Theoretical and Experimental Analysis of Sandwich Structure of Overhead Crane Girder for Weight Reduction

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***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 theoretical and experimental analysis of I section and web core sandwich structure with stainless steel (C40) face sheets and core(C40) is done using ANSYS work bench. Compressive strength, deflection, is compared with theoretical analytical (ANSYS) value as well as experimental value (universal testing machine). The model of the Web core sandwich structure is done in CATIA and the weight, equivalent stress, deformation are analysed and this values compare to I section beam.**

***Key Words* - 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]

Web core sandwich structure has been investigated for the overhead crane weight, stress and deflection analyzed. In this paper structural analysis of I section beam and sandwich structure of stress, deflection and weight considered the uniform loading. The Web core sandwich structure investigated for weight reduction. Theoretical, analytical (ANSYS) and experimental representative cases are discussed in this paper.

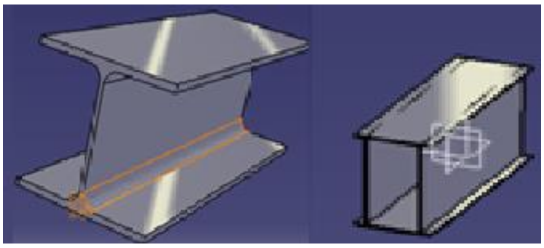

Figure 1. various sandwich structures studied in this work: I section, Web core sandwich structure

Mathematical Formulation

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

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

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

Maximum deflection =Y = $\frac{5WL^3}{384EI}$ (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 1: Theoretical values of deflection, stress and weight of sandwich structure

structure	I section	Web core
Load (KN)	22.612	22.612
Theoretical:		
Deflection(mm)	1.66	0.9
Stress(Mpa)	50.95	43.69
Weight (kg)	253	221.3

II. ANALYSIS OF SANDWICH STRUCTURE

I section and web core sandwich structure 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 von misses 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.

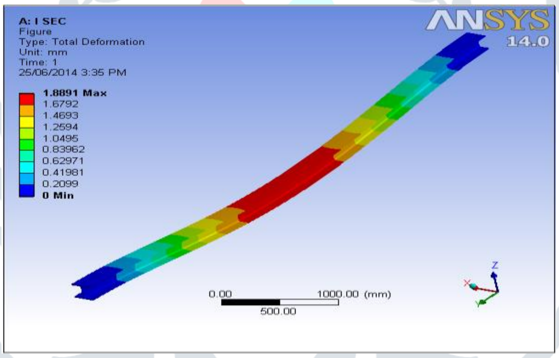

Figure 2 Deflection of I section

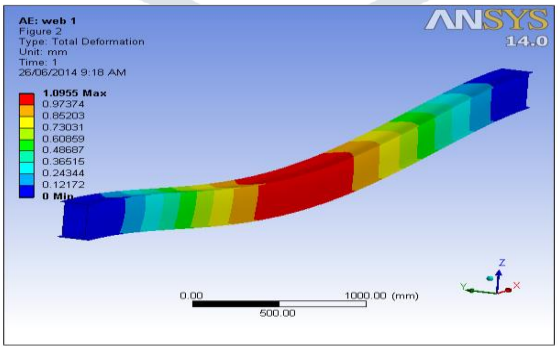

Figure 3 Deflection of web core sandwich structure

B. Equivalent stress of sandwich structure

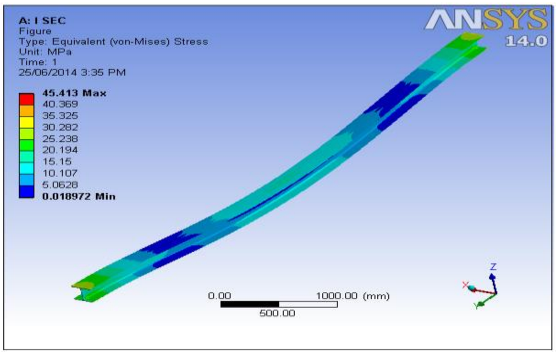

Figure 4 Equivalent stress of I section

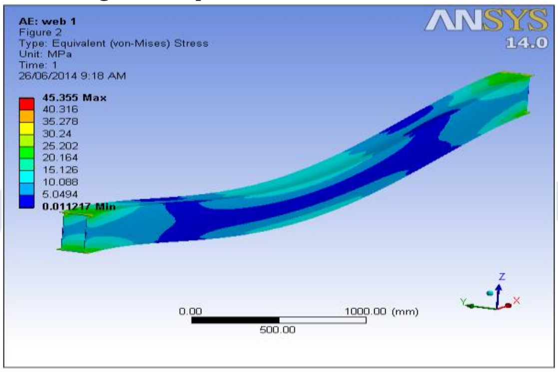

Figure 5 Equivalent stress of web core sandwich structure

III. EXPERIMENTAL SET UP

Load is applied uniformly and deflection and compression strength are noted. Photo1 shows actual experimental set-up of the used in this study. For experimental result 600 mm span model manufactured and results taken.

Photo1 compression test set up

In experimental result of Web core sandwich structure the web core sandwich structure is fixed on universal testing machine load is gradually increases up to 30 KN and deflection is noted.In load 30 KN the deflection is 0.14 mm

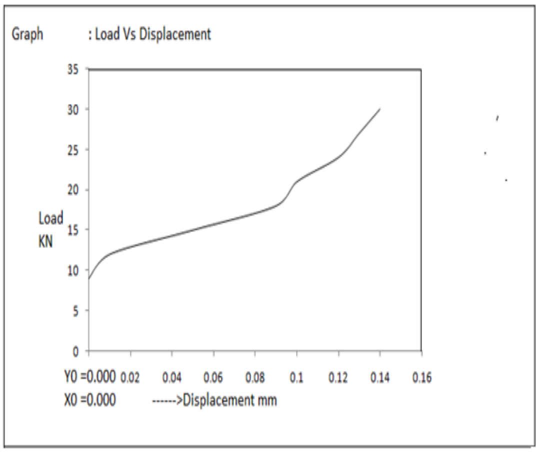

Figure 6 Load Vs Deflection curve of experimental result of web core

IV. VALIDATION

C. Analytical and theoretical validation

The analytical values of deflection of web core sandwich structure is 1.0955 mm, comparing with the theoretical value of web core sandwich structure is 0.901 mm and equivalent stress of web core sandwich structure is in theoretical is 43.69MPa and analytical is 44.355 MPa. Using the geometric parameters, the stress and deflection of web core sandwich structure and I section, shows that our

computed values are in good agreement with that of the theoretical values of deflection and stress.

Table 2 Validation of Theoretical and ANSYS workbench : Equivalent stress, deflection of I section and Web core

sandwich structure		I section	Web core
Deflection (mm)	ANSYS workbench	1.8891	1.0955
	Theoretical	1.6595	0.901
Stress(MPa)	ANSYS workbench	45.413	44.355
	Theoretical	50.948	43.69

D. Analytical and Experimental validation

Experimatal value of deflection of web core sandwich structure is 0.14 mm and load is 30KN.In theoretical value of web core sandwich structure is 0.12mm at 22.612KN load, shows that our computed proportional values are in good agreement with that of the experimental values of deflection.

Table 3 Validation of UTM and ANSYS workbench : stress, deflection of I sec and Web core sandwich structure

	Load (KN)	Deflection
ANSYS workbench	22.612	0.13
UTM	30	0.14

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 and web core sandwich structure of deformation and equivalent stress.

Table 4 Validationof web core and I section: Equivalent stress, deflection, self weight

sandwich structure		I section	web core
Load (KN)		22.612	22.612
Deflection (mm)	ANSYS workbench	1.8891	1.0955
	Theoretical	1.6595	0.901
Stress(MPa)	ANSYS workbench	45.413	44.355
	Theoretical	50.948	43.69
Self Weight (kg)		253	221.34

In table IV shows the deflection, equivalent stress and self weight of investigated web core sandwich structure is small as compare to the I section beam. In sandwich structure the weight of web core sandwich structure is 221.34 kg is small as compare to the I section. The deflection of web core sandwich structure is 1.0955 mm is also small as compare to I section. Then the web core sandwich structure is optimum sandwich structure as compare to existing section(I section beam)

E. Weight reduction:

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

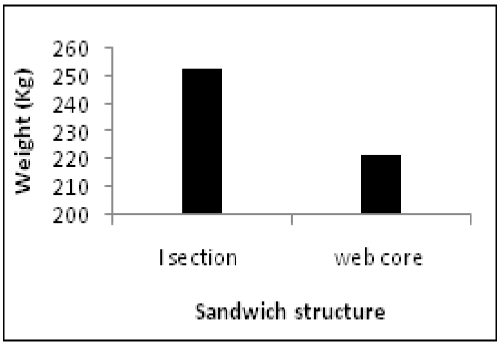

Figure 7 comparison of weight I section and web core

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 Web core sandwich structure) also the strength increases and deflection decreases effectively. For decrease of 12.514% weight, the strength increases 0.13% the total deflection is decreases to 52.30%.We have reduced the overall mass of the girder by 12.514%. 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.

VII. NOMENCLATURE

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

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