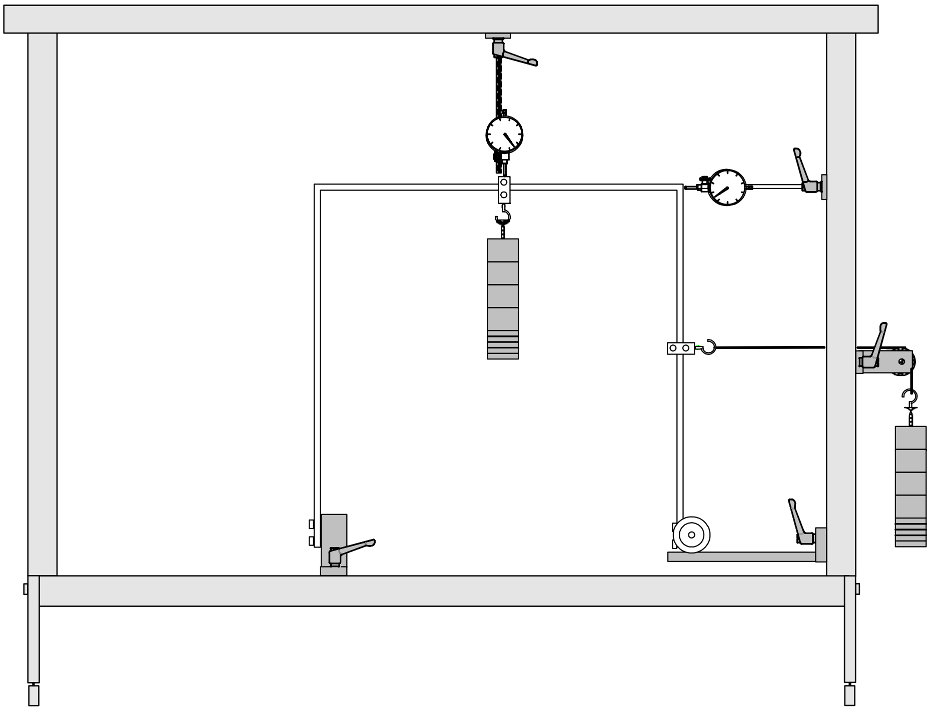
Experiment Instructions

SE 110.20   Deformation of Frames



Experiment Instructions

This manual must be kept by the unit.

Before operating the unit:
- Read this manual.
- All participants must be instructed on handling of the unit and, where appropriate, on the necessary safety precautions.

Table of Contents

1 Description of the Unit 1

1.1 Intended Use 2

2 Basic Principles 3

3 Experiments 6

3.1 Experiment Set-up: U Frame with Horizontal Loading 6

3.2 Performance of the Experiment 7

3.3 Evaluation of the Experiment 8

3.4 Experiment Set-up: S Frame with Vertical Loading 9

4 Appendix 10

4.1 Technical Data 10

4.2 List of the Most Important Symbols of Formulae and Units 11

1 Description of the Unit

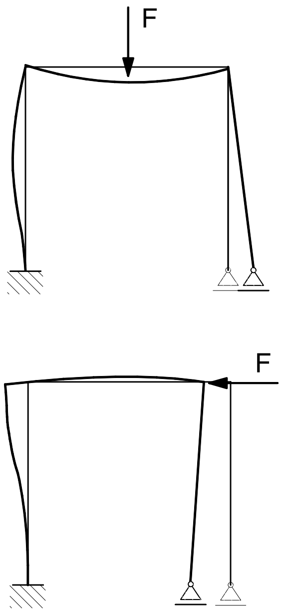


Fig. 1.1

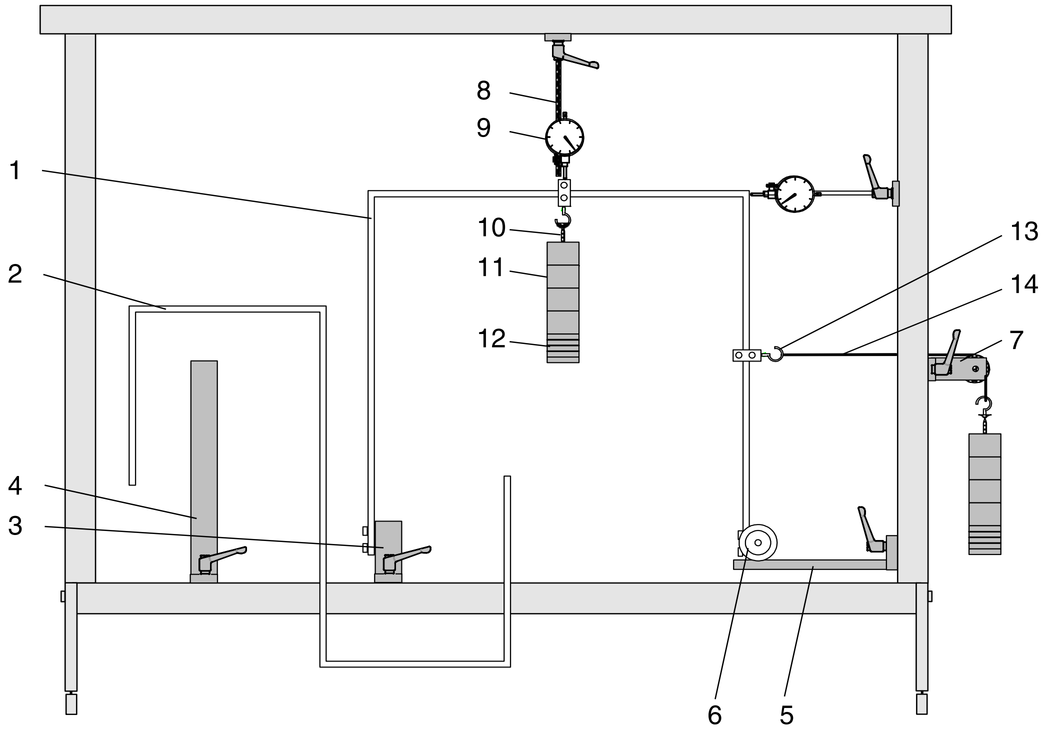
The unit **SE 110.20 Deformation of frames** is designed to be used in conjunction with the Universal Structural Testing Frame SE 110.

The apparatus enables the experimental investigation of the deformation of frames.

- Various loading conditions
- Measurement of deformation
- Relation between loading and deformation
- Superposition principle
- Application of the elasticity theory on statically determined and undetermined systems
- Comparison of calculated results with the measurements.

The apparatus SE 110.20 has the following features:

- Two different steel frames
- Bearing statically determined or undetermined
- Loading by means of weights set
- Accurate measurement of deformation by means of dial gauges.



Item	Designation	Quantity
1	U frame 600mm x 600mm, cross section 10mm x 20mm, steel	1
2	S frame 600mm x 600mm, cross section 10mm x 20mm, steel	1
3	Short fastening column	1
4	Long fastening column	1
5	Bearing plate	1
6	Loose bearing with deflection roller	1
7	Pulley with bearing	1
8	Dial gauge support, short	2
9	Dial gauge, 0...20mm	2
10	Weights hanger, own weight 1N	2
11	Weight, 5N	6
12	Weight, 1N	8
13	Hook, sliding	2
14	Rope	1

Fig. 1.2 Delivered parts

1.1 Intended Use

The unit is to be used only for teaching purposes.

2 Basic Principles

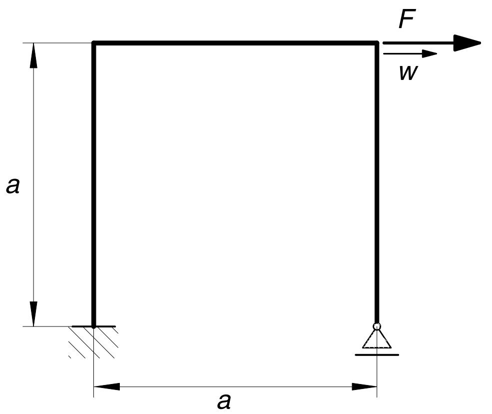


Fig. 2.1

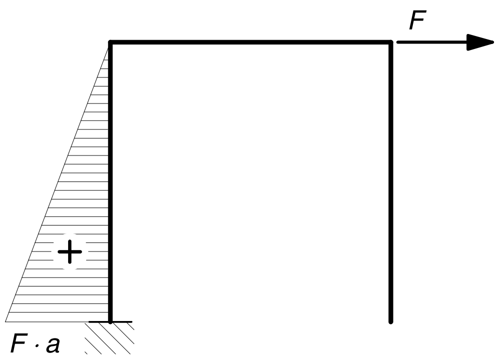


Fig. 2.2

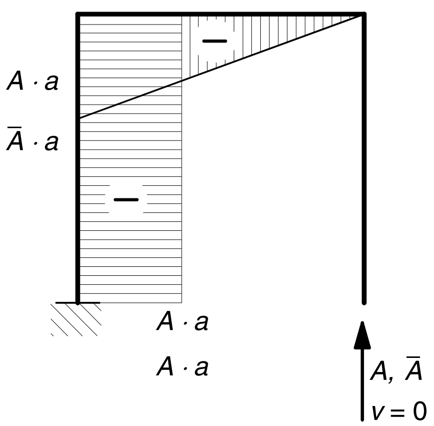


Fig. 2.3

The basic principles set out in the following make no claim to completeness. For further theoretical explanations, refer to the specialist literature.

A force F attacks horizontally on the upper right corner of the frame. The horizontal deflection w at the influence point is going to be determined.

The calculation is based on the principle of virtual work. First, we must determine the unknown force A on the bearing. For this, a virtual bearing force $\bar{A}$ is introduced. To determine the virtual work, the bending moments gradients due to real forces are coupled with their corresponding virtual forces. The virtual work results from the real displacement v on the bearing and the virtual bearing force, and must be zero for the bearing due to zero displacement.

$$v \cdot \bar{A} = 0 = \frac{1}{E \cdot I} \cdot \int \{ M(x) \cdot \bar{M}(x) \} dx \qquad (2.1)$$

The works of the normal and lateral forces are ignored, because the opposite forces are small.

The evaluation of the bending moment gradient in the side diagram give:

$$v \cdot \bar{A} = 0 = \frac{1}{E \cdot I} \cdot \left(\frac{1}{3} \cdot A \cdot \bar{A} \cdot a^3 + A \cdot \bar{A} \cdot a^3 - \frac{1}{2} \cdot F \cdot \bar{A} \cdot a^3\right) \quad (2.2)$$

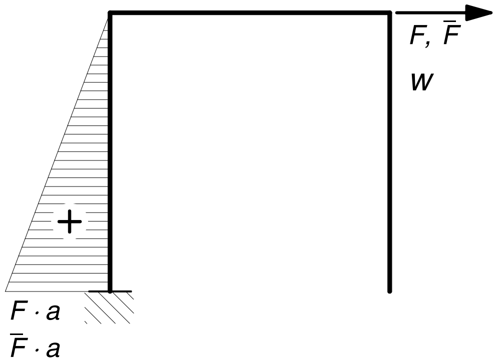


Fig. 2.4

The virtual force can be abbreviated and the equation is solved for the bearing force, where:

$$A = \frac{3}{8} \cdot F \quad (2.3)$$

Using the known bearing force, the displacement w at the force influence point can be calculated. For this, a virtual force F is introduced in the direction of displacement to be calculated.

The virtual work is calculated from

$$w \cdot \bar{F} = 0 = \frac{1}{E \cdot I} \cdot \int \{ M(x) \cdot \bar{M}(x) \} \mathrm{d}x \quad (2.4)$$

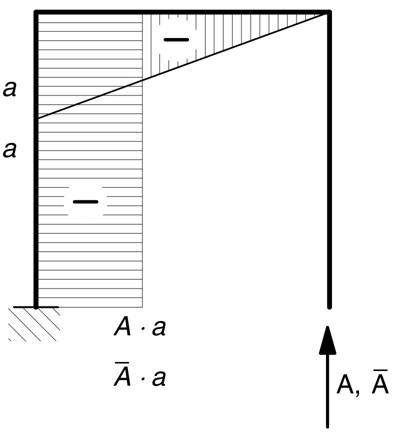


Fig. 2.5

Substitution and integration of the shown bending moments gradients result in:

$$w \cdot \bar{F} = 0 = \frac{a^3}{E \cdot I} \cdot \left(\frac{1}{3} \cdot F \cdot \bar{F} - \frac{1}{2} \cdot A \cdot \bar{F} - \frac{1}{2} \cdot F \cdot \bar{A} + A \cdot \bar{A} + \frac{1}{3} \cdot A \cdot \bar{A}\right) \quad (2.5)$$

After substitution of the bearing force and abbreviating the virtual force, the displacement is obtained from

$$w = \frac{7}{48} \cdot \frac{F \cdot a^3}{E \cdot I} \qquad (2.6)$$

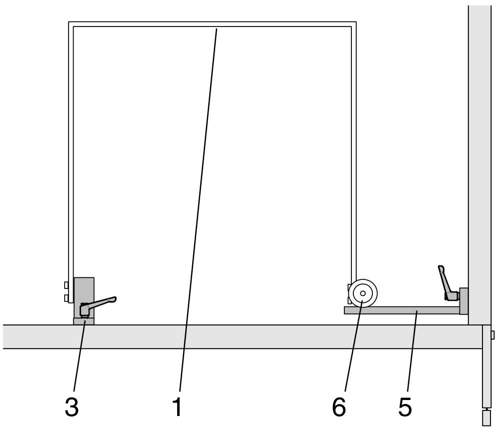
Similarly, the other loading cases or displacement at other positions of the frame can also be calculated.

3 Experiments

The selection of experiments makes no claims of completeness but is intended to be used as a stimulus for your own experiments.
The results shown are intended as a guide only. Depending on the construction of the individual components, experimental skills and environmental conditions, deviations may occur in the experiments. Nevertheless, the laws can be clearly demonstrated.

Various experiments with different loading conditions can be performed with the unit. In the following, selected loading conditions are examined.

3.1 Experiment Set-up: U Frame with Horizontal Loading

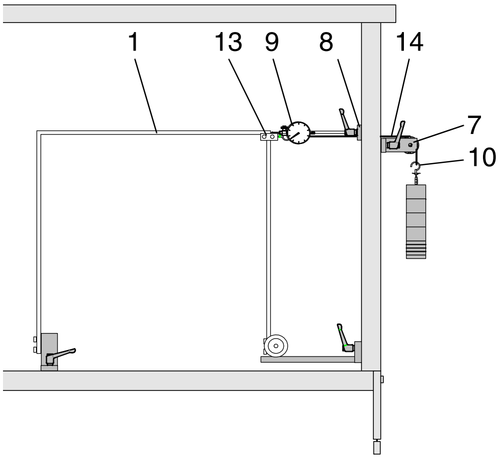


1	U frame
3	Fastening column, short
5	Bearing plate
6	Loose bearing with deflection roller

Fig. 3.1

This experimental set-up corresponds to calculation example in Chapter 2.

- Clamp the fastening column (3) on the lower side of the testing frame at 750mm distance from the right side.
- Mount the U-Frame (1) on the other side with the loose bearing and the roller (6).
- Screw the U-Frame (1) into the fastening column (3).
- Fasten the bearing plate (5) on the right vertical side of the testing frame so that the bearing slider sits lightly.



1	U frame
7	Bearing
8	Dial gauge support
9	Dial gauge
10	Weight hanger
13	Hook
14	Rope

Fig. 3.2

Loading with horizontal force

- Clamp the pulley with bearing (7) on the outer side of the frame at the same level of the force influence point.
- Connect the hook (13) to the point of force influence and hook the rope (14) with the weight hanger (10).
- Align the pulley (7) so that the direction of the rope's effect becomes horizontal.
- Clamp the dial gauge (9) with its support (8) in the inner side of the frame at the same height of the force influence point. Align the dial gauge with the influence point.

3.2 Performance of the Experiment

- Detach the weights hanger.
- Set the dial gauge to zero.
- Load the weights hanger with 3 x 5N and 4 x 1N weights (total weight 20N).
- Hang the weights hanger again.
- Read the dial gauge and note down the displacement.

The experiment can be repeated for other force influence points and measuring positions.

3.3 Evaluation of the Experiment

The measured displacement is compared with the calculated value.

The measured value at the force influence point is:

$w = 2{,}02\,\text{mm}$

For the calculations, the following data are available:

Elasticity Modulus:
$E = 205000\,\text{N/mm}^2$

Side length of the U frame:
$a = 600\,\text{mm}$

Area moment of inertia
for 10 x 20 cross section:

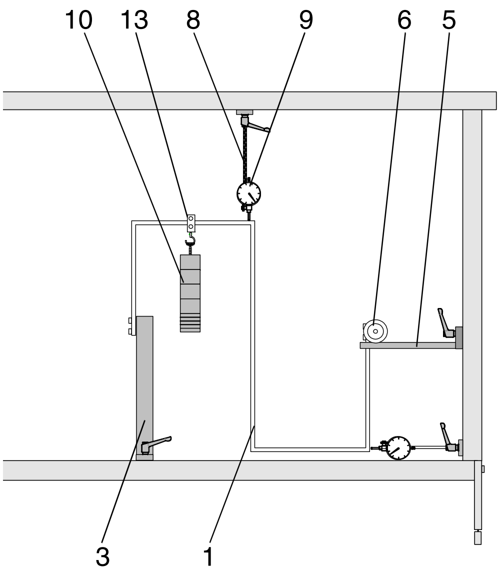
$$I = \frac{b \cdot h^3}{12} = \frac{20 \cdot 10^3}{12} = 1667\,\text{mm}^4$$

For the force-influence point, calculation of the displacement gives:

$$w = \frac{7}{48} \cdot \frac{F \cdot a^3}{E \cdot I} = \frac{7 \cdot 20 \cdot 600^3}{48 \cdot 210000 \cdot 1667} = 1{,}84\,\text{mm}$$

The coincidence of the values is good. The deviation is less than 10%.

3.4 Experiment Set-up: S Frame with Vertical Loading



1	S frame
3	Fastening column, long
5	Bearing plate
6	Loose bearing with deflection roller
8	Dial gauge support
9	Dial gauge
10	Weights hanger
13	Hook

Fig. 3.3

- Clamp the long fastening column (3) on the lower side of the testing frame at 750mm distance from the right side.
- Mount the S frame (1) on the other side with the loose bearing and the roller (6).
- Screw the S frame (1) into the fastening column (3).
- Fasten the bearing plate (5) on the right vertical side of the testing frame so that the S frame comes from below through the slot and the bearing roller sets on upper side of the bearing plate lightly.
- For vertical loading, connect the hook (13) to the point of force influence and hook the weight hanger (10).
- Use the dial gauge support (8) to clamp the dial gauge (9) at the frame and align the dial gauge with the desired measuring point.

Horizontal loading can be used alone or combined with the vertical loading.

The displacement can be measured also on two positions simultaneously, since two dial gauges are delivered.

4 Appendix

4.1 Technical Data

Frame

Form:	U or S	
Side length:	600	mm
Cross section:	10mm x 20	mm
Area moment of inertia:	1667	mm^4
Material:	Steel	
Elasticity modulus:	205000	N/mm^2

Dial gauges

Range:	0...20	mm
Resolution:	0,01	mm

Weights set

Weights hanger, own weight		1	N
Weight set:	8 x	1	N
	6 x	5	N

4.2 List of Symbols of Formulae and Units

Symbols of formulae	Mathematical / physical quantity
a	Side length of frame
A	Bearing force
b	Width
E	Elasticity modulus
F	Horizontal force
h	Height
I	Area moment of inertia
M	Moment
v	Real displacement
w	Horizontal deflection