



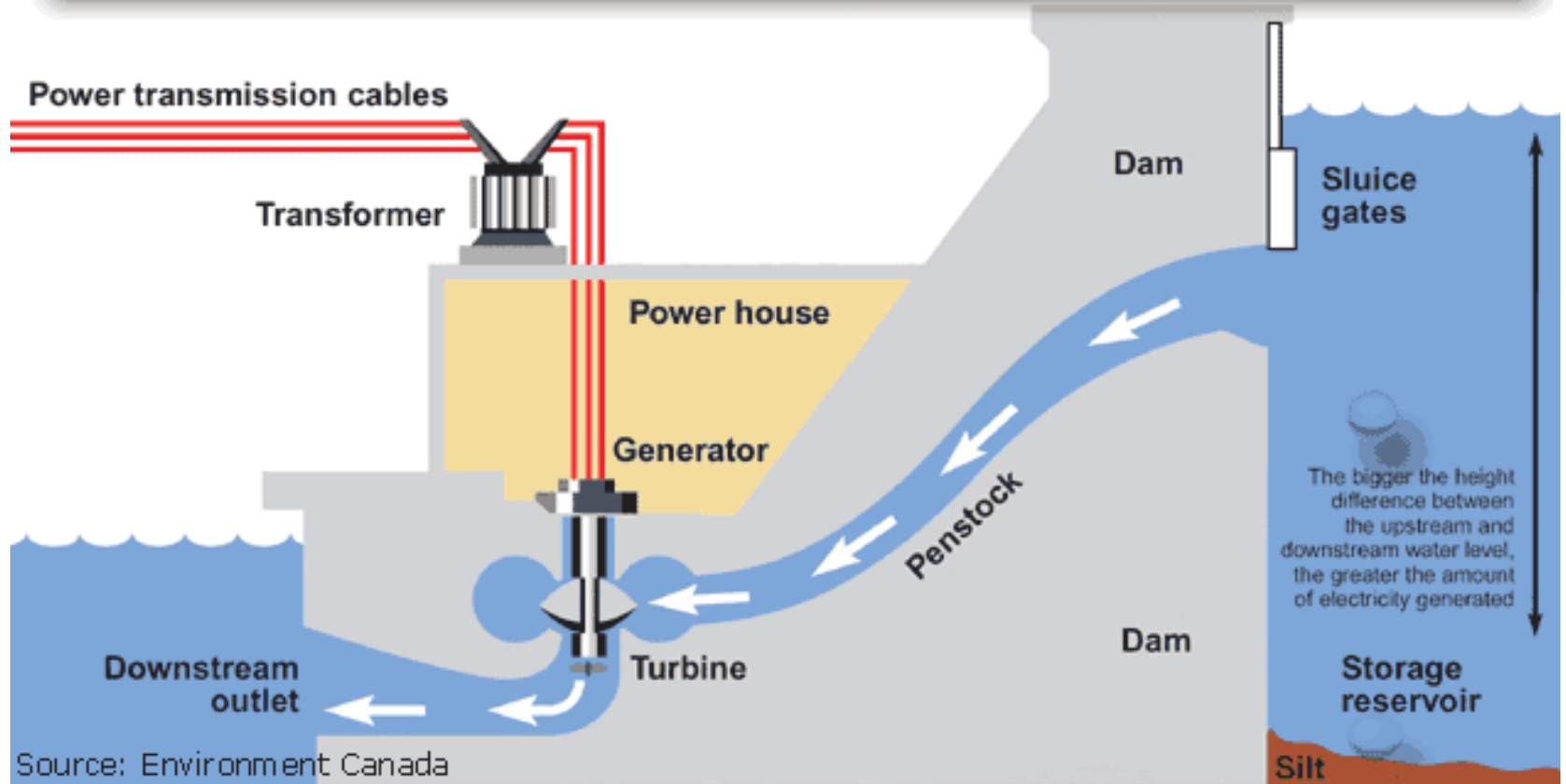
**Fakultet građevinarstva, arhitekture i
geodezije Sveučilište u Splitu**

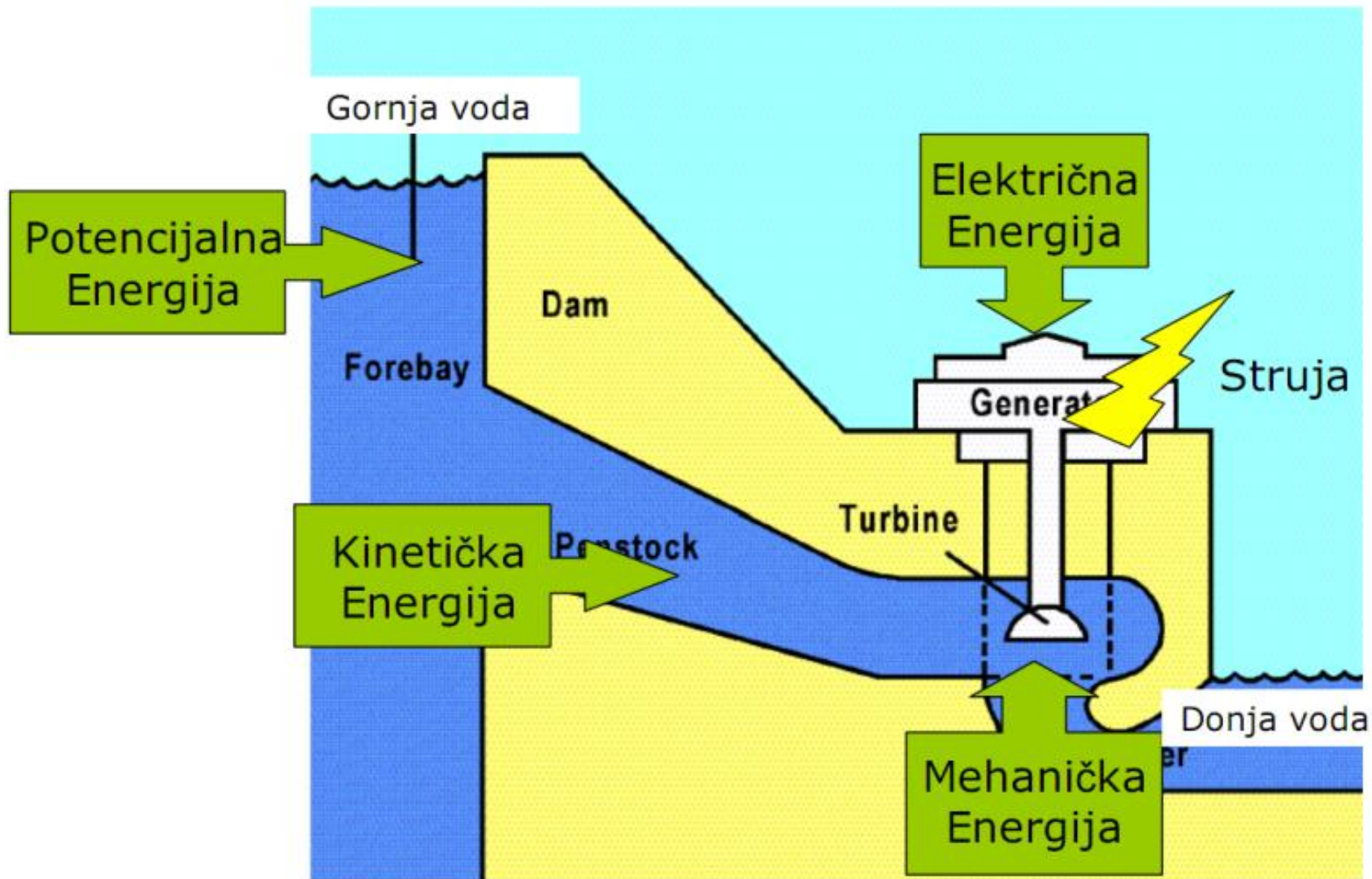
VJEŽBE 7

Stabilnost betonske gravitacijske brane



Hydroelectric power generation

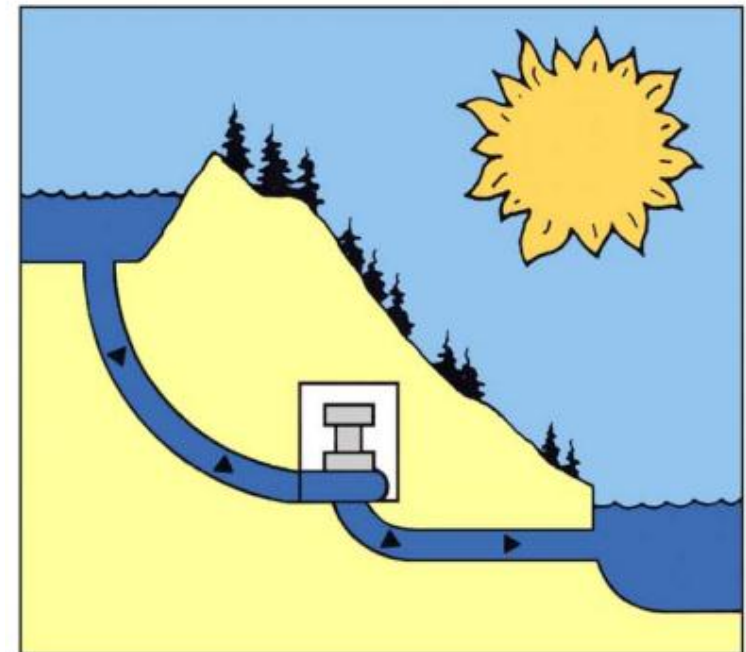
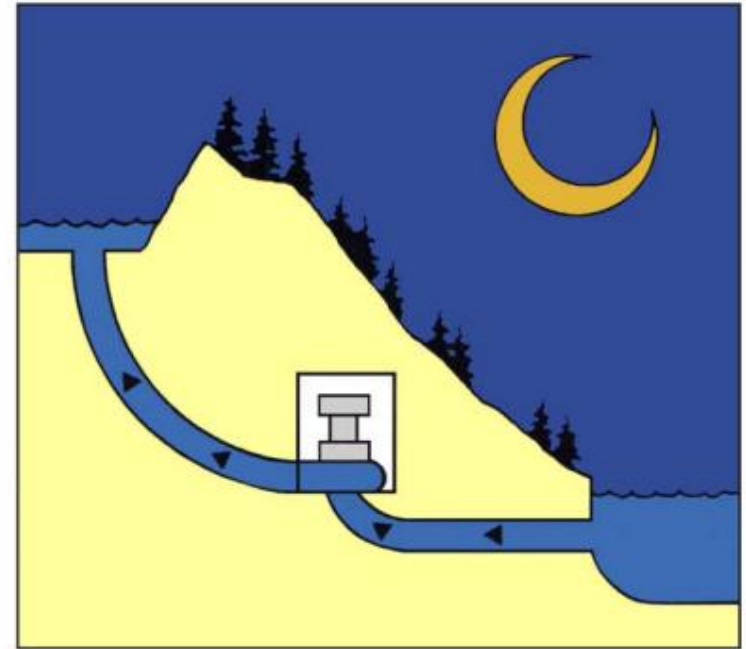




Primjer reverzibilne brane

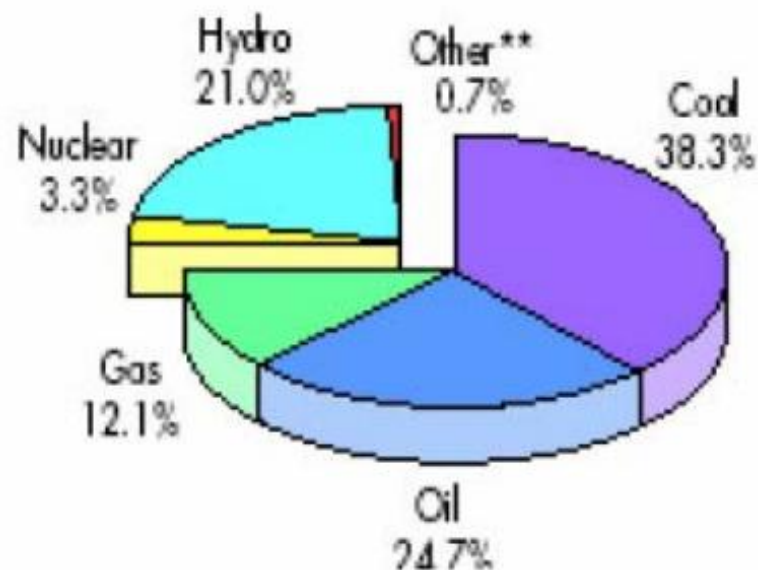
Hidroenergija: prednosti vs. mane

- Nema izgaranja goriva (zagađenje reducirano)
 - Glavna komponenta energ.sektora za smanjenje emisije stakleničkih plinova
 - Relativno mali troškovi rada i održavanja
 - Tehnologija je pouzdana
 - Obnovljivi izvor!!!
- ...ali
- Visoki troškovi ulaganja
 - Ovisnost o hidrologiji (padaline)
 - Poplavljanje i značajna izmjena staništa (ponekad)
 - Promjene parametara akumulacije i kvalitete vode (ponekad)
 - Preseljenje ljudi (Three Gorges Dam npr.)



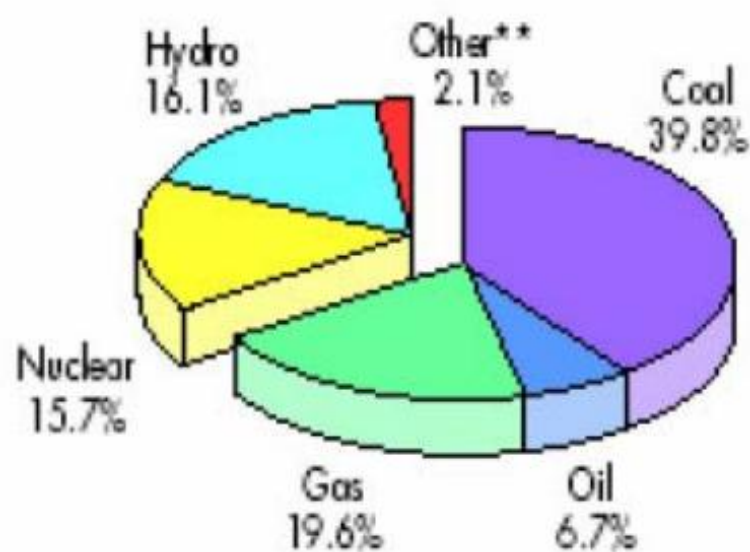
Udio pojedinih izvora u proizvodnji električne energije od 1971. do 2004.

1973



6 117 TWh

2004



17 450 TWh

HE LEŠĆE





HE LEŠĆE



HE MOSTAR



HE MOSTAR



HE MOSTAR

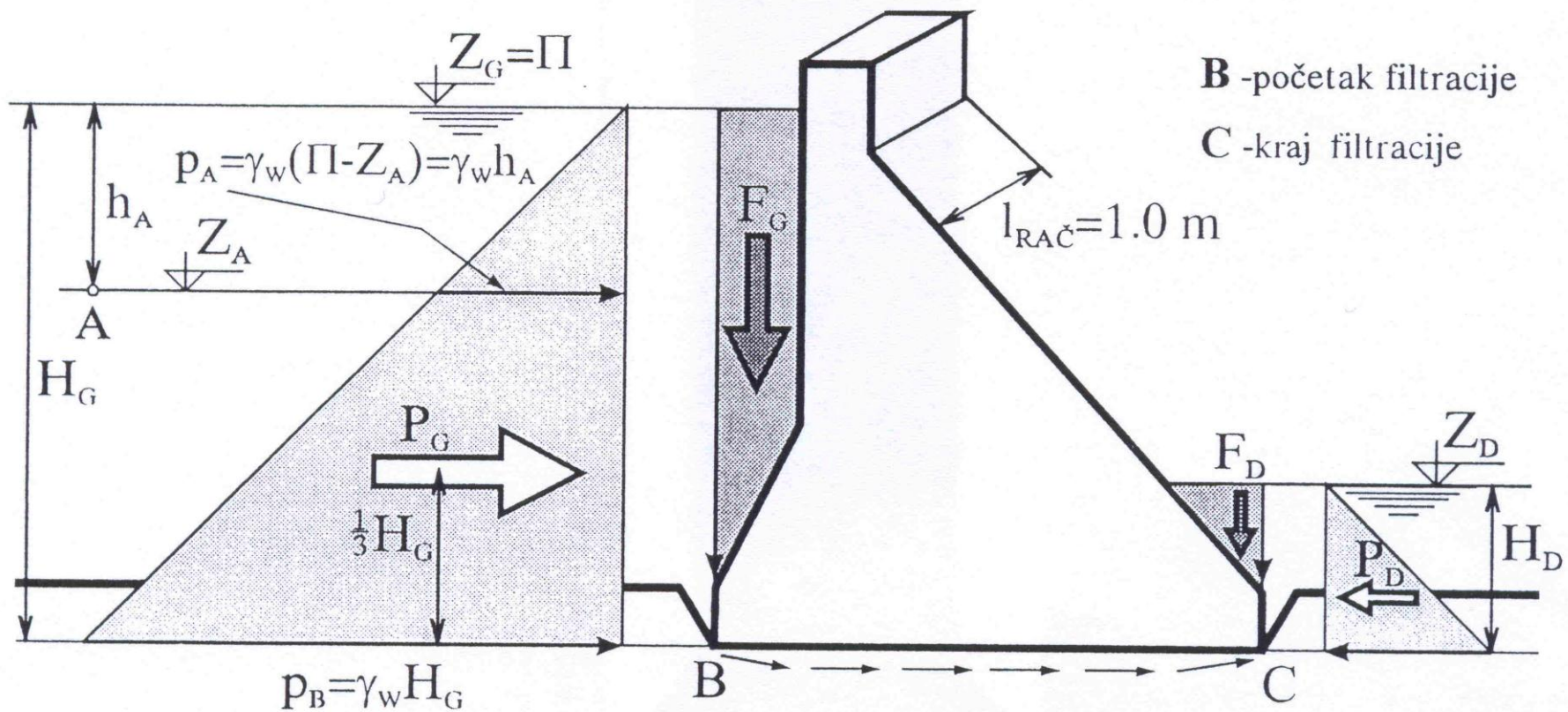




HE MOSTAR



HIDROSTATSKI TLAK



$$P_G = \gamma_w \frac{H_G^2}{2}$$

$$P_D = \gamma_w \frac{H_D^2}{2}$$

$$F_D = \gamma_w V_D$$

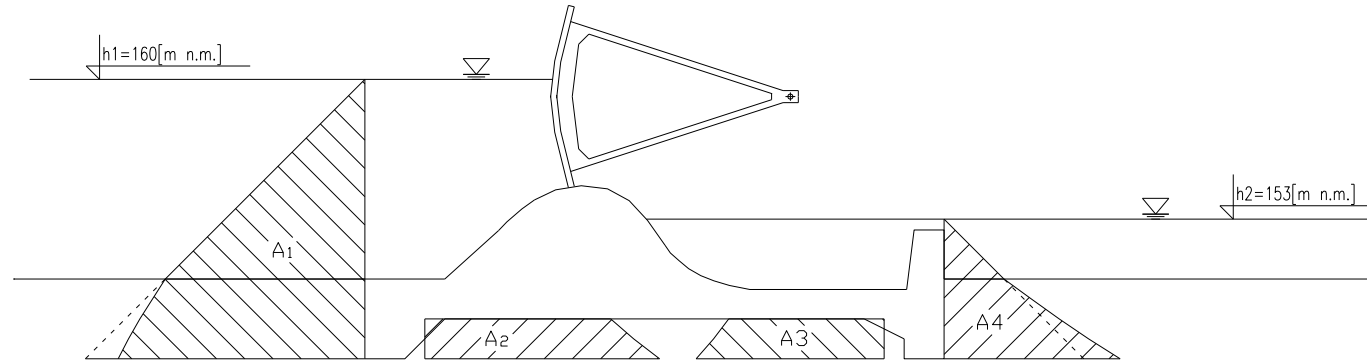
$$F_G = \gamma_w V_G$$

OPĆENITO:

Sila na površine dijelova brane dobiju se integracijom svih elementarnih sila:

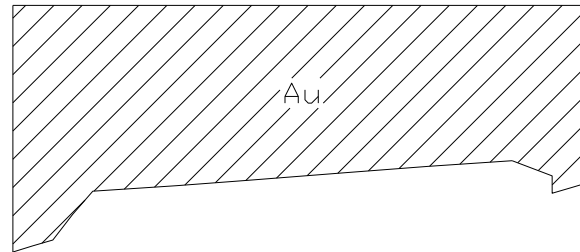
$$dF = pdA = \rho ghBdl$$

$$F = \int dF = \rho gB \int hdl$$



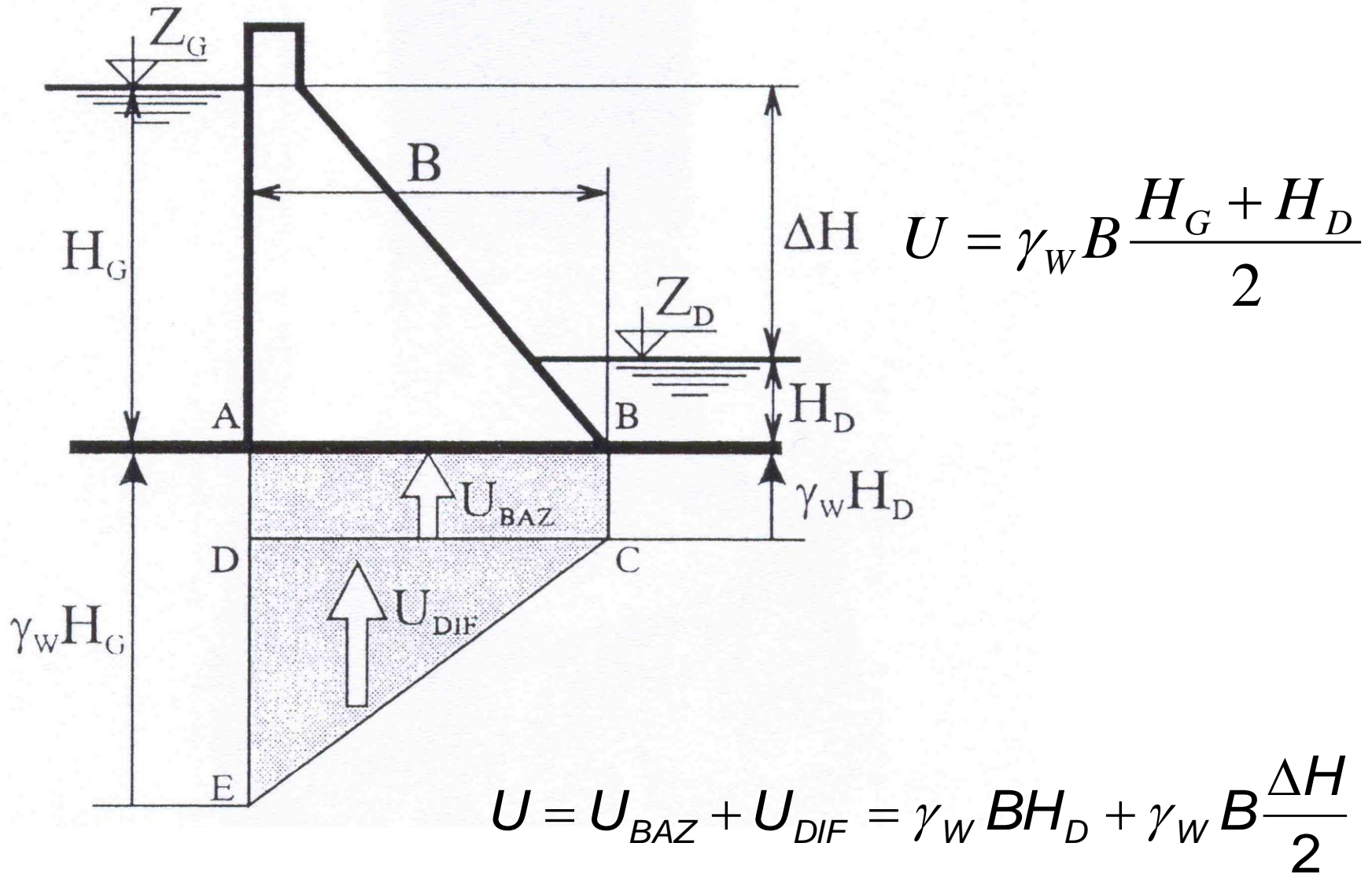
$$F = \rho gB \cdot A_{D.T}$$

; gdje je $A_{D.T}$ površina dijagrama tlaka



- Dijagram tlaka crtan je u metrima vodnog stupca – h – u mjerilu , te je stoga gornji integral zapravo površina dijagrama tlaka i pomoću tog dijagrama se stoga računaju sile koje djeluju na branu

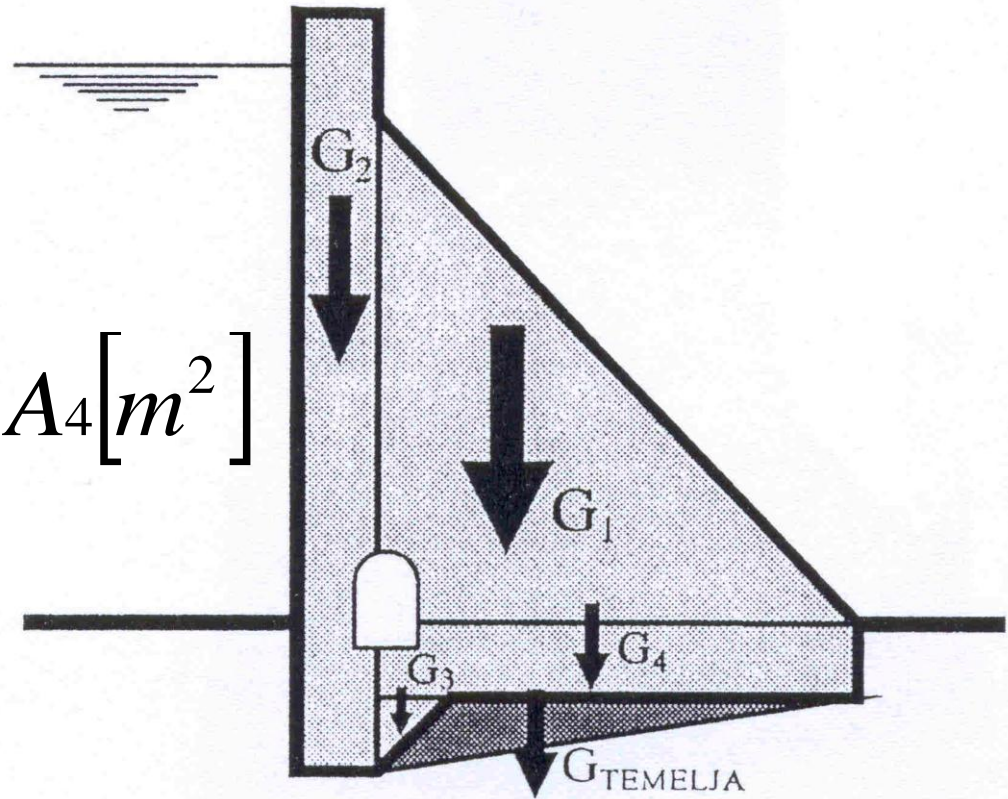
UZGON



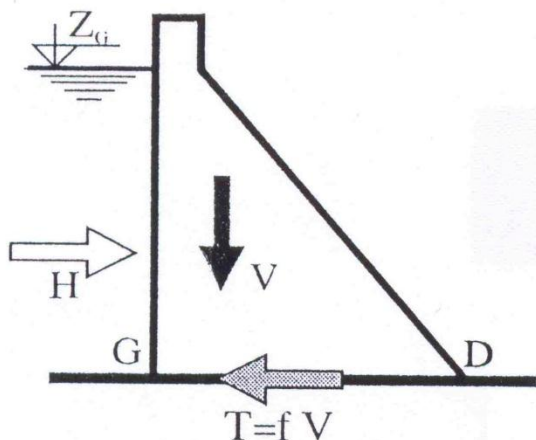
TEŽINA BRANE I TEMELJA

$$G = \gamma_B A [kN/m]$$

$$A = A_1 + A_2 + A_3 + A_4 [m^2]$$

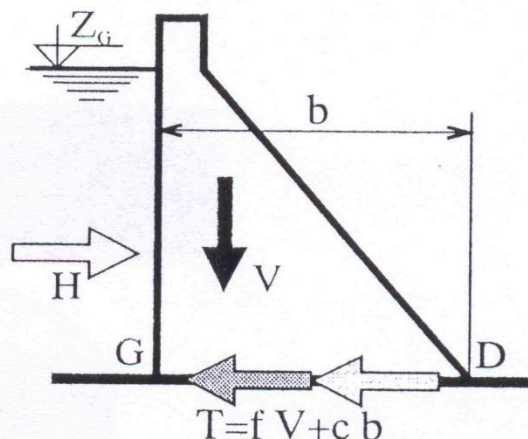


Stabilnost na klizanje (smicanje)



a) Materijal bez kohezije

$$\frac{fV}{C_s} > H$$



b) Materijal sa kohezijom

$$\frac{fV + cb}{C_s} > H$$

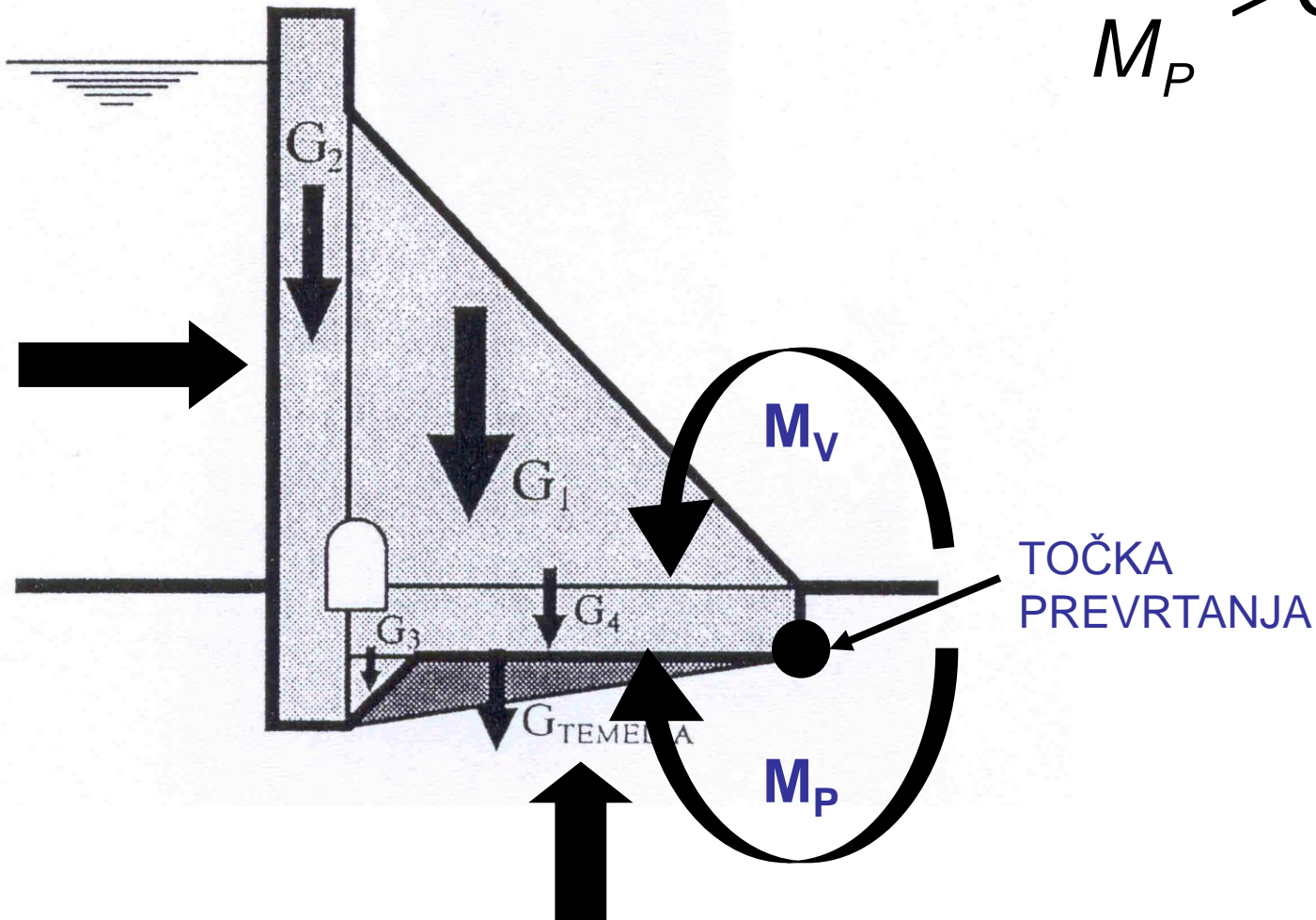
Koeficijent trenja, f , ovisi o kutu unutrašnjeg trenja materijala:

$$f = \operatorname{tg} \varphi$$

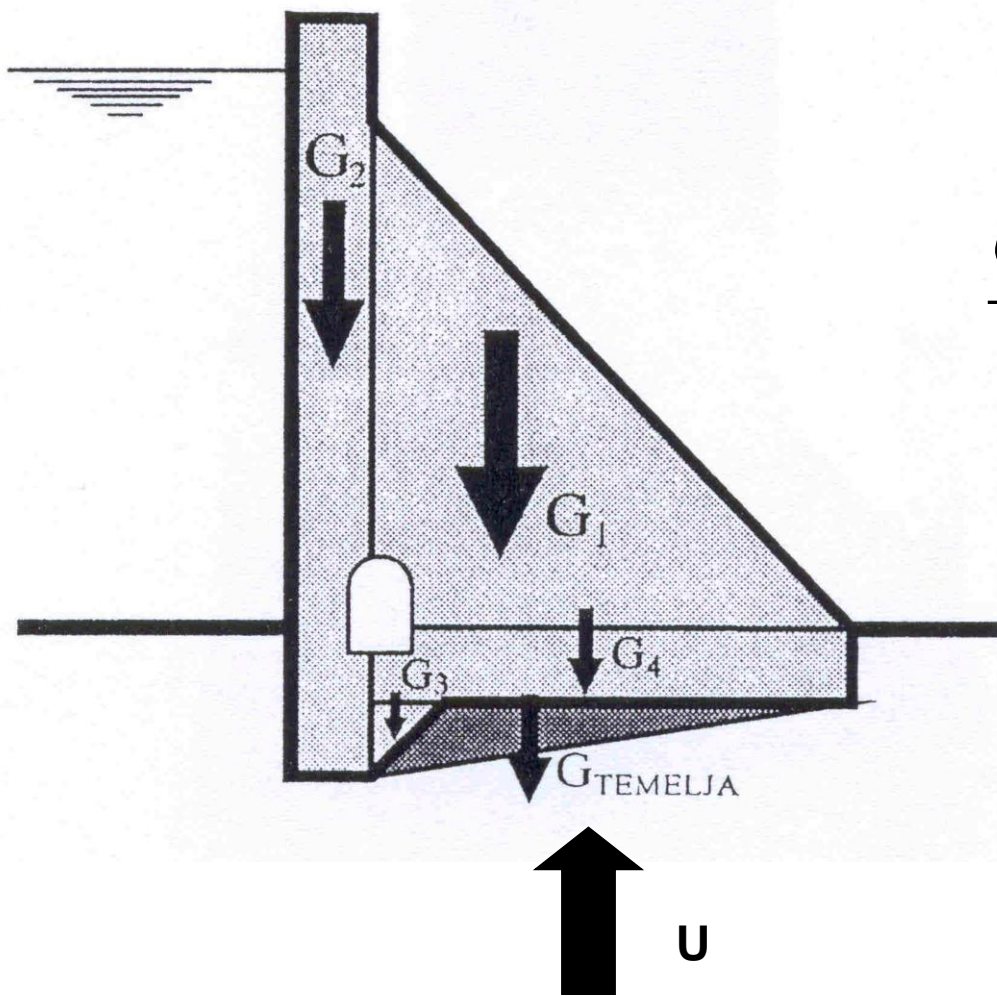
gdje je φ = kut unutrašnjeg trenja (kut pri kome je kosina stabilna). Za materijale koji su pogodni za temeljenje gravitacijske brane $\varphi = 20\text{-}35^\circ$.

Stabilnost na prevrtanje

$$\frac{M_V}{M_P} > C_P$$

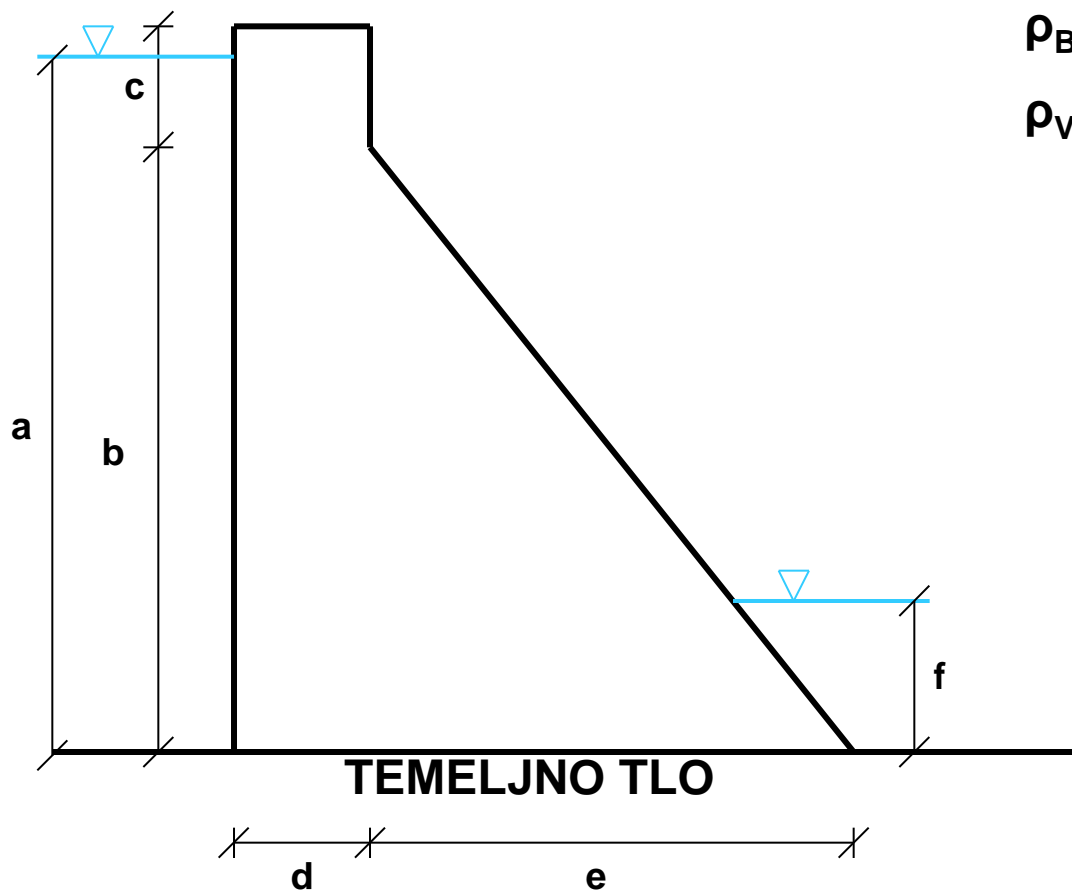


Stabilnost na isplivavanje



$$\frac{G_1 + G_2 + G_3 + G_4}{U} > C_I$$

1. ZADATAK: Za zadanu geometriju i podatke potrebno je izvršiti kontrolu stabilnosti betonske gravitacijske brane na isplivavanje, klizanje i prevrtanje. Sve jedinice na slici su u metrima, temeljno tlo je nekoherentno, koeficijent trenja na dodirnoj plohi objekt – tlo iznosi $\mu = 0,25$.

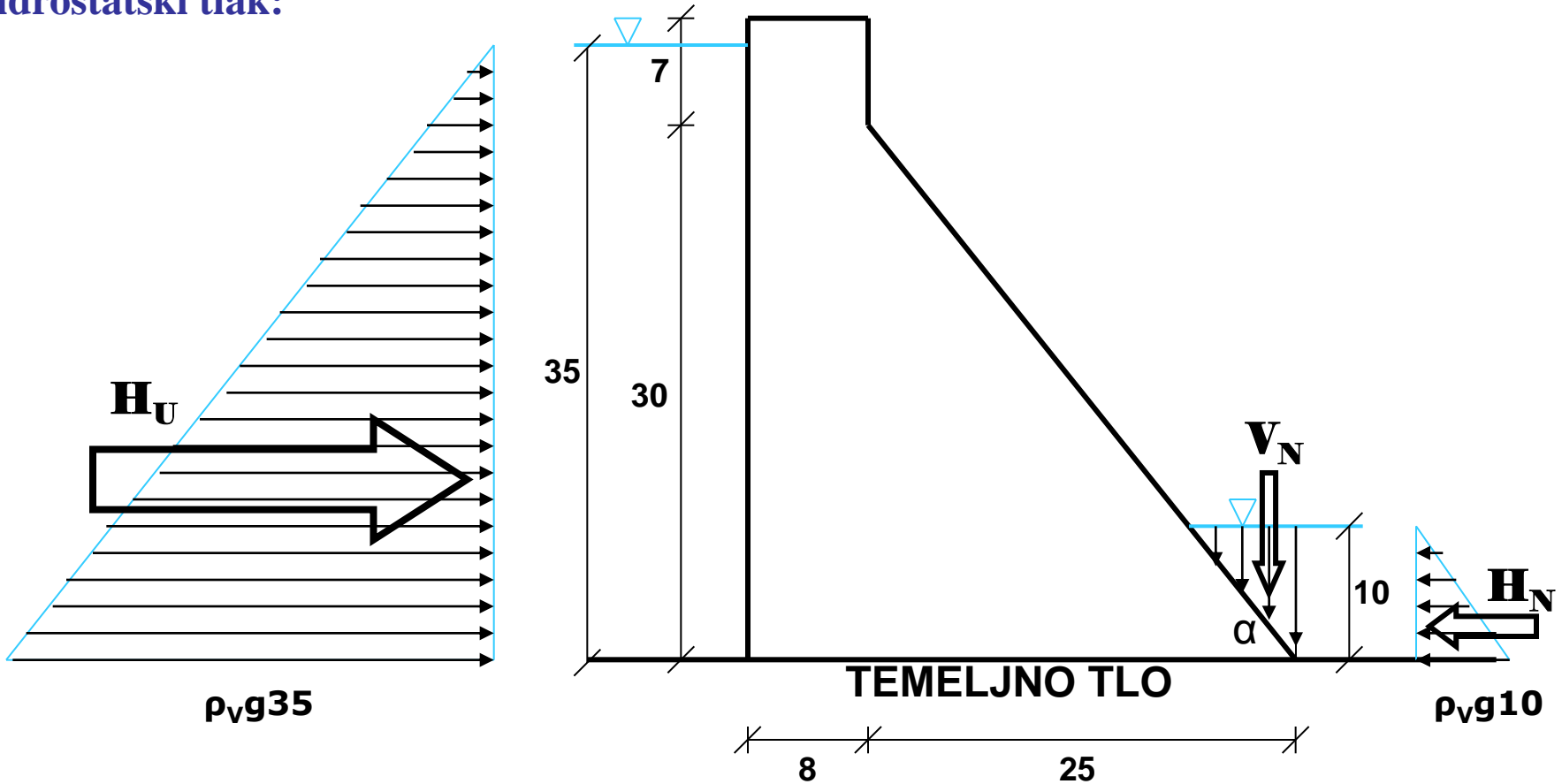


$$\rho_{\text{BETONA}} = 2600 \text{ kg/m}^3$$

$$\rho_{\text{VODE}} = 1000 \text{ kg/m}^3$$

OPTEREČENJA NA BRANU:

Hidrostatski tlak:

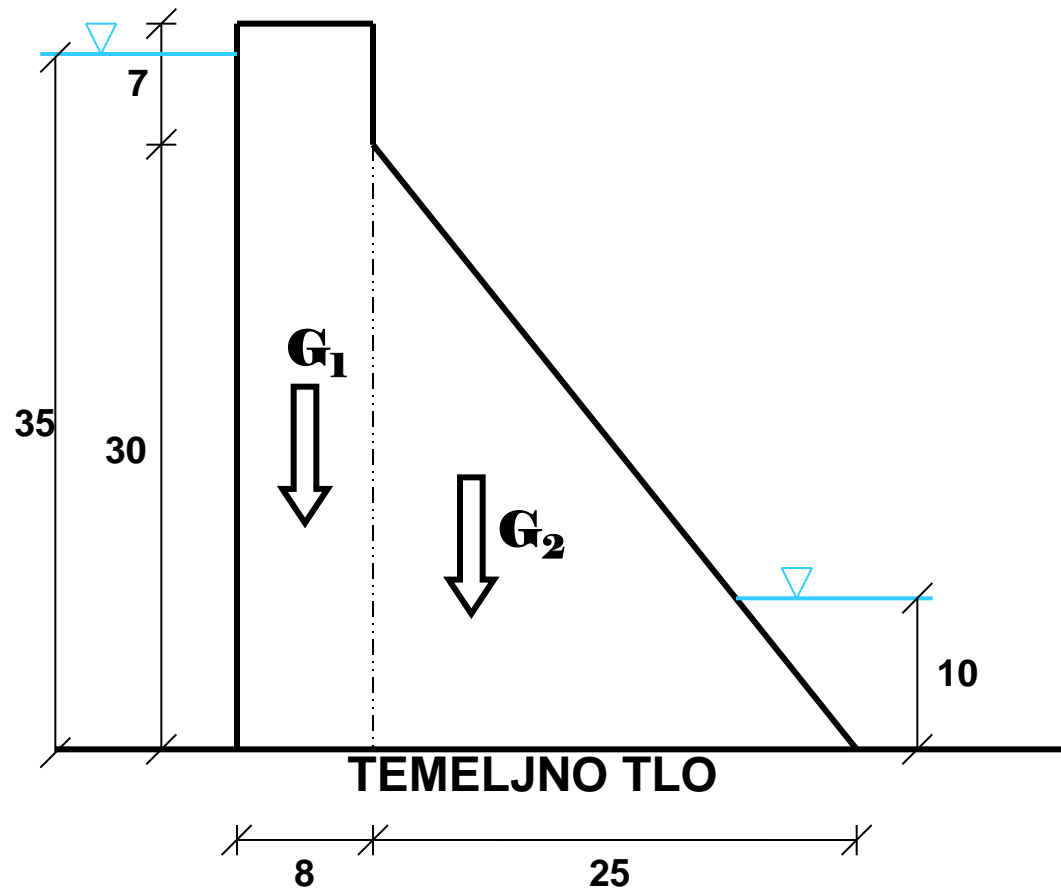


$$H_U = \rho_V g \frac{(35m)^2}{2} \cdot 1m = 6008,625kN$$

$$H_N = \rho_V g \frac{(10m)^2}{2} \cdot 1m = 490,50kN$$

$$V_N = \rho_V g \frac{(10 / \operatorname{tg} \alpha) \cdot 10m}{2} \cdot 1m = 408,75kN$$

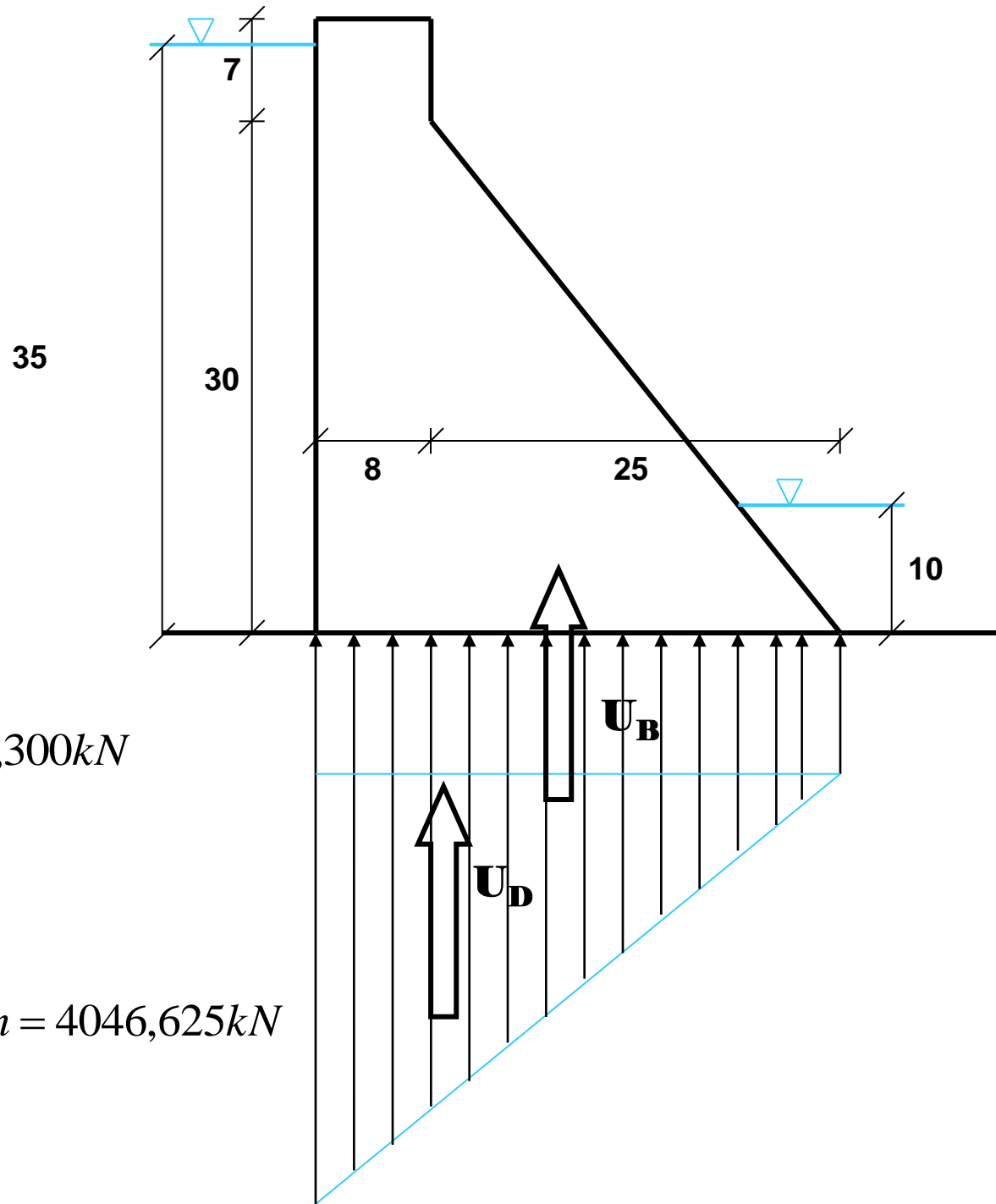
Težina brane:



$$G_1 = \rho_B g \cdot 37m \cdot 8m \cdot 1m = 7549,776kN$$

$$G_2 = \rho_B g \frac{30m \cdot 25m}{2} \cdot 1m = 9564,75kN$$

Uzgon na tijelo brane:



$$U_B = \rho_v \cdot g \cdot 33m \cdot 10m \cdot 1m = 3237,300kN$$

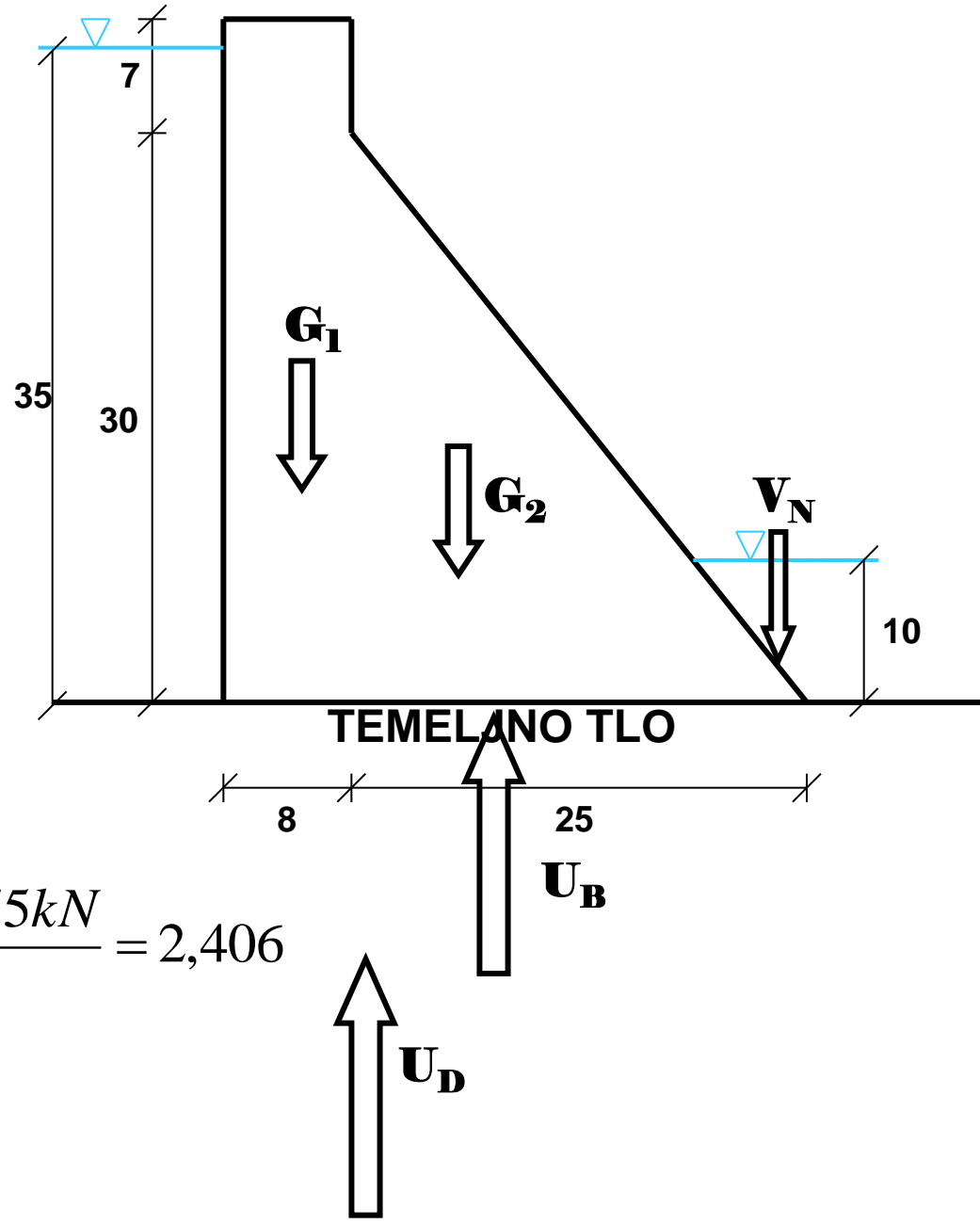
$$U_D = \rho_v \cdot g \cdot \frac{(35m - 10m) \cdot 33m}{2} \cdot 1m = 4046,625kN$$

Sigurnost na isplivavanje

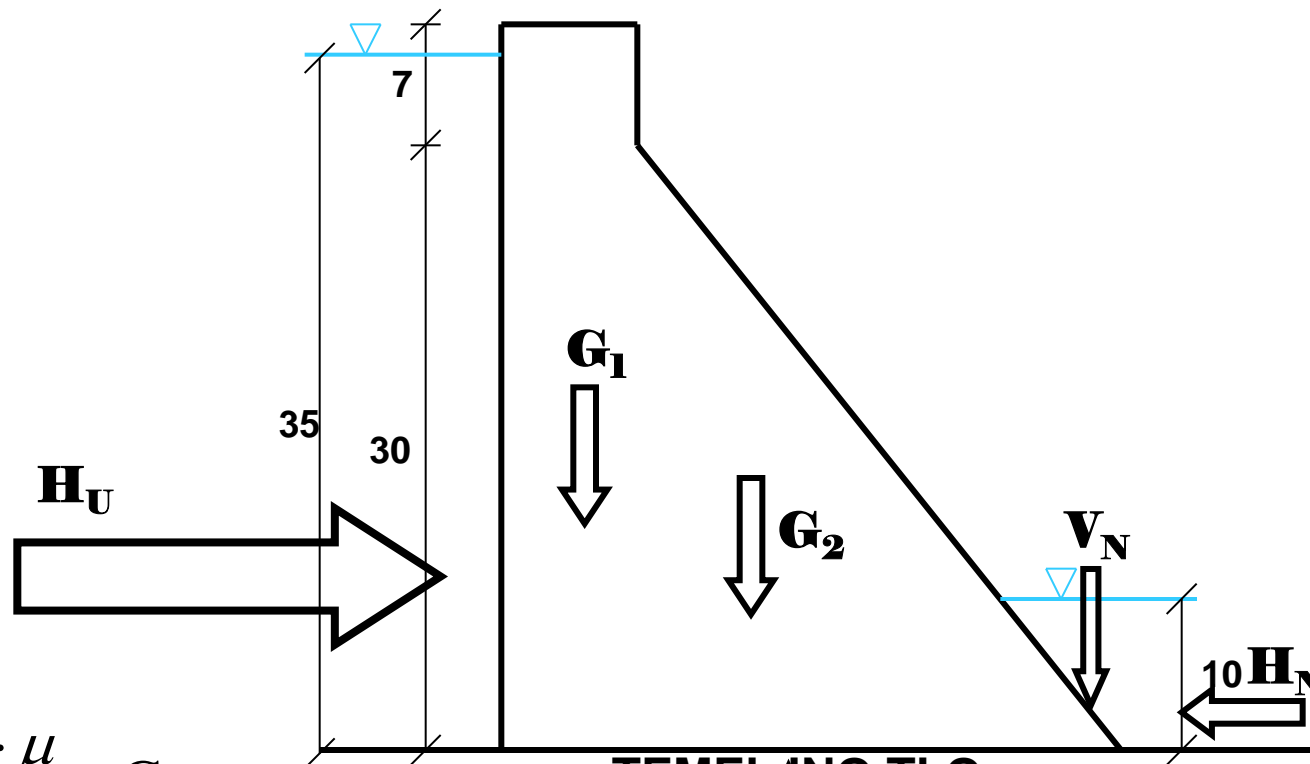
$$\frac{G_1 + G_2 + V_N}{U_B + U_D} = C_I$$

$$\frac{7549,776kN + 9564,76kN + 408,75kN}{3237,300kN + 4046,625kN} = 2,406$$

ZADOVOLJAVA!!!



Sigurnost na klizanje (smicanje)



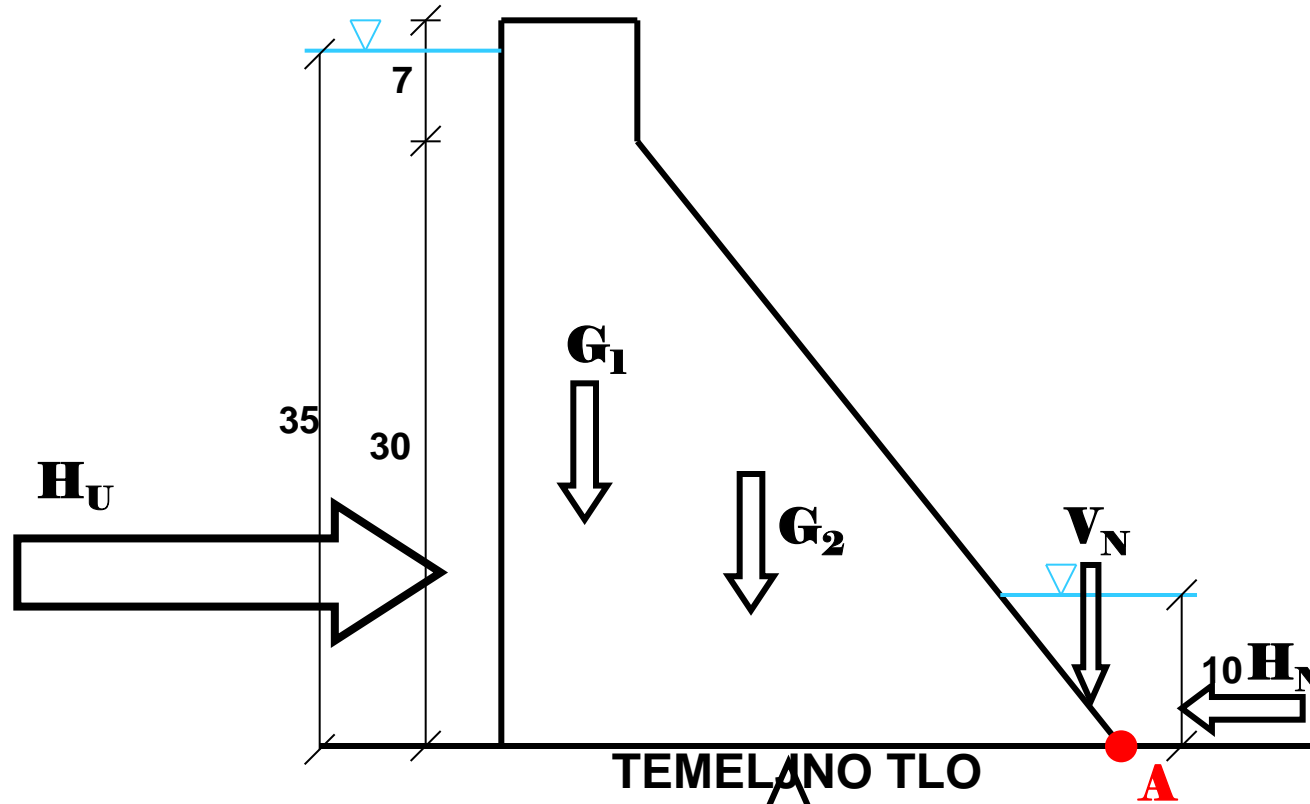
$$\frac{(G_1 + G_2 + V_N - U_B - U_D) \cdot \mu}{H_U - H_N} = C_K$$

$$\frac{(7549,776 + 9564,75 + 408,75 - 3237,300 - 4046,625) \cdot 0,25}{6008,625 - 490,50} = 0,46$$

NE ZADOVOLJAVA!!!

Sigurnost na prevrtanje

$$\frac{M_V}{M_P} = C_P$$



$$\frac{G_1 \cdot 29m + G_2 \cdot \left(\frac{2}{3} \cdot 25m\right) + V_N \cdot \left(\frac{10 / \operatorname{tg} \alpha}{3}\right) + H_N \cdot \frac{10}{3} m}{H_U \cdot \frac{35}{3} m + U_B \cdot \frac{33}{2} m + U_D \cdot \left(\frac{2 \cdot (25 + 8)}{3} m\right)} = 1,793$$

ZADOVOLJAVA!!!

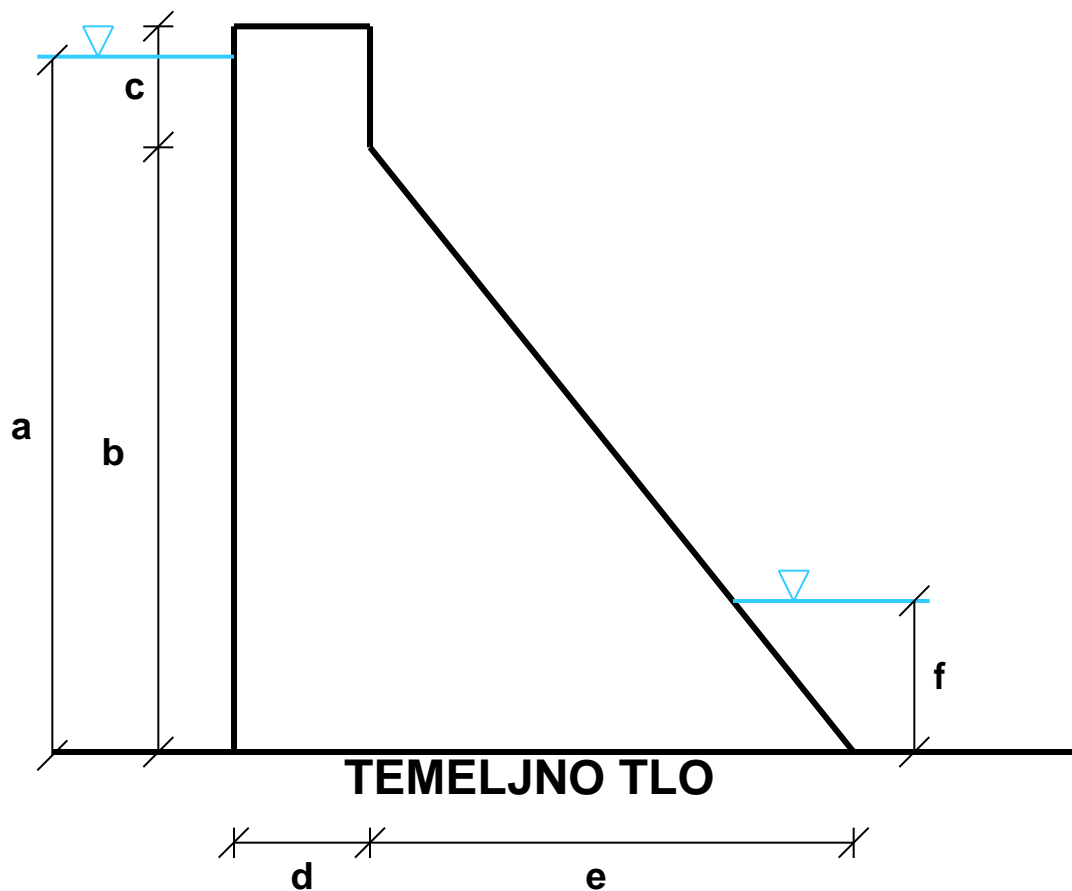
TEMELJNO TLO

A

U_B

U_D

2. ZADATAK: Za zadane podatke potrebno je odabrati dimenziju "e" betonske gravitacijske brane uz uvjet da budu zadovoljeni zadani koeficijenti sigurnosti na isplivavanje, klizanje i prevrtanje. Sve jedinice na slici su u metrima, temeljno tlo je koherentno, koeficijent trenja na dodirnoj plohi objekt – tlo iznosi $\mu = 0,35$, kohezija = 30 kPa.



$$\rho_{\text{BETONA}} = 2700 \text{ kg/m}^3$$

$$\rho_{\text{VODE}} = 1020 \text{ kg/m}^3$$

$$a = 40 \text{ m}$$

$$b = 35 \text{ m}$$

$$c = 7 \text{ m}$$

$$d = 5 \text{ m}$$

$$f = 8 \text{ m}$$

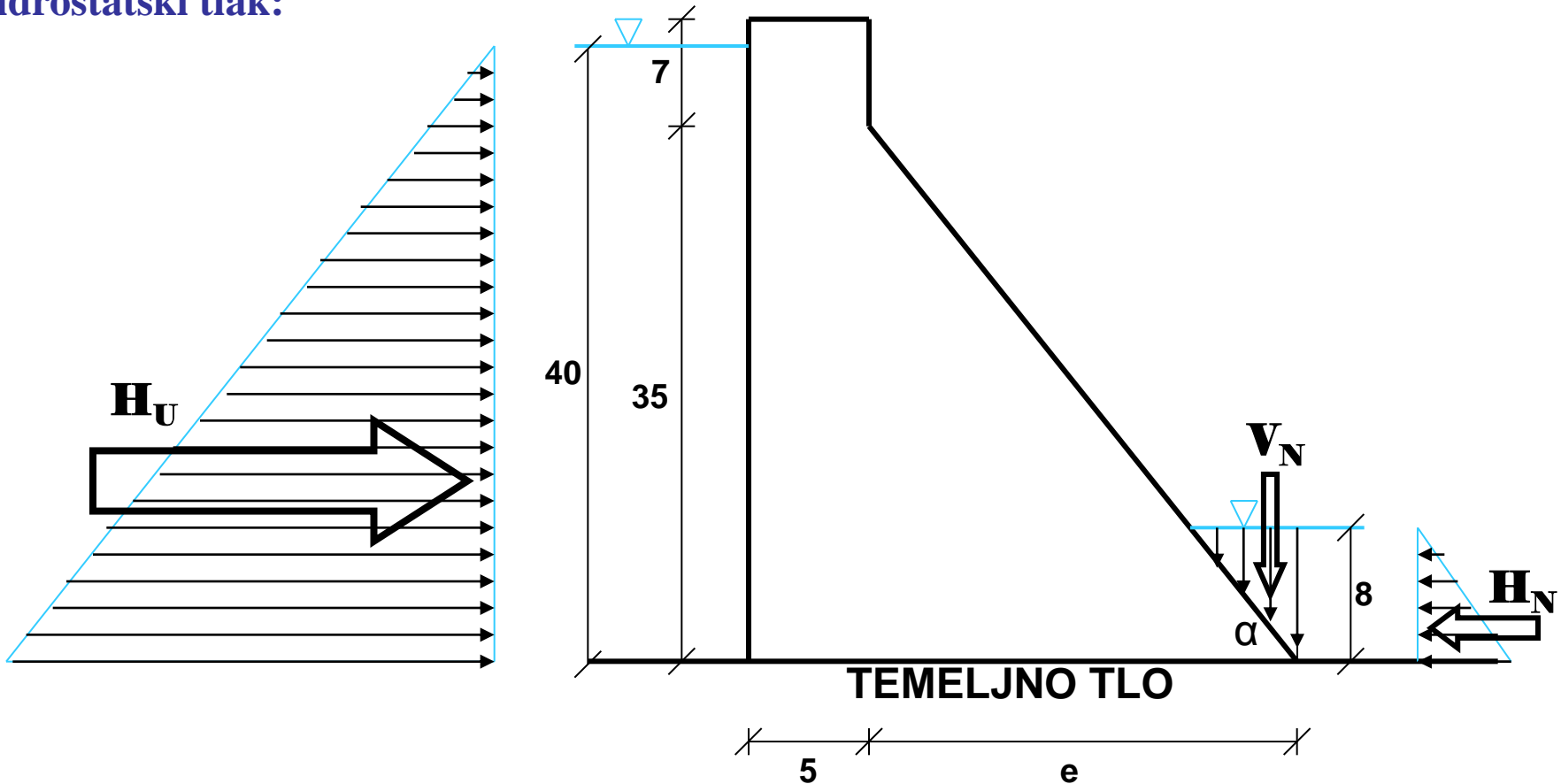
$$KSI = 1,5$$

$$KSK = 1,0$$

$$KSP = 1,3$$

OPTEREĆENJA NA BRANU:

Hidrostatski tlak:



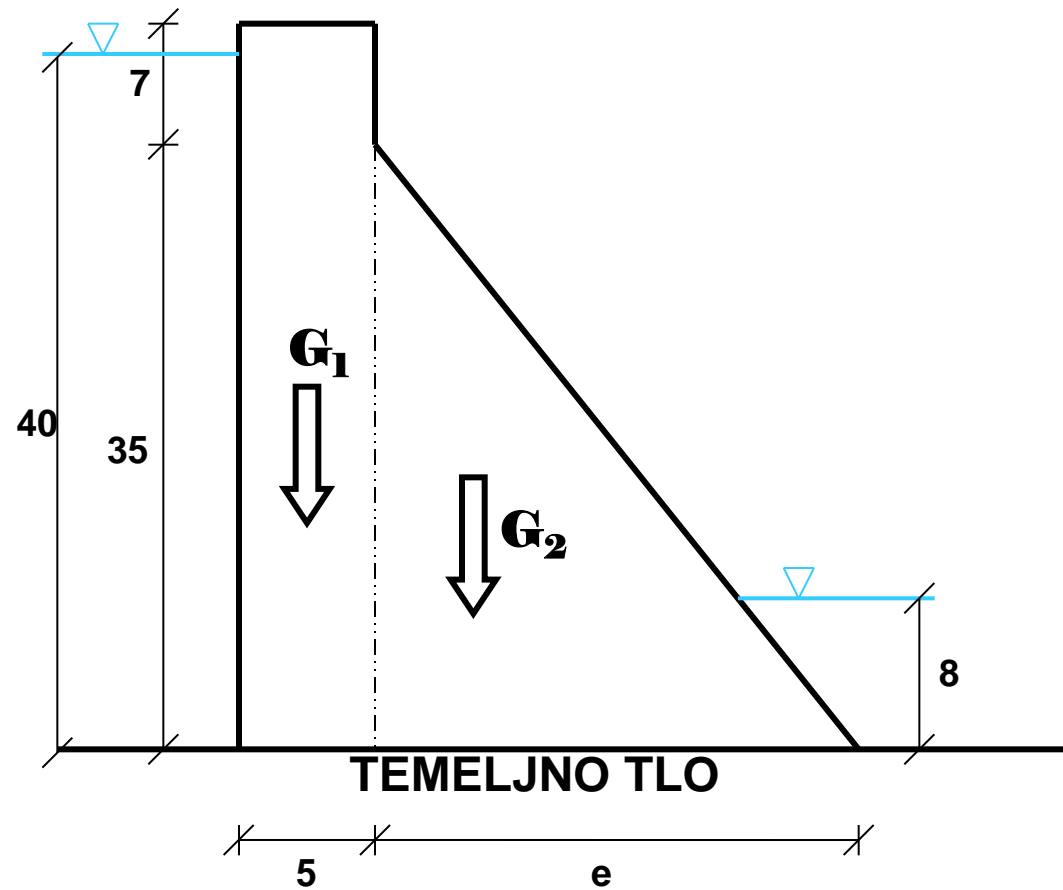
$$H_U = \rho_V g \frac{(40m)^2}{2} \cdot 1m = 8004,96kN$$

$$H_N = \rho_V g \frac{(8m)^2}{2} \cdot 1m = 320,198kN$$

$$V_N = \rho_V g \frac{(8 / \operatorname{tg} \alpha) \cdot 8m}{2} \cdot 1m$$

$$\operatorname{tg} \alpha = \frac{35}{e}$$

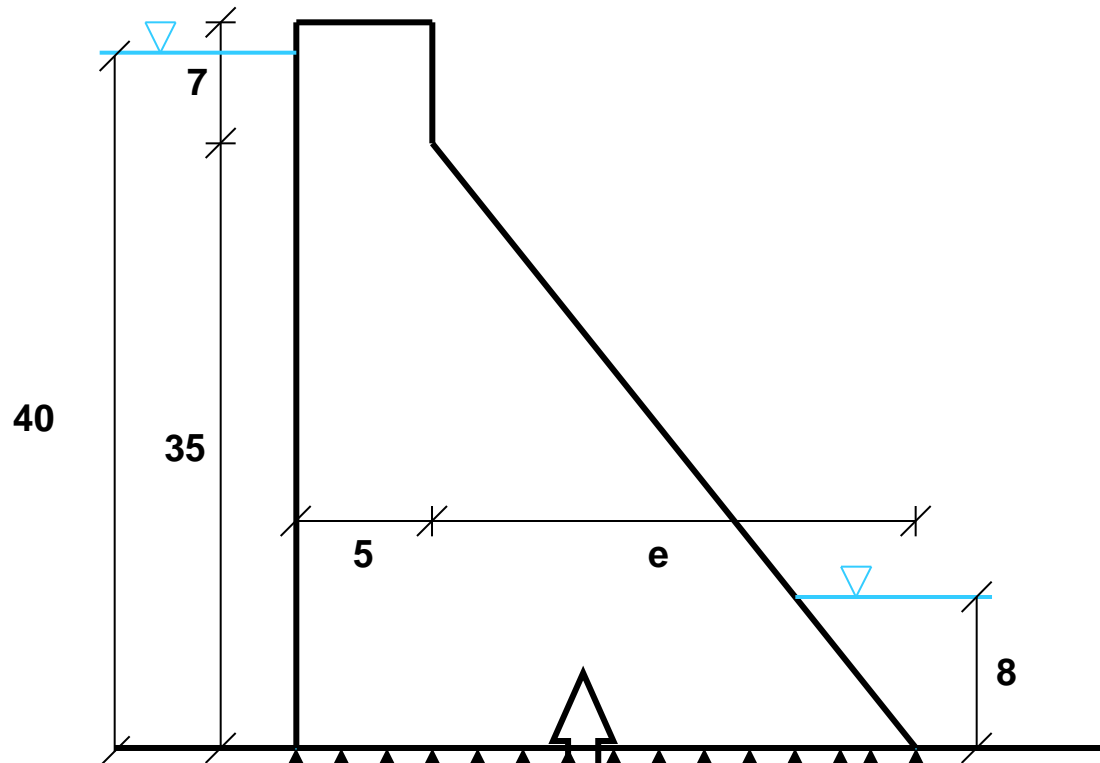
Težina brane:



$$G_1 = \rho_B g \cdot 42m \cdot 5m \cdot 1m = 5562,27kN$$

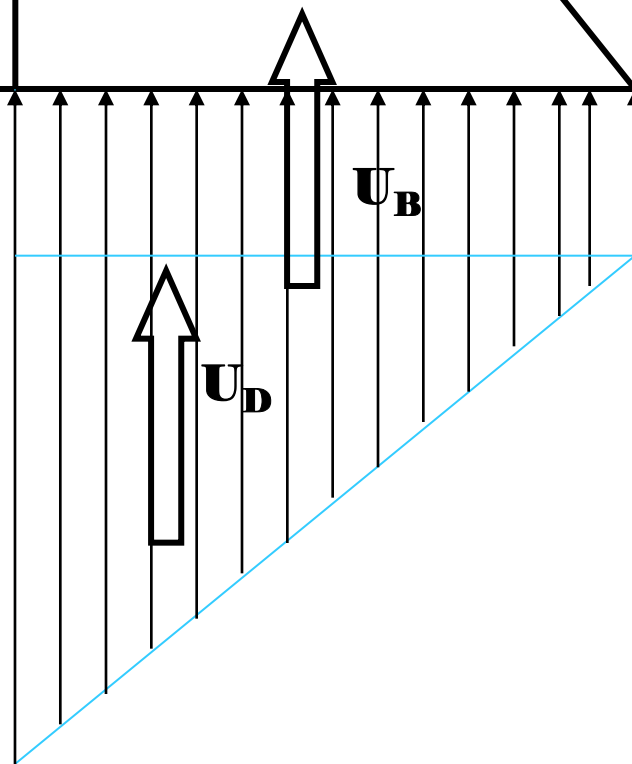
$$G_2 = \rho_B g \frac{35m \cdot e}{2} \cdot 1m$$

Uzgon na tijelo brane:



$$U_B = \rho_V \cdot g \cdot 8m \cdot (e + 5m) \cdot 1m$$

$$U_D = \rho_V \cdot g \cdot \frac{(40m - 8m) \cdot (e + 5m)}{2} \cdot 1m$$



Sigurnost na isplivavanje

$$\frac{G_1 + G_2 + V_N}{U_B + U_D} = \text{KSI}$$

Sigurnost na klizanje (smicanje)

$$\frac{(G_1 + G_2 + V_N - U_B - U_D) \cdot \mu + C \cdot (e + 5m) \cdot 1m}{H_U - H_N} = \text{KSK}$$

Sigurnost na prevrtanje

$$\frac{G_1 \cdot (e + 2,5m) + G_2 \cdot \left(\frac{2}{3} \cdot e\right) + V_N \cdot \left(\frac{8/\text{tg } \alpha}{3}\right) + H_N \cdot \frac{8}{3}m}{H_U \cdot \frac{40}{3}m + U_B \cdot \frac{e + 5m}{2}m + U_D \cdot \left(\frac{2 \cdot (e + 5m)}{3}m\right)} = \text{KSP}$$

e (m)	G ₁ (kN)	G ₂ (kN)	H _U (kN)	H _N (kN)	V _N (kN)	U _B (kN)	U _D (kN)	KSI	KSK	KSP	STATUS
0	5562,27	0,00	8004,96	320,20	0,00	400,25	800,50	4,63	0,22	0,13	NE ZADOVOLJAVA
5	5562,27	2317,61	8004,96	320,20	45,74	800,50	1600,99	3,30	0,29	0,41	NE ZADOVOLJAVA
10	5562,27	4635,23	8004,96	320,20	91,49	1200,74	2401,49	2,86	0,36	0,73	NE ZADOVOLJAVA
15	5562,27	6952,84	8004,96	320,20	137,23	1600,99	3201,98	2,63	0,44	1,01	NE ZADOVOLJAVA
20	5562,27	9270,45	8004,96	320,20	182,97	2001,24	4002,48	2,50	0,51	1,26	NE ZADOVOLJAVA
25	5562,27	11588,06	8004,96	320,20	228,71	2401,49	4802,98	2,41	0,58	1,45	NE ZADOVOLJAVA
30	5562,27	13905,68	8004,96	320,20	274,46	2801,74	5603,47	2,35	0,65	1,61	NE ZADOVOLJAVA
35	5562,27	16223,29	8004,96	320,20	320,20	3201,98	6403,97	2,30	0,73	1,72	NE ZADOVOLJAVA
40	5562,27	18540,90	8004,96	320,20	365,94	3602,23	7204,46	2,26	0,80	1,81	NE ZADOVOLJAVA
45	5562,27	20858,51	8004,96	320,20	411,68	4002,48	8004,96	2,23	0,87	1,88	NE ZADOVOLJAVA
50	5562,27	23176,13	8004,96	320,20	457,43	4402,73	8805,46	2,21	0,94	1,94	NE ZADOVOLJAVA
55	5562,27	25493,74	8004,96	320,20	503,17	4802,98	9605,95	2,19	1,02	1,98	ZADOVOLJAVA
60	5562,27	27811,35	8004,96	320,20	548,91	5203,22	10406,45	2,17	1,09	2,01	ZADOVOLJAVA
65	5562,27	30128,96	8004,96	320,20	594,65	5603,47	11206,94	2,16	1,16	2,04	ZADOVOLJAVA
70	5562,27	32446,58	8004,96	320,20	640,40	6003,72	12007,44	2,15	1,23	2,06	ZADOVOLJAVA

