Chapter 13: Construction methods for granular material

ct5308 Breakwaters and Closure Dams

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Elements to consider

- Bed fixation or bed protection
  mattresses, etc.
- Shore connected and intermediate dam sections
  sand fill/quarry; execution
- Abutments
  sheetpile, caisson
- Breakwater core; dumped sills
- Cover layer, armour

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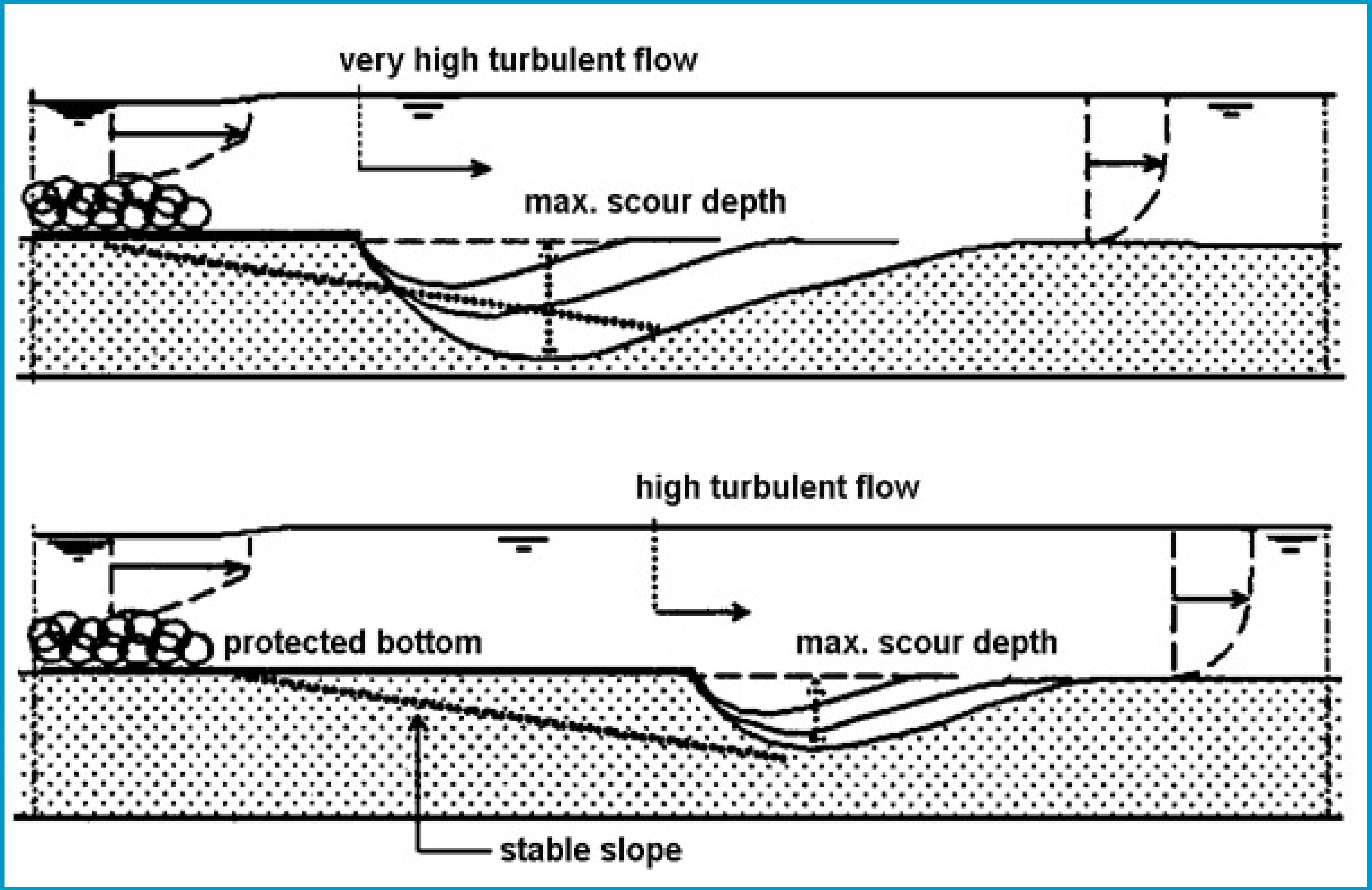
Scour prevention

- Change of flow in course of time
- Flow distribution over the vertical
- Flow is not saturated with sediment
- Turbulence intensity increases

development of a scour hole



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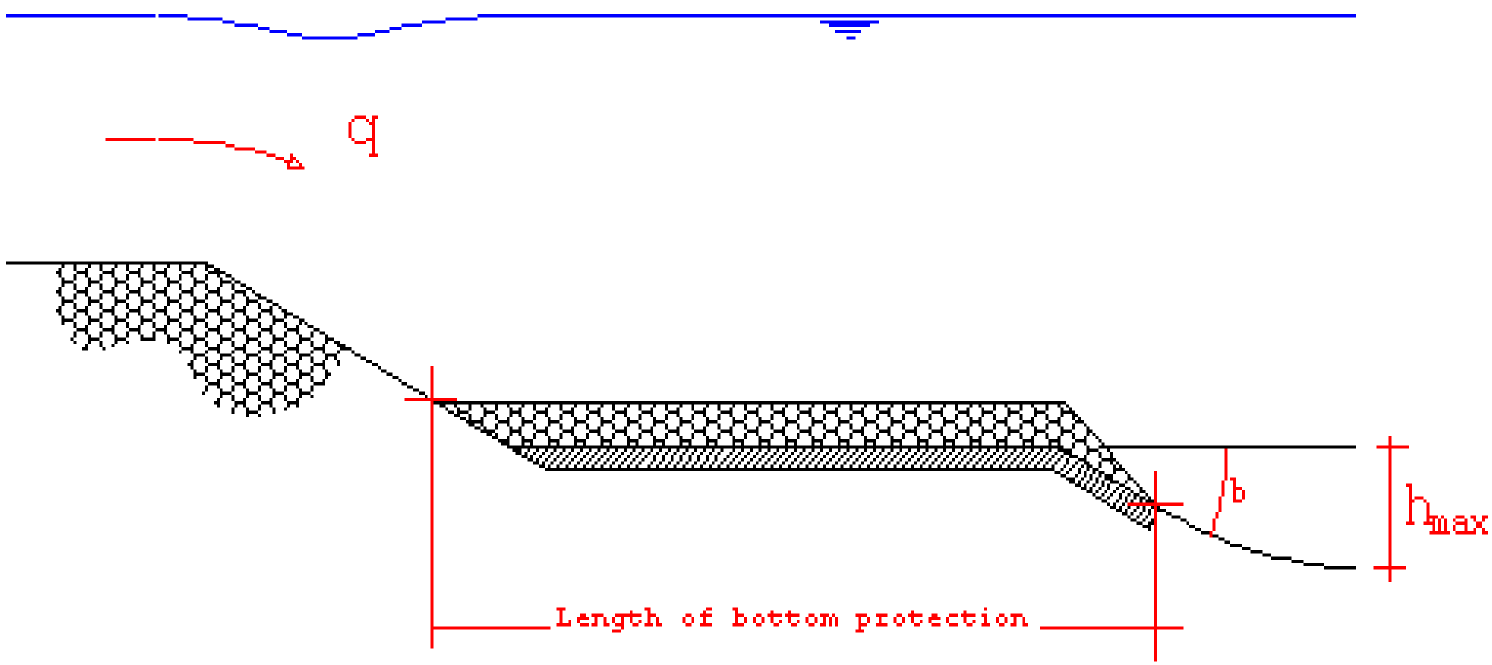
length



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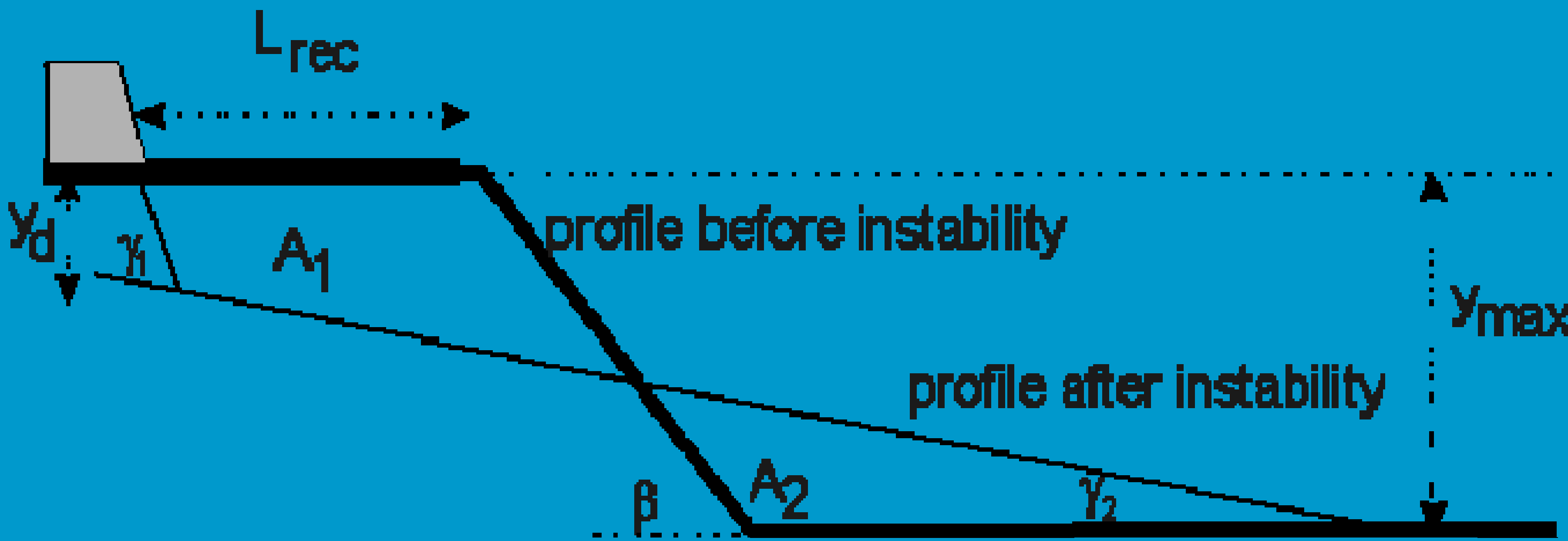
balance of material



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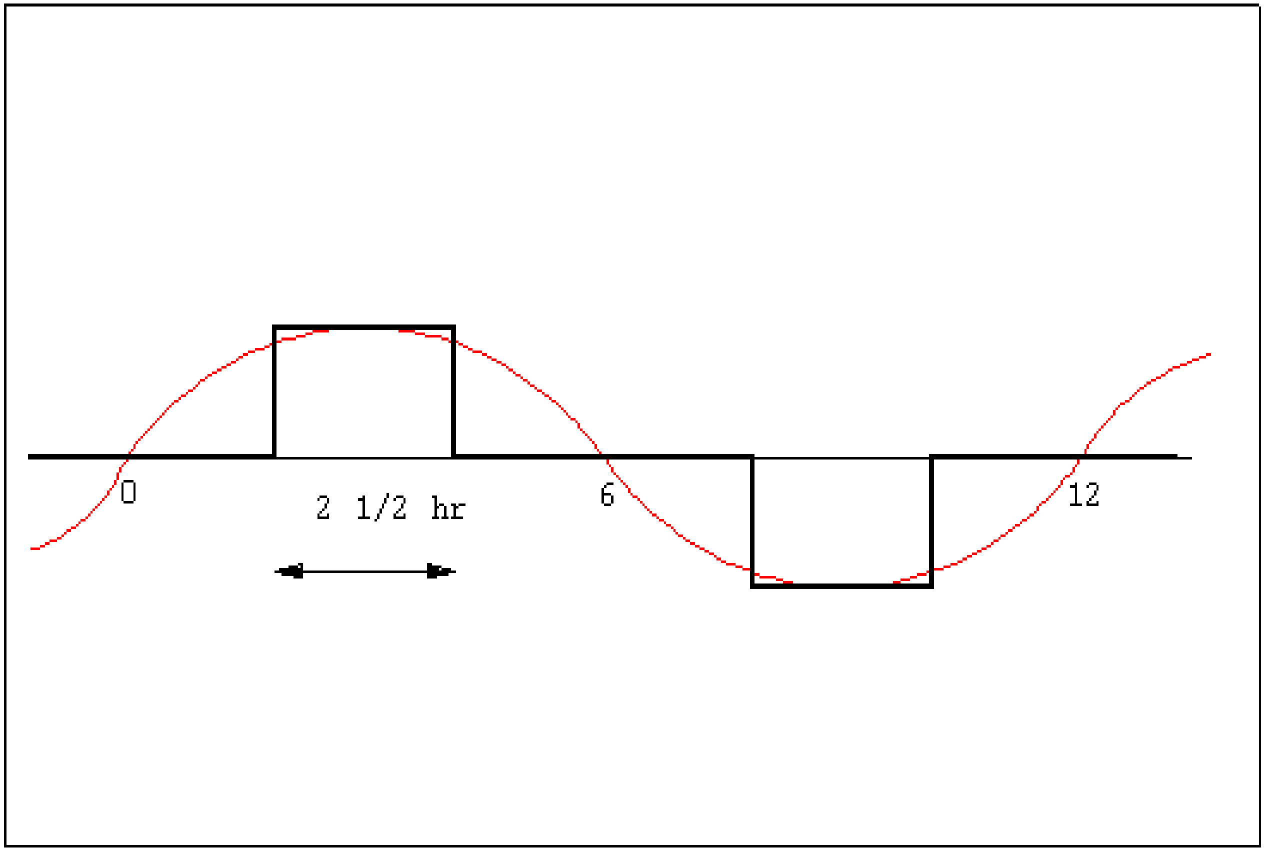
effective scour time



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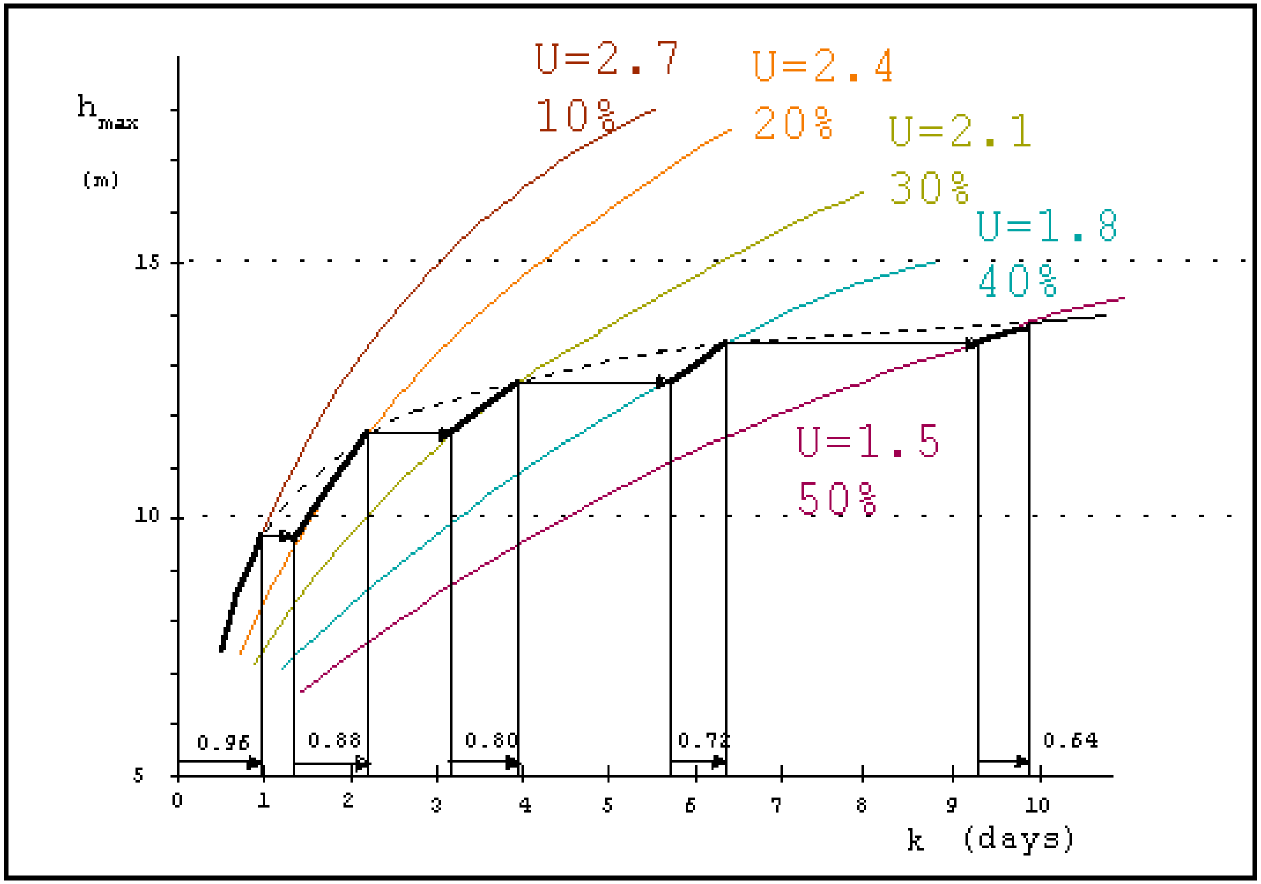
development of a scour hole



mattresses or granular filters

- limited construction height
- applicable on steep slopes
- difficult to remove
- presence of structural joints
- vulnerable to mechanical damage
- restricted lifetime

- self healing after minor damage
- absence of structural joints
- simple to remove by dredging
- no sudden change at the end; they can fade out gradually
- absence of structural coherence
- disintegration on steep slopes
- considerable construction height

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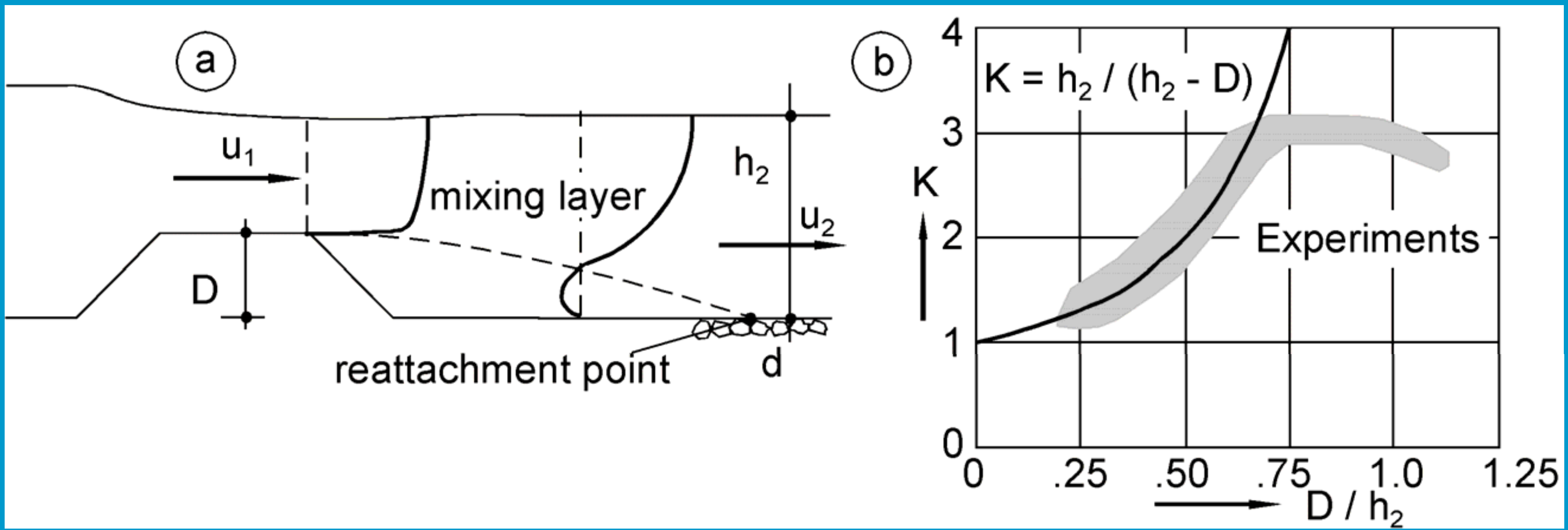
stability downstream of a sill



$$K_v = \frac{u_c\, uniform\, flow}{u_c\, with\, load\, increase}$$

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Shields with corrections

$$d = \frac{K_v^2 \overline{u}_c^2}{K_s \Psi_c \Delta C^2}$$

$$In\ Cress: K_t = \frac{K_v - 1}{0.4} + 1$$

Rectangular Abutments: K_v = 1.7 => K_t= 2.75

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example bed protection

- Bs = 2.5 * 20 = 50 km^2
- depth = 10 m
- B = 500 m
- tidal difference = 3 m

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Bed protection in case of horizontal closure

width	u0 (max)			D (cm)	W(kg)	
500	2,13			5	0	80/200
450	2,35			6	0	80/200
400	2,60			8	1	80/200
350	2,90			11	2	80/200
300	3,26			17	7	80/200
250	3,68			23	20	10/60
200	4,16			35	65	60/300
150	4,63			50	192	60/300
100	5,13			71	653	300/1000
50	5,47			90	1161	1/3
25	5,68			105	1794	1/3
10	6,27			158	6166	special

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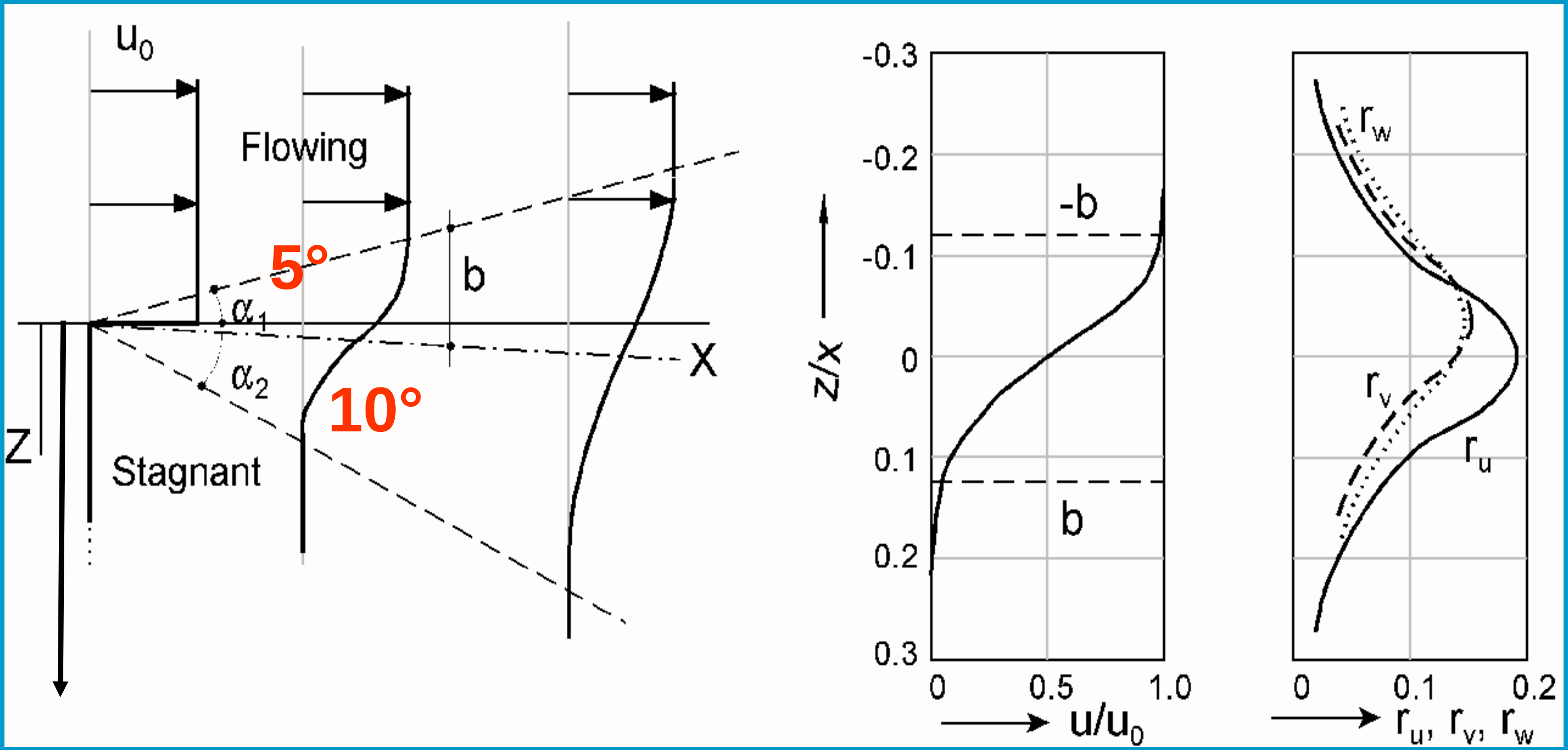
Mixing layers (from ct4310)



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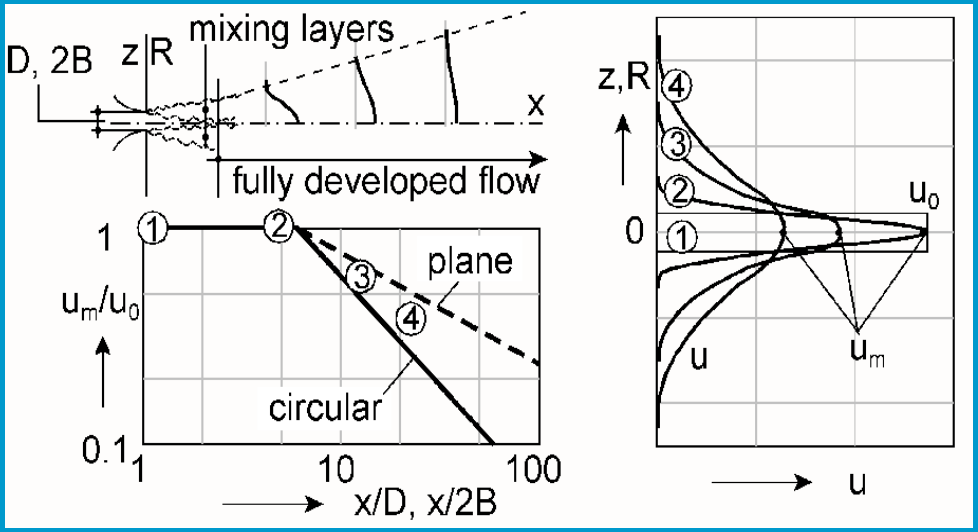
Jet equations (from ct4310)

$$Plane\ jets: u_m = \frac{3.5\,u_0}{\sqrt{x/B}} \quad b = 0.1\,x \quad u = u_m\, e^{\left(-0.693\left(\frac{z}{b}\right)^2\right)}$$

$$Circular\ jets: \quad u_m = \frac{6.3\,u_0}{x/D} \quad b = 0.1\,x \quad u = u_m\, e^{\left(-0.693\left(\frac{R}{b}\right)^2\right)}$$



x = distance from sill

B = width of gap

Bed protection in case of vertical closure

depth	U0	u2	3*U2	D (cm)	W(kg)	
10	2.13	2.13	2.13	5	0	80/200
9	2.36	2.15	2.36	6	0	80/200
8	2.64	2.18	2.64	8	1	80/200
7	2.97	2.20	2.97	14	4	80/200
6	3.38	2.20	3.38	21	14	10/60
5	3.86	2.18	3.86	27	32	10/60
4	4.33	2.07	4.33	39	97	60/300
3	4.63	1.81	4.63	50	192	60/300
2	4.64	1.41	4.24	37	79	60/300
1	3.42	0.74	2.23	5	0	
0	3.13	0.41	1.22	1	0	

Conclusion: everywhere 60/300 is needed

providing quarry material

- by road
- by rail
- by water
- a combination

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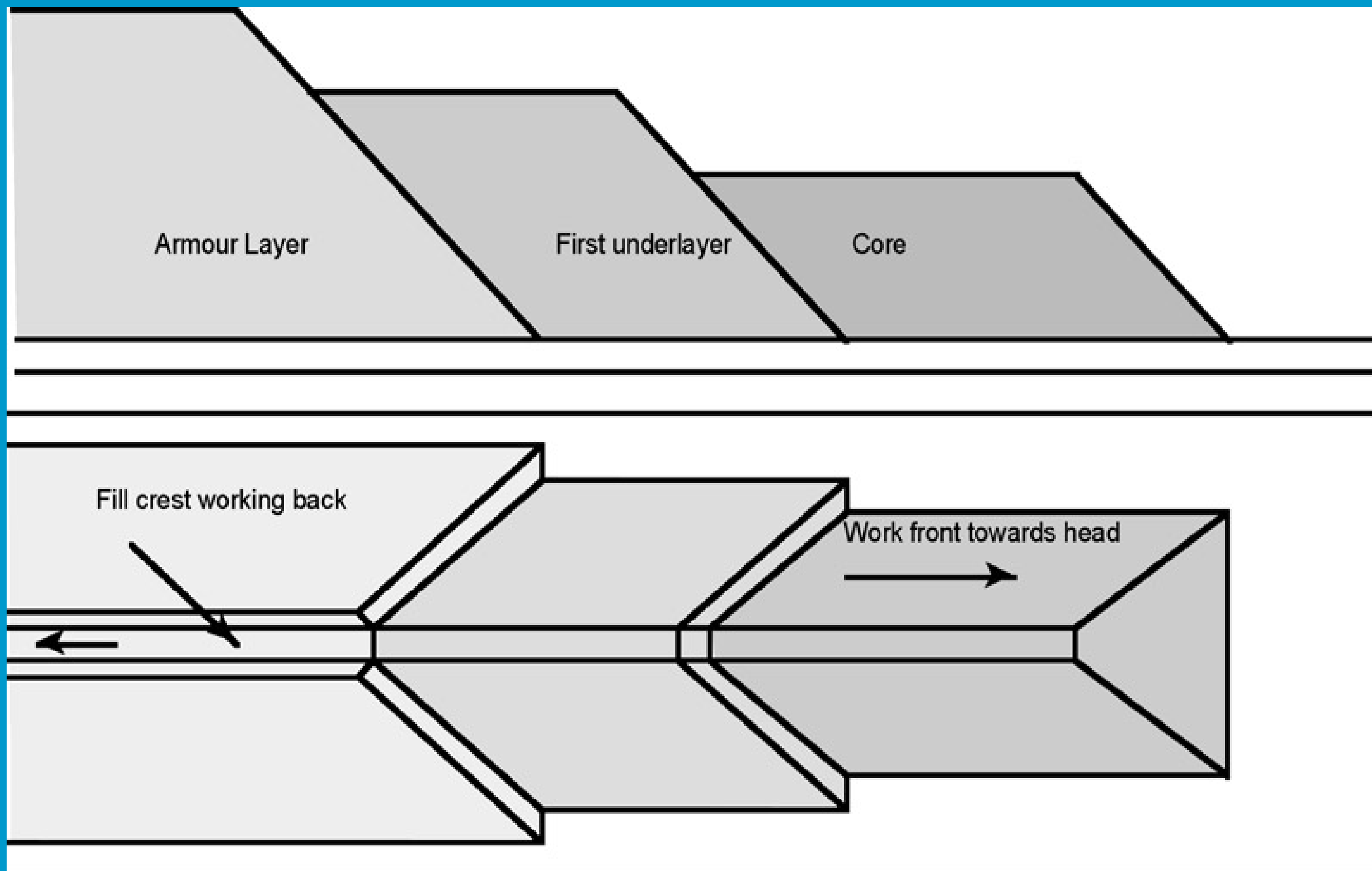
subsequent working fronts



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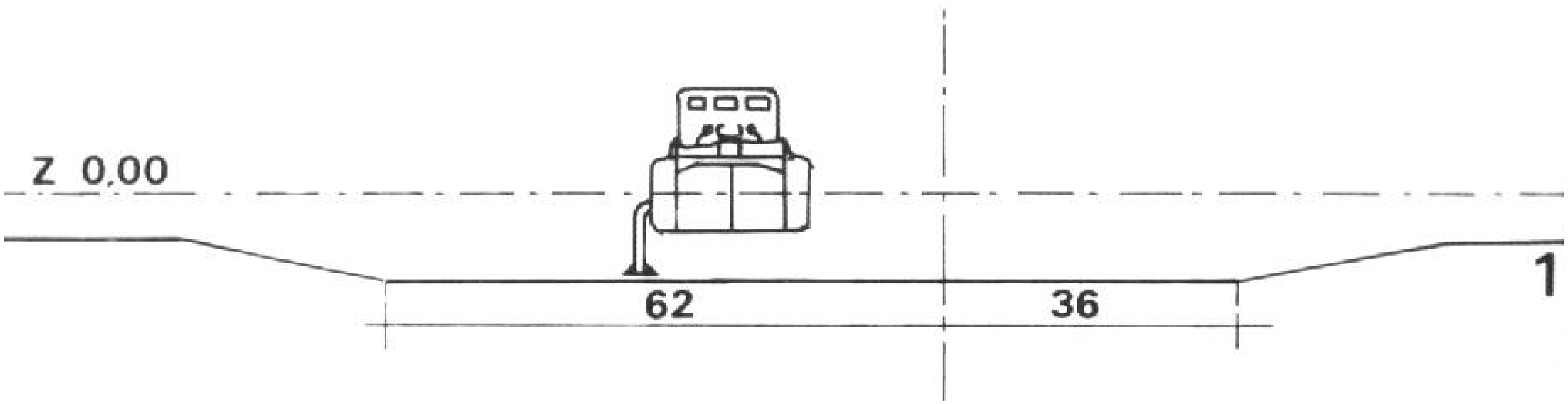
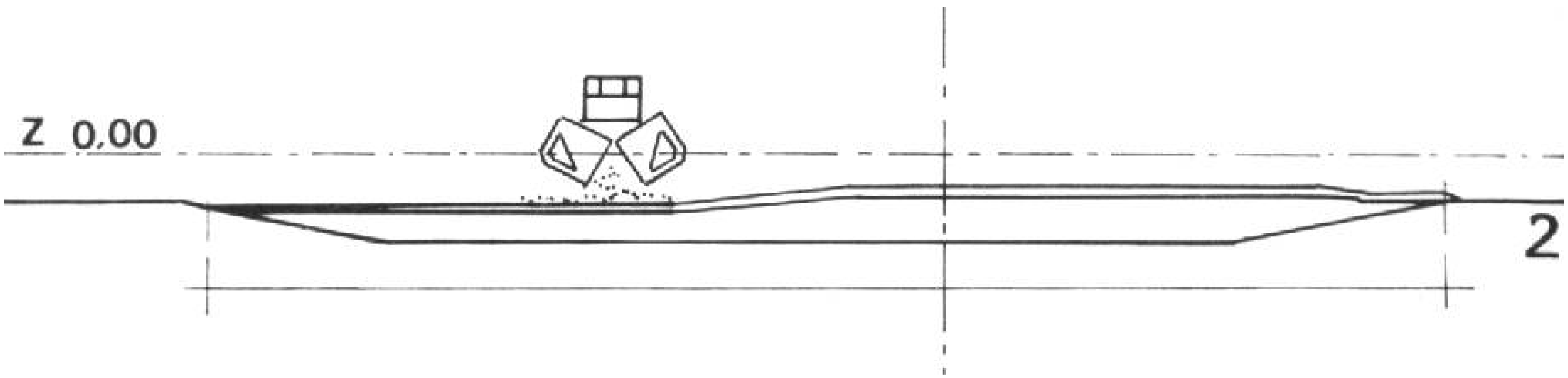
Construction phases of the Zeebrugge Breakwater (1)



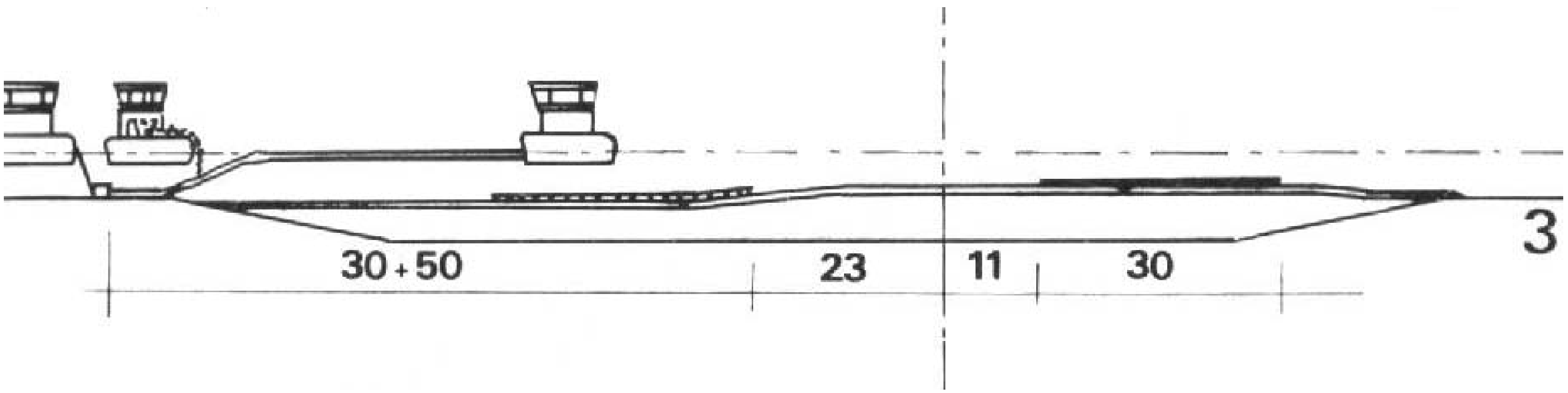
Unsustainable material in the location of the breakwater is removed by sea going cutter suction dredge

Construction phases of the Zeebrugge Breakwater (2)



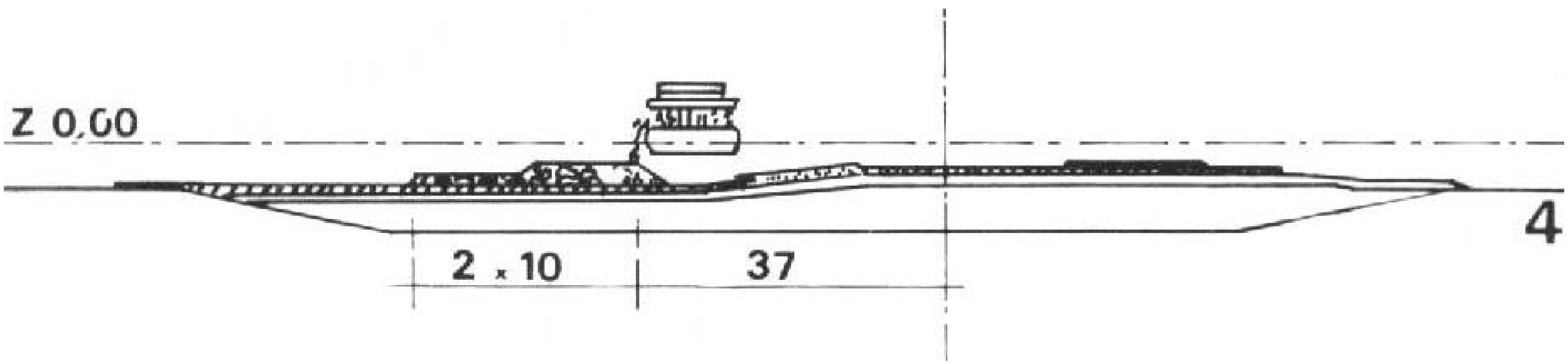
Split-hopper replaces material with sea sand and sea gravel

Construction phases of the Zeebrugge Breakwater (3)



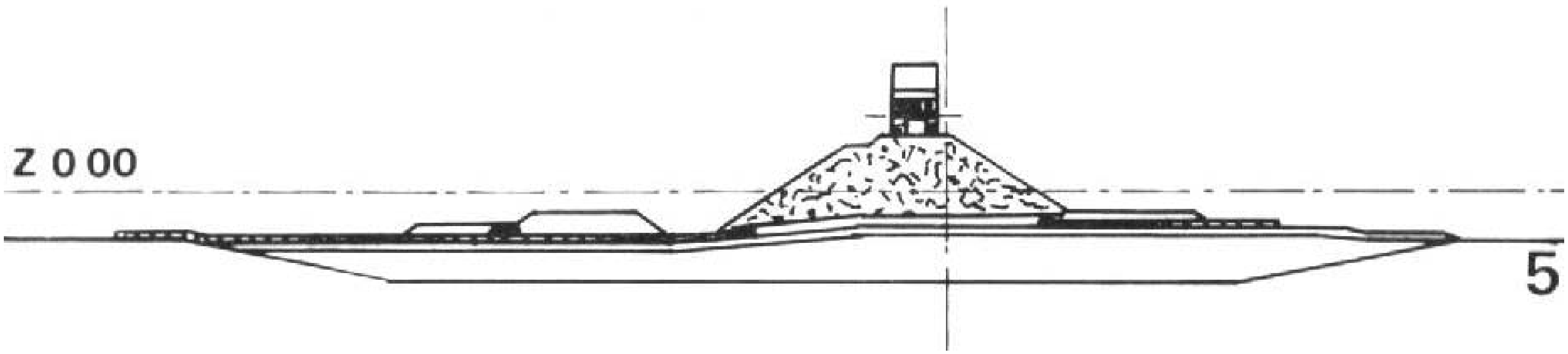
Willow mattresses are sunk with two sink pontoons and specialised stone barges

Construction phases of the Zeebrugge Breakwater (4)



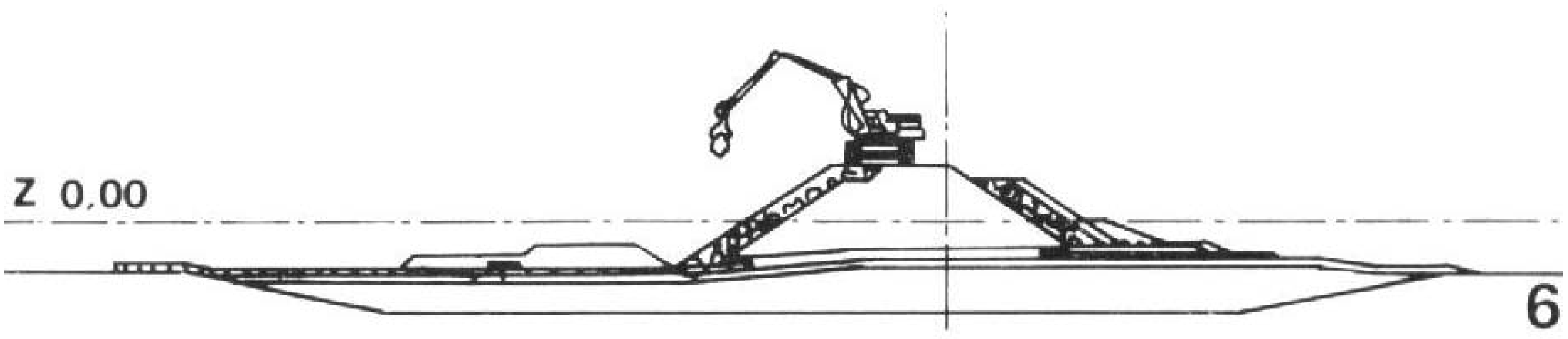
Lateral berms are constructed with quarried stones of 3-6 tons with specialised stone barges

Construction phases of the Zeebrugge Breakwater (5)



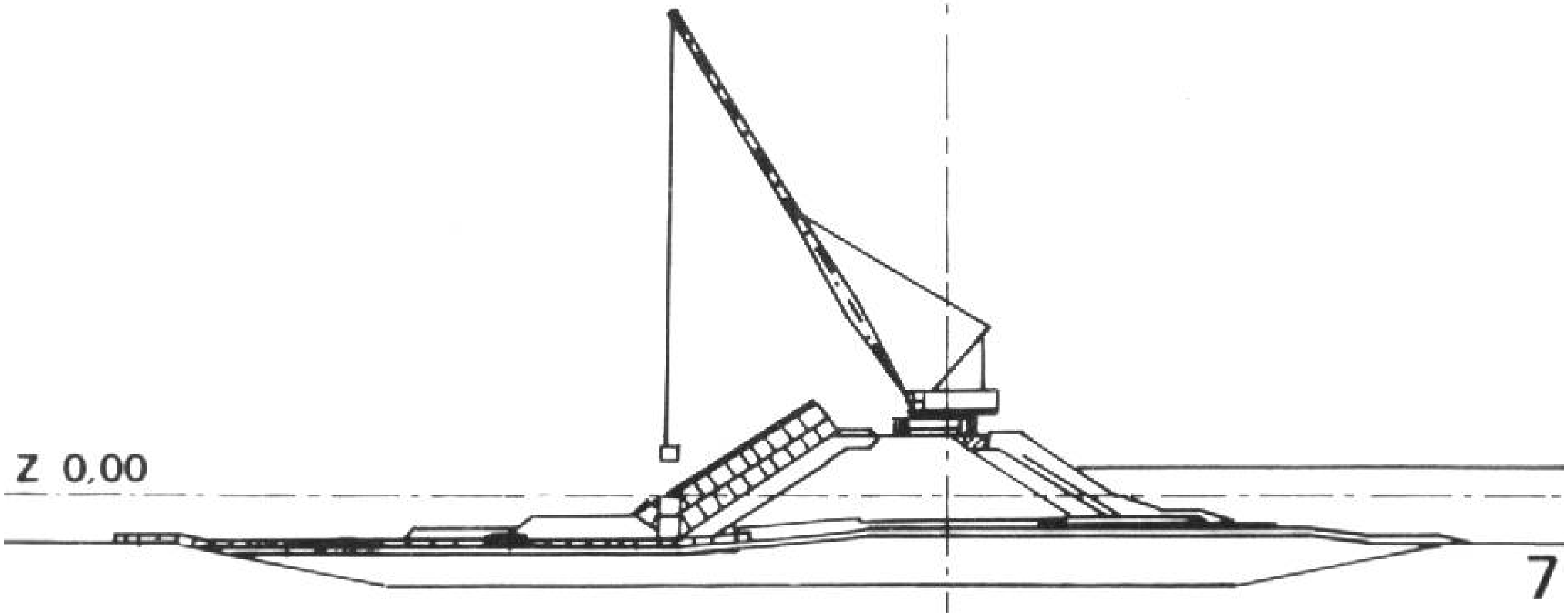
The dam core is built with quarry stone using heavy duty earth moving equipment

Construction phases of the Zeebrugge Breakwater (6)



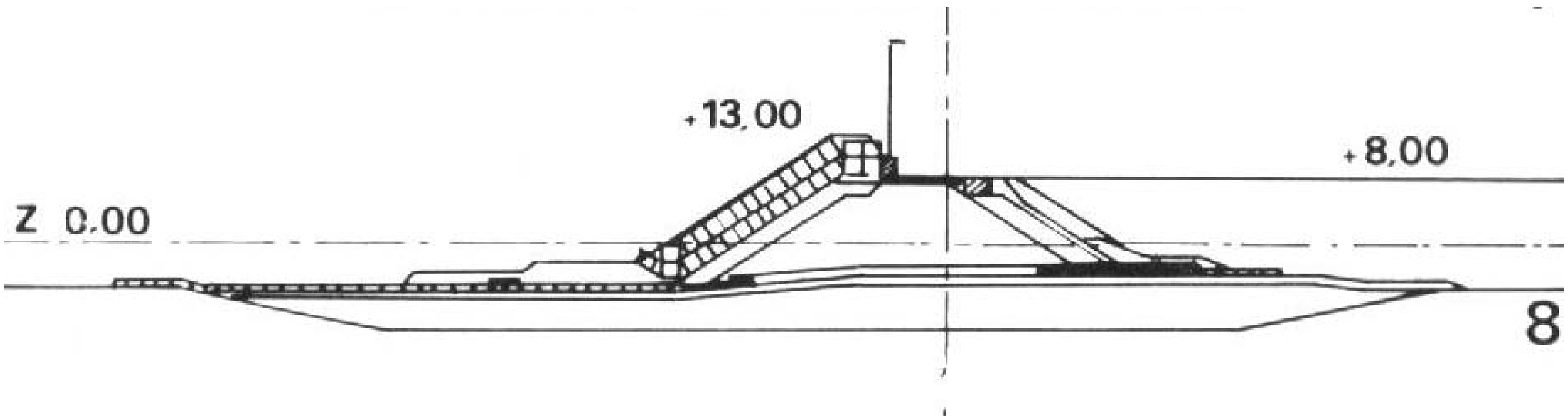
The stones are faces with a layer of 1-3 tons stones plus filter construction with Poclain 600

Construction phases of the Zeebrugge Breakwater (7)



The seaward side is protected by 25-30 ton concrete blocks with an American Hoist 11-310

Construction phases of the Zeebrugge Breakwater (8)



Finishing: crown block, service road, lighting

a breakwater under construction

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trucks waiting on the breakwater

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use of cheap local equipment

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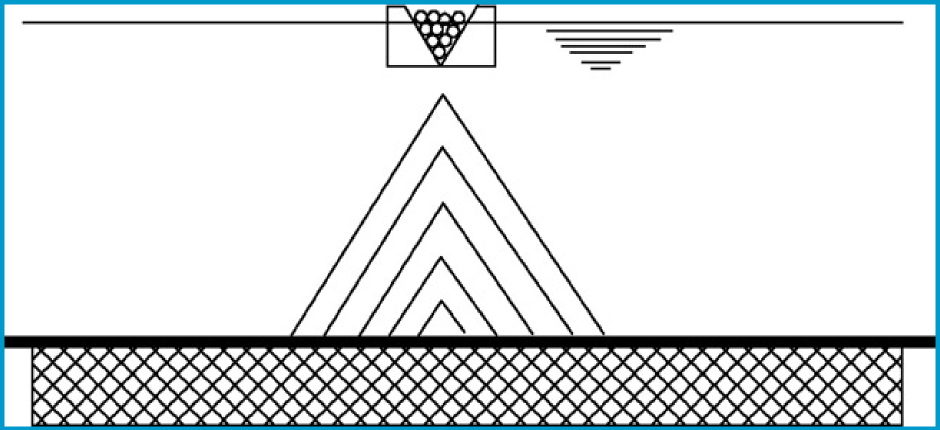
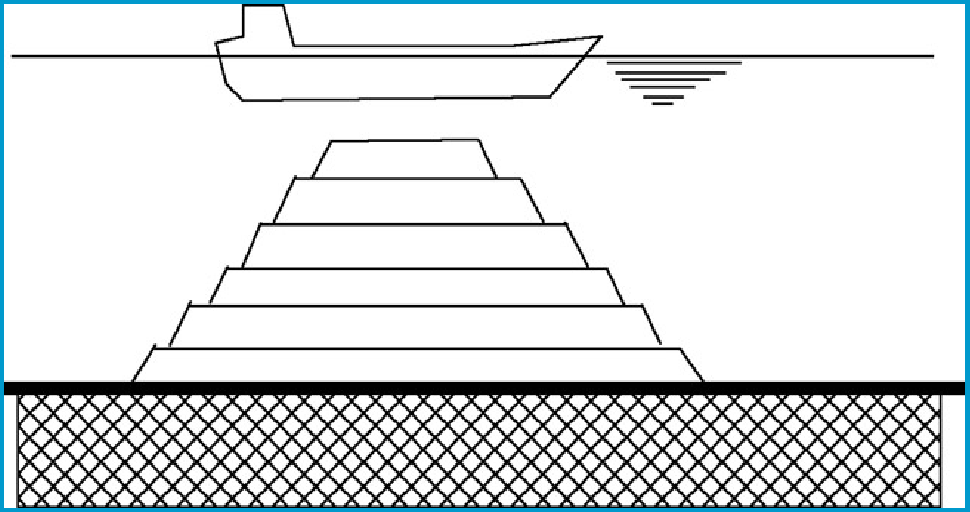
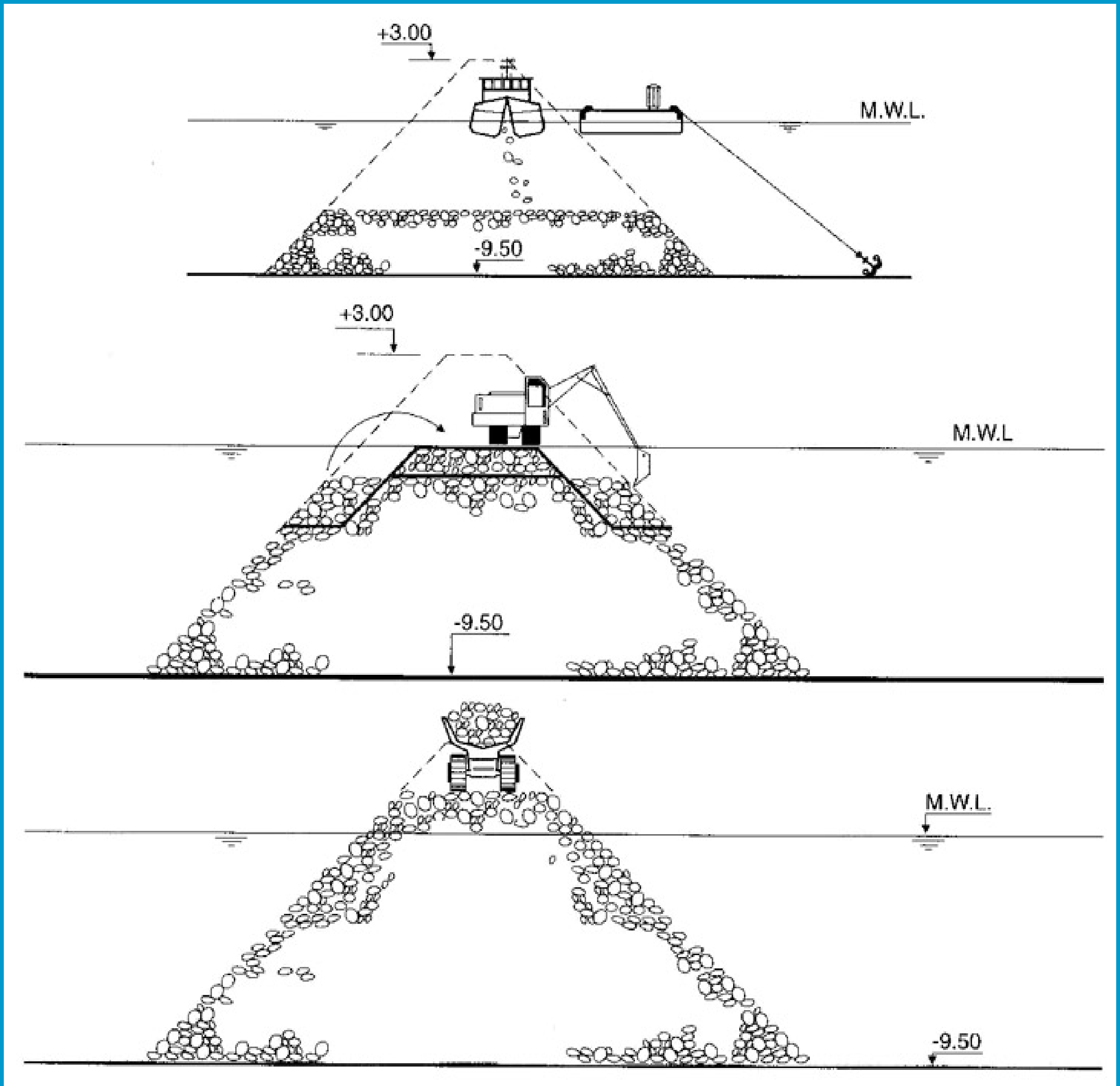
build up of profiles



line dump



horizontal layers



use of waterborne and land based equipment

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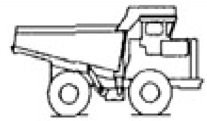
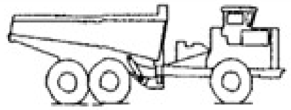
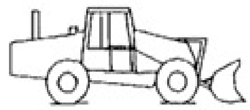
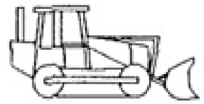
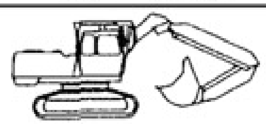
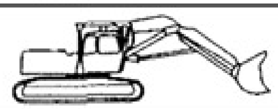
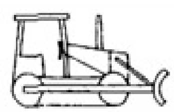
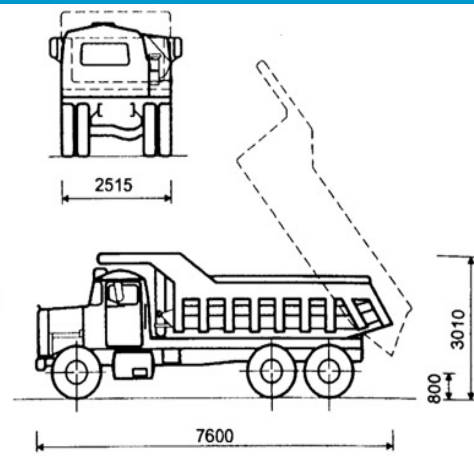
land based equipment

type		capacity (m^3)	weight (ton)	wheel load (ton) ground pressure	width (m)
(off higway) dump truck		20 - 90	empty: 30 - 110 loaded: 60 - 270	front/rear (ton) empty: 15/15 - 50/60 loaded: 20/40 - 90/180	wheel base 3.7 - 5.7
articulated dump truck		12 - 27	empty: 20 - 40 loaded: 40 - 90	front/rear (ton) empty: 10/10 - 20/20 loaded: 14/26 - 30/60	wheel base 5.7 - 6.8
wheel loader		2.5 - 9	15 - 86		bucket width 2.7 - 4.7
track loader		2.5 - 3	25	60 - 90 kPa	bucket width 2.7
backhoe crane		0.5 - 15	15 - 200	40 - 150 kPa	track gauge 2 - 5
front shovel		2 - 15	40 - 200	70 - 190 kPa	track gauge 2 - 5
bulldozer		blade width 2.5 - 5 m	10 - 80	50 - 100 kPa	track gauge 2 - 3

tipper truck vs. dump truck

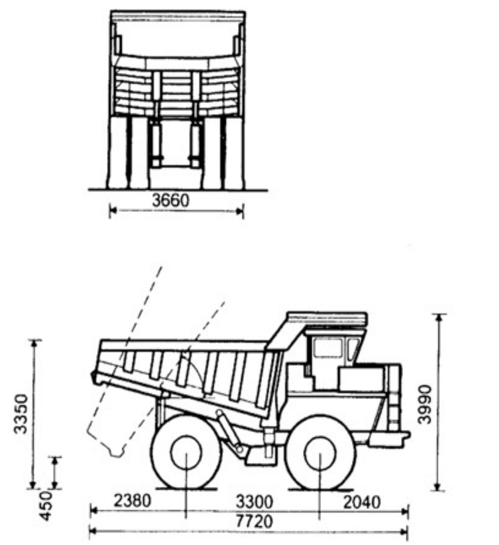
MACK DM 686 SX(6 x 4)

nett carrying capacity	25,000 kg
gross vehicle weight	
front	8,200 kg
rear	29,480 kg
total	37,680 kg
nett weight	12,680 kg
engine	em 6-285; 210 kw at 2,100 rpm
fuel tank capacity	340 ltr
tyres	12.00 x 24
rock body	12 m^3



WABCO 35C (4 X 4)

nett carrying capacity	31,750 kg
gross vehicle weight	
front	18,865 kg
rear	39,358 kg
total	58,223 kg
nett weight	
front	13,399 kg
rear	13,073 kg
total	26,472 kg
engine: detroit 12v - 71n	320 kW at 2,100 rpm
max. speed	
forward	66 km/hr
backward	8.8 km/hr
turning circle	14.9 m
fuel tank capacity	454 ltr
body contents	
struck	17.6 m^3
heaped 1:1	26 m^3
tyres	18.00 x 33 24 PLY



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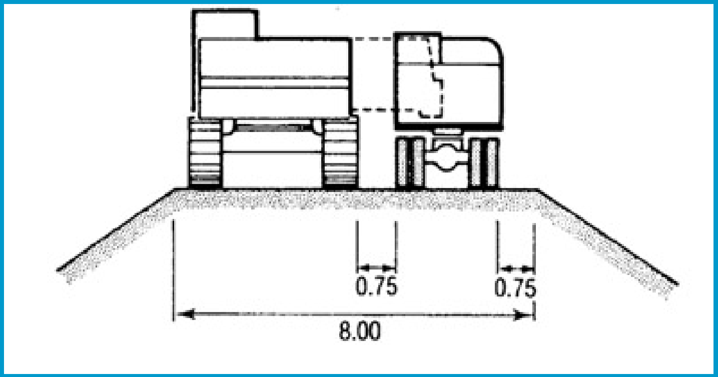
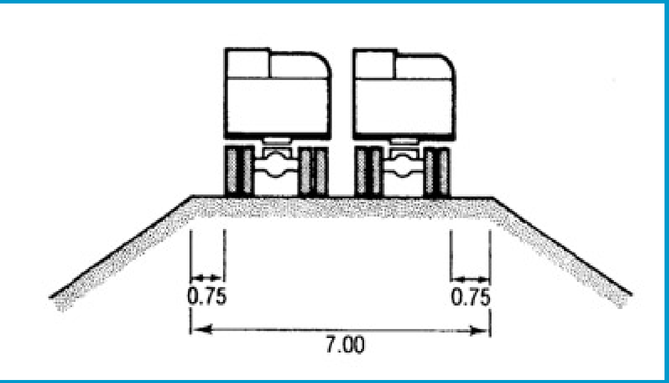
space requirements for heavy equipment





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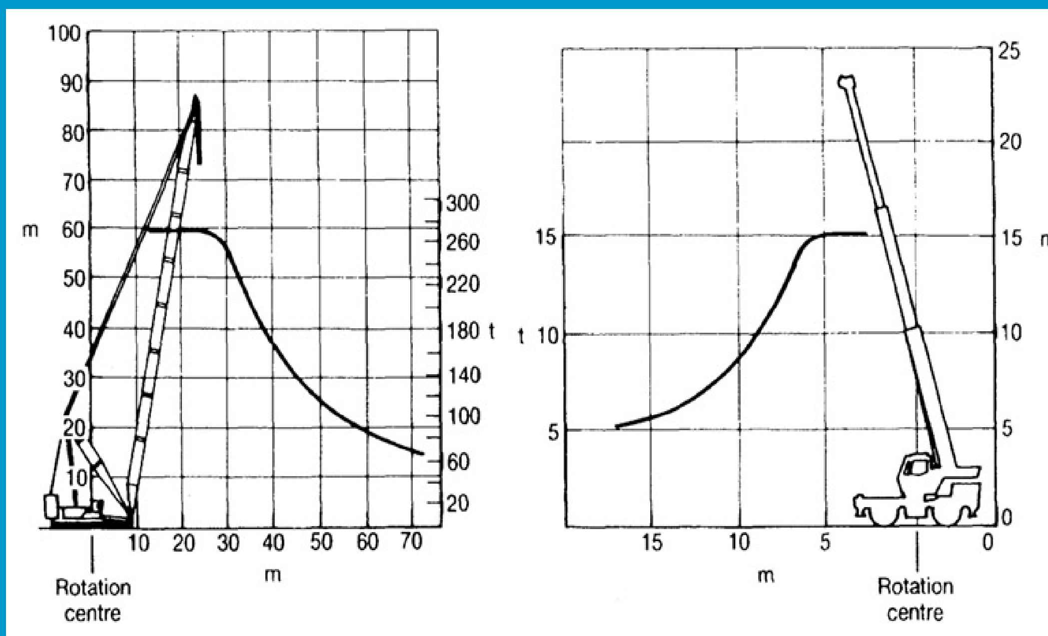
lifting capacity of a crane



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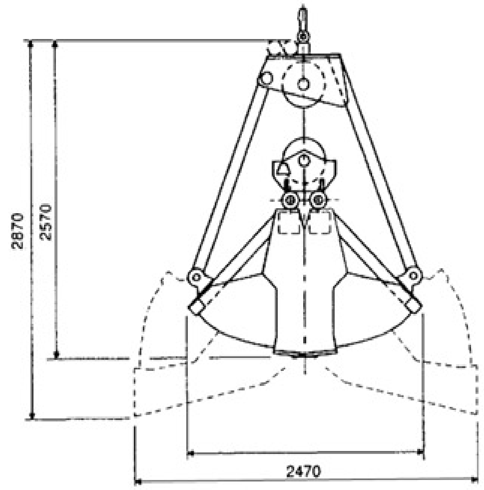
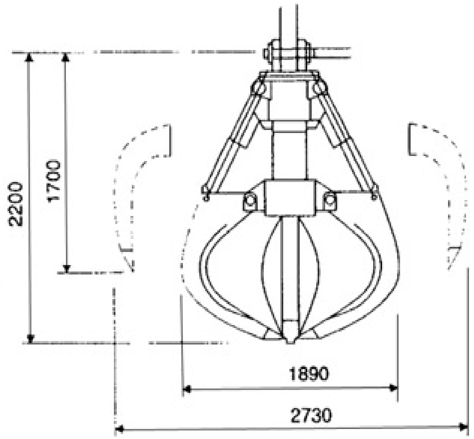
grab types



ROPE CLAMSHELL

capacity	1000 ltrs
type	2 ropes, digging
dead weight	1550 kg
width	1200mm



HYDR. GRAB

capacity	1000 ltrs
type	hydraulic grab with orange peel shells with mechanical swivel 360
no. of shells	5
max. load	8 tons
dead weight	1890 kg.

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Waterborne equipment

- Bulk
  - Pipeline
  - Floating
    - flat deck barges
    - bottom door barges
    - split barges
    - tilt barges
    - side unloading vessels
- Individual placement

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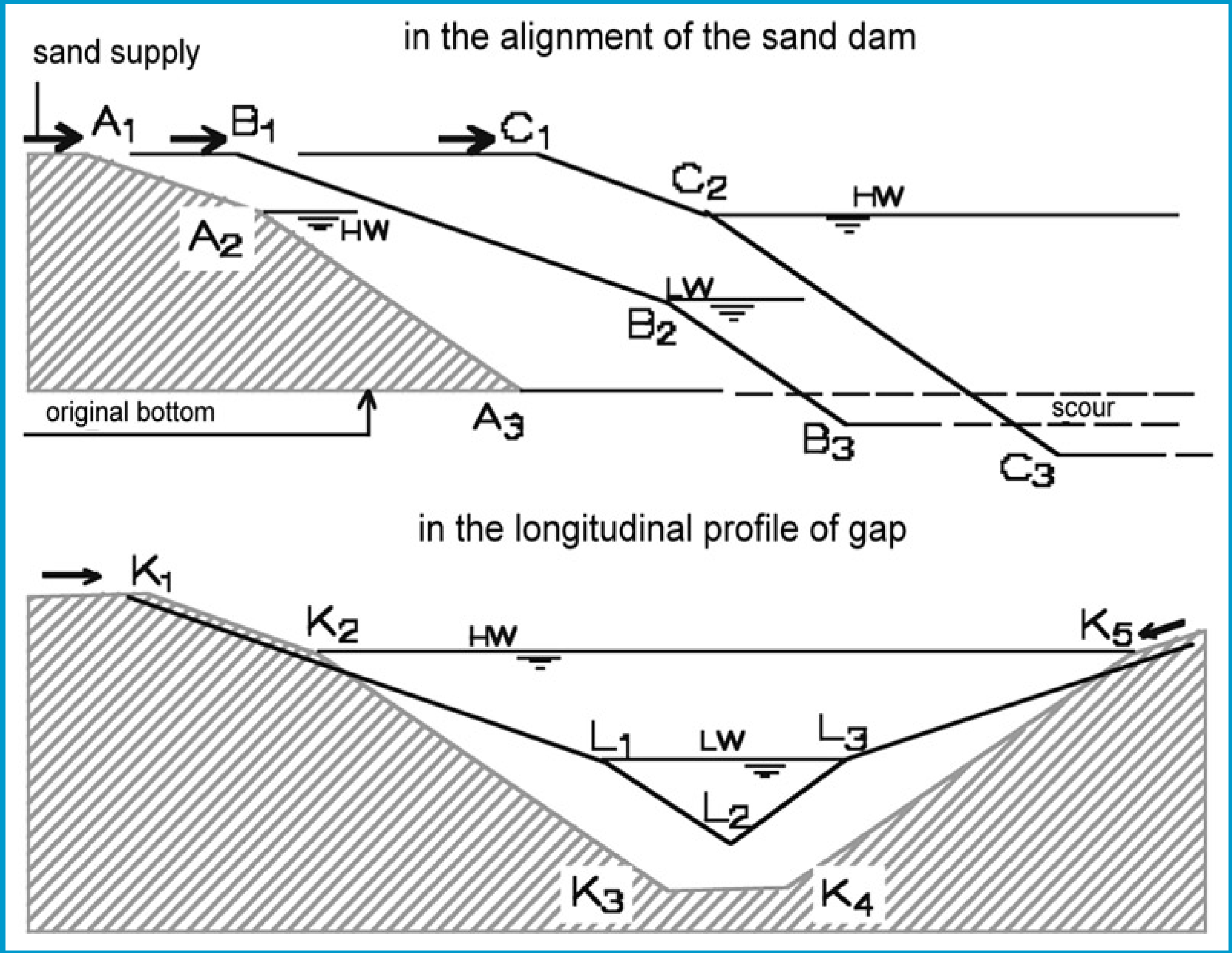
closure by pumping sand



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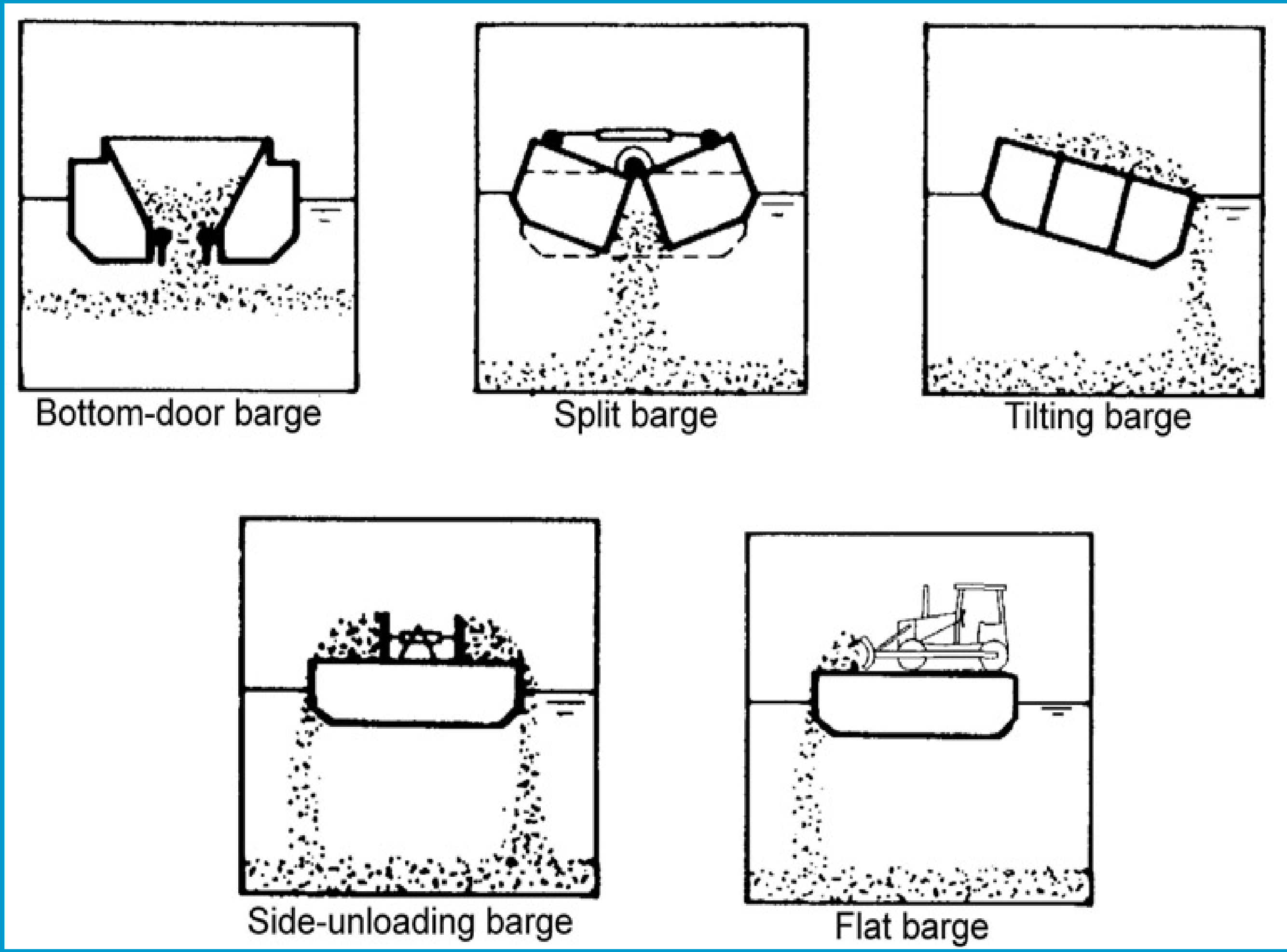
barges for dumping material



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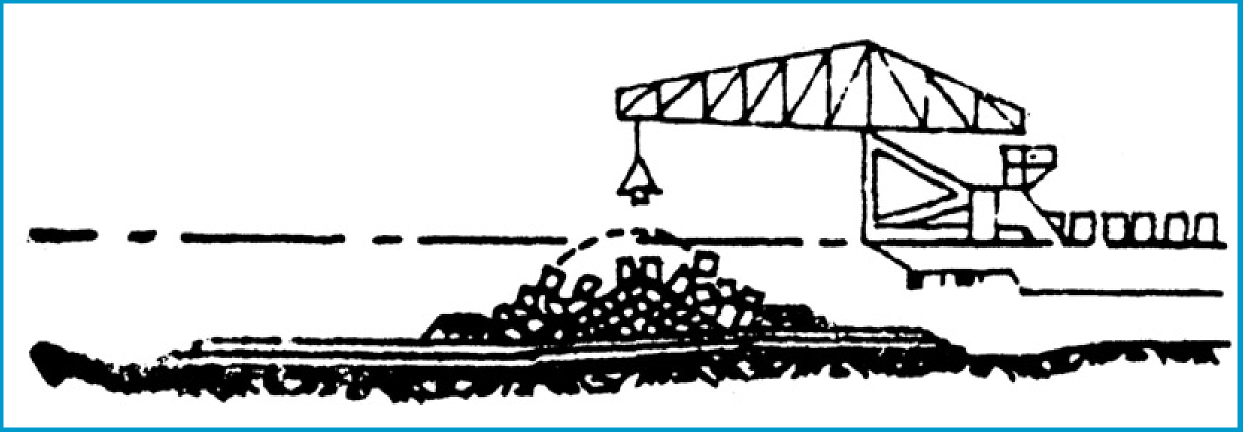
example of combined transport and crane vessel



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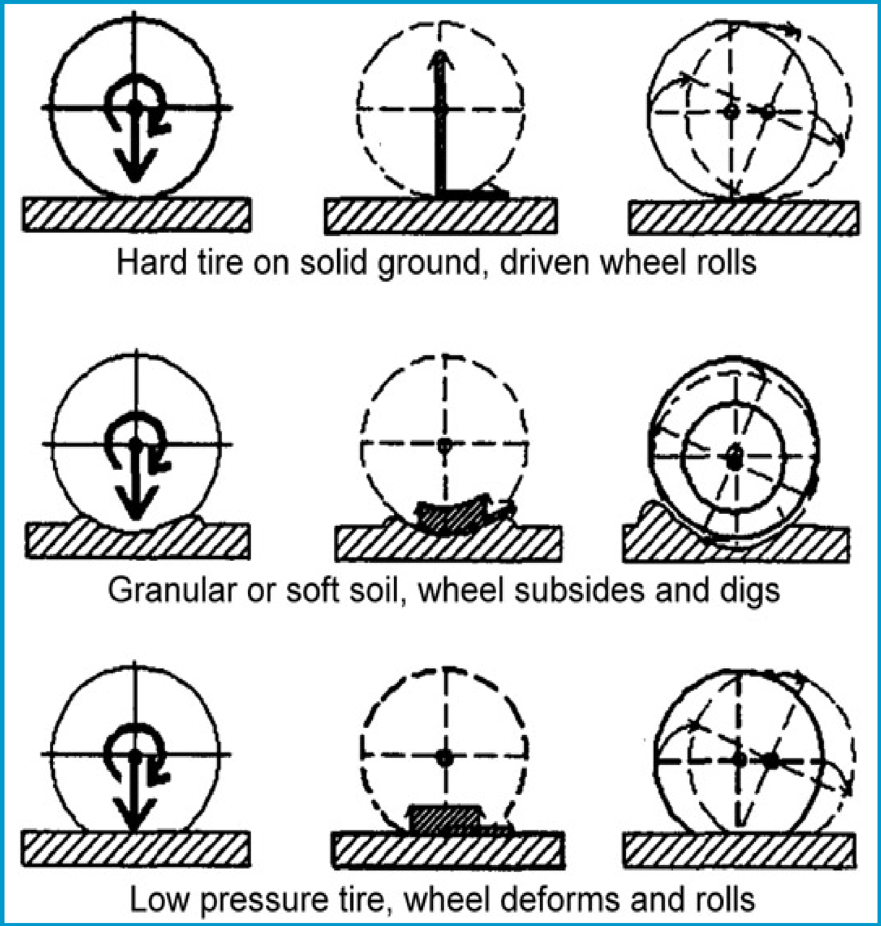
motion of a driven wheel



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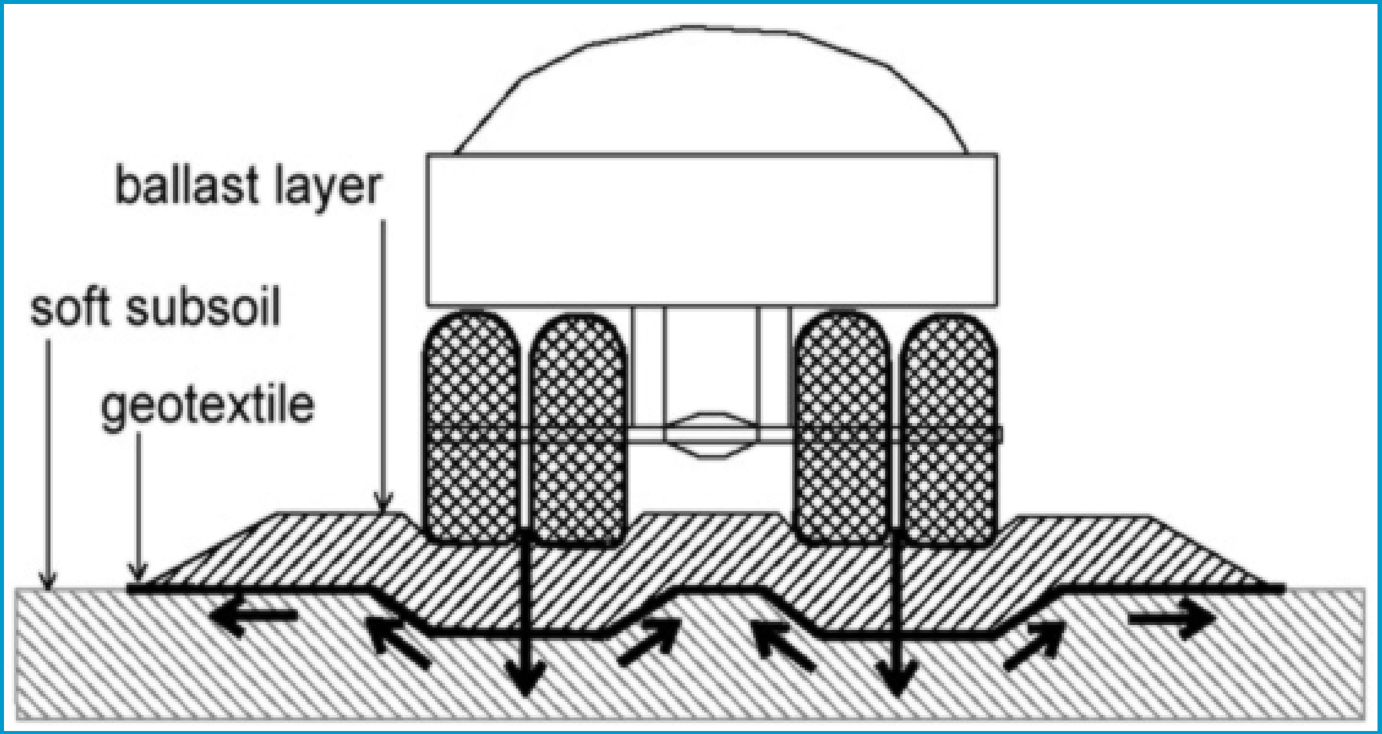
temporary road on soft subsoil



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final closure with sand only

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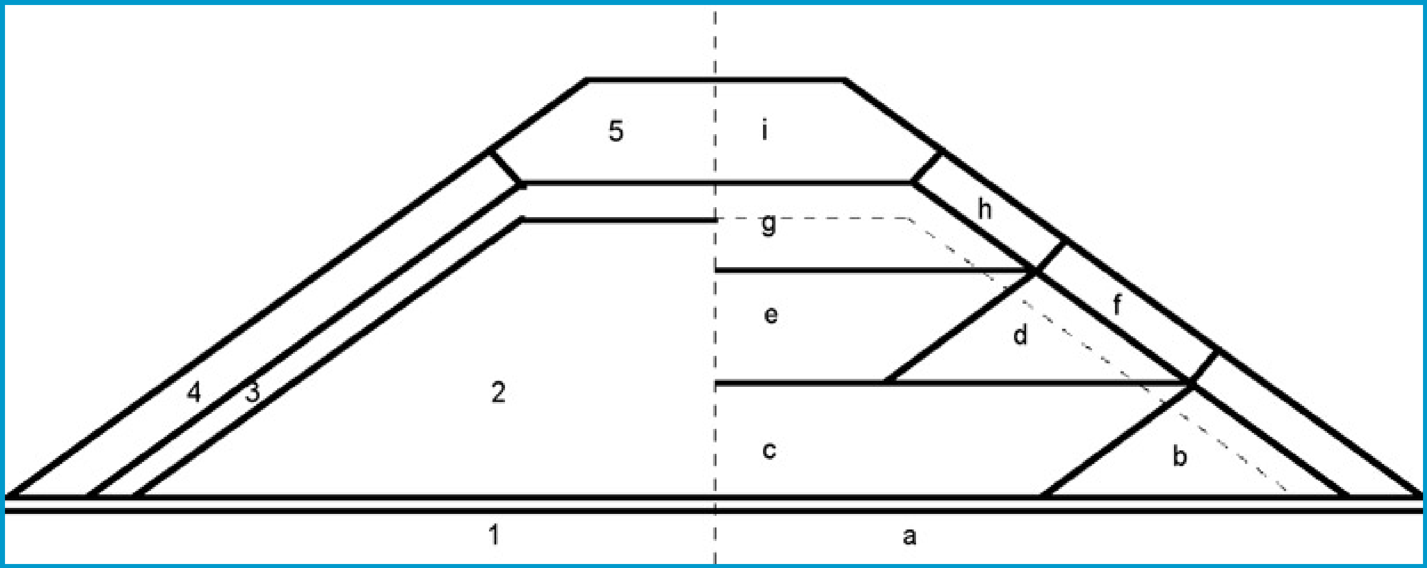
closure with a cable car

varying construction sequence



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