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1. Scope

This document defines the design basis of all mechanical systems and components of the facility to withstand earthquakes.

2. Definitions

I. Earthquake zone: risk categories of local regions regarding earthquakes

II. Design ground acceleration a_g: design basis of a defined risk category

III. Importance class for buildings γ_1: Classification of buildings regarding public safety, civil protection and social and economic consequences

IV. Soil factor S and periods T_B, T_C, T_D: Values to describe the shape of the elastic response spectrum $S_e(T)$ depending on the ground type

V. Behaviour factor q: factor to describe the material behaviour scenario

VI. Non-structural elements: mechanical or electrical element, system or component, which is not considered in the seismic as load carrying element

3. Codes and Standards

The DIN EN 1998 Eurocode 8: Design of structures for earthquake resistance is the legal basis to design structures in order to withstand earthquakes .

Remark: Up to the date of this technical guideline in Hessen, Germany DIN EN 1998-1 is not introduced as the legal building control procedure. That means, that up to the date of this guideline the legal working basis is DIN 4149: 2005-04.

4. Design basis

The FAIR facility is located in the earthquake zone 1 [1]. The earthquake zone 1 summarizes regions with intensity ranges between 6,5 and < 7,0 regarding based risk levels.

The building ground class is given as C and the geological sub class is given as between S and T.

The importance class for buildings is defined by the FAIR GmbH as class III.

This leads to the following parameters of the elastic response spectrum:

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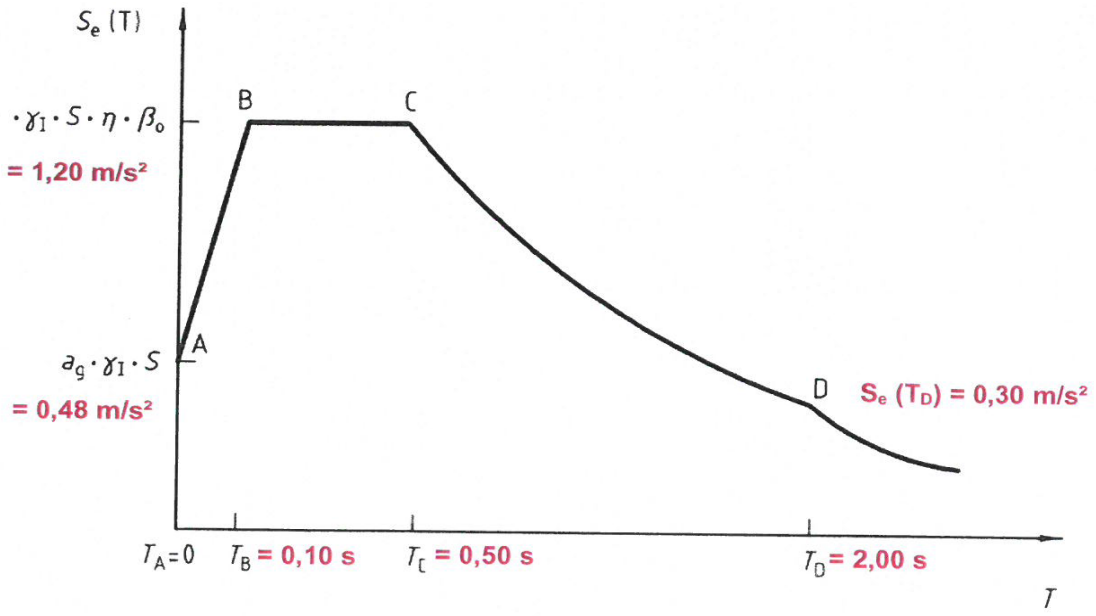
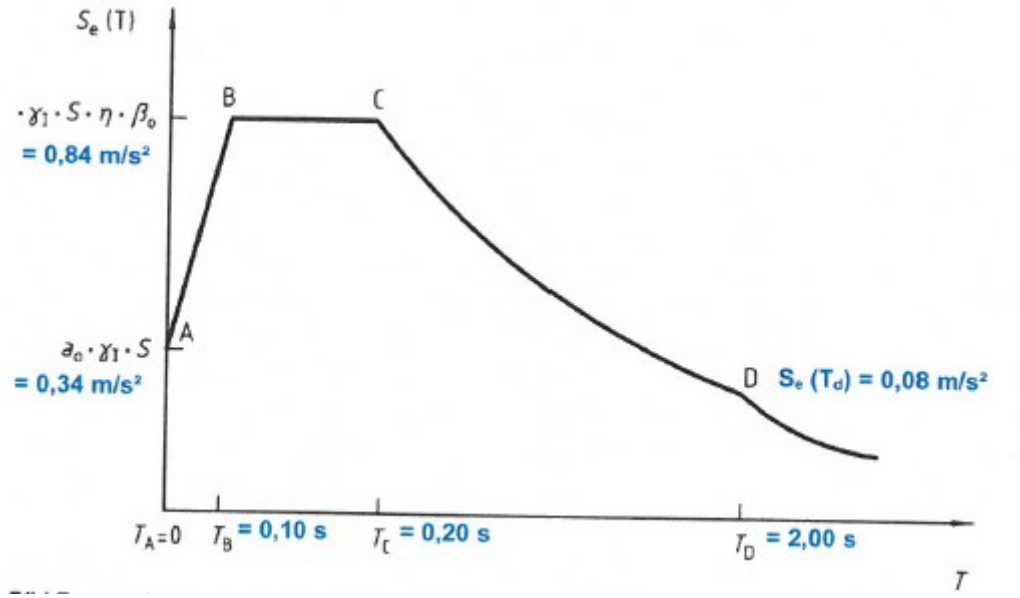
a_g = 0.4 m/s^2
γ_1 = 1.2
S = 1
T_B = 0.1 s
T_C = 0.2 s for the horizontal and 0,5 s for the vertical response
T_D = 2 s
Additional values are given by DIN 4149 as:
η = 1.0
β_0 = 2.5

As a result of the by norm defined formulas you get the following horizontal elastic response spectrum.



The vertical elastic response spectrum is defined as follows:



Non-structural elements of buildings (e.g. mechanical equipment, machinery, electrical cabinets, machine frames), that might, in case of failure, cause risks to persons or affect the main structure of the building or services of critical facilities, shall be verified to resist the design seismic action.

The effects of the seismic action may be determined by applying to the non-structural element a horizontal force F_a, which is defined as follows:

$$F_a = S_a * m_a * \frac{\gamma_a}{q_a}$$

$$S_a = \alpha * S * \left(\frac{3 * \left(1 + \frac{z}{H}\right)}{1 + \left(1 - \frac{T_a}{T_1}\right)^2} - 0.5 \right)$$

where

F_a is the horizontal seismic force, acting at the centre of mass of the non-structural element in the most unfavourable direction;

m_a is the mass of the element;

S_a is the seismic coefficient applicable to non-structural elements;

γ_a is the importance factor of the element;

q_a is the behaviour factor of the element;

α is the ratio of the design ground acceleration a_g to the acceleration of gravity g;

S is the soil factor;

T_a is the fundamental vibration period of the non-structural element;

T_1 is the fundamental vibration period of the building in the relevant direction;

z is the height of the non-structural element above the level of application of the seismic action (foundation or top of the rigid basement) and

H is the building height measured from the foundation or from the top of the rigid basement.

For the following non-structural elements the importance factor γ_a shall not be less than 1.5:

- Anchorage elements of machinery and equipment required for life safety systems;
- Tanks and vessels containing toxic or explosive substances considered to be hazardous to the safety of general public.

In all other cases the importance factor γ_a of non-structural elements may be assumed to be γ_a =1,0.

The behaviour factor q_a should be 1 to avoid non elastic deformation of the structures by seismic force.

5. References

[1] DIN EN 1998-1/NA:2011-01 Erdbebenzonenkarte (formerly DIN 4149:2005-04)
DIN EN 1998 Eurocode 8: Design of structures for earthquake resistance