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The bending test on Beam of Aluminium alloy, Gray cast iron, Stainless steel and Structural steel using Ansys Workbench 15

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ABSTRACT: In my work presents the result of effect of the varying the load at different materials (aluminum alloy, grey cast iron, stainless steel and structural steel). The simply supported and fixed beam have been subjected to varying load 5000N – 7000 N. cantilever beam has been subjected to varying load 500N-700 N. we got the result in form of Directional Deflection and Equivalent Stresses. This analysis is done by the ANSYS Workbench 14.0 software under the static structural analysis. The results obtained via simulation and mathematical formula based on type of beam and boundary conditions.

KEYWORDS: FEM, Impact of varying Loads, ANSYS Workbench.

I. INTRODUCTION

Past few decades have seen an increasing application of Computer Aided Engineering (CAE) for simulation of bending phenomenon particularly due to development of high computing machines and parallel computing techniques. The increase in safety standards can be attributed to the improvement of structural without bending performance through Finite Element Analysis (FEA). The effect of load on structures is one problem and the second one is of prime importance is the safety of occupants. It seems that occupant safety simulation offers today reasonably accurate result which can save a lot of testing time and overall decision cycle time. Beam is an inclined or horizontal structural member casing a distance among one or additional supports, and carrying vertical loads across (transverse to) its longitudinal axis, as a purlin, girder or rafter. Beams use as shaft with circular cross section which may be supported at both ends with bearing and carrying a load like that pullies, Gears, Dead Weights etc. Therefore in this paper we compared the Mathematical and Ansys Workbench results, plotted the graphs between Mathematical and Ansys Analysis and determined the percentage errors with the help of Formulas and Ansys Workbench 15.0
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II. FINITE ELEMENT ANALYSIS OF BEAM

Finite element analysis (FEA) is one of the efficient and well-known numerical methods for various engineering problems. FEA was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems as cited by Swatantra and Pradeep [1]. For the last 30 years it has been used for the solution of many types of problems. FEA has become an integral part of design process in automotive, aviation, civil construction and various consumer and industrial goods industries, cut throat competition in the market puts tremendous pressure on the corporations to launch reasonably priced products in short time, making them to rely more on virtual tools (CAD/CAE) accelerate the design and development of products. FEA tools are being used to analyse multi-disciplinary problems, including but not limited to structures, thermal and fluid flow, NVH applications, biotechnology etc. [2]. FEA is used to predict multiple types of static and dynamic structural responses.

III. ANSYS DEFLECTION ANALYSIS OF BEAM

The commercial software package ANSYS used as a FEA tool in the stress analysis. The ANSYS program is a powerful, multi-purpose analysis tool that can be used in a wide variety of engineering disciplines [3]. Using ANSYS software can avoid expensive and time-consuming development loops, so the design period is shortened [4]. There are three main approaches to constructing an approximate solution based on the concept of FEA.

- **Direct Approach** This approach is used for relatively simple problems, and it usually serves as a means to explain the concept of FEA and its important steps.
- **Weighted Residuals** This is a versatile method, allowing the application of FEA to problems that’s functional cannot be constructed. This approach directly utilizes the governing differential equations, such as those of heat transfer and fluid mechanics.
- **Vibrational Approach** This approach relies on the calculus of variations, which involves extremizing a functional. This functional corresponds to the potential energy in structural mechanics.

IV. CALCULATION AND RESULTS

A. SIMPLY SUPPORTED BEAM WITH UNIFORM DISTRIBUTED LOAD (UDL)

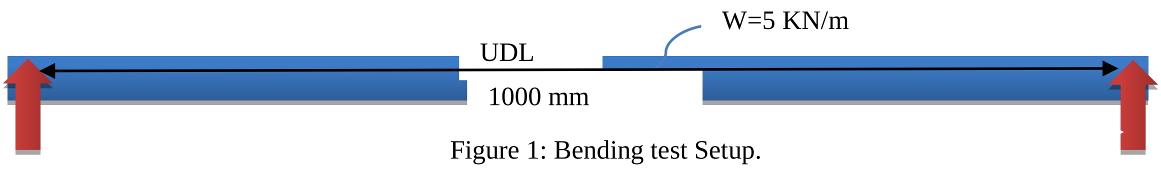

Figure 1: Bending test Setup.

- **MATHEMATICAL CALCULATION**

According to given data we can calculated the maximum deformation (Y), Bending Moment (M) and stress (σ_)

- W = 5 KN/m
  = 5 * 1000 = 5000 N
- L = 1 m = 1000 m
- b = t = 40 mm
- $E = 210 * 10^{3}$ N/ mm^2
- $I = bt^3 / 12$
  = 213333.33 mm^4

- $Y = -5wl^3/ 384 * EI$
  = -1.4532 mm
- $M = (wL^2) /8$
  = (5*1000*1000)/8
  = 625000 N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$
  $\sigma = 58.59\ N/\text{mm}^2$

- **MATHEMATICAL RESULT**

Directional Deflection	**-1.4532 mm**
Equivalent Stress	**58.59 Pa**

- **ANSYS ANALYSIS AND RESULT:**

Ansys Result Shown in the below figure –

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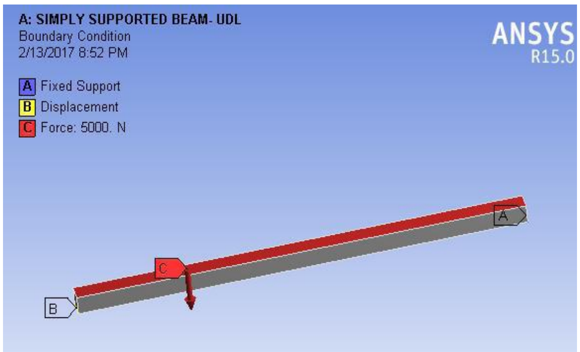

Figure 2: Boundary Condition

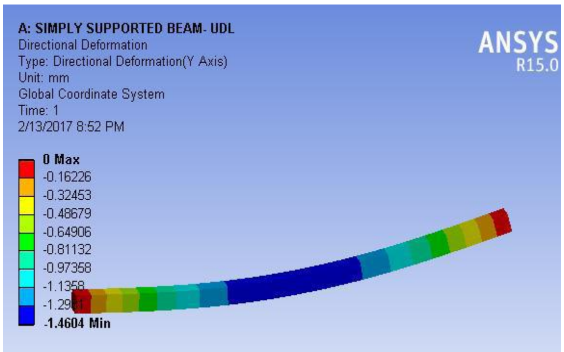

Figure 3: Directional Deformation Diagram

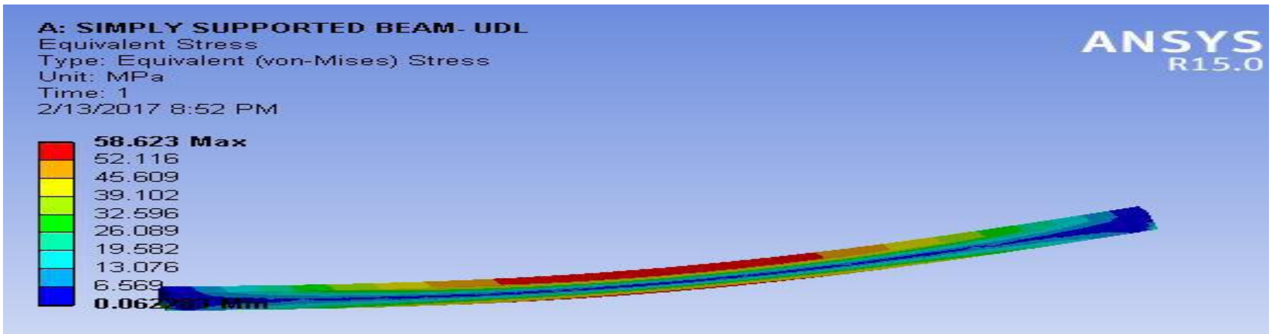

Figure 4: Bending Stress Diagram.

B. SIMPLY SUPPORTED BEAM WITH CENTRAL LOAD

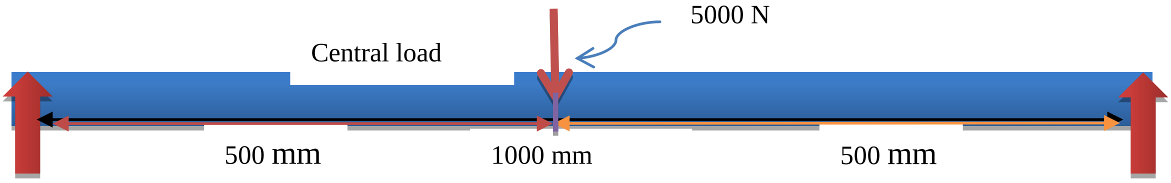

Figure 5: Bending test Setup

➢ MATHEMATICAL CALCULATION

According to given data we can calculated the maximum deformation (Y), Bending Moment (M) and stress (σ)-

- $W = 5$ KN/m
  $= 5 * 1000 = 5000$ N
- $L = 1$ m $= 1000$ m
- $b = t = 40$ mm
  $E = 210 * 10^{3}$ N/ mm^2
- $I = bt^3 / 12$
  $= 213333.33$ mm^4

- $Y = -wl^3 / 48 * EI$
  $= -2.325$ mm
- $M = (wL)/4$
  $= (5*1000*1000)/4$
  $= 1250000$ N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$
  $\sigma = 117.18\ N/\mathrm{mm}^2$

➢ MATHEMATICAL RESULT

Directional Deflection	**-2.325 mm**
Equivalent Stress	**117.187 MPa**

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- **ANSYS ANALYSIS AND RESULTS**

Ansys Result Shown in the below figure –

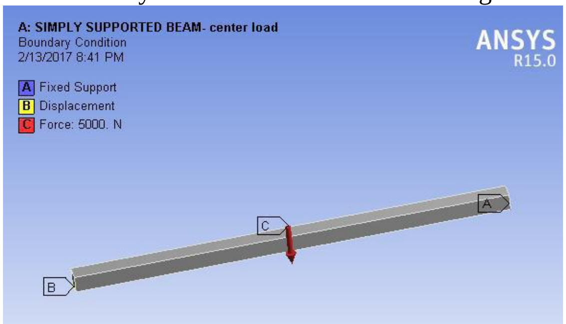

Figure 6: Boundary condition.

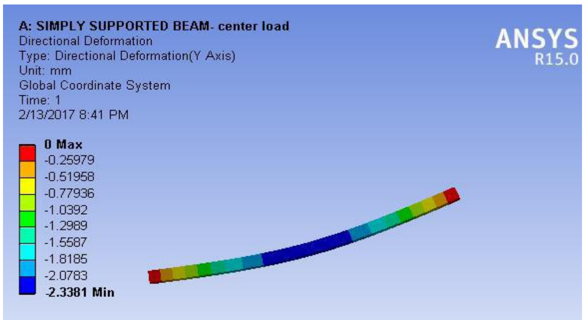

Figure 7: Directional deformation.

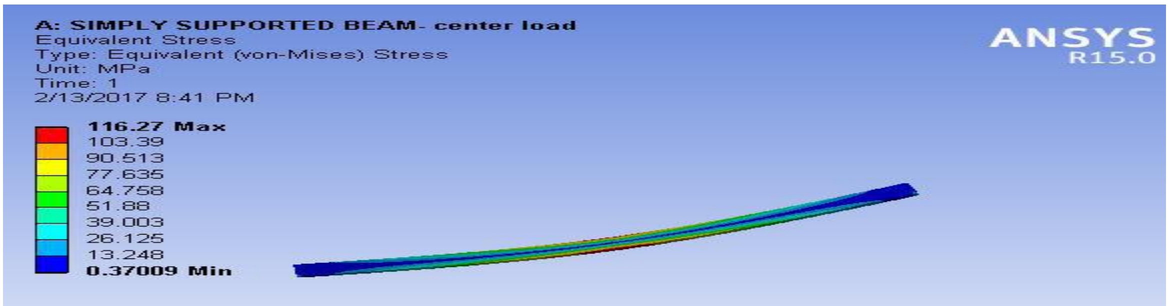

Figure 8: Equivalent stress diagram.

C. CANTILEVER BEAM WITH POINT LOAD

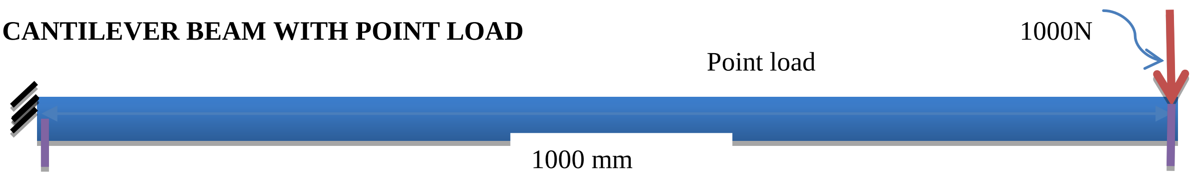

Figure 9: Bending test Setup

- **MATHEMATICAL CALCULATION**

According to given data we can calculated the maximum deformation (Y), Bending Moment (M) and stress (σ)

- W = 1000 N
- L = 1 m = 1000 m
- b = t = 40 mm
  $E = 210 * 10^{3}$ N/ mm^2
- $I = bt^3 / 12$
  $= 213333.33$ mm^4

- $Y = -WL^3 / 3 * EI$
  $= -7.442$ mm
- M = (WL)
  = (1000*1000)
  = 1000000 N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$
  $\sigma = 93.750\ N/\text{mm}^2$

- **MATHEMATICAL RESUL**

Directional Deflection	**-7.442 mm**
Equivalent Stress	**93.750 MPa**

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- **ANSYS ANALYSIS AND RESULT**

Ansys Result Shown in the below figure

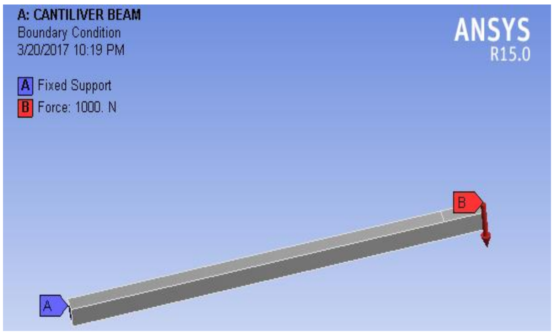

Figure 10: Boundary condition.

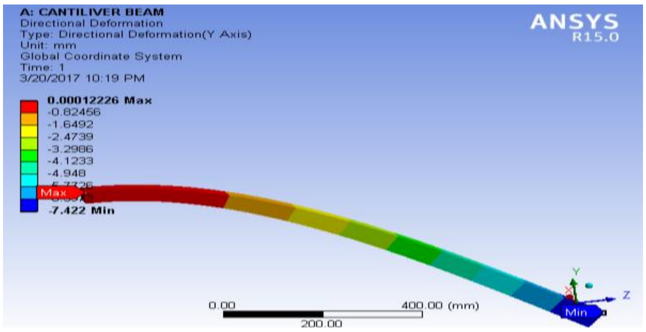

Figure 11: Directional deformation.

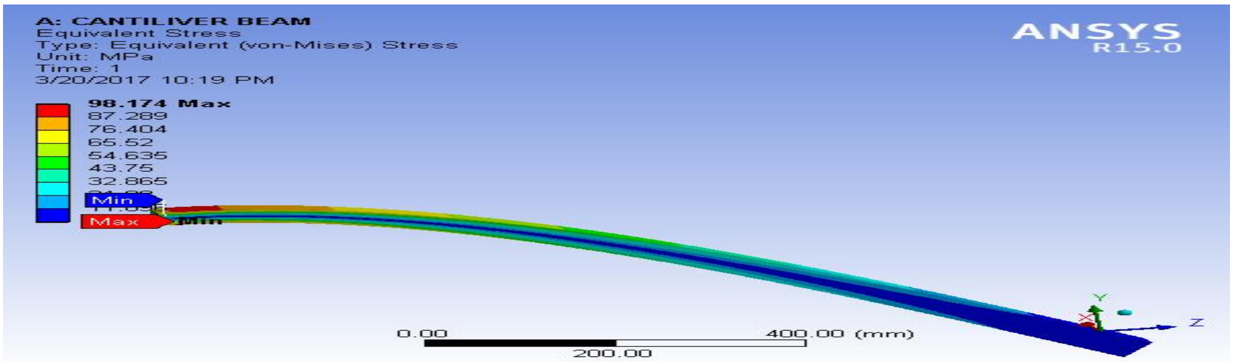

Figure 12: Diagram & Chart of Directional deformation at the path.

V. RESULT OF VARIOUS LOADS AT DIFFERENT MATERIALS

A. SIMPLY SUPPORTED BEAM-UDL: We are showing the impact of load (5000-7000 N) at Deferent material for the simply supported beam which is subjected to Uniform distributed load.

- **ALUMINIUM ALLOY:** Aluminium Alloy have young modulus (E= 71 GPa), poison ratio (υ= 0.33) and product of young modulus and moment of inertia (E×I =1.5146×10^{10}N-mm^2).

Table 5.1: Impact at Aluminium

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	5000	-4.298	-4.319	58.593	58.950	-0.489	-0.609
ii	6000	-5.158	-5.1837	70.312	70.347	-0.498	-0.050
iii	7000	-6.017	-6.047	82.031	82.072	-0.499	-0.050

- **GREY COST IRON:** Grey Cost Iron has young modulus (E= 110 GPa), poison ratio (υ= 0.28) and product of young modulus and moment of inertia (E×I =2.3466×10^{10}N-mm^2).

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Table 5.2: Impact at Grey Cost Iron.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	5000	-2.774	-2.787	58.593	58.950	-0.469	-0.609
ii	6000	-3.329	-3.334	70.312	70.347	-0.150	-0.050
iii	7000	-3.884	-3.903	82.031	82.072	-0.489	-0.050

- **STAINLESS STEEL:** Stainless Steel have young modulus **(**E= 193 GPa), poison ratio (υ= 0.31) and product of young modulus and moment of inertia (E×I =4.117×10^{10}N-mm^2).

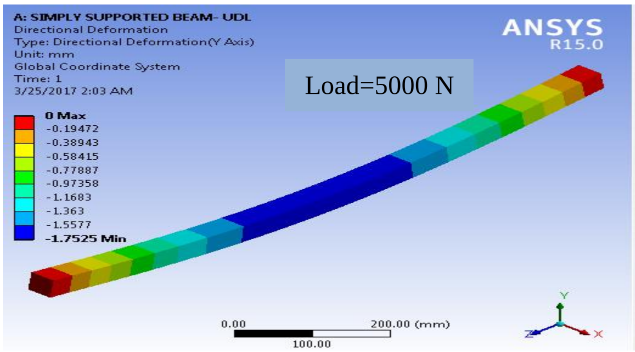
Table 5.3: Impact at Stainless Steel.

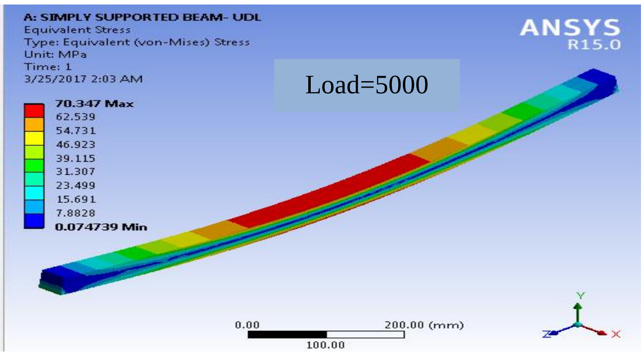
S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	5000	-1.581	-1.589	58.593	58.950	-0.512	-0.609
ii	6000	-1.897	-1.906	70.312	70.347	-0.474	-0.050
iii	7000	-2.213	-2.224	82.031	82.072	-0.497	-0.050

- **STRUCTURAL STEEL:** Structural Steel have young modulus **(**E= 210 GPa), poison ratio (υ= 0.3) and product of young modulus and moment of inertia (E×I =4.479×10^{10}N-mm^2).

Table 5.4: Impact at Structural Steel.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	5000	-1.453	-1.4	58.593	58.950	3.648	-0.609
ii	6000	-1.744	-1.7525	70.312	70.347	-0.487	-0.050
iii	7000	-2.034	-2.044	82.031	82.072	-0.492	-0.050





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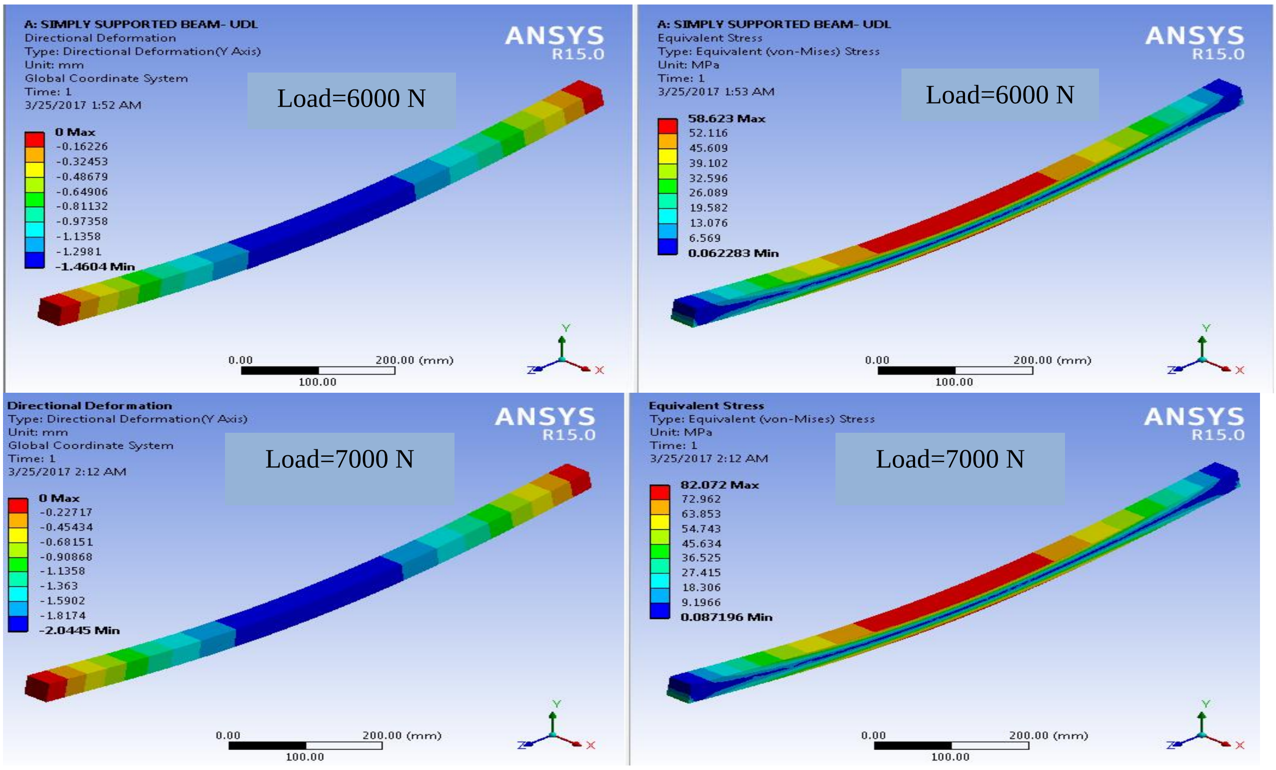

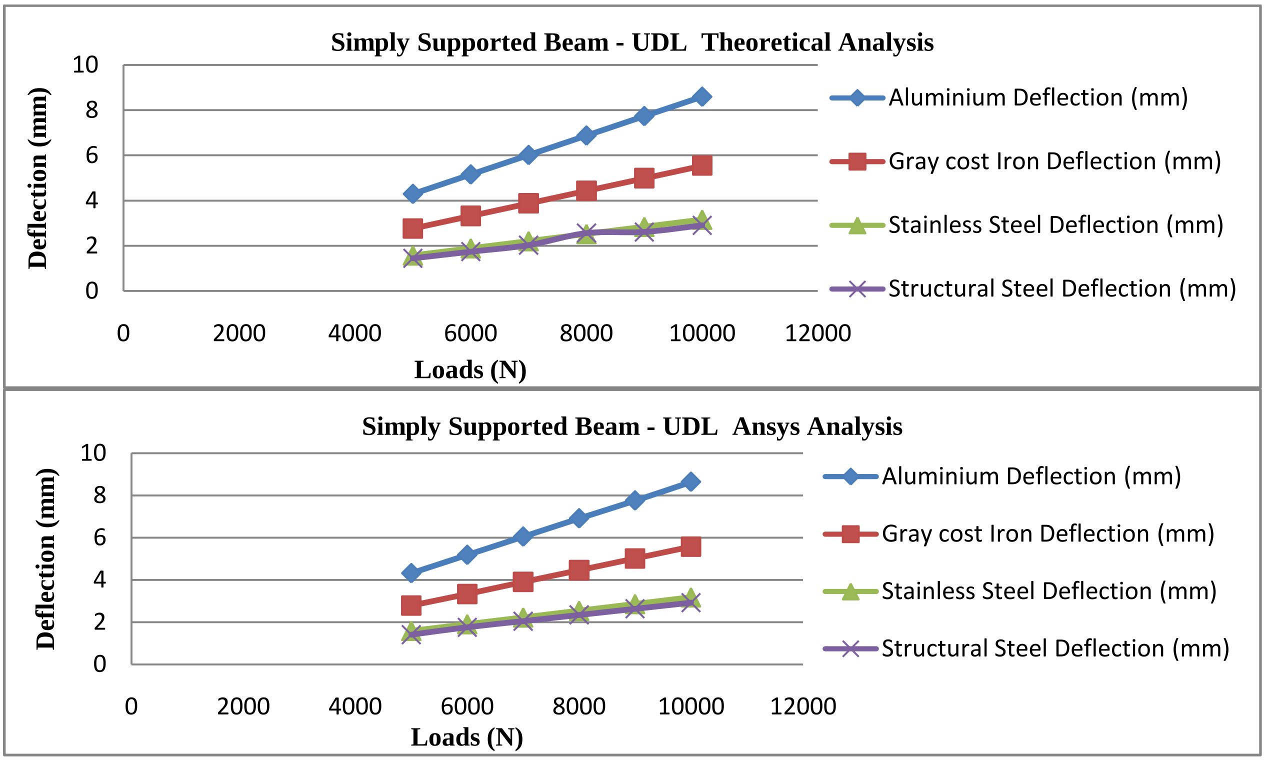

Figure 5.1: Graph Between Theoretical & Ansys Analysis for Simply Supported Beam Subjected To UDL.

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B. CANTILEVER BEAM-POINT LOAD: We are showing the impact of load (500-700 N) at Deferent material for the Cantilever beam which is subjected to point load.

- **7.4.1 ALUMINIUM ALLOY:** Aluminium Alloy have young modulus **(**E= 71 GPa), poison ratio (υ= 0.33) and product of young modulus and moment of inertia (E×I =1.5146×10^{10}N-mm^2).

Table 5.5: Impact at Aluminium.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys deflection Y_{Ansys} (mm)	Theoretical stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys stress σ_{Ansys} (N/mm^2)	Percentage error deflection Y_{Error}	Percentage error Stress σ_{Error}
i	500	-11.004	-10.967	46.87	49.007	0.003362	-0.04559
ii	600	-13.204	-13.16	56.25	58.904	0.003332	-0.04718
iii	700	-15.405	-15.354	65.625	68.722	0.003310	-0.04719

- **GREY COST IRON:** Grey Cost Iron has young modulus **(**E= 110 GPa), poison ratio (υ= 0.28) and product of young modulus and moment of inertia (E×I =2.3466×10^{10}N-mm^2).

Table 5.6: Impact at Grey Cost Iron.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys deflection Y_{Ansys} (mm)	Theoretical stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys stress σ_{Ansys} (N/mm^2)	Percentage error deflection Y_{Error}	Percentage error stress σ_{Error}
i	500	-7.102	-7.088	46.87	49.007	0.001971	-0.04559
ii	600	-8.522	-8.505	56.25	58.904	0.001994	-0.04718
iii	700	-9.943	-9.923	65.625	68.722	0.002011	-0.04719

- **STAINLESS STEEL:** Stainless Steel have young modulus **(**E= 193 GPa), poison ratio (υ= 0.31) and product of young modulus and moment of inertia (E×I =4.117×10^{10}N-mm^2).

Table 5.7: Impact at Stainless Steel.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys deflection Y_{Ansys} (mm)	Theoretical stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys stress σ_{Ansys} (N/mm^2)	Percentage error deflection Y_{Error}	Percentage error stress σ_{Error}
i	500	-4.048	-4.036	46.87	49.007	0.002964	-0.04559
ii	600	-4.857	-4.844	56.25	58.904	0.002676	-0.04718
iii	700	-5.667	-5.651	65.625	68.722	0.002823	-0.04719

- **STRUCTURAL STEEL:** Structural Steel have young modulus **(**E= 210 GPa), poison ratio (υ= 0.3) and product of young modulus and moment of inertia (E×I =4.479×10^{10}N-mm^2).

Table 5.8: Impact at Structural Steel.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys deflection Y_{Ansys} (mm)	Theoretical stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys stress σ_{Ansys} (N/mm^2)	Percentage error deflection Y_{Error}	Percentage error stress σ_{Error}
i	500	-3.721	-3.711	46.87	49.007	.00268744	-0.04559
ii	600	-4.465	-4.453	56.25	58.904	.00268756	-0.04718
iii	700	-5.209	-5.195	65.625	68.722	.00268765	-0.04719

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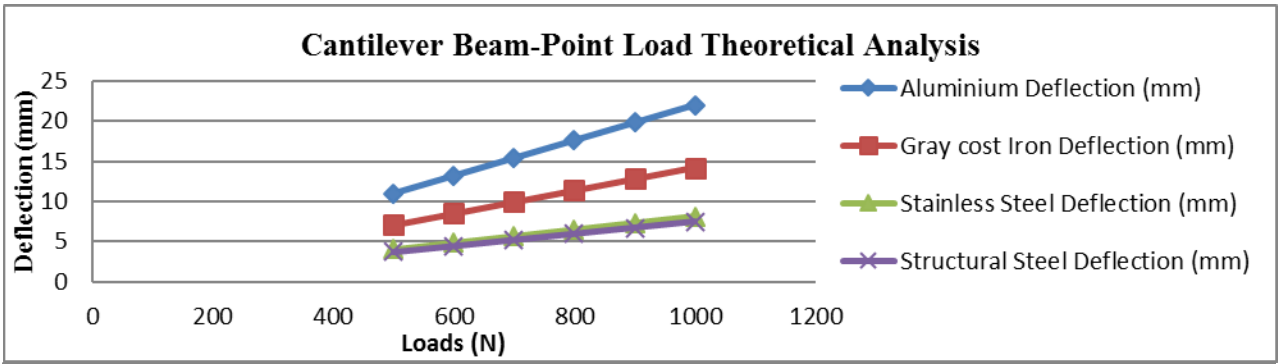

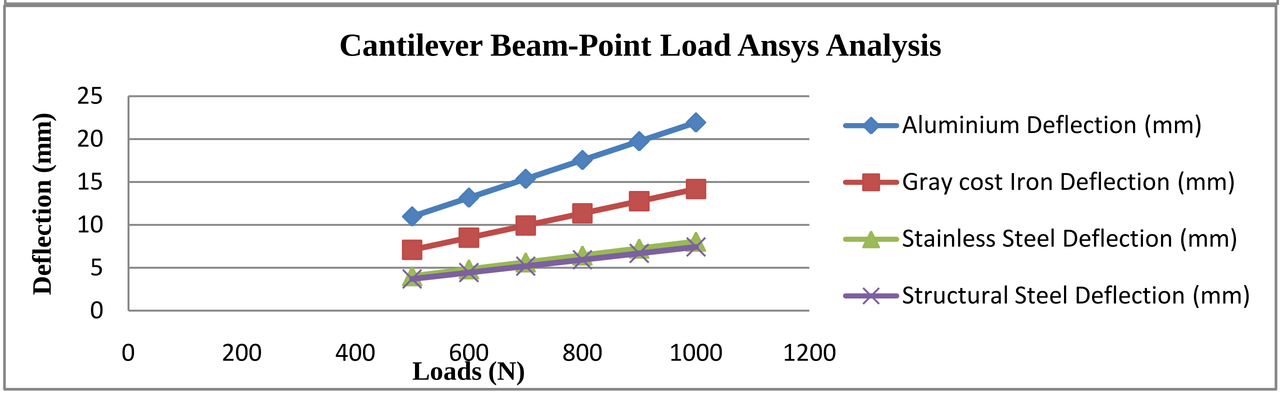

Figure 5.2: Graph Between Theoretical and Ansys Analysis for Cantilever Beam Subjected To Point Load.

VI. CONCLUSION

The present work has been carried out to study the deflection and bending stress of simply supported beam, fixed beam and cantilever beam under uniformly distributed load of 5000 N to 7000 N. The calculation has been made theoretically as well as using ANSYS WORKBENCH 15. From the obtained result it can be concluded that out of Aluminum alloy, Gray cast Iron, Stainless Steel and Structural steel, Structural Steel has minimum deflection and maximum bending stress in all loading conditions.

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