HERMI®

SLO-PV 2026 – MATERIALI

Korozijska odpornost konstrukcijskih sistemov

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Korozijska odpornost – splošno

Definicija korozije:

Pretvorba „čistega“ materiala v kemično bolj **stabilno obliko**.

Je **kemična ali elektrokemična** reakcija z okolico.

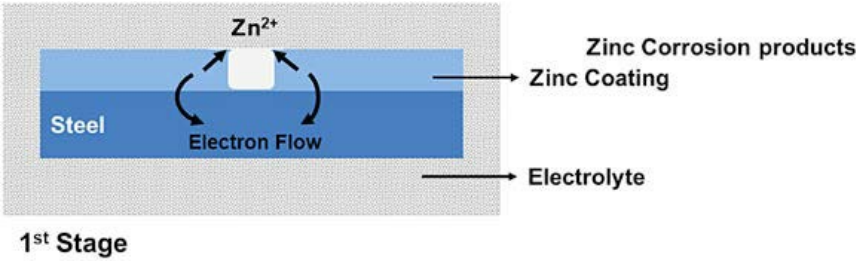
Podvrženi so vsi materiali. Praviloma govorimo o **kovinah**.

Zakaj je pomembna:

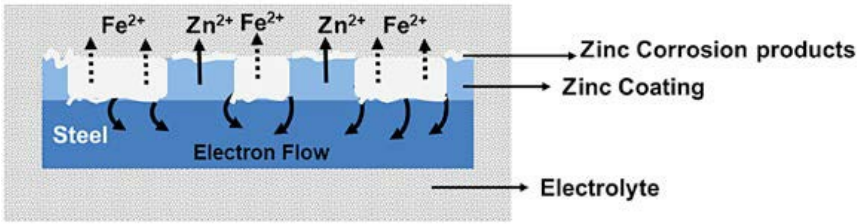
Ocenjena ekonomska škoda **3,4 % svetovnega BDP** (*vir*).

Zahteve po obnovi zaščitne plasti, zamenjavi delov.

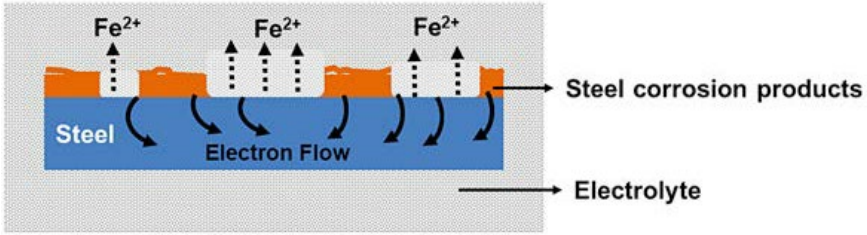
Je **znaten strošek** pri izgradnji sistema (za HDG je cca 1:2)



1st Stage



2nd Stage



3rd Stage

Namen in cilji

Namen predstavitve

Predstaviti način popisa korozije po standardih in podati tolmačenja zahtev za zaščitne prevleke.

Cilji:

- Razumeti, kaj je korozija.
- Smo seznanjeni z osnovnimi dejavniki.
- Znamo se opredeliti do postavljenih zahtev ali poiskati podporo.

r_{corr} r_{av} r_{lin}

T [°C] RH [%] ...

IZZIV: *Ad hoc zahteve pogosto izven okvirov ekonomske upravičenosti ali pa celo podcenijo vplive!*

Standardi ISO

Obseg:

Opredelijo **6 razredov** agresivnosti okolice (empirika).

Določijo 4 ključne **vplive** + **čas omočitve.**

Opisno **opredelijo okolja** glede na agresivnost okolice C1-CX.

Podajo smernice za napoved intenzivnosti korozije.

C1 – C2 – C3 – C4 – C5 –CX

T [°C] RH [%]

S_d P_d

r_{corr}

Omejitve:

Vrednosti so močno pogojene z **razvojem agresivnosti okolja**.

Nekatere manj izrazite dejavnike zavestno ne upoštevajo.

Parametri vpliva

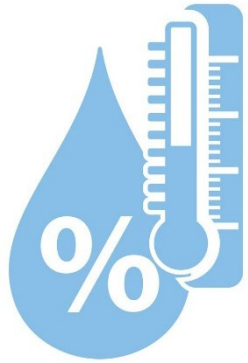
Dominantni **vplivi okolja** (4):

Symbol	Description	Interval	Unit
T	Temperature	–17,1 to 28,7	°C
RH	Relative humidity	34 to 93	%
P_d	SO_2 deposition	0,7 to 150,4	mg/(m^2·d)
S_d	Cl^- deposition	0,4 to 760,5	mg/(m^2·d)

The sulfur dioxide (SO_2) values determined by the deposition method, P_d, and volumetric method, P_c, are equivalent for the purposes of this International Standard. The relationship between measurements using both methods may be approximately expressed as $P_d = 0{,}8\ P_c$ [P_d in mg/(m^2·d), P_c in µg/m^3].

NOTE All parameters are expressed as annual averages.

Kompleks: T in RH



Opredeljen **čas omočitve "τ"** :

Time of wetness h/a	Level	Example of occurrence
$\tau \leq 10$	τ_1	Internal microclimates with climatic control
$10 < \tau \leq 250$	τ_2	Internal microclimates without climatic control except for internal non-air conditioned spaces in damp climates
$250 < \tau \leq 2\,500$	τ_3	Outdoor atmospheres in dry, cold climates and some zones of temperate climates; properly ventilated sheds in temperate climates
$2\,500 < \tau \leq 5\,500$	τ_4	Outdoor atmospheres in all climates (except for dry and cold climates); ventilated sheds in humid conditions; unventilated sheds in temperate climates
$5\,500 < \tau$	τ_5	Some zones of damp climates; unventilated sheds in humid conditions

NOTE 1 The time of wetness of a given locality depends on the temperature-humidity complex of the open-air atmosphere and the category of the location and is expressed in hours per year (h/a).

NOTE 2 Sheltered surfaces in marine atmospheres, where chlorides are deposited, can experience substantially increased times of wetness, due to the presence of hygroscopic salts.

NOTE 3 In indoor atmospheres without climatic control, sources of water vapour cause higher times of wetness.

Kriterij omočitve (τ): **RH>80 % in T>0 °C**

Povzeto po: ISO 9223:2012

Funkcije intenzivnosti korozije

Določitev: „dose-respone“:

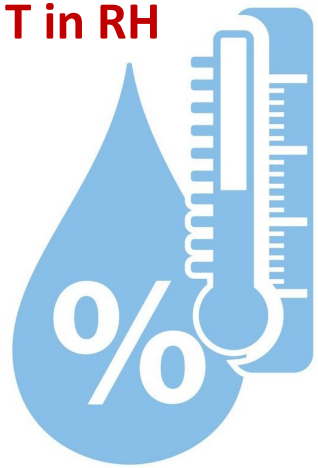
Use Equation (1) for carbon steel:

$$r_{corr} = 1{,}77 \cdot P_d^{0{,}52} \cdot \exp(0{,}020 \cdot RH + f_{St}) + 0{,}102 \cdot S_d^{0{,}62} \cdot \exp(0{,}033 \cdot RH + 0{,}040 \cdot T) \quad (1)$$

$f_{St} = 0{,}150 \cdot (T - 10)$ when $T \leq 10$ °C; otherwise $-0{,}054 \cdot (T - 10)$

$N = 128$, $R^2 = 0{,}85$

Kompleks: T in RH



Analogno še za **Zn; Cu; Al**.

Izrazito omejena uporaba.

POZOR: še vedno le r_{corr} za 1st-y

Omejeno območje uporabe →

Symbol	Description	Interval	Unit
T	Temperature	–17,1 to 28,7	°C
RH	Relative humidity	34 to 93	%
P_d	SO_2 deposition	0,7 to 150,4	mg/(m^2·d)
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NOTE All parameters are expressed as annual averages.

Povzeto po: ISO 9223:2012

Klasifikacija okolij

C. category	Corrosivity	Typical environments	
		INDOOR	OUTDOOR
C1	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	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 (SO2 < 5 µg/m3), e.g. **rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, subarctic areas**
C3	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 (SO2: 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 zone, atmosphere with low pollution**
C4	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 (SO2: 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 or, exposure to strong effect of de-icing salts** **Subtropical and tropical zone, atmosphere with medium pollution**
C5	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 subtropical and tropical zones**	Temperate and subtropical zone, atmospheric environment with very high pollution (SO2: 90 µg/m3 to 250 µg/m3) and/or significant effect of chlorides, e.g. **industrial areas, coastal areas, sheltered positions on coastline**
CX	EXTREMELY HIGH	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 & corrosion-stimulating particulate matter**	Subtropical and tropical zone (very high time of wetness), atmospheric environment with very high SO2 pollution (higher than 250 µg/m3) 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**

C5 je že ekstremno; CX pa zahteva 1-letno merjenje r_{corr}

Povzeto po: ISO 9223:2012

Korozija v različnih okoljih

Razširimo na:

- Korozija v **atmosferi** (C1 – CX),
- korozija v **vodi** (Im1 in Im2) in
- korozija v **zemljini** (Im3).

Povzeto po: EN ISO 14713:2017

Korozija v različnih okoljih

Korozija v **atmosferi** (C1-CX):

- **Makro** okolje: 4 parametri (T; Rh; Sd in Pd).
- **Mikro** okolje: zavetrje / mostovi / nadstreški.

Korozijo v **vodi** (Im1 in Im2):

- V slani vodi (Im2) ima največ vpliva Cl^-.
- Sladka voda bolj kompleksna in NI del standarda (Im1).
- Zn najbolj propada če voda: $55°\mathrm{C} < T < 80°C$.
- Če $T < 60°C$ → Zn nudi **zaščito katodi.**

Korozija v **zemljini** (Im3):

- Parametri: **pH** (2,6-12); **upornost** $N \cdot 10 \ldots 100\ \mathrm{k\Omega}$ …
- Kvalitativni parametri: vrst zemljine, **homogenost**; vsebnost $\boldsymbol{H_2O}$ **in** $\boldsymbol{O_2}$ …

Povzeto po: EN ISO 14713:2017 in EN ISO 14713-1:2017

Korozija v zemlji

Možna stanja v zemlji: - stik z zemljino

- stik z zemljino ob prisotnosti vode – stalna omočitev
- stik z zemljino ob mešanju z O_2 iz atmosfere

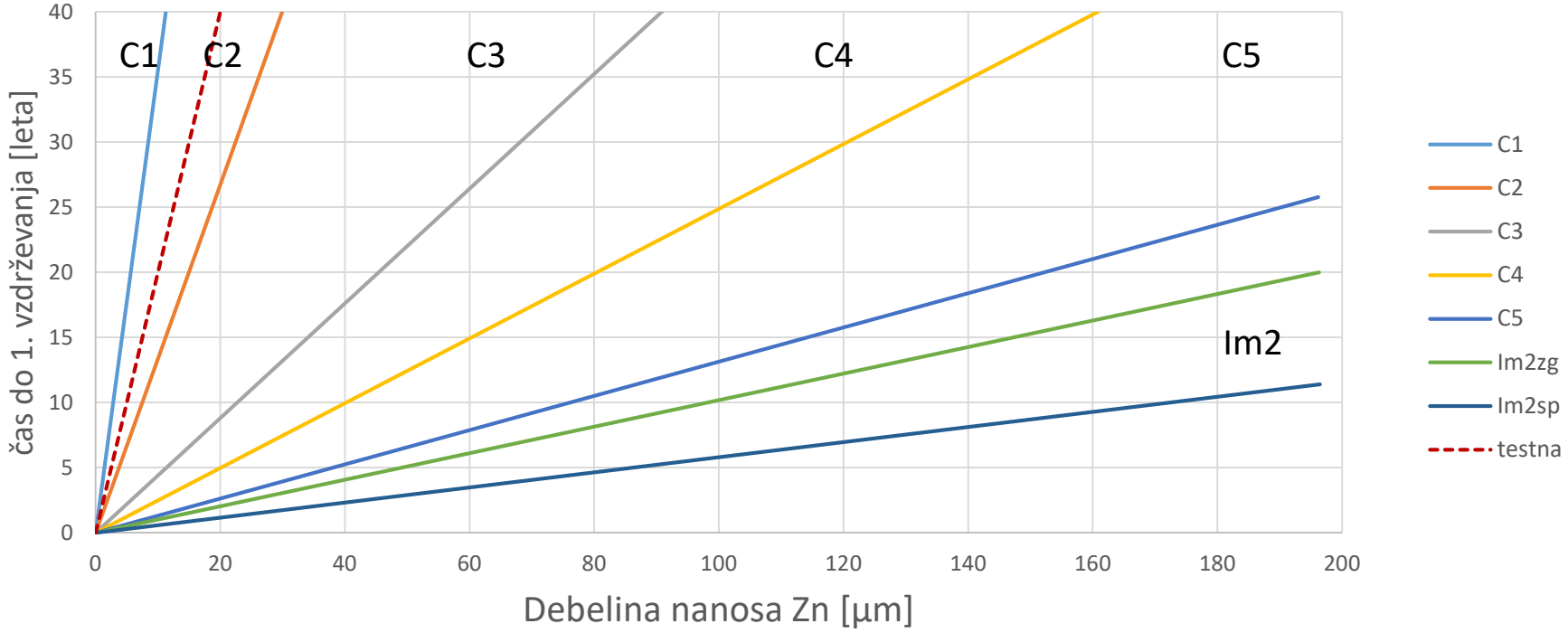
Vpliv korozije v zemlji opredelimo z:

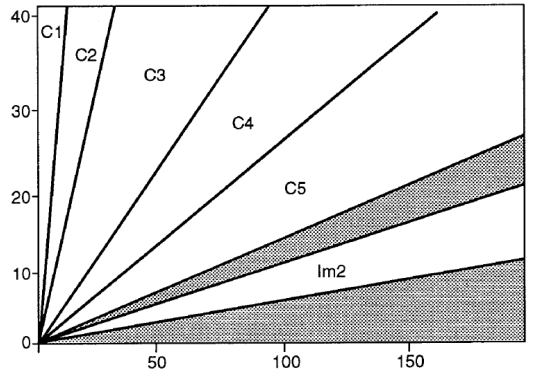
1. Ocenimo korozivnost zemljine (ρ in **pH** vrednost).
2. Ocenimo **tveganje pojava poškodb** zaradi korozije.

Kvalitativna ocena verjetnosti za korozijo				Intenzivnost korozije [mm/a]		
Klasa zemljine	Obremenitev s korozijo	Verjetnost za nastop koroz.		r_{const} za dobo 100 a	$r_{loc-max}$ za dobo 30 a	Opomba
		Jamičenje	Površinska korozija			
I-a	Very low	Very low	Very low	0,005	0,03	S časom pada
I-b	Low	Low	Very low	0,01	0,056	S časom pada
II	Medium	Medium	low	0,02	0,2	S časom pada
III	high	high	Medium	0,06	0,4	Časovno konstantna

Povzeto po: EN 12501-(1):2003 in DIN 50929-3:2018

Korelacija trajnosti nanosa in agresivnosti okolja





Zveza med:

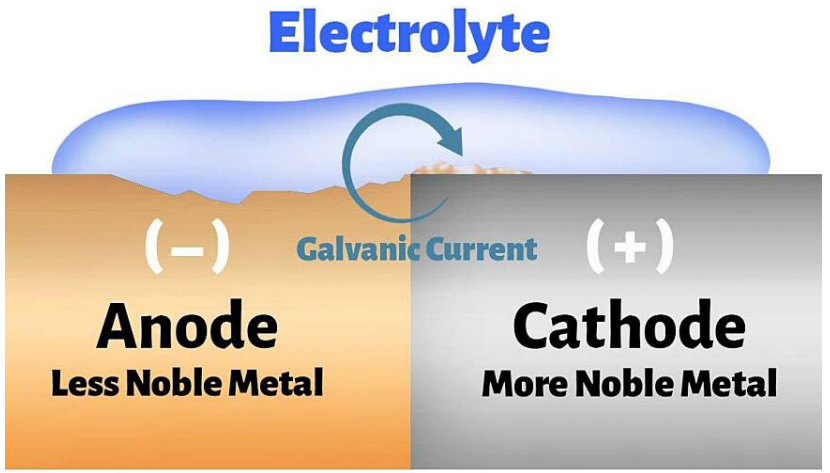
- vrednostmi r_{corr} in
- trajnostjo (t>1 leto) in
- razredi C1-CX.

Povzeto po: EN ISO 14713:2017

Galvanska zaščita in korozija

BIMETAL – tvorjenje galvanskega člena med kovinami:

Anodic — more prone to corrosion
Magnesium
Zinc
Aluminium
Carbon and low-alloy steels
Cast iron
Lead
Tin
Copper, brass, bronze
Nickel (passive)
Titanium
Stainless steel
Cathodic — less prone to corrosion



Povzeto po: EN ISO 14713-1:2017

POVZETEK

Funkcija zaščitnih prevlek:

Zaščitni sloji **niso večni**, temveč se postopoma **obrabljajo**, da zagotovijo zadostno zaščito osnovnemu materialu za **predviden čas**!

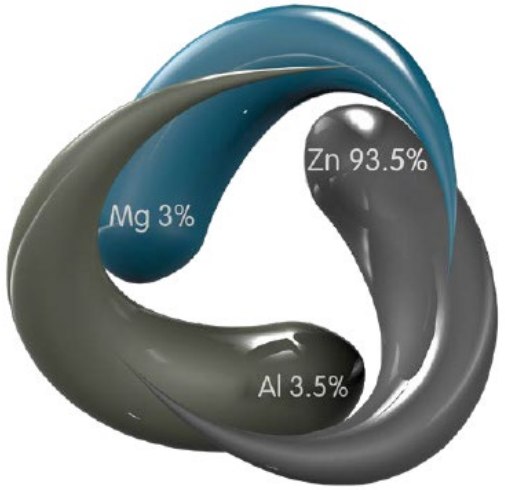
Osnovni material lahko opravlja svojo funkcijo znotraj predvidene življenjske dobe.

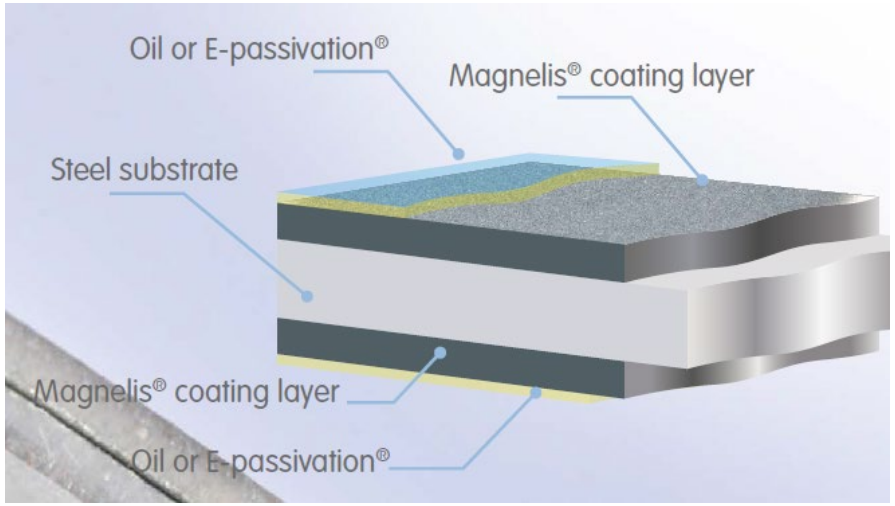
POVZETEK

Funkcija zaščitnih prevlek:

POVZETEK

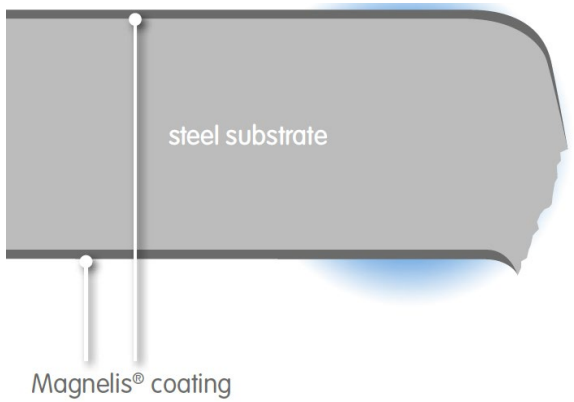
MAGNELIS®:





Smernice za izbiro materiala oz. zaščite glede na agresivnost atmosfere.

Material	C1	C2	C3	C4	C5	CX
FeZn						
FeZn-EPC						
Mgs						
FeZn-H						
Alu						
Rf						
Rf-H4						



Anodic — more prone to corrosion
Magnesium
Zinc
Aluminium
Carbon and low-alloy steels
Cast iron
Lead
Tin
Copper, brass, bronze
Nickel (passive)
Titanium
Stainless steel
Cathodic — less prone to corrosion

HVALA!

HERMI®

Moč narave,
premoč znanja.

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