TC 17

INTERNATIONAL STANDARD ISO 4998

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Continuous hot-dip zinc-coated carbon steel sheet of structural quality

Tôles en acier au carbone galvanisées en continu par immersion à chaud, de qualité destinée à la construction

First edition — 1977-08-01

UDC 669.14.018.29-415 : 669.586.5 **Ref. No. ISO 4998-1977 (E)**

Descriptors : iron and steel products, metal plates, galvanized materials, structural steels, unalloyed steels, materials specifications, chemical composition, mechanical properties, acceptance inspection, marking, zinc coatings, surface density, dimensional tolerances, form tolerances.

Price based on 12 pages

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4998 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in January 1976.

It has been approved by the member bodies of the following countries :

Belgium	Germany	Romania
Brazil	Hungary	South Africa, Rep. of
Bulgaria	India	Spain
Canada	Italy	Sweden
Chile	Japan	Switzerland
Czechoslovakia	Korea, Rep. of	Turkey
Denmark	Mexico	United Kingdom
Finland	Netherlands	U.S.A.
France	Portugal	U.S.S.R.

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Australia
Austria
New Zealand

Printed in Switzerland

Continuous hot-dip zinc-coated carbon steel sheet of structural quality

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard applies to continuous hot-dip zinc-coated carbon steel sheet of structural quality in the grades listed in table 2. The product is intended for structural purposes where particular mechanical properties are required. It is also intended for applications where resistance to corrosion is of prime importance and is produced to coating designations as shown in table 3. Under atmospheric conditions the protection afforded by the coating is directly proportional to the mass of coating. The mass of coating specified shall be compatible with the desired service life, thickness of the base metal and with the forming requirements involved. The coating is expressed as the total coating on both surfaces in grams per square metre. A designation system (see 3.2) includes the coating designation, coating condition, and grade. Various types (see 3.3) of zinc coating are available depending on the application.

1.2 Zinc-coated structural quality sheet is produced in the range of thicknesses 0,25 to 5 mm[1] inclusive after zinc coating, and in widths 600 mm and over in coils and cut lengths. Zinc-coated sheet less than 600 mm wide may be slit from wide sheet and will be considered as sheet.

NOTE – Thicknesses less than 0,4 mm may not be available in grades 220, 250, 280 and 320.

1.3 This International Standard does not cover steels designated as commercial quality, lock-forming quality or drawing qualities, which are covered in ISO 3575.

2 REFERENCES

ISO 82, *Steel – Tensile testing.*

ISO/R 85, *Bend test for steel.*

ISO 86, *Steel – Tensile testing of sheet and strip less than 3 mm and not less than 0,5 mm thick.*

ISO/R 87, *Simple bend testing of steel sheet and strip less than 3 mm thick.*

ISO 1460, *Metallic coatings – Hot-dip galvanized coatings on ferrous materials – Determination of the mass per unit area – Gravimetric method.*

ISO 3575, *Continuous hot-dip zinc-coated carbon steel sheet of commercial, lock-forming and drawing qualities.*

3 DEFINITIONS AND OTHER INFORMATION

3.1 continuous hot-dip zinc-coated[2] steel sheet : A product obtained by hot-dip zinc coating cold-reduced sheet coils or hot-rolled descaled sheet coils on a continuous zinc-coating line to produce either zinc-coated coils or zinc-coated cut lengths.

3.2 Designation system – Zinc coating and grades

The "as produced" or normal continuous hot-dip spangled zinc coatings are designated "Z" and the alloyed coatings are designated "ZF" as shown in table 3. The coating mass designation follows the "Z" or "ZF" and three spaces are allocated for coating mass designation. If the product is skin passed, designation "S" is used to indicate the coating condition. If the product has not been skin passed, the designation "N" for normal coating (as produced) is shown. The designation "M" following the coating mass designation is used for minimized spangle and "E" for minimized spangle and skin passed. The final three numbers indicate the grade of steel in accordance with table 2. An example of a complete designation including coating, coating mass, coating condition and grade is Z275 M250. This is composed by combining the following :

Z = Zinc coating
275 = Coating mass designation (see table 3)
M = Minimized spangle
250 = Steel grade (see table 2)

1) Approximate conversions into inches are given in the annex (for information only).

2) *Sometimes referred to as galvanized.*

3.3 Types of zinc coatings

3.3.1 spangle coating : A coating formed as a result of unrestricted growth of zinc crystals during normal solidification. This coating, designated Z, has a metallic lustre and is the type normally furnished for a wide variety of applications.

3.3.2 minimized spangle coating : A coating obtained by restricting normal spangle formation during the solidification of the zinc. This product may have some lack of uniformity in surface appearance within a coil or from coil to coil. It is normally furnished in designations Z350 M or E, Z275 M or E, Z200 M or E and Z180 M or E, and in the range of thicknesses 0,40 to 3 mm inclusive.

3.3.3 zinc-iron alloy coating : A coating produced by processing the zinc-coated steel sheet so that the coating formed on the base metal is composed of zinc-iron alloys. This product, designated ZF, is not spangled, is normally dull in appearance, and for some applications may be suitable for immediate painting without further treatment, except normal cleaning. Zinc-iron alloy coatings may powder during severe forming.

3.3.4 differential coating : A coating having a specified coating mass on one surface, and a significantly lighter coating mass on the other surface.

3.4 skin pass : A light cold-rolling of the zinc-coated steel sheet. If the material is required skin passed, it shall be ordered with an "Extra Smooth" finish. The purposes of skin passing are one or more of the following :

a) To produce a higher degree of surface smoothness for sheet supplied in coating designations Z350, Z275, Z200, Z180, Z100, Z001, ZF180, ZF100 and ZF001 and to improve appearance or suitability for decorative painting.

This process may adversely affect the ductility of the base metal.

Zinc coating defined in 3.3 may be variable in appearance and not suitable for decorative painting.

b) To minimize temporarily the occurrence of conditions known as stretcher strain (Lüder's lines) or fluting during fabrication of finished parts.

3.5 Strain ageing

Zinc-coated steel sheet tends to strain age, and this may lead to the following :

a) surface markings from stretcher strain or fluting when the steel is formed;

b) deterioration in ductility.

Because of these factors it is essential that the period between final processing at the mill and fabrication be kept to a minimum.

3.6 Mill passivating

A chemical treatment is normally applied to zinc coatings to minimize the hazard of wet storage stain (white rust) during shipment and storage. However, the inhibiting characteristics of the treatment are limited, and if a shipment is received wet, the material shall be used immediately or dried. This treatment is not usually applied to zinc-iron alloyed coatings because it interferes with the adhesion of most paints. The mill will passivate other types of zinc coatings, except extra smooth surface, as a normal procedure.

3.7 Mill phosphating

Zinc-coated steel sheet may be processed chemically at the manufacturer's mill to prepare all types of coatings for painting without further treatment except normal cleaning.

3.8 Oiling

The zinc-coated steel sheet as produced may be oiled to minimize wet storage stain. When the zinc-coated sheet has received a passivating treatment, oiling will minimize further the hazard of wet storage stain.

4 CONDITIONS OF MANUFACTURE

4.1 Steelmaking

Unless otherwise agreed between the interested parties, the processes used in making the steel and in manufacturing zinc-coated sheet of structural quality are left to the discretion of the manufacturer. On request, the purchaser shall be informed of the steelmaking process being used.

4.2 Chemical composition

The chemical composition (cast analysis) would not be expected to exceed the values given in table 1.

TABLE 1 — **Chemical composition (cast analysis)**

Element	% max.
Carbon	0,25
Manganese	1,70
Phosphorus	0,05
Sulphur	0,05

4.3 Chemical analysis

4.3.1 *Cast analysis*

A cast analysis of each cast of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus, and sulphur. On request, this analysis shall be reported to the purchaser or his representative.

4.3.2 *Verification analysis*

A verification analysis may be made by the purchaser to verify the specified analysis of the semi-finished or finished steel and shall take into consideration any normal heterogeneity. Non-killed steels (such as rimmed or capped) are not technologically suited to verification analysis, except for copper analysis when copper-bearing steel is specified. For killed steels, or when copper-bearing steel is specified, the sampling method and deviation limits shall be agreed upon between the interested parties at the time of ordering.

4.4 Zinc coating mass

The mass of coating shall conform to the specified requirements in table 3 for the specific coating designation. The mass of coating is the total amount of zinc on both surfaces of the sheet expressed in grams per square metre (g/m^2) of sheet. The coating mass of differentially coated material shall be agreed between the interested parties. If a maximum coating mass is required, the manufacturer shall be notified at the time of ordering. Methods of checking that the material is in compliance with this International Standard are given in 6.2.1, 7.2 and 8.4.

4.5 Weldability

The product is normally suitable for welding if appropriate welding conditions are selected with special attention to the heavier coatings. If appropriate welding conditions are selected, the product is suitable for spot welding and roller seam welding, as well as fusion welding. As carbon content increases above 0,15 % spot welding becomes increasingly difficult. Because the heat of welding might have a significant effect on lowering the strength of grade 550, this grade is not recommended for welding.

4.6 Painting

Hot-dip zinc-coated steel sheet is a suitable base for paint but the first treatment may be different from those used on mild steel. Pre-treatment primers, chemical conversion coatings (chromate, phosphate or oxide type) and some paints specially formulated for direct application to zinc surfaces are all appropriate first treatments for hot-dip zinc-coated sheet. In drawing up a painting schedule, consideration shall be given to whether the hot-dip zinc-coated sheet shall be ordered passivated or not passivated.

4.7 Application

It is desirable that zinc-coated sheet of structural quality be identified for fabrication by name of the part or by the intended application, which shall be compatible with the grade and coating designation specified.

4.8 Mechanical properties

At the time that the steel is made available for shipment, the mechanical properties shall be as stated in table 2 when they are determined on test pieces obtained according to the requirements of 7.1.

5 DIMENSIONAL TOLERANCES

Dimensional tolerances applicable to zinc-coated steel sheet of structural quality shall be as given in tables 5 to 11 inclusive.

6 SAMPLING

6.1 Mechanical property tests

6.1.1 *Tensile test*

One representative sample for the tensile test required in table 2 shall be taken from each lot of sheet for shipment. A lot consists of 50 tonnes or less of sheet of the same grade rolled to the same thickness and condition.

6.1.2 *Bend test (when specified)*

One representative sample for the bend test (not applicable to grade 550) shall be taken from each lot of sheet for shipment. A lot consists of all sheet of the same grade rolled to the same thickness and condition.

6.2 Coating tests

6.2.1 *Mass of coating*

The manufacturer shall make such tests and measurements as he deems necessary to ensure that the material produced complies with the values in table 3. The purchaser may verify the mass of coating by use of the following sampling method :

Three specimens shall be cut, one from the mid-width position, and one from each side not closer than 25 mm to the side edge. The minimum specimen area shall be 2 000 mm^2.

6.2.2 *Bend test (when specified)*

One representative sample shall be taken from each lot of sheet for shipment. The specimens shall be taken for the coated bend test, not closer than 25 mm from the side edge. The minimum specimen width shall be 50 mm.

7 TEST METHODS

7.1 Mechanical property tests (base metal)

7.1.1 *Tensile test*

The tensile test shall be carried out in accordance with ISO 82 and ISO 86. Transverse test pieces shall be taken mid-way between the centre and edge of the sheet as rolled. Since the tensile test is for determination of properties of the base metal, ends of test pieces shall be stripped of the coating to measure base metal thickness for calculation of cross-sectional area.

7.1.2 *Bend test (when specified : not applicable to grade 550)*

The transverse bend test piece, stripped of coating in a suitably inhibited acid, shall withstand being bent through 180° in the direction shown in figure 1, around the inside diameter as shown in table 2, without cracking on the outside of the bent portion. The bend test is to be performed at ambient temperature and is described in ISO/R 85 and ISO/R 87.

Small cracks on the edge of test pieces and cracks which require magnification to be visible shall be disregarded.

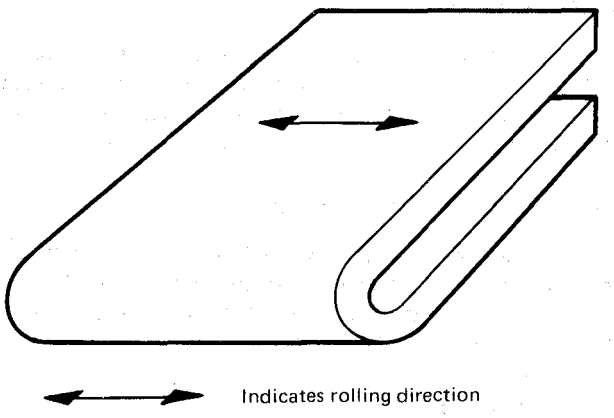

FIGURE 1 — **Transverse bend test piece (after bending)**

7.2 Coating tests

7.2.1 *Triple spot test*

The triple spot test result shall be the average coating mass found on the three specimens taken according to 6.2.1. The test is normally carried out by stamping out a known area of sheet and calculating the coating mass from the loss in mass after removing the zinc in suitably inhibited acid. ISO 1460 may be used as a reference method.

7.2.2 *Single spot test*

The single spot test result shall be the minimum coating mass found on any one of the three specimens used for the triple spot test. Material which has been slit from wide coil shall be subject to a single spot test only.

7.2.3 *Bend test (applied only to zinc coatings prefixed by coating designation Z as in table 3)*

Bend test pieces taken after coating (before additional processing) shall withstand being bent through 180° in either direction without flaking of the coating on the outside of the bend. The radius of the bend is determined by the number of pieces of the same thickness (or mandrel equivalent) as shown in table 4. Flaking of coating within 7 mm from the edge of the test piece shall not be cause for rejection.

8 RETESTS

8.1 Machining and flaws

If any test piece shows defective machining or develops flaws, it shall be discarded and another test piece substituted.

8.2 Elongation

If the percentage elongation of any tested piece is less than that specified in table 2 and if any part of the fracture is outside the middle half of the gauge length as scribed before the test, the test shall be discarded and a retest shall be carried out.

8.3 Bend test

If a bend test piece fails, due to conditions of bending more severe than required by this International Standard, a retest shall be permitted either on a duplicate test piece or on a remaining portion of the failed test piece.

8.4 Additional tests

If a test does not give the required results, two more tests shall be made at random on the same lot. Should either of these tests fail to meet the specified requirements the material shall be deemed not to comply with the requirements of this International Standard.

9 RESUBMISSION

9.1 The manufacturer may resubmit for acceptance the products that have been rejected during earlier inspection because of unsatisfactory properties after he has subjected them to a suitable treatment (selection, heat treatment) which, on request, will be indicated to the purchaser. In this case, the tests shall be carried out as if they applied to a new batch.

9.2 The manufacturer has the right to present the rejected products to a new examination for compliance with the requirements of another grade.

10 WORKMANSHIP

The zinc-coated steel sheet in cut lengths shall be free from amounts of laminations, surface flaws and other imperfections that are detrimental to subsequent appropriate processing. Processing for shipment in coils does not afford the manufacturer the opportunity to observe readily or to remove imperfections as can be carried out on the cut length product.

11 INSPECTION AND ACCEPTANCE

11.1 While not usually required for products covered by this International Standard, when the purchaser specifies that inspection and tests for acceptance be observed prior to shipment from the manufacturer's works, the manufacturer shall afford the purchaser's inspector all reasonable facilities to determine that the steel is being furnished in accordance with this International Standard.

11.2 Steel that is reported to be defective after arrival at the user's works shall be set aside, properly and correctly identified and adequately protected. The supplier shall be notified in order that he may properly investigate.

12 COIL SIZE

When zinc-coated steel sheet is ordered in coils, a minimum inside diameter or range of acceptable inside diameters (I.D.) shall be specified. In addition, the maximum outside diameter (O.D.) and maximum acceptable boil mass shall be specified.

13 MARKING

Unless otherwise stated, the following minimum requirements for identifying the steel shall be legibly stencilled on the top of each lift or shown on a tag attached to each coil or shipping unit :

a) the manufacturer's name or identifying brand;

b) the number of this International Standard;

c) the quality designation;

d) the order number;

e) the product dimensions;

f) the lot number;

g) the mass.

14 INFORMATION TO BE PROVIDED BY THE PURCHASER

To specify adequately the requirements under this International Standard, inquiries and orders shall include the following information :

a) the number of this International Standard;

b) the name and designation of the material (to include coating, condition and grade), for example hot-dip zinc-coated steel sheet of structural quality, Z275 N250 (see 3.2 and table 3);

c) the dimensions of the product (the thickness includes the coating) in the sequence thickness, width, length and mass, and the quantity required;

d) the application (name of part) if possible (see 4.7);

e) whether oiled or not (see 3.8);

f) whether mill passivated or not (see 3.6 and 4.6);

g) whether mill phosphated or not (see 3.7);

h) extra smooth, if required (see 3.4);

i) the coil size requirements (see clause 12);

j) the report of the mechanical properties (see 4.8) and/or the cast analysis (see 4.3.1), if required;

k) inspection and tests for the acceptance prior to shipment from the manufacturer's works, if required (see 11.1).

NOTE – A typical ordering description is as follows :

International Standard ISO 4998, Hot-dip zinc-coated steel sheet, structural quality, designation Z275 N250, 2 × 1 200 × 2 500 mm, 10 000 kg maximum lift to fabricate building parts with 90° bend.

TABLE 2 — **Mechanical properties**[1] (see 4.8)

Grade	R_{eL}[3] min. N/mm² 5)	R_m (For information only) N/mm²	A min. %[2]		Base metal 180° bend mandrel diameter[4]	
			$L_o = 50$ mm	$L_o = 80$ mm	$e < 3$ mm	$e \geqslant 3$ mm
220	220	320	20	18	1*a*	2*a*
250	250	350	18	16	1*a*	2*a*
280	280	390	18	14	2*a*	3*a*
320	320	430	16	12	3*a*	3*a*
550	550	560	–	–	–	–

1) R_{eL} = lower yield stress
R_m = tensile strength
A = percentage elongation after fracture
L_o = gauge length on test piece
a = thickness of bend test piece
e = thickness of steel sheet, in millimetres

2) Use either $L_o = 50$ mm or $L_o = 80$ mm to measure elongation. For material up to and including 0,6 mm in thickness, the elongation values in the table shall be reduced by 2.

3) The yield stress specified in table 2 shall be the lower yield stress (R_{eL}). The values can also be measured by 0,5 % total elongation proof stress (proof stress under load) or by 0,2 % offset when a definite yield phenomenon is not present.

4) The bend test is performed only when specified (see 7.1.2). The bend mandrel diameters in table 2 are for specimens prepared for laboratory testing. Conditions during fabrication may be more severe and may not simulate those during laboratory testing.

5) 1 N/mm² = 1 MPa

TABLE 3 — **Mass of coating (total both sides)**[1]

Coating designation	Minimum check limit	
	Triple spot test	Single spot test
	g/m² (of sheet)	g/m² (of sheet)
Z700[2]	700	595
Z600[2]	600	510
Z450[2]	450	385
Z350	350	300
Z275	275	235
Z200	200	170
Z180	180	150
Z100	100	85
Z001	No minimum[3]	No minimum[3]
ZF180	180	150
ZF100	100	85
ZF001	No minimum	No minimum

1) The mass of coating is not always evenly divided between the two surfaces of a zinc-coated sheet; neither is the zinc coating evenly distributed from edge to edge. However, it can normally be expected that not less than 40 % of the single-spot check limit will be found on either surface.

2) Coating mass corresponding to the designations Z450, Z600, and Z700 are not available for steels with minimum yield stresses of 320 and 550 N/mm².

3) "No minimum" means that there are no established minimum check limits for triple and single spot tests.

TABLE 4 — **Coating bend test requirements**

Grade	180° Bend mandrel diameter								
	$e < 1,6$ mm			1,6 mm $\leqslant e < 3$ mm			$e \geqslant 3$ mm		
	Coating designation								
	up to Z350	Z450 Z600	Z700	up to Z350	Z450 Z600	Z700	up to Z0450	Z600	Z700
220	1*a*	2*a*	3*a*	1*a*	2*a*	3*a*	2*a*	3*a*	4*a*
250	1*a*	2*a*	3*a*	1*a*	2*a*	3*a*	2*a*	3*a*	4*a*
280	2*a*	2*a*	3*a*	2*a*	2*a*	3*a*	3*a*	3*a*	4*a*
320	3*a*	3*a*	3*a*	3*a*	3*a*	3*a*	3*a*	3*a*	4*a*

e = thickness of sheet, in millimetres

a = thickness of bend test piece

TABLE 5 — **Thickness tolerances for coils and cut lengths**

Values in millimetres

Specified widths	Thickness tolerances[1], over and under, for specified thicknesses										
	0,25 up to and including 0,4	over 0,4 up to and including 0,6	over 0,6 up to and including 0,8	over 0,8 up to and including 1,0	over 1,0 up to and including 1,2	over 1,2 up to and including 1,6	over 1,6 up to and including 2,0	over 2,0 up to and including 2,5	over 2,5 up to and including 3,0	over 3,0 up to and including 4,0	over 4,0 up to and including 5,0
600 up to and including 1 200	0,08	0,09	0,10	0,11	0,13	0,15	0,19	0,21	0,22	0,24	0,28
Over 1 200 up to and including 1500	0,09	0,10	0,11	0,12	0,14	0,16	0,21	0,23	0,24	0,26	0,29
Over 1 500 up to and including 1 800	—	0,11	0,12	0,14	0,15	0,18	0,23	0,25	0,26	0,28	0,30

1) Thickness is measured at any point on the sheet not less than 40 mm from a side edge.

NOTE — The tolerance for grade 320 will be increased by 25 %, applying normal rounding-off procedures.

TABLE 6 — **Width tolerances for coils and cut lengths, not resquared**

Values in millimetres

Specified widths	Tolerance
Up to and including 1 500	$+\ 7\ 0$
Over 1 500 up to and including 1 800	$+\ 10\ 0$

TABLE 7 — **Length tolerances for cut lengths, not resquared**

Values in millimetres

Specified lengths	Tolerance
Up to and including 3 000	$+\ 20\ 0$
Over 3 000 up to and including 6 000	$+\ 30\ 0$
Over 6 000	$+\ 0,5$ % 0

TABLE 8 — **Camber tolerances for coils and cut lengths, not resquared**

Form	Camber tolerance
Cut lengths	0,5 % × length
Coils	25 mm in any 5 000 mm length

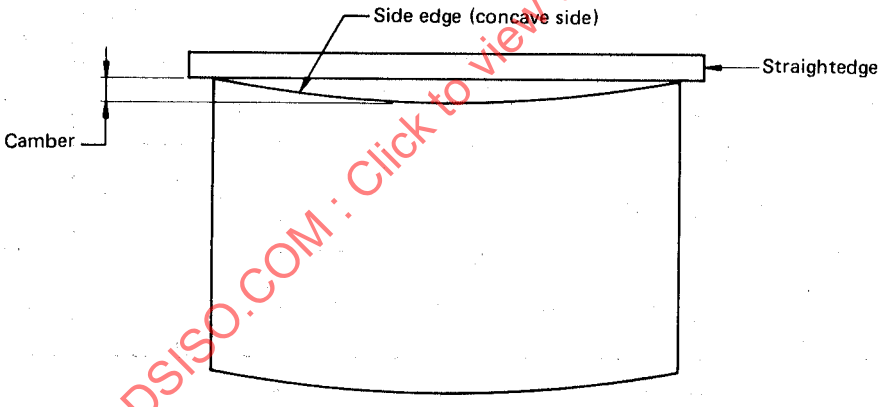

FIGURE 2 — **Measurement of camber**

Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

TABLE 9 – **Out-of-square tolerance for cut lengths, not resquared**

Dimensions	*Out-of-square tolerance*
All thicknesses and all sizes	1,0 % × width

TABLE 10 – **Out-of-square[1], width, and length tolerances for resquared[2] material**

Values in millimetres

Specified lengths	Specified widths	Tolerance
Up to and including 3 000	Up to and including 1 200	$^{+2}_{0}$
	Over 1 200	$^{+3}_{0}$
Over 3 000	All widths	$^{+3}_{0}$

1) See figure 3.

2) When measuring material ordered to resquared tolerances, consideration may have to be given to extreme variations in temperature.

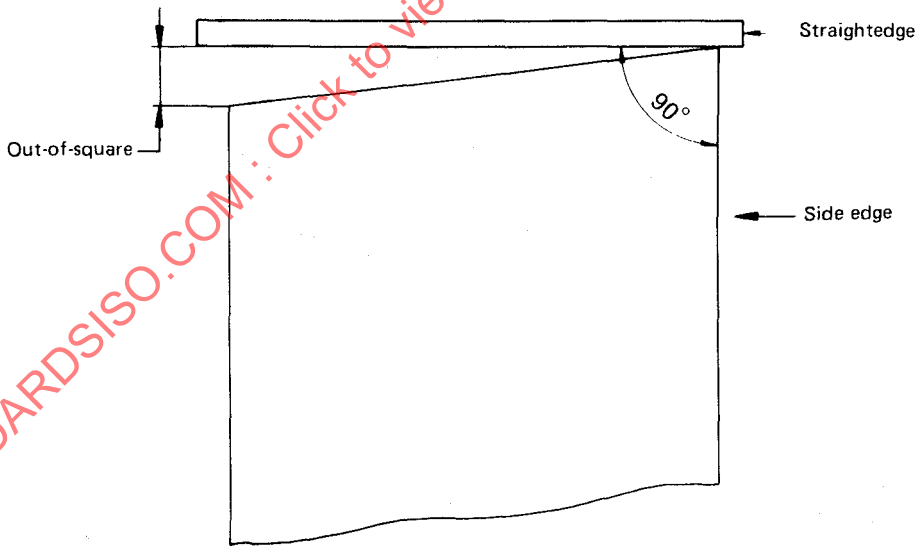

FIGURE 3 – **Measurement of out-of-square**

Out-of-square is the greatest deviation of an end edge from a straight line at right angles to a side and touching one corner, the measurement being taken as shown in figure 3. It can also be measured as one half the difference between the diagonals of the cut length sheet.

TABLE 11 — **Standard flatness tolerances**[1] **for cut lengths**

Values in millimetres

Thicknesses	Widths	Flatness tolerance[2]
Up to and including 0,7	Up to and including 1 200	23
	Over 1 200 up to and including 1 500	27
	Over 1 500 up to and including 1 800	33
Over 0,7 up to and including 1,2	Up to and including 1 200	18
	Over 1 200 up to and including 1 500	23
	Over 1 500 up to and including 1 800	29
Over 1,2	Up to and including 1 200	15
	Over 1 200 up to and including 1 500	18
	Over 1 500 up to and including 1 800	26

1) These tolerances are only applicable to sheet up to and including 5 000 mm length when the thickness is 5 mm or less. This table also applies to sheet cut to length from coil by the customer when adequate flattening procedures are performed. Tolerances for sheet exceeding 5 000 mm in length shall be subject to agreement.

2) Maximum deviation from a flat horizontal surface. With the sheet lying under its own weight on a flat surface, the maximum distance between the lower surface of the sheet and the flat horizontal surface is the maximum deviation from flatness.

NOTE — The tolerances for grade 320 will be increased by 25 %. There are no flatness tolerances for grade 550.

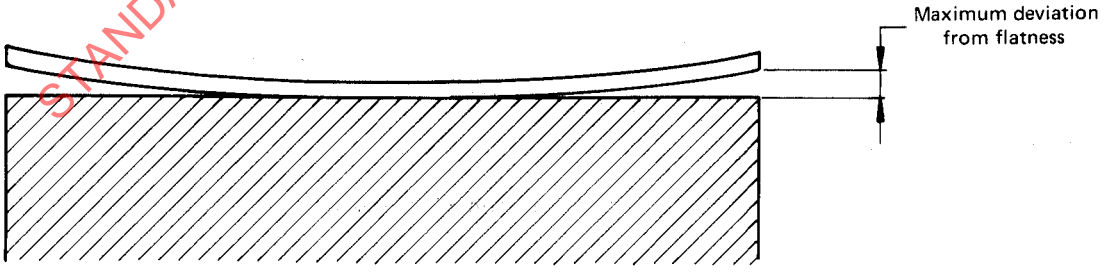

FIGURE 4 — **Measurement of flatness**