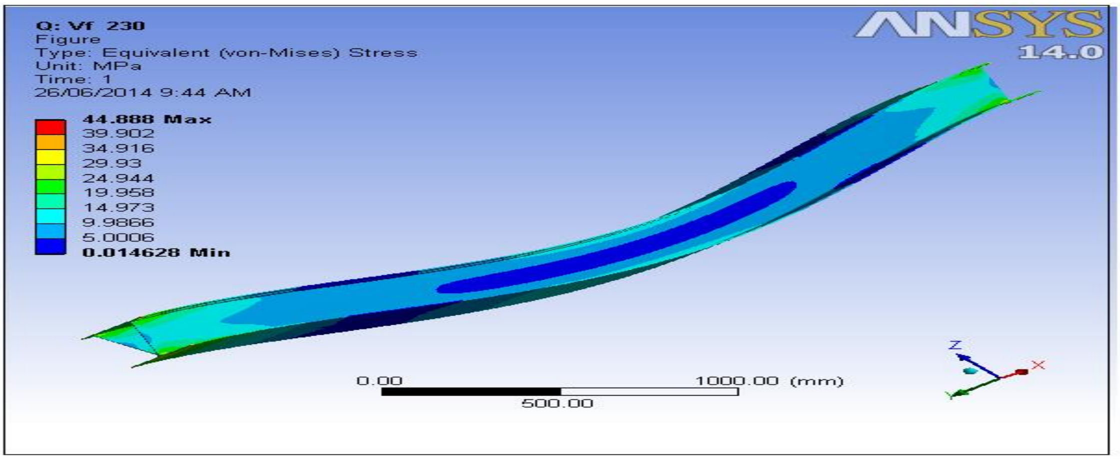

Fig. 10 Equivalent stress of Vf core sandwich structure

IV. VALIDATION

The analytical values of deflection of I section beam is 1.8891 mm, analytical values of sandwich structure is 1.1014 mm (X core)and 1.4627 mm (Vf core). Using the geometric parameters, the self weight of X core sandwich structure Vf core sandwich structure, and I section beam calculated the theoretical values, shows that our computed values are in good agreement with that of the theoretical values of deflection and stress

TABLE III: Validation with ANSYS workbench : Equivalent stress, deflection of all structures

sandwich structure	Deflection(mm)		Stress$\left(N/_{mm^2}\right)$	
	ANSYS workbench	Theoretical	ANSYS workbench	Theoretical
I section	1.8891	1.6595	45.413	50.948
X core	1.1014	1.011	44.819	47.948
Vf core	1.4627	1.4195	44.888	52.76

V. RESULTS AND DISCUSSIONS

ANSYS result and Theoretical result of all sandwich structure of span 6m. Comparison between the theoretical and analytical result of I section, X core sandwich structure and Vf core sandwich structures of deformation and equivalent stress.

TABLE IIIII: Validation with I section beam : Equivalent stress, deflection, self weight

sandwich structure	Load (KN)	ANSYS workbench		Theoretical		Self Weight (kg)
		Deflection (mm)	Stress$\left(N/_{mm^2}\right)$	Deflection (mm)	Stress$\left(N/_{mm^2}\right)$	
I section	22.612	1.8891	45.413	1.6595	50.948	253.00
X core	22.612	1.1014	44.819	1.011	47.948	230.57
Vf core	22.612	1.4627	44.888	1.4195	52.76	240.33

In table III shows the deflection and self weight of X core sandwich structure is small as compare to the investigated sandwich structures. In sandwich structure the weight of X core sandwich structure is 230.56 kg is small as compare to the Vf core sandwich structure and I section. The deflection of X core sandwich structure is 1.011 mm is also small as compare to I section, Vf core sandwich structure. Then X core sandwich structure is optimum sandwich structure as compare to existing section(I section beam)

A. ***Weight optimization:***

The aim of this investigation is I beam weight reduction replace the sandwich structure. The weight of existing I section beam is 253 Kg and weight of optimize sandwich structure is shown in fig 6.1

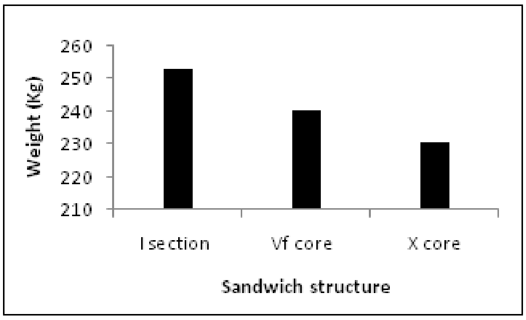

Fig.4.validation with I section beam: self weight

VI. CONCLUSION

The sandwich structure models in CATIA are efficiently imported into ANSYS workbench structural analysis is done and max stress and total deflection is observed. For given span of the structure, decreasing the weight of sandwich structure (I section beam to X core sandwich structure) also the strength increases and deflection decreases effectively. For decrease of 8.87 % weight, the strength increases 1.3% the total deflection is decreases to 41.70%.We have reduced the overall mass of the girder by 8.87%. As the overall weight of the girder has reduced, the initial cost for the structural building, civil work and electrical consumption for the crane has also reduced.

ACKNOWLEDGMENT

The authors would like to present their sincere gratitude towards the Faculty of Mechanical Engineering in Paravatibai Genba Moze College of Engineering Pune, Kashibai Navale College of Engineering pune and Genaba sopanrao moze College of Engineering, Pune.

REFERENCES

[1] O.T. Thomson et al. (eds), sandwich structures 7; advancing with Sandwich Structure and materials, 3-12..

[2] Kevin J. Doherty, Aristedes Yiournas, Jordan A. Wagner, and Yellapu Murty, "Structural Performance of Aluminum and Stainless Steel Pyramidal Truss Core Sandwich Panels" ,ARL-TR-4867 July 2009.

[3] Aydıncak, İlke " investigation of design and analyses principles of honeycomb structures"

[4] Jukka Säynäjäkangas and Tero Taulavuori, Outokumpu Stainless Oy, Finland "A review in design and manufacturing of stainless steel sandwich panels" stainless steel world oktober 2004

[5] Tomas Nordstrand," Basic Testing And Strength Design Of Corrugated Board And ContainersDivision of Structural Mechanics, LTH, Lund University, Box 118, SE-221 00 Lund, Sweden.

[6] Pentti kujala, Alan Klanac," Steel Sandwich Panels in Marine Applications" PrihvaÊeno, 2005-05-05

[7] Jani Romanoff "Bending Response of LaserWelded Web-Core Sandwich Plates"ISSN (printed) 1795-2239

[8] Pentti Kujala "Steel Sandwich Panels – From Basic Research To Practical Applications" 2Vol. 16/ISSN 0784-6010 2002

[9] Narayan Pokharel and Mahen Mahendran "Finite Element Analysis and Design of Sandwich Panels Subject to Local Buckling Effects"

[10] Pentti kujala "ultimate strength analysis of all steel sandwich panels"Rakenteiden Makaniikka,vol.31 Nrot 1-2,1998,s. 32-45

[11] A. Gopichand, Dr.G.Krishnaiah, B.Mahesh Krishna, Dr.Diwakar Reddy.V, A.V.N.L.Sharma "Design And Analysis Of Corrugated Steel Sandwich Structures Using Ansys Workbench", International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 8, October – 2012.