Plastic Collapse of Portal Frame Lab
Group T05

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1 Introduction

The purpose of this experiment is to investigate the behaviour of a mild steel portal frame model when subjected to increasing loads.

The rig consists of a loading system that applies a vertical load at the center of the beam and a horizontal load at the top of one column.

2 Experiment

The frame is made of mild steel and has a uniform rectangular cross-section. Also, The rig is equipped with two gauges to monitor the horizontal deflection of the beam and its central vertical deflection.

The experimental parameters are shown in the following table.2

Data type	Height	Length	Thickness	Width
Theory	200	300	3.3	13
Actual	200	304	3.27	12.97

(Unit: mm)

Table 1: Experiment parameters

The experiment entails the following steps:

1. Measure and record the dimensions of the frame and its cross-section.
2. Ensure the loading rig is in proper working condition and inspect cables for damage.
3. Zero the force and displacement readings while the rig is still unloaded.
4. Gradually apply increasing horizontal and vertical loads to the frame in increments of 10 N.
5. Record the applied forces and corresponding deflections for each increment.
6. Continue the process until a plastic failure occurs, and observe the formation of plastic hinges and position.
7. Unload the frame and identify the locations of plastic hinges by observing permanent rotation in the joints.

Force(N)	Vertical	10	20	30	40	50	60	70	80	90	100	110	120	130
	Horizontal	10	20	30	40	50	60	70	80	90	100	110	120	130
Distance(mm)	Vertical	0.06	0.05	0.1	1.42	2.13	2.26	2.8	3.22	3.62	4.28	5.23	7.46	12.88
	Horizontal	0.88	1.58	2.15	2.99	4.04	4.44	5.06	6.48	7.63	8.55	9.31	15.05	23.08

Table 2: Record data

3 Theory

In this section, finite element analysis (ANSYS) is performed on the components.

Analysis

ANSYS analysis results are shown in Figure 1.

The finite element analysis in Figure 1 gives the deformation-position curves for different materials under different forces, where the maximum deformation of the component can be easily determined.

The data are shown in Table 3.

Bending Displacement	Mild Steel	Aluminium
$\delta_{FE\_1}(P = 50N)$	0.1150	0.3237
$\delta_{FE\_2}(P = 100N)$	0.2300	0.6473
$\delta_{FE\_3}(P = 150N)$	0.3451	0.9710

(Unit: mm)

Table 3: FEA results - maximum deformation

Summary

By using ANSYS analysis, deformation-displacement diagrams were obtained for two materials under three different forces, revealing that the maximum deformation exists at the midpoint of the element (the point where the forces are applied).

The comparison also shows that even under theoretical conditions, the deformation of aluminium is larger than that of mild steel under the same forces.

4 Analysis

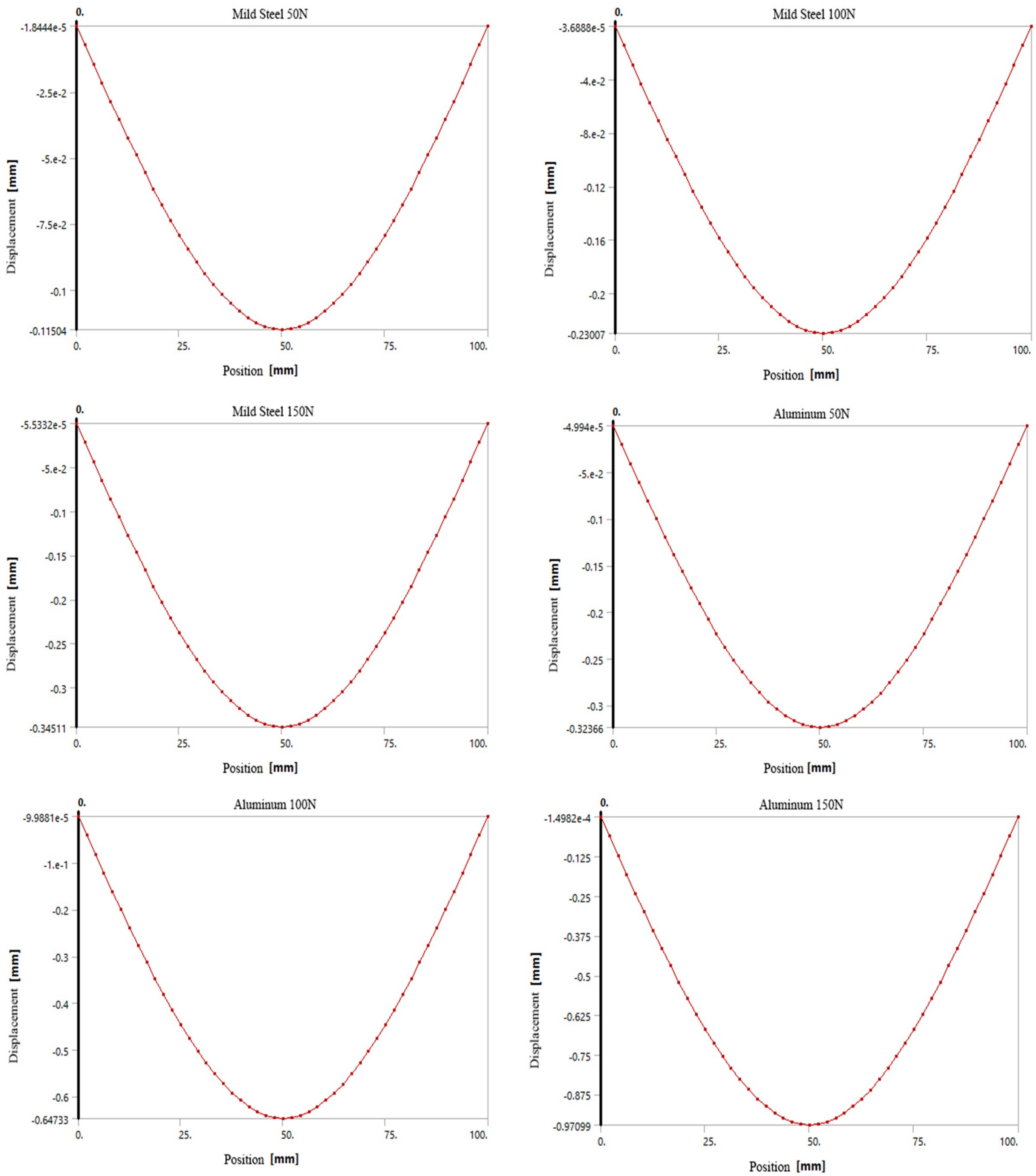

Figure 1: Figure of ANSYS analysis

Comparison of results

By comparing the experimental data(See Table ??) with the results of the ANSYS analysis(See Table 3), it can be found that all six groups of data measured in the laboratory have larger deformation values than the ANSYS analysis. This is due to the fact that the modulus of elasticity of the laboratory material is 172.67GPa(Mild Steel) and 63.75GPa(Aluminium), both of which are smaller than the theoretical value of the material(210GPa and 71GPa).

In addition, the percentage deformation of mild steel is larger than that of aluminium (i.e. $\frac{\delta_{AN}-\delta_{FE}}{\delta_{FE}} * 100\%$) and this may also be due to the larger modulus of elasticity of mild steel. Result shows in Table 4.

Force	Mild Steel(mm)	Error(%)	Aluminium(mm)	Error(%)
$P = 50N$	0.0190	16.534	0.0363	11.219
$P = 100N$	0.0381	16.539	0.0789	12.186
$P = 150N$	0.0571	16.537	0.1183	12.187
Average		16.54		11.86

Table 4: Difference deformation in Mild Steel and Aluminium

Possible reasons in error analysis

• Insufficient material purity or inhomogeneous density resulting in a modulus of elasticity less than the theoretical value.

• The memory effect of the metal caused by repeated use of the original experimental piece resulted in inaccurate deformation of the measurement.

• Errors caused by machines not being calibrated before measurement or by the machine's own measurement issues.

Experimental improvements and optimisation

• Replacement of materials with new materials which are not affected by the memory effects.

• Choose higher purity and more homogeneous density with higher precision components for measurement.

• Change the machine and take several measurements to avoid experimental chance.

5 Conclusion

From the results of the regression analysis, the R-square value of both experiment A1 and A2 are larger than 0.98, which demonstrates a strong linear correlation between the x and y axes. Additionally, from the above it follows that $C_v = 0.955$,$C_d = 0.615$(3mm),$C_d = 0.8816$ (6mm). Both of the coefficient are less than 1.This satisfies the hypothetical conditions.

Therefore, the data from the regression analysis is valid.

For C_v, due to vena contracta , the real area that approximates the area of the orifice with a little smaller, and its value is 0.95, which does not deviate much from the theoretical value..

For C_d(3mm), the value is 0.615, whereas it should actually be between 0.8 and 0.95(C_v) (equation **??**), probably due to experimental error. This should be done several times for the 3mm diameter orifice to avoid experimental coincidence and make it more accurate.

For C_d(6mm), the value is 0.8816, which is less than 0.95(C_v). This data is valid.