Dimensions

chapter 10

ct 4310 Bed, bank and shoreline protection

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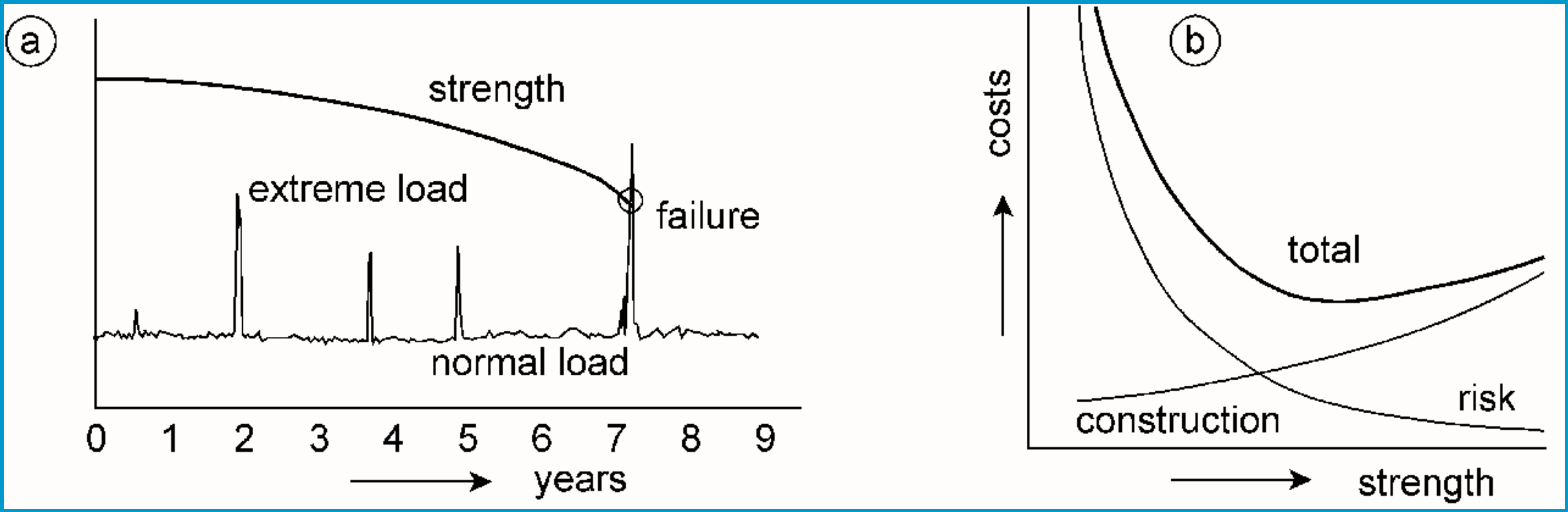
Faculty of Civil Engineering and Geosciences
Section Hydraulic Engineering

Introduction

- relation between strength and loads
- risk analysis
- ULS and SLS
- Maintenance strategies

failure, risk and costs



definitions of risk

- probability of an unwanted event
- consequences of an unwanted event
- the product of probability and consequences of the unwanted event
- the previous risk, but to the power N, in which N is the number of events per year

risk = probability * consequence

definitions of risk

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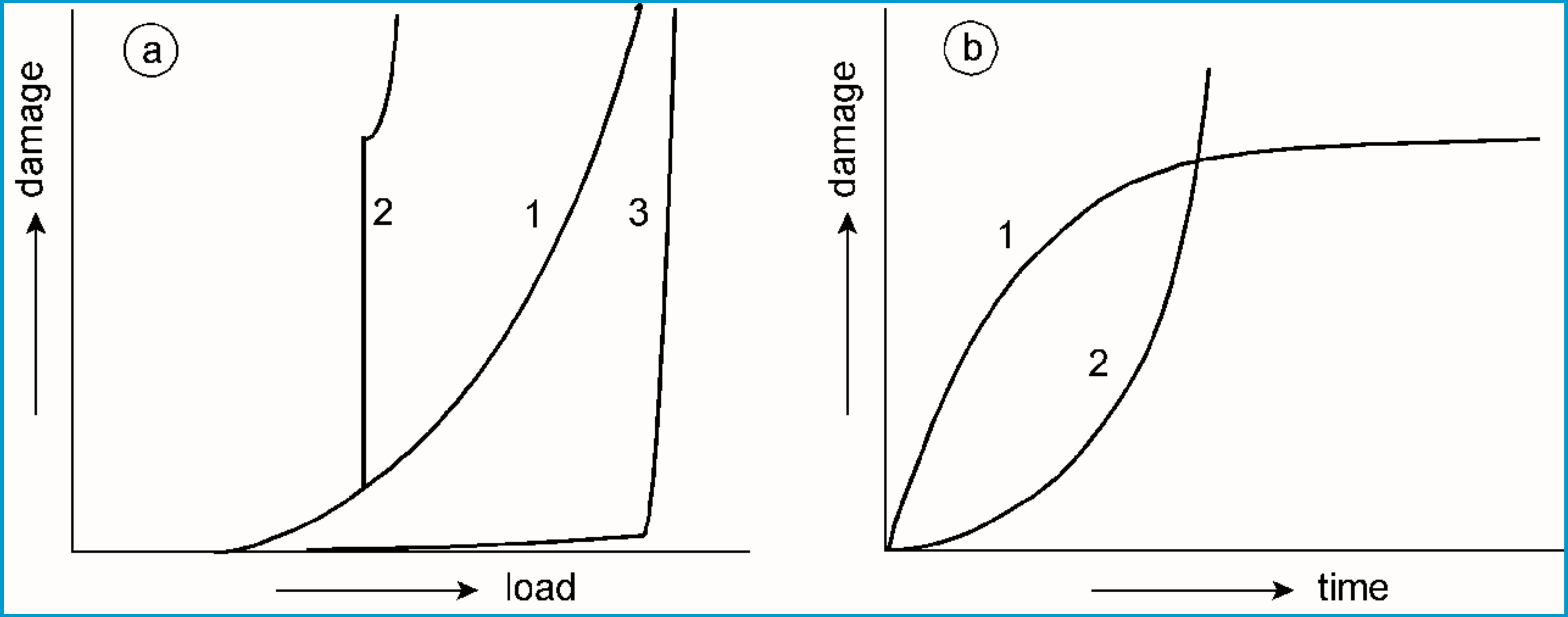
differences in structural behaviour



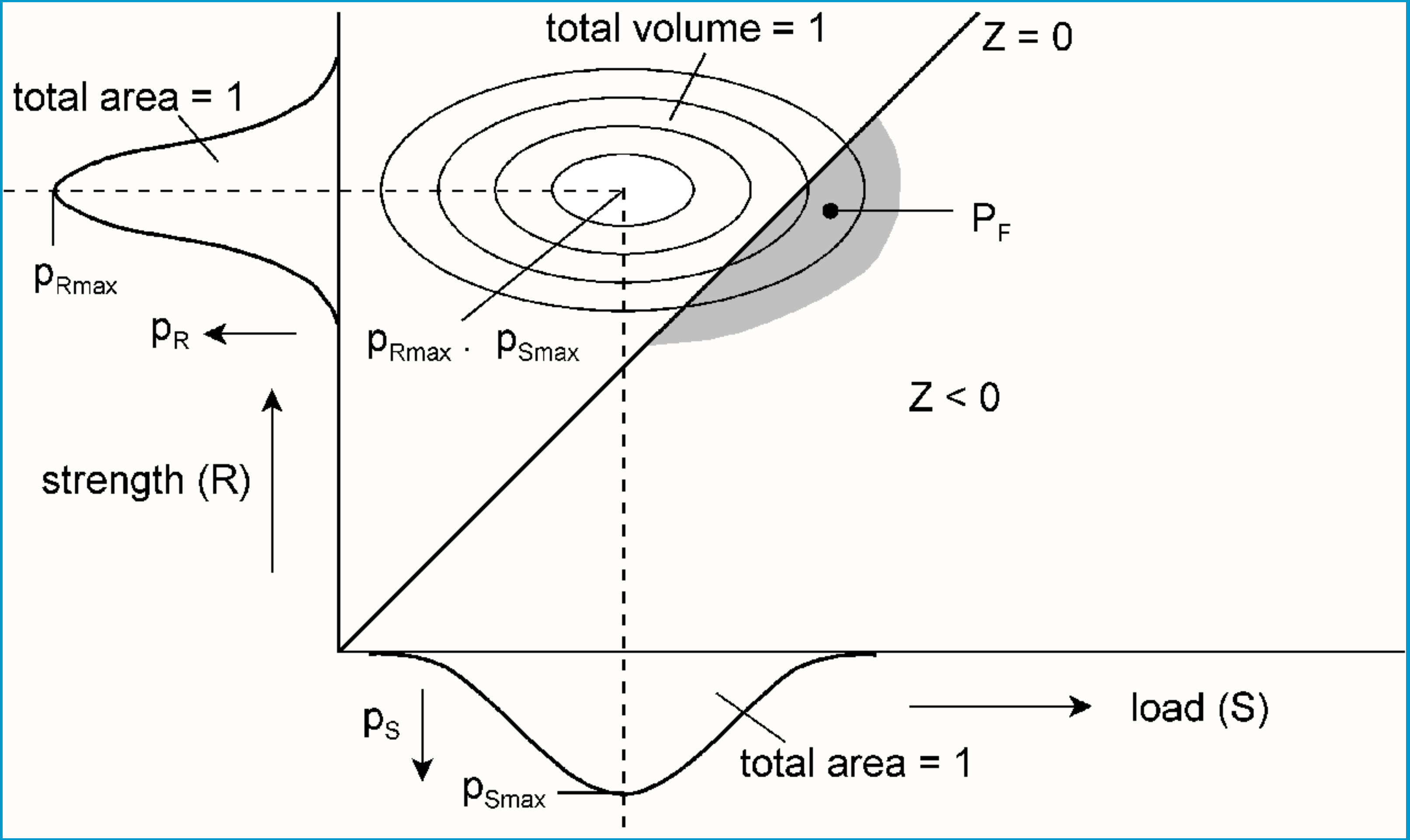
probabilistics

Z = Strength - Load

= R - S

$$= R(x_1, x_2, x_3, \ldots\ldots x_m) - S(x_{m+p}, \ldots\ldots x_n)$$

probability mountain



Integral of the probability mountain

$$P_F = P\left(Z < 0\right) = \iint\limits_{Z(x)<0} \ldots \int p_{\underline{x}}\left(x\right) dx_1 \ldots . dx_n$$

Levels of approach

- Level III

  Fully probabilistic approach
- Level II

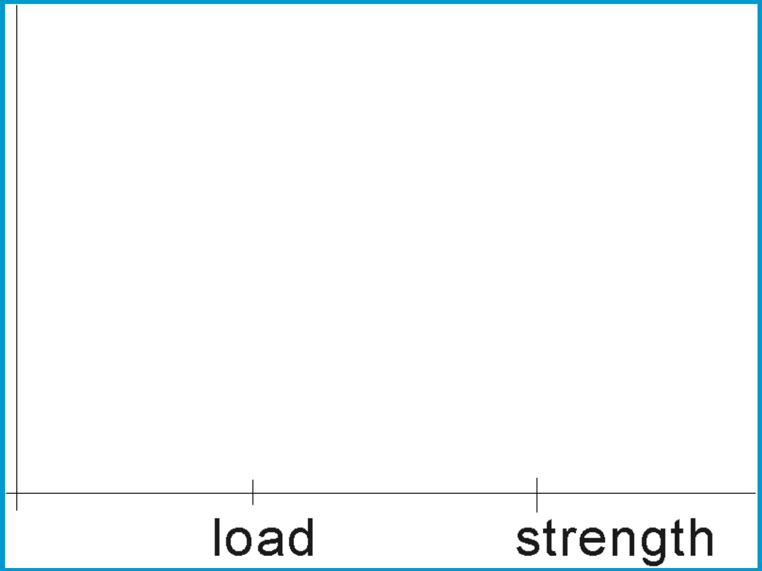
  approximate probabilistic approach
- Level I

  quasi probabilistic approach
- Level 0

  deterministic approach

Load and strength

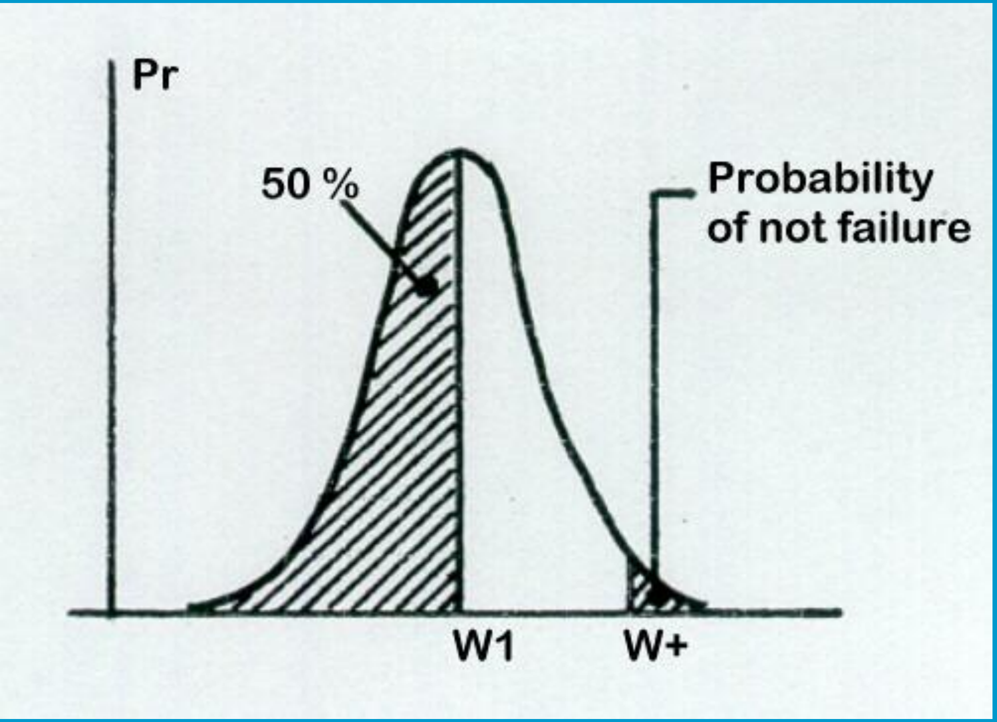
- In traditional design:
strength > load
- usually:
strength = γ * load
- in which:
γ is safety factor



Probability of failure

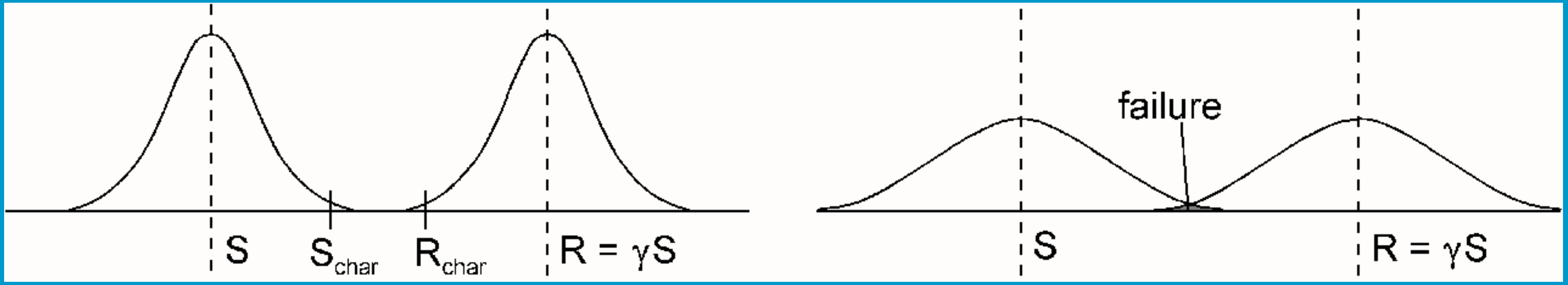
•When you design your strength equal to your design load, then: prob. of fail = 50%

•So for small failure use higher strength



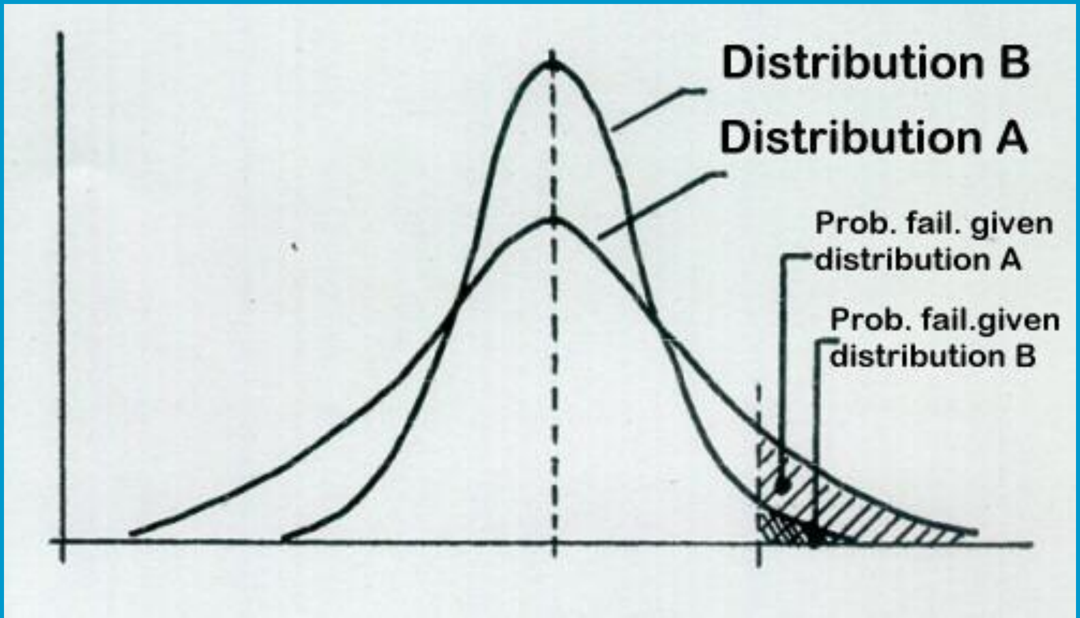
Load and strength distribution

- In probabilistic design full load and strength distribution is used
- the probability of failure can be quantified:
It is the overlap of both curves

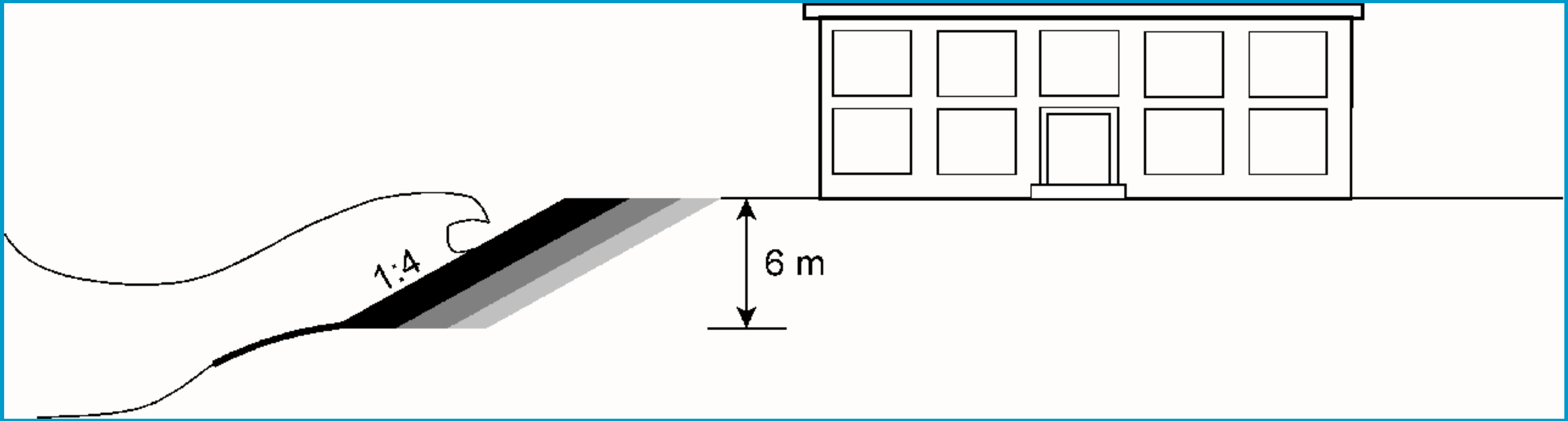


advantages

- A narrower distribution leads to to more safety, using the same average strength



example for the comparison



Deterministic approach

Available wave data:
Ten years of observations, highest observation in 10 years is H_s = 1.62 m

$$d_{n50} = \frac{H_{sc}\xi^{0.5}}{\Delta 6.2 P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2}}$$

No swell, so s= 0.05
slope 1:4, so plunging
P (revetment) = 0.1
Δ = 1.65
N = 7000
S = 2

From computation follows d_{n50} = 0.56 ➔ rock 300/1000 kg

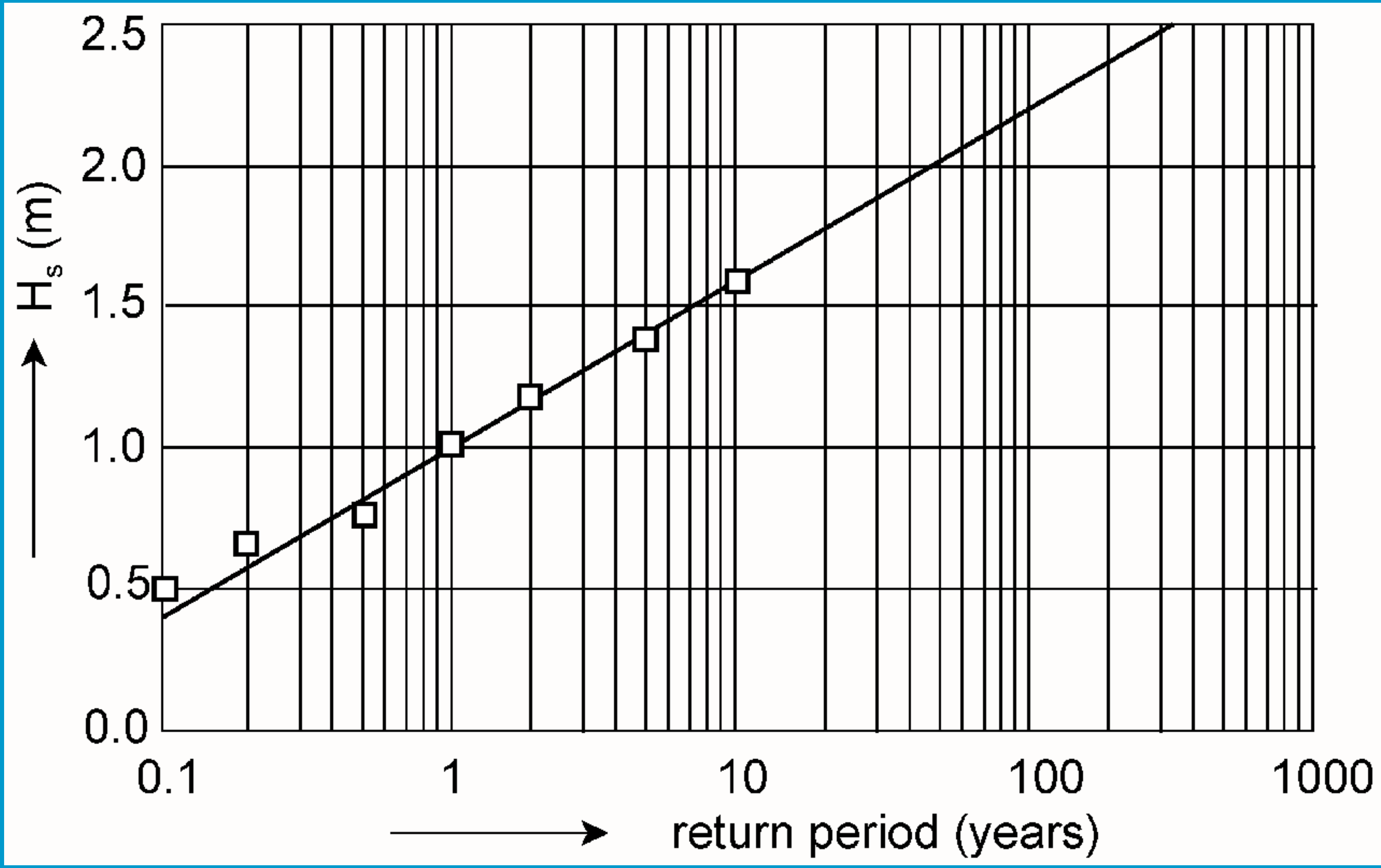
probabilistic approach

Rewrite Van der Meer as:

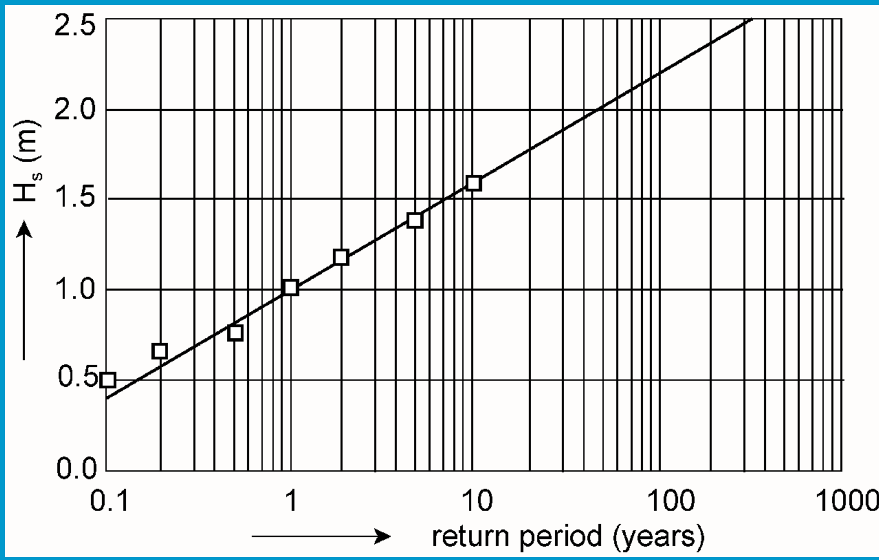
$$Z = 6.2\,P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2}\xi^{-0.5} - \frac{H_{sc}}{\Delta d_{n50}}$$

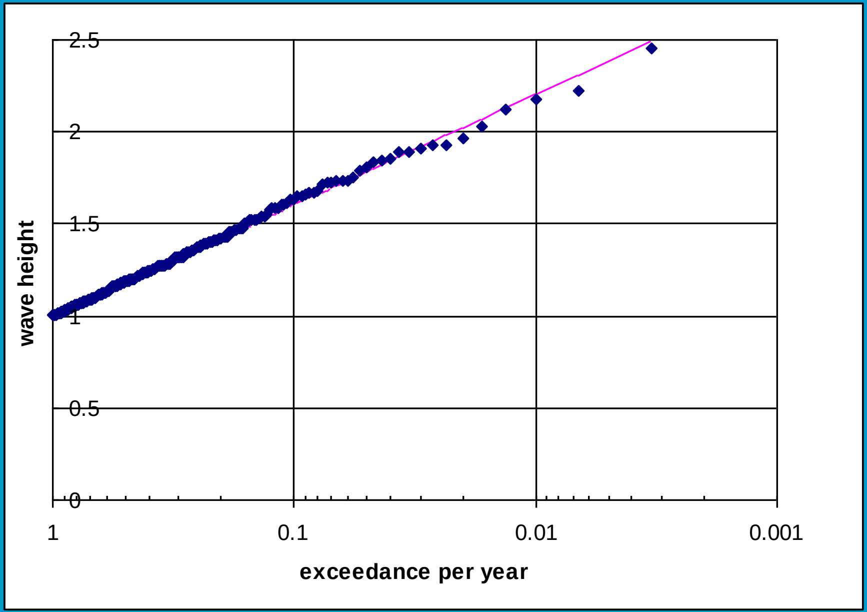
parameter	Distribution type	mean	σ
H_s	Weibull		
Δ	Normal		
D_{n50}	Normal		
S	Uniform		
N	Normal		
P	Normal		
ξ	??		

wave climate to be used



Simulated distribution





$$H = \frac{-1}{\lambda}\ln(P) + \varepsilon$$

$$\varepsilon = 1.0$$

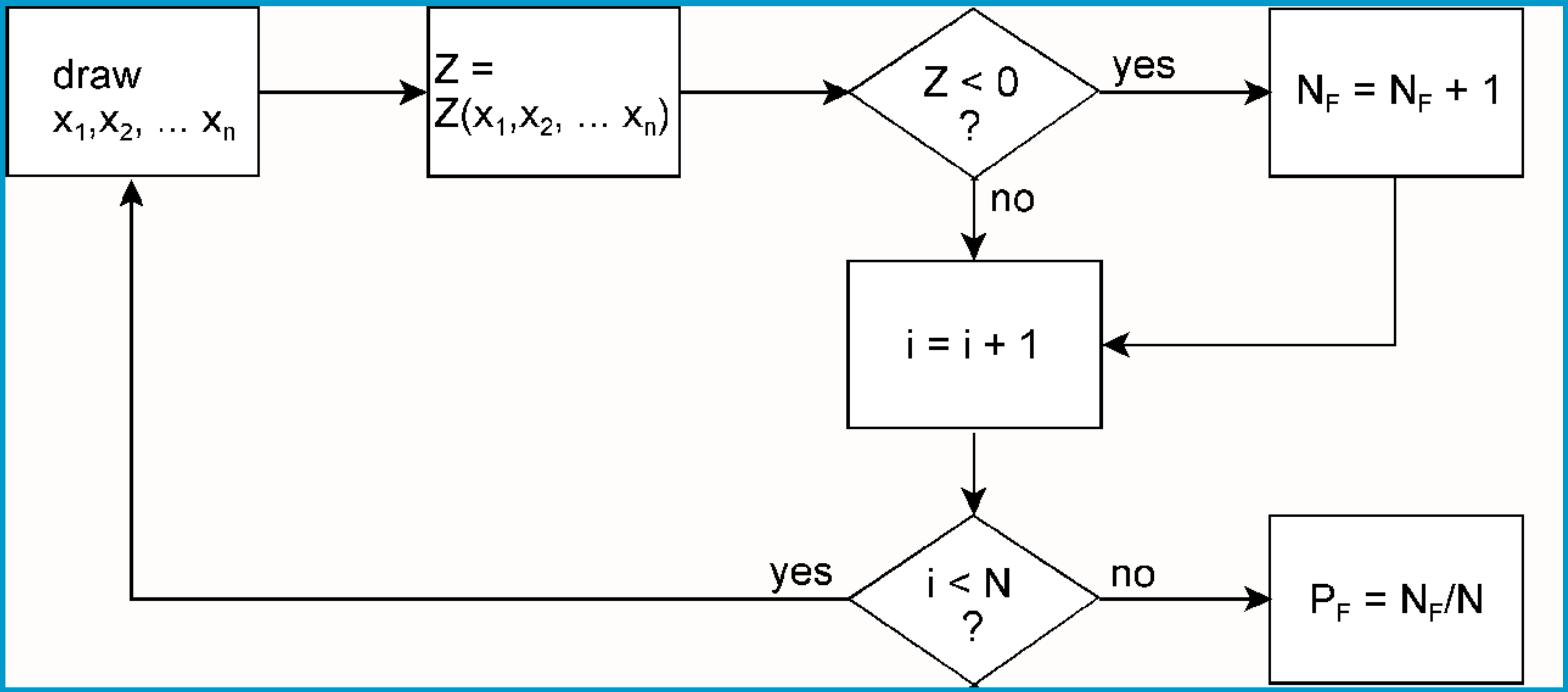
$$\lambda = \frac{-\ln(P)}{h-\varepsilon} = \frac{-\ln(0.01)}{2.2-1} = \frac{4.605}{1.2} = 3.83$$

full input table

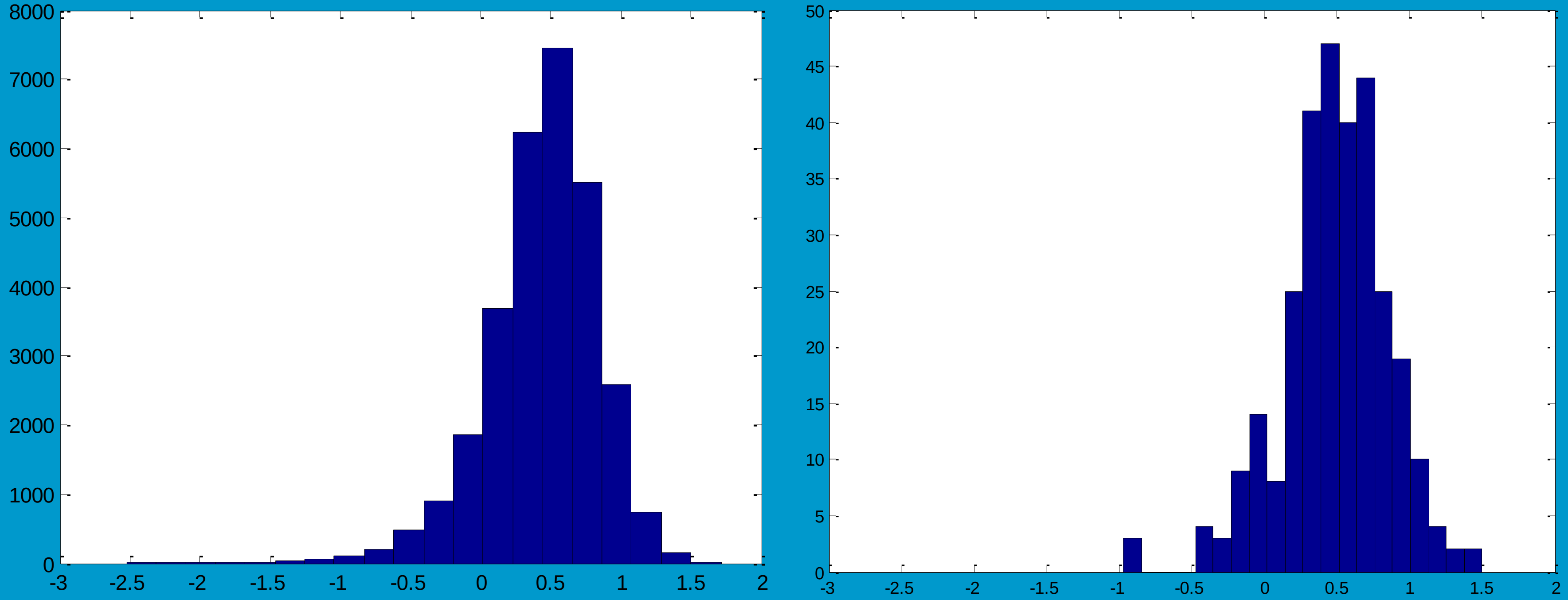
$$Z = 6.2\,P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2}\left(\frac{\tan\alpha}{\sqrt{s}}\right)^{-0.5} - \frac{H_{sc}}{\Delta d_{n50}}$$

parameter	Distribution type	mean	σ
H_s	Exponential	$\varepsilon = 1$	$\lambda = 3.83$
ρ_s	Normal	2600	100
ρ_w	Normal	1030	5
D_{n50}	Normal	0.6	0.05
S	Determin.	2	
N	Determin.	7000	
P	Lognormal	0.1	0.05
s	Normal	0.05	0.01
$\tan\alpha$	Normal	0.25	0.0125
Cpl	Normal	6.2	0.43

procedure of Monte Carlo



Results of Monte Carlo



Two realisations for S=2; NoOfSamples = 30000 and 300

pf = 0.1152 and pf = 0.1

In FORM: pf = 0.098

Results of FORM (β = 1.29, pF = 0.098)

variable	α-value	Mean value	Design point
ρ_s	0.18	2650	2626
ρ_w	-0.02	1030	1030
tan α	-0.07	0.25	0.25
Steep	0.15	0.05	0.048
P	0.25	0.1	0.076
S	0	2	2
N	0	7000	7000
H_s	-0.88	3.83	1.53
d_{n50}	0.25	0.6	0.58
Cpl	0.21	6.2	6.08

risk analysis

P_f for S=2 (damage) = 0.09
P_f for S=10 (failure) = 0.011

There is 1% chance per year of total collapse of the building.

Lifetime of building is 50 years

P_f in 50 years = $1-(1-P_f/\text{year})^{50} = 0.42$

So there is 42% chance that the building will be destroyed during its lifetime

capitalised risk

$$R = \sum_{n=1}^{50} P_F D \frac{1}{(1+r)^{50}} = P_F D \frac{1 - \left(\frac{1}{1+r}\right)^{50}}{r}$$

D = total damage (suppose it is, including econ. activities 10 million € r = interest rate (assume 5%)

For D (in case of full destruction of slope) assume 10 million €

The capitalised risk is $0.011 \cdot 10 \cdot 10^6 \cdot 18.25$ = 2 million €.

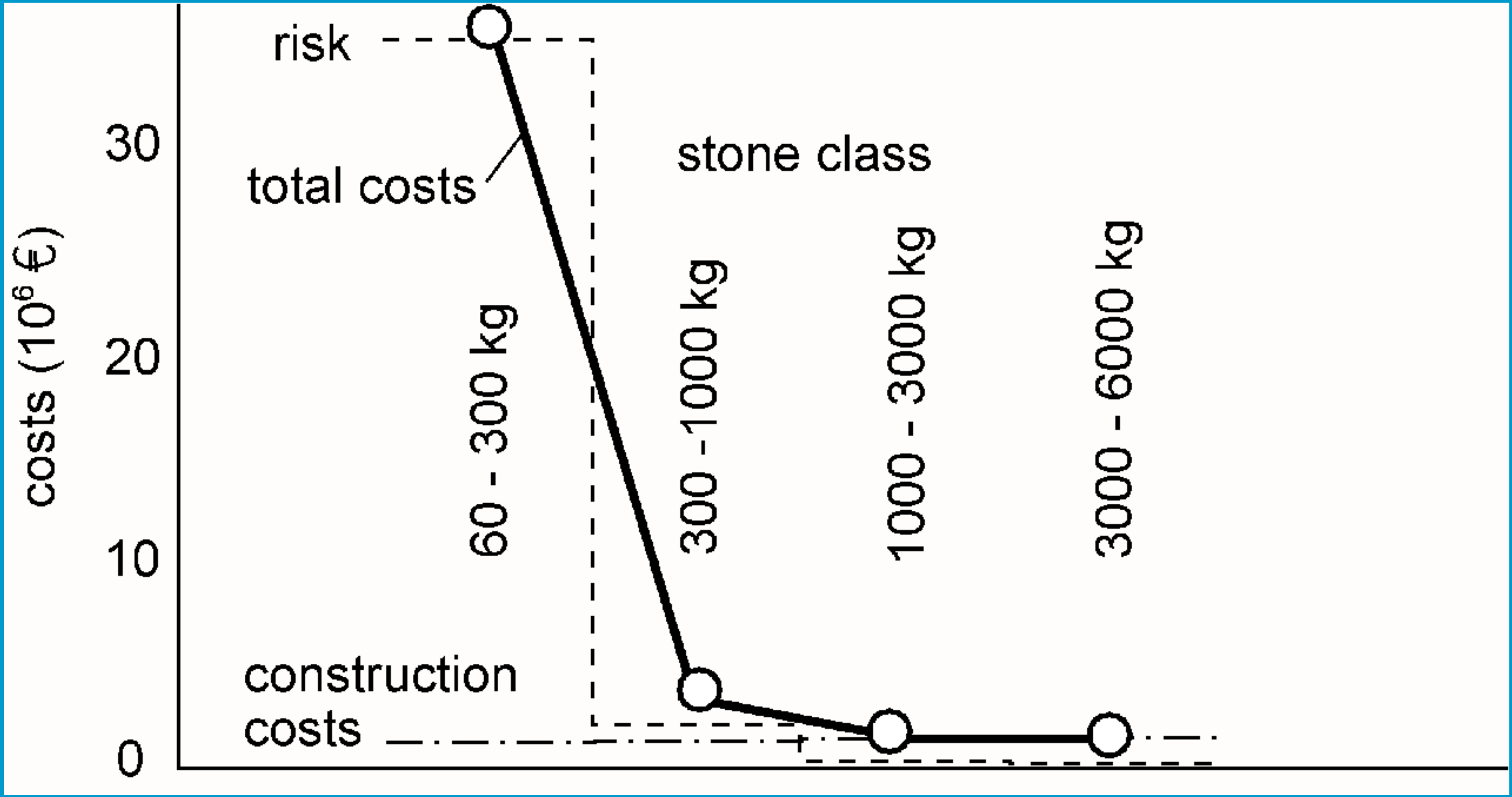
Armour layer (kg)	d_{n50} (m)	P_F per year (-)	P_F per 50 years (-)	Risk (10^6 €)
60 - 300	0.4	0.189	0.999	34.5
300 - 1000	0.6	0.011	0.42	2.0
1000 – 3000	0.85	0.001	0.049	0.18
3000 – 6000	1.1	0.00017	0.0085	0.03

construction costs

Armour layer (kg)	Cost per m^3 (€)	Volume (m^3)	Costs extra filter layer (10^6 €)	Costs (incl. extra filter) (10^6 €)	Total costs revetment (10^6 €)
60 - 300	20	4000	0	0.08	1.08
300 - 1000	24	6000	0	0.14	1.14
1000 – 3000	30	9000	0.02	0.27	1.27
3000 – 6000	36	11500	0.02	0.42	1.42

The differences in costs are small !!

comparison construction costs and risk

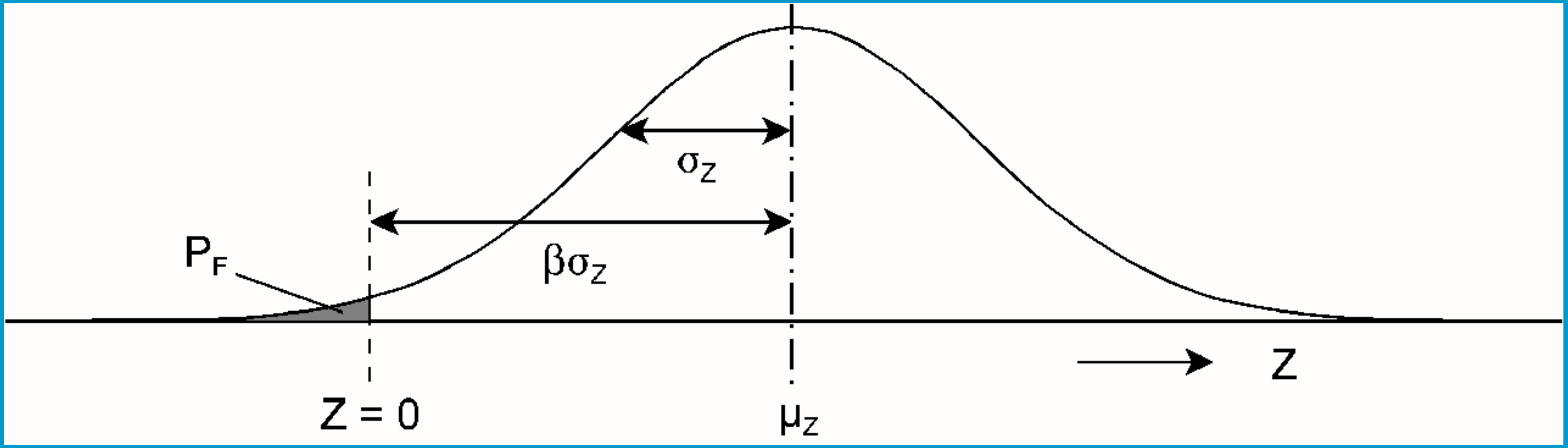


conclusion

Heavy revetments are in this case the best conclusion.

But: in case of no (expensive) building, result will be completely different

basics of level II approach



$$\beta = \frac{\mu_Z}{\sigma_Z}$$

level I approach

partial safety coefficients:

$$\gamma_i = \frac{\mu_i - \alpha_i \beta \sigma_i}{\mu_i}$$

evaluation of risk analysis

approximation using Poisson equation:

$$P = 1 - \exp(-f\,T)$$

in which:

P probability of occurence of an event one or more times in period T

T considered number of years

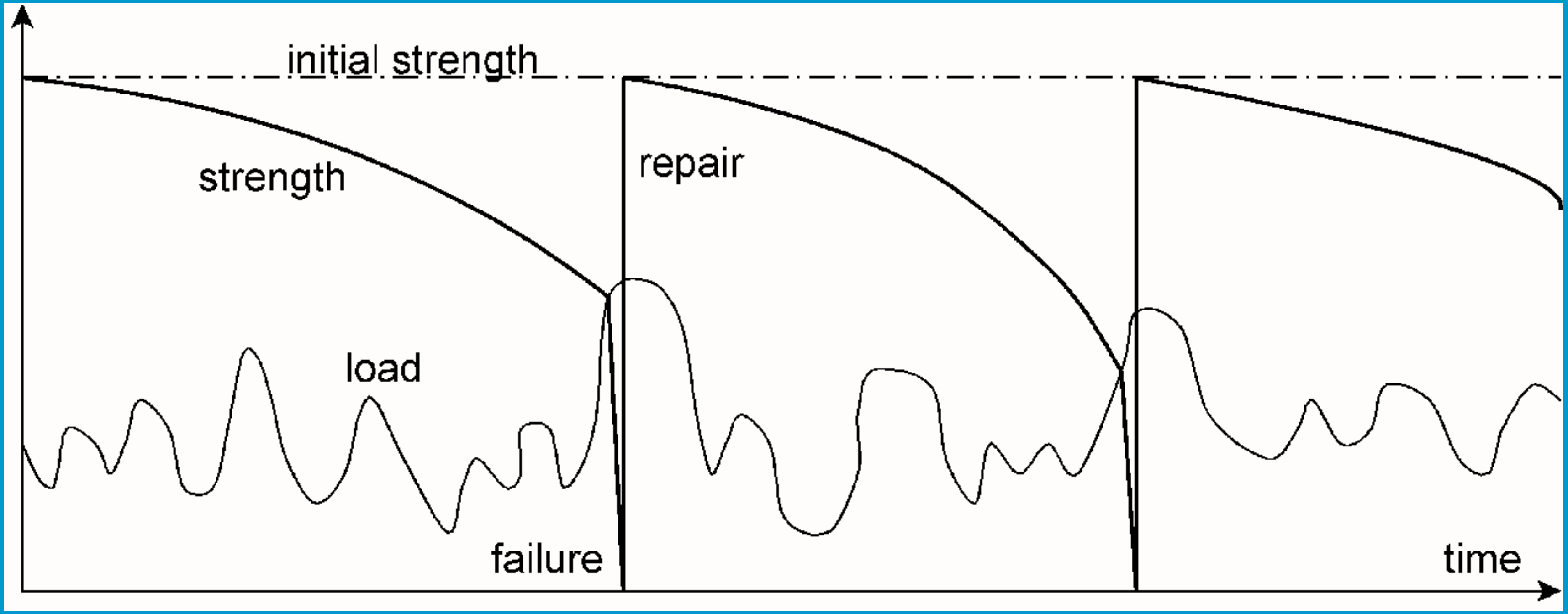
f average frequency of the event per year

So: if a probability of failure during the lifetime (50 years) of the building should be 5 % then f has to be 1/1000.

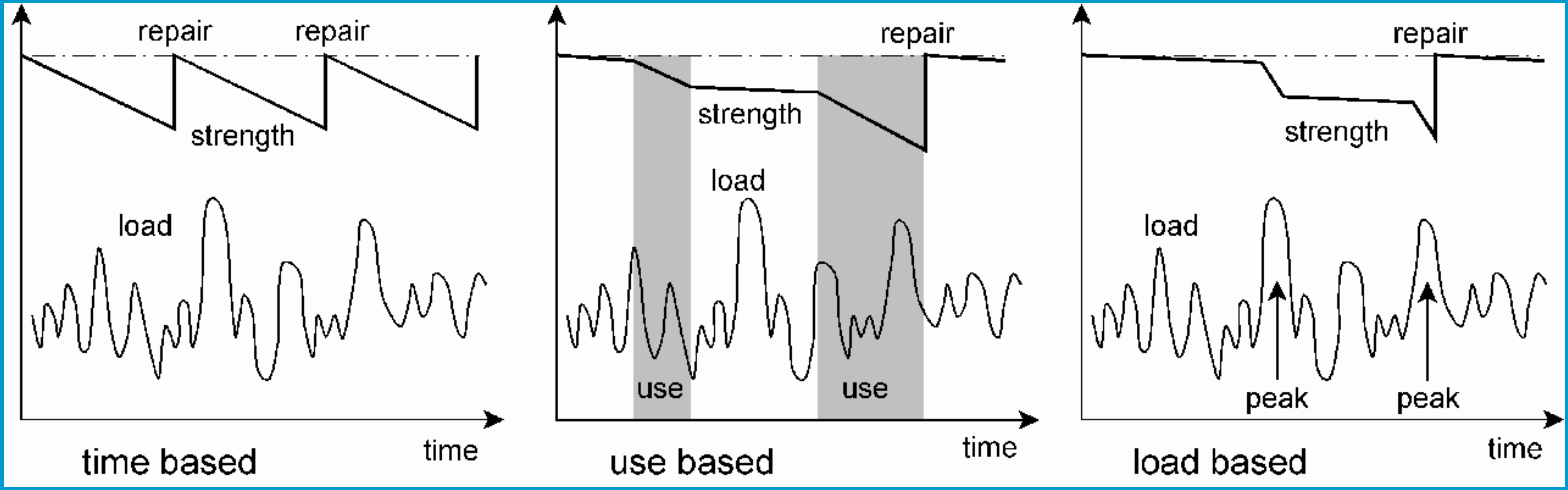
H_s 1/1000 is 2.8 m

Acc, to VanderMeer D_{n50} = 0.7, i.e. 1000-3000 kg

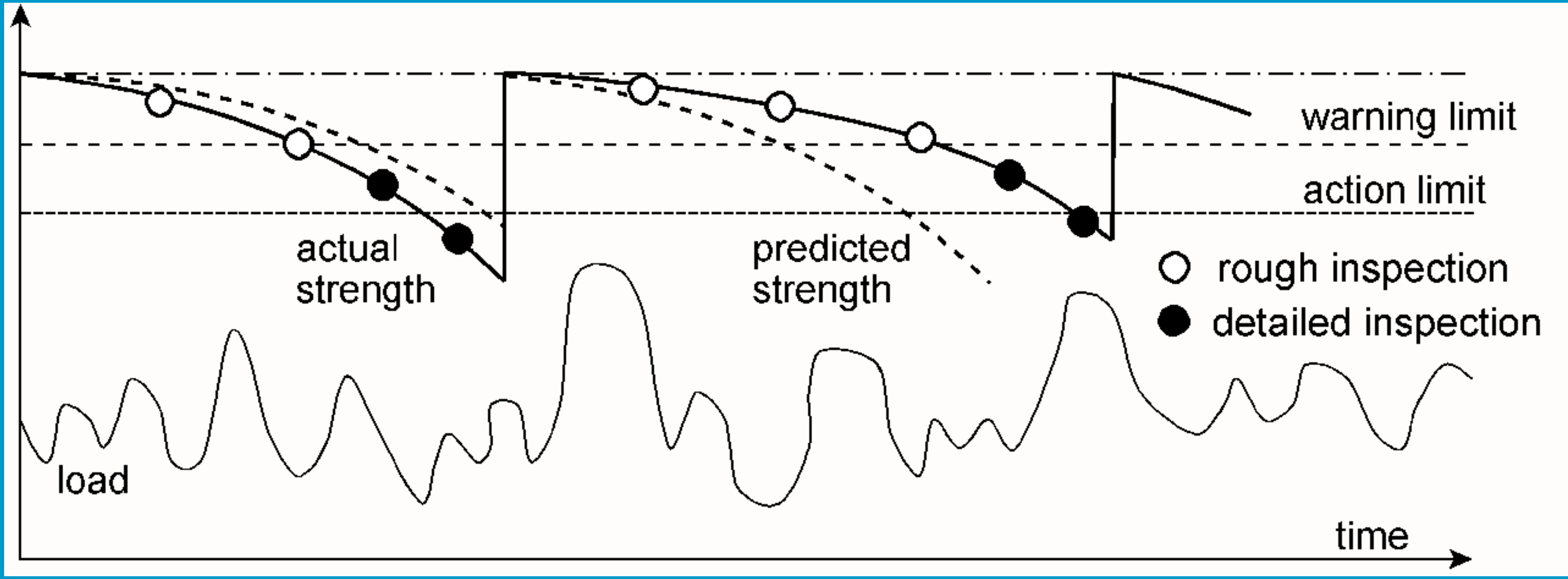
Failure based maintenance



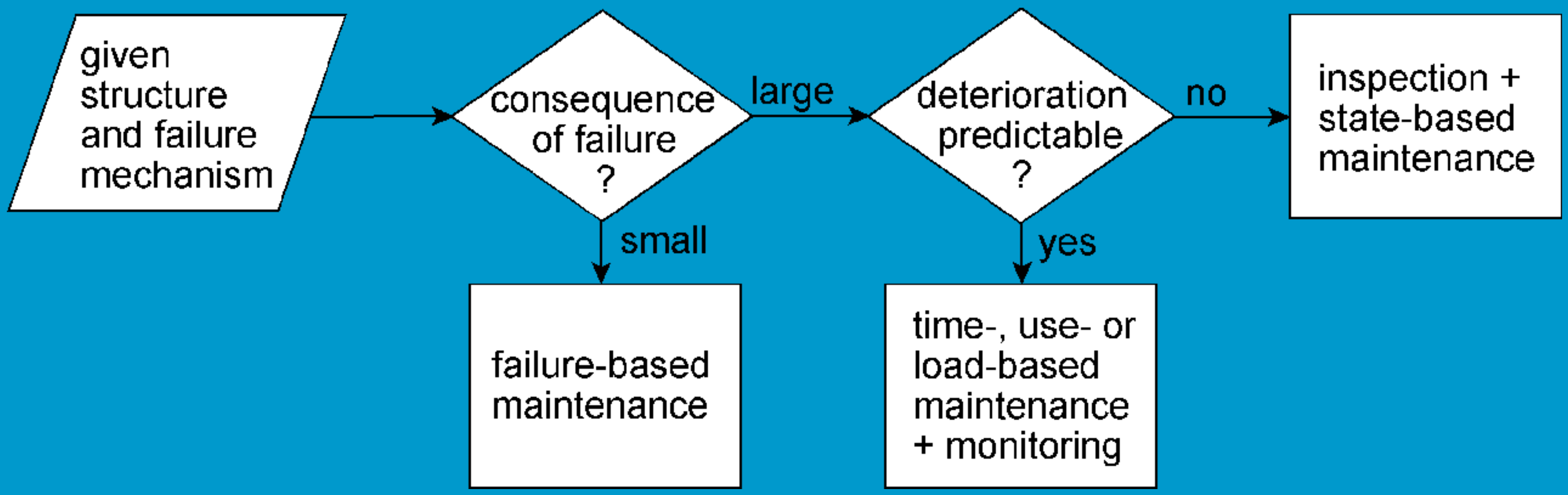
Time-, use-, or load-based maintenance



state based maintenance

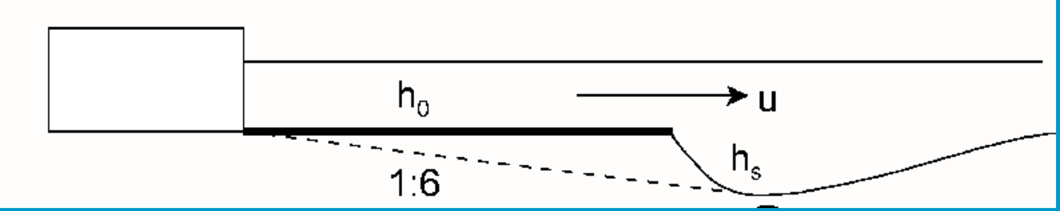


choice of a maintenance policy



Example of probabilistic maintenance

Outlet sluice:
In case $h_s > 8$m
emergency operation is needed



How frequently is sounding needed ??

Scouring function:

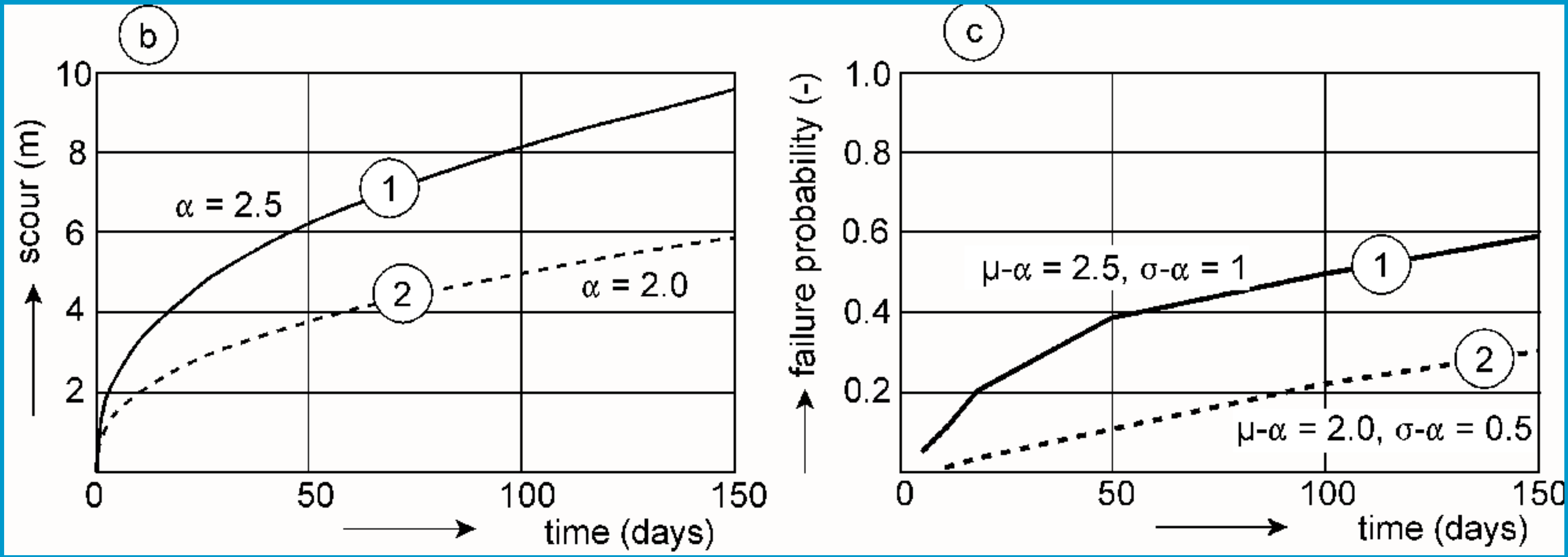
$$h_s(t) = \frac{(\alpha \bar{u} - \bar{u}_c)^{1.7} h_0^{0.2}}{10 \Delta^{0.7}} t^{0.4}$$

Z-function:

$$Z = h_{sc}(t) - \frac{(\alpha \bar{u} - \bar{u}_c)^{1.7} h_0^{0.2}}{10 \Delta^{0.7}} t^{0.4}$$

Parameter	α	u	u_c	h_0	Δ	h_{sc}
Mean (μ)	2.5	1 m/s	0.5 m/s	10 m	1.65	8
Deviation (σ)	1	0.1 m/s	0.05 m/s	0.25 m	0.05	2

failure probability of a scour hole



Deterministic calculation with two values for α

Assume α=2.5 then

h_s = 8m after 95 days

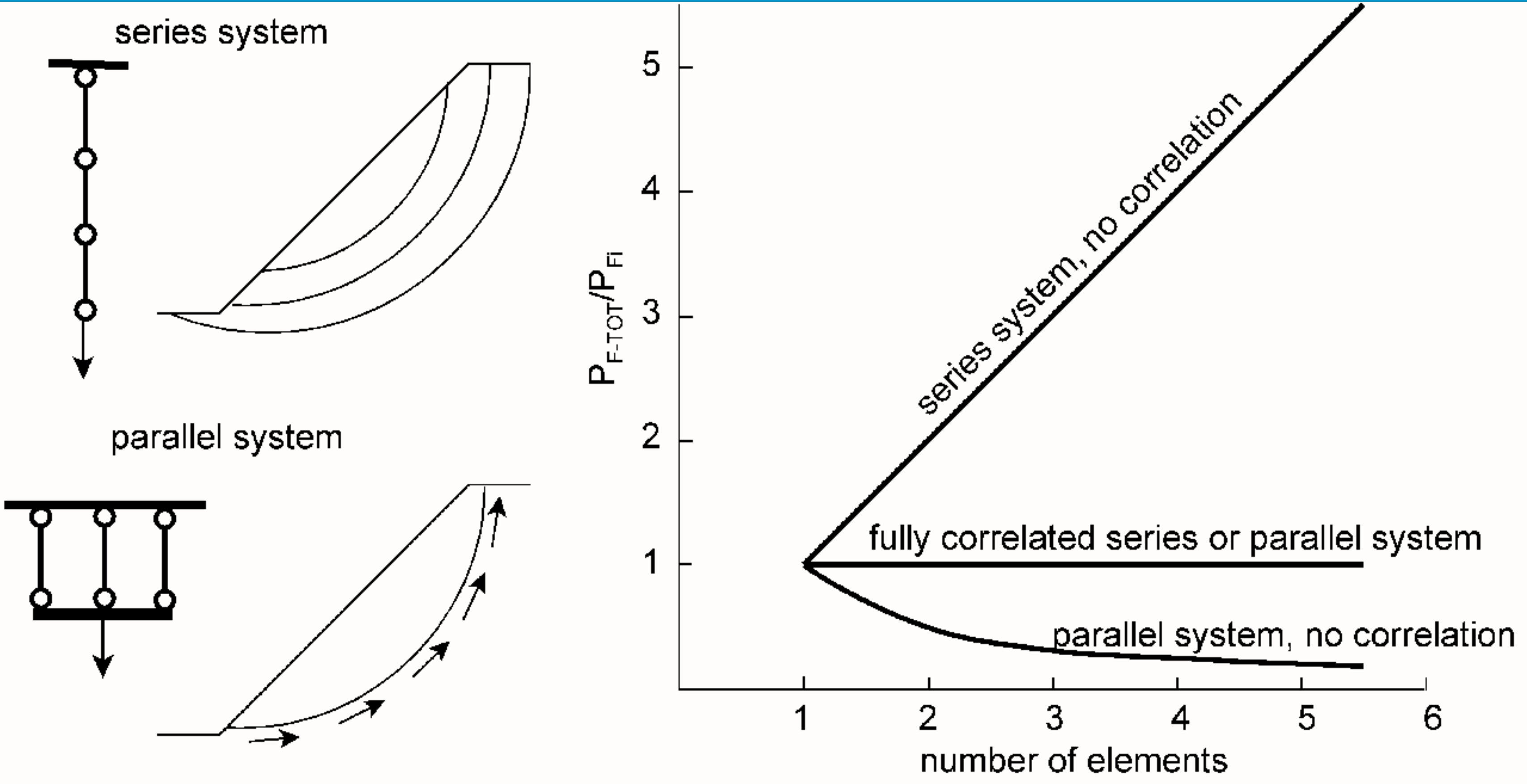
Probabilistic calculation:

50% probability that h_s = 8m after 95 days

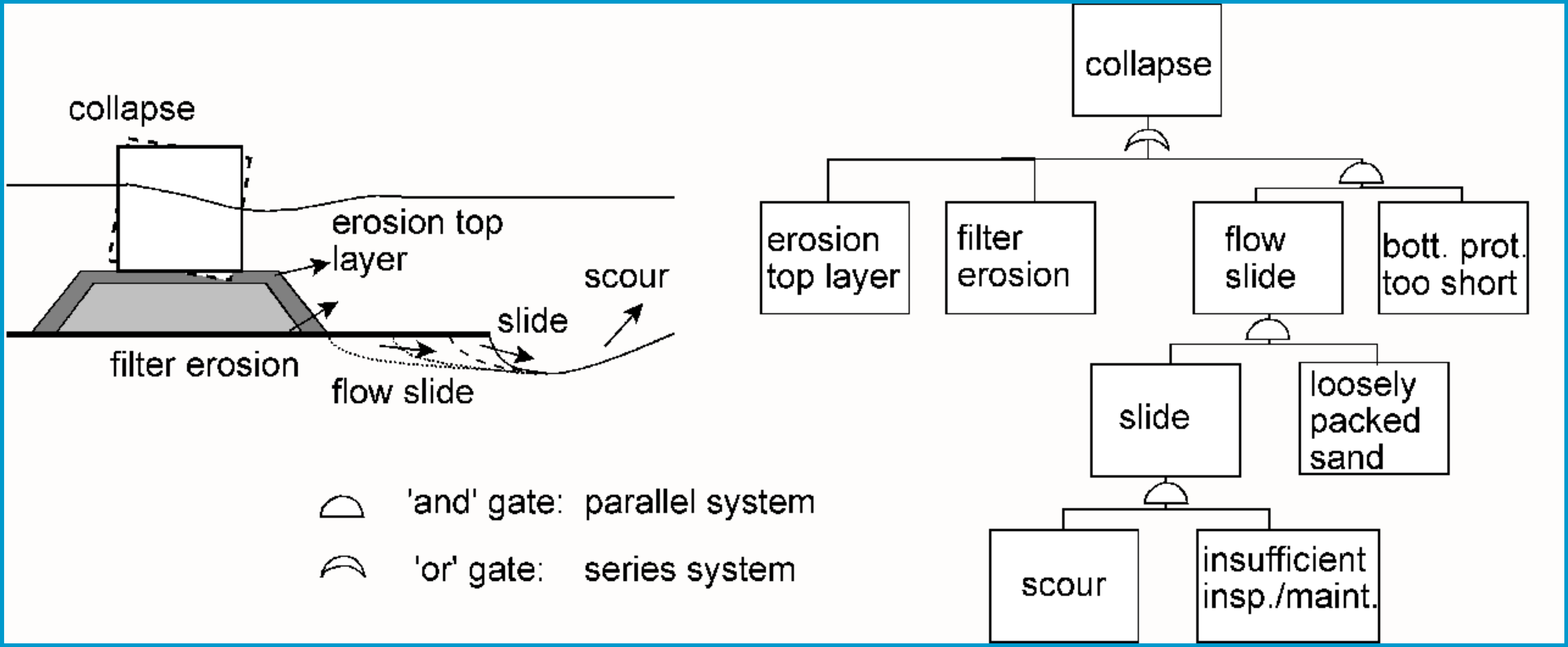
20% probability that h_s = 8m after 20 days

5% probability that h_s = 8m after 5 days

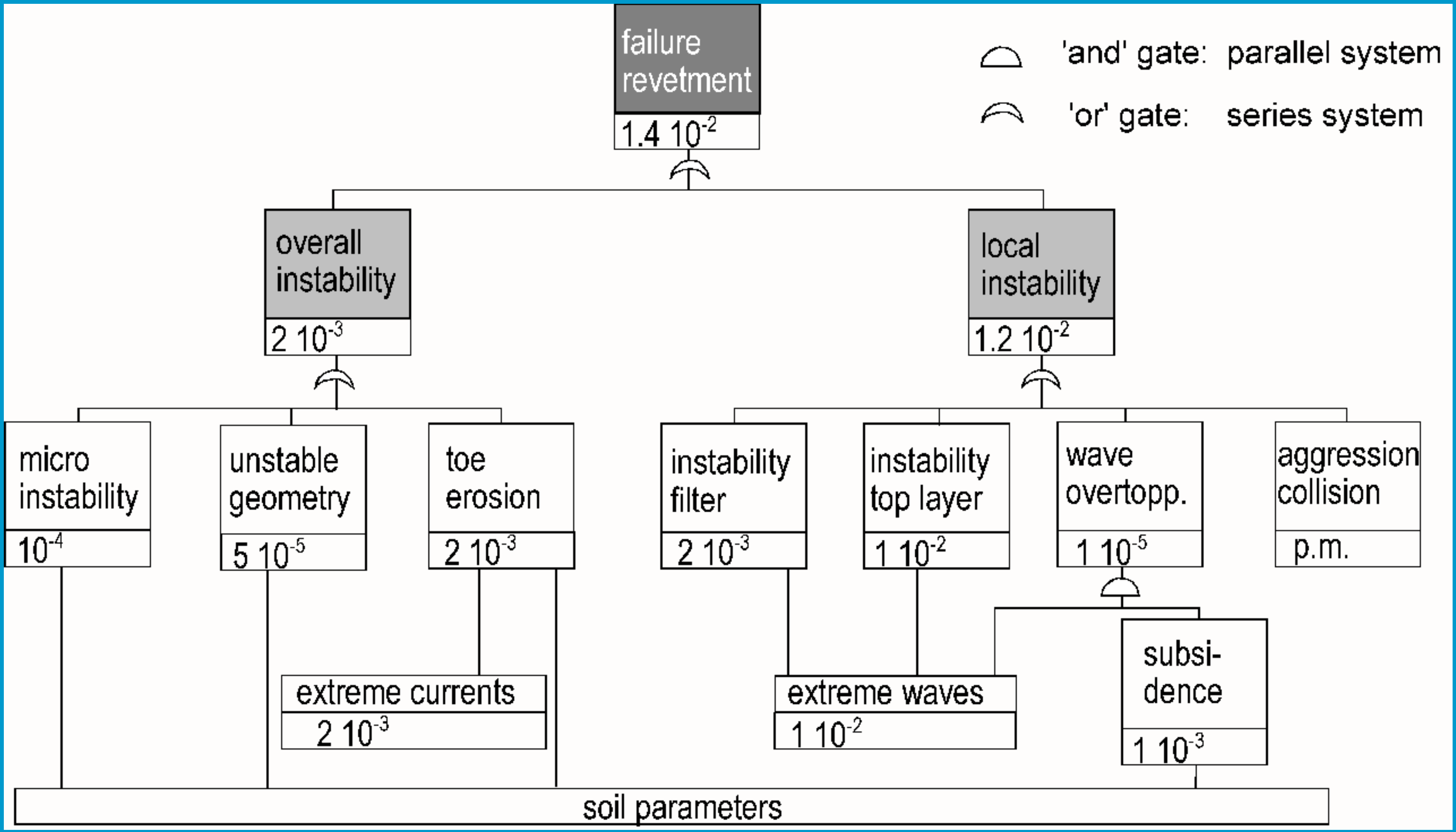
series and parallel systems



fault trees


collapse
erosion top
layer
scour
slide
filter erosion
flow slide
'and' gate: parallel system
'or' gate: series system
collapse
erosion
top layer
filter
erosion
flow
slide
bott. prot.
too short
slide
loosely
packed
sand
scour
insufficient
insp./maint.

fault tree of a revetment

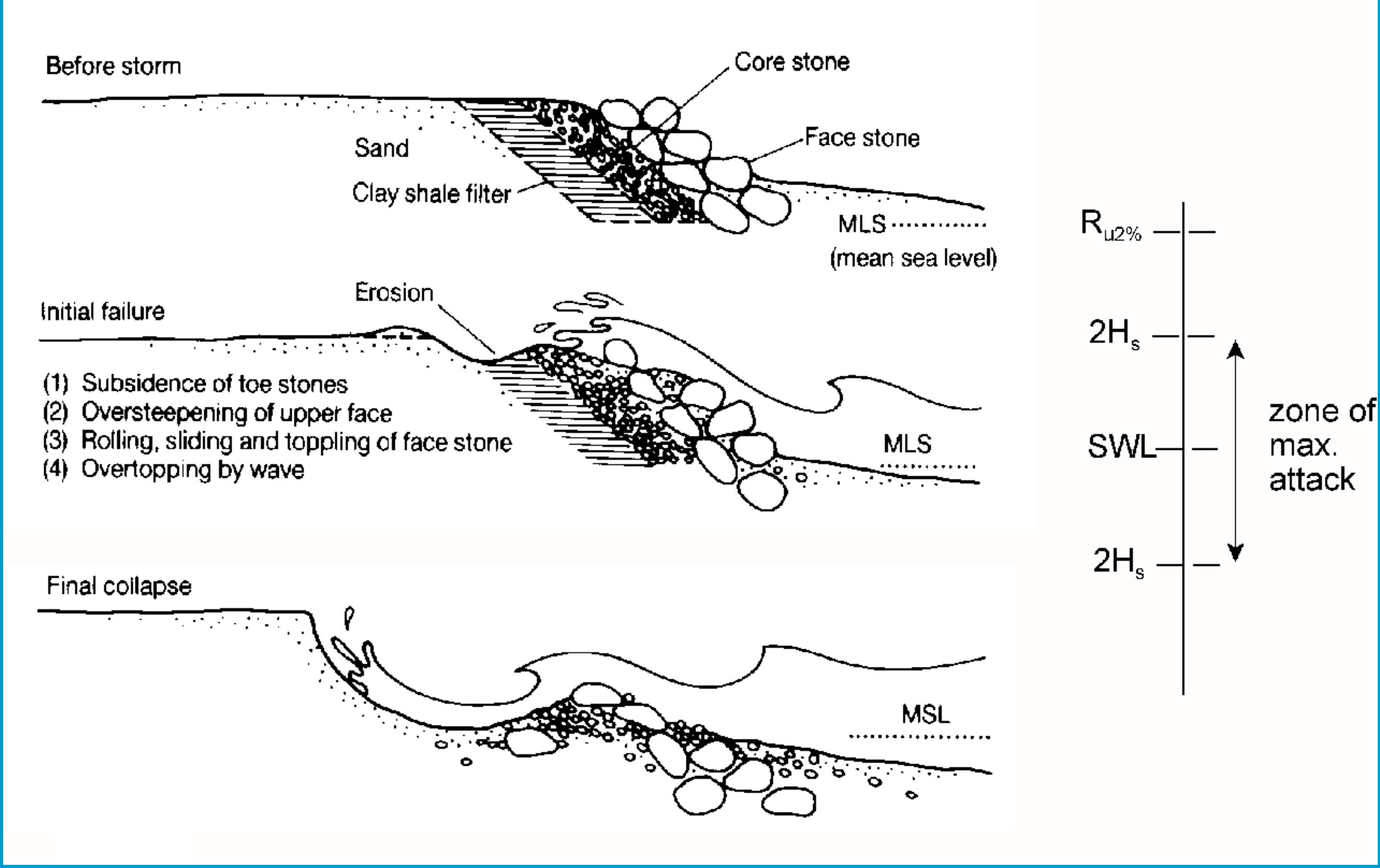


Resilient strength

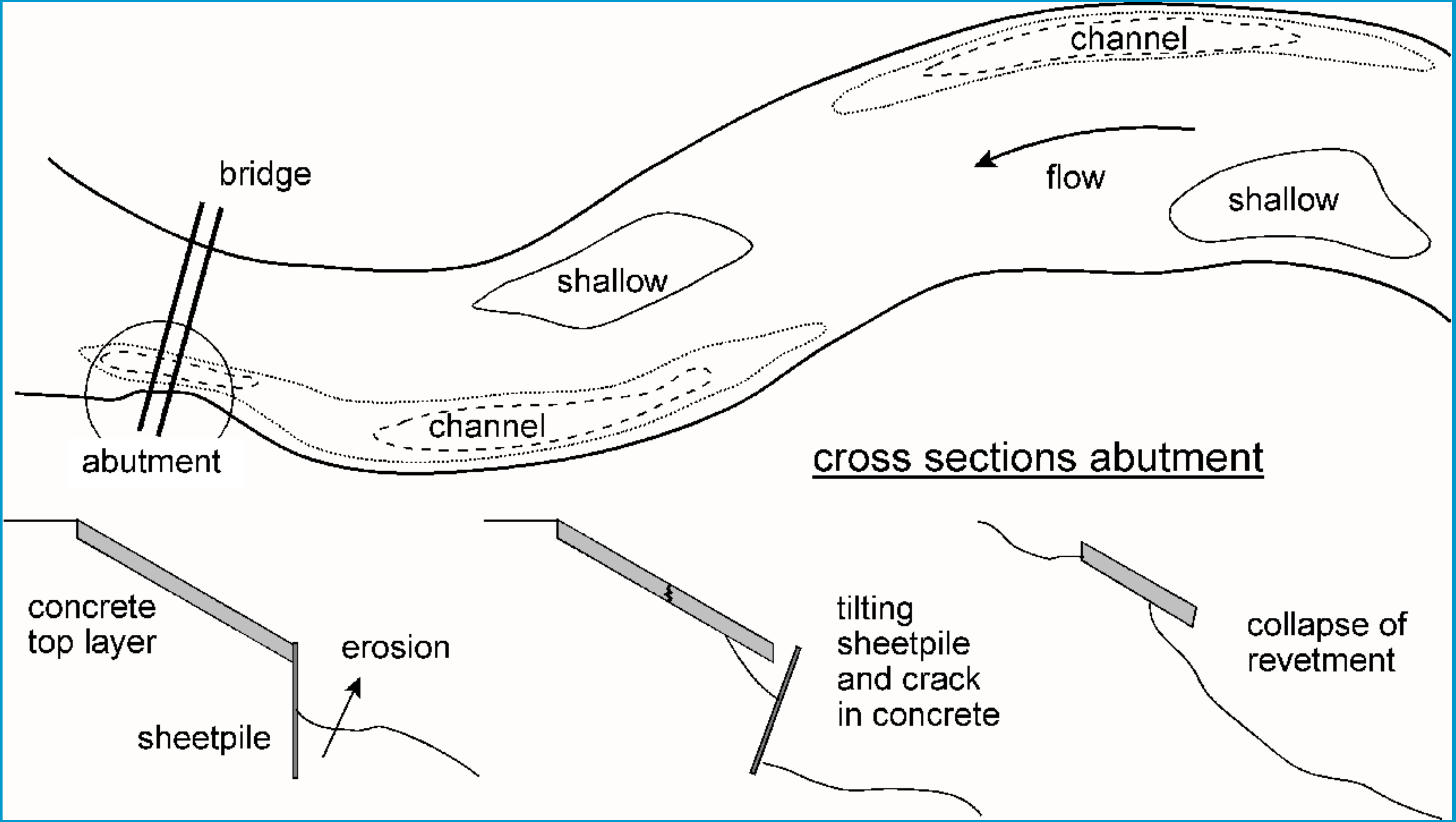
Failure of revetment +
failure of sublayer +
failure of core
= failure of dike

Resilient strength

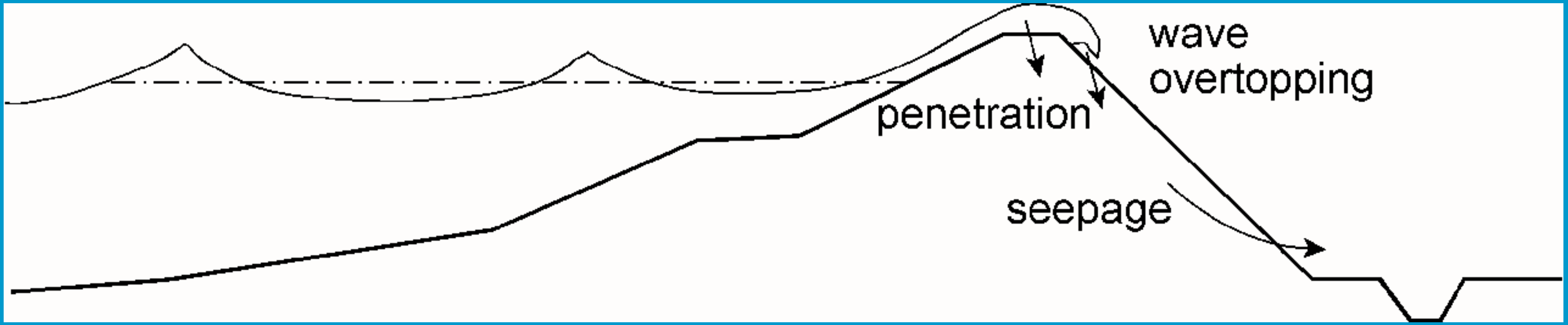
collapse due to wave overtopping



collapse due to toe erosion



collapse due to micro-instability



appendix
Probabilistic approach level II

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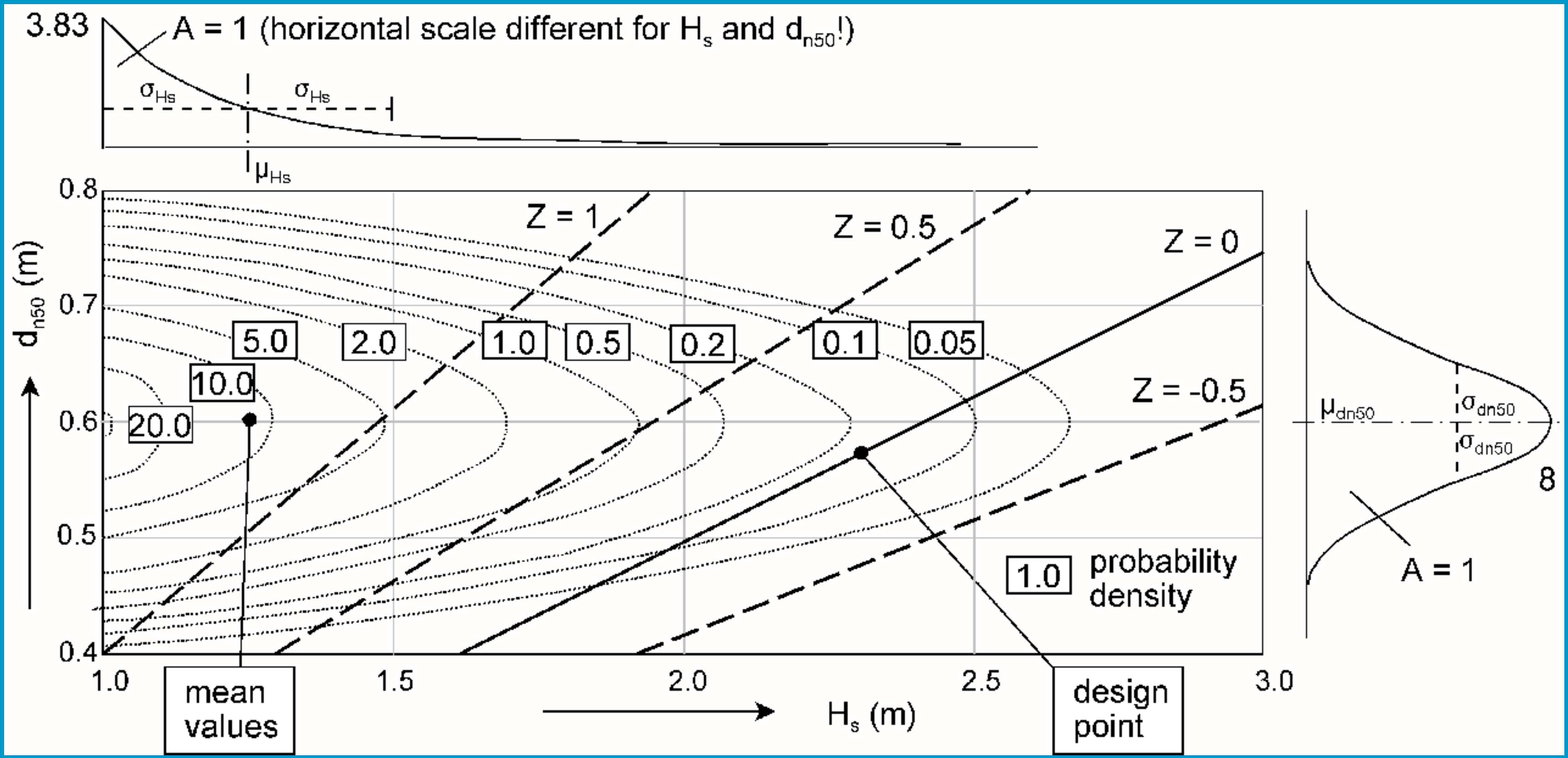
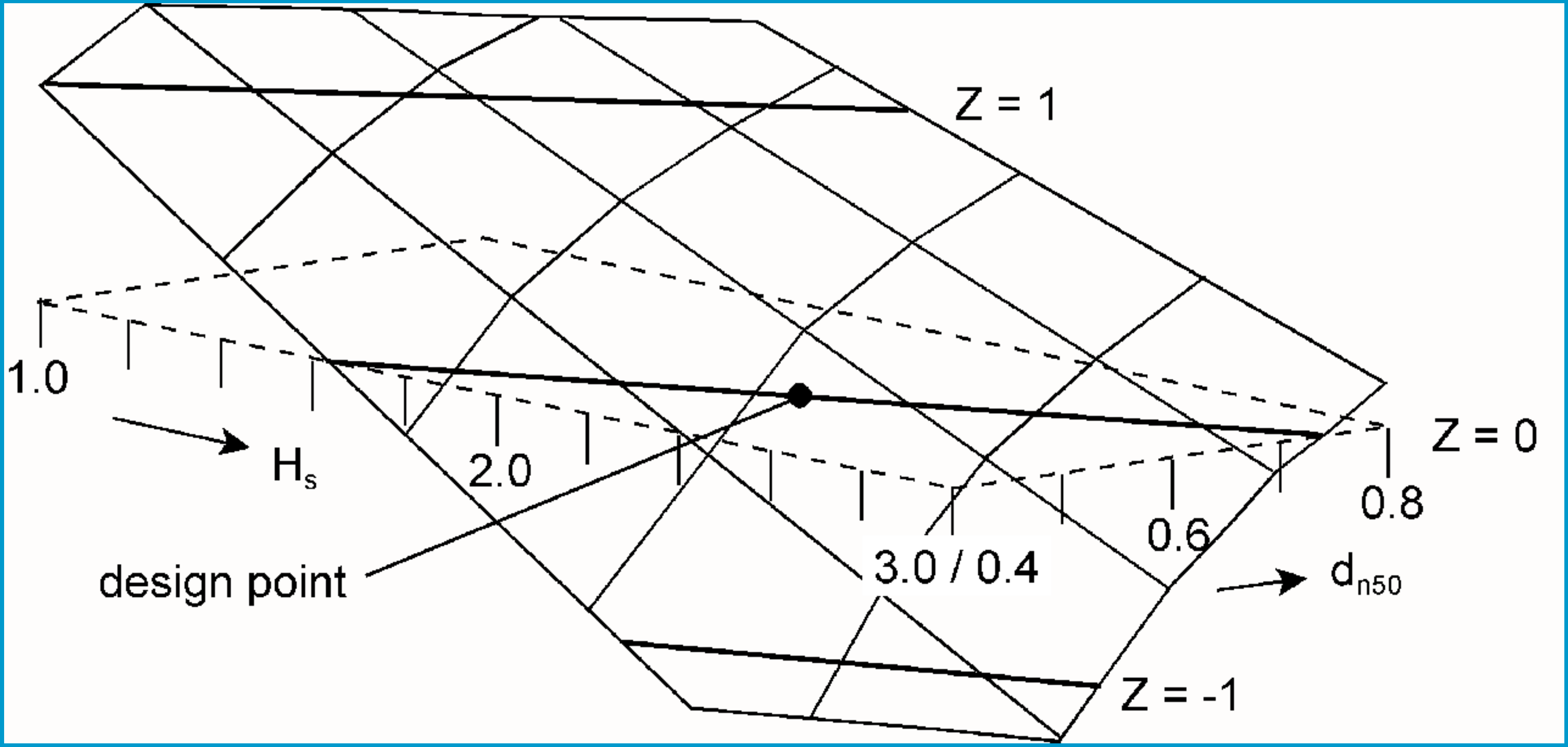
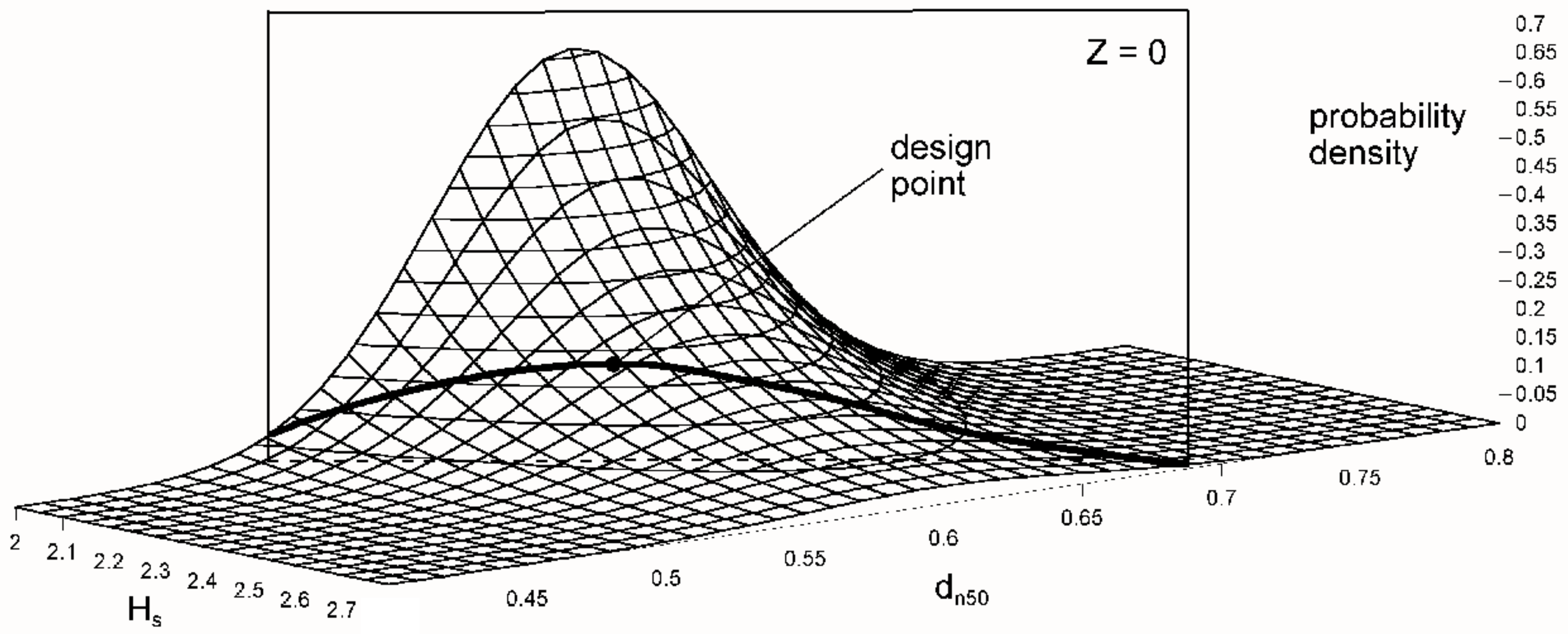
top view of probability mountain



3-d view of z function



3-d view of probability mountain



exponential distribution and substitute normal distribution