GSV®
Güteschutzverband
Betonschalungen

# Application comments regarding safety concepts for formwork and scaffolding

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# 1. Explanatory remarks

Since the end of 2007 a consistent series of standards (Eurocodes EC) is existing for the construction industry in Europe which determines the requirements regarding the serviceability, structural safety and durability of structures. These Eurocodes are valid throughout Europe and provide the basics for product specifications, tenders and mathematical calculation. They are the world´s most highly developed set of standards in the field of construction.

The Eurocodes along with the associated national standards are based on the concept of limit state design with partial safety factors. This verification procedure replaces the widely used "$\sigma_{perm}$ concept" (permissible stress design) which compares the actual stresses with the permissible stresses of the material.

The Eurocodes compare the actions $E_d$ (loads) with the resistance $R_d$ (capacity). The previous safety factor, used when determining the permissible stresses, is now divided into several partial safety factors on the action and resistance sides. The safety level remains the same!

This document contains exemplary values of the European standards and presents the design concept in the form of extracts. For specific application the standards shall be considered.

In the user manuals of the GSV member companies "permissible values" are used unless otherwise stated.

**It is important to make sure that "permissible values" (e.g. $M_{perml}$ = 50 kNm) are not mixed with design values (e.g. $M_{Rd}$ = 75 kNm).**

The correlations are shown in the following table and illustration:

$$E_d \leq R_d$$

| Action side | Resistance side |
|---|---|
| $E_d$ Design value of effect of actions, e.g. $V_{Ed}$, $N_{Ed}$, $M_{Ed}$ (*E* – effect; Index *d* – design); Internal forces from action $F_d$ | $R_d$ Design value of the resistance (*R* – resistance); Design capacity of cross-section ($V_{Rd}$, $N_{Rd}$, $M_{Rd}$)<br>Steel: $R_d = \frac{R_k}{\gamma_M}$<br>Timber: $R_d = \frac{k_{mod} * R_k}{\gamma_M}$ |
| $F_d$ Design value of an action (*F* – force); $F_d = \gamma_F * F_k$ | |
| $F_k$ Characteristic value of an action (service load) (Index *k* – characteristic); e.g. dead weight, live load, concrete pressure, wind | $R_k$ Characteristic value of the resistance $V_{Rk}$, $N_{Rk}$, $M_{Rk}$ etc.; e.g. bending moment of resistance to yield stress |
| $\gamma_F$ Partial safety factor for actions (in terms of load; Index *F* – force); values from EN 12812 | $\gamma_M$ Partial safety factor for a material property (in terms of material; Index *M* – material); e.g. for steel, timber, etc.; values from EN 12812 |
| | $k_{mod}$ Modification factor (only for timber - to take account of the moisture and duration of the load action); e.g. for timber formwork beam: values from EN 1995-1-1 and EN 13377 |

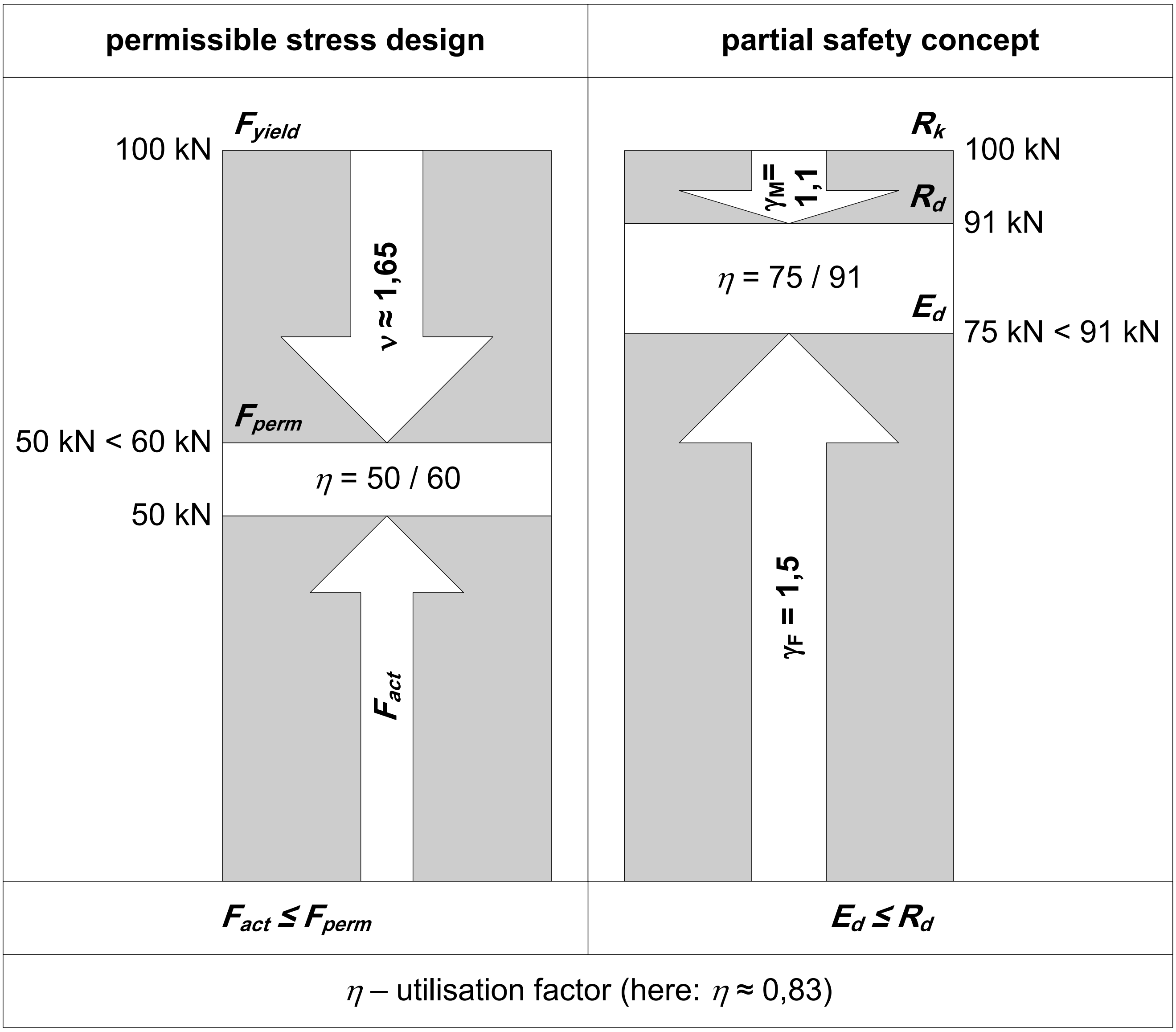


*Fig. 1: Comparison of the safety concepts*

From the "permissible values", the design values for the design capacity are determined with the following typical partial safety factors:

$\gamma_F$ = 1,5
$\gamma_{M\ Stahl}$ = 1,1
$\gamma_{M\ Holz}$ = 1,3
$k_{mod}$ = 0,9 (timber formwork beam)

In general, the following applies for steel:

$$F_{perm} = \frac{R_k}{\gamma_F * \gamma_M}$$

for timber:

$$F_{perm} = \frac{R_k * k_{\mathrm{mod}}}{\gamma_F * \gamma_M}$$

Proof of serviceability (deflection) is realised with the partial safety factor $\gamma_F$ = 1.0.

# 2. Examples

## 2.1 Example: conversion between the verification concepts

Timber formwork beam (EN 13377, DIN V 20000-2)

According to EN 13377, the timber formwork beam - Type P20 - has a permissible shear force *Q* in accordance with Table E.1 (EN 13377) and *V* in accordance with DIN V 20000-2:2006-07, Table 1: ***V* = 11.0 kN**. It is assumed that this value corresponds to the characteristic action $F_k$ – utilisation factor $\eta$ = 100 %.

How large is the design value $F_d$ of the action $F_k$?

$$\boxed{F_d = \gamma_F * F_k} \Rightarrow \boxed{F_d = 1{,}5 * 11\,\text{kN} = 16{,}5\,\text{kN}}$$

In terms of resistance, the design value of the shear force $V_d$ must be more than or equal to the design value of the action $F_d$. From this, the characteristic shear bearing capacity $V_k$ is calculated:

$$\boxed{V_d = \frac{k_{\text{mod}} * V_k}{\gamma_M}} \Rightarrow \boxed{V_k = \frac{\gamma_M * V_d}{k_{\text{mod}}} = \frac{1{,}3 * 16{,}5\,\text{kN}}{0{,}9} \approx 23{,}9\,\text{kN}}$$

This value is identical to the one in EN 13377, Table 1 is specified as characteristic design capacity
**$V_k$ = 23.9 kN** for the Type P20 timber formwork beam.

## 2.2 Example: illustrating the uniform safety level

Steel beam subject to elastic bending

Beam: IPE 200 with $W_y$ = 194.300 mm³

Material: St 37 (old) with $\sigma_{b,perm}$ = 140 N/mm² and
S235 (new) with $f_{y,k}$ = 235 N/mm² (according to EC)

Span: $L$ = 2 m

Variable load $q_k$ = 50 kN/m

| $\sigma_{perm}$-concept (permissible stress design) | partial safety concept |
|---|---|
| $q = q_k$ = 50 kN/m | $q_d = q_k * \gamma_F$ = 50 kN/m * 1,5 = 75 kN/m |
| $M_y = q * L^2 / 8$<br>$M_y$ = 50 kN/m * 2² m² / 8<br>$M_y$ = 25 kNm | $M_d = q_d * L^2 / 8$<br>$M_d$ = 75 kN/m * 2² m² / 8<br>$M_d$ = 37,5 kNm |
| $\sigma_b = M_y / W_y$<br>$\sigma_b$ = 25*10⁶ Nmm / 194.300 mm³<br>$\sigma_b$ = 129 N/mm² | $\sigma_d = M_d / W_y$<br>$\sigma_d$ = 37,5*10⁶ Nmm / 194.300 mm³<br>$\sigma_d$ = 193 N/mm² |
| $\sigma_{b,zul}$ = 140 N/mm² | $f_{y,d} = f_{y,k} / \gamma_M$ = 235 N/mm² / 1,1<br>$f_{y,d}$ = 214 N/mm² |
| **Utilisation Factor**<br>$\eta = \sigma_b / \sigma_{b,zul}$ = 129 / 140 = **0,92** | $\eta = \sigma_d / f_{y,d}$ = 193 / 214 = **0,90** |
| $\sigma_b \leq \sigma_{b,zul}$ ✓ | $\sigma_d \leq f_{y,d}$ ✓ |

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