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STANDARD ROMÂN

SR EN 1993-1-6/NA

……………… 2011

Eurocode 3: Design of steel structures.
Part 1-6: Strength and Stability of Shell Structures
National Annex

Eurocod 3: Proiectarea structurilor de oțel
Partea 1-6: Rezistența şi stabilitatea plăcilor curbe subțiri
Anexa națională

Eurocode 3. Calcul des structures en acier.
Partie 1-6: Résistance et stabilité des structures en coque
Annexe Nationale

APPROVAL | Approved by the Director General of ASRO on

ROMANIAN STANDARDS ASSOCIATION (ASRO)
21-25 Mendeleev Street, cod 010362, Bucharest ROMANIA
General Director: Phone: +40 21 316 32 96, Fax: +40 21 316 08 70
Director of Standardization Division: Phone: +40 21 310 17 30, +40 21 310 43 08, +40 21 312 47 44, Fax: +40 21 315 58 70
Sales Department – Subscriptions Department: Phone: +40 21 316 77 25, Fax + 40 21 317 25 14, +40 21 312 94 88
Marketing Editorial Staff- Copyright Department: Phone: +40 21 316.99.74

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Forward

This standard represents the National Annex NA which defines the conditions of application on the territory of Romania of the standard SR EN 1993-1-6:2007 *Eurocode 3: Design of steel structures. Part 1-6: Strength and Stability of Shell Structures,* together with the corrigendum SR EN 1993-1-6:2007/AC:2009.

This National Annex has been prepared within the Technical Committee ASRO/CT 343 *Basis of the Design and Structural Eurocodes*, the secretariat of which is held by ASRO.

This National Annex:
- provides Nationally Determined Parameters (NDP) for the following clauses of the European Standard EN 1993-1-6:2007 and corrigendum EN 1993-1-6:2007/AC:2009, for which the national choice is allowed, namely:

- 3.1 (4)
- 4.1.4 (3)
- 5.2.4 (1)
- 6.3 (5)
- 7.3.1 (1)
- 7.3.2 (1)
- 8.4.2 (3)
- 8.4.3 (2)
- 8.4.3 (4)
- 8.4.4 (4)
- 8.4.5 (1)
- 8.5.2 (2)
- 8.5.2 (4)
- 8.7.2 (7)
- 8.7.2 (16)
- 8.7.2 (18) (2 ori)
- 9.2.1 (2)P

- establishes the conditions of application of normative annexes A, B, C and D from Romanian standard SR EN 1993-1-6:2007 and corrigendum SR EN 1993-1-6:2007/AC:2009.

SR EN 1993-1-6:2007/NA:2011 and SR EN 1993-1-6:2007 should be used together with the provisions of Eurocodes EN 1990 to EN 1999, after their national endorsement and implementation, together with their national annexes.

The names and the numbers of the clauses in the national annex are identical with those of the Romanian standard SR EN 1993-1-6:2007 and corrigendum SR EN 1993-1-6:2007/AC:2009.

This National Annex belongs to the patrimoine of ASRO/CT 343, *Basis of the Design and Structural Eurocodes*.

I. Nationally Determined Parameters for SR EN 1993-1-6:2007 and corrigendum SR EN 1993-1-6:2007/AC:2009

Section 3: Materials and geometry

3.1 Material properties

(4) The material properties apply to temperatures not exceeding 150℃.

NOTE – The national annex may give information about material properties at temperatures exceeding 150℃.

For material properties at temperatures exceeding 150℃, the values given in SR EN 1993-1-2, Table 3.1 are used.

Section 4: Ultimate limit states in steel shells

4.1 Ultimate limit states to be considered

4.1.4 LS4: Fatigue

(3) All variable actions that will be applied with more than N_f cycles in the design life time of the structure according to the relevant action spectrum in EN 1991 in accordance with the appropriate application part of EN 1993-3 or EN 1993-4, should be accounted for when checking LS4.

NOTE – The National Annex may choose the value of N_f. The value N_f =10 000 is recommended.

The recommended value N_f =10 000 is used.

Section 5: Stress resultants and stresses in shells

5.2 Modelling of the shell for analysis

5.2.4 Stress resultants and stresses

(1) Provided that the radius to thickness ratio is greater than $(r/t)_{min}$, the curvature of the shell may be ignored when calculating the stress resultants from the stresses in the shell wall.

NOTĂ – The National Annex may choose the value of $(r/t)_{min}$. The value $(r/t)_{min}$ = 25 is recommended.

The recommended value $(r/t)_{min}$ = 25 is used.

Section 6: Plastic limit state (LS1)

6.3 Design by global numerical MNA or GMNA analysis

(5) Where a GMNA analysis is used, if the analysis predicts a maximum load followed by a descending path, the maximum value should be used to determine the load ratio $r_{R,GMNA}$. Where a GMNA analysis does not predict a maximum load, but produces a progressively rising action-displacement relationship without strain hardening of the material, the load ratio $r_{R,GMNA}$ should be taken as no larger than the value at which the maximum von Mises equivalent plastic strain in the structure attains the value $\varepsilon_{mps} = n_{mps} (f_{yd} / E)$.

NOTE – The National Annex may choose the value of n_{mps}. The value n_{mps} = 50 is recommended.

The recommended value n_{mps} = 50 is used.

Section 7: Cyclic plasticity limit state (LS2)

7.3 Design by global numerical MNA or GMNA analysis

7.3.1 Design values of total accumulated plastic strain

(1) Where a materially nonlinear global numerical analysis (MNA or GMNA) is used, the shell should be subject to the design values of the varying and permanent actions detailed in 7.1.

NOTE 1 – It is usual to use an MNA analysis for this purpose.

NOTE 2 – The National Annex may give recommendations for a more refined analysis.

The use of an analysis MNA or GMNA is recommended.

7.3.2 Total accumulated plastic strain limitation

(1) Unless a more sophisticated low cycle fatigue assessment is undertaken, the design value of the total accumulated von Mises equivalent plastic strain $\varepsilon_{p,eq,Ed}$ should satisfy the condition:

$$\varepsilon_{p,eq,Ed} \leq n_{p,eq} \ (f_{yd} / E) \qquad \text{... (7.5)}$$

NOTE – The National Annex may choose the value of $n_{p,eq}$. The value $n_{p,eq}$ = 25 is recommended.

The recommended value $n_{p,eq}$ = 25 is used.

Section 8: Buckling limit state (LS3)

8.4 Buckling-relevant geometrical tolerances

8.4.2 Out-of-roundness tolerance

(3) The out-of-roundness parameter U_r should satisfy the condition:

$$U_r \leq U_{r,max} \qquad \text{... (8.2)}$$

where:

$U_{r,max}$ is the out-of-roundness tolerance parameter for the relevant fabrication tolerance quality class.

NOTE – Values for the out-of-roundness tolerance parameter $U_{r,max}$ may be obtained from the National Annex. The recommended values are given in Table 8.1.

Table 8.1 – Recommended values for out-of-roundness tolerance parameter $U_{r,max}$

	Diameter range	d [m] ≤ 0,50m	0,50m < d [m] < 1,25m	1,25m ≤ d [m]
Fabrication tolerance quality class	Description	Valoarea recomandată pentru $U_{r,max}$		
Class A	Excellent	0,014	0,007 + 0,0093(1,25−d)	0,007
Class B	High	0,020	0,010 + 0,0133(1,25−d)	0,010
Class C	Normal	0,030	0,015 + 0,0200(1,25−d)	0,015

Recommended values from Table 8.1 are used.

8.4.3 Accidental eccentricity tolerance

(2) The accidental eccentricity e_a should be less than the maximum permitted accidental eccentricity $e_{a,max}$, for the relevant fabrication tolerance quality class.

NOTE – Values for the maximum permitted accidental eccentricity $e_{a,max}$ may be obtained from the National Annex. The recommended values are given in Table 8.2.

Table 8.2 – Recommended values for maximum permitted accidental eccentricities

Fabrication tolerance quality class	Description	Recommended values for maximum permitted accidental eccentricity $e_{a,max}$
Class A	Excellent	2 mm
Class B	High	3 mm
Class C	Normal	4 mm

Recommended values from Table 8.2 are used.

(4) The accidental eccentricity parameter U_e should satisfy the condition:

$$U_e \leq U_{e,max} \quad (8.5)$$

where:

$U_{e,max}$ is the accidental eccentricity tolerance parameter for the relevant fabrication tolerance quality class.

NOTE 1 – Values for the accidental eccentricity tolerance parameter $U_{e,max}$ may be obtained from the National Annex. The recommended values are given in Table 8.3.

Table 8.3 – Recommended values for accidental eccentricity tolerances

Fabrication tolerance quality class	Description	Recommended value of $U_{e,max}$
Class A	Excellent	0,14
Class B	High	0,20
Class C	Normal	0,30

Recommended values from Table 8.3 are used.

8.4.4 Dimple tolerances

(4) The value of the dimple parameters U_{0x}, $U_{0\theta}$, U_{0w} should satisfy the conditions:

$$U_{0x} \leq U_{0,max} \qquad U_{0\theta} \leq U_{0,max} \qquad U_{0w} \leq U_{0,max} \quad ... (8.10)$$

where:

$U_{0,max}$ is the dimple tolerance parameter for the relevant fabrication tolerance quality class.

NOTE 1 – Values for the dimple tolerance parameter $U_{0,max}$ may be obtained from the National Annex. The recommended values are given in Table 8.4.

Table 8.4 – Recommended values for dimple tolerance parameter $U_{0,max}$

Fabrication tolerance quality class	Description	Recommended value of $U_{0.max}$
Class A	Excellent	0,006
Class B	High	0,010
Class C	Normal	0,016

Recommended values from Table 8.4 are used.

8.4.5 Interface flatness tolerance

(1) Where another structure continuously supports a shell (such as a foundation), its deviation from flatness at the interface should not include a local slope in the circumferential direction greater than β_θ.

NOTE – The National Annex may choose the value of β_θ. The value β_θ = 0,1% = 0,001 radians is recommended.

The recommended value β_θ = 0,1% = 0,001 radians is used.

8.5 Stress design

8.5.2 Design resistance (buckling strength)

(2) The partial factor for resistance to buckling γ_{M1} should be taken from the relevant application standard.

NOTE – The value of the partial factor γ_{M1} may be defined in the National Annex. Where no application standard exists for the form of construction involved, or the application standard does not define the relevant values of γ_{M1}, it is recommended that the value of γ_{M1} should not be taken as smaller than γ_{M1} = 1,1.

The recommended value γ_{M1} = 1,1 is used.

(4) The buckling reduction factors χ_x, χ_θ şi χ_τ should be determined as a function of the relative slenderness of the shell $\overline{\lambda}$ from:

$$\chi = 1 \quad \text{when} \quad \overline{\lambda} \le \overline{\lambda}_0 \qquad \text{... (8.13)}$$

$$\chi = 1 - \beta\left(\frac{\overline{\lambda} - \overline{\lambda}_0}{\overline{\lambda}_p - \overline{\lambda}_0}\right)^{\eta} \quad \text{when} \quad \overline{\lambda}_0 < \overline{\lambda} < \overline{\lambda}_p \qquad \text{... (8.14)}$$

$$\chi = \frac{\alpha}{\overline{\lambda}^2} \quad \text{when} \quad \overline{\lambda}_p \le \overline{\lambda} \qquad \text{… (8.15)}$$

where:

- **α is the elastic imperfection reduction factor;**
- **β is the plastic range factor;**
- **η is the interaction exponent;**
- **$\overline{\lambda}_0$ is the squash limit relative slenderness.**

NOTE 1 - The values of these parameters should be taken from Annex D. Where Annex D does not define the values of these parameters, they may be given by the National Annex.

Recommended values from Annex D are used.

8.7 Design by global numerical analysis using GMNIA analysis

8.7.2 Design value of resistance

(7) The largest tolerable deformation should be assessed relative to the conditions of the individual structure. If no other value is available, the largest tolerable deformation may be deemed to have been reached when the greatest local rotation of the shell surface (slope of the surface relative to its original geometry) attains the value β.

NOTE – The National Annex may choose the value of β. The value β = 0,1 radians is recommended.

The recommended value β = 0,1 radians is used.

(16) Modification of the adopted mode of geometric imperfections to include realistic structural details (such as axisymmetric weld depressions) should be explored.

NOTE - The National Annex may define additional requirements for the assessment of appropriate patterns of imperfections.

Additional requirements for the assessment of appropriate patterns of imperfections are not defined.

(18) The amplitude of the adopted equivalent geometric imperfection form should be taken as dependent on the fabrication tolerance quality class. The maximum deviation of the

geometry of the equivalent imperfection from the perfect shape $\Delta w_{0,eq}$ should be the larger of $\Delta w_{0,eq,1}$ and $\Delta w_{0,eq,2}$, where:

$$\Delta w_{0,eq,1} = \ell_g \; U_{n1} \quad \text{.. (8.29)}$$

$$\Delta w_{0,eq,2} = n_i \; t \, U_{n2} \quad \text{... (8.30)}$$

where:

- **ℓ_g is all relevant gauge lengths according to 8.4.4 (2);**
- **t is the local shell wall thickness;**
- **n_i is a multiplier to achieve an appropriate tolerance level;**
- **U_{n1} and U_{n2} are the dimple imperfection amplitude parameters for the relevant fabrication tolerance quality class.**

NOTE 1 - The National Annex may choose the value of n_i. The value n_i = 25 is recommended.

The recommended value n_i = 25 is used.

NOTE 2 – Values for the dimple tolerance parameter U_{n1} and U_{n2} may be obtained from the National Annex. The recommended values are given in Table 8.5.

Table 8.5 - Recommended values for dimple imperfection amplitude parameters U_{n1} and U_{n2}

Fabrication tolerance quality class	Description	Recommended value of U_{n1}	Recommended value of U_{n2}
Class A	Excellent	0,010	0,010
Class B	High	0,016	0,016
Class C	Normal	0,025	0,025

Recommended values from Table 8.5 are used.

Section 9: Fatigue limit state (LS4)

9.2 Stress design

9.2.1 General

(2)P The partial factor for resistance to fatigue γ_{Mf} shall be taken from the relevant application standard.

NOTE - The value of the partial factor γ_{Mf} may be defined in the National Annex. Where no application standard exists for the form of construction involved, or the application standard does not define the relevant values of γ_{Mf}, the value of γ_{Mf} should be taken from EN 1993-1-9. It is recommended that the value of γ_{Mf} should not be taken as smaller than γ_{Mf} = 1,1.

The recommended value γ_{Mf} = 1,1 is used.

II. Conditions of application of SR EN 1993-1-6:2007 Annexes and corrigendum SR EN 1993-1-6:2007/AC:2009

Annex A (normative): Membrane theory stresses in shells

Annex A remains informative for the purpose of SR EN 1993-1-6:2007, corrigendum SR EN 1993-1-6:2007/AC:2009 and National Annex.

Annex B (normative): Additional expressions for plastic collapse resistances

Annex B remains informative for the purpose of SR EN 1993-1-6:2007, corrigendum SR EN 1993-1-6:2007/AC:2009 and National Annex.

Annex C (normative): Expressions for linear elastic membrane and bending stresses

Annex C remains informative for the purpose of SR EN 1993-1-6:2007, corrigendum SR EN 1993-1-6:2007/AC:2009 and National Annex.

Annex D (normative): Expressions for buckling stress design

Annex D remains informative for the purpose of SR EN 1993-1-6:2007, corrigendum SR EN 1993-1-6:2007/AC:2009 and National Annex.