DEVELOPMENT OF AN IMPROVED DEFLECTION TESTING APPARATUS FOR SHORT COLUMN

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ABSTRACT

The excessive deflection in engineering structures will leads to structural failure such as buckling or crushing. Therefore the fabrication and testing of an improved deflection testing apparatus for short column will improve columns stability and thereby preventing failure. The apparatus was fabricated using plywood, and aluminium, steel and tested with varying loads of between 4N and 10N, the results shown a 0.3% error and 0.03% disagreement with literature.

Keyword: short column, slender column, apparatus, buckling load.

1.0 INTRODUCTION

The mechanical deflection apparatus is an instrument used to determining the deflection of small columns in the laboratory which are subjected to axial load; hence the deflection of various columns will be known thereby determining the allowable loads that the column can be subjected to without failure. The apparatus consist of a slender steel column, dial gauge indicator, dial gauge indicator stand, hinge made from Aluminum for different column end conditions and a wooden frame. This fabrication of this apparatus is necessitate because either they are not found or their available one are obsolete in most Nigeria higher institution laboratories. This apparatus can be used to study the deflection behaviors of slender column for the four major column end condition. Loaded and suspended structures experience varying degree of deflections, which may deterrent to preventive maintenance, therefore the need for constantly checking the allowable deflections of these structures is inevitable, hence avoiding failure, [4]. This apparatus can be used to demonstrate the deflection in columns in terms of it profile and maximum in the teaching laboratories.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

Frame: - a three quarter plywood were used to fabricate the frame. The frame support and housed all other component listed. The frame needed to be light in weight and reasonable strength to support other components. The frame is not subjected to heavy load that will require its detailed design. The edges of the wooden frame were screwed and glued to together.

Slender column: any material can be used as the columns, since it's the component been tested. But must be slender and fit into the hinges, in terms of length and thickness. The dimensions of the column.

Aluminum hinges and dial indicator stand: the weight of the upper hinge rest on the column and taken as initial weight. The lower hinges rest on the frame. So lightweight material is best fitted.

Dial indicator: In the most sensitive component cause it measures no visible deflections. Dial indicator is acquire in the market.

2.2 Design Considerations

The most important property of a column, as far as the determination of it's load carrying capacity is concerned in it's slenderness and buckling load, because is a function of its length and has a direct bearing on it's critical load [2].

2.2.1 Slenderness ratio

The slenderness ratio for a compression member should not exceed 200. Mathematically the slenderness ratio is given as [1]

Slenderness ratio:

$$P = KL / \rho \quad \ldots\ldots \quad 2.1$$

Where: k = factor dependent on the column end condition, L = effective column length, ρ = radius of gyration.

2.2.2 Buckling loads:

The load groves on columns (made of isotropic materials). It reaches a certain value where large deflection is being developed. That particular loads that cause this large deflection is called buckling load. The deflection shapes of the columns depend on the column's end conditions, [6]. The Table 2.1 shows column end conditions and their respective critical loads.

Table 2.1: Column end conditions and their critical loads [3].

S. No.	End condition	Critical load (P_{cr}) N
1	Clamped-free ends	$=\pi^2EI/4L^2$
2	Clamped-hinged ends	$=2.05\pi^2EI/L2$
3	Clamped-clamped ends	$4\pi^2EI/L^2$
4	Pined ends	π^2EI/L^2

3.0 FABRICATION DETAILS

The frame of the apparatus is made from three quarter of plywood board. This were marked and cut to the specified dimension in figure 1. The cut plywood were permanently joined with the aid of the glue and screwed. The column hinges were machined from sand casted aluminium, Two numbers of diameter ϕ75mm and ϕ100mm aluminium was machined to ϕ50mm diameter over ϕ60mm length. ϕ8mm diameter hole was drilled at 25mm from the machined end. A column slot of 6mm, 3mm was created from the machined hinges. A dial indicator stands of diameter ϕ75mm x ϕ100mm were machined from aluminium to the dimension in Figure 1. The columns were made of 300mm x 19mm x 0.6mm stainless steel.

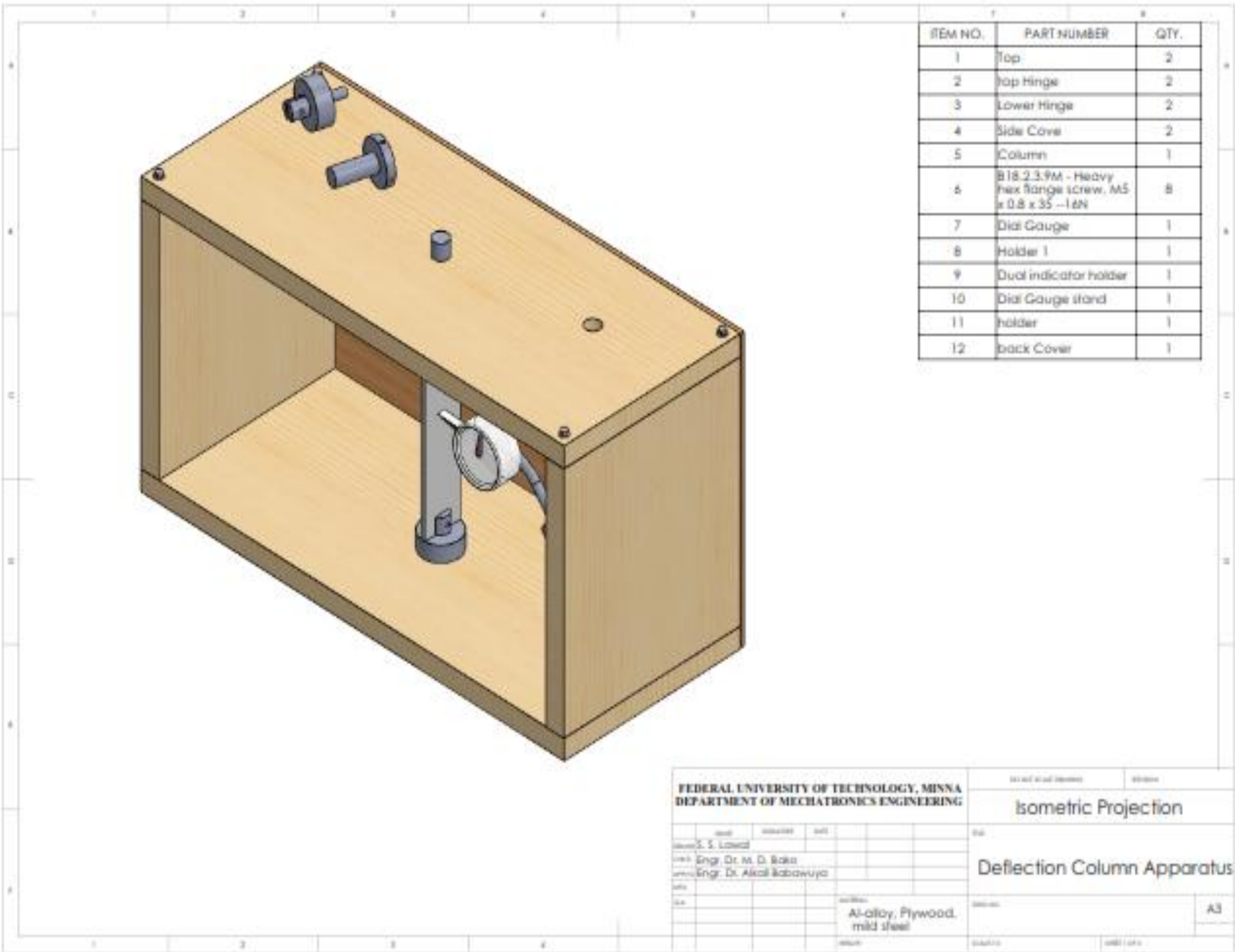


Figure 1: Isometric Projection of the Apparatus.

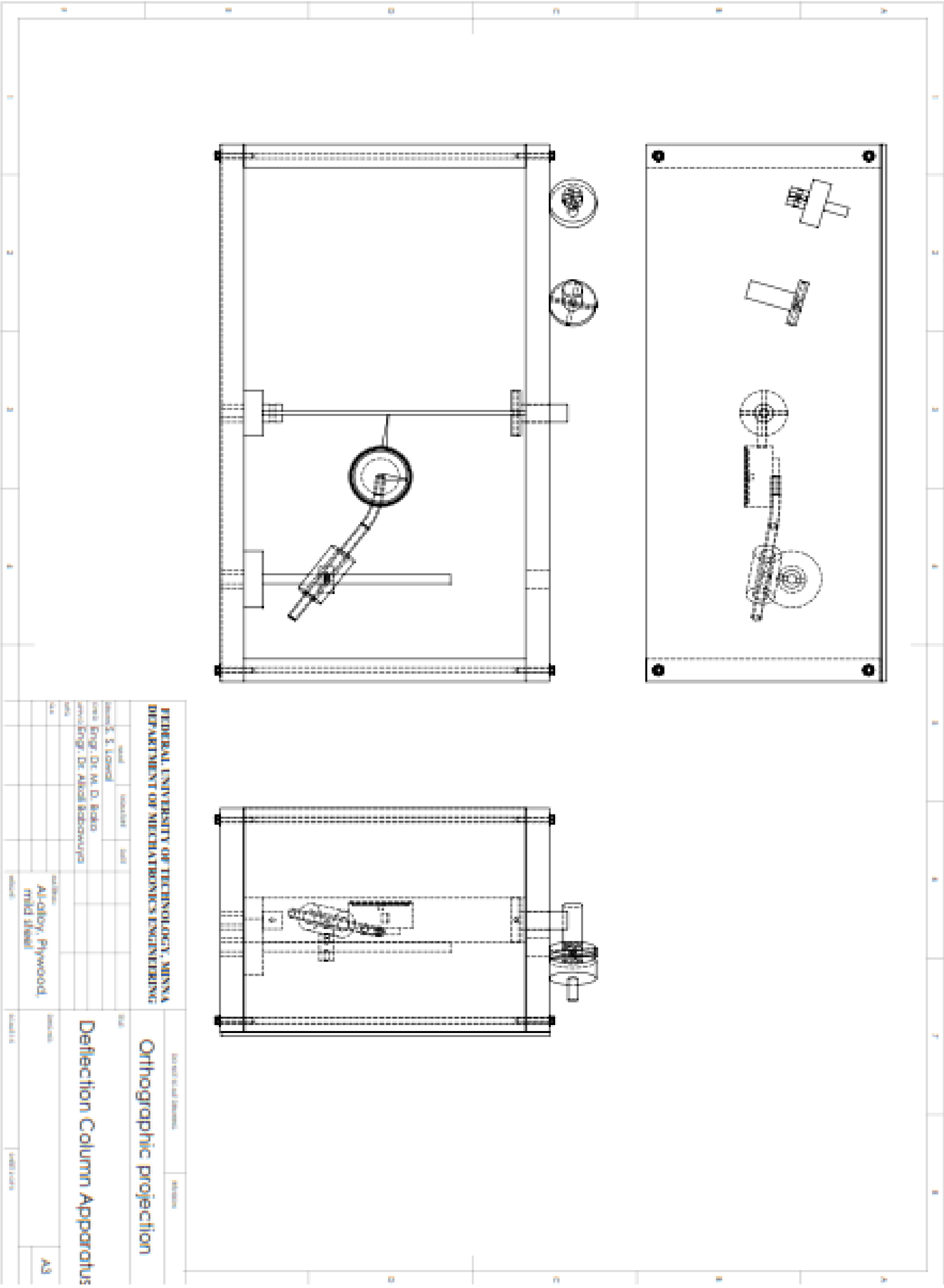


Figure 2: Orthographic Projection.

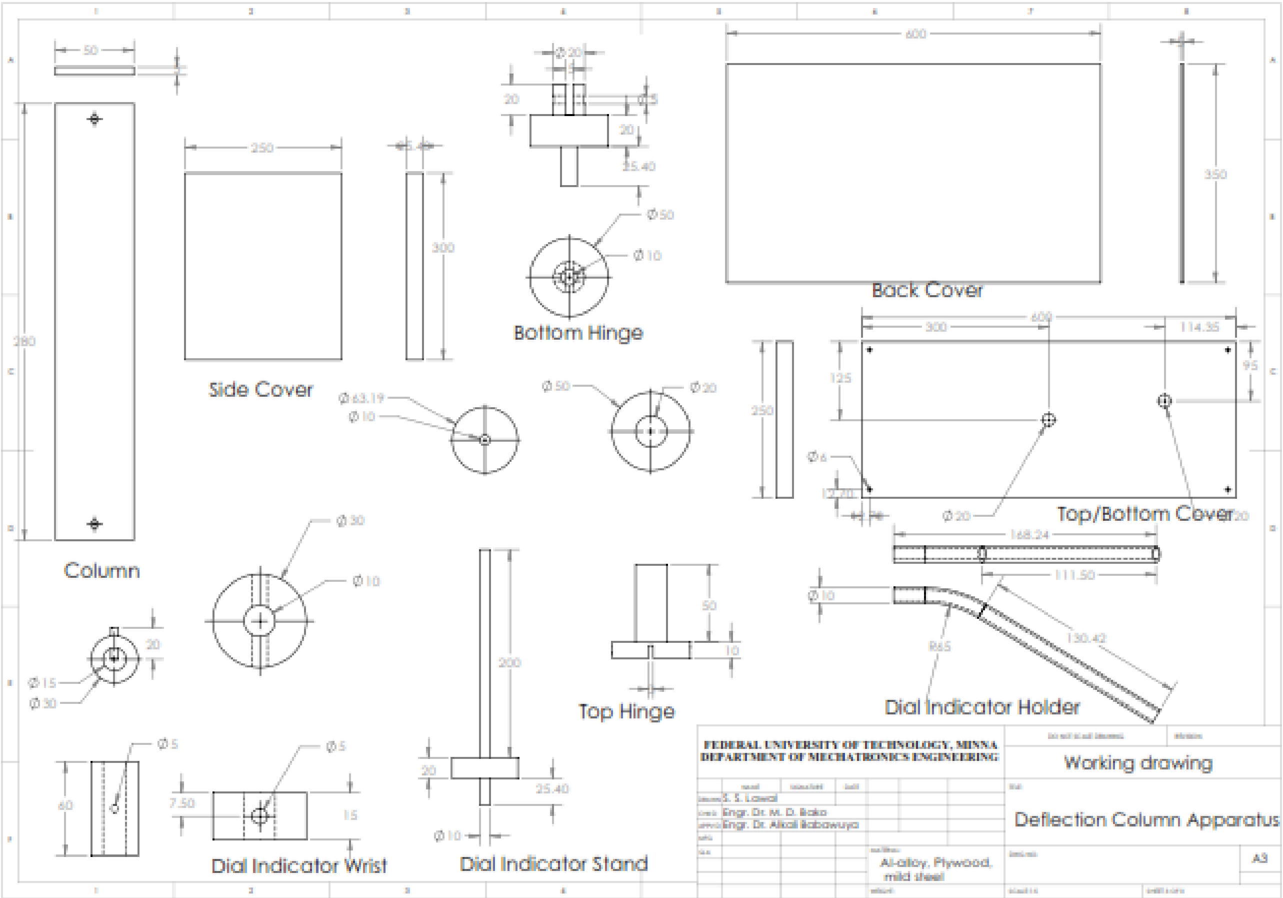


Figure 3: Working Drawing

3.1 Testing and Result

The apparatus was tested using the experimental manual detailed below, and the results shown in Tables 1-4.

Table 1: Results of Both End Pinned

S/No	Load (N)	Deflection y (mm)		Mean y (mm)
		Loading	Unloading	
1	4	0.020	0.020	0.02
2	5	0.040	0.041	0.0405
3	6	0.700	0.23	0.2
4	7	0.410	0.417	0.4135
5	8	0.570	0.580	0.575

6	9	0.660	0.662	0.661
7	10	0.68	0.72	0.700

Table 2: Results of Both Ends Fixed

S/No	Load (N)	Deflection y (mm)		Mean y (mm)
		Loading	Unloading	
1	4	0.010	0.015	0.013
2	5	0.020	0.020	0.020
3	6	0.165	0.175	0.170
4	7	0.295	0.310	0.303
5	8	0.365	0.380	0.373
6	9	0.385	0.395	0.390
7	10	0.385	0.420	0.403

Table 3: Results of One End Fixed and One Pinned.

S/No	Load (N)	Deflection y (mm)		Mean y (mm)
		Loading	Unloading	
1	4	0.05	0.050	0.05
2	5	0.08	0.080	0.08
3	6	0.11	0.112	0.111
4	7	0.35	0.350	0.35
5	8	0.55	0.750	0.65
6	9	0.93	0.930	0.93
7	10	1.00	1.300	1.15

Table 4: Results of One End Fixed and One End Free.

S/No	Load (N)	Deflection y (mm)		Mean y (mm)
		Loading	Unloading	
1	4	0.11	0.112	0.111
2	5	0.24	0.241	0.2405
3	6	0.25	0.27	0.260
4	7	0.28	0.282	0.281

5	8	0.35	0.350	0.350
6	9	0.54	0.543	0.5415
7	10	0.75	0.752	0.751

The readings recorded in the Tables 1- 4, are plotted in the Figures 1-5 for all the four hinge type.

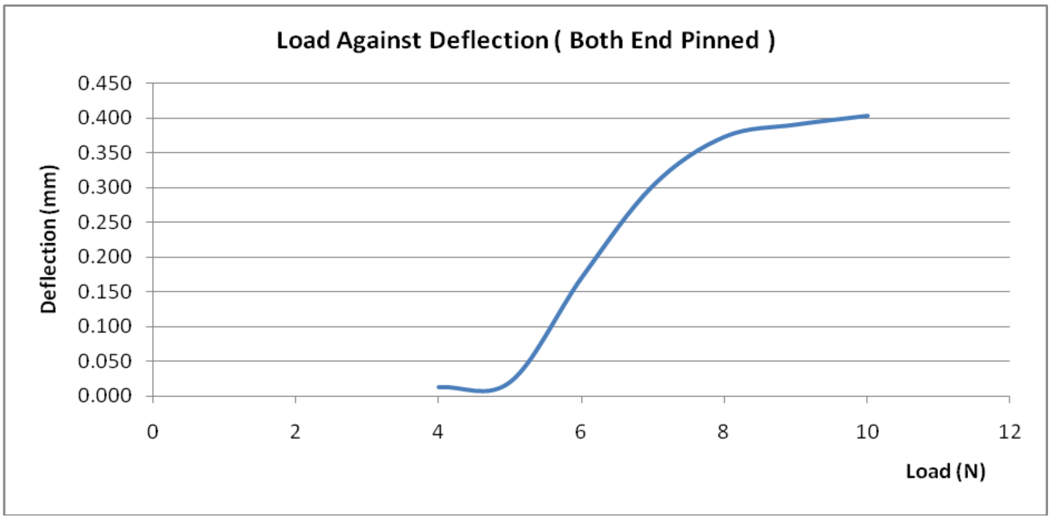


Figure 1: The graph deflection against load for both end pinned (Slope, k = 0.2 N/mm)

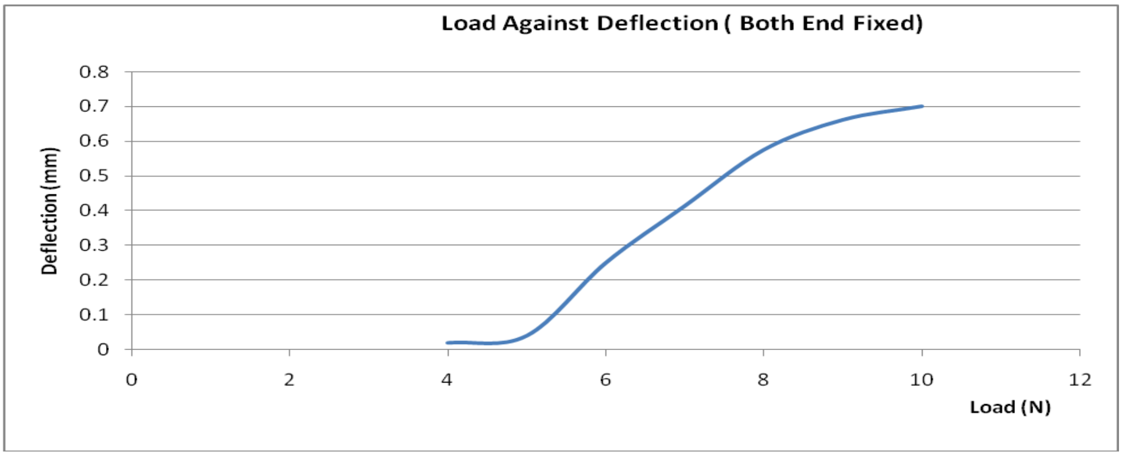


Figure 2: The graph deflection against load for both end fixed (Slope, k = 0.188 N/mm).

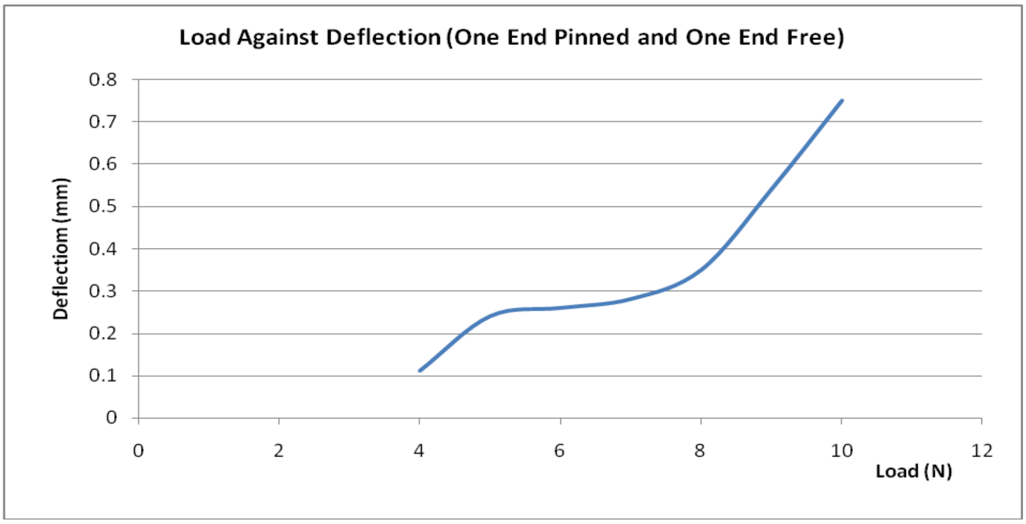


Figure 3: The graph deflection against load for one end pinned and one end free (Slope, k = 0.179 N/mm)

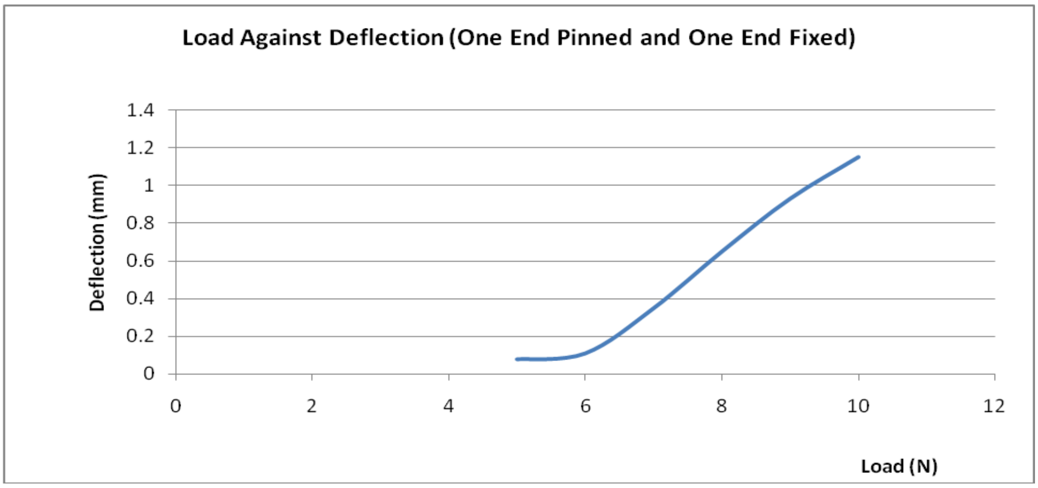


Figure 4: The graph deflection against load for one end pinned and one fixed

(Slope, k = 0.23 N/mm)

The moment of inertia for the column, I = 342.95 mm^4

And the Cross sectional area of the Column, A = 11.4 mm^2.

3.2 Experimental Manual

Title of Experiment: Measuring the deflection of a short column.

Aim and Objective: To determine the maximum deflection point of the short column.

Theory : Assuming material obeys Hook's law, the column shown in Figure 1 are subjected to a compressive load, P, only shortening of the column occur no matter the value of load, P.

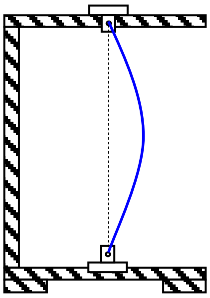
$P_{cr} = n\pi^2 EI / L^2$.[6] …… 3.1

Apparatus: Deflection testing apparatus with calibrated dial indicator, short column and varying loads.

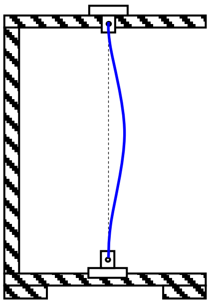
Method: The experiment can be conducted following the steps below:

- Place the apparatus on a plane table.
- Fix the column hinges and column as shown in the figure 1
- Set the dial indicator correctly to the deflection point.
- Apply the loads (P_1, P_2, P_3, P_4 ..) and reading the deflections x_1, x_2, x_3, x_4, …, for loading.
- And remove the loads as they were placed i.e. P_4, P_3, P_2, P_1, also reading the deflection for unloading.
- Repeat the same procedure for all the column end conditions.
- Tabulate the value of loads and deflection for loading and unloading.
- Plot the graph of deflections against loads, from the graph determine the stiffness of the column, K (deflection coefficient in N/mm.). Also calculate the modulus of elasticity, E, moment of inertia, I for the column.

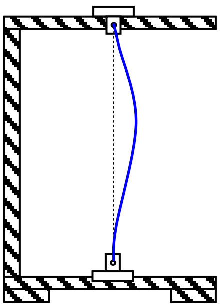
Diagram:



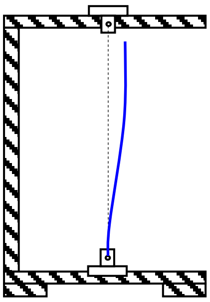
a. Both end Pinned



b. Both end fix



c. One End Pinned, One end fixed



d. One end fixed, one free

Further Consideration

1. State any conclusion in the light of the result obtained, has the basic theory verify compare the values obtained with the theoretical values, compute the errors.
2. Account for any error and how to eliminate the errors.

4.0 CONCLUSION

The fabrication and testing of an improved deflection testing apparatus was successful because the apparatus was fabricated using local cheap and widely available materials. The test result compared favorable with standard result available. The size of the columns will give best results within the load range of 4N to 10N. The 0.03% error shown in the discussion of results may likely be due to the edge of material used for the columns and the dimensions inaccuracies in the apparatus.

- A more lighter materials is recommended to reduce column initial load
- A newer and more sensitive material is recommended for the column.
- And the hinges head should be made hexagonal in shape to absorb twisting of the column in the application of the loads.

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