— total force: ± 7 %.

4.2.3.2.3 Minimum concrete strength at transfer

At transfer of the prestressing force, the concrete shall have a minimum strength $f_{cm,p}$ of 1,5 times the maximum compressive stress in the concrete and not less than 20 MPa (cylinder strength).

The requirements according to EN 1992-1-1:2004, 5.10.2.2 (5) shall be considered.

In any case the strength shall be adequate for the anchorage of the strands.

4.2.3.2.4 Slippage of tendons

Slippage, which is the shortening of the tendon at each end of the element after transfer of the prestress force, shall be limited to the following values:

— for individual tendons (strands or wires): 1,3 ΔL_0;

— for the mean value of all tendons on one end of an element: ΔL_0.

For strands the average value of three circumferentially positioned wires shall be taken into account.

The value of ΔL_0, in millimetres, shall be calculated from:

$$\Delta L_0 = 0,4 l_{pt2} \frac{\sigma_{pmo}}{E_p} \tag{4}$$

where

l_{pt2} is the upper bound value of transmission length = 1,2 l_{pt}, in mm according to EN 1992–1-1:2004, 8.10.2.2;

σ_{pmo} is the initial stress in the prestressing steel immediately after release, in MPa;

E_p is the modulus of elasticity of the prestressing steel, in MPa.

In general, slippage of tendons is measured except for one piece moulded products (see Table D.3). On sawn products, visual inspection alone may indicate no slippage and no further measurement is required.

4.3 Finished product requirements

4.3.1 Geometrical properties

4.3.1.1 Production tolerances

Recommendations for maximum deviations of cross-sectional dimensions [width (Δb) and height (Δh)], and for maximum deviation of concrete cover (Δc_{dev}) to bars, wires and strands are given in Table 4:

Table 4 — Deviations

Target dimension mm	Cross-section Δb, Δh [a] mm	Concrete cover [a] [b] Δc_{dev} mm
$L \leq 150$	+ 10/− 5	±5
$L = 400$	+15/− 10	+ 15/− 10
$L \geq 2\,500$	±30	+25/− 10

[a] Linear interpolation for intermediate values.

[b] According to EN 1992-1-1:2004, 4.4.1.1:

$c_{nom} = c_{min} + \Delta c_{dev}$ (use the numerical value for $-\Delta c_{dev}$). Δc_{dev} is a Nationally Determined Parameter; hence other values may be valid in the place of use. A manufacturer may achieve and declare smaller values for Δc_{dev} than given in the National Annex by taking the appropriate measures.

The structural design of the works shall take into account the tolerances on the supports as specified in the structural design for the works.

EN 1992-1-1:2004, 10.9.5.2 may be used as guidance to determine the assumed ineffective distances from the edge of the support and from the end of the precast concrete product. A combination of global tolerances may not be used to determine tolerances at the support, as in most cases they have to be stricter than tolerances achieved by such combinations.

For slabs and beams, the average deviation of concrete cover may be determined as the mean deviation of the individual bars, wires or strands in a beam cross-section or over a maximum width of 1 m in a slab. No individual bar, wire or strand shall have a negative deviation numerically larger than the recommended negative deviation.

NOTE Guidance on concrete cover can be found in Annex A.

Production tolerances of geometrical properties may be determined by measurements according to H.1 to H.3 of Annex H.

a) Recommendations for maximum deviations on length:

$$\Delta l = \pm\left(10 + \frac{L}{1000}\right) \leq \pm 40 \text{ mm} \tag{5}$$

where

L is the nominal length in millimetres.

b) Recommendations for maximum deviations on holes, openings, steel plates, inserts, etc:

1) size of hole or opening ± 10 mm.

2) location of holes, openings, steel plates, inserts, etc. ± 25 mm.

4.3.1.2 Minimum dimensions and detailing

The geometrical characteristics of precast concrete products shall comply with the required minimum dimensions and detailing.

The values of the minimum dimensions and detailing are based on the nominal dimensions and may be taken from the relevant Clauses 7, 8, 9, 10 and 11 of EN 1992-1-1:2004.

4.3.2 Surface characteristics

For the specification of the surface characteristics of a finished product, reference should be made to H.4, where also recommended values are given.

Other maximum deviations may be specified.

For identification of concrete finishes, CEN/TR 15739 may be used.

4.3.3 Mechanical resistance

4.3.3.1 General

The compressive strength class of the concrete shall be declared unless both of the following conditions are fulfilled:

— mechanical resistance of the product is verified and declared on the basis of initial type testing and regular tests for this property during factory production control on the finished product;

— compressive strength class is not a relevant parameter to demonstrate durability of the finished product (see 4.3.7.1 and 4.3.7.5).

All relevant structural properties of the product shall be considered in both ultimate and serviceability limit states.

For prestressing losses, reference may be made to Annex I, in cases specified in that annex.

Mechanical resistance shall be verified by one of the following means:

— calculation (see 4.3.3.2);

— calculation aided by testing (see 4.3.3.3);

— testing (see 4.3.3.4).

The use of these means is submitted to provisions in the place of use.

4.3.3.2 Verification by calculation

Design values of mechanical resistance obtained by calculation shall be verified according to the relevant clauses of EN 1992-1-1, or to the rules valid in the place of use. Pertinent complementary rules given in this and in product standards apply.

4.3.3.3 Verification by calculation aided by physical testing

Physical testing on finished products is required to aid calculation in the following cases:

— alternative design rules with respect to 4.3.3.2;

— structural arrangements with unusual design models not covered by 4.3.3.2.

In these cases, physical testing on a small number of full scale specimens is needed before starting production in order to verify the reliability of the design model assumed for calculation. This shall be done with load-tests up to ultimate limit state (design conditions).

Physical testing is not required in case of reliable theoretical verification following the principles of EN 1992-1-1. Relevant information is also found in EN 1990:2002, Annex D.

— or on representative cores according to EN 12504-1.

For the determination of structural strength, the curing conditions of EN 12390-2 do not apply.

NOTE 1 The different shapes and dimensions of test specimens give different values for the concrete strength.

Proper shape factors shall be applied to give the standard cylinder or cube strength.

Cubes with a nominal size of at least 100 mm and not more than 150 mm and cylinders or cores with equal nominal length and diameter from 100 mm up to 150 mm can be assumed to give a strength value equivalent to the standard cube strength value obtained under the same ambient conditions.

Cylinders and cores with a nominal diameter of at least 100 mm and not larger than 150 mm and with a nominal length to diameter ratio equal to 2 can be assumed to give a strength value equivalent to the standard cylinder strength value obtained under the same ambient conditions.

For other shapes and sizes of specimens, conversion factors shall be established by initial testing according to EN 206:2013+A1:2016, 5.5.1.1.

Cores with a nominal diameter less than 50 mm and/or a nominal length less than 0,7 times the diameter shall not be used. Cubes with a nominal size less than 50 mm shall not be used.

NOTE 2 Annex G provides information on shape correlation factors.

Conversion factors for the relationship between indirect structural strength and direct structural strength shall be established by initial testing. Depending on the shape and/or size of the specimens to be considered this conversion factor may or may not include a shape and/or size conversion factor.

5.1.2 Water absorption

When the water absorption of concrete is measured, the test method given in normative Annex F shall apply.

5.1.3 Dry density of concrete

When the dry density of concrete is required, the test shall be carried out on representative specimens in accordance with EN 12390-7.

5.2 Measuring of dimensions and surface characteristics

When not defined in the specific product standard, information on measuring of dimensions are given in Annex H.

Dimensions are assumed at reference temperatures between 10 °C and 30 °C, and at the reference age of 28 days. If necessary, theoretical corrections shall be made for inherent deviations of the dimensions when measuring at other temperatures or ages.

The equipment used to check deviations shall be read with an accuracy of at least 1/5 of the deviation to be checked.

Angular deviation of a plane surface shall be measured in two perpendicular directions.

For wide elements, such as ribbed elements and special roof elements, the length should be measured at three locations, for example at 100 mm from both edges and in the centre.

If considered necessary, the width and height shall also be measured at least at three locations along the length of the element. For dimensions that may be difficult to measure directly on the element, leveling rods or leveling instruments may be used to aid in the measuring.

Lateral bow and camber shall be measured at midspan.

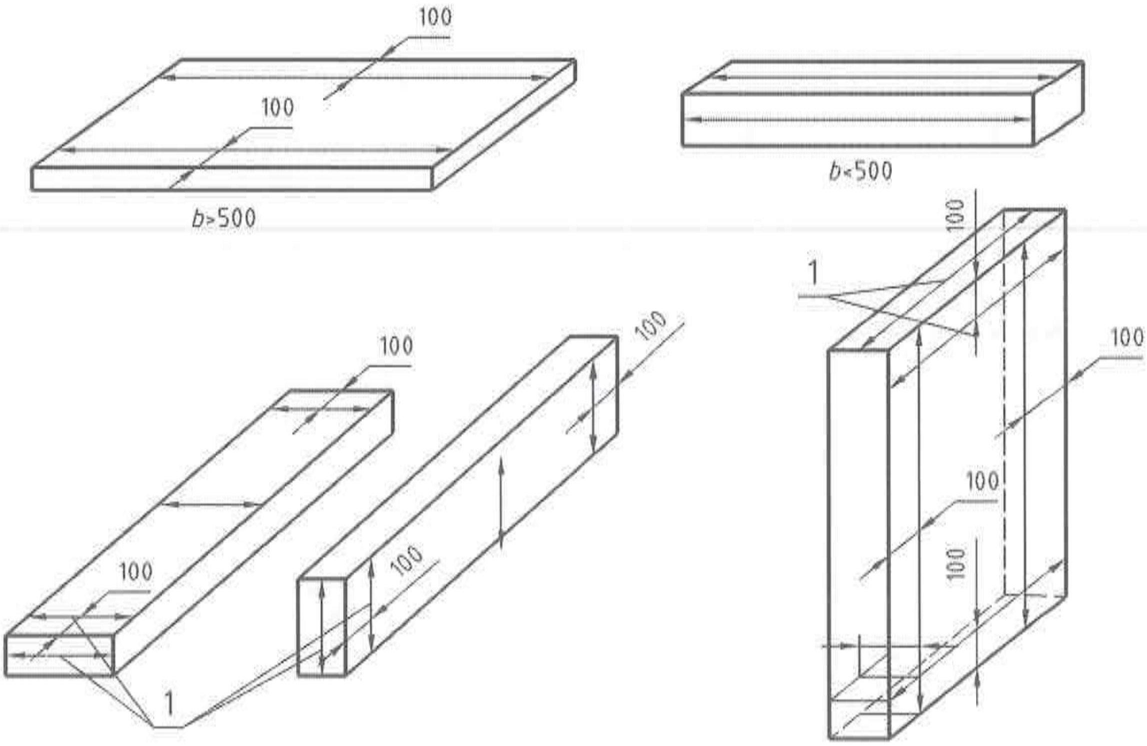
Annex H
(informative)

Measurement of dimensions

H.1 Length, height, width and thickness

Dimensions should not be measured along the edges.

Dimensions in millimetres



Key
b width
1 either - or

Figure H.1 — Measuring points for length, height, width and thickness

H.2 Warp and straightness

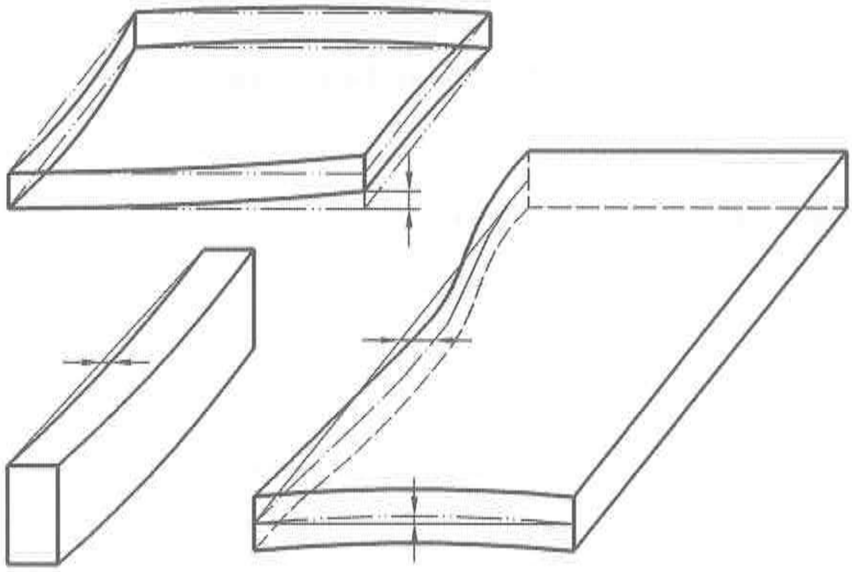


Figure H.2 — Measurement of warp and straightness

H.3 Out of squareness

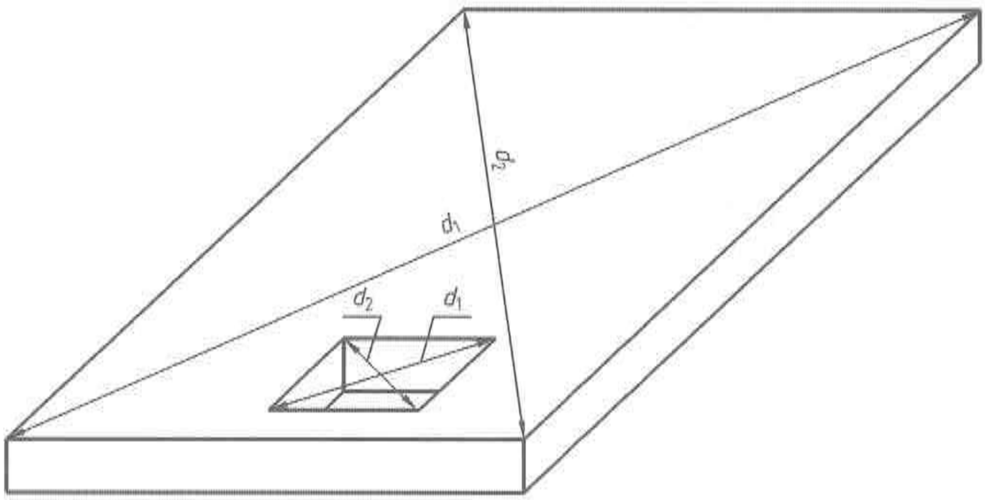


Figure H.3 — Measurement of diagonals

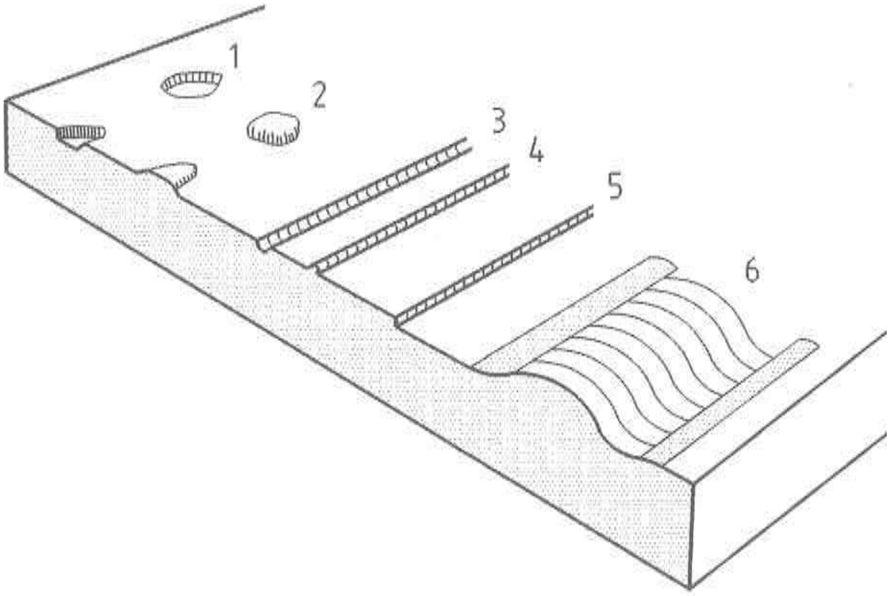
The tolerance requirement should be given as the difference in length between the two diagonals:

$$d_1 - d_2 \quad \text{(H.1)}$$

H.4 Surface characteristics

For the specification of the surface characteristics of a finished product, reference should be made to the vocabulary defined in Figure H.4.

Specially treated surfaces, such as with exposed aggregate, polished, cast against a matrix, etc. are not covered by these tolerance recommendations.

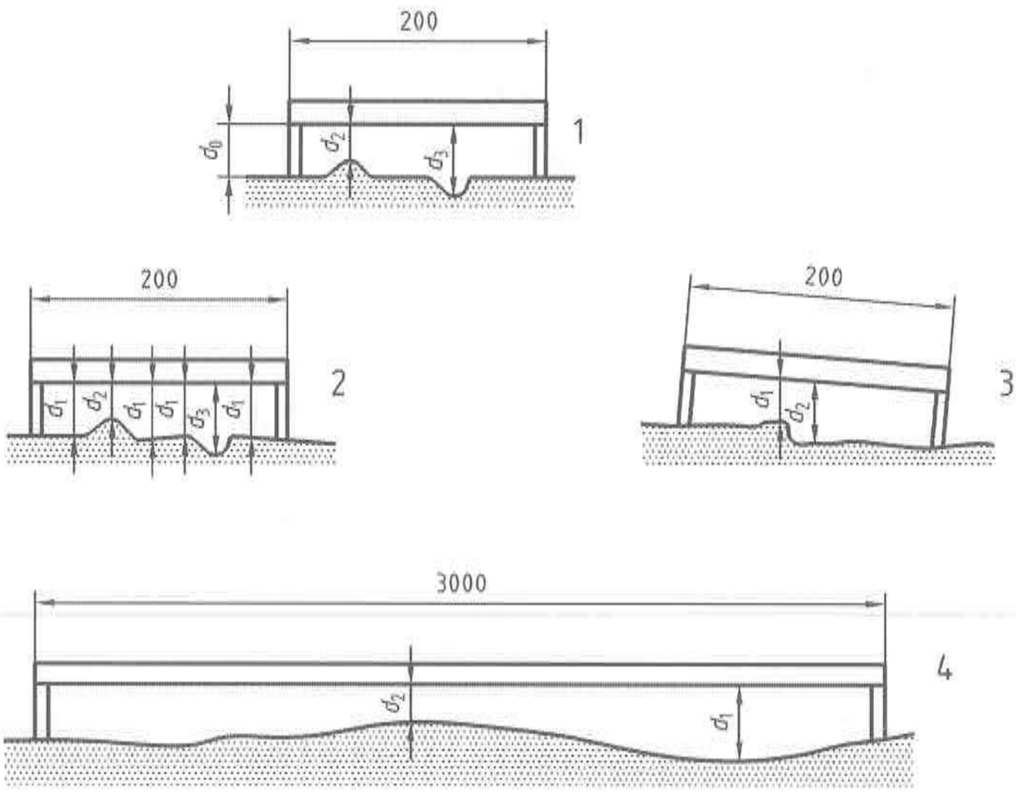


Key

1 recess
2 lump
3 groove
4 ridge
5 step discontinuity
6 undulation

Figure H.4 — Definitions of surface characteristics

Dimensions in millimetres



Key

1 lump: $d_0 - d_2$
recess: $d_3 - d_0$
The ruler should be shifted to find the largest lump and recess.

2 ridge: $d_1 - d_2$
groove: $d_3 - d_1$
The largest value of the differences is governing.

3 step discontinuity: $d_2 - d_1$

4 undulation: $d_1 - d_2$
To be measured at the highest and lowest point within the ruler.

Figure H.5 — Measurement of surface characteristics

The distance d_0 given in Figure H.5 is from the concrete surface at the location of the support of the reference ruler to the ruler. In most cases this will be the height of the supporting piece.

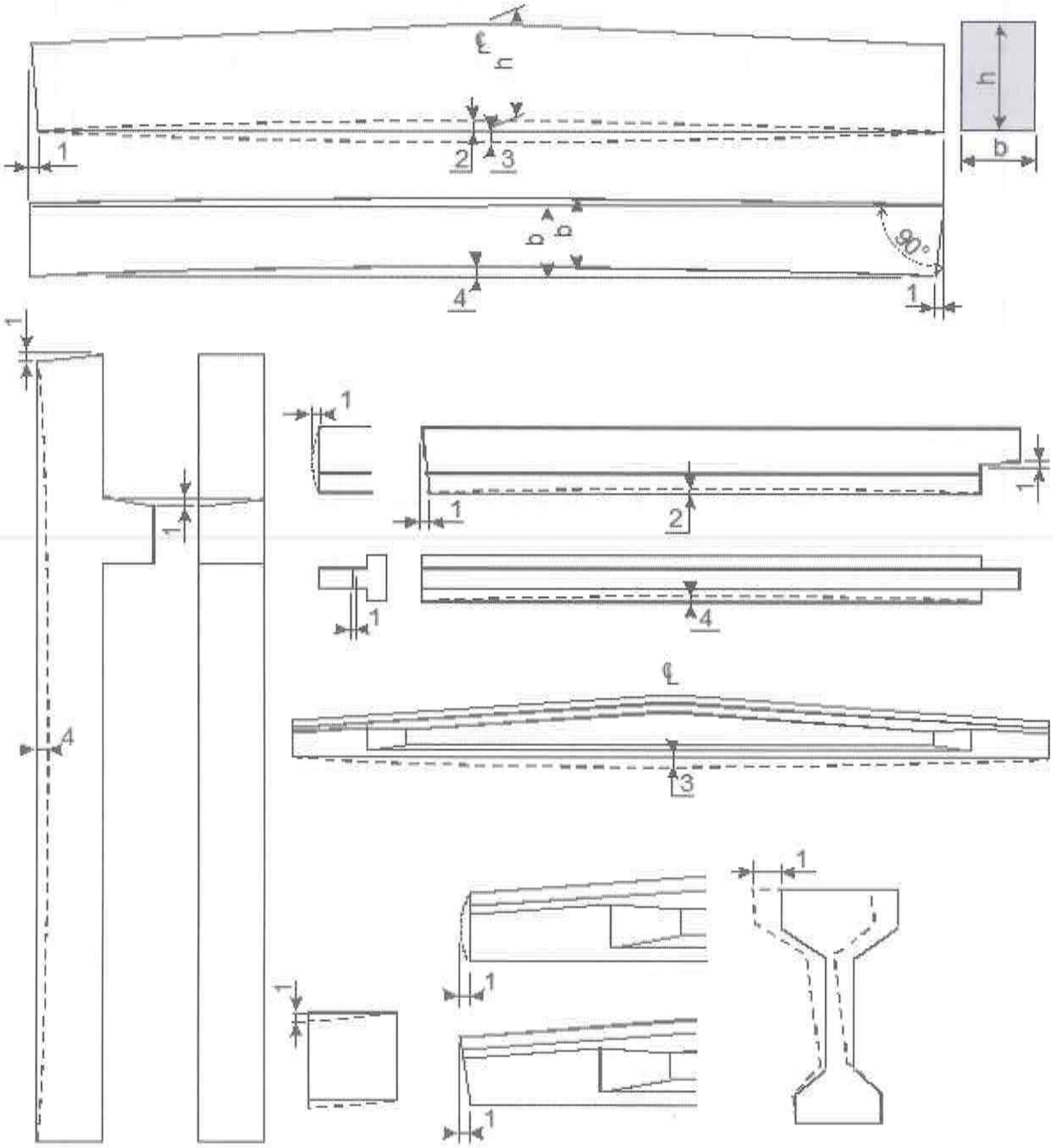
Recommended values for surface deviations are given in Table H.1.

Table H.1 — Surface deviations

Characteristic	Length of ruler	Recommended maximum deviation			
		Class 1		Class 2	
		Against form	Trowelled	Against form	Trowelled
Recess	200 mm	4 mm	3 mm	4 mm	3 mm
Lump	200 mm	2 mm	3 mm	2 mm	2 mm
Groove	200 mm	2 mm	2 mm	1 mm	1 mm
Ridge b	200 mm	5 mm	5 mm	3 mm	3 mm
Ridge h		3 mm	3 mm	2 mm	2 mm
Step discontinuity	200 mm	3 mm	2 mm	1 mm	2 mm
Undulation	3 000 mm	15 mm	8 mm	5 mm	4 mm

NOTE Requirements on surface tolerances cannot be used to describe the appearance of the surface.

H.5 Angular deviation lateral bow, camber and sag



Key

h height

b width

1 angular deviation

2 camber

3 sag

4 lateral bow

Figure H.6 — Measurement of angular deviation, lateral bow, camber and sag

Annex I
(informative)

Prestressing losses

I.1 General

NOTE This annex refers to pretensioning techniques and contains additional information for the calculation of prestressing losses.

Three stages should be considered for the calculation of the final loss in the case of pretensioned members:

— before the transfer of the prestressing force to the concrete;

— at transfer;

— after transfer.

I.2 Calculation of losses (general method)

I.2.1 Losses before transfer of the prestress force

Before transfer, the prestress loss is due to:

— The anchorage slip. This loss, ΔP_{S1}, is very small for long length casting beds.

— The short term steel relaxation. Where accelerated hardening is applied, this loss, ΔP_{P1}, is accelerated by the temperature of the treatment.

Appropriate methods taking into account this acceleration should be applied. Otherwise, if the degree of hardening reached by the concrete after 10 h or less is at least 50 % of the required strength after 28 days, it may be assumed that this relaxation loss is equal to 75 % of the total relaxation at 20 °C of the tendon submitted to the same tension.

— The shrinkage of the concrete. This loss may be ignored when protection against drying out is maintained during manufacturing.

— The loss of tension in the tendons and the restrained dilatation of the concrete due to the temperature in the case of accelerated hardening. When a production inspection is applied this loss $[\Delta P_\theta]$ may be estimated by the following expression:

$$[\Delta P_\theta] = 0{,}5\ Ap\ E_p\ \alpha_c\ (\theta_{max} - \theta_0) \quad \text{(I.1)}$$

where

Ap is the cross-section of tendons;

E_p is the elastic modulus of tendons;

α_c concrete thermal expansion (10×10^{-6}/°C);