Intelligent testing

Testing of plastics:

Flexural tests, ISO 178

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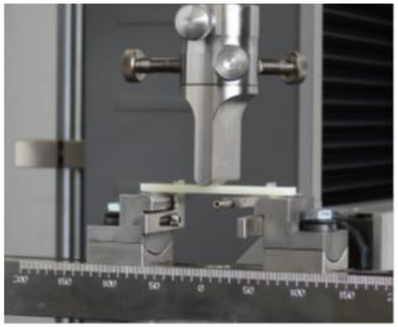

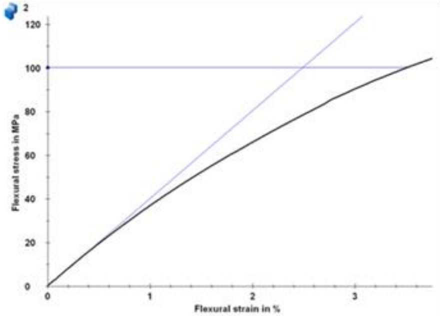

Reliable Test Results

Measurements which are 'true' and 'precise' are 'accurate'.

True but not precise

Precise but not true

Not true and not precise

True and precise

Content

Zwick Roell

Test pieces

Particular points of the standard

Comparison to tensile

Multipurpose specimen

Bar test specimen (type B) for flexural tests can be cut from the center part of the Multipurpose Specimen according to ISO 20753

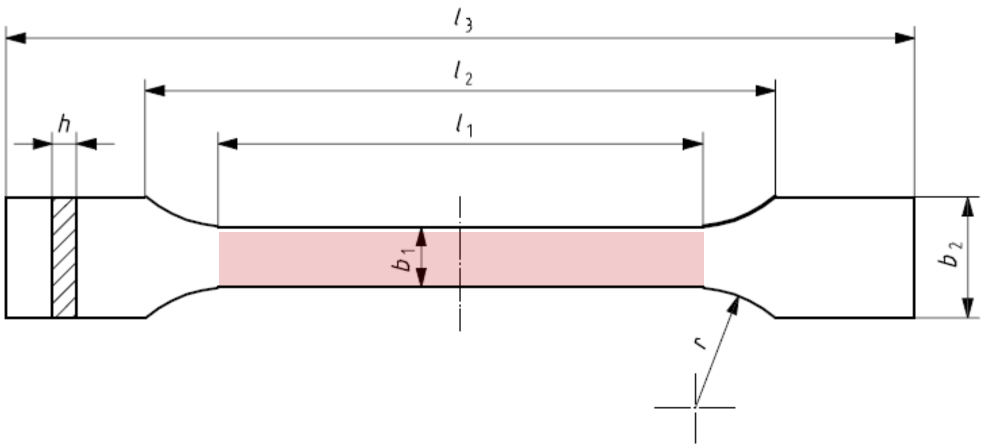

Table 3 — Dimensions of type A1 and type A2 test specimens

Dimensions in millimetres

	Dimension	Type A1 multipurpose (injection moulded)	Type A2 (machined)
l_3	Overall length[a]	≥170	≥150
l_2	Distance between broad parallel-sided sections[b]	109,3 ± 3,2	108,0 ± 1,6
l_1	Length of narrow parallel-sided section	80 ± 2	60,0 ± 0,5
r	Radius of shoulder	24 ± 1	60,0 ± 0,5
b_2	Width at ends	20,0 ± 0,2	
b_1	Width of narrow parallel-sided section	10,0 ± 0,2	
h	Thickness (preferred)	4,0 ± 0,2	

[a] The recommended overall length of 170 mm of the type A1 test specimen is consistent with ISO 294-1 and ISO 10724-1. For some materials, the length of the tabs may need to be extended (e.g. l_3 = 200 mm) to prevent breakage or slippage in the jaws of the test machine.

[b] Resulting from l_1, r, b_1 and b_2, but within the indicated tolerance limits.

6.3 Bar test specimens (type B)

Bar test specimens shall have the following dimensions:

- length l_1: (80 ± 2) mm;
- width b_1: (10,0 ± 0,2) mm;
- thickness h: (4,0 ± 0,2) mm.

The designation of bar test specimens is type Bx, where

- B is the specimen type;
- *x* indicates the method of preparation.

They can be prepared as follows:

- type B1: by injection moulding;
- type B2: by machining from the central section of the type A1 test specimen (see also Figure 1);
- type B3: by machining from sheets or shaped articles, or by compression moulding to the required dimensions.

Multipurpose specimen

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The multipurpose specimens as per ISO 20753 are used for many test types.

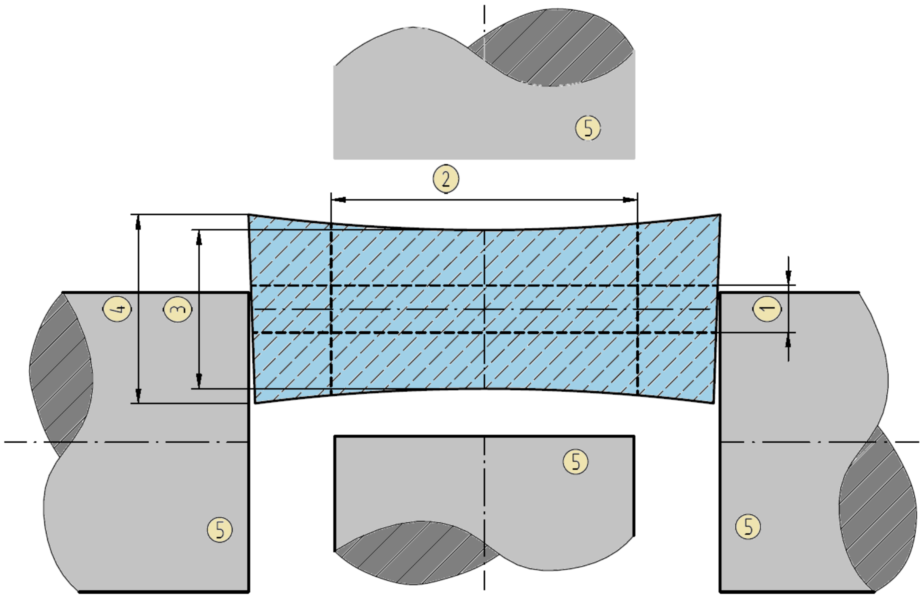
Method	Reference[a]	Type of specimen and/ or dimensions mm
Tensile test	ISO 527-2	A
Tensile creep test	ISO 899-1	A
Flexural test	ISO 178	B
Flexural creep test	ISO 899-2	B
Compressive test	ISO 604	(10 or 50) × 10 × 4
Impact strength, Charpy	ISO 179-1, ISO 179-2	B
Impact strength, Izod	ISO 180	B
Impact strength, tensile	ISO 8256	B
Temperature of deflection under load	ISO 75-2	B
Vicat softening temperature	ISO 306	(≥10) × 10 × 4
Hardness, ball indentation	ISO 2039-1	(≥20) × 20 × 4
Hardness, Rockwell	ISO 2039-2	(≥20) × 20 × 4
Hardness, Shore	ISO 868	(≥20) × 20 × 4
Environmental stress cracking	ISO 22088-1, ISO 22088-2, ISO 22088-3, ISO 22088-4, ISO 22088-5, ISO 22088-6	A or B
Density	ISO 1183-1, ISO 1183-2, ISO 1183-3	B (≥10) × 10 × 4
Oxygen index	ISO 4589-2, ISO 4589-3	B
Comparative tracking index (CTI)	IEC 60112	20 × 20 × 4
Electrolytic corrosion	IEC 60426	30 × 10 × 4
Linear expansion	ISO 11359-2	(≥10) × 10 × 4

Dimension measurement

ISO 178 (Flexural tests) and ISO 16012 (Dimension measurement) give clear advise on dimension measurement methods.

- **The error of the specimen height measurement influences the calculation of mechanical stresses by square !**

- A difference of only 0.1 mm produces 5% of error in stress calculation.
- Thickness measurements to be done by a micrometer with ratchet, ensuring constant contact pressure
- Thickness measurement shall be well centered
- Width measurement at the edges of the specimen shall be avoided



Dimension measurement
1 measuring range for width determination ±0,5 mm
2 measuring range for thickness determination ±3,25 mm
3 minimum thickness *h*min
4 maximum thickness *h*max
5 micrometer tips

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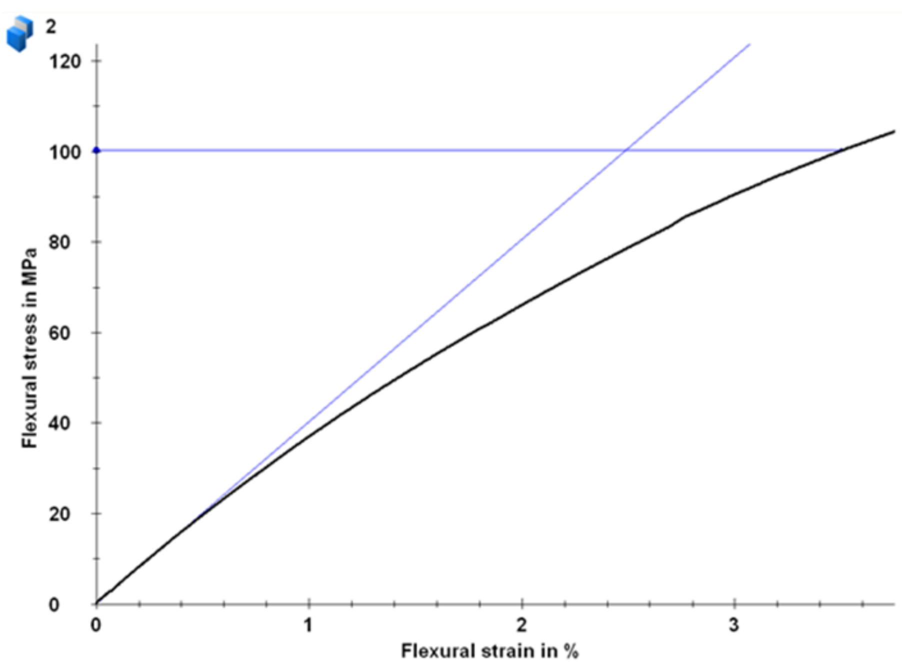
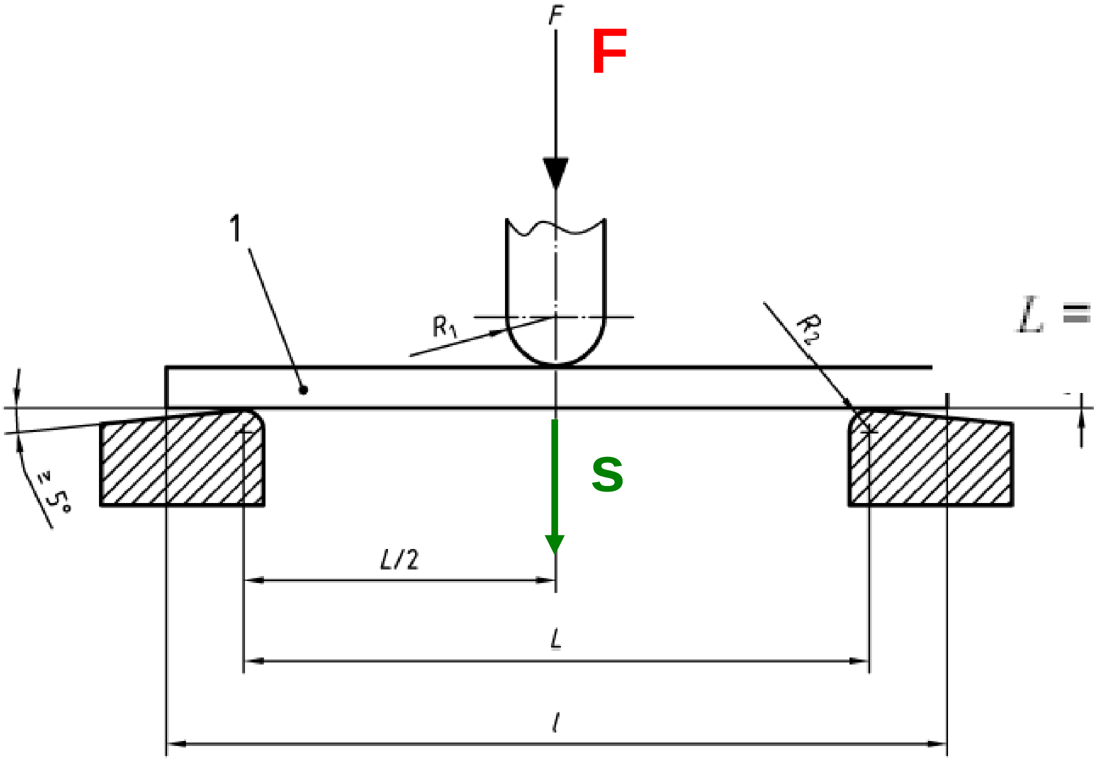
Comparison to tensile



Flexural

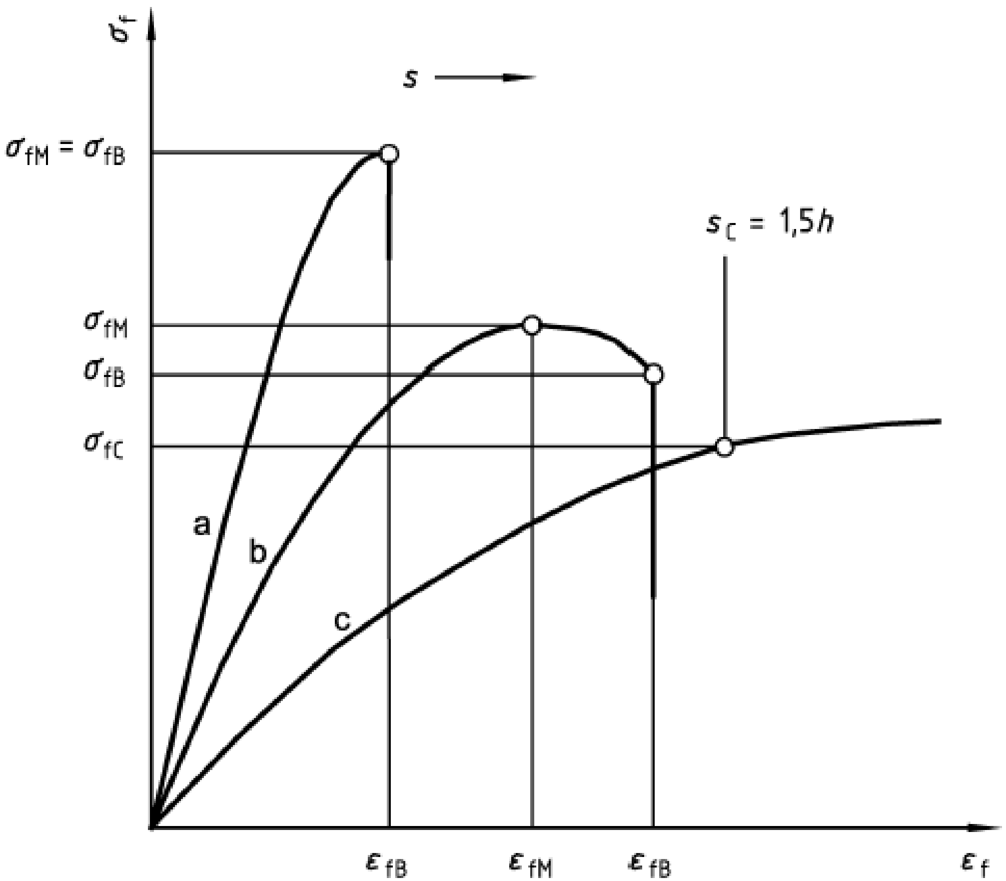
The support distance is a fixed function of the specimen thickness. It is 64 mm for standard testpieces having 4 mm in thickness.



$$L = (16 \pm 1)\ \bar{h}$$

Flexural

Specific formula apply for stress and strain calculation. These formula are only valid for small flexural angles.



$$\sigma_f = \frac{3FL}{2bh^2}$$

$$\varepsilon_f = \frac{600sh}{L^2}\%$$

$$E_f = \frac{\sigma_{f2} - \sigma_{f1}}{\varepsilon_{f2} - \varepsilon_{f1}}$$

Flexural

Angular errors and friction shall be compensated in case of deflections exceeding 0.1 L (only testing of composites ISO 14125, not for ISO 178 !)

$$\sigma_f = \frac{3FL}{2bh^2}$$

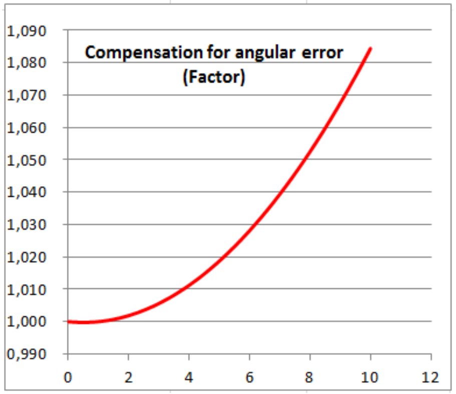
Basic formula

$$\sigma_f = \frac{3FL}{2bh^2}\left\{1 + 6\left(\frac{s}{L}\right)^2 - 3\left(\frac{sh}{L^2}\right)\right\}$$

Formula incl. angular compensation

$$\sigma_f = \frac{3FL}{2bh^2}\left\{1 + 6\left(\frac{s}{L}\right)^2 - 3\left(\frac{sh}{L^2}\right) - \mu\left(2\frac{s}{L} - \frac{h}{L}\right)\right\}$$

Formula incl. angular and friction compensation



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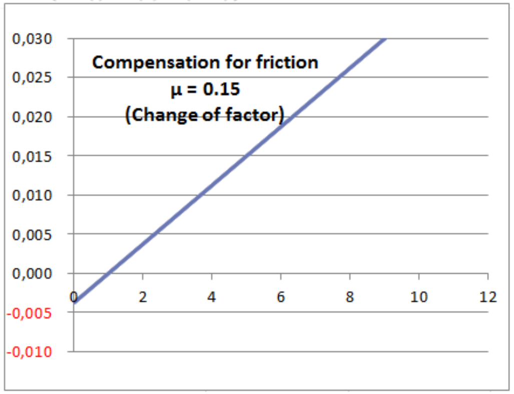

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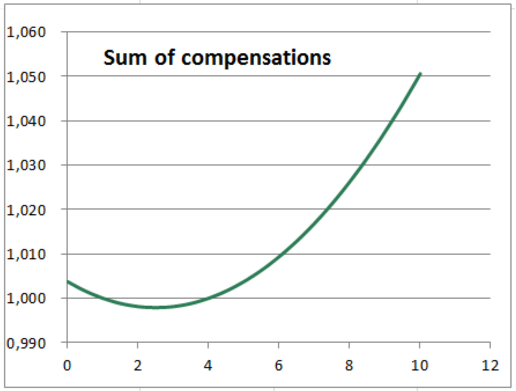
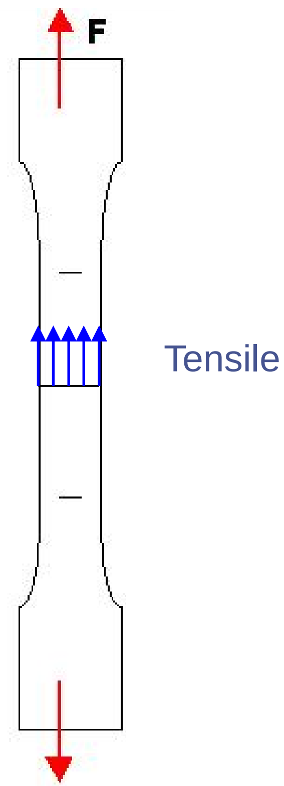


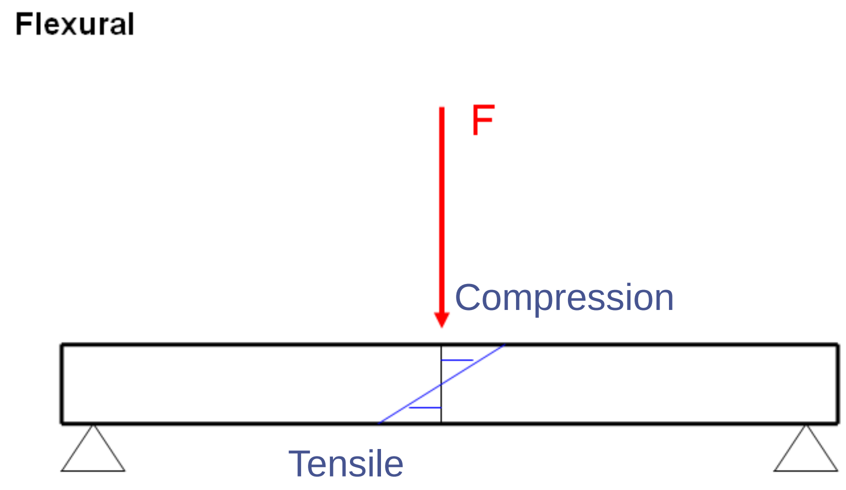
Example:Specimen thickness 2 mm, support distance 80 mm. For a 10 by 4 by 80 mm specimen, the compensation is about 1 % at 6mm deflection

Content

Comparison to tensile

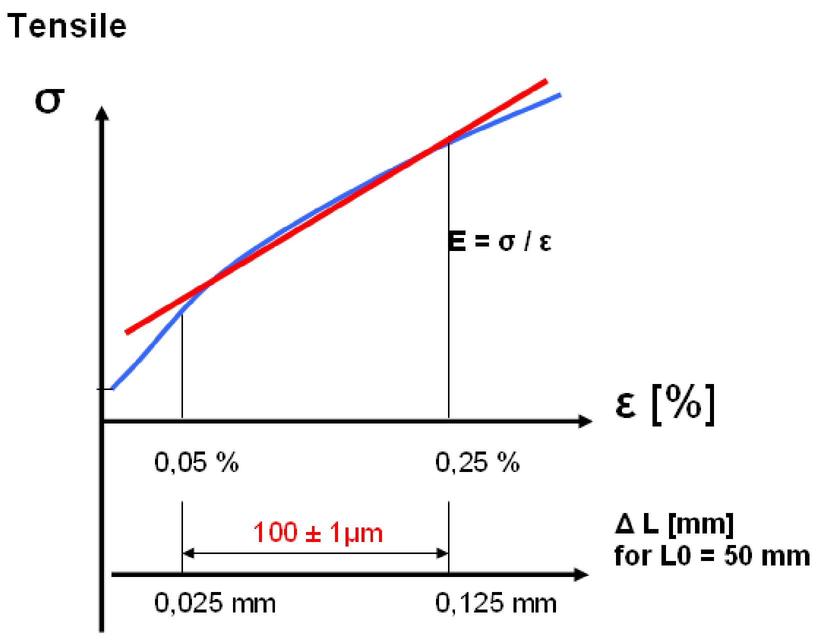
The tensile tests shows an average behavior over the whole cross-section. The flexural test shows more the materials characteristic close to the outer region of the cross section

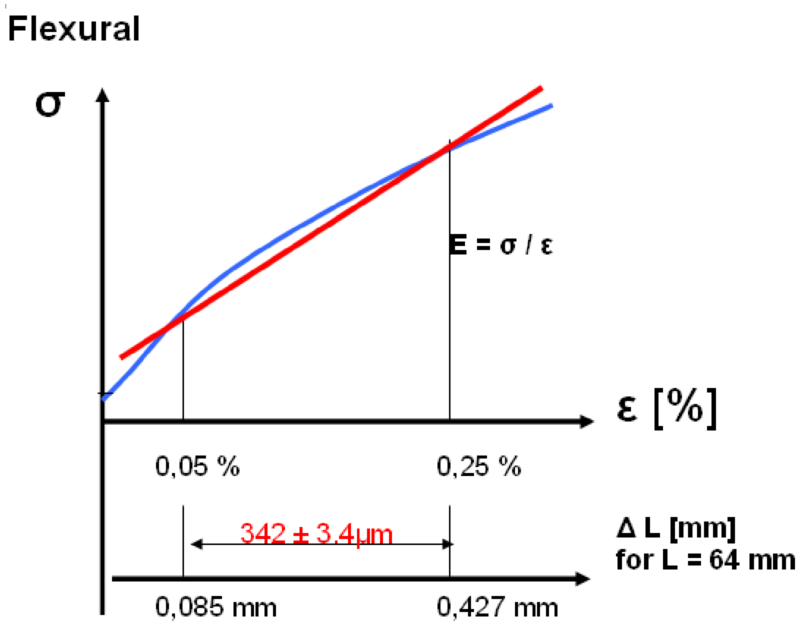




Comparison to tensile

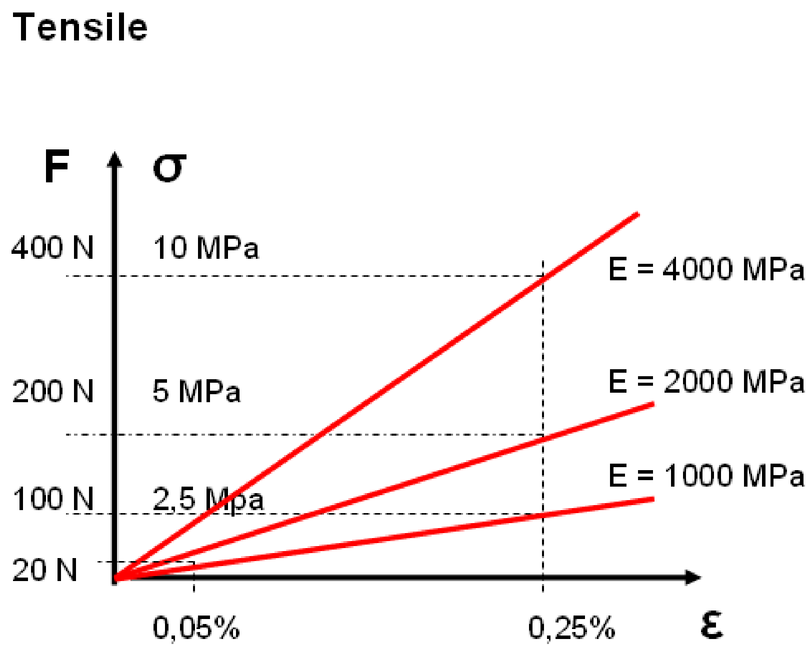
The flexural modulus is determined in the same strain range as the tensile modulus, but in flexural the measured travel is more than 3 times larger.

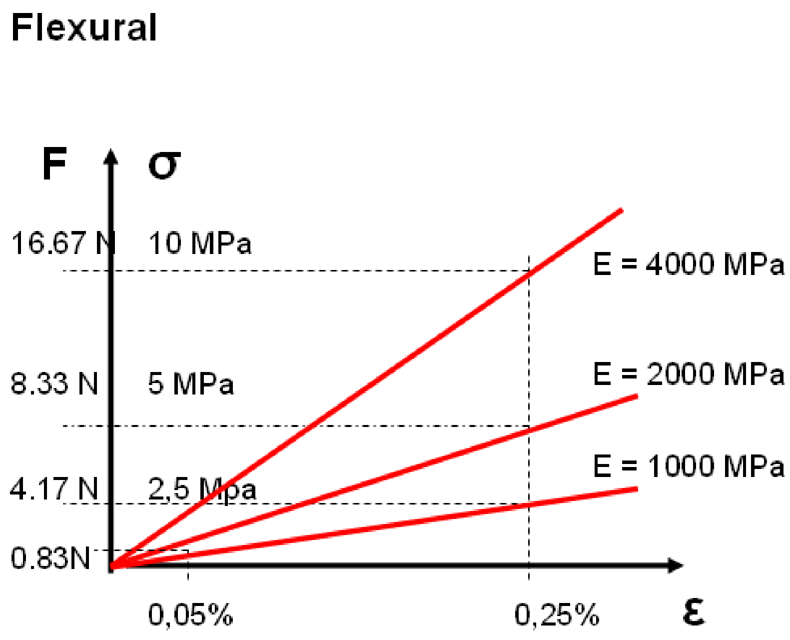




Comparison to tensile

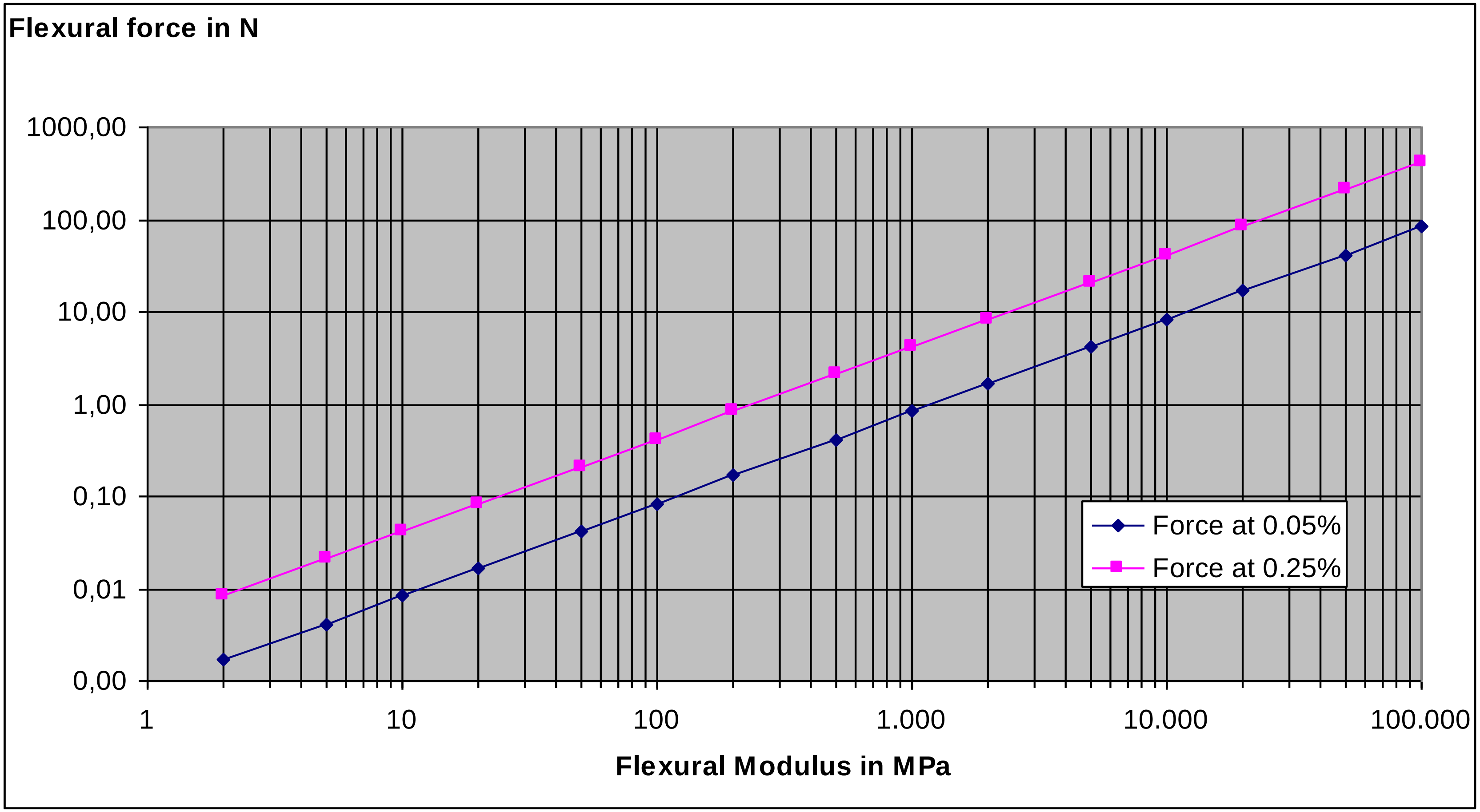
Forces to determine the modulus are about 24 times smaller in flexural than in tensile.





Comparison to tensile

In practice, the forces in flexural tests are quite low.

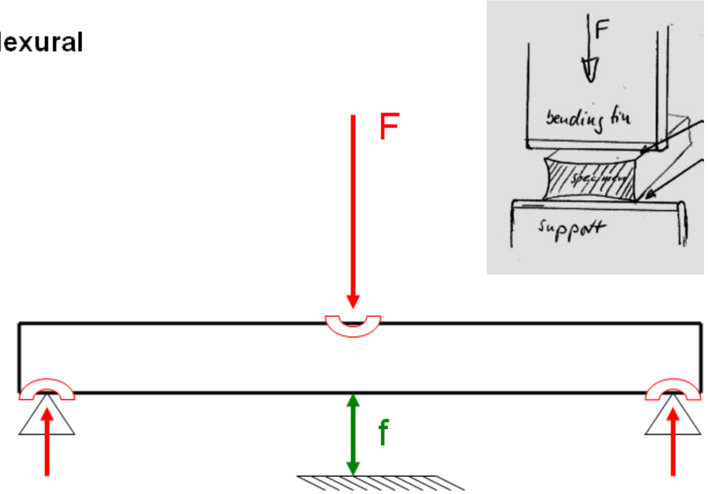


Comparison to tensile

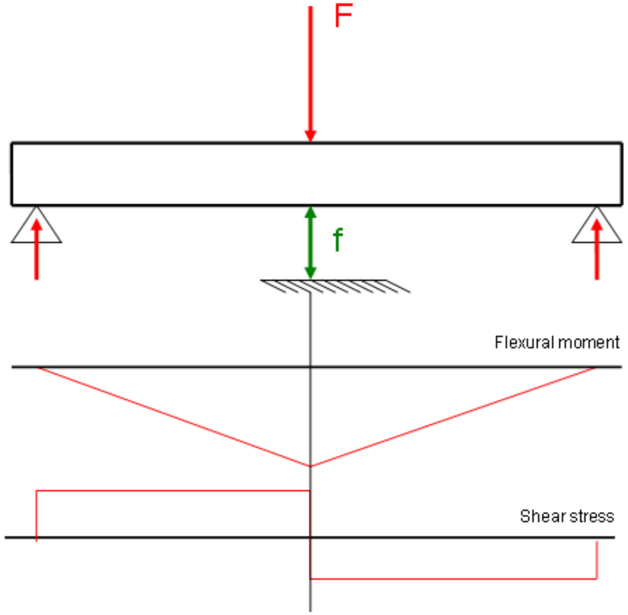
The 3-point flexural test contains some systematic problems

The indentation of the supports is calculated as a strain, while the indentation of the loading nose is compensated by the type of travel measurement, if direct travel measurement is applied.

Flexural

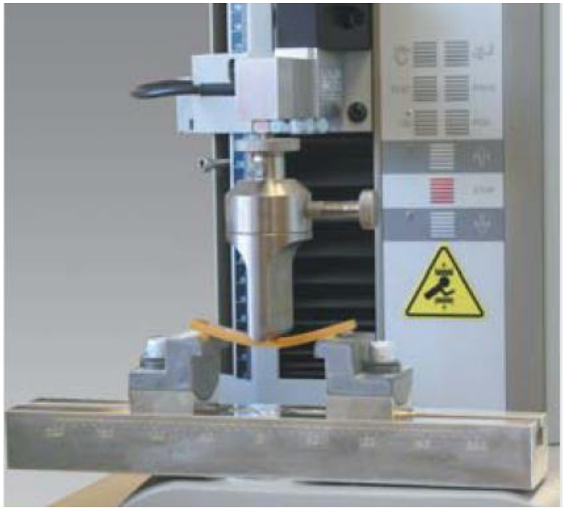
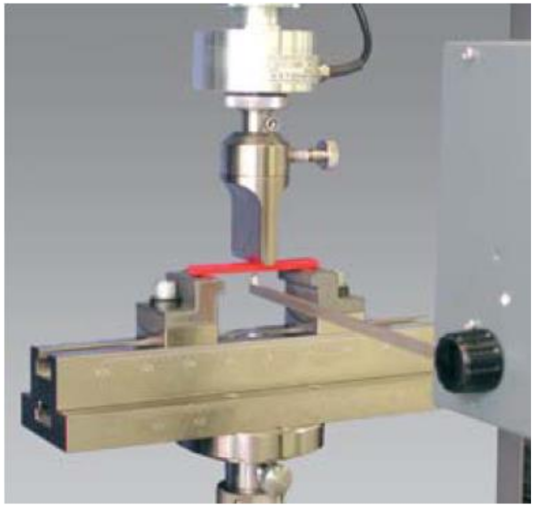


The stress and strain calculation neglects the presence of shear stresses.



Comparison to tensile

The flexural test can be performed with direct travel measurement using a transducer, or just with crosshead travel measurement, provided that a compliance compensation is applied.

Deflection measurement

ISO 178 defines the requirements for deflection measurement as a function of the objectives for the test.

Table 2 — Types of tests and calibration requirements

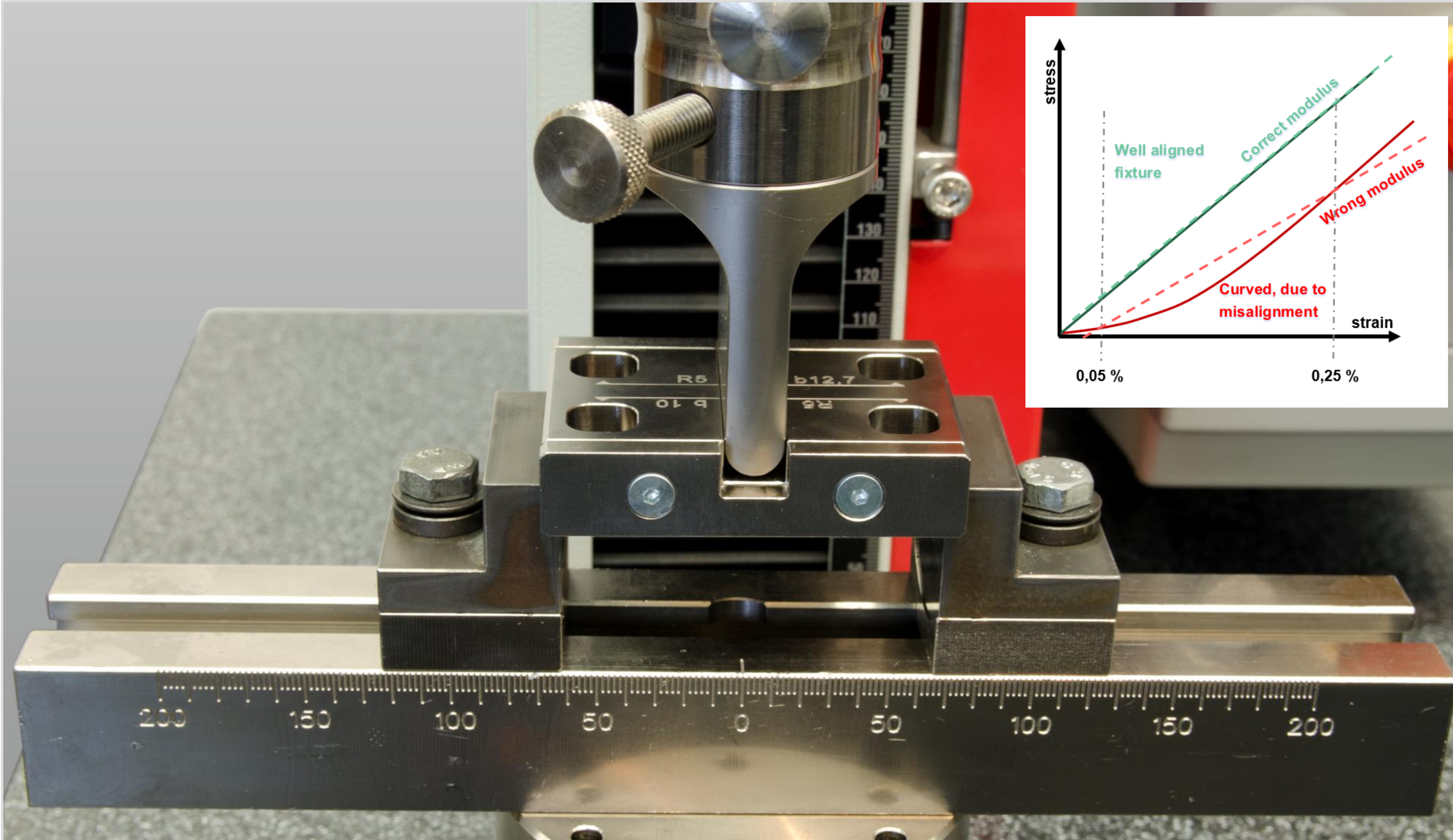
	Types (I-IV) of tests in increasing order of complexity and requirements for accuracy			
Required objective of testing	Stress/strength only	Stress/strength/ strains > 1%	Stress/strength/ strains/**repeatable and precise** modulus	Stress/strength/ strains/true and precise = **accurate** modulus
Property	**I**	**II**	**III**	**IV**
σ_{fB}	×	×	×	×
σ_{fM}	×	×	×	×
σ_{fC}		×	×	×
σ_{fC}		×	×	×
σ_{fB}		×	×	×
σ_{fM}		×	×	×
E_f			×	×
Calibration requirement				
Force	ISO 7500-1, class 1			
Deflection measurement	—	ISO 9513/class 2	ISO 9513/class 2 plus condition set in clause 5.4.3	ISO 9513/class 1 plus condition set in clause 5.4.3
Type of deflection measurement	—	Crosshead displacement	Crosshead displacement with compliance correction	Direct measurement using a deflectometer

True but not precise

Precise but not true

Not true, not precise

True and precise



Exact alignment of a flex tool