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ProtaStructure Design Guide

Calculation Target Displacement for Pushover Analysis (EC8)

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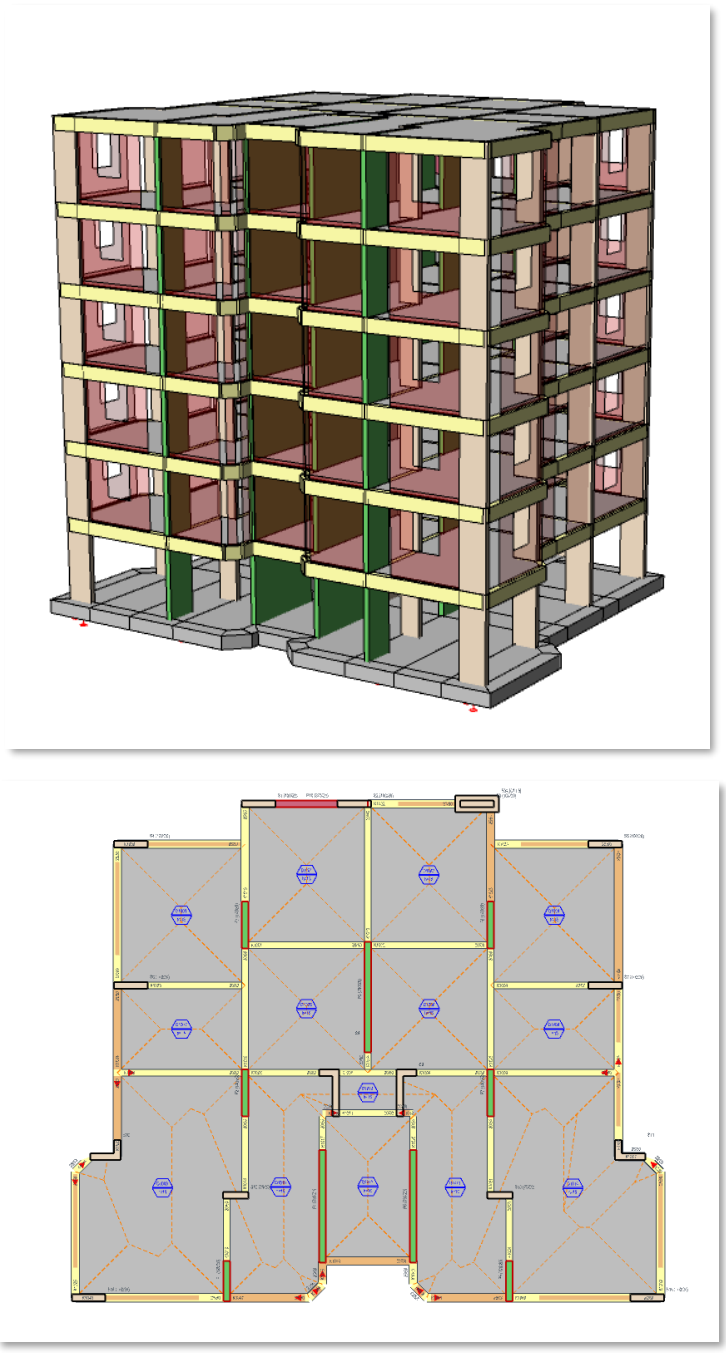
Introduction

In ProtaStructure, the “Nonlinear Analysis” feature enables the user to perform nonlinear analysis methods such as Pushover Analysis and Time-History Analysis.

This document will explain target displacement calculation for nonlinear pushover analysis according to EC8 Annex B in detail and verified with the hand calculation.

Building Model

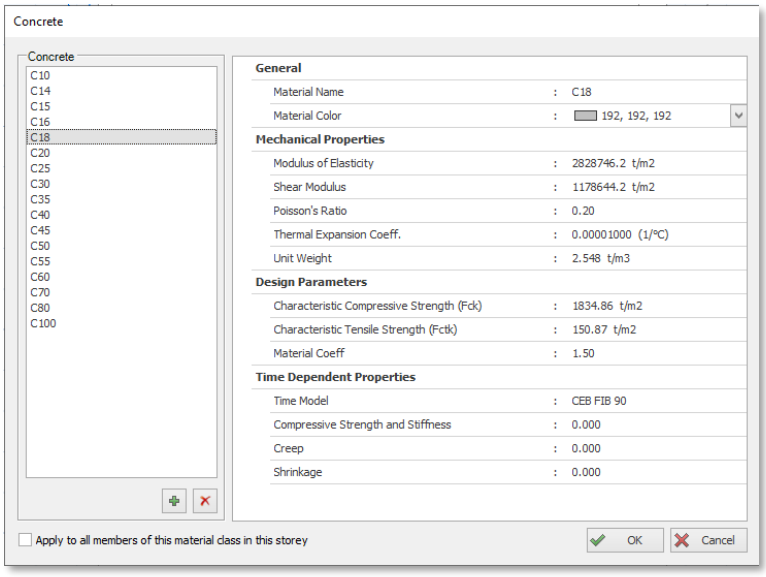
The building model consists of 7 floors. 3D and typical story plan views are shown below.



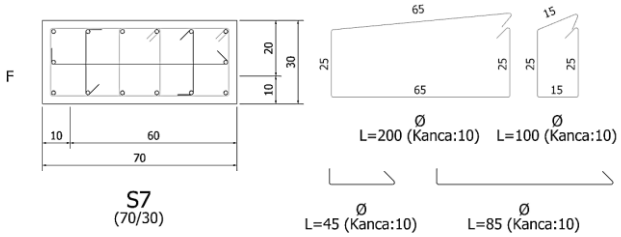
3D and Typical Plan View of Building Model

Material And Section Details

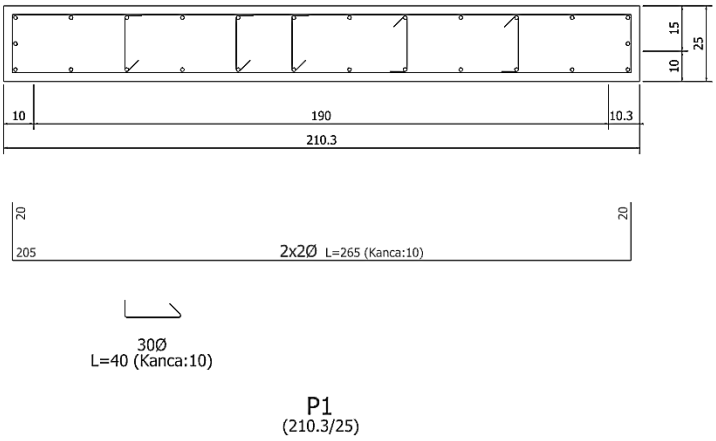
Concrete Material



Typical Column Section Details



Typical Wall Section Details



Estimated rebar ratios are used for beam members. Estimated rebar details are given below;

Calculation Details

Calculation Of Transformation Factor

According to **EC 8 Annex B**, the multi degree of freedom (MDOF) structural system needs to be transformed into a single degree of freedom (SDOF) system to calculate the target displacement.

According to EC 8 B.2, the SDOF system's equivalent mass and transformation factors are below.

$$m^* = \sum_{i=1}^{N} m_i \phi_{ix} \qquad (\boldsymbol{B.2})$$

$$\Gamma = \frac{m^*}{\sum_{i=1}^{N} m_i {\phi_i}^2} \qquad (\boldsymbol{B.3})$$

According to **EC 8 B.2**, "The force F* and displacement d* of the equivalent SDOF system is computed as:

$$F^* = \frac{F_b}{\Gamma} \qquad (\boldsymbol{B.4})$$

$$d^* = \frac{d_n}{\Gamma} \qquad (\boldsymbol{B.5})$$

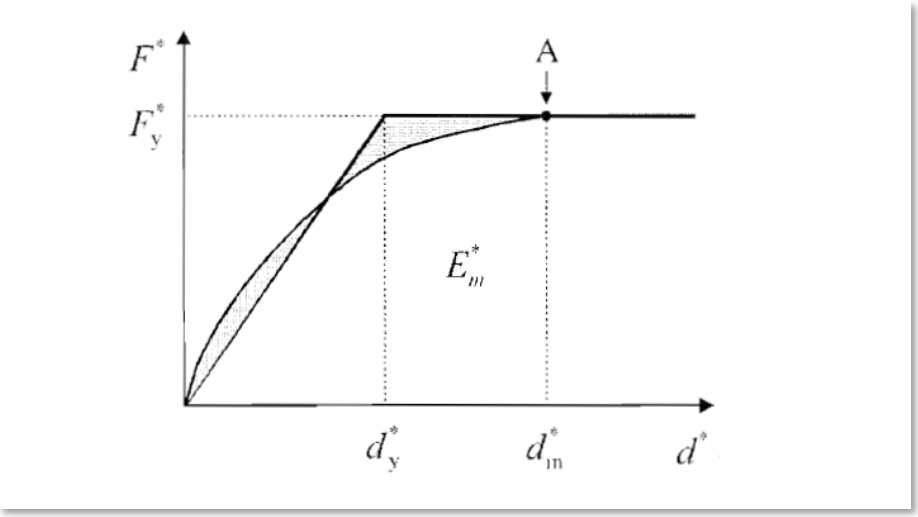
Where F_b and d_n are, respectively, the base shear force and the control node displacement of the Multi Degree of Freedom (MDOF) system.

Bilinearized Curve

According to **EC8 B.3,** "The yield force Fy, which represents the idealized system's ultimate strength, is equal to the base shear force at the formulation of the plastic mechanism. The initial stiffness of the idealized system is determined so that the areas under the actual and the idealized force-deformation curves are equal (Figure B.1). Based on this assumption, the yield displacement of the idealized SDOF system dy*is given by:

$$d*_y = 2(d*_m - \frac{E*_m}{F*_y}) \qquad (\boldsymbol{B.6})$$

Where E_m* is the actual deformation energy up to the formation of the plastic mechanism.



EC 8 Figure B.1 Determination of the idealized elastic-perfectly plastic force-displacement relationship.

Calculation Of Period T*

According to **EC 8 B.4**, "The period T* of the idealized equivalent SDOF system is determined by:

$$T^* = 2\pi\sqrt{\frac{m* \; d*_y}{F*_y}} \qquad (\boldsymbol{B.4})$$

Calculation of Target Displacement of SDOF and MDOF Systems

According to **EC8 B.5**, "The target displacement of the structure with period T* and unlimited elastic behavior is given by:

$$d_{et}{}^* = S_e(T*)\left[\frac{T*}{2\pi}\right] \qquad (\boldsymbol{B.7})$$

S_e(T*) is the elastic acceleration response spectrum at the period T*.

Different expressions should be used to determine target displacement dt* for short periods and di for medium/long period structures. The corner period between the short- and medium-period range is Tc.

a) $T* < T_c$

If $F_y*/m* \geq S_e(T*)$, the response is elastic and thus

$d_t* = d_{et}*$ $B.9$

If $F_y*/m* < S_e(T*)$, the response is nonlinear and

$$d_t* = \frac{d_{et}*}{q_u}(1 + (q_u - 1)\frac{T_c}{T*}) \geq d_{et}* \qquad B.10$$

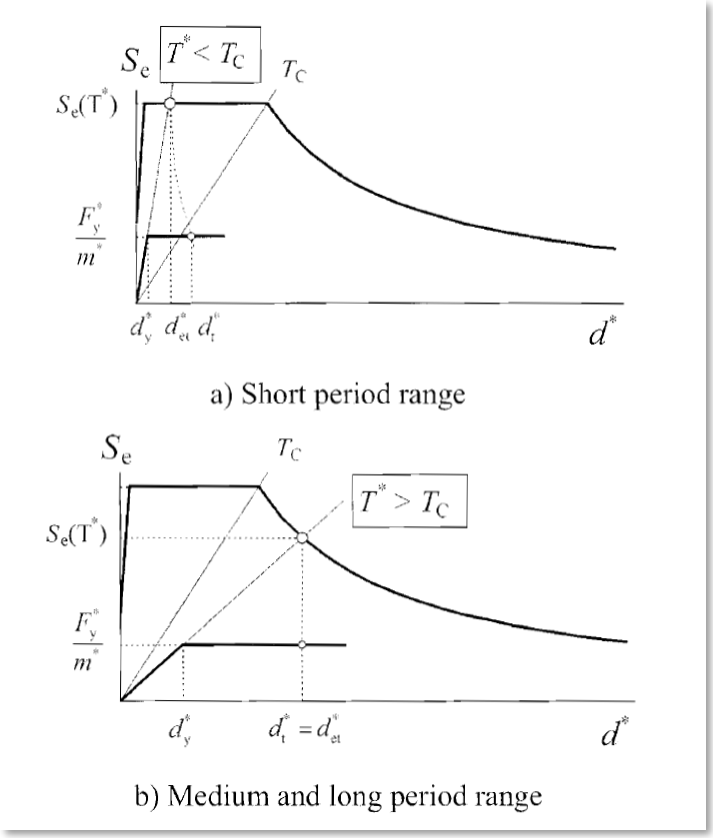
q_u is the ratio between the acceleration in the structure with unlimited elastic behavior S_c(T*) and in the structure with limited strength F_y*/m*.

$$q_u = \frac{S_e(T*)m*}{F_y*} \qquad B.11$$

b) $T* \geq T_c$ (medium and long period range)

$$d_t* = d_{et}* \qquad B.12$$

Explanatory figures from EC.8 about the determination of the target displacement for the equivalent SDOF system are given below. The exact figures are given in the ProtaStructure target displacement calculation report.



EC 8 Figure B.2: Determination of the target displacement for the equivalent SDOF system

The final step is the determination of the target displacement for the MDOF system. According to **EC8 B.6,** "The target displacement of the MDOF system is given by:

$$d_t = \Gamma\, d_t* \qquad B.13$$

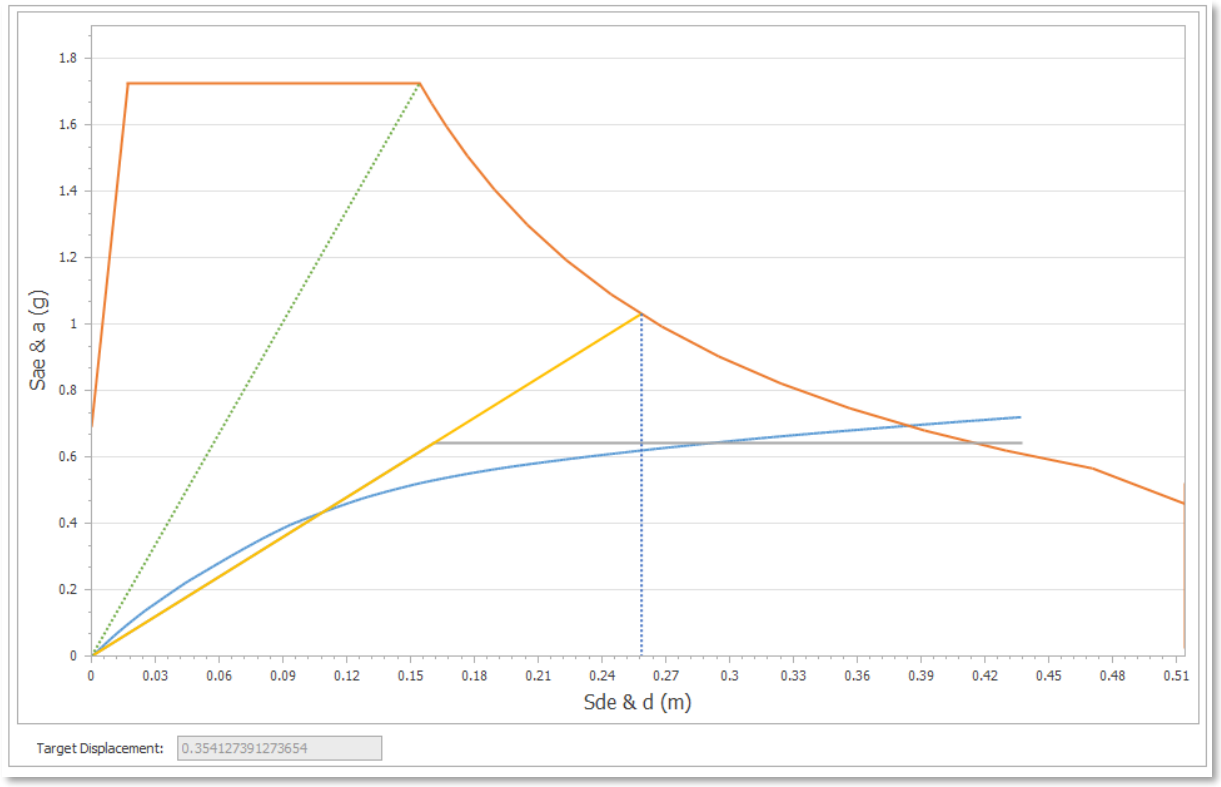
Verification of the ProtaStructure Target Displacement Results

For the given model, calculated parameters are given below.

Mass of an Equivalent SDOF System m* = 773.350 t
Transformation Factor Γ = 1.37

Since the period T* of the idealized equivalent SDOF system is higher than the corner period (Tc), **Equation B.12** and **Figure B.2 (b)** are used to determine target displacement.

The force-displacement relation of the equivalent SDOF system determined according to **EC8 B.2** is given below (The Figure is taken from the ProtaStructure target displacement calculation report).



Yield Force F_y^* = 4872.1 kN
Energy up to Plastic Mechanism E_m^* = 1737.4 kN.cm
Yield Displacement d_y^* = 16.1 (According to EC8 B.6)

Period of Equivalent SDOF System T* = 1.005 s (According to EC8 B.7)
Target Displacement For Elastic Behavior d_{et}^*= 25.87 cm

Target Displacement of MDOF System d_t = 35.42 cm (According to EC8 B.13)

Summary

This document explains the calculation details of target displacement according to EC8 Annex B. Results of the ProtaStructure are verified with hand calculations.

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