NAVODILA IN PRIPOROČILA ZA IZVEDBO ANTIKOROZIJSKE ZAŠČITE ZA KLIMATSKI RAZRED C5 Z ZAHTEVO ŽIVLJENSKE DOBE H (15-25 let) ali VH (nad 25 let)

1. Korozijski razredi

ISO 12944-2 (2017) določa korozijske razrede:

Atmospheric corrosivity categories according to EN ISO 12944-2 with examples of typical environments.

Corrosivity category	Environmental corrosion	Examples of typical outdoor environments	Examples of typical indoor environments
C1	Very low	_	Heated areas with dry air and minor amounts of impurities (e.g. offices, shops, schools, hotels)
C2	Low	Environments with low levels of atmospheric pollution. Rural areas.	Unheated areas with varying temperature and humidity levels. Low frequency of condensation and low level of atmospheric pollution, e.g. sports halls and warehouses.
C3	Moderate	Environments with low salinity or moderate atmospheric pollution. Urban areas and light industrial areas. Areas with certain coastal influence.	Areas with moderate air humidity and some atmospheric pollution from production processes (e.g. breweries, dairies, laundries, etc.)
C4	High	Environments with moderate salinity or significant atmospheric pollution. Industrial and coastal areas.	Areas with high air humidity and high atmospheric pollution from production processes (e.g. chemical plants, swimming pools, shipyards, etc.)
C5-I	Very high (Industrial)	Industrial areas with high air humidity and aggressive atmosphere.	Areas with almost constant condensation and high levels of atmospheric pollution.
C5-M	Very high (Maritime)	Coastal and offshore areas with high salinity.	Areas with almost constant condensation and high levels of atmospheric pollution.

…ter korozijo jekla in cinka v prvem letu eksploatacije (ta kasneje upade);

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m^2	Thickness loss µm	Mass loss g/m^2	Thickness loss µm		
C1 very low	≤ 10	≤ 1,3	≤ 0,7	≤ 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels
C2 low	> 10 to 200	> 1,3 to 25	> 0,7 to 5	> 0,1 to 0,7	Atmospheres with low level of pollution: mostly rural areas	Unheated buildings where condensation can occur, e.g. depots, sports halls
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution; coastal areas with low salinity	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boatyards
C5 very high	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution
CX extreme	> 1 500 to 5 500	> 200 to 700	> 60 to 180	> 8,4 to 25	Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and subtropical and tropical atmospheres	Industrial areas with extreme humidity and aggressive atmosphere
NOTE The loss values used for the corrosivity categories are identical to those given in ISO 9223.						

2. Zahtevana življenska doba antikorozijske zaščite

ISO 12944-1 (2017) definira zahteve trajnosti antikorozijske zaščite (L,M,H,VH);

- Low durability (L): <7 years
- Medium durability (M): 7-15 years
- High durability (H): 15-25 years
- Very high durability (VH): >25 years

3. Antikorozijska zaščita z barvanjem

Potrebne debeline premazov glede na korozijski razred C in zahtevano trajnost v letih (ISO -12944-5:2018) :

ISO 12944-5:2018(E)

Table B.2 — Summary of the minimum number of coats (MNOC) and minimum NDFT of the paint system depending on durability and corrosivity category on abrasive blasted steel substrates

Durability		Low (l)			Medium (m)			High (h)			Very high (vh)		
Type of primer		Zn (R)	Misc.		Zn (R)	Misc.		Zn (R)	Misc.		Zn (R)	Misc.	
Binder base of primer		ESI, EP, PUR	EP, PUR, ESI	AK, AY	ESI, EP, PUR	EP, PUR, ESI	AK, AY	ESI, EP, PUR	EP, PUR, ESI	AK, AY	ESI, EP, PUR	EP, PUR, ESI	AK, AY
Binder base of subsequent coats		EP, PUR, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	EP, PUR, AY	AK, AY	EP, PUR, AY	EP, PUR, AY	AK, AY
C2	MNOC	[a]			—	—	1	1	1	1	2	2	2
	NDFT				—	—	100	60	120	160	160	180	200
C3	MNOC	—	—	1	1	1	1	2	2	2	2	2	2
	NDFT	—	—	100	60	120	160	160	180	200	200	240	260
C4	MNOC	1	1	1	2	2	2	2	2	2	3	2	—
	NDFT	60	120	160	160	180	200	200	240	260	260	300	—
C5	MNOC	2	2	—	2	2	—	3	2	—	3	3	—
	NDFT	160	180	—	200	240	—	260	300	—	320	360	—

NOTE 1 The abbreviations are described in Table A.1. For single coats, the binder base of the primer is recommended.

NOTE 2 In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

[a] If a coating is desired, use a system from a higher corrosivity category or durability, e.g. C2 high or C3 medium.

Kratice premazov;

Table A.1 — Abbreviated terms and descriptions

	Abbreviated term	Description			
Type of primer	Zn (R)	Zinc-rich primer, see 7.1.2 for further details. The usual nominal dry film thickness varies from 40 µm up to 80 µm.			
	Misc.	All other categories of primers			
Binder base for primers and subsequent coats		**Main binder**	**Type**	**Water-borne possible**	**Additional remarks**
	AK	Alkyd	single pack	X	
	AY	Acrylic	single pack	X	Usually water-borne
	EP	Epoxy	two pack	X	Poor UV-resistance
	PUR	Polyurethane	single or two pack	X	Only aliphatic types for topcoats
	ESI	Ethyl silicate	single or two pack		It is recommended to use a tie coat compatible with the next subsequent coat
	C2 to C5	Corrosivity categories, see ISO 12944-2.			
	Im1 to Im3	Immersion categories, see ISO 12944-2.			
	NDFT	Nominal dry film thickness. See 7.3 for further details.			
	MNOC	Minimum number of coats. Depending on the coating material, the application method and the design of the parts, it may be necessary to apply a higher number of coats.			

Iz tabel je razvidno, da za mora biti premaz za trajnost H (do 25 let) - ob obveznem peskanju Sa 2,5 - debeline; 300 qm (Zn-rich primer, EP, PUR - 3 sloji) ali 300 qm (EP, PUR, EPC, 2 sloja)

Takšen sistem barvanja je izredno zahteven (spoštovanje pogojev peskanja in barvanja ter vmesnega časa, medpremazni intervali,…). Slaba stran so ; skrite nedoslednosti peskanja, občutljivost premaza na mehanske poškodbe med prevozom, montažo in kasneje med eksploatacijo (kamenje, itd).

4. Antikorozijska zaščita z vročim cinkanjem (EN ISO 1461:2022)

Tabela letne korozije cinka po korozijskih tipih -Standard EN ISO 14713 – (2017)

Table 1 — Description of typical atmospheric environments related to the estimation of corrosivity categories

Corrosivity category C Corrosion rate for zinc (based upon first year of exposure), r_{corr} in $\mu m \cdot a^{-1}$ and corrosion level	Typical environments (examples)	
	Indoor	Outdoor
C1 $r_{corr} \leq 0,1$ Very low	Heated spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, central Arctic/Antarctica
C2 $0,1 < r_{corr} \leq 0,7$ Low	Unheated spaces with varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage, sport halls	Temperate zone, atmospheric environment with low pollution (SO_2 < 5 µg/m³), e.g. rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, sub-arctic areas
C3 $0,7 < r_{corr} \leq 2,1$ Medium	Spaces with moderate frequency of condensation and moderate pollution from production process, e.g. food-processing plants, laundries, breweries, dairies	Temperate zone, atmospheric environment with medium pollution (SO_2: 5 µg/m³ to 30 µg/m³) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides. Subtropical and tropical zones with atmosphere with low pollution
C4 $2,1 < r_{corr} \leq 4,2$ High	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools	Temperate zone, atmospheric environment with high pollution (SO_2: 30 µg/m³ to 90 µg/m³) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water, exposure to strong effect of de-icing salts. Subtropical and tropical zones with atmosphere with medium pollution

Corrosivity category C Corrosion rate for zinc (based upon first year of exposure), r_{corr} in $\mu m \cdot a^{-1}$ and corrosion level	Typical environments (examples)	
	Indoor	Outdoor
C5 $4,2 < r_{corr} \leq 8,4$ Very high	Spaces with very high frequency of condensation and/or with high pollution from production process, e.g. mines, caverns for industrial purposes, unventilated sheds in sub-tropical and tropical zones	Temperate and subtropical zones, atmospheric environment with very high pollution (SO_2: 90 $\mu g/m^3$ to 250 $\mu g/m^3$) and/or important effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline
CX $8,4 < r_{corr} \leq 25$ Extreme	Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/or with high pollution from production process, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter	Subtropical and tropical zones (very high time of wetness), atmospheric environment with very high (SO_2) pollution (higher than 250 $\mu g/m^3$), including accompanying and production factors and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and offshore areas, occasional contact with salt spray

NOTE 1 Deposition of chlorides in coastal areas is strongly dependent on the variables influencing the transport inland of sea salt, such as wind direction, wind velocity, local topography, wind sheltering islands beyond the coast, distance of the site from the sea, etc.

NOTE 2 Corrosivity classification of specific service atmospheres, e.g. in chemical industries, is beyond the scope of ISO 9223.

NOTE 3 Sheltered and not rain-washed surfaces, in a marine atmospheric environment where chlorides are deposited, can experience a higher corrosivity category due to the presence of hygroscopic salts.

NOTE 4 In environments with an expected "CX category", it is recommended to determine the atmospheric corrosivity classification from one-year corrosion losses.

NOTE 5 The concentration of sulfur dioxide (SO_2) should be determined during at least 1 year and is expressed as the annual average.

NOTE 6 Detailed descriptions of types of indoor environments within corrosivity categories C1 and C2 is given in ISO 11844-1. Indoor corrosivity categories IC1 to IC5 are defined and classified.

NOTE 7 The classification criterion is based on the methods of determination of corrosion rates of standard specimens for the evaluation of corrosivity (see ISO 9226).

NOTE 8 The thickness-loss values are identical to those given in ISO 9223.

NOTE 9 The zinc reference material is characterized in ISO 9226.

NOTE 10 Corrosion rates exceeding the upper limits in category C5 are considered as extreme. Corrosivity category CX refers to specific marine and marine/industrial environments.

NOTE 11 To a first approximation, the corrosion of all metallic zinc surfaces is at the same rate in a particular environment. Iron and steel will normally corrode 10 to 40 times faster than zinc, the higher ratios usually being in high-chloride environments. The data is related to data on flat sheet given in ISO 9223 and ISO 9224.

NOTE 12 Change in atmospheric environments occurs with time. For many regions, the concentrations of pollutants (particularly SO_2) in the atmosphere have reduced with time. This has led to a lowering of the corrosivity category for these regions. This has, in turn, led to the zinc coatings experiencing lower corrosion rates compared to historical corrosion performance data. Other regions have experienced increasing pollution and industrial activity and therefore would be expected to develop environments more accurately described by higher corrosivity categories.

NOTE 13 The corrosion rate for zinc and for zinc-iron alloy layers are approximately the same.

C5 opredeljuje:

Temperate and subtropical zones, atmospheric environment with very high pollution (SO_2: 90 µg/m3 to 250 µg/m3) and/or important effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline

Podatki veljajo za prvo leto eksploatacije, stopnja izgube cinkove prevleke se v naslednjih letih zniža zaradi učinka cink patine (Zn in CO_2 iz atmosfere tvorita cinkov karbonat) !

Tabela korozije v naslednjih 10 letih eksploatacije

Category	Steel corrosion rate		Zinc corrosion rate	
	First-year	Average 10 year	First-year	Average 10 year
C1	<1.3 µm	<0.4 µm/y	<0.1 µm	<0.07 µm/y
C2	1.3–25 µm	0.4–8.3 µm/y	0.1–0.7 µm	0.07–0.5 µm/y
C3	25–50 µm	8.3–17 µm/y	0.7–2.1 µm	0.4–1.4 µm/y
C4	50–80 µm	17–27 µm/y	2.1–4.2 µm	1.4–2.7 µm/y
C5	80–200 µm	27–67 µm/y	4.2–8.4 µm	2.7–5.5 µm/y
CX	200–700 µm	67–233 µm/y	8.4–25 µm	5.5–16 µm/y

Vir: Olaf Knudsen: Norwegian Experience with Zinc Thermal Spraying for Bridges

Tabeli prikazujeta življensko dobo vroče cinkane prevleke (leta) v odvisnosti od: njene začetne debeline, korozijskega tipa (letne min. in maks. korozije) in zahteve trajnosti (H ali VH)

ISO 14713-1:2017(E)

Table 2 — Life to first maintenance for a selection of zinc coating systems in a range of corrosivity categories

System	Reference standard	Minimum thickness µm	Selected corrosivity category (ISO 9223) life minimum/maximum (years) and durability class (VL, L, M, H, VH)							
			C3		C4		C5		CX	
Hot dip galvanizing	ISO 1461	85	40/>100	VH	20/40	VH	10/20	H	3/10	M
		140	67/>100	VH	33/67	VH	17/33	VH	6/17	H
		200	95/>100	VH	48/95	VH	24/48	VH	8/24	H

Coating thicknesses according to EN ISO 1461[1]		Life time of zinc coating in different corrosion categories				
Steel thickness mm	**(Local coating thickness[3]) Mean thickness[4] µm**	**C1**	**C2**	**C3**	**C4**	**C5[5]**
Steel > 6 mm	(70) 85	100+	100-100+	40-100+	20-40	10-20
Steel > 3 - ≤ 6 mm	(55) 70	100+	100-100+	33-100	17-33	8-17
Steel ≥ 1,5 - ≤ 3 mm	(45) 55	100+	78-100+	26-78	13-26	6-13
Steel < 1,5 mm	(35) 45	100+	64-100+	21-64	11-21	5-11
Castings ≥ 6 mm	(70) 80	100+	100-100+	38-100+	19-38	10-19
Castings < 6 mm	(60) 70	100+	100-100+	33-100	17-33	8-17
Steel > 6 mm Special[2]	(100) 115	100+	100+	55-100+	27-55	14-27
Steel > 6 mm Special[2]	(145) 165	100+	100+	78-100+	39-78	20-39
Steel > 6 mm Special[2]	(190) 215	100+	100+	100-100+	39-100+	25-51

Notes:

1) Minimum coating thickness on samples that are not centrifuged.
2) Larger coating thicknesses can only be achieved when the steel has a specified silicon content.
3) Minimum local coating thickness according to EN ISO 1461:2009.
4) Mean coating thickness according to EN ISO 1461:2009.
5) In category C5 it may be necessary to use duplex (galvanizing + painting) to reach longer life times.

Table 4. The life in years for galvanized coatings used in corrosion categories C1 -C5. The lifetimes are based on mean coating thickness according to EN ISO 1461:2009.

Vir: Nordic galvanizers – Hot dip galvanazing and categories – 2020

Zahtevane debeline cinkove prevleke po EN ISO 1461(2022)

Table 3 — Minimum galvanized coating thickness and mass on samples that are not centrifuged

Article and its thickness	Local galvanized coating thickness (minimum) µm	Local galvanized coating mass[a] (minimum) g/m²	Mean galvanized coating thickness (minimum) µm	Mean galvanized coating mass[a] (minimum) g/m²
Steel: >6 mm	70	505	85	610
Steel: >3 mm to ≤6 mm	55	395	70	505
Steel: ≥1,5 mm to ≤3 mm	45	325	55	395
Steel: <1,5 mm	35	250	45	325
Castings: >6 mm	70	505	80	575
Castings: ≤6 mm	60	430	70	505

NOTE This table is for general use: individual product standards can include different requirements including different categories of thickness. Local and mean galvanized coating mass requirements are set out in this table for reference in such cases of dispute.

[a] Equivalent galvanized coating mass using a nominal density of 7,2 g/cm³ (see Annex D).

For articles with steel section thicknesses greater than 3 mm, produced from steels with compositions ≤0,01 % silicon that also have aluminium contents >0,035 %, that exhibit ultra-low reactivity during galvanizing and therefore cannot satisfy the minimum galvanized coating thickness in Table 3, the next lowest category of steel article section thickness given in Column 1 of Table 3 shall be applied. In such cases, if a declaration of compliance must be provided then it shall state this variation including the adjusted minimum mean galvanized coating thickness requirement that has been applied to the inspection lot.

Kategorije jekel glede na vsebnost Si in P (EN ISO 14713-2;2019)

Table 1 — Coating characteristics related to steel composition

Category	Typical levels of reactive elements % (mass fraction)	Additional information	Typical coating characteristics
A	≤ 0,03 % Si and < 0,02 % P	See NOTE 1 and NOTE 4	Coating has a shiny appearance with a finer texture. Coating structure includes outer zinc layer.
B	≥ 0,14 % Si to ≤ 0,25 % Si	Other elements can also affect steel reactivity. In particular, phosphorus levels greater than 0,035 % will give increased reactivity.	Coating can have shiny or matt appearance. Coating structure can include outer zinc layer or iron-zinc alloy can extend through to the coating surface depending on steel composition.
C	> 0,03 % Si to < 0,14 % Si	Excessively thick coatings can be formed.	Coating has a darker appearance with a coarser texture. Iron/zinc alloys dominate coating structure and often extend to the coating surface, with reduced resistance to handling damage.
D	> 0,25 % Si	Coating thickness increases with increasing silicon content.	

NOTE 1 Steels with compositions satisfying the formula Si ≤ 0,03 % and Si + 2,5P ≤ 0,09 % are also expected to exhibit these characteristics. For cold rolled steels, these characteristics are expected to be observed when the steel composition satisfies the formula Si + 2,5P ≤ 0,04 %.

NOTE 2 The presence of alloying elements (e.g. nickel or aluminium) in the zinc melt can have a significant effect on the coating characteristics indicated in this table. This table does not provide relevant guidance for high-temperature galvanizing (i.e. immersion in molten zinc at 530 °C to 560 °C).

NOTE 3 The steel compositions indicated in this table will vary under the influence of other factors (e.g. hot rolling) and the boundaries of each range will vary accordingly.

NOTE 4 Steels with compositions < 0,01 % silicon that also have aluminium contents > 0,035 % can exhibit lower reactivity that could result in a lower than expected coating thickness. These steels can exhibit reduced levels of coating cohesion.

NOTE 5 The design of the article to be galvanized can also influence coating characteristics.

C5 življenska doba cinkove prevleke deb. 85 qm;

Ker je letna izguba cinkove prevleke v C5 , min. 4,2 qm in maks.8,4 qm (v praksi samo prvo leto takšna, potem se zmanjša na 2,7 – 5,5 qm), pomeni da pop. debelina cinkove prevleke 85 qm zadostuje - ob upoštevanju podatka za prvo leto – dobi 10 do 20 let, ob upoštevanju poprečne korozije v prvih 10 letih (2,7qm – 5,5 qm) pa 15 do 30 let.

Za dosego trajnosti 25 let, bi morala debelina znašati vsaj 137 qm.

Pri vročem cinkanju je doseči takšno debelino možno, a v praksi zelo zahtevno in se odsvetuje. Vso jeklo mora biti B kategorije - silicij 0,15-0,25% (EN ISO

14713-2), potrebni so podaljšani časi potapljanja, kar podraži postopek. Ker je potapljanjem ekspozicija jekla v cinkovi talini časovno različna (zgornji - spodnji del konstrukcije), prihaja do nepotrebno previsokih debelin nanosa na spodnjih površinah (preko 200 qm), to pa vpliva na slabšo oprijemljivost in slabši vizuelni izgled. Iz teh razlogov se ta način odsvetuje.
Pocinkovalnica zagotavlja največjo pop. debelino 85 qm, vendar ob pogoju, da je jeklo B kategorije.

Posledično - v primeru zahteve trajnosti 25 let v C5 je potreben duplex sistem. Pri ostalih korozijskih razredih; C1,C2,C3,C4 že zadostuje samo vroče cinkanje.

5. Duplex sistem:

Duplex sistem (cinkanje + barvanje) je potreben v atmosferi C5 z zahtevo H ali VH (25 let oz. nad 25 let) oz. Cx . Slednji poveča antikorozijsko zaščito za 1,5 - 3,2x (sinergijski efekt).

Potrebne debeline cinkovega nanosa in nato premaza, definira tabela standarda 12944-5 (2018)

Durability		Low (l)		Medium (m)		High (h)		Very high (vh)	
Binder base of primer		EP, PUR	AY	EP, PUR	AY	EP, PUR	AY	EP, PUR	AY
Binder base of subsequent coats		EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY	EP, PUR, AY	AY
C2	MNOC	[a]		[a]		1	1	1	2
	NDFT					80	80	120	160
C3	MNOC	[a]		1	1	1	2	2	2
	NDFT			80	80	120	160	160	200
C4	MNOC	1	1	1	2	2	2	2	—
	NDFT	80	80	120	160	160	200	200	—
C5	MNOC	1	2	2	2	2	—	2	—
	NDFT	120	160	160	200	200	—	240	—

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE 1 The abbreviations are described in Table A.1. For single coats, the binder base of the primer is recommended.

NOTE 2 The durability is in this case related to the paint system adhesion to the hot dip galvanized surface. In case of damaged paint system, the remaining hot dip galvanized layer delivers further protection to the steel.

[a] If coating is desired, use a system from higher corrosivity categories or durability, e.g. C2 high or C3 medium.

Zaradi sinergijskega efekta pri Duplex sistemu, debelina cinkove prevleke ni posebej predpisana , dovolj je skladnost po tabeli iz EN ISO 1461. Pred premazom je obvezen sweeping, pod strogim upoštevanjem navodil izvedbe. Premaz mora znašati za zahtevo H ; 200 qm – 2 sloja (EP,PUR,AY) oz. za VH 240 qm – 2 sloja (EP,PUR,AY).