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** γ_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: $3T_f \leq T_{eff} \leq 3$ 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: $K_v/K_{eff} \geq 150$
- Rigid substructure (to minimise differential displacements)
- Vertical period: $T_v = 2\pi \sqrt{(M/K_v)} \leq 0{,}1$ 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)