(7) A sequence of fine layers with greatly differing composition and/or mechanical properties may be considered as one stratum if the overall behaviour is relevant, and the behaviour can be adequately represented by ground parameters selected for the stratum.

(8) When deriving the boundary between different ground layers and the groundwater level, there may be interpolated linearly between the investigation points provided the spacing is sufficiently small and the geological conditions are sufficiently homogeneous. Such application of linear interpolations and their justification should be reported.

6.4 Establishment of derived values

(1)P If correlations have been used to derive geotechnical parameters or coefficients, the correlations and their applicability shall be documented.

Annex A
(informative)

List of test results of geotechnical test standards

(1) In Table A.1, field and laboratory tests are listed together with the respective test results which should be presented in the Ground Investigation Report (if applicable).

Table A.1 — List of test results of geotechnical standards

Field test [a]	**Test results**
CPT	– Cone penetration resistance (q_c) – Local unit side friction (f_s) – Friction ratio (R_f)
CPTU	– Corrected cone resistance (q_t) – Local unit side friction (f_s) – Measured pore pressure (u)
Dynamic probing	– Number of blows N_{10} for the following tests: DPL, DPM, DPH – Number of blows (N_{10}) or (N_{20}) for the DPSH test
SPT	– Number of blows N – Energy correction E_r – Soil description
Ménard pressuremeter test	– Pressuremeter modulus (E_M) – Creep pressure (p_f) – Limit pressure (p_{LM}) – Expansion curve
Flexible dilatometer test	– Dilatometer modulus (E_{FDT}) – Deformation curve
All other pressuremeter tests	– Expansion curve
Field vane test	– Undrained shear strength (uncorrected) (c_{fv}) – Remoulded undrained shear strength (c_{rv}) – Torque-rotation curve

Weight sounding test	– Continuous record of weight sounding resistance
	– Weight sounding resistance is:
	  – either the penetration depth for a standard load;
	  – or the number of half-turns required for every 0,2 m penetration, at the standard load of 1 kN

Plate loading test	– Ultimate contact pressure (p_u)
Flat dilatometer test	– Corrected lift-off pressure (p_0) – Corrected expansion pressure (p_1) at 1,1 mm – Dilatometer modulus E_{DMT}, material index (I_{DMT}) and horizontal stress index (K_{DMT})

Table A.1 (*continued*)

Laboratory test [b]	**Test results**
Water content (soil)	– Value of (w)
Bulk mass density (soil)	– Value of (ρ)
Particle mass density (soil)	– Value of (ρ_s)
Particle size distribution (soil)	– Grain size distribution curve
Consistency limits (soil)	– Plastic and liquid limit values (w_P), (w_L)
Density index (soil)	– Values of e_{max}, e_{min} and I_D
Organic content (soil)	– AC⟩ Loss on ignition ⟨AC (C_{OM})
Carbonate content (soil)	– Value of carbonate content (C_{CaCO3})
Sulfate content (soil)	– Value of sulfate content ($C_{SO4}{}^{2-}$) or ($C_{SO3}{}^{2-}$)
Chlorite content (soil)	– Value of chlorite content (C_{Cl})
pH (soil)	– Value of pH
Compressibility oedometer (soil)	– Compressibility curve (different options) – Consolidation curves (different options) – Secondary compression curve (creep curve) – Values of E_{oed} (stress interval) and σ'_p or C_s, C_c, σ'_p – Value of C_α
Laboratory vane (soil)	– Value of strength index (c_u)
Fall cone (soil)	– Value of strength index (c_u)
Unconfined compression (soil)	– Value of strength index $q_u = 2c_u$
Unconsolidated undrained compression (soil)	– Value of undrained shear strength (c_u)
Consolidated triaxial compression (soil)	– Stress-strain curve(s) and pore pressure curve – Stress paths – Mohr circles – c', φ' or c_u – Variations of c_u with σ'_c – Deformation parameter(s) (E') or (E_u)
Consolidated direct shear box (soil)	– Stress-displacement curve – τ–σ diagram – c', φ' – Residual parameters

Table A.1 (*continued*)

Laboratory test [b]	Test results
California bearing ratio (soil)	– Value of the CBR index (I_{CBR})
Permeability (soil)	– Value of the coefficient of permeability (k): – from direct laboratory permeability test – from field permeability tests – from oedometer test
Water content (rock)	– Value of w
Density and porosity (rock)	– Value of ρ and n
Swelling (rock)	– Swelling Strain Index – Swelling pressure – Free swell – Swell under constant load
Uniaxial compression and deformability (rock)	– Value of σ_C – Value of deformation modulus (E) – Value of Poisson's ratio (ν)
Point-load test (rock)	– Strength index I_{s50}
Direct shear test (rock)	– Stress-displacement curve – Mohr diagram – c', φ' – Residual parameters
Brazil test (rock)	– Tensile strength (σ_T)
Triaxial compression test (rock)	– Stress-strain curve(s) – Stress paths – Mohr circles – c', φ' – Values of deformation modulus (E) and Poisson's ratio (ν)

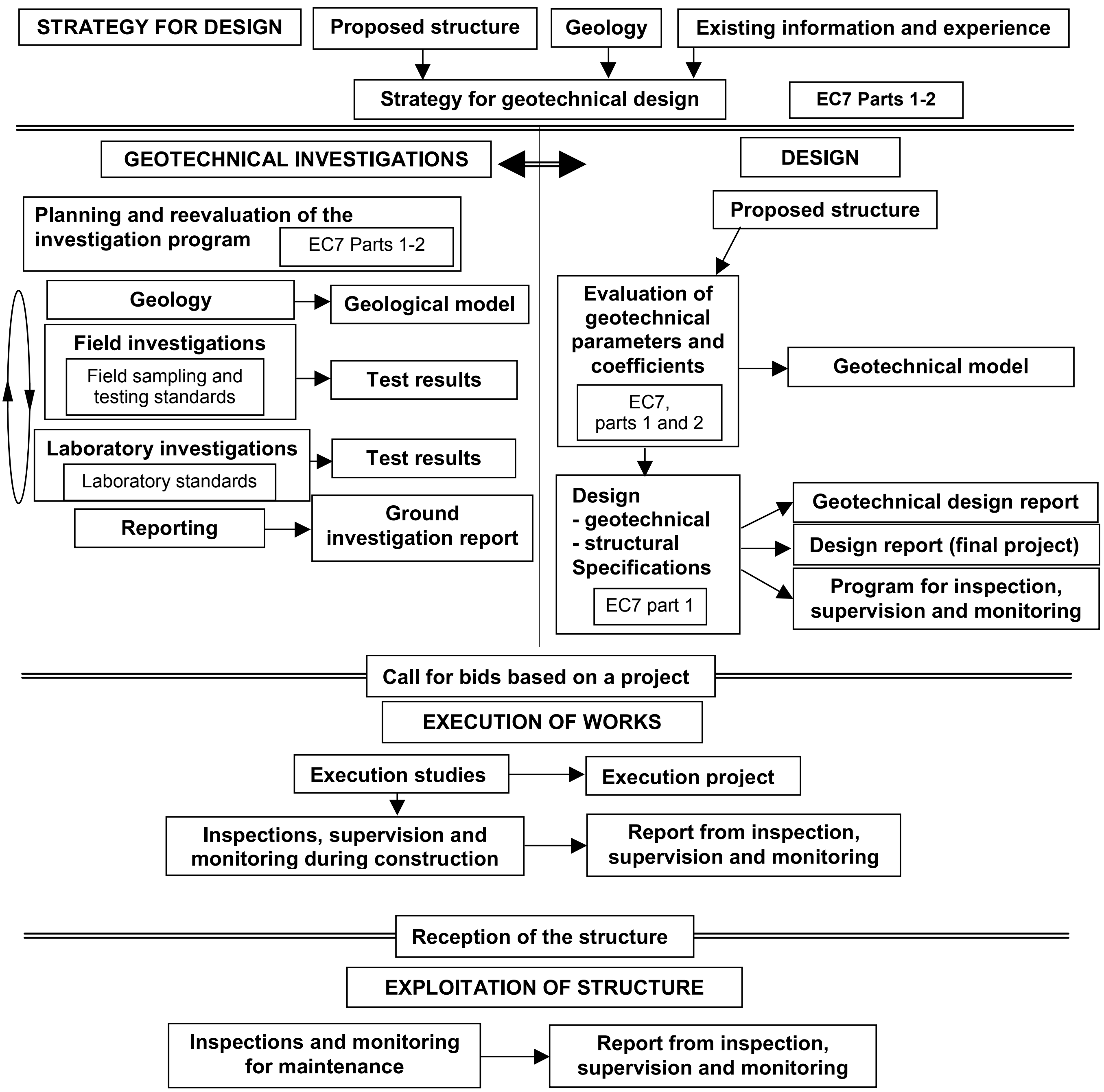
[a] See Section 4.

[b] See Section 5.

Annex B
(informative)

Planning of geotechnical investigations

B.1 Stages of ground investigations in geotechnical design, execution of works and exploitation of the structure



B.2 Selection of ground investigation methods in different stages

Table B.1 — Example of the selection of ground investigation methods in different stages

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<table>
<tr><th colspan="2">Preliminary investigations</th><th colspan="3">Design investigations</th><th colspan="2">Control investigations</th></tr>
<tr><td rowspan="5">Desk study of topographical, historical, geological and hydrogeological maps

Mineral extraction

Aerial photo-interpretation

Archives of previous construction works and investigations

Site inspection

Preliminary geophysical surveys

Preliminary intrusive investigations</td><td rowspan="5">Fine soil
CPT, SS, DP, SE
FVT or SPT

OS TP, PS, OS

GW

Coarse soil
SS, CPT, DP, SR
SPT

AS, OS, TP

GW

Rock
SR, CPT, MWD
PLT

CS, AS, TP

GW</td><td rowspan="5">Preliminary choice of foundation method
Preliminary choice of foundation method
Preliminary choice of foundation method</td><td>Pile foundation</td><td>SS, CPT, DP, SR
FVT, SPT, PIL
PS, OS, CS, PMT
GWC</td><td rowspan="5">Verification of choice of foundation method and design procedure, control of ground improvement works and stability during construction</td><td>PIL, Pile driving tests, Stress wave measurements
GWC, settlements, Inclinometers</td></tr>
<tr><td>Shallow foundation</td><td>SS or CPT, DP
FVT, DMT or PMT, BJT
PS, OS, CS, TP
GWC</td><td>Check of the soil type
Check of the stiffness (CPT) Settlements, Inclinometers,
GWC
Volume change potential due to water content change</td></tr>
<tr><td>Pile foundation</td><td>CPT, DP, SR
SPT, DMT, PIL
OS,, TP
GWO</td><td>PIL, Pile driving tests
Stress wave measurements GWC, settlements
Inclinometers</td></tr>
<tr><td>Shallow foundation</td><td>CPT,DP
SPT, PMT, BJT, DMT, PLT
OS, TP
GWO</td><td>Check of the soil type
Check of the stiffness (CPT, DP, SPT)
Settlements</td></tr>
<tr><td>Pile or shallow foundation</td><td>SR, MWD, mapping of discontinuities
RDT, PMT, BJT
TP, CS
GWO</td><td>Check inclination and discontinuities in the rock and its surface
Check contact between pile toe/ foundation and rock surface
Verify water conditions of flow and pressure</td></tr>
</table>

Table B.1 (*continued*)

Abbreviations		
Field testing		**Sampling**
BJT	Borehole jack test	PS Piston sampler
DP	Dynamic probing	CS Core sampler
SR	Soil/rock sounding	AS Auger sampler
SS	Static sounding (e,g, weight sounding test, WST)	OS Open sampler
CPT(U)	Cone penetration test (with pore pressure recording)	TP Test pit sampling
SPT	Standard penetration test	
PMT	Pressuremeter test	
DMT	Dilatometer test	**Groundwater measurements**
FVT	Field vane test	GW Groundwater measurements
PLT	Plate load test	GWO Groundwater measurements with open system
MWD	Measuring while drilling	GWC Groundwater measurements with closed system
SE	Seismic measurements	
PIL	Pile load test	
RDT	Rock dilatometer test	
	Notes: Soils include naturally deposited and anthropogenic deposits Surveying and logging are not included in this chart Laboratory tests are not presented on this table	

AC

B.3 examples of recommendations for the spacing and depth of investigations

(1) The following spacing of investigation points should be used as guidance:

- for high-rise and industrial structures, a grid pattern with points at 15 m to 40 m distance;
- for large-area structures, a grid pattern with points at not more than 60 m distance;
- for linear structures (roads, railways, channels, pipelines, dikes, tunnels, retaining walls), a spacing of 20 m to 200 m;
- for special structures (e.g. bridges, stacks, machinery foundations), two to six investigation points per foundation;
- for dams and weirs, 25 m to 75 m distance, along relevant sections.

(2) For the investigation depth z_a the following values should be used as guidance. (The reference level for z_a is the lowest point of the foundation of the structure or structural element, or the excavation base.) Where more than one alternative is specified for establishing z_a, the one which yields the largest value should be applied.

NOTE For very large or highly complex projects, some of the investigation points generally extend to greater depths than those specified under B.3 (5) to B.3 (13).

(3) Greater investigation depths should always be selected, where unfavourable geological conditions, such as weak or compressible strata below strata of higher bearing capacity, are presumed.

(4) Where structures under B.3 (5) to B.3 (8) and B.3 (13) are built on competent strata, the depth of investigation can be reduced to $z_a = 2$ m, unless the geology is indistinct, in which case at least one borehole should be taken down to a minimum of $z_a = 5$ m. If a bedrock formation is encountered at the proposed base of the structure, this should be taken as the reference level for z_a. Otherwise, z_a refers to the surface of the bedrock formation.

(5) For high-rise structures and civil engineering projects, the larger value of the following conditions should be applied (see Figure B.1 a)):

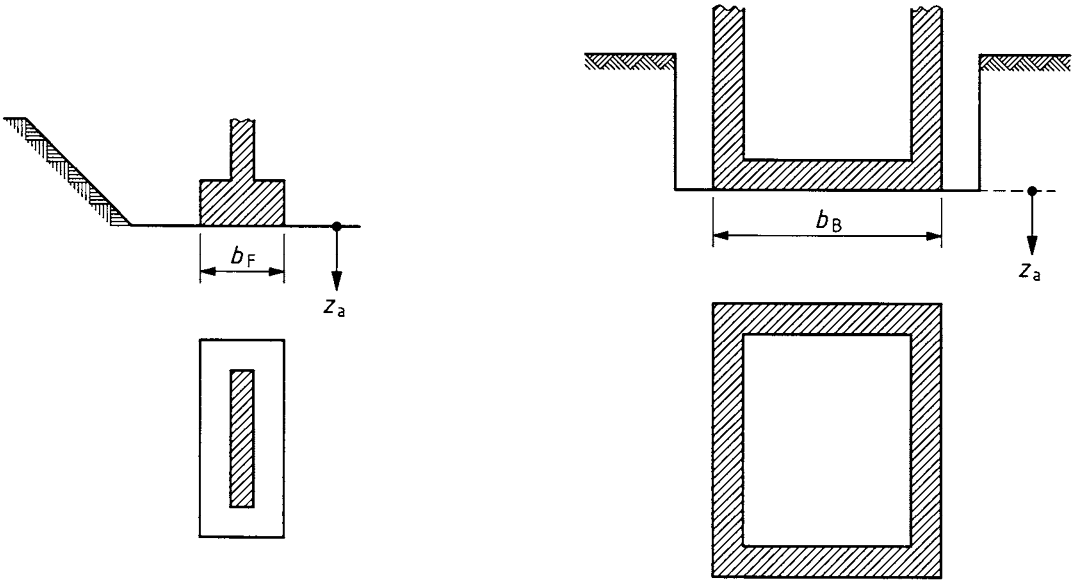
- $z_a \geq 6$ m;
- $z_a \geq 3{,}0 b_F$.

where b_F is the smaller side length of the foundation.

(6) For raft foundations and structures with several foundation elements whose effects in deeper strata are superimposed on each other:

$$z_a \geq 1{,}5 \cdot b_B$$

where b_B is the smaller side of the structure, (see Fig. B.1 b)).



a) foundation b) structure

Figure B.1 — High-rise structures, civil engineering projects

(7) Embankments and cuttings, the larger value of the following conditions should be met (see Figure B.2):

a) embankment b) cutting

Figure B.2 — Embankments and cuttings

a) For dams:

- $0{,}8h < z_a < 1{,}2h$
- $z_a \geq 6$ m

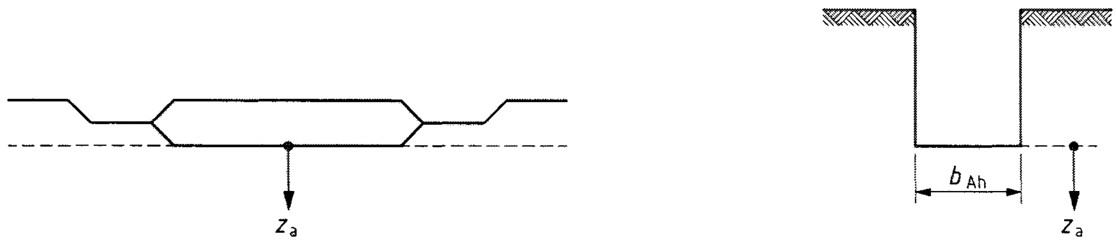
where h is the embankment height.

b) For cuttings:

- $z_a \geq 2{,}0$ m
- $z_a \geq 0{,}4h$

where h is the dam height or depth of cutting.

(8) Linear structures, the larger value of the following conditions should be met (see Figure B.3):



a) road

b) trench

Figure B.3 — Linear structures

a) For roads and airfields:

$z_a \geq 2$ m below the proposed formation level.

b) For trenches and pipelines, the larger value of:

- $z_a \geq 2$ m below the invert level;
- $z_a \geq 1{,}5 b_{Ah}$

where b_{Ah} is the width of excavation.

c) Where relevant, the recommendations for embankments and cuttings should be followed.

(9) For small tunnels and caverns, (see Figure B.4):

$b_{Ab} < z_a < 2{,}0 b_{Ab}$

where b_{Ab} is the width of excavation.

The groundwater conditions described in (10) b) should also be taken into account.

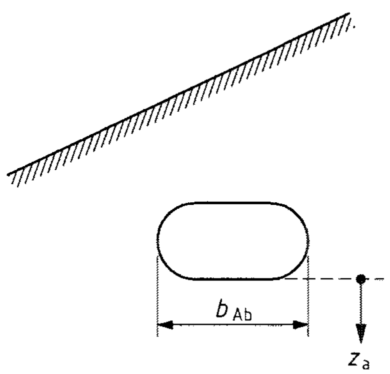


Figure B.4 — Tunnels and caverns

(10) Excavations (see Figure B.5).

a) Where the piezometric surface and the groundwater tables are below the excavation base, the larger value of the following conditions should be met:

- $z_a \geq 0{,}4h$
- $z_a \geq (t + 2{,}0)$ m

where
t is the embedded length of the support; and
h is the excavation depth.

b) Where the piezometric surface and the groundwater tables are above the excavation base, the larger value of the following conditions should be met:

- $z_a \geq (1{,}0H + 2{,}0)$ m
- $z_a \geq (t + 2{,}0)$ m

where
H is the height of the groundwater level above the excavation base; and
t is the embedded length of the support.

AC If no stratum of low permeability is encountered AC down to these depths:
$z_a \geq t + 5$ m.

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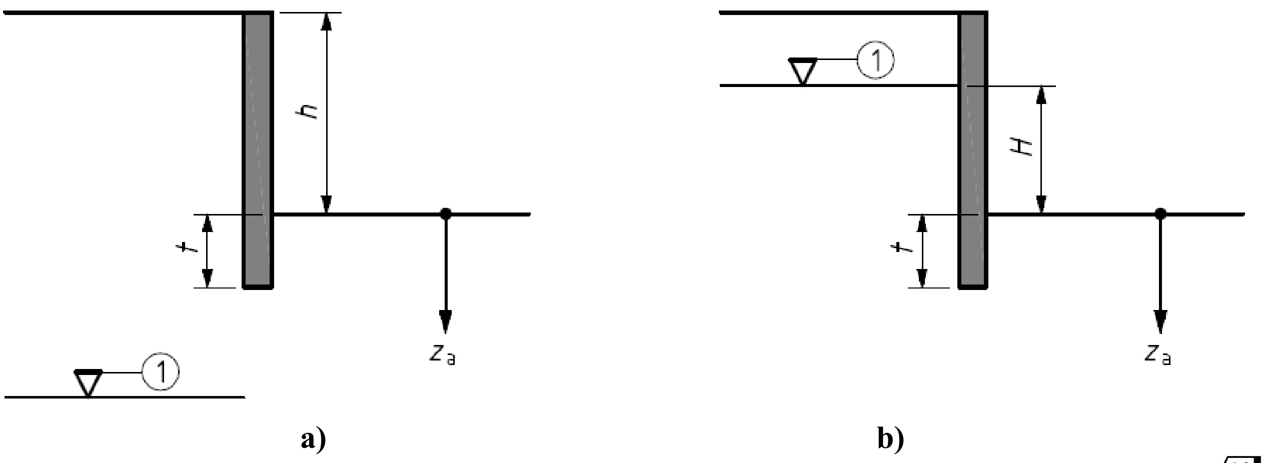

AC

Key

1 groundwater

Figure B.5 — Excavations

(11) For water-retaining structures, z_a should be specified as a function of the proposed level of impounded water, the hydrogeological conditions and the construction method.

(12) For cut-off walls (see Figure B.6):

- $z_a \geq 2$ m below the surface of the stratum impermeable to groundwater.