

# DIN EN 1999-1-5:2017-03 (E)

## Eurocode 9 - Design of aluminium structures - Part 1-5: Shell structures (includes Corrigendum 5:2009)

---

<b>Contents</b>	<b>Page</b>
<b>Foreword</b> .....	<b>5</b>
<b>National Annex for EN 1999-1-5</b> .....	<b>7</b>
<b>1 General</b> .....	<b>8</b>
1.1 Scope.....	8
1.1.1 Scope of EN 1999.....	8
1.1.2 Scope of EN 1999-1-5.....	8
1.2 Normative references.....	9
1.3 Terms and definitions.....	10
1.3.1 Structural forms and geometry.....	10
1.3.2 Special definitions for buckling calculations.....	11
1.4 Symbols.....	12
1.5 Sign conventions.....	15
1.6 Coordinate systems.....	15
<b>2 Basis of design</b> .....	<b>17</b>
2.1 General.....	17
2.2 Consequence class and execution class.....	17
<b>3 Materials and geometry</b> .....	<b>17</b>
3.1 Material properties.....	17
3.2 Design values of geometrical data.....	17
3.3 Geometrical tolerances and geometrical imperfections.....	18
<b>4 Durability</b> .....	<b>18</b>
<b>5 Structural analysis</b> .....	<b>18</b>
5.1 Geometry.....	18
5.2 Boundary conditions.....	19
5.3 Actions and environmental influences.....	19
5.4 Stress resultants and stresses.....	20
5.5 Types of analysis.....	20
<b>6 Ultimate limit state</b> .....	<b>21</b>
6.1 Resistance of cross section.....	21
6.1.1 Design values of stresses.....	21
6.1.2 Design values of resistance.....	22
6.1.3 Stress limitation.....	22
6.1.4 Design by numerical analysis.....	22
6.2 Buckling resistance.....	23
6.2.1 General.....	23
6.2.2 Buckling-relevant geometrical tolerances.....	24
6.2.3 Shell in compression and shear.....	25
6.2.4 Effect of welding.....	27
6.2.5 Design by numerical analysis.....	30

<b>7</b>	<b>Serviceability limit states</b> .....	<b>31</b>
7.1	General .....	31
7.2	Deflections.....	31
<b>Annex A [normative] - Expressions for shell buckling analysis</b> .....		<b>32</b>
<b>A.1</b>	<b>Unstiffened cylindrical shells of constant wall thickness</b> .....	<b>32</b>
A.1.1	Notations and boundary conditions .....	32
A.1.2	Meridional (axial) compression.....	32
A.1.2.1	Critical meridional buckling stresses.....	32
A.1.2.2	Meridional buckling parameter.....	33
A.1.3	Circumferential (hoop) compression .....	34
A.1.3.1	Critical circumferential buckling stresses.....	34
A.1.3.2	Circumferential buckling parameter .....	35
A.1.4	Shear .....	37
A.1.4.1	Critical shear buckling stresses.....	37
A.1.4.2	Shear buckling parameters.....	38
A.1.5	Meridional (axial) compression with coexistent internal pressure .....	38
A.1.5.1	Pressurised critical meridional buckling stress.....	38
A.1.5.2	Pressurised meridional buckling parameters .....	38
A.1.6	Combinations of meridional (axial) compression, circumferential (hoop) compression and shear	39
<b>A.2</b>	<b>Unstiffened cylindrical shells of stepwise wall thickness</b> .....	<b>40</b>
A.2.1	General .....	40
A.2.1.1	Notations and boundary conditions .....	40
A.2.1.2	Geometry and joint offsets .....	41
A.2.2	Meridional (axial) compression.....	41
A.2.3	Circumferential (hoop) compression .....	41
A.2.3.1	Critical circumferential buckling stresses.....	41
A.2.3.2	Buckling strength verification for circumferential compression.....	44
A.2.4	Shear .....	44
A.2.4.1	Critical shear buckling stress.....	44
A.2.4.2	Buckling strength verification for shear .....	45
<b>A.3</b>	<b>Unstiffened lap jointed cylindrical shells</b> .....	<b>45</b>
A.3.1	General .....	45
A.3.1.1	Definitions .....	45
A.3.1.2	Geometry and stress resultants .....	45
A.3.2	Meridional (axial) compression.....	45
A.3.3	Circumferential (hoop) compression .....	45
A.3.4	Shear .....	46
<b>A.4</b>	<b>Unstiffened conical shells</b> .....	<b>46</b>
A.4.1	General .....	46
A.4.1.1	Notation .....	46
A.4.1.2	Boundary conditions.....	46
A.4.1.3	Geometry .....	47
A.4.2	Design buckling stresses.....	47
A.4.2.1	Equivalent cylinder.....	47
A.4.3	Buckling strength verification .....	47
A.4.3.1	Meridional compression .....	47
A.4.3.2	Circumferential (hoop) compression.....	48
A.4.3.3	Shear and uniform torsion .....	48

<b>A.5</b>	<b>Stiffened cylindrical shells of constant wall thickness.....</b>	<b>48</b>
A.5.1	General .....	48
A.5.2	Isotropic walls with meridional stiffeners .....	48
A.5.2.1	General .....	48
A.5.2.2	Meridional (axial) compression.....	49
A.5.2.3	Circumferential (hoop) compression .....	49
A.5.2.4	Shear.....	49
A.5.3	Isotropic walls with circumferential stiffeners .....	50
A.5.4	Circumferentially corrugated walls with meridional stiffeners .....	50
A.5.4.1	General .....	50
A.5.4.2	Axial compression.....	51
A.5.4.3	Stiffened wall treated as carrying axial compression only in the stiffeners .....	52
A.5.4.4	Circumferential (hoop) compression .....	53
A.5.5	Axially corrugated walls with ring stiffeners .....	53
A.5.5.1	General .....	53
A.5.5.2	Axial compression.....	54
A.5.5.3	Circumferential (hoop) compression .....	54
A.5.6	Stiffened wall treated as an orthotropic shell .....	54
A.5.6.1	General .....	54
A.5.6.2	Axial compression.....	55
A.5.6.3	Circumferential (hoop) compression .....	56
A.5.6.4	Shear.....	56
A.5.7	Equivalent orthotropic properties of corrugated sheeting.....	57
<b>A.6</b>	<b>Unstiffened spherical shells under uniform circumferential compression.....</b>	<b>58</b>
A.6.1	Notations and boundary conditions .....	58
A.6.2	Critical buckling stresses.....	59
A.6.3	Circumferential buckling parameter.....	59
<b>Annex B [informative]</b>	<b>- Expressions for buckling analysis of toriconical and torispherical shells.....</b>	<b>60</b>
B.1	General .....	60
B.2	Notations and boundary conditions .....	60
B.3	External pressure .....	61
B.3.1	Critical external pressure .....	61
B.3.2	Uniform squash limit external pressure.....	62
B.3.3	External pressure buckling parameter .....	63
B.4	Internal pressure .....	63
B.4.1	Critical internal pressure.....	63
B.4.2	Uniform squash limit internal pressure.....	64
B.4.3	Internal pressure buckling parameter.....	65