



Eurocode 8

Base Isolation (for buildings)

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EN1998-1: **General rules, seismic actions and rules for buildings**

Section 10 - Base isolation

Deals with seismically isolated structures (specific rules for buildings)

Aim:

Reduce the seismic response of the lateral-force resisting system by:

- Increasing the Fundamental Period
- Modifying the shape of the fundamental mode
- Increasing the damping
- Combining various effects

Distributed energy dissipation systems not covered by Section 10

Specific rules for Bridges in EN 1998-2



Base isolation strategies

Period elongation

- Reduction of spectral accelerations
- Increase of displacements (mostly occurring in the isolation system)

Force limitation

- Reduction of the force transmitted to the structure
- Displacements controlled by damping (provided by the isolation system)
- Design of the structure akin of the capacity design concept

*In both cases with **increased energy dissipation capacity***



Main Definitions

Isolation system – **Collection of components** used for providing seismic isolation, which are arranged over the isolation interface.

Isolation interface – Surface which separates the substructure and the superstructure and **where the isolation system is located**.

Normally at the base of buildings, tanks and silos or between piers and deck in bridges.

Isolator units – **Elements** constituting the isolation system.

Full isolation – The **structure** is fully isolated if, in the design seismic situation, it **remains within the elastic range**.



Types of Isolator units

Laminated **elastomeric bearings** (quasi elastic response with equivalent damping from 5% - LDRBs to 20% - HDRBs)

Elastoplastic devices (hysteretic response of metals)

Viscous or friction dampers

Pendulums (low friction sliders – stainless steel/PTFE)

Functions/capabilities

Vertical-load carrying capacity

Energy dissipation capacity

Recentering capability

Lateral restraint



Design Objectives as for non base-isolated structures:

In the event of earthquakes:

Human lives are protected

Damage (structural, non-structural and to contents) is limited

Structures important for civil protection **remain operational**

Fundamental requirements as for non base-isolated structures:

No-collapse requirement

Damage limitation requirement

*But an **increased reliability** is required for the isolating devices*

Magnification factor γ_x on the seismic displacements of each unit
(NDP recommended value $\gamma_x = 1,2$)



Compliance criteria

For the DLS, **lifelines** crossing joints **remain elastic**

For the ULS, gas lines and other hazardous lifelines crossing joints **accommodate the relative displacements** including the **magnification factor χ_x**

Interstorey drift limited as for non base isolated buildings

At ULS, **substructure and superstructure** remain **elastic**



General Design Provisions

Arrangement of devices allowing for **inspection, maintenance and replacement**

Protection of devices against fire, chemical or biological attack

Distribution of devices to **minimize torsion effects**

Sufficient stiffness of structure above and below the isolation interface to **avoid differential movement**

Sufficient space around the devices to allow free movement with **no hammering**



Seismic action

Two horizontal and vertical components acting simultaneously

Elastic spectrum (and alternative representations) as for non-base isolated buildings

Site specific spectra required for Class IV buildings if distance from potentially active fault with a $M_S \geq 6,5$ is less than 15 km

*(When applicable) behaviour factor $q = 1,0$ except for the **superstructure** where $q = 1,5$ may be used.*



Properties of isolation system

For **analysis purposes** use the **most unfavourable** values of mechanical properties (account for rate of loading, effect of vertical load, temperature and aging)

Maximum stiffness and Minimum damping for the **evaluation of accelerations and forces**

Minimum stiffness, damping and friction for the **evaluation of displacements**

*In Class I and II buildings **mean values** may be used provided that **extreme values** are **within 15%** of the mean*



Structural Analysis

Equivalent linear analysis

Simplified linear analysis

Modal simplified linear analysis

Modal linear analysis

Time history analysis



Equivalent linear analysis

Use **equivalent stiffness and damping** at displacement d_{dc}
(evaluated in an iterative procedure)

Conditions (for “equivalence”):

- Effective (secant) stiffness of the Isolation System (at total design displacement) is not less than 50% of the effective stiffness at $0,2d_{dc}$
- Effective damping of the Isolation System does not exceed 30%.
- The force-displacement characteristics of the Isolation System do not vary more than 10% due to the rate of loading and the vertical load variation (in the range of design values)
- The increase of force in the Isolation System for displacements between $0,5d_{dc}$ and d_{dc} is not less than 2,5% of the total gravity load above the system (to provide recentering capability)



Simplified (static) linear analysis

The structure is **assumed to behave like a SDOF system** in both horizontal directions (superstructure acting as a **rigid block**)

Conditions (*for “simplification”*):

- Maximum eccentricity between stiffness of the Isolation System and centre of mass of the structure does not exceed 7,5% of plan
- Distance from potentially active faults with $M_S \geq 6,5$ greater than 15 km
- Maximum plan dimension not greater than 50 m
- Rigid substructure (to minimise differential displacements)
- All devices above elements of substructure that support vertical load
- Effective period in the range: $3T_f \leq T_{\text{eff}} \leq 3 \text{ s}$ (T_f is the period for the same structure with a fixed base)



Simplified (static) linear analysis

Conditions (for “simplification”) (additional for buildings):

- **Regularity and symmetry** of the superstructure (in two axis)
- **Negligible rocking** rotation at the base
- Ratio between vertical and horizontal stiffness of the Isolation System: $K_v/K_{\text{eff}} \geq 150$
- **Rigid substructure** (to minimise differential displacements)
- **Vertical period**: $T_v = 2\pi \sqrt{M/K_v} \leq 0,1 \text{ s}$



Simplified (static) linear analysis

- Apply **static forces** to the structure in **two directions**
- Horizontal forces proportional to storey masses (**constant acceleration along the height**)
- **Torsional effects** taken approximately increasing the effects in structural members according to their distance to the centre of mass (**as for conventional symmetrical structures**)



Modal simplified linear analysis

Applicable when the **conditions** for the simplified (static) analysis **are met except** the one for maximum eccentricity

The structure is **assumed to behave like a 3DOF system** (superstructure acting as a rigid block with its motion described by 2 horizontal displacements and the rotation about the vertical axis)

Modal linear analysis

Applicable when the **conditions** for the simplified analysis **are not met**

A linear model of the **complete structural system** including both the stiffness of the **superstructure** (according to the modelling rules applicable to “conventional” structures) **and the “equivalent”** stiffness and damping properties of the **isolator units** should be used for a **complete modal analysis**



Time history analysis

Can always be used (any type of structure and isolation system)

- **Mandatory** if it is not possible to model the Isolation System with an equivalent linear system
- The **superstructure** may be **modelled elastically** (for full isolation)
- The **constitutive model of the devices** shall represent its **actual behaviour** in the range of deformations and velocities associated with the seismic design situation (use the **most unfavourable** values)
- **Seismic action** represented as defined for time history analysis of “conventional” structures (**alternative representations** of the seismic action)