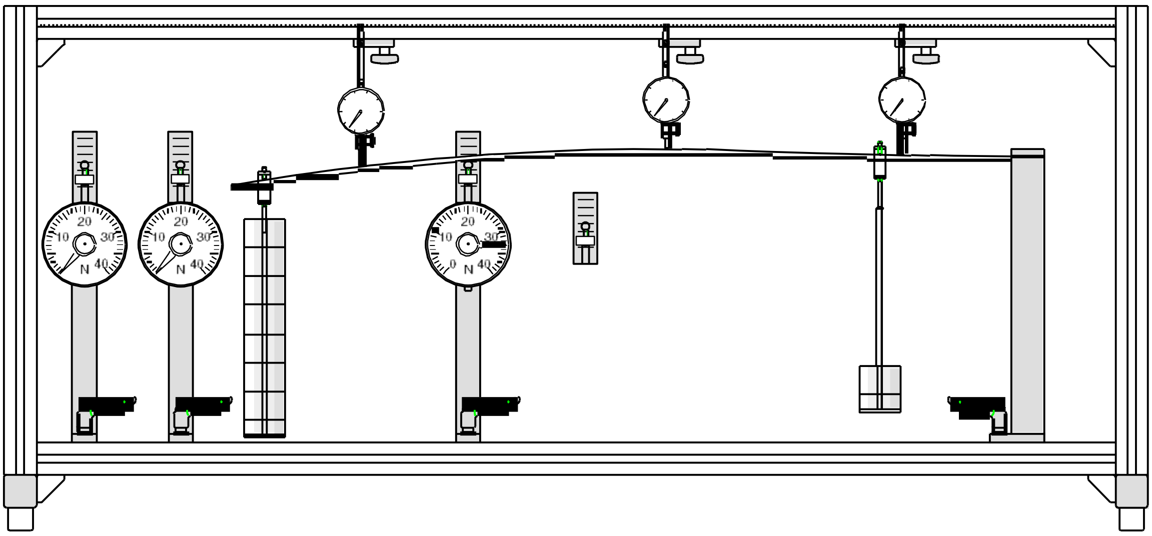
Laboratory 1

Deformation of Straight Beams



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Contents

1. Objectives:

Students are required to study the principles of bending loading, practice its experimental skills and interpreting the experimental results.

Students are required explain deflection-distance relationships and represent them in graphical forms.

Students are required check the mathematically determined deflection of the bar subjected to bending loading.

Students are required measures the elastic line of a bar subjected to bending loading and compares it with the result of the mathematical calculation.

2. Introduction:

The deformation of straight beams device permits a broad spectrum of experiments on the deformation of a bending bar.

The experiments include

- ✓ Elastic line under different support conditions
- ✓ Elastic line under different loads
- ✓ Demonstration of the Maxwell-Betti law
- ✓ Supporting forces in statically undetermined systems

The loads are applied in a visual manner using sets of weights.

Deformation of the bar is measured using dial gauges.

Supporting forces can be determined via the dynamometers integrated in the supports.

Bars of various materials are available in order to demonstrate the influence of the modulus of elasticity on deflection.

By using very thin, elastic bars, deformation of the bar under load can be seen very clearly, even without dial gauges. The dynamometers have large, clear scales and can easily be read from some distance away.

3. Equipment description:

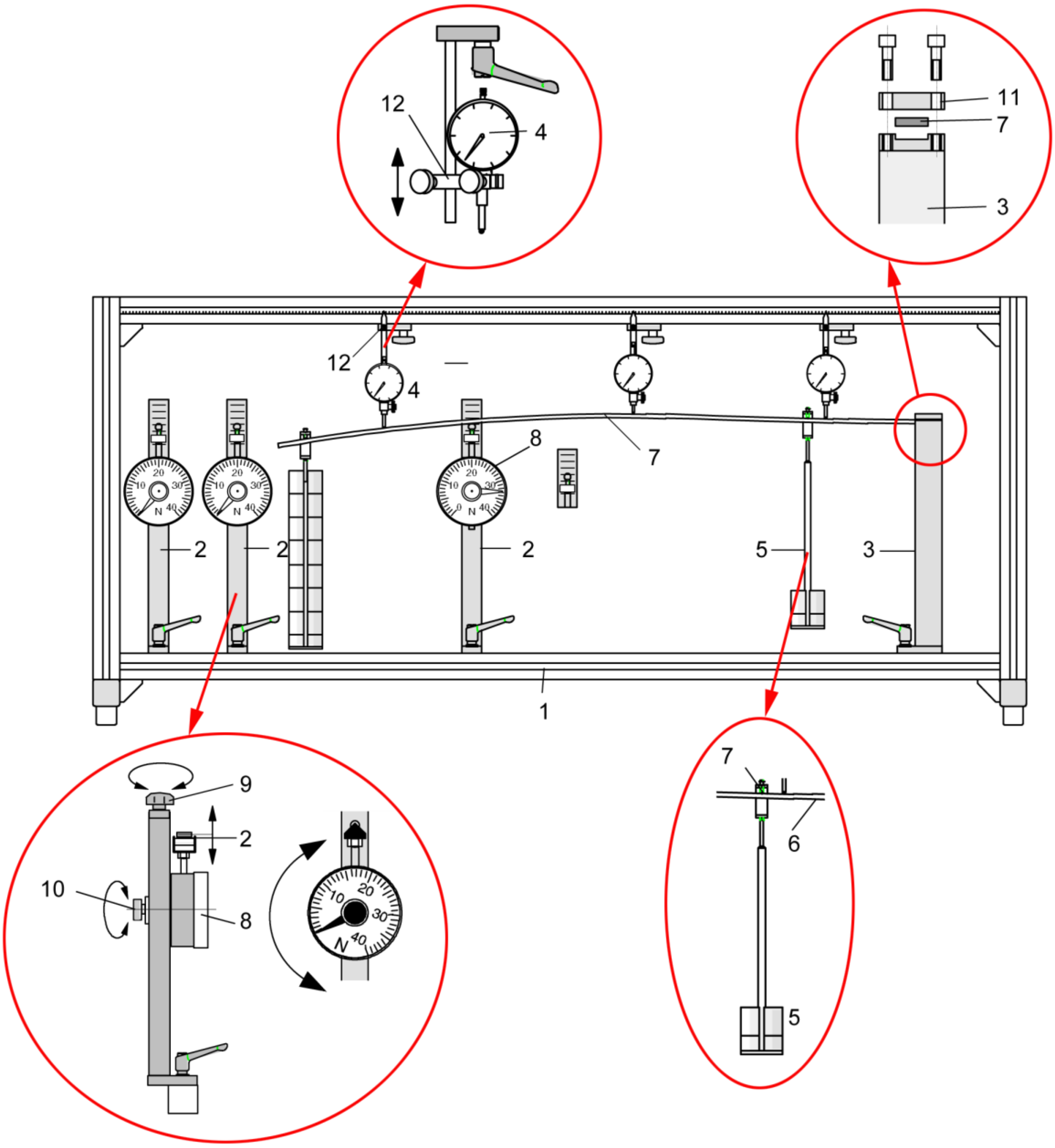

Fig. 1.1 Unit design

The bar bending device consists of a light, stable frame (1) made of aluminum. The various supports (2, 3) are fastened to the lower girder with clamping levers. The dial gauges (4) are fastened to the upper girder with holders.

The load weights (5) are attached to the bar (7) via movable riders (6). The riders can be locked in position. Rider and support together weigh 2.5 N. The load can be adjusted in increments of 2,5 N and 5 N using additional weight blocks.

The articulated supports (2) are fitted with dynamometers (8). The height of the support can be adjusted using a threaded spindle (9). The support can be locked in position by the screw (10). This compensates deformation of the bar by its own weight or deflection of the support caused by spring excursion of the dynamometer.

In statically undetermined systems, it is possible to demonstrate the influence of support deflection on load distribution.

The scales on the dynamometers (8) rotate to enable taring.

The bar (7) is fixed in the support with clamp (3) by means of a clamping plate (11).

The height of the dial gauges (4) can be adjusted on their holders (12).

4. Formula Symbols and Units Used

Symbol	Mathematical/physical quantity	Unit
a, aij:	Distance, influence coefficient	mm
A, B:	Supporting force	N
b:	Width of cross-section, distance	mm
E:	Modulus of elasticity	N/mm^2
f:	Deflection	mm
F:	Force, Load	N
h:	Height of cross-section	mm
Iy:	Planar moment of inertia	mm^4
L:	Length	mm
M:	Bending moment	N.mm
w:	Deflection downwards	mm
x:	Longitudinal coordinate of bar	mm
α:	Inclination	rad

5. Coefficients and specimen's characteristics

	Bar 1	Bar 2	Bar 3	Bar 4	Bar 5
L [mm]	1000	1000	1000	1000	1000
b [mm]	20	20	20	20	20
h [mm]	2	3	6	6	6
Material	Steel	Steel	Steel	Brass	Aluminum
E [GPa]	210	210	210	90	70

6. Safety Instructions

NOTICE

The test beams would be ruined by plastic deformation and thus become unusable. So, respect the load mentioned in the procedure for specific material and cross-section.

7. Basic principles

a. Bending on the cantilever bar:

In a cantilever bar, one side of the bar is fixed, and the other side is free. This is known as a trivalent support which transmits normal force, transverse force and moment. The bar is therefore supported in a **statically determined** manner.

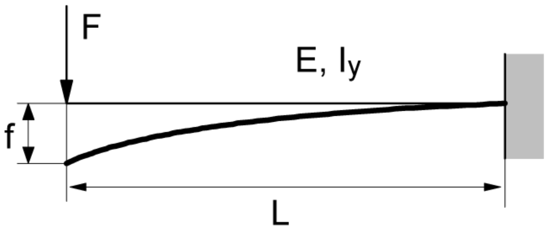

Fig. 1.2 cantilever beam

The equation for the deflection f of the bar at the point of application of force is

$$f = \frac{FL^3}{3EI_y} \qquad \text{Eq. 1.1}$$

Where

F : Load

L : Length of the bar

E : Modulus of elasticity

I_y : Planar moment of intertie

Planar moment of intertie of a rectangular cross-section is

$$I_y = \frac{bh^3}{12} \qquad \text{Eq. 1.2}$$

Deflection is proportional to the load F and the cube of the length of the bar L is d; and inversely proportional to the modulus of elasticity E and planar moment of intertie I_y.

b. Determining the elastic line

The equation for the elastic line of a cantilever bar loaded with a single force is as follows for the loaded section II with $0 \le x_2 \le a$:

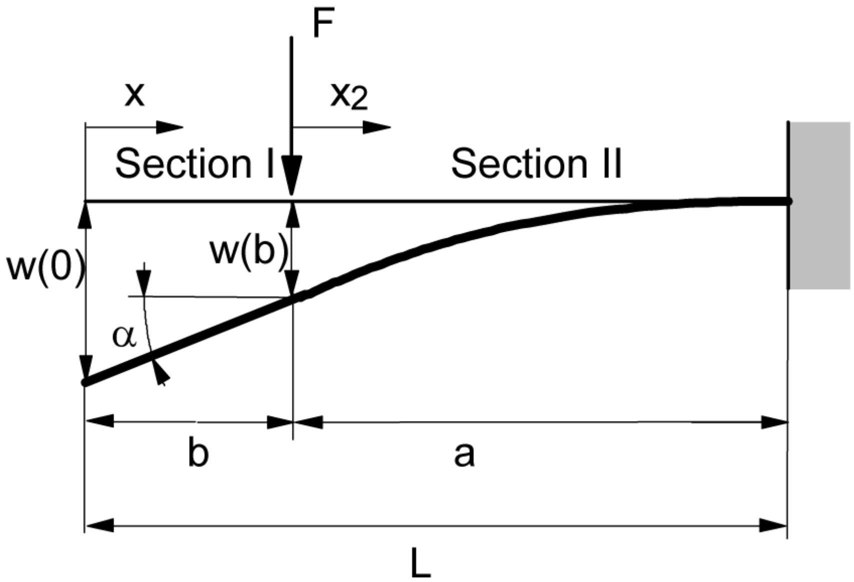

Fig. 1.3 Elastic line of a cantilever beam

$$\mathrm{W}(\mathrm{x}_2) = \frac{F\mathrm{a}^3}{6EI_Y}\left[2 - 3\frac{X_2}{a} + \frac{X_2^3}{a^3}\right] \qquad \text{Eq. 1.3}$$

In the unloaded section I between the point of application of the force and the free end, the deflection is a linear function of the length and the inclination α in the point of application of force. This is not bending, but slanting

$$W(x) = W(b) + (b - x)\alpha \qquad \text{Eq. 1.4}$$

Where

$$W(b) = \frac{Fa^3}{3EI_y} \qquad \text{Eq. 1.5}$$

and

$$\alpha = \frac{Fa^2}{3EI_y} \qquad \text{Eq. 1.6}$$

8. Experimental Procedure

Below are descriptions of some of the experiments which can be performed. They represent only a small proportion of the experiments which are possible with the device and should provide ideas for other experiments.

a. Experiment 1: Bending on the cantilever bar:

The aim of this experiment is to check the mathematically determined deflection of the cantilever bar.

The influence of the length L should be demonstrated in this experiment, for this purpose, the force should be constant.

The experiment is set up as shown in Fig.1.2.

The following equipment is required:

- Steel bar 6 x 20 x 1000 mm (7)
- Rider for weight (6)
- Suspender for weights (5)
- 3 weights 5N
- Dial gauge with holder (4, 12)
- Support pillar with clamp (3)

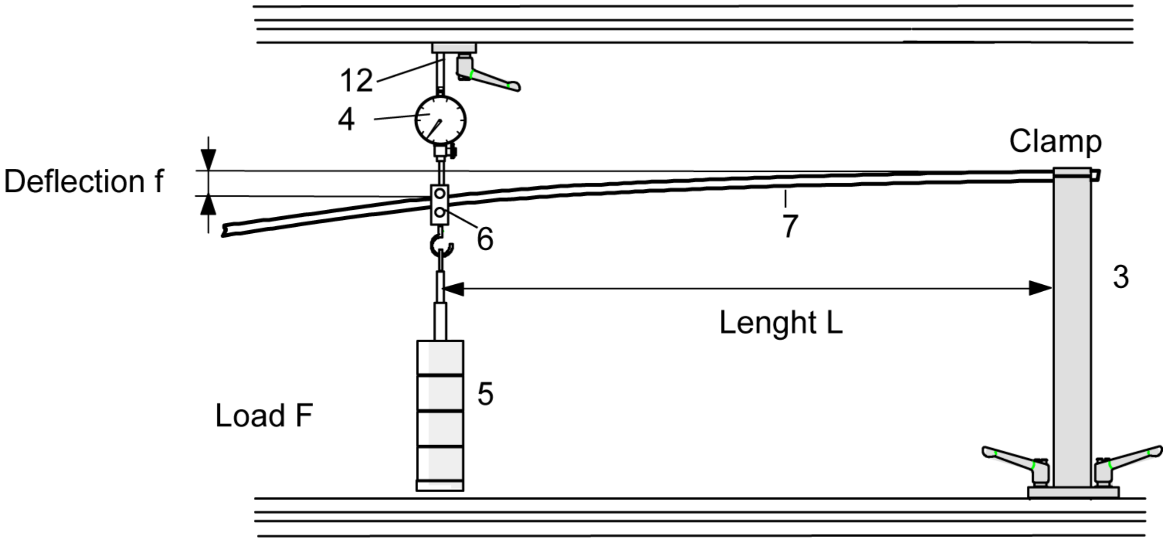

Fig. 1.2 experiment setup

To perform the experiment, you must follow the following steps:

1. Fasten the support pillar to the frame
2. Clamp the bar in the support pillar
3. Place the rider on the bar and lock in the required position (300, 400 and 500 mm)
4. Fasten the dial gauge to the frame with the holder in such a way that the tracer pin is touching the flattened part of the rider bolt
5. Set the dial gauge to zero with the bar unloaded. To do so, adjust the holder and rotate the scale for precise adjustment
6. Suspend the load weight 17.5 N (suspender 2.5N + 3 weights 5N), read the deflection on the dial gauge and record
7. Draw a table to compare the results of the experiment with the results of the mathematical calculation.

b. Experiment 2: Determining the elastic line

This experiment measures the elastic line of a cantilever bar and compares it with the result of the mathematical calculation.

The experiment is set up as described in Experiment 1.

The load remains constant and is applied at a = 500 mm.

The deflection of the bar is measured at intervals of 100 mm with the dial gauge

1. Clamp the bar in the support pillar at a +b = 800 mm
2. Apply the dial gauge at the required position and set to zero
3. Load the bar
4. Read the deflection value and record
5. Relieve the bar and move the dial gauge to the next position

6. Repeat the measuring procedure
7. Draw a table to compare the results of the experiment with the results of the mathematical calculation.

9. Questions

1- Do the experiment 1 by using the steel bar, and measure the deflection for the length 300, 400, and 500, then compare the measured values by calculated deflection (Eq. 1.1),
-Discuss the obtained experimental results and give conclusions.

2- Do the experiment 2 by using the steel bar, and measure the deflection for the length 0 to 800 (increment 100), then compare the measured values by calculated deflection (Eq. 1.3, Eq. 1.4),
-Draw in a graph the elastic line for both measured and calculated deflection values
-Discuss the obtained experimental results and give conclusions.

10. Results

a. Bending on the cantilever bar:

1- Mathematical calculation

2- Results

Table 1.1. Comparison between measured and calculated deflections

Length (L) [mm]	Deflection (f) [mm]	
	Measured	Calculated
300		
400		
500		

3- Discussion the results and conclusion:

b. Determining the elastic line

1- Mathematical calculation

2- Results

Table 1.2. Comparison between measured and calculated deflections

(x) [mm]	Deflection (f) [mm]	
	Measured	Calculated
0		
100		
200		
300		
400		
500		
600		
700		
800		

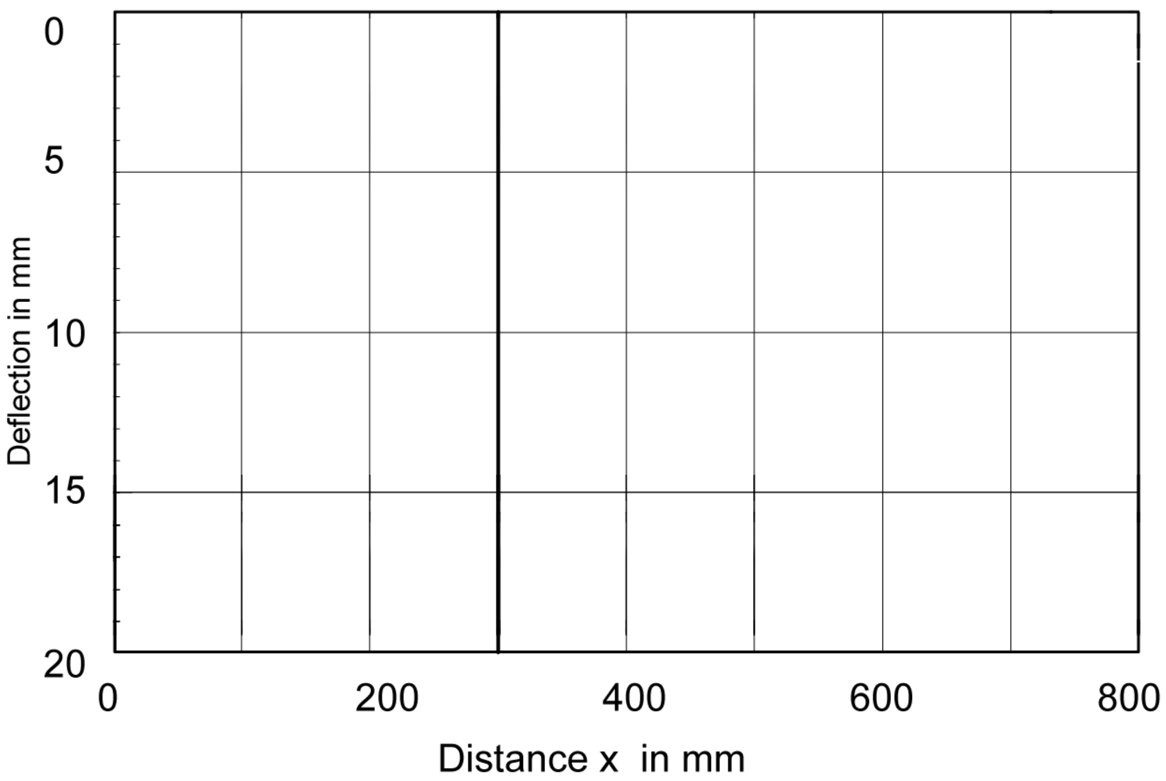

Fig. 1.3. Elastic line of cantilever bar

3- Discussion the results and conclusion: