PRORAČUN PARAMETARA JEDNOŠINSKE VISEĆE ŽELJEZNICE (JVŽ) U PROSTORIJAMA TRASE JAMA POGONA „HALJINIĆI“ ZD RMU „KAKANJ“ D.O.O. KAKANJ

CALCULATION OF PARAMETERS FOR OVERHEAD MONORAIL ON THE ROUTE IN HALJINIĆI PIT, ZD RMU "KAKANJ" D.O.O. KAKANJ

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REZIME

Analizirajući osnovnu problematiku jama pogona „Haljinići“, doprema materijala predstavlja jednu od osnovnih faza rada bitnih za funkcionisanje pogona, te se praćenje i rješavanje problematike vezane za ovaj segment rada, nameće kao ključni u cilju realizacije svih planiranih veličina.

Proizvodne aktivnosti, način eksploatacije, vrsta opreme koja se koristi pri tome i niz drugih faktora u značajnoj mjeri zahtijevaju visoku pouzdanost sistema za dopremu repromaterijala kao i transport, odnosno eventualnu dislokaciju iste na druge lokalitete ili van jame.

Da bi se postigli navedeni ciljevi, pored pouzdanosti mašina za dopremu, osnovni uslov predstavlja trasa jednošinske viseće željeznice (JVŽ), odnosno prostorije u kojima je ista postavljena, a koje svojim dimenzijama i kvalitetom moraju omogućiti transport opreme veće težine i gabarita.

Professional paper

SUMMARY

Haulage of material is one of the basic operational phases of the production process in Haljinići Pit. The monitoring and problem-solving in this segment are of crucial significance for achievement of all planned quantities.

Production activities, manner of exploitation, type of equipment used and a number of other factors involved in this activity require high reliability of the haulage system, especially in case it needs to be moved to other underground or surface sites.

Necessary precondition towards achievement of this goal, along with reliability of the haulage machinery, is an appropriate route of overhead monorail and the room it is set in. The dimensions and quality of the route and room need to allow the transport of equipment of large size and weight.

1. UVOD

Trasa jednošinske viseće željeznice (JVŽ) sa površine do križišta sa glavnim izvoznim niskopom (GIN) koja služi za dopremu repromaterijala i opreme do radilišta u jamama pogona „Haljinići“ i obratno, ima problema u postojećoj trasi. Iz tih razloga potrebno je izabrati novu sigurniju trasu i izvršiti proračune, kako bi se utvrdilo da nova trasa zadovoljava.

Izvršen je izbor i opis elemenata jednošinske viseće željeznice koji će se polagati na novoizabranoj trasi. Kao transportno sredstvo izabrana je dizel-hidraulična lokomotiva tipa DZ 66-3.1 proizvođača „[Scharf]“ Njemačka.

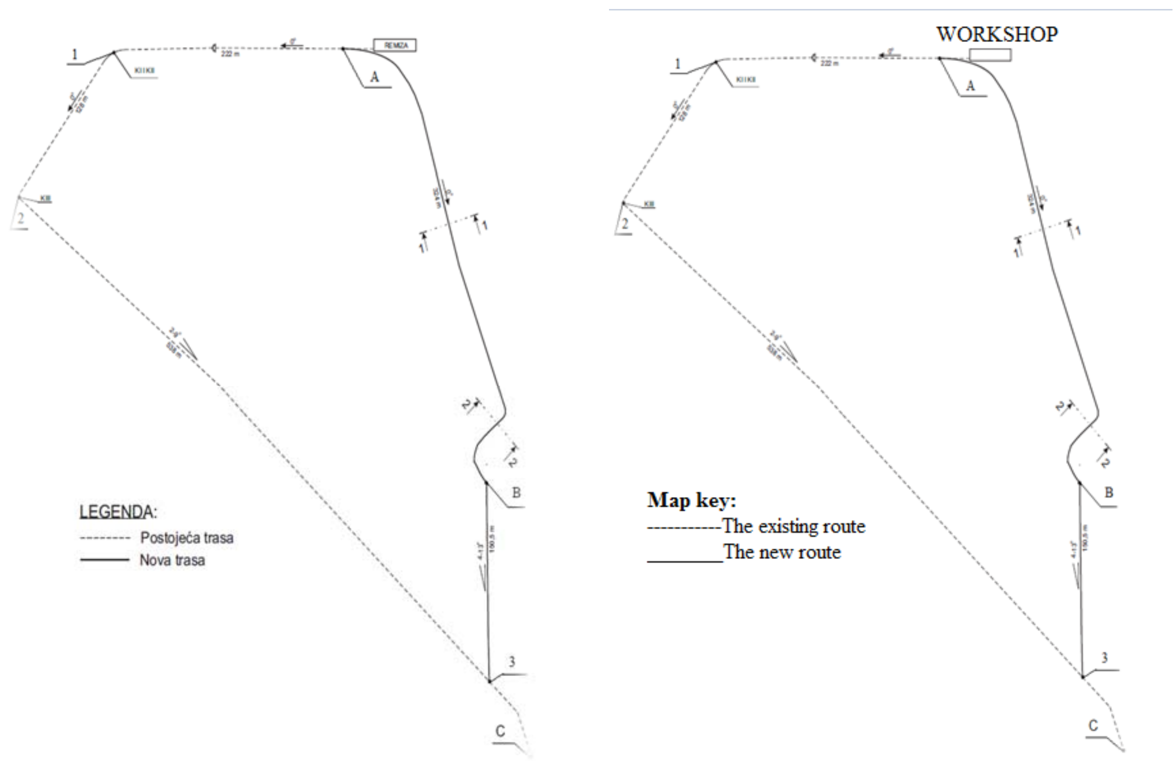
1. INTRODUCTION

In the pits of Haljinići Section, there are problems on the existing route of the overhead monorail used for haulage of raw material and equipment to the face and back to surface. Therefore, a new, safer route has to be selected and calculations made in order to determine whether the new route is appropriate.

The segments of the overhead monorail to be installed on the new route have already been selected, as well as the pulling device - a diesel-powered hydraulic locomotive type DZ 66-3.1, manufactured by Scharf Germany.

Izvršit će se proračun parametara jednošinske viseće željeznice i provjera elemenata za ugradnju.
Na slici broj 1 data je postojeća trasa i nova trasa koju treba proračunati.

Parameters of the overhead monorail shall be calculated and the railway segments inspected.
Picture 1 shows both the existing route and the new route that need to be calculated.



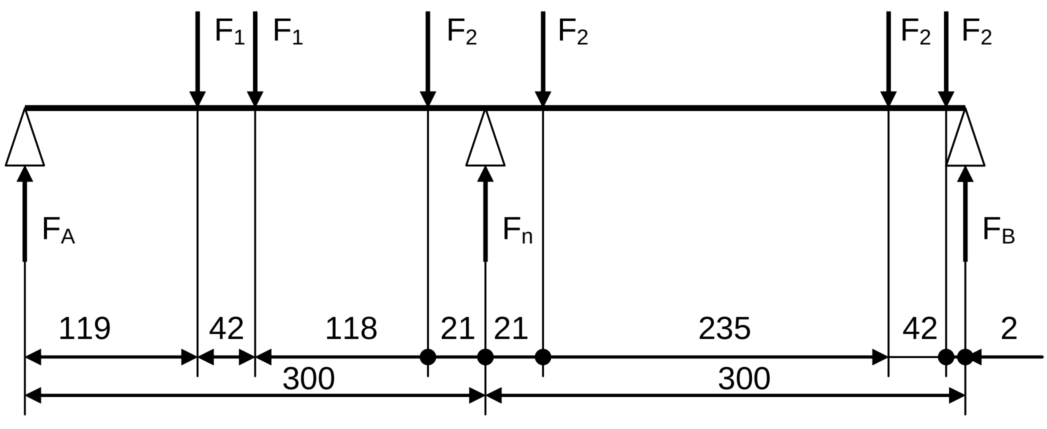
Slika 1. *Trasa jednošinske viseće željeznice (JVŽ) u tlocrtu*
Picture 1. *The route of the overhead monorail, layout*

2. PRORAČUN MAKSIMALNE SILE NA SPOJU IZMEĐU DVIJE ŠINE

Opterećenje para šina izgleda kao na slici 2:

2. CALCULATION OF THE MAXIMUM FORCE AT THE RAIL JOINT

Picture 2 shows the load of the pair of rails:



Slika 2. *Opterećenje para šina*
Picture 2. *Pair of rails load*

Postoji mogućnost da se na isti par šina ubaci i kontejner sa teretom na istim rasponima i opterećenjem para točkova F_2 sa veličinom tereta od 50 [kN] i vlastitom težinom 6 [kN], te bi ukupna sila na spoju šine iznosila:

This pair of rails could be loaded with a container with cargo in the same range and the load of a pair of wheels of F_2 with cargo load of 50 [kN] and dead load of 6 [kN]. In this case, the total force at the rail joint would be:

$$F_2 = \frac{50+6}{4} = 14 \text{ [kN]}, \quad (1)$$

F_l – dio težine kabine

F_l – part of the cabin weight

$F_l = 1{,}5$ [kN].

$\Sigma Y = 0$,

$$F_A - F_l - F_l - F_2 + F_{n1} = 0. \quad (2)$$

$\Sigma M_A = 0$,

$$F_l \cdot 119 + F_l \cdot (119 + 42) + F_2 \cdot (119 + 42 + 118) - F_{n1} \cdot 300 = 0, \quad (3)$$

$$F_{n1} = \frac{F_1 \cdot 119 + F_1 \cdot (119 + 42) + F_2 \cdot (119 + 42 + 118)}{300}, \quad (4)$$

$$F_{n1} = \frac{1{,}5 \cdot 119 + 1{,}5 \cdot (119 + 42) + 14 \cdot (119 + 42 + 118)}{300} = 14{,}42 \text{ [kN]}. \quad (5)$$

$\Sigma M_B = 0$,

$$F_{n2} \cdot 300 - F_2 \cdot 279 - F_2 \cdot 44 - F_2 \cdot 2 = 0, \quad (6)$$

$$F_{n2} = \frac{F_2 \cdot 279 + F_2 \cdot 44 + F_2 \cdot 2}{300}, \quad (7)$$

$$F_{n2} = \frac{14 \cdot 279 + 14 \cdot 44 + 14 \cdot 2}{300} = 15{,}17 \text{ [kN]}, \quad (8)$$

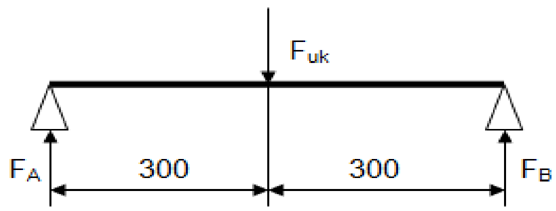
$$F_n = F_{n1} + F_{n2} = 14{,}42 + 15{,}17 = 29{,}59 \text{ [kN]}. \quad (9)$$

Ako se na ovo doda i težina grede od 660 [N], tada je maksimalna sila na spoju između dvije šine:

$$F_{uk} = 29{,}59 + 0{,}66 = 30{,}25 \text{ [kN]}, \quad (10)$$

If we add the beam load of 660 [N], the maximum force at the rail joint is:

$$F_{uk} = 29{,}59 + 0{,}66 = 30{,}25 \text{ [kN]}, \quad (10)$$



Slika 3. *Maksimalna sila*
Picture 3. *Maximum force*

$$F_A = F_B = \frac{F_{uk}}{2} = \frac{30{,}25}{2} = 15{,}125 \text{ [kN]}, \quad (11)$$

$$M_{Bmax} = 15{,}125 \cdot 300 = 4537{,}5 \text{ [kNcm]}. \quad (12)$$

Proračun kružnog luka

Na osnovu prethodnog proračuna zaključuje se da sila koja djeluje na luk u najnepovoljnijoj varijanti kretanja dizel lokomotive po trasi iznosi:

Semicircular arch calculation

Based on the previous calculation, we can conclude that the force acting on the arch in the worst-case variant of the diesel-powered locomotive motion along the track is:

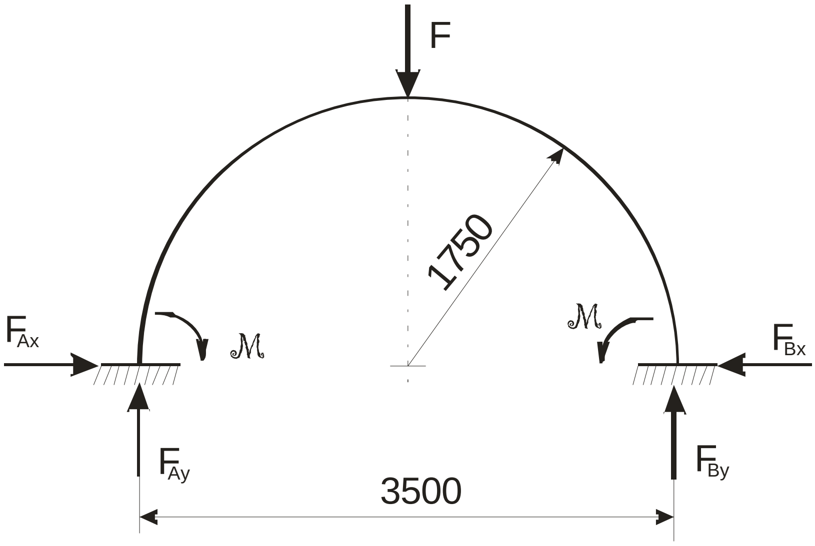
$$F = F_{uk} + F_l = 30{,}25 + 1{,}98 = 32{,}23 \text{ [kN]}, \quad (13)$$

gdje su:

- F_{uk}=30,25 [kN] – sila na spoju između dvije šine, (14)
- F_l=1983 N=1,98 [kN] – sopstvena težina luka (K 24). (15)

where:

- F_{uk}=30,25 [kN] – is the force at the rail joint, (14)
- F_l=1983 N=1,98 [kN] – is the dead load of the arch (K 24). (15)



Slika 4. *Opterećenje luka*
Picture 4. *Arch load*

$$F_{Ax} = F_{Bx} = 0{,}46 \cdot F = 0{,}46 \cdot 32{,}23 = 14{,}83 \text{ [kN]}, \quad (16)$$

$$F_{Ay} = F_{By} = \frac{F}{2} = 16{,}115 \text{ [kN]}, \quad (17)$$

$$M = \frac{4 + 2\pi - \pi^2}{2(\pi^2 - 8)} F \cdot R = \frac{4 + 2\pi - \pi^2}{2(\pi^2 - 8)} 32{,}23 \cdot 175 = 637{,}97 \quad \text{[kNcm]}, \quad (18)$$

$$M_F = F_{Ay} \cdot 175 - F_{Ax} \cdot 175 + M = 16{,}115 \cdot 175 - 14{,}83 \cdot 175 + 637{,}97 = 862{,}84 \text{ [kNcm]}. \quad (19)$$

Iz tablica za profil K-24 otporni moment iznosi W_x=76,7 [cm^3].

According to the tables for cross-section K-24, section modulus is W_x=76,7 [cm^3]

Tabela broj 1. *Otporni moment za profil K-24 kod čelične popustljive podgrade*
Table 1*. Section modulus for K-24 cross-section at the yielding steel support*

Tip	Glavne mjere			Statičke vrijednosti							F	G
	B (mm)	H (mm)	S (mm)	Ix (cm^4)	ex$_1$ (mm)	ex$_2$ (mm)	Wx$_1$ (cm^3)	Wx$_2$ (cm^3)	Iy (cm^4)	Wy (cm^3)	(cm^2)	(kp/m)
K - 21	140,0	110,0	14,0	375,9	54,8	55,2	68,5	68,0	475,0	68,5	27,0	21,2
K - 24	142,9	112,2	16,2	437,3	55,2	57,0	79,2	76,7	564,5	79,96	31,06	24,41

$$\sigma_b = \frac{M_F}{W_{X1}} = \frac{862{,}84}{76{,}7} = 11{,}25 \text{ [kN/cm}^2\text{]} <$$

σ_{doz}=35,3 [kN/cm^2] za čelik Č.0561. (20)

$$\sigma_b = \frac{M_F}{W_{X1}} = \frac{862{,}84}{76{,}7} = 11{,}25 \text{ [kN/cm}^2\text{]} <$$

σ_{doz}=35,3 [kN/cm^2] for steel Č.0561. (20)

Sila na temelj iznosi:

$$F_T = \frac{F}{2} = 16{,}115 \quad [\text{kN}]. \tag{21}$$

Specifični pritisak na podlogu iznosi:

$$P = \frac{F_T}{A} = \frac{16115}{60 \cdot 60} = 4{,}48\,[\text{N/cm2}] < \text{Pdoz} = 10\,[\text{N/cm2}] \tag{22}$$

2.1. Provjera dimenzija varova na vezi čelični luk - vezna ploča

Površina zavara na vezi luk - vezna ploča iznosi:

$$A = O_v \cdot b = 53 \cdot 0{,}4 = 21{,}2 \ [\text{cm}^2], \tag{23}$$

gdje su:

- $O_v \approx 53$ [cm] – obim poprečnog presjeka luka (dužina zavara),
- b=0,4 [cm] – širina zavara.

$$\tau = \frac{F_{Ax}}{A} = \frac{14830}{21{,}2} = 699{,}53 \ [\text{N/cm}^2] < \tau_{doz} = 2000 \ [\text{N/cm}^2]. \tag{24}$$

2.2. Provjera dimenzija vijaka ugrađenih u temelj

Vezna ploča će za temelj biti pričvršćena sa četiri vijka M 20x500. Uzimajući u obzir da sila F djeluje na tijelo vijaka svojom aksijalnom komponentom $F_{Ax} = F_{Bx} = 14830$ [N] to će napon smicanja po jednom vijku iznositi [7]:

$$\tau = \frac{F_{Ax}}{4 \cdot A} = \frac{14830}{4 \cdot 314} = 11{,}81 \ [\text{N/mm}^2] < \tau_{doz} = 390 \ [\text{N/mm}^2] \ \text{za kvalitet 8.8,} \tag{25}$$

gdje je:

$$A = \frac{d^2 \cdot \pi}{4} = \frac{20^2 \cdot \pi}{4} = 314\,[\text{mm}^2]. \tag{26}$$

2.3. Provjera dimenzija profila INP 14 ugrađenih u betonskoj volti na ulazu u prostoriju

Za proračun je uzet najnepovoljniji slučaj opterećenja (sila djeluje na sredini nosača) od težine voza i tereta koji se prevozi .

The force on the foundation is:

$$F_T = \frac{F}{2} = 16{,}115 \ [\text{kN}]. \tag{21}$$

The specific pressure on the surface is:

$$P = \frac{F_T}{A} = \frac{16115}{60 \cdot 60} = 4{,}48\,[\text{N/cm2}] < \text{Pdoz} = 10\,[\text{N/cm2}] \tag{22}$$

2.1. Verifying welded joint dimensions at the connection of the steel arch and connecting plate

The surface of welded joints at the connection of the arch and connecting plate is:

$$A = O_v \cdot b = 53 \cdot 0{,}4 = 21{,}2 \ [\text{cm}^2], \tag{23}$$

where:

- $O_v \approx 53$ [cm] – is the circumference of the cross-section of the arch (welded joint length),
- b=0,4 [cm] – is the welded joint width.

$$\tau = \frac{F_{Ax}}{A} = \frac{14830}{21{,}2} = 699{,}53 \ [\text{N/cm}^2] < \tau_{doz} = 2000 \ [\text{N/cm}^2]. \tag{24}$$

2.2. Verifying dimensions of bolts installed in the foundation

The connecting plate will be fastened to the foundation with four bolts M 20x500. Since the force F acts on the body of a bolt with its axial component $F_{Ax} = F_{Bx} = 14830$ [N], the shear stress on each bolt is [7]:

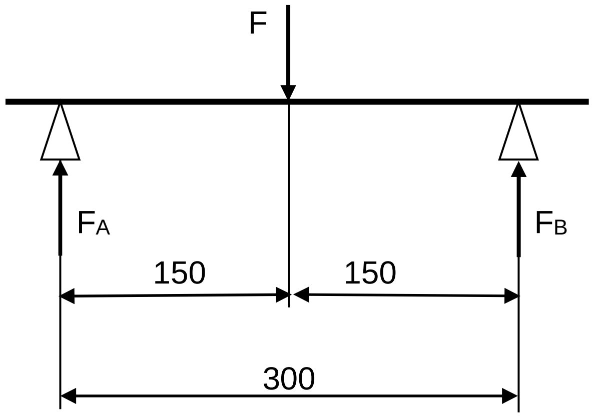
$$\tau = \frac{F_{Ax}}{4 \cdot A} = \frac{14830}{4 \cdot 314} = 11{,}81 \ [\text{N/mm}^2] < \tau_{doz} = 390 \ [\text{N/mm}^2] \ \text{for quality 8.8,} \tag{25}$$

where:

$$A = \frac{d^2 \cdot \pi}{4} = \frac{20^2 \cdot \pi}{4} = 314\,[\text{mm}^2]. \tag{26}$$

2.3. Verifying dimensions of cross-sections INP 14 installed in the concrete entrance

The calculation is based on the worst-case load (the force acts on the center of the beam) of the weight of the train and its cargo.



Slika 5. *Najnepovoljniji slučaj opterećenja*
Picture 5. *Worst-case load*

$$F_A = F_B = \frac{F}{2} = 16{,}115 \text{ [kN]}. \quad (27)$$

Maksimalni moment savijanja djeluje na sredini grede i iznosi:

$$M_F = F_A \cdot 150 = 16{,}115 \cdot 150 = 2417{,}25 \text{ [kNcm]}. \quad (28)$$

Otporni moment za INP14 je W_x=81,9 [cm^3] pa je napon savijanja:

$$\sigma = \frac{M_F}{W} = \frac{2417{,}25}{81{,}9} = 29{,}51 \text{ [kN/cm}^2\text{]} <$$

σ_{doz}=35,3 [kN/cm^2] za čelik Č.0561. (29)

2.4. Provjera dimenzija varova na držaču spojke grede

Provjera se vrši na napon smicanja koji je (za varove i drugi stepen opterećenja) $\boldsymbol{\tau_{doz}} = 2$ [kN/cm²].

Maksimalna sila: F = 32,23 [kN].

- A – površina varova opterećenih na smicanje,
- A = 2·10·0,4 + 4·6·0,4 + 2·4·0,4 = 20,8 [cm²]. (30)

- napon na smicanje:

$$\tau = \frac{F}{A} = \frac{32{,}23}{20{,}8} = 1{,}55 \left[\frac{\text{kN}}{\text{cm}^2}\right], \quad (31)$$

1,55 < 2 [kN/cm²] - za varove i drugi slučaj opterećenja.

$$\tau \leq \tau_{doz}$$

$$F_A = F_B = \frac{F}{2} = 16{,}115 \text{ [kN]}. \quad (27)$$

The maximum bending moment acts on the center of the beam and amounts to:

$$M_F = F_A \cdot 150 = 16{,}115 \cdot 150 = 2417{,}25 \text{ [kNcm]}. \quad (28)$$

The section modulus for INP14 is W_x=81,9 [cm^3], so the bending stress is:

$$\sigma = \frac{M_F}{W} = \frac{2417{,}25}{81{,}9} = 29{,}51 \text{ [kN/cm}^2\text{]} <$$

σ_{doz}=35,3 [kN/cm^2] for steel Č.0561. (29)

2.4. Verifying dimensions of welding joints at the bean connection retainer

The verification is done for shear stress which is (for welded joints and 2nd degree load) $\boldsymbol{\tau_{doz}} = 2$ [kN/cm²].

Maximum force: F= 32,23 [kN]

- A – the surface of shear loaded welding joints,
- A = 2·10·0,4 + 4·6·0,4 + 2·4·0,4 = 20,8 [cm²]. (30)

- shearing stress:

$$\tau = \frac{F}{A} = \frac{32{,}23}{20{,}8} = 1{,}55 \left[\frac{\text{kN}}{\text{cm}^2}\right], \quad (31)$$

1,55 < 2 [kN/cm²] - for welding joints and other case of load.

$$\tau \leq \tau_{doz}$$

2.5. Provjera dimenzija držača spojke grede na smicanje

Napon smicanja držača spojke grede ovisan je od maksimalne sile i računa se na najnepovoljniji slučaj.

$$\boldsymbol{\tau = \frac{F}{2 \cdot 3 \cdot 4} = \frac{32{,}23}{24} = 1{,}34 \left[\frac{kN}{cm^2}\right]}. \quad (32)$$

$$\tau \leq \tau_{doz}$$

1,34 < 2 [kN/cm²] - drugi slučaj opterećenja.

2.6. Provjera osovinice (spoj između držača spojke i spojke)

Provjera se vrši za materijal Č.0545, a spoj između držača spojke i spojke ovisan je od maksimalne sile i prečnika osovinice.

$$\tau = \frac{F}{2 \cdot \frac{d^2 \cdot \pi}{4}} = \frac{32{,}23}{2 \cdot \frac{2{,}2^2 \cdot 3{,}14}{4}} = 4{,}2\ [kN/cm^2]. \quad (33)$$

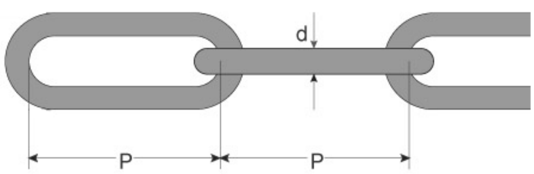
d – prečnik osovinice (d = 2,2 cm),

$$\tau \leq \tau_{doz}$$

4,2 < 5 [kN/cm²] - za drugi slučaj opterećenja za Č.0545.

2.7. Provjera dimenzija lanca koji služi za ovjes spoja šina za ankere, lučne i ravne nosače

Lanac za ovjes provjerava se na osnovu dozvoljene nosivosti.



***Slika 6.** Izgled lanca*

Sila u lancu je – F = 32,23 [kN].

Na osnovu sile u lancu usvaja se lanac Ø16 x 64 sa najmanjom prekidnom silom od 140 [kN] čija je dozvoljena nosivost od 35 [kN].
d = 16 mm
P = 64 mm

Koeficijent sigurnosti:

$$\nu = \frac{140}{35} = 4$$

2.5. Verifying dimensions of the bean connection retainer to shearing

Shear stress of the bean connection retainer depends on the maximum force and it is calculated based on the worst-case scenario.

$$\boldsymbol{\tau = \frac{F}{2 \cdot 3 \cdot 4} = \frac{32{,}23}{24} = 1{,}34 \left[\frac{kN}{cm^2}\right]}. \quad (32)$$

$$\tau \leq \tau_{doz}$$

1,34 < 2 [kN/cm²] - the other case of load.

2.6. Verifying the pin (the joint between the connection retainer and the connection)

The verification is done for material Č.0545 – the joint between the connection retainer and the connection depends on the maximum force and diameter of the base.

$$\tau = \frac{F}{2 \cdot \frac{d^2 \cdot \pi}{4}} = \frac{32{,}23}{2 \cdot \frac{2{,}2^2 \cdot 3{,}14}{4}} = 4{,}2\ [kN/cm^2] \quad (33)$$

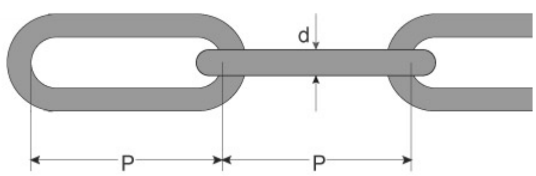
d – the pin diameter (d = 2,2 cm)

$$\tau \leq \tau_{doz}$$

4,2 < 5 [kN/cm²] – for the other case of load for Č.0545

2.7. Verifying dimensions of the chain used as rail suspension joint to anchors, arch and straight beams

The chain for suspension is verified based on the permissible load.



***Picture 6**. The chain*

The force in the chain is – F = 32,23 [kN]

Based on the force in the chain, we select chain Ø16 x 64 with the minimum breaking force of 140 [kN] and allowable load bearing capacity of 35 [kN].
d = 16 mm
P = 64 mm

Safety factor:

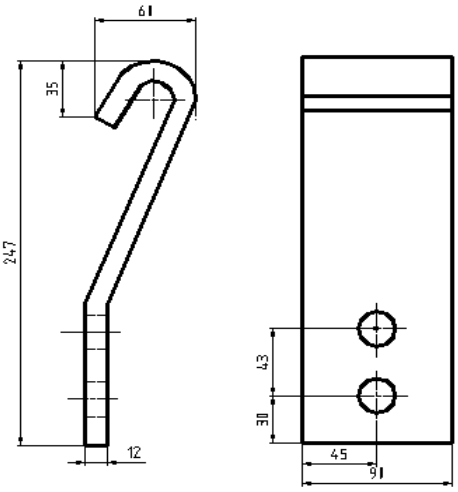
$$\nu = \frac{140}{35} = 4$$

2.8. Provjera spojnice za lučnu podgradu (zakačka)

Napon smicanja spojnice direktno zavisi od površine zakačke i maksimalne sile (težine voza i tereta koji se prevozi).

2.8. Verification of the arch support connection (hook)

Shear stress of the connection directly depends on the surface area of the hook and the maximum force (the weight of the train and its cargo).



Slika 7. *Izgled spojnice za luk (zakačka)*
Picture 7. *Arch connection (hook)*

$$\tau = \frac{F_{max}}{A}, \quad (34)$$

$$A = a \cdot b = 9 \cdot 24{,}7 = 222{,}3 \left[cm^2\right], \quad (35)$$

$$\tau = \frac{32230}{222{,}3} = 144{,}98 \left[N/cm^2\right], \quad (36)$$

$\tau \leq \tau_{doz} \rightarrow 129 \div 500 \left[daN/cm^2\right]$ – **za drugi sučaj opterećenja.** (37)

$\tau \leq \tau_{doz} \rightarrow 129 \div 500 \left[daN/cm^2\right]$ – for the other case of load. (37)

2.9. Provjera dimenzija anker vijka

Na svaki spoj šina se ubacuju po dva ankera pa bi teoretska maximalna sila iznosila F/2.

Za proračun će se usvojiti da je sila u pravcu ankera: F = 32,23 [kN].

2.9. Verifying dimensions of the anchor bolt

Each rail joint has two anchors inserted. Thus, the theoretical maximum force amounts to F/2.

For the purpose of the calculation, we take that the force in the direction of the anchor is: F= 32,23 [kN].

$$\sigma = \frac{F}{A} = \frac{32{,}23}{3{,}14} = 10{,}2 \left[\frac{kN}{cm^2}\right], \quad (38)$$

$$\sigma \leq \sigma_{doz} \quad (39)$$

$$10{,}2 \leq 12 \left[\frac{kN}{cm^2}\right]. \quad (40)$$

A – površina presjeka anker vijka – Č.0545,

A - the sectional area of the anchor bolt – Č.0545,

$$A = \frac{d^2 \cdot \pi}{4} = \frac{2^2 \cdot 3{,}14}{4} = 3{,}14 \left[cm^2\right] \quad (41)$$

Visina navrtke:
H = 0,7·22 = 15,4 [mm] < 20 [mm]. (42)

The nut height:
H = 0,7·22 = 15,4 [mm] < 20 [mm].(42)

Naprezanje u varovima iznosi:

$\sigma = \frac{F}{A} = \frac{32,23}{19,2} = 1,68\ [kN/cm^2].$ (43)

$\tau \leq \tau_{doz}$

$1,68 \leq 2\ [kN/cm^2]$ – za zavare. (44)

A = 4·8·0,6 =19,2 [cm²]. (45)

Naprezanje na savijanje vijka iznosi:

$$\sigma = \frac{M_B}{W} = \frac{16,115 \cdot 2,6}{0,1 \cdot d^3} = \frac{16,115 \cdot 2,6}{0,1 \cdot 2^3} = 52,3\ \left[\frac{kN}{cm^2}\right]. \quad (46)$$

2.10. Provjera spojnice (klobanj)

The tension in the welding joints is:

$\sigma = \frac{F}{A} = \frac{32,23}{19,2} = 1,68\ [kN/cm^2].$ (43)

$\tau \leq \tau_{doz}$

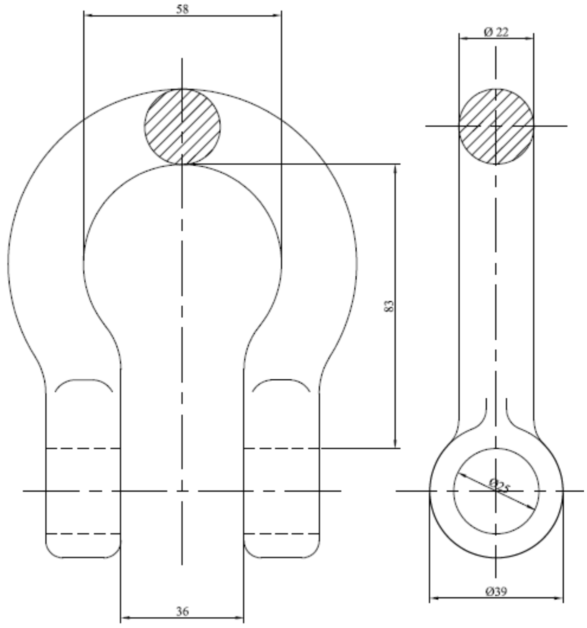
$1,68 \leq 2\ [kN/cm^2]$ – for welding joints. (44)

A = 4·8·0,6 =19,2 [cm²]. (45)

The bending stress of the bolt is:

$$\sigma = \frac{M_B}{W} = \frac{16,115 \cdot 2,6}{0,1 \cdot d^3} = \frac{16,115 \cdot 2,6}{0,1 \cdot 2^3} = 52,3\ \left[\frac{kN}{cm^2}\right]. \quad (46)$$

2.10. Verifying the connection (*klobanj*)



$\sigma = \frac{F}{A} = \frac{4F}{d^2\pi} = \frac{4 \cdot 32,23}{22^2 \cdot \pi} = 0,08\ [kN/cm^2],$ (47)

$\sigma < \sigma_{doz}$ (48)

Kako je najmanja površina poprečnog presjeka na mjestu otvora za vijak, na tom mjestu će se vršiti provjera napona na zatezanje.

$$\sigma = \frac{F}{2(b-D)s} = \frac{32,23}{2 \cdot (39-25) \cdot 22} 0,05\ [kN/cm^2] < \sigma_{doz} = 16\ [kN/cm^2], \quad (49)$$

$$\sigma_{doz} = 16\ [kN/cm^2] \ \text{čelik Č.0361},$$

Specifični pritisak na mjestu dodira sa vijkom je: (50)

$P = \frac{F}{2\,D\,s} = \frac{32,23 \cdot 10^3}{2 \cdot 25 \cdot 22} = 29,3\ [N/mm^2].$ (51)

$\sigma = \frac{F}{A} = \frac{4F}{d^2\pi} = \frac{4 \cdot 32,23}{22^2 \cdot \pi} = 0,08\ [kN/cm^2],$ (47)

$\sigma < \sigma_{doz}.$ (48)

The smallest surface of the cross-section is at the opening for the bolt and tensile stress is verified at that location:

$$\sigma = \frac{F}{2(b-D)s} = \frac{32,23}{2 \cdot (39-25) \cdot 22} 0,05\ [kN/cm^2] < \sigma_{doz} = 16\ [kN/cm^2], \quad (49)$$

$$\sigma_{doz} = 16\ [kN/cm^2] \ \text{steel Č.0361},$$

Specific pressure at the place of contact with the bolt is: (50)

$P = \frac{F}{2\,D\,s} = \frac{32,23 \cdot 10^3}{2 \cdot 25 \cdot 22} = 29,3\ [N/mm^2].$ (51)

Pojašnjenje: Napon na zatezanje spojnice (klobnja) iz proračuna iznosi 0,08 [kN/cm^2], što je dosta manje u odnosu na dozvoljeni napon zatezanja spojnice (klobnja) koji iznosi 16[kN/cm^2] za čelik Č. 0361.

Explanation: Tensile stress of the connection (klobanj), according to the calculation, is 0,08 [kN/cm^2], which is considerably less than the permissible tensile stres of the connection i.e. 16 [kN/cm^2] for Č.0361 steel; therefore, the verification proves that the connection (klobanj) was well-chosen.

3. KINEMATIKA VOŽNJE DIZEL - HIDRAULIČNE LOKOMOTIVE DUŽ TRANSPORTNE TRASE S PRORAČUNIMA NA KARAKTERISTIČNIM DIONICAMA

Brzina kretanja voza po gornjoj šini sa dizel vučom ovisi o teretu koji se prevlači, nagibu željeznice, kvaliteti izrade željeznice i skretnica kao i od krivina po transportnoj trasi.
Sa povećanjem uspona vožnje smanjuje se brzina kretanja kao i vučna sila na kuki.

3.1. Proračun transporta

Analizirajući nagibe terena na dionici od garaže za dizel lokomotive (remize) pa do mjesta uklapanja u postojeću trasu na K+419,14, (tačka 3 slika br. 3) može se reći da na ovom dijelu trase postoje dvije dionice. Prva dionica je od garaže „[Scharf]"-a (tačka A) do ulaza u novu prostoriju (tačka B) sa nagibom od 8^0, dok drugu dionicu čini dio trase od ulaza u novu prostoriju pa do mjesta uklapanja u postojeću trasu na K+419,14 (tačka 3 slika br. 3). Na osnovu prethodne podjele izvršit će se proračun kinematike vožnje sa dizel lokomotivom „[Scharf]".

3.1.1. Proračun transporta uz uskop od tačke 3 do tačke B

Duž trase uz uskop (dionica tačka 3 - tačka B), maksimalni nagib iznosi 13^0 . Budući da je ovaj uspon uglavnom manji, za proračun se usvaja maksimalni uspon od 13° .

3. KINEMATICS OF DRIVING THE DIESEL-POWERED HYDRAULIC LOCOMOTIVE ALONG THE TRANSPORT ROUTE, WITH CALCULATIONS FOR SPECIFIC SECTIONS

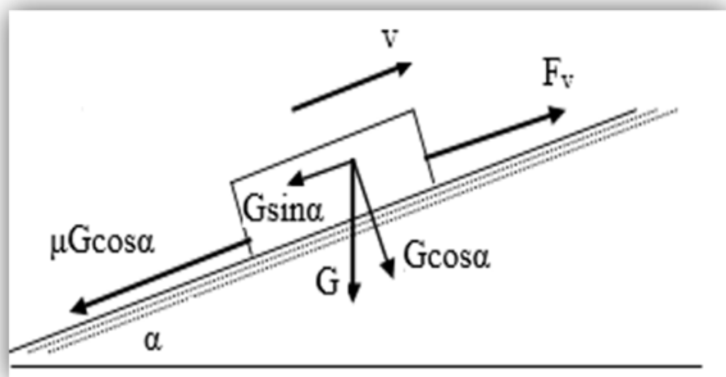
A diesel-powered train speed depends on the cargo, inclination of the overhead monorail, quality of the railway system and its switches and on the curves along the transport route.
The speed and the pulling force on the hook reduce when ascending.

3.1. Calculation of transport

The analysis of inclinations on the route, from the diesel-powered locomotive garage (the train depot) to the point where it connects to the existing route at K+419,14, (mark 3, picture 3) shows that there are two sections at this route. The first section starts at the train depot and ends at the entrance into the new room (mark B) with the inclination of 8^0; the second section starts at the entrance into the new room and ends at the point where it connects to the existing route at K+419,14 (mark 3, picture 3). The kinematics calculations for the diesel-powered locomotive Scharf are based on the above division of the in two sections.

3.1.1. Calculation for the transport up the inclined shaft from mark 3 to mark B

On the route up the inclined shaft (the section from mark 3 to mark B), the maximum inclination is 13°. The calculation below is based on this maximum inclination (13°).



Slika 9. *Dijagram vučne sile i brzine ovisno o nagibu vožnje*
Picture 9. *Diagram: pulling forces and speed, depending on inclination*

Iz dijagrama vučne sile i brzine ovisno o nagibu vožnje iznosi da je kod:

α_{max}=13°
v= 0,6 m/s – usvojeno.
vučna sila na kuki sa tri pogonska uređaja:
Fv=34,4 [kN]
Σx=0

$$F_v - G\sin\alpha - \mu\cdot\cos\alpha = 0 \quad (52)$$
$$F_v = G(\sin\alpha + \mu\cdot\cos\alpha) = 0 \quad (53)$$
$$G = F_v/(\sin\alpha + \mu\cdot\cos\alpha) \quad (54)$$

Prema uputstvima i podacima njemačke firme “[Scharf]” proračun treba izvršiti sa 80% opterećenja vučne sile, tako da je stvarna vučna sila [8]:

$$F_{vs} = 0{,}8\cdot 34{,}4 = 27{,}52\ [kN], \quad (55)$$
$$G_s = F_{vs}/(\sin\alpha + \mu\cdot\cos\alpha) = 27{,}52/(\sin 13^o + 0{,}03\cdot\cos 13^o), \quad (56)$$
$$G_s = 108{,}27\ [kN]. \quad (57)$$

Tabela broj 2. *Maksimalno opterećenje visećeg voza*

hidraulična greda	4 kom.	težine 21,6 [kN]
kontejner	4 kom.	težine 17,6 [kN]
dupli kočioni uređaj	1 kom.	težine 4,2 [kN]
vučna poluga	4 kom.	težine 0,6 [kN]
vlastiti teret voza		G_v = 44 [kN]

Korisni teret u vozu iznosi po kontejneru 15 [kN], odnosno

$$G_k = 4\cdot 15 = 60\ [kN]. \quad (58)$$

Ukupni maksimalni vučni teret iznosi: (59)

$$G_{u\ max.} = G_k + G_v = 60 + 44 = 104\ [kN]. \quad (60)$$

Pošto je G = 108,27 > $G_{u\ max.}$= 104 [kN] to lokomotiva može po usponu od 13° izvući gore navedeni teret.

3.1.2. Proračun transporta niz niskop od tačke B do 3

Za kretanje kompozicije voza niskopnim prostorijama težina voza i teret djeluju mnogo povoljnije te se može usvojiti obzirom na kočione sposobnosti voza.
Usporenje pri kočenju iznosi:

$$a_2 = g\cdot(\frac{\mu_p\cdot F_P}{G} + \sin\alpha - \mu\cdot\cos\alpha). \quad (61)$$

The diagram of the pulling forces and speed depending on the inclination, shows that at:
α_{max}=13°
v= 0,6 m/s – adopted,
the pulling force on the hook with three pulling devices is:
Fv=34,4 [kN]
Σx=0

$$F_v - G\sin\alpha - \mu\cdot\cos\alpha = 0 \quad (52)$$
$$F_v = G(\sin\alpha + \mu\cdot\cos\alpha) = 0 \quad (53)$$
$$G = F_v/(\sin\alpha + \mu\cdot\cos\alpha) \quad (54)$$

According to the manuals and data provided by German company Scharf, calculations should be made with 80% pulling force load, so the actual pulling force is [8]:

$$F_{vs} = 0{,}8\cdot 34{,}4 = 27{,}52\ [kN], \quad (55)$$
$$G_s = F_{vs}/(\sin\alpha + \mu\cdot\cos\alpha) = 27{,}52/(\sin 13^o + 0{,}03\cdot\cos 13^o), \quad (56)$$
$$G_s = 108{,}27\ [kN]. \quad (57)$$

Table 2. *Maximum load of the overhead train*

Hydraulic beam	4 pie.	weight 21,6 [kN]
Container	4 pie.	weight 17,6 [kN]
Double brake system	1 pie.	weight 4,2 [kN]
Pulling rack	4 pie.	weight 0,6 [kN]
Dead load of the train		**G_v = 44 [kN]**

The payload in the train amounts to 15 [kN] per container, i.e.

$$G_k = 4\cdot 15 = 60\ [kN]. \quad (58)$$

The total maximum pulling load is: (59)

$$G_{u\ max.} = G_k + G_v = 60 + 44 = 104\ [kN]. \quad (60)$$

Since G = 108,27 > $G_{u\ max.}$= 104 [kN], the locomotive can pull the said load when inclination is 13°.

3.1.1. Calculation for the transport down the inclined shaft from mark B to mark 3

When the train is driven down the inclined shaft, the weight of the train and cargo act in favor of the movement. Taking into consideration the braking ability of the train, the following calculations apply.
Deceleration when breaking is:

$$a_2 = g\cdot(\frac{\mu_p\cdot F_p}{G} + \sin\alpha - \mu\cdot\cos\alpha)$$

(61)

gdje su :

F_p = 240 [kN] – sila pritiskanja sigurnosne kočnice,

μ_p = 0,25 – kočione obloge su od sinter materijala,

G=108,27 [kN] (izračunato u tački 3.1.1.). (62)

where:

F_p = 240 [kN] – is the force of pressuring the emergency brake,

μ_p = 0,25 – brake pads are made of sintered material,

G=108,27 [kN] - (calculated under 3.1.1.).(62)

$$a_2 = 9{,}81 \cdot (\frac{0{,}25 \cdot 240}{108{,}27} + \sin 13° - 0{,}03 \cdot \cos 13°)$$ (63)

$$a_2 = 7{,}356 \text{ [m/s}^2\text{]}$$ (64)

$$a_2 = 7{,}356 \text{ [m/s}^2\text{]}$$ (64)

Prosječno ubrzanje iznosi:

$$a = \frac{a_1 + a_2}{2} = \frac{1{,}92 + 7{,}356}{2} = 4{,}64 \text{ [m/s}^2\text{]}.$$ (65)

The average acceleration is:

$$a = \frac{a_1 + a_2}{2} = \frac{1{,}92 + 7{,}356}{2} = 4{,}64 \text{ [m/s}^2\text{]}.$$ (65)

4. ZAKLJUČAK

Proračunom parametara jednošinske viseće željeznice (JVŽ) u prostorijama trase jama pogona „Haljinići“ ZD RMU „Kakanj“ d.o.o. Kakanj, dokazano je da svi izabrani elementi jednošinske viseće željeznice daju visoku pouzdanost sistema za dopremu repromaterijala i zadovoljavaju zakonske propise i propise iz Pravilnika koji se odnose na naslovnu temu.

4. CONCLUSION

The calculation of parameters of the overhead monorail in the rooms of Haljinići Pit, ZD RMU "Kakanj" d.o.o. Kakanj, proves that all the selected segments of the overhead monorail provide the high safety to the system for raw material haulage and satisfy all the legal requirements and applicable regulations.

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