1 General Recommendations

1.1 Engineering requirements for applying the Recommendations (R l)

If no other stipulations are explicitly made in the individual Recommendations, they shall apply under the following engineering preconditions:

1. The complete height of the retaining wall is lined.
2. The soldier piles of soldier pile walls are installed so that intimate contact with the ground is ensured. The infilling or lining can consist of wood, concrete, steel, hardened cement-bentonite suspension or stabilised soil. It shall be installed so that the contact to the soil is as uniform as possible. Soil excavation should not advance considerably faster than piling advance.
3. Sheet pile walls and trench sheet piles are installed so that intimate contact with the ground is ensured. Toe reinforcement is permitted.
4. In-situ concrete walls are executed as diaphragm walls or as bored pile walls. See DIN 1538 for execution of diaphragm walls. For bored pile walls proceed according to DIN EN 1536. Accidental or planned spacing between the piles is generally lined according to Paragraph 2.
5. In the horizontal projection, struts or anchors are arranged perpendicular to the retaining wall. They are wedged or prestressed so that contact by traction with the retaining wall is guaranteed.
6. Braced excavations are lined in the same manner on both sides with vertical soldier pile walls, sheet pile walls or in-situ concrete walls. The struts are arranged horizontally. The ground on both sides of the braced excavation displays approximately the same height, similar surface features and similar subsurface properties.

If these preconditions are not fulfilled, or those in the individual Recommendations, and no Recommendations are available for such special cases, this does not exclude adoption of the remaining Recommendations. However, the consequences of any deviations shall be investigated and taken into consideration.

1.2 Governing regulations (R 76)

1. In the long term a considerable proportion of current German standards relating to structural engineering will be replaced by European standards. They were initiated in the shape of Eurocodes by what was then the Commission of the European Community and further developed under the support of the European Committee for Standardisation (Comité Européen de Normalisation, CEN). Although these Eurocodes, represented by the EN 1997 “Draft, Geotechnical Design” for geotechnical and foundation engineering, have

meanwhile achieved a considerable degree of maturity, their introduction as building regulations is not yet envisaged at the time of publication of the 4th German edition of the EAB.

2. The new generation of national standards based on the partial safety factor approach serves as a temporary solution for all fields of structural engineering until the introduction of the Eurocodes. All standards mentioned refer to the latest version using the partial safety factor approach. Year and month data are not provided here. The following codes in particular are the governing standards for excavation structures:

DIN 1055-100	"Basis of design"
DIN 1054	"Verification of the safety of earthworks and foundations"
DIN 18 800	"Steel structures" including the steel structure adaptation directive
DIN 1045	"Concrete, reinforced and prestressed concrete structures"
DIN 1052	"Timber structures"
DIN 1055-2	"Soil properties"

3. DIN 1054 only regulates fundamental questions of geotechnical and foundation engineering. It is supplemented by the analysis standards which, where necessary, have been adapted to the partial safety factor approach. The following codes in particular represent the governing standards for excavation structures:

DIN 4084	"Calculation of embankment failure and overall stability of retaining structures"
DIN 4085	"Calculation of earth-pressure"
DIN 4126	"Stability analysis of diaphragm walls"

4. The existing standards covering the exploration, investigation and description of ground are not affected by the adaptation to partial safety factors and therefore remain valid in their respective latest editions:

DIN 4020:	Geotechnical investigations for civil engineering purposes
DIN 4021:	Exploration by excavation and borings
DIN 4022:	Designation and description of soil and rock
DIN 4023:	Graphical presentation of logs and boreholes
DIN 4094:	Investigation by soundings (Part 3 replaced by EN ISO 22 476-2:2005)
DIN 18 121 to DIN 18 137:	Soil investigation and testing
DIN 18 196:	Soil classification for civil engineering purposes

5. DIN 1054 only replaces the analysis section of the previous standards DIN 4014 "Bored piles", DIN 4026 "Driven piles", DIN 4125 "Ground anchorages, temporary and permanent anchorages" and DIN 4128 "Injection

piles (in-situ concrete and composite piles)" with small diameter. The new European standards from the "Execution of special geotechnical works" series now take the place of the execution sections of these standards:

DIN EN 1536:	Bored piles
DIN EN 1537:	Ground anchors
DIN EN 1538:	Diaphragm walls
DIN EN 12 063:	Sheet pile walls
DIN EN 12 699:	Displacement piles
DIN EN 12 715:	Grouting
DIN EN 12 716:	Jet grouting
DIN EN 12 794:	Precast concrete foundation piles
DIN EN 14 199:	Micropiles

6. The following execution standards are not affected by the adaptation to European standards and therefore continue to be valid for excavation structures:

DIN 4095:	Drainage for the protection of structures
DIN 4123:	Excavations, foundations and underpinnings in the range of existing buildings
DIN 4124:	Excavations and trenches

7. Until all relevant technical building regulations, standards and recommendations are adapted to the partial safety factor approach, the transitional regulations given in DIN 1054, Appendices F and G, apply.

1.3 New safety factor approach (R 77)

1. In contrast to the original probabilistic safety factor approach, the new safety factor approach, upon which both the new European standards generation and the new national standards generation are based, no longer rests on probability theory investigations, e.g. the beta-method, but on a pragmatic splitting of the previously utilised global safety factors into partial safety factors for actions or effects and partial safety factors for resistances.

2. The foundation for stability analyses is represented by the characteristic values for actions and resistances. The characteristic value is a value with an assumed probability which is not exceeded or fallen short of during the reference period, taking the lifetime or the corresponding design situation of the civil engineering structure into consideration; characterised by the index "k". Characteristic values are generally specified based on testing, measurements, analyses or empiricism.

3. If the bearing capacity in a given cross-section of the retaining wall or in an interface between the retaining wall and the ground needs to be analysed, the effects in these sections are required:

- as action effects, e.g. axial force, shear force, bending moment;
- as stresses, e.g. compression, tension, bending stress, shear stress or equivalent stress.

In addition further effects of actions may occur:

- as oscillation effects or vibrations;
- as changes to the structural element, e.g. strain, deformation or crack width;
- as changes in the position of the retaining wall, e.g. displacement, settlement, rotation.

4. Two types of ground resistances are differentiated:

   a) The shear strength of the soil is the decisive basic resistance parameter. For consolidated soils or soils drained for testing these are the shear parameters φ′ and c′; for unconsolidated soils or soils not drained for testing the shear parameters φ_u and $c_{u.}$ These variables are defined as cautious estimates of the mean values, because the shear strength at a single point of the slip surface is not the decisive value but the average shear strength in the slip surface.

   b) The soil resistances are derived from the shear strength, directly:
      - the sliding resistance;
      - the bearing capacity;
      - the passive earth pressure;

      and indirectly via load tests or empirical values:
      - the toe resistance of soldier piles, sheet pile walls and in-situ concrete walls;
      - the skin resistance of soldier piles, sheet piles walls, in-situ concrete walls and of ground anchors, and soil and rock nails.

   The term “resistance” is only used for the failure state of the soil. As long as the failure state of the soil is not achieved by effects, the term “soil reaction” is used.

5. The cross-section and internal resistance of the material are the decisive factors in the design of individual components. The detailed specification standards continue to be the governing standards here.

6. The characteristic values for effects are multiplied by partial safety factors; the characteristic values for resistances are divided by partial safety factors. The variables acquired in this way are known as the design values of effects or resistances respectively and are characterised by the index “d”. Three limit states are differentiated for stability analyses, according to R 78 (Section 1.4).

1.4 Limit states (R 78)

1. The term “limit state” is used with two different meanings:

   a) In soil mechanics, the state in the soil in which the displacement of the individual soil particles against each other is so great that the mobilisable shear strength achieves its greatest values in either the entire soil mass, or at least in the region of a failure plane, is known as the “limit state of plastic flow”. It cannot become greater even if more movement occurs, but may become smaller. The limit state of plastic flow characterises the active earth pressure, passive earth pressure, bearing capacity, embankment stability and overall stability of retaining structures.
   b) A limit state in the sense of the new safety factor approach is a state of the load-bearing structure where, if exceeded, the design requirements are no longer fulfilled.

2. The following limit states are differentiated using the new safety factor approach:

   a) The ultimate limit state is a condition of the structure which, if exceeded, immediately leads to a mathematical collapse or other form of failure. It is known as the ultimate limit state (ULS) in DIN 1054. Three cases of ULS are differentiated, see Paragraphs 3, 4 and 5.
   b) The serviceability limit state (SLS) is a condition of the structure which, if exceeded, no longer fulfils the conditions specified for its use. It is known as the serviceability limit state (SLS) in DIN 1054.

3. The EQU limit state describes the loss of static equilibrium. These include:

   – analysis of safety against failure by toppling;
   – analysis of safety against hydraulic failure by uplift (buoyancy);
   – analysis of safety against hydraulic failure by heave.

   The EQU limit state incorporates actions, but no resistances. The decisive limit state condition is:

   $$F_d = F_k \cdot \gamma_{dst} \leq G_k \cdot \gamma_{stb} = G_d$$

   i.e. the destabilising action F_k, multiplied by the partial safety factor $\gamma_{dst} \geq 1$, may only become as large as the stabilising action G_k, multiplied by the partial safety factor $\gamma_{stb} < 1$.

4. The STR limit state describes the failure of structures and structural elements or failure of the ground. These include:

   – analysis of the bearing capacity of structures and structural elements subject to soil loads or supported by the soil;
   – verification that the bearing capacity of the soil is not exceeded, e.g. by passive earth pressure, bearing capacity or sliding resistance.

Verification that the bearing capacity of the soil is not exceeded is performed exactly as for any other construction material. The limit state condition is always the decisive condition:

$E_d = E_k \cdot \gamma_F \leq R_k / \gamma_R = R_d$

i.e. the characteristic action effect E_k, multiplied by the partial safety factor γ_F for actions or loads, may only become as large as the characteristic resistance R_k, divided by the partial safety factor γ_R.

5. The GEO limit state is peculiar to geotechnical engineering. It describes the loss of overall stability. These include:

   – analysis of safety against embankment failure;
   – analysis of overall stability of retaining structures.

   The limit state condition is always the decisive condition:

   $E_d \leq R_d$

   i.e. the load design value E_d may only become as large as the design value of the resistance R_d. The geotechnical actions and resistances are determined using the design values for shear strength:

   $\tan \varphi'_d = \tan \varphi'_k / \gamma_\varphi$ and $c'_d = c'_k / \gamma_c$ or
   $\tan \varphi_{u,d} = \tan \varphi_{u,k} / \gamma_\varphi$ and $c_{u,d} = c_{,k} / \gamma_c$

   i.e. the friction tan φ and the cohesion c are reduced at the beginning using the partial safety factors γ_φ and γ_c.

6. The serviceability limit state SLS describes the state of a structure at which the conditions specified for its use are no longer fulfilled, without a loss of bearing capacity. It is based on verification that the anticipated displacements and deformations are compatible with the purpose of the structure. For excavations, the SLS includes the serviceability of neighbouring buildings or structures.

1.5 Support of retaining walls (R 67)

1. Retaining walls are called unsupported if they are neither braced nor anchored and their stability is based solely on their restraint in the ground.
2. Retaining walls are called yieldingly supported if the wall support points can yield with increasing load, e.g. in cases where the supports are heavily inclined and when using non-prestressed or only slightly prestressed anchors.
3. Retaining wall supports are called slightly yielding in the following cases:

   a) Struts are at least tightly connected by frictional contact (e.g. by wedges).
   b) Ground anchors are tested according to EN 1537, Method 1, and are prestressed to at least 80% of the computed force required for the next construction stage.

c) A tight connection via frictional contact is established with displacement piles (previously “driven piles”), bored piles or micropiles (previously “grouted piles”), which verifiably display only small head deflection under load.

4. Retaining wall supports are known as nearly inflexible if designed according to R 22, Paragraph 1 (Section 9.5), utilising increased active earth pressure, and the struts and anchors are according to R 22, Paragraph 10.

5. Retaining wall supports are defined as inflexible only if they are designed either for reduced or for the full at-rest earth pressure according to R 23 (Section 9.6) and the supports are prestressed accordingly. Furthermore, the anchors of anchored retaining walls shall reach into non-yielding rock strata or be designed substantially longer than required by calculations.

If the requirements of Paragraphs 4 or 5 are fulfilled and, in addition:

- a rigid retaining wall is installed and;
- excessive toe deflections are avoided;

an excavation structure may be regarded as a low-deflection and low-deformation structure.

1.6 Using the EAB in conjunction with Eurocode 7-1 (R 105, draft)

1. This edition of the EAB is based on the specifications provided in DIN 1054 (2005). This publication in turn was closely harmonized with EN 1997-1 – Eurocode EC7-1. DIN 1054 is not identical in every detail with Eurocode EC7-1, but neither does it contradict it. As soon as Eurocode EC7-1 can be adopted, with the permission of the responsible authorities, DIN 1054 must at least be formally adapted to the specifications of Eurocode EC-7. The consequences associated with this for applying this edition of the Recommendations are related below as well as a preview will allow.

2. The following stipulations have been agreed upon in terms of the validity of the regulations:

   a) Once the DIN 1054 (2005) has been included in the model list of the Acknowledged Technical Rules for Works (*Technische Baubestimmungen*), it can be introduced by the responsible authorities of the federal states during 2005 and 2006. The end of the validity period of DIN 1054 (1976) is given as the end of 2007 in the model list.
   b) A two-year transition period began at the end of 2004; during this period a national annex to the Eurocode EC7-1 was to be compiled and published jointly with the Eurocode, and approved for use on the basis of European agreements.
   c) In addition, at the end of 2004 a five-year transition period began, at the end of which Eurocode EC7-1 was to be introduced by the responsible authorities and all contradictory national regulations be withdrawn.

d) The end of the validity period of DIN 1054 (2005) is fixed at the end of 2009 by the stipulations of Paragraph c).

The competent responsible authorities are:

– the higher building control authorities of the federal states for building measures subject to the respective state building code;
– the departments of the Federal Ministry of Transport, Building and Urban Affairs (*Bundesministerium für Verkehr, Bau- und Stadtentwicklung* (*BMVBS*)) responsible for inland waterways, for federal roads and road bridges, and the Federal Railway Authority (*Eisenbahn-Bundesamt*) responsible for rail traffic.

3. In terms of the STR limit state safety analyses according to R 78, Paragraph 4 (Section 1.4), Eurocode EC7-1 provides three options. DIN 1054 (2005) is based on analysis procedure 2 inasmuch as the partial safety factors are applied to the loads and to the resistances. To differentiate between this and the other scenario, in which the partial safety factors are not applied to the loads but to the actions, this procedure is designated as analysis method 2* in the Commentary to Eurocode EC7-1 [134]. DIN 1054 also utilises a number of gaps that are not specifically codified, e.g. using load cases according to R 79, Paragraph 1 (Section 2.4).

4. The National Annex represents a formal link between Eurocode EC7-1 and national standards. This National Annex states which of the possible analysis methods and partial safety factors are applicable in the respective national domains. Remarks, clarifications or supplements to Eurocode EC7-1 are not permitted. However, the applicable, complementary national codes may be given. The complementary national codes may not contradict Eurocode EC7-1. Moreover, the National Annex may not repeat information already given in Eurocode EC7-1.

5. The reworked DIN 1054 will be paramount in the complementary national code; it has the working title "DIN 1054 (2007)" and is the application rule to Eurocode EC7-1. It is likely that the following points will differ from the DIN 1054 (2005) edition:

   – where feasible it will be shortened to avoid the problem of repetitions;
   – from a formal point of view it will be more closely adapted to Eurocode EC7-1;
   – it will include supplements, improvements and modifications.

   The supplements, improvements and modifications shall be adhered to inasmuch as they affect the regulations of the EAB, if the respective excavation structure is designed to Eurocode EC7-1. However, they may also be accordingly utilised if the design is based on DIN 1054 (2005).

6. In the governing version, Eurocode 7-1 defines the following limit states in place of the GZ 1A, GZ 1B and GZ 1C limit states:

a) EQU: loss of equilibrium of the structure, regarded as rigid, without the influence of soil resistances. The designation is derived from “equilibrium”.
b) STR: inner failure or very large deformation of the structure or its components, whereby the strength of the materials is decisive for resistance. The designation is derived from “structure”.
c) GEO: failure or very large deformation of the ground, whereby the strength of the soil or rock is decisive for resistance. The designation is derived from “geotechnical”.
d) UPL: loss of equilibrium of the structure or ground due to uplift (buoyancy) or water pressure. The designation is derived from “uplift”.
e) HYD: hydraulic failure by heave, inner erosion or piping in the ground, caused by a flow gradient. The designation is derived from “hydraulic”.

7. In order to transfer the GZ 1B and GZ 1C limit states to the terminology used in EC7-1 the GEO limit state is divided into GEO B and GEO C:

a) GEO B: failure or very large deformation of the ground in conjunction with identification of the action effects and dimensions; i.e. when utilising the shear strength for passive earth pressure, for sliding resistance and bearing capacity and when analysing stability in the low failure plane.
b) GEO C: failure or very large deformation of the ground in conjunction with analysis of overall stability, i.e. when utilising the shear strength for analysis of the safety against embankment failure and overall stability of retaining structures, generally, when analysing the stability of engineered slope stabilisation measures.

8. The previous limit states are now replaced as follows:

a) The previous limit state GZ 1A now corresponds without restrictions to the EQU, UPL and HYD limit states.
b) The previous limit state GZ 1B corresponds without restrictions to the STR limit state. In addition, the GEO B limit state applies in conjunction with external design, i.e. when utilising the shear strength for passive earth pressure, sliding resistance and bearing capacity and when analysing stability in the low failure plane.
c) The previous limit state GZ 1C corresponds to the GEO C limit state in conjunction with analysis of overall stability, i.e. when utilising the shear strength for analysis of safety against embankment failure and overall stability of retaining structures.

Analysis of the stability of engineered slope stabilisation measures is always allocated to the GEO limit state. Depending on the specific design and function they may be dealt with:

– either in the sense of the previous limit state GZ 1B using the regulations of the GEO B limit state;
– or in the sense of the previous limit state GZ 1C using the regulations of the GEO C limit state.