

Push-Over-Analyse von Bestandsgebäuden

Univ. Prof. DI Peter Bauer - werkraum ingenieure ZT GmbH

Symposium Earthquake Engineering -- FCP - VCE - OIAV





ANSICHT SALVATORGASSE M1:100



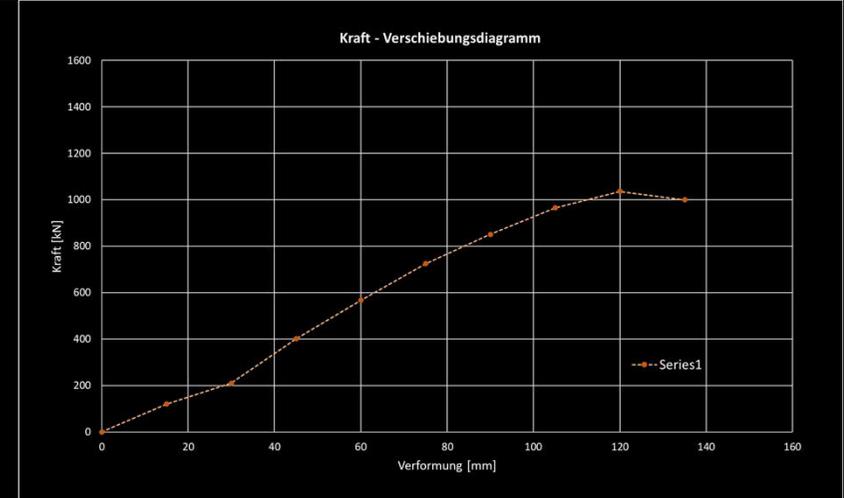
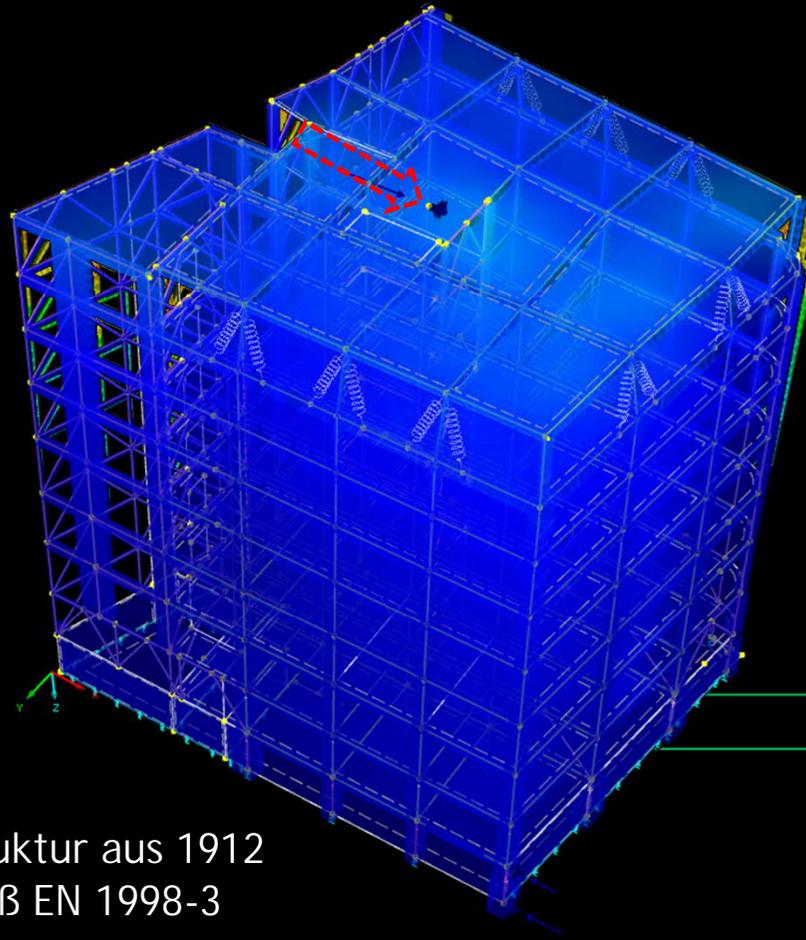
Legende:
 * ... Kernbohrung gemäß Detail F Plan Nr. f1001
 - - - Achsen Exoskelett

ANSICHT STERNGASSE M1:100

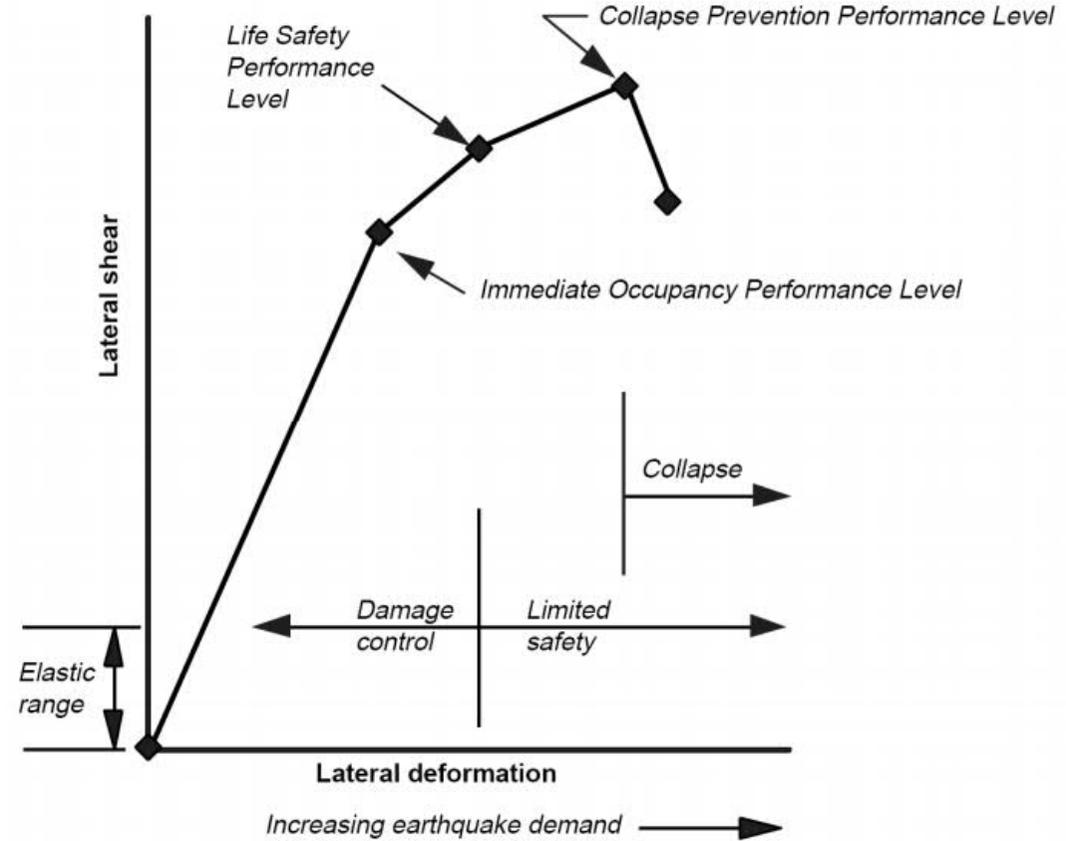
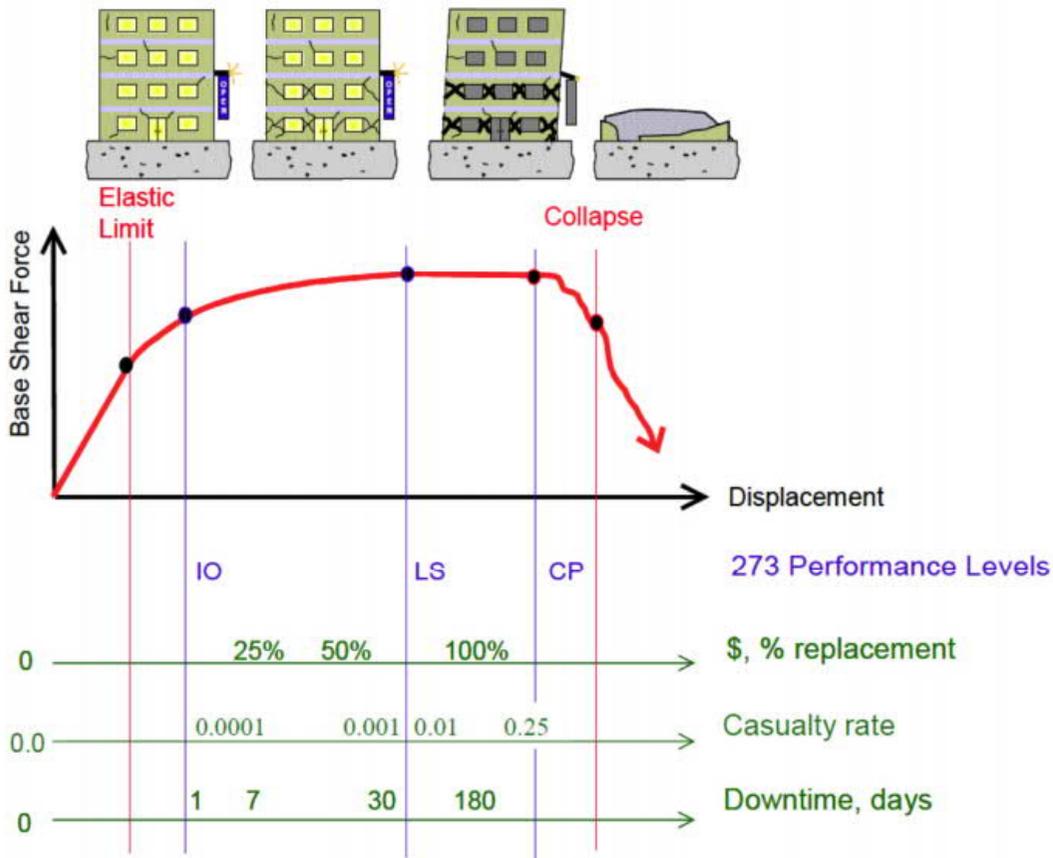


Push-Over

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Eisenbeton-Rahmen-Struktur aus 1912
Kapazitätsanalyse gemäß EN 1998-3



Structural performance levels FEMA 356
-ductile response

Eurocode 8 -3 DL (Schadensbegrenzung)
SD (wesentliche Schädigung)
NC (Quasiversagen)

Common design strategy

$$F_{E,max} = m a_{E,max}(T) < F_{R,max}$$

Updated design strategy

$$a_{E,max} = \frac{F_{R,max}}{m} = a_{R,max}$$

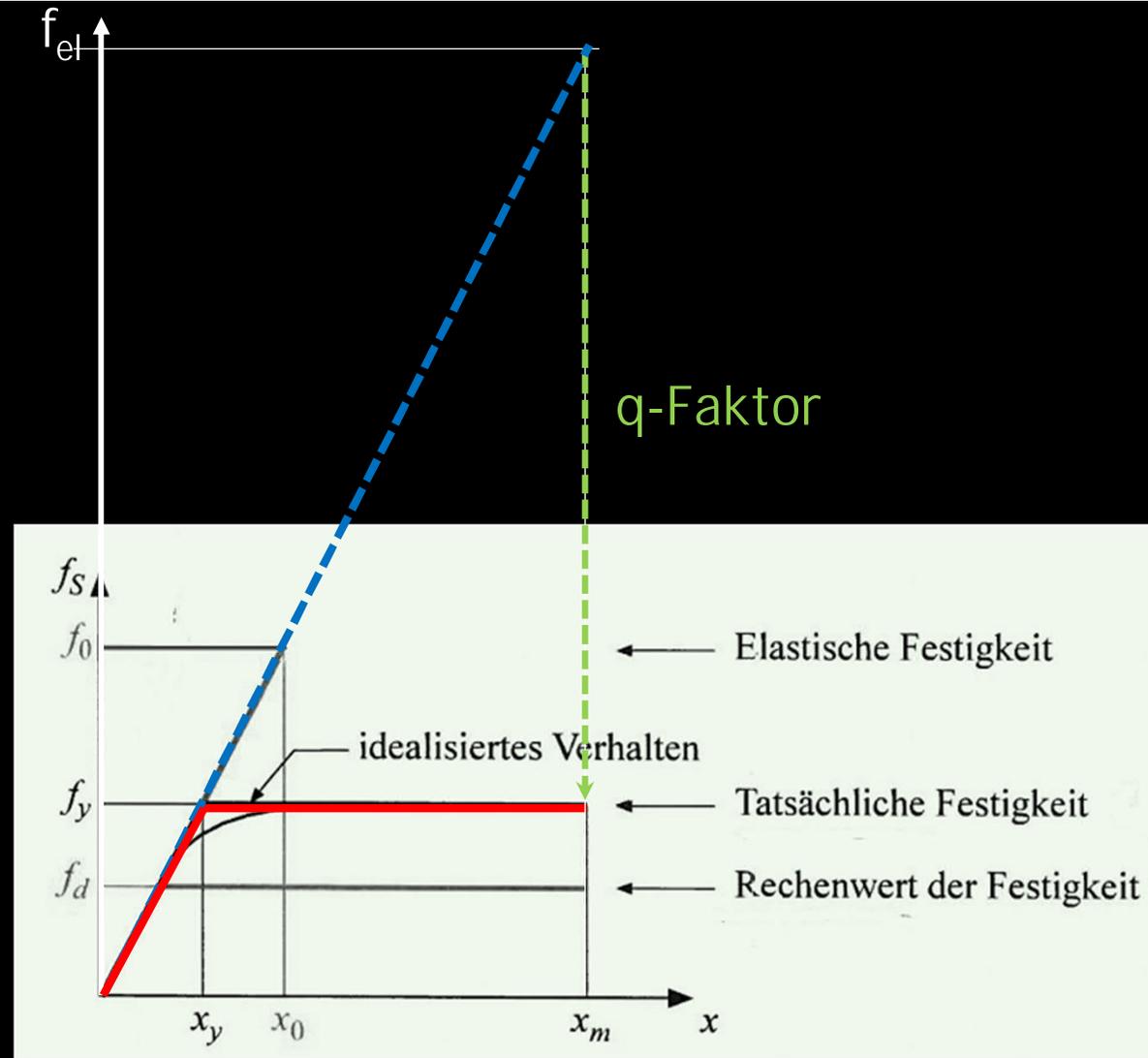
Target:

$k = k(f_i/x_i)$ or $c ==$ „high“

$f_y ==$ „low“ (Note: windforce)

Achtung!

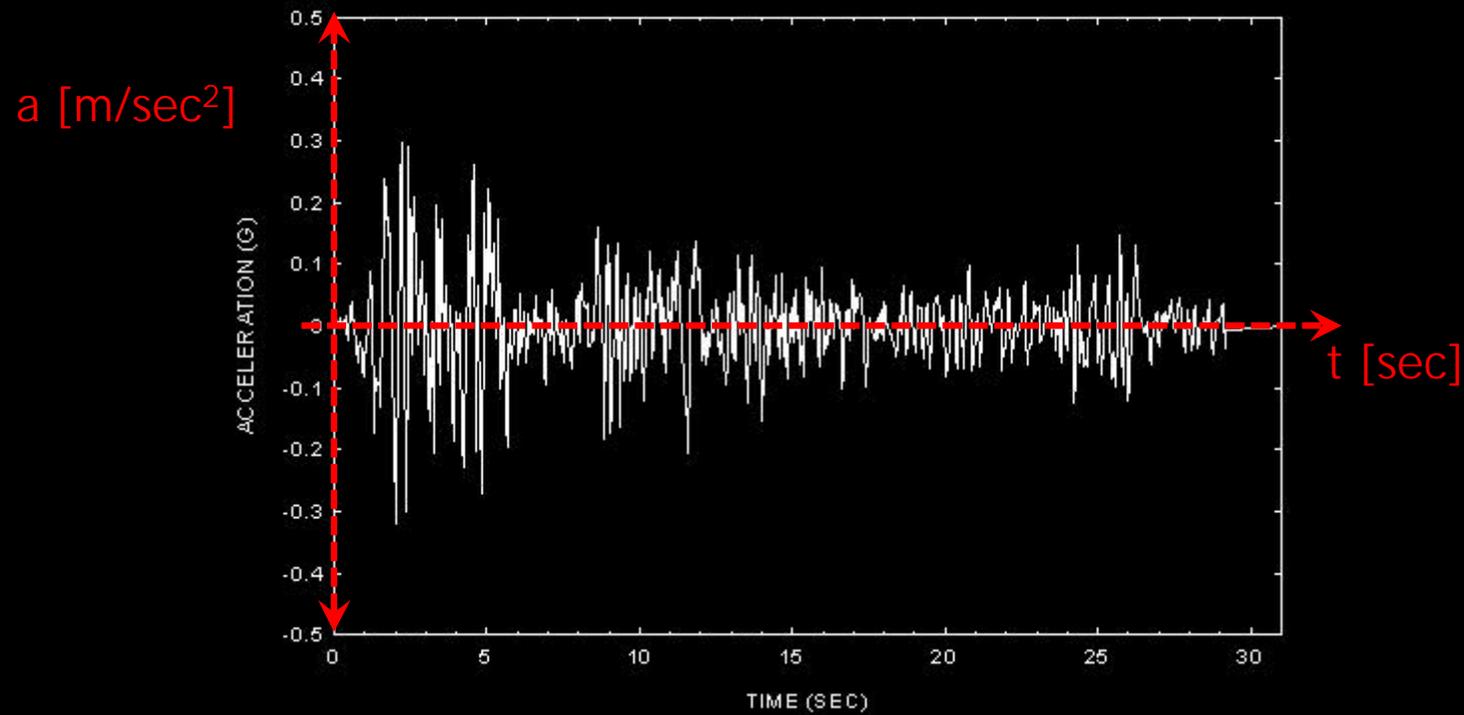
Bei nichtlinearen Verfahren liegt der Ansatz $f_d < f_y$ nicht immer auf der sicheren Seite (wenn z.B. daraus die max. auftretenden Beschleunigungen für Bewohner oder Geräte abgeschätzt werden)



Erdbeben "Kräfte"

Dynamisch,
Variabler Anteil: Gesamt
Richtung: „Zufällig“

EL CENTRO EARTHQUAKE MAY 18, 1940
NORTH-SOUTH COMPONENT

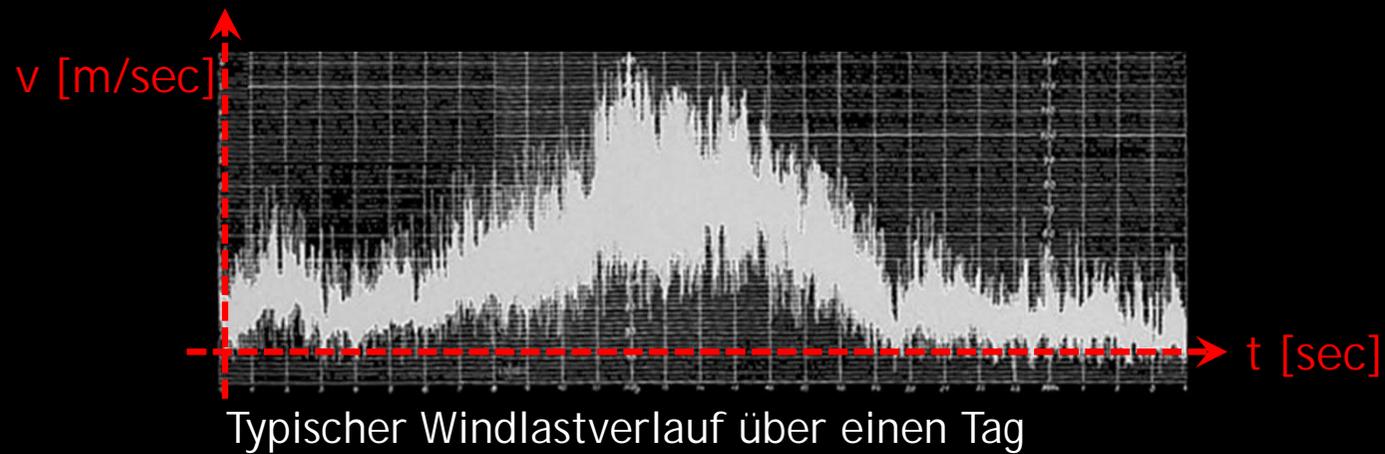


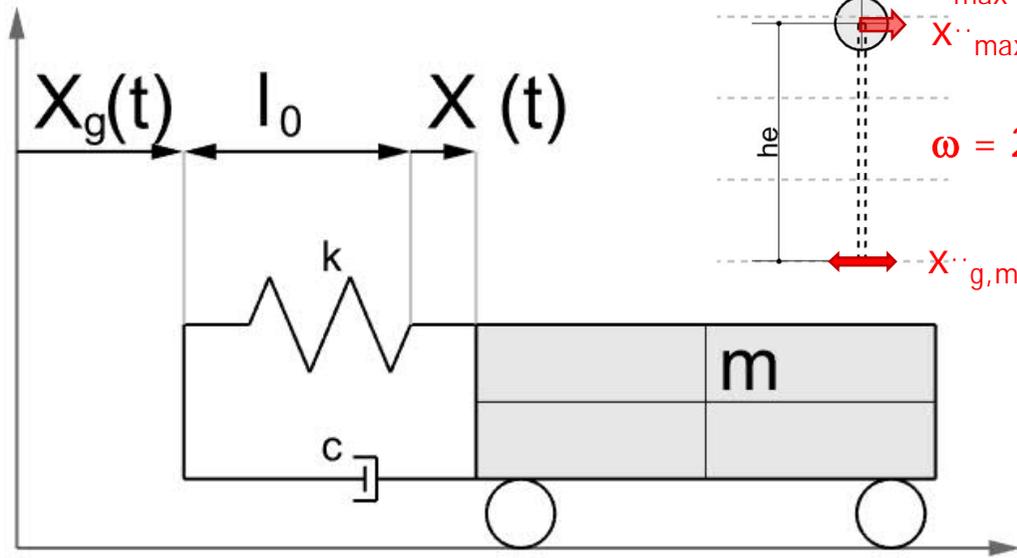
Stabilisierungskräfte

Statisch,
Variabler Anteil: Nutzlast
Richtung: Konstant (Abhängig von der Schiefstellung Ψ_0)

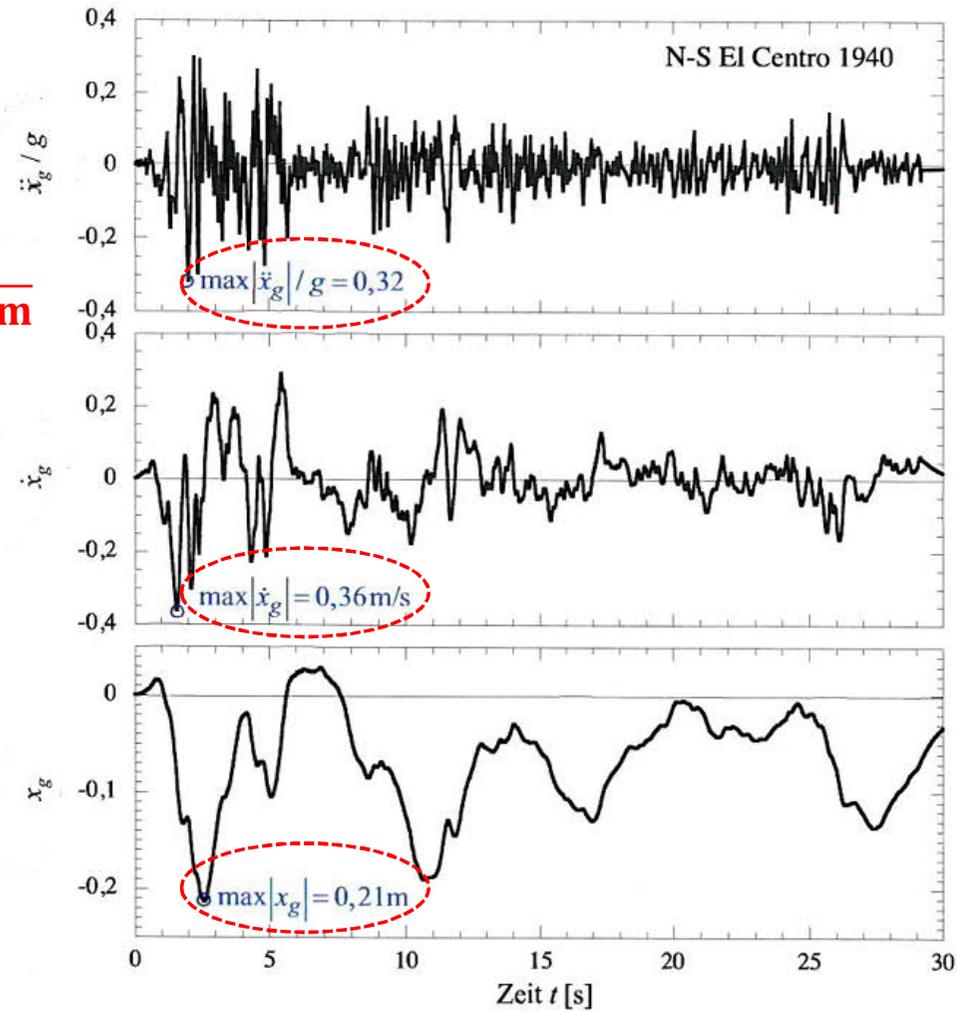
Wind

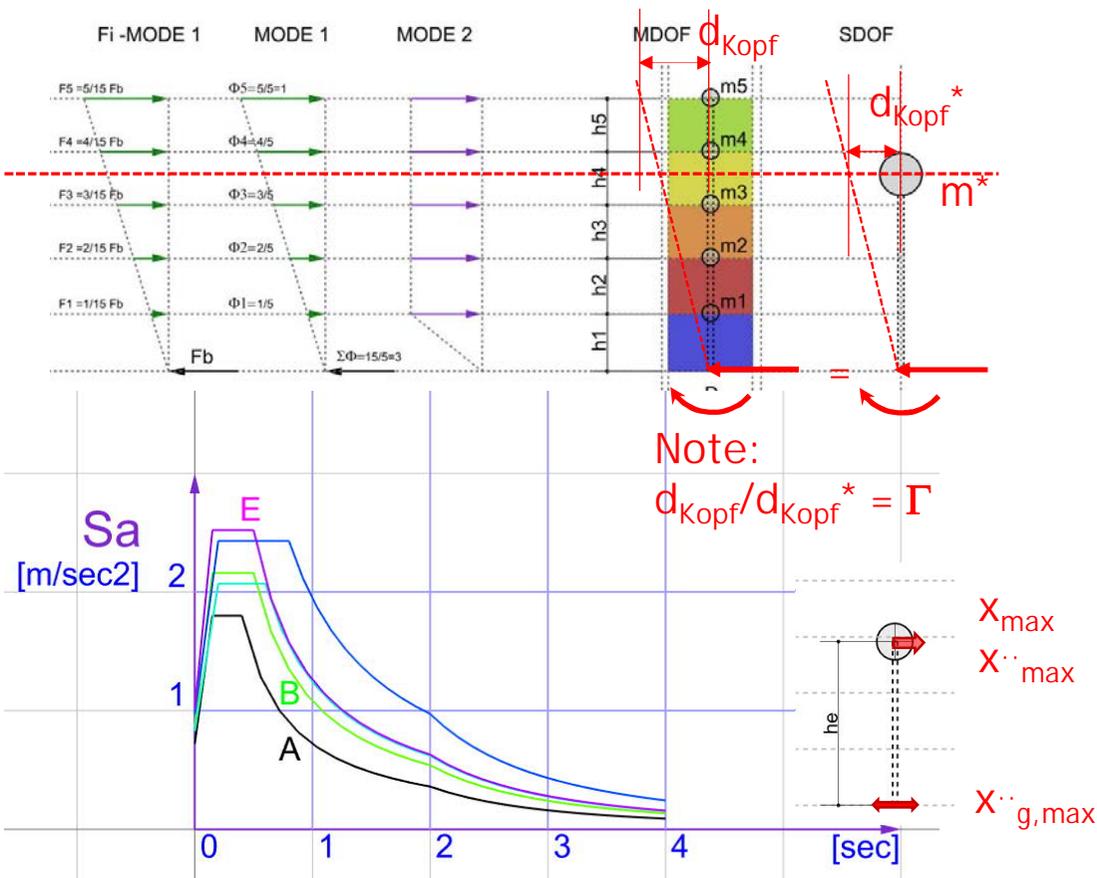
„Statisch“
Variabler Anteil: „Gesamt“
Richtung: Konstant (Abhängig von der Windrichtung)





Erstellung von Codes:
 Normierte Beben und Bebenantworten





Antwortspektrum Typ I in Abhängigkeit des Bodens, normiert auf $a_g = 1.0 \text{ m/sec}^2$ für 5% Dämpfung; aus EN 1998-1

Grundlagen Baudynamik

Die Bewegungsgleichung des Einmassenschwingers ist gegeben durch:

$$m\ddot{x} + c\dot{x} + kx = -m\ddot{x}_g(t)$$

c und k als Dämpfungs- bzw. Federkonstante

Vernachlässigt man die Dämpfung ($c = 0$), setzt $\omega = \sqrt{k/m}$ und betrachtet man vorerst den homogenen Teil der Differentialgleichung, so erhält man

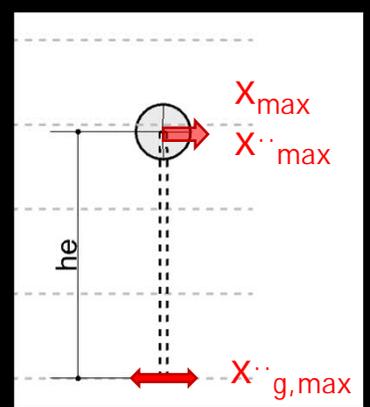
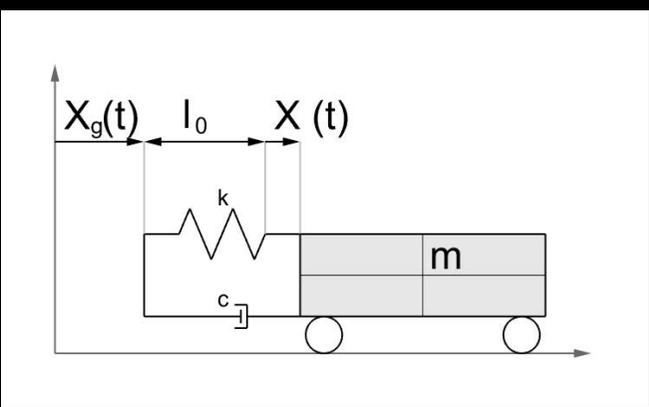
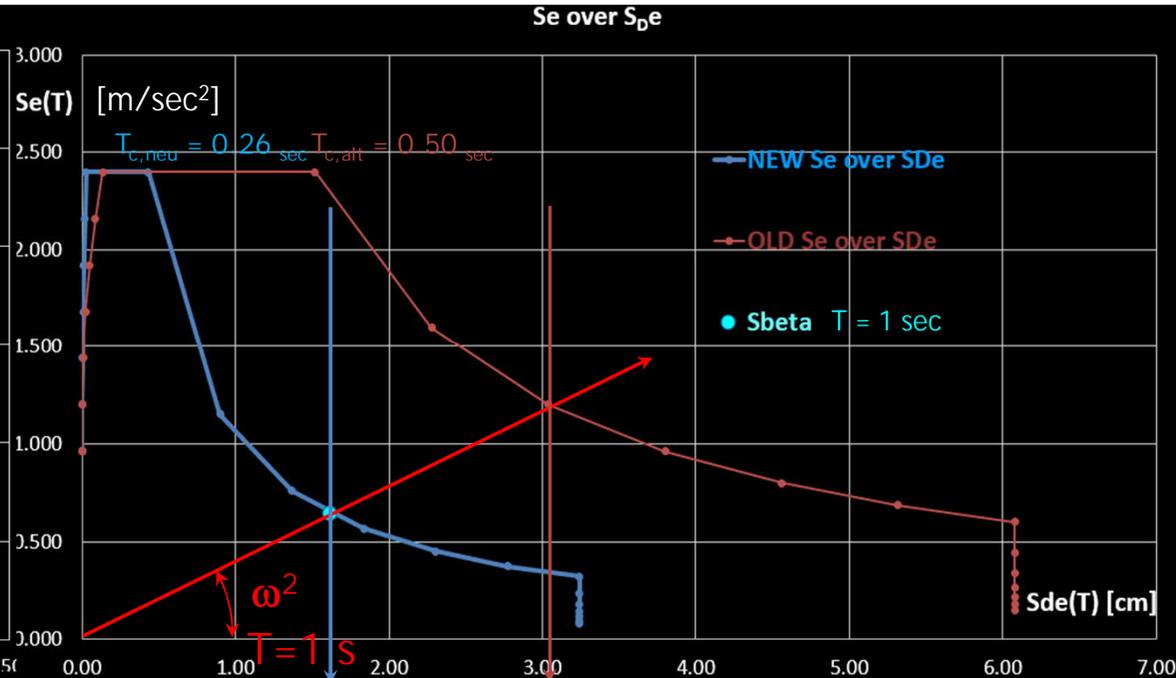
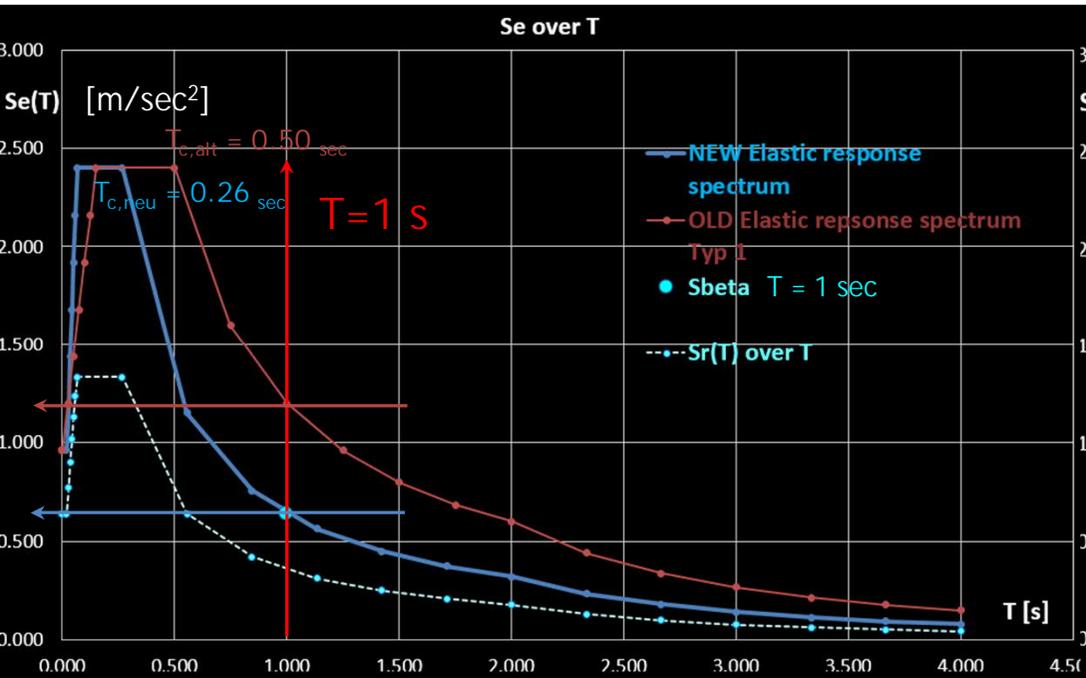
$$\ddot{x} + \omega^2 x = 0$$

Diese Gleichung kann mit dem Ansatz $x = A \sin(\omega t) + B \cos(\omega t)$ gelöst werden. Wenn nur der jeweilige Maximalwert interessiert, führt das auf

$$x = B \cos(\omega t) \quad == \quad x''/\omega^2$$

$$\dot{x} = -\omega B \sin(\omega t)$$

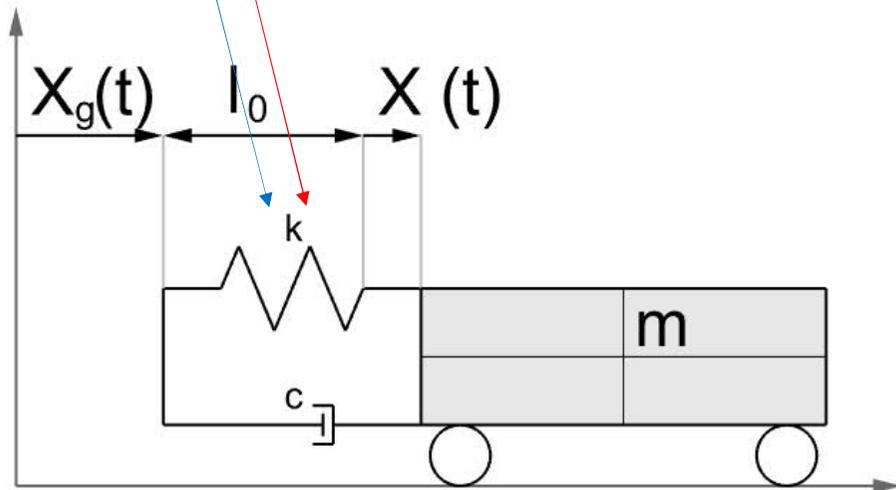
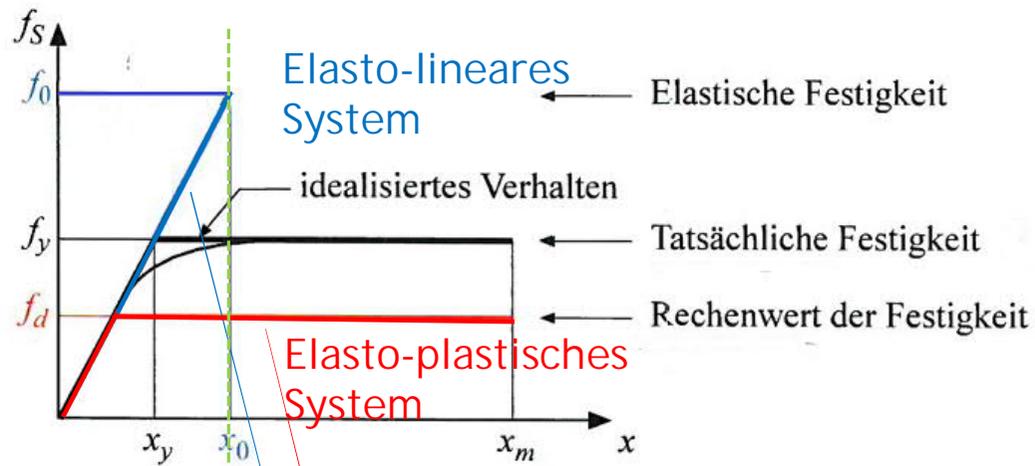
$$x'' = \omega^2 B \cos(\omega t)$$



Elastisches Antwortspektrum aus EN 1998-1 normiert auf $a_g = 0.8 \text{ m/sec}^2$ für 5% Dämpfung; Bodenklasse B

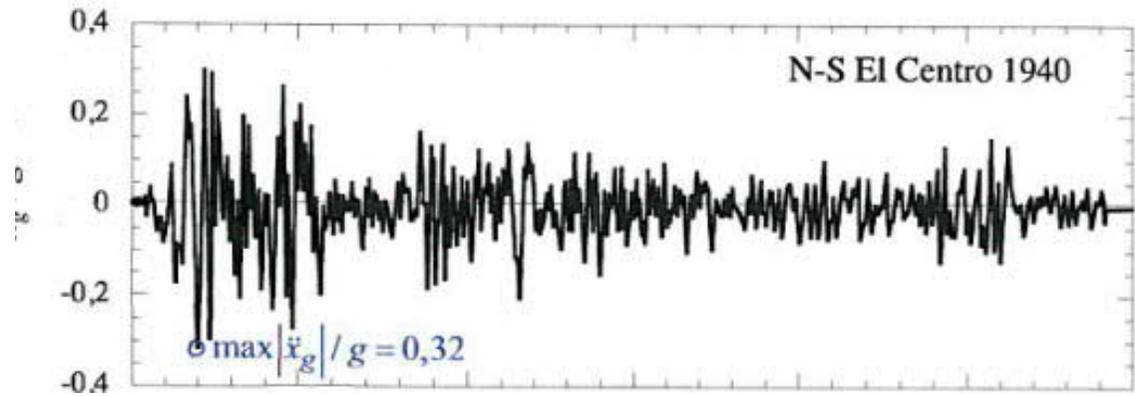
$$S_{de} = \frac{1}{\omega^2} S_e = \frac{T^2}{4\pi^2} S_e$$

$$\omega = 2\pi f = 2\pi / T \dots \text{System, Bauteil}$$



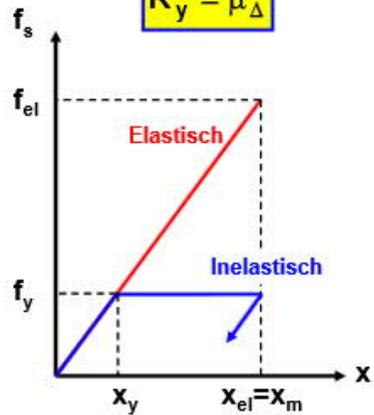
Überfestigkeit $\Omega_d = f_y/f_d$;

Der Festigkeitsreduktionsfaktor $R_\mu = f_0/f_y = x_0/x_y$ stellt den Zusammenhang von einem „realen“ elastoplastischen System mit dem zugehörigem linearen System her)



Prinzip der gleichen
Verschiebung ($T > T_C$)

$$R_y = \mu_{\Delta}$$



Prinzip der gleichen
Energie ($T_B < T < \sim T_C$)

$$R_y = \sqrt{2\mu_{\Delta} - 1}$$

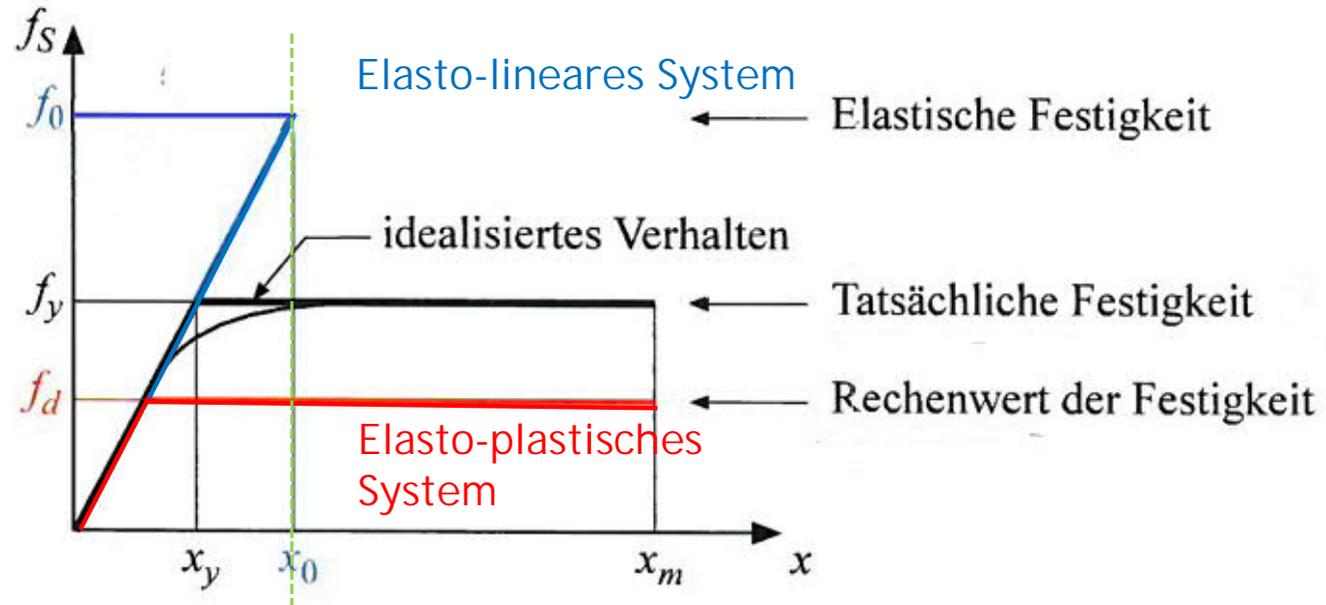
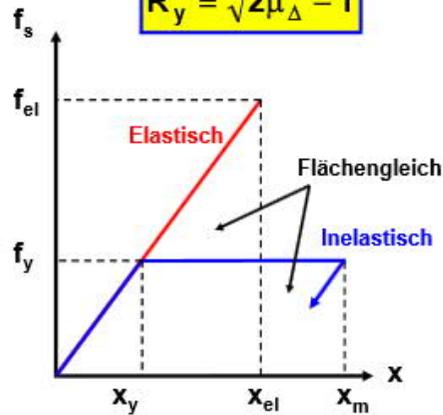


Abb. aus: SIA, Erdbebenbemessung mit den neuen SIA-Tragwerksnormen

Peter Fajfar, M. Eeri
 A Nonlinear Analysis Method
 for Performance Based
 Seismic Design

$$T < T_c \quad R_u = (u - 1) \frac{T}{T_c} + 1$$

$$T > T_c \quad R_u = u$$

and

$$S_{e,pl} = S_e(T) / R_u$$

$$S_{D,pl} = S_D \cdot \text{MIN}(3; u/R_u)$$

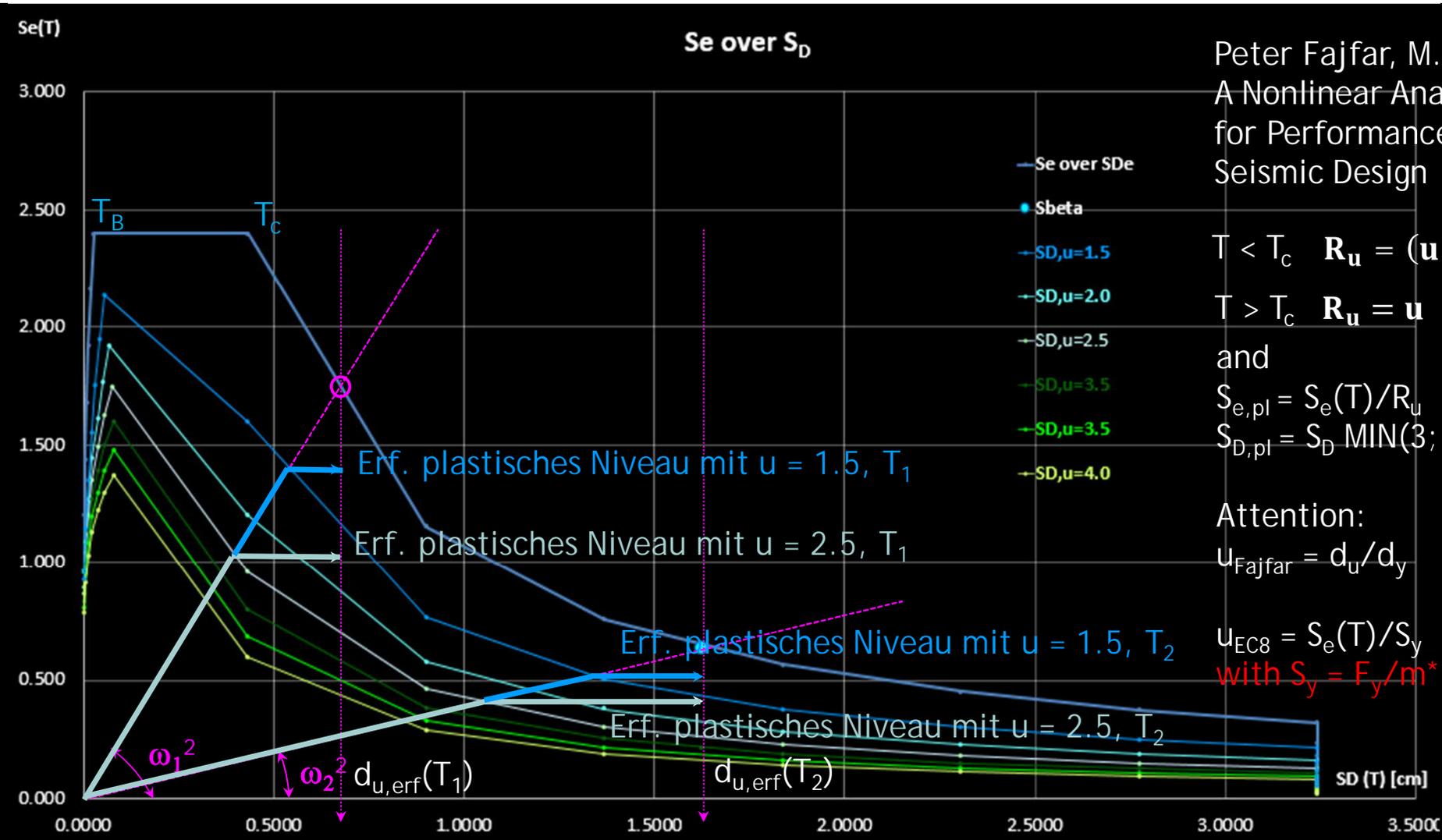
Attention:

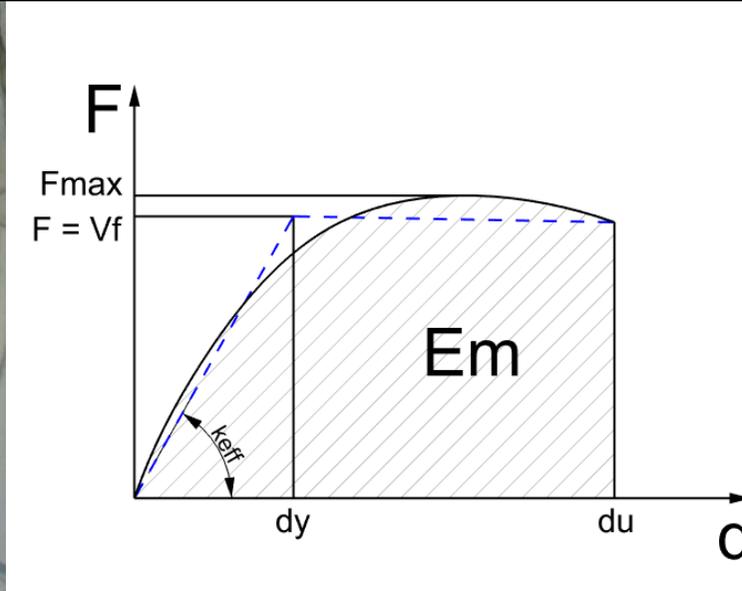
$$u_{\text{Fajfar}} = d_u / d_y$$

$$u_{\text{EC8}} = S_e(T) / S_y$$

with $S_y = F_y / m^*$..yield acceleration

Se over S_D





EUROCODE 1998-3/C - Biegung/Kippen

$$V_f = \frac{D N}{2H_0} (1 - 1.15v_d) \quad \text{mit } v_d = N/(D t f_d)$$

$$\text{und } d_{u,max} = 0.008 H_{tot}/D * H_{tot}$$

Plastisches Tragvermögen einer Wand gemäß EN 1998-3/ Anhang C

EUROCODE 1998-3/C - Schub/Gleiten

$$V_f = f_{vd} D` t \quad \text{mit } f_{vd} = f_{mv0} + 0.4 N/(D` t) \leq 0.065 f_m$$

$$\text{und } d_{u,max} = 0.004 * H_{tot}$$

11.4.1.2.3 Elements failing by shear sliding

(1) The ultimate deformation capacity of an unreinforced masonry pier controlled by shear sliding should be expressed in terms of the chord rotation at the end section where the mechanism occurs and is taken equal to a) or b), as appropriate:

- a) in pre-modern masonry buildings: $\theta_{s,u} = 0,008$, unless the shear strength of the panel due to the failure of masonry units $V_{s,units}$ is attained (see Formula (11.19)), in which case $\theta_{s,u} = 0,005$;
- b) in modern masonry buildings (hollow units): the limit threshold should be limited to $\theta_{d,u} = 0,004$.

(2) The deformation capacity $\theta_{s,u2}$ of an unreinforced masonry pier controlled by shear sliding (see Figure 11.5) should be expressed in terms of drift ratio and taken as 4/3 of the values in (1) ($\theta_{s,u2} = 4/3 \theta_{s,u}$).

(3) The reduced shear force corresponding to $\theta_{s,u2}$ in a pier is a fraction of the shear resistance, proportional to the level of compression. Its value may be directly obtained from Formula (11.19), neglecting the contribution of $f_{v,0}$. This shear force may be taken as residual strength after $\theta_{s,u2}$. If in 11.4.1.1.3(3) the shear strength V_s is given by the limit $V_{s,units}$, the residual strength should be taken as half of the reduced shear force corresponding to $\theta_{s,u2}$.

Auszug: EN 1998-3 - Diskussionsfassung

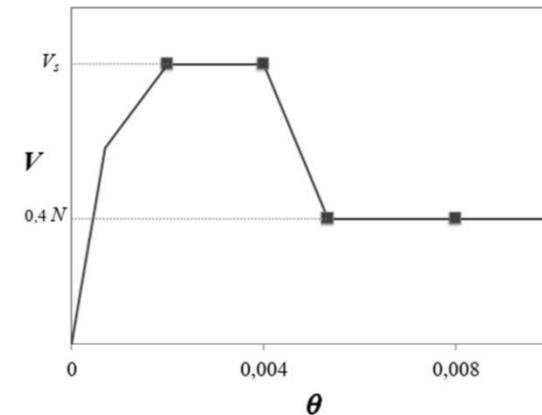


Figure 11.5 — Force-deformation relationship of regular masonry element due to shear sliding

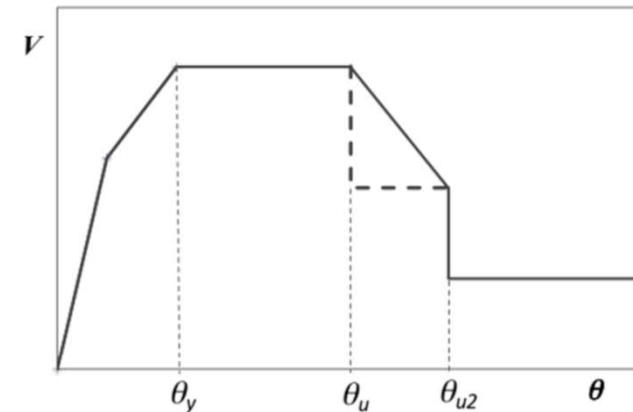


Figure 11.1 — Force-deformation relationship for masonry elements

Nachweis des erforderlichen Zuverlässigkeitsniveaus

EC8 - Derzeitige Fassung

$$d_{u,erf} > 1.5 d_{u,Spektrum}$$

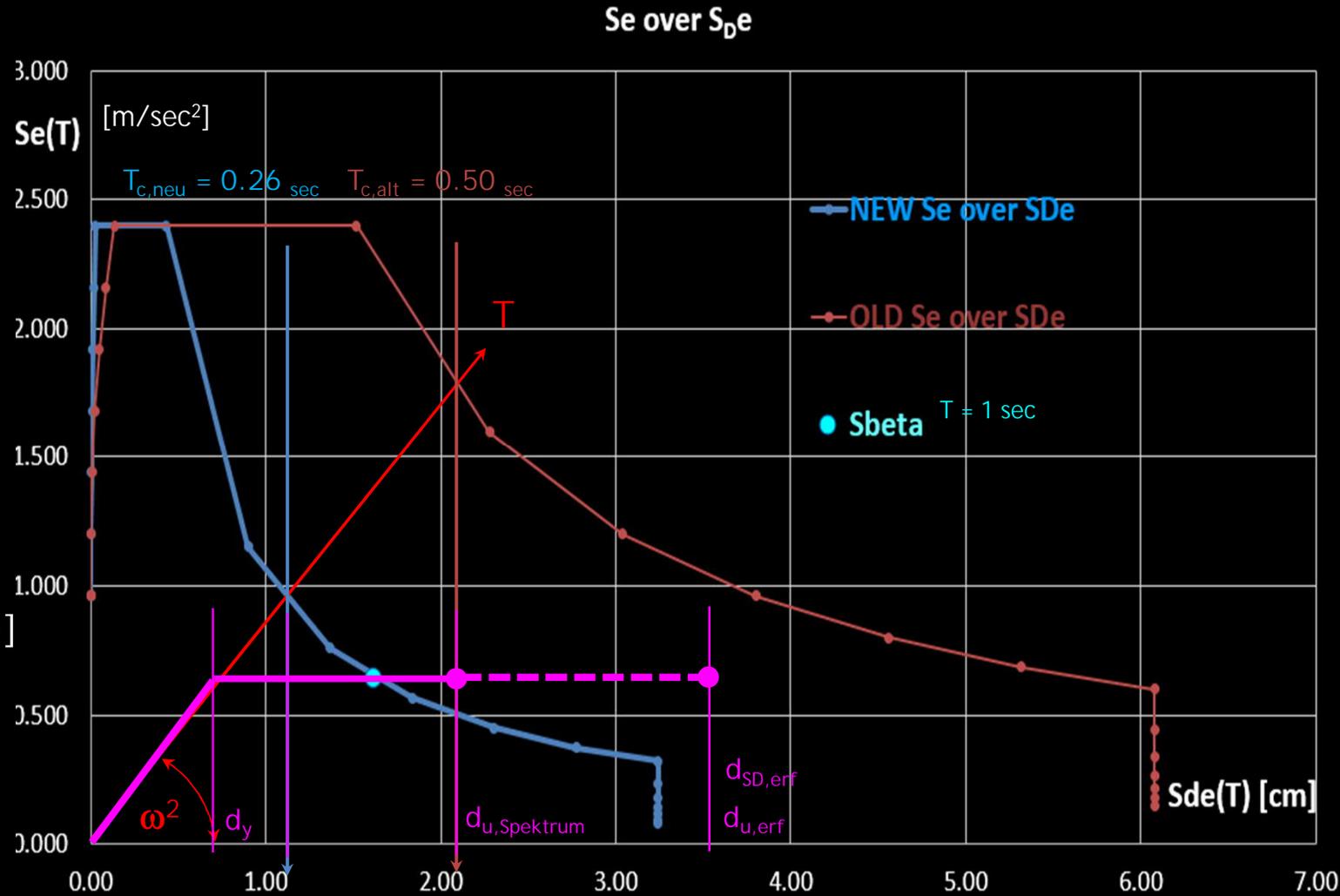
EC8 - Neue Fassung

$$d_{SD,erf} > 1/\gamma_{RD,SD,d} [d_y + \alpha_{SD,d}(d_u - d_y)]$$

mit

$$\alpha_{SD,d} = 0.35 \dots 0.5$$

$\gamma_{RD,SD,d}$ = Materialabhängig?

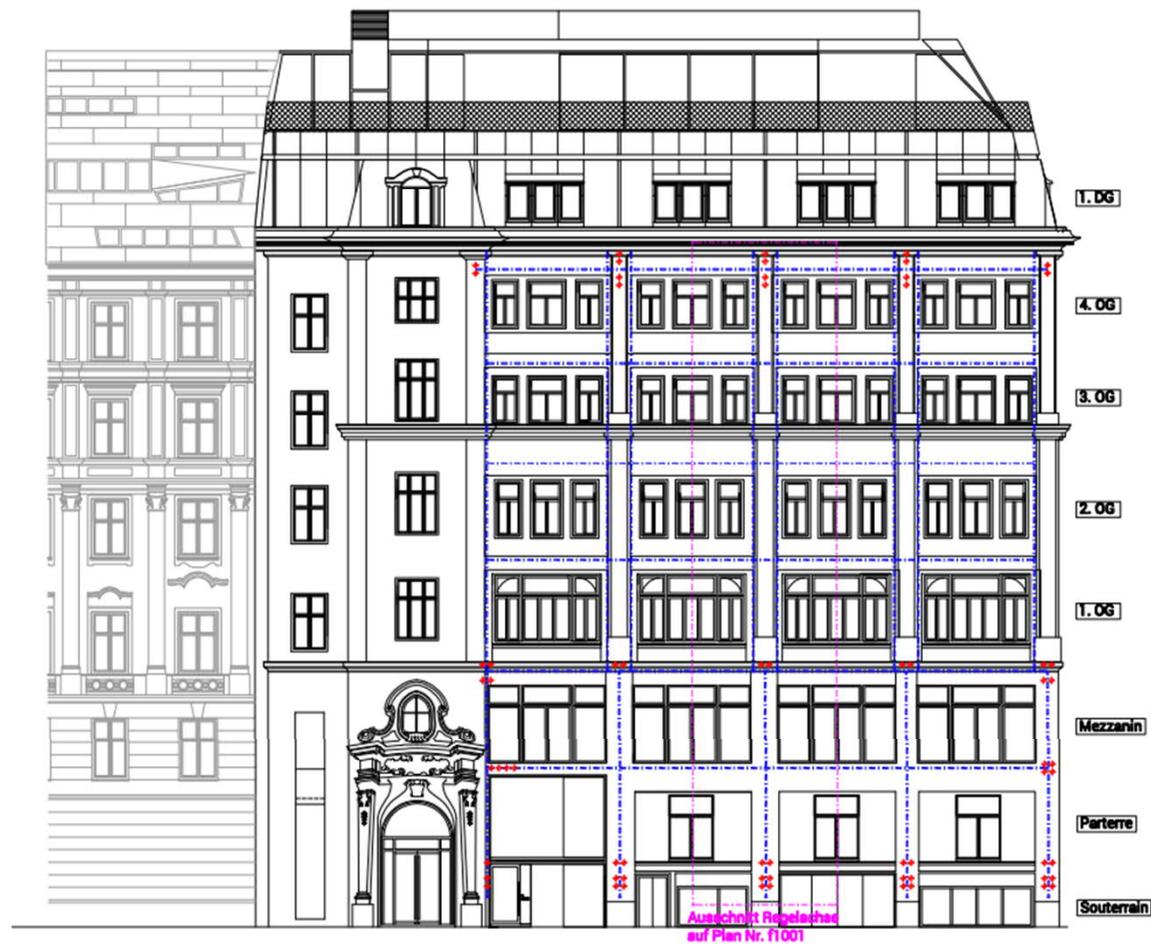


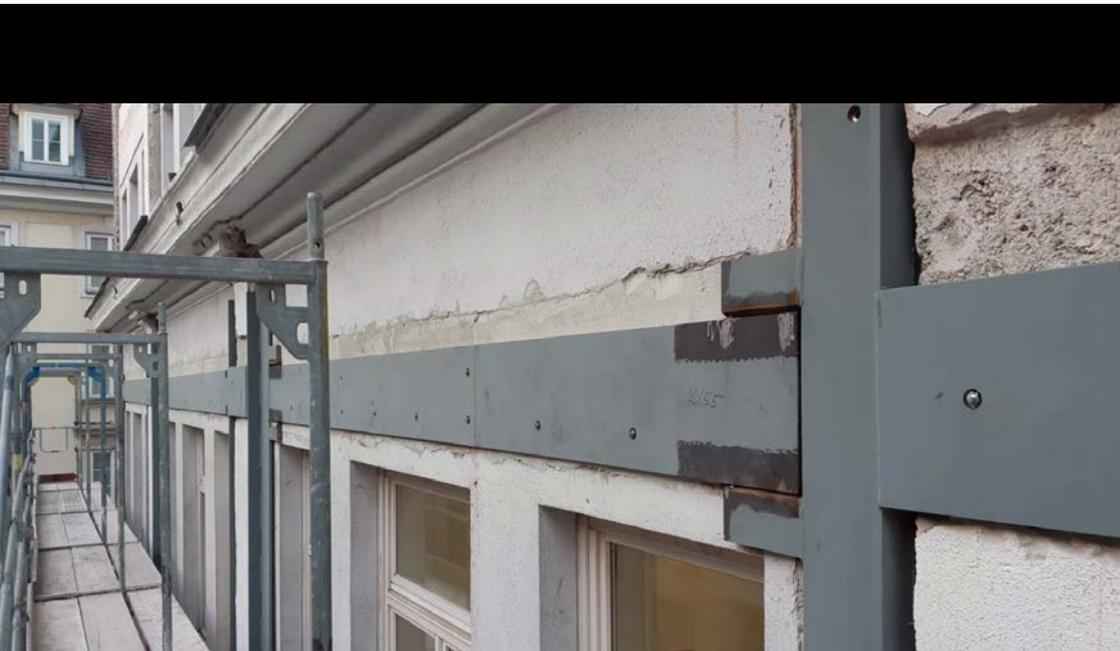
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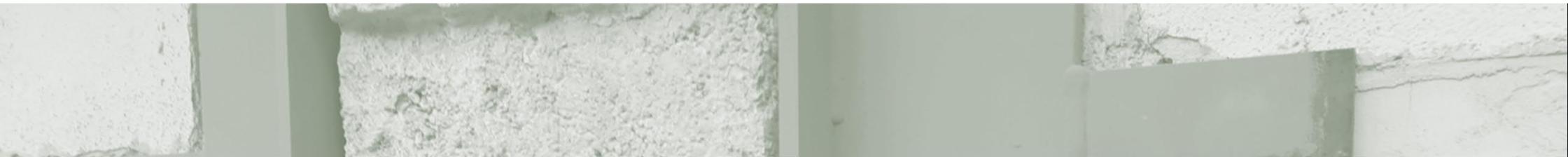


Legende:
 * ... Kernbohrung gemäß Detail F Plan Nr. f1001
 - - - Achsen Exoskelett

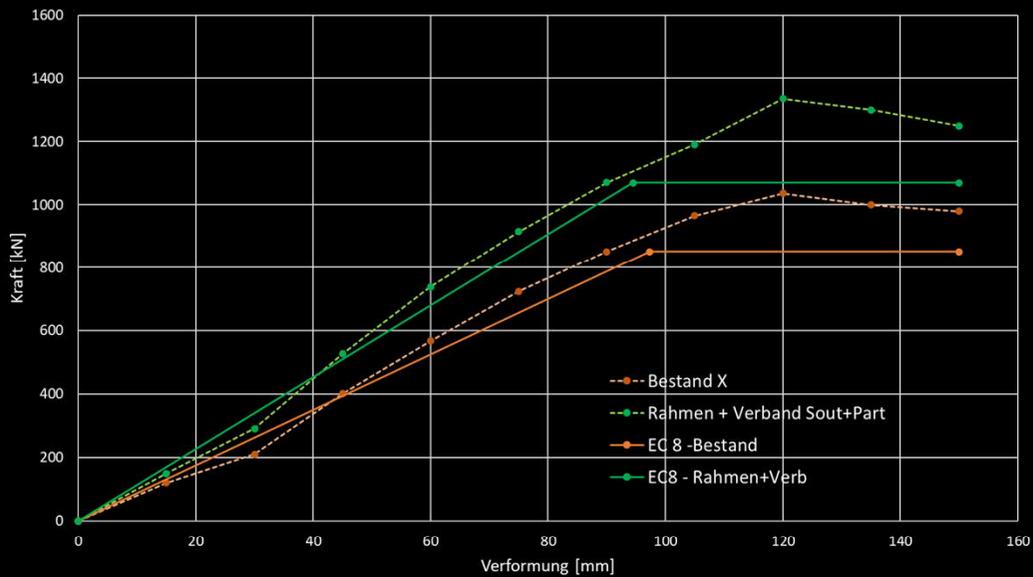
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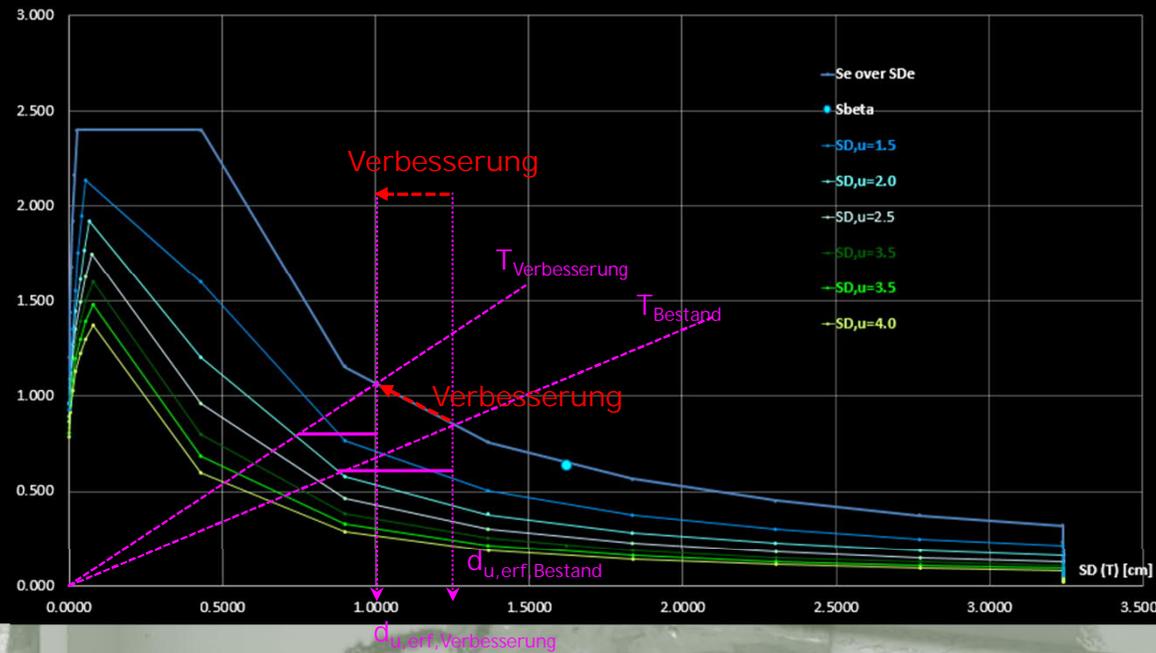


Kraft - Verschiebungsdiagramm



Se(T)

Se over S_0





Danke für Ihre Aufmerksamkeit

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