The Second Generation Eurocodes

Key changes and benefits through design examples

Online, 3-5 June 2025

EN 1999-1-3: Structures susceptible to fatigue

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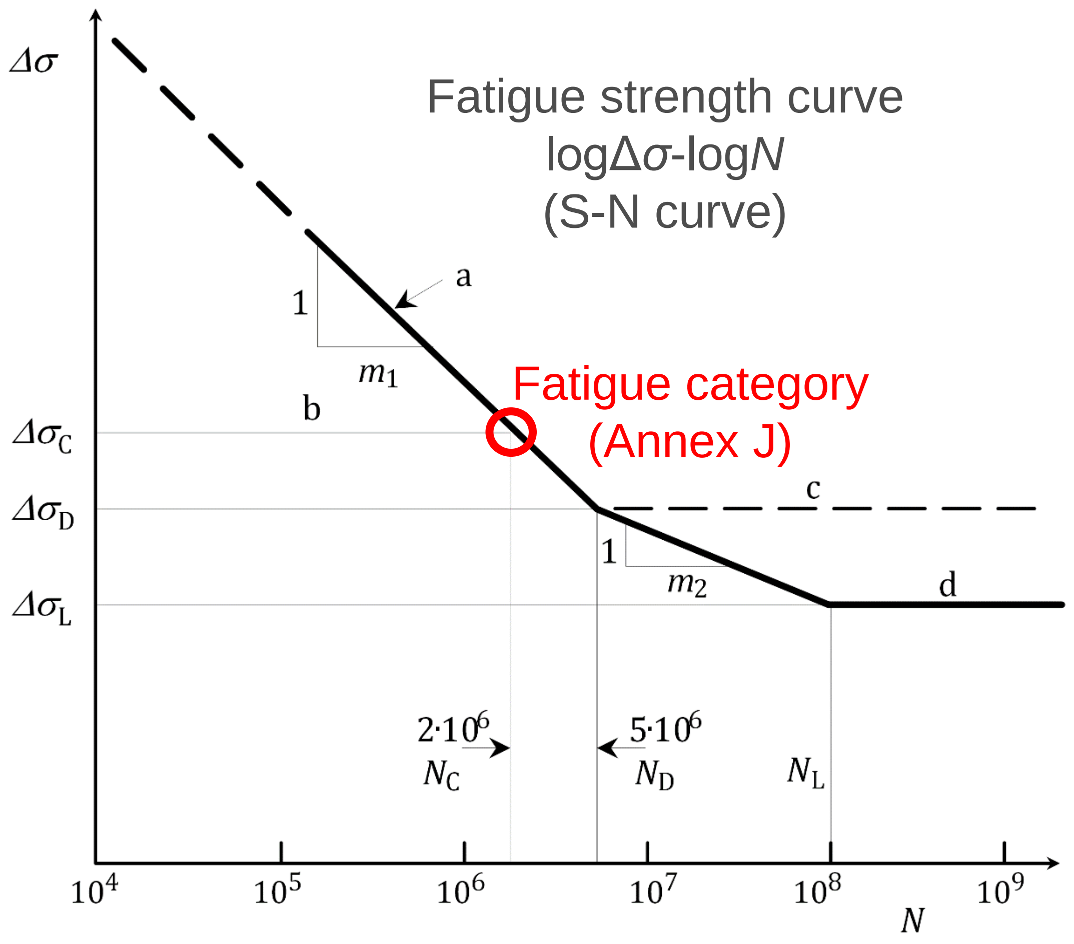
Fatigue resistance according to EN 1999-1-3



Fatigue category of the constructional details given together with slope m_1 ; slope m_2 related to slope m_1 and the family to which the detail belongs:

$(m_1 ; m_2) = (7 ; 7)$
$(m_1 ; m_2) = (3{,}4 ; 5{,}4)$
$(m_1 ; m_2) = (4{,}3 ; 6{,}3)$
$(m_1 ; m_2) = (7 ; 9)$
$(m_1 ; m_2) = (4 ; 4)$.

Fatigue verification according to EN 1999-1-3

1. Fatigue verification criterion based on stress range:

$$\gamma_{Mf}\gamma_{Ff}\Delta\sigma_{E,d} \leq \Delta\sigma_D \quad \text{or} \quad \gamma_{Mf}\gamma_{Ff}\Delta\sigma_{E,2e} \leq \Delta\sigma_C$$

γ_{Mf} – partial factor on fatigue resistance

γ_{Ff} – partial factor on fatigue loading

$\Delta\sigma_{E,d}$ – stress range repeated *n* times

$\Delta\sigma_D$ – constant amplitude fatigue limit

$\Delta\sigma_{E,2e}$ – stress range repeated 2 million times

$\Delta\sigma_C$ – detail category

2. Fatigue verification criterion based on cumulative damage (Palmgren-Miner rule):

$$\boxed{D_{L,d} = \sum_i \frac{n_i}{N_i} < 1}$$

n_i - the number of applied cycles, corresponding to the stress range $\Delta\sigma_i$, during the required lifetime

N_i - the number of cycles at failure deduced from an S-N curve, corresponding to the weighted stress range $\gamma_{Mf}\,\gamma_{Ff}\,\Delta\sigma_i$.

Methods of fatigue verification in EN 1999-1-3

Safe life method, either in the event of inaccessibility for a fatigue inspection or when there is no justification for its implementation:

- SLD-I: does not require a regular inspection program
- SLD-II: requires a general inspection program (not fatigue)

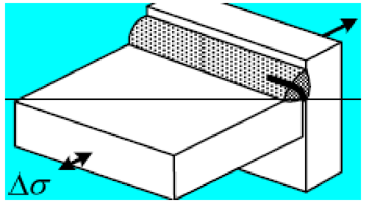
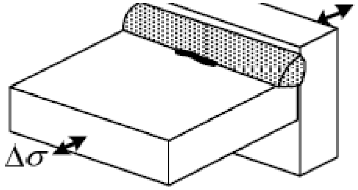
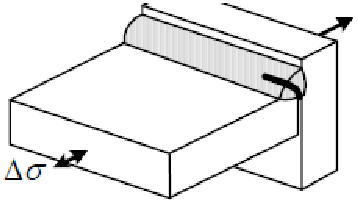
Damage tolerance method, the prerequisite for which is the development of a fatigue inspection program:

- DTD-I: repair of any detected crack or the replacement of the cracked element
- DTD-II: allows fatigue cracks provided that their propagation is monitored

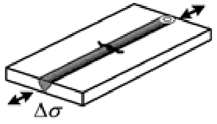
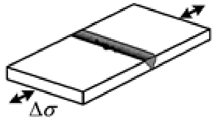
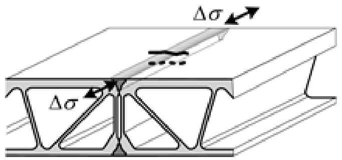
Choice of the method and consequence of the failure give γ_{Mf}
(ranging from γ_{Mf} =1,0 to γ_{Mf} =1,3) (γ_{Ff} – generally γ_{Ff} = 1)

Key changes

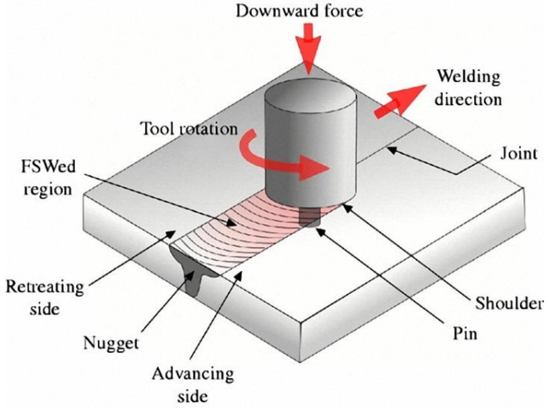
Improvement of detail categories for: **fillet welds** (ex. ➔) and bolted joints

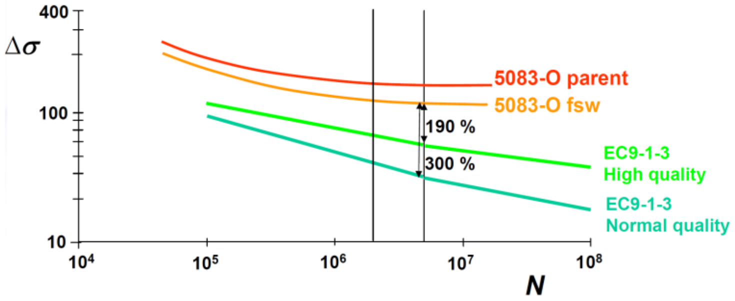
Detail type	Detail category $\Delta\sigma - m_1$ 1)	Constructional detail Initiation site	Type of weld	Stress analysis: Stress parameter	Stress analysis: Stress concentrations already allowed for	Execution requirements: Welding requirement	Quality level3): internal	Quality level3): surface and geometric	additional
~~9.3~~	~~12-3,4~~	 ~~Weld~~	~~Onesided fillet weld; root crack for a/t ≤0,6~~	~~Net throat~~	Stiffening effect of transverse element	Extension plates used on ends, cut off and ground flush in direction of $\Delta\sigma$	~~C~~	~~C~~	
9.34	28-3,4	Tubular cross-section  Weld toe	One sided fillet or partial penetration weld; toe crack for $a/t > 1{,}1$	Net section			C	C	
9.4 ~~5~~	25-3,4	Tubular cross-section5)  Weld toe	One sided fillet or partial penetration weld; root crack for $a/t \leq 1{,}1$	Net throat3)			C	C	

New content included in scope of EN 1999-1-3

Detail type	Detail category $\Delta\sigma$-m_1[a]	Constructional detail Initiation site Stress orientation	Weld type	Stress analysis		Execution requirements		
				Stress parameter	Stress concentrations already allowed for	Welding requirements	Quality level [b] Internal	Quality level [b] Surface and geometric
17.1	**56–7**	 At weld surface or backing Stress due to longitudinal axial force	Full penetration FSW	Nominal stress at initiation site	-	Continuous automatic welding	-	As welded, no start and stop at initiation site
17.2	**56–7**	 At weld surface or backing Stress due to transverse axial force	Full penetration FSW	Nominal stress at initiation site	-	Continuous automatic welding	-	As welded, no start and stop at initiation site
17.3	**56–7**	 At weld root or weld surface Stress due to longitudinal bending, axial and or shear force on profiles	Continuous FSW, no backing	Nominal stress on basis of the whole cross section (profiles)	-	Continuous automatic welding	-	As welded, no start and stop at initiation site

Inclusion of FSW (Friction Stir Welding)



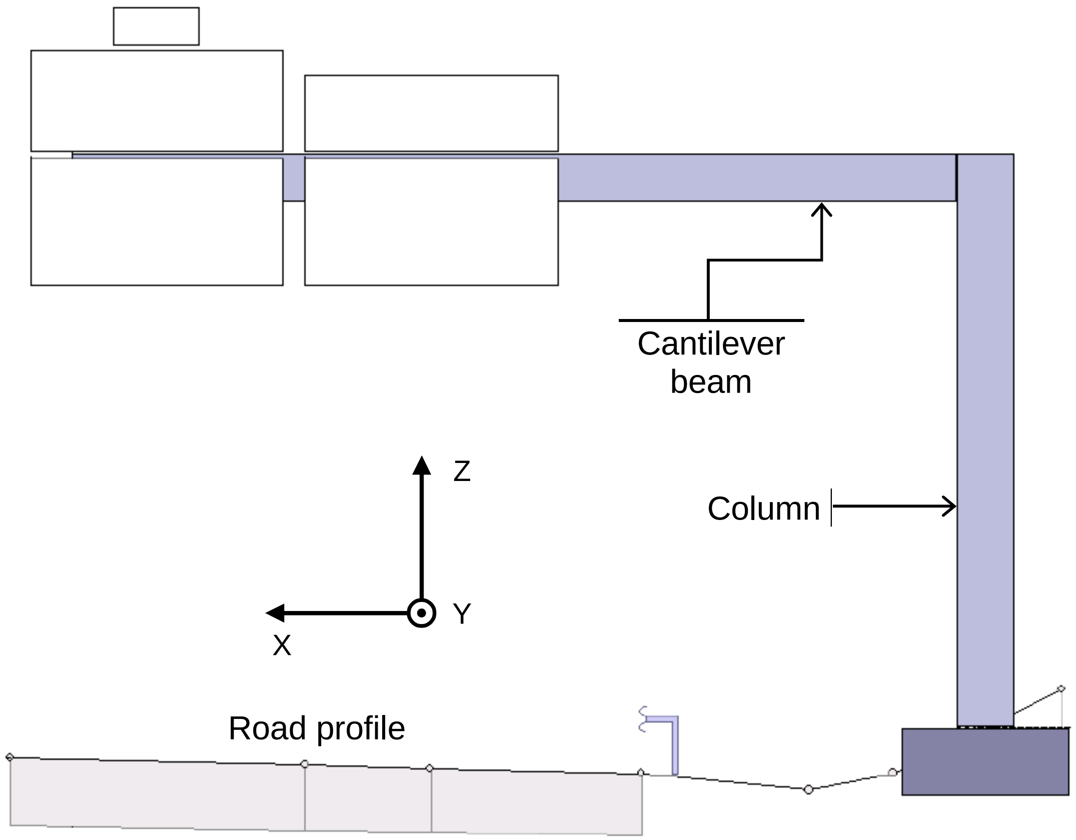


Worked example using EN 1999-1-3

Analysed structure

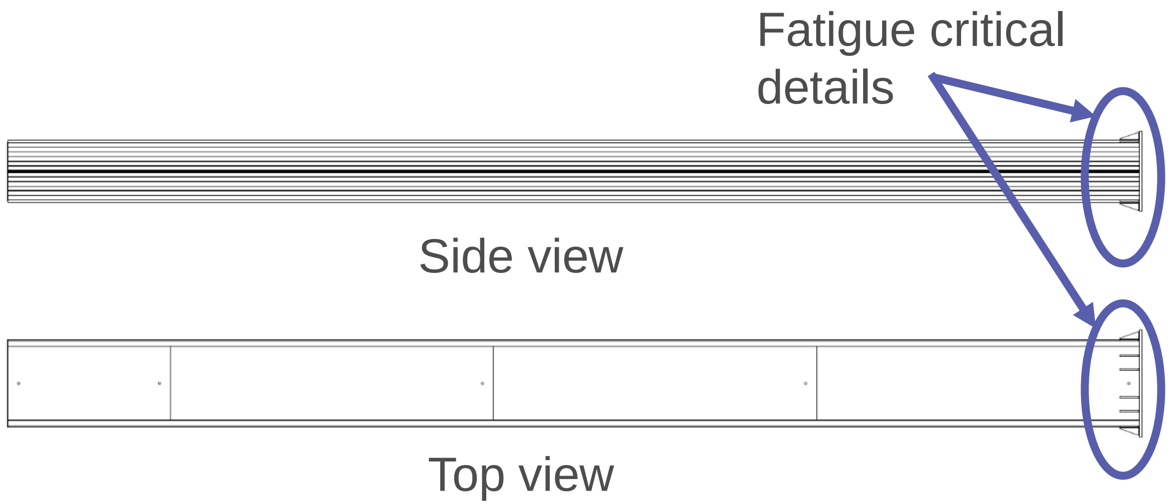
Motorway sign support structure:

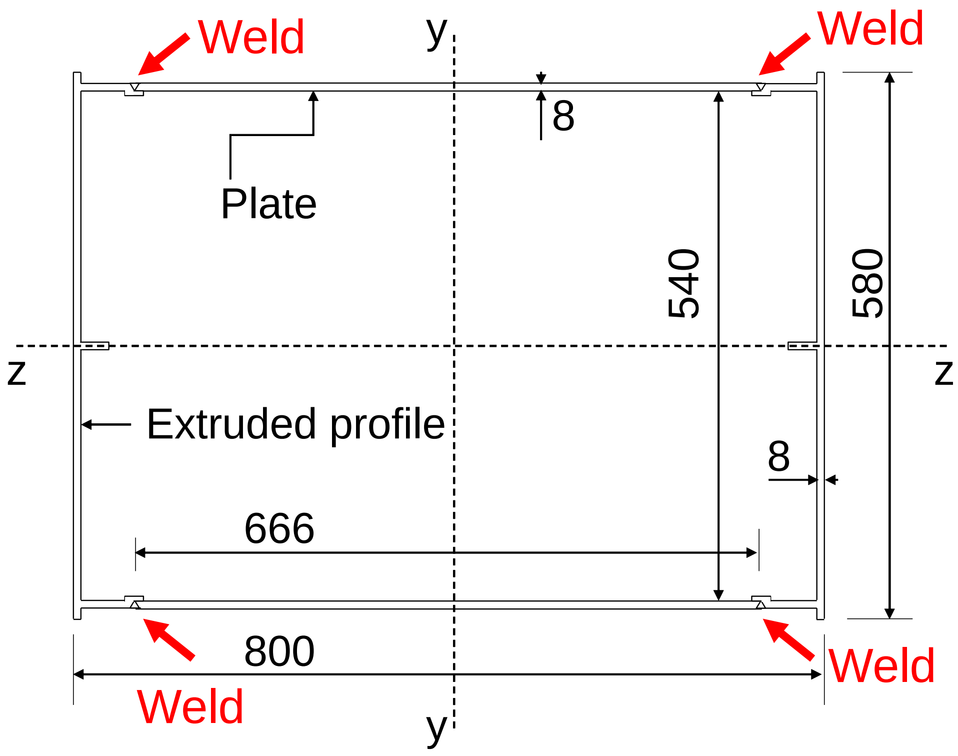
- Members: welded, built-up hollow sections
- Quality level (important for determining fatigue strength): "C“ (weld execution, according to EN ISO 10042)
- The design lifespan: 30 years



Worked example using EN 1999-1-3

Cantilever beam

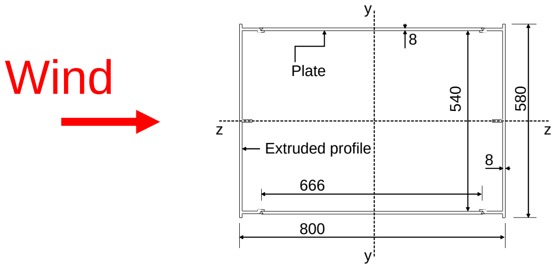


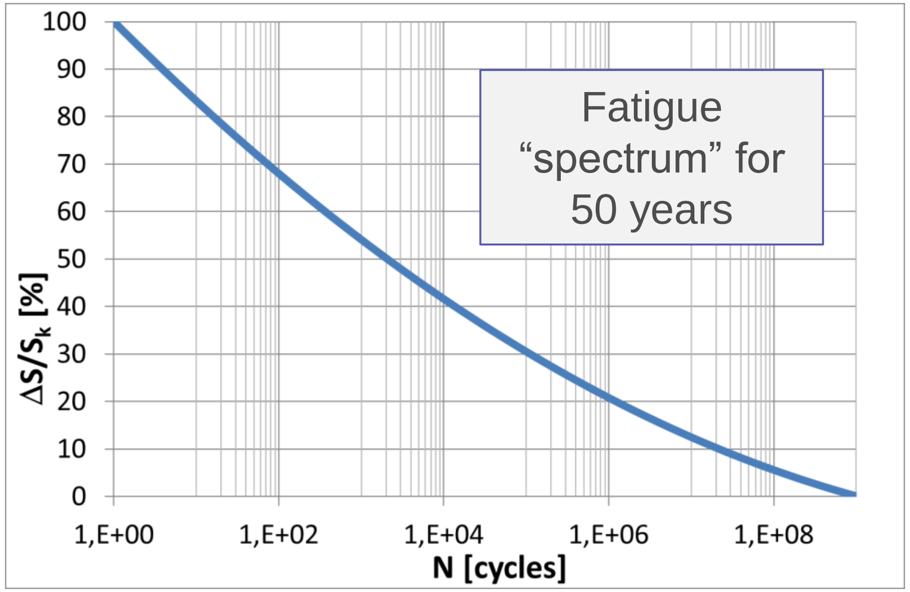


Cross section
(EN AW-6005A T6)

Worked example using EN 1999-1-3

Effects of fatigue actions



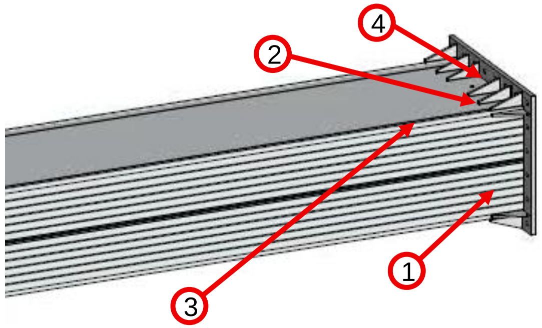


Maximum unfactored stresses from wind actions [MPa]

Wind direction	$\Delta\sigma_{max}$ [MPa]			$\Delta\tau_{max}$ [MPa]		
	N	M_y	M_z	V_y	V_z	M_T
X	0,185	0,362	0,534	0	0	0
Y	0	71,58	0	7,785	0	2,601
Z	0	0	7,482	0	0,571	0,000

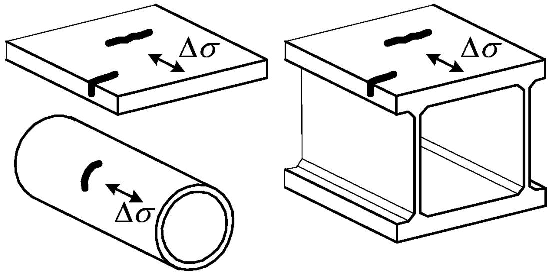
Worked example using EN 1999-1-3

Fatigue-sensitive details

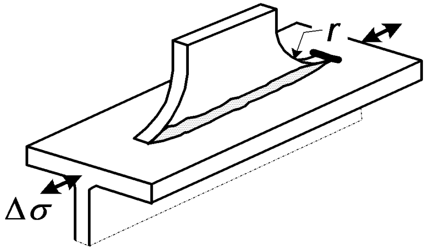


Detail categories
(extract from Annex J of EN 1999-1-3)

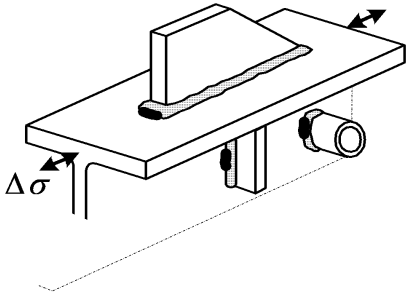
Detail (1)
Type: 1.4
Category Δσ-m_1: **71-7**



Detail (2a)
Type: 3.7
Category Δσ-m_1: **36-3,4**

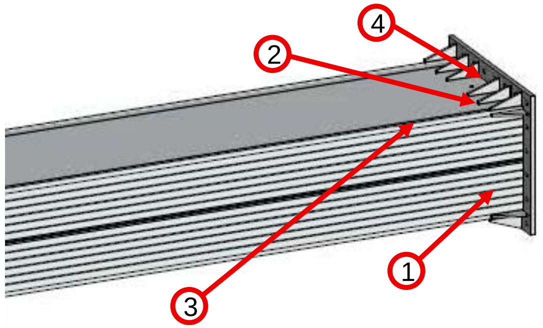


Detail (2b)
Type: 3.8
Category Δσ-m_1: **23-3,4**



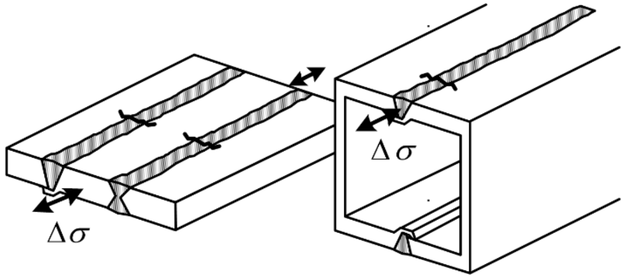
Worked example using EN 1999-1-3

Fatigue-sensitive details

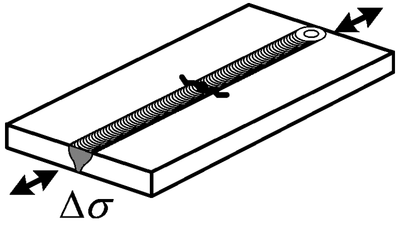


Detail categories
(extract from Annex J of EN 1999-1-3)

Detail (3a)
Type: 5.3
Category Δσ-m_1: **45-4,3**



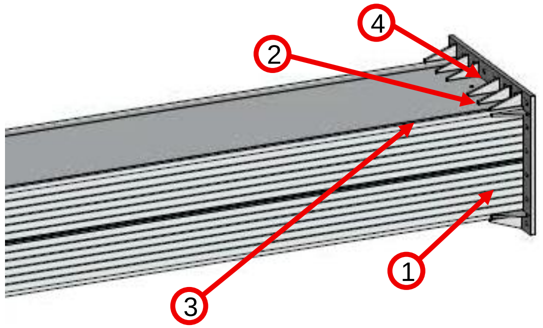
Detail (3b)
Type: 17.1
Category Δσ-m_1: **56-7**



Welding with FSW
(Friction Stir Welds)

Worked example using EN 1999-1-3

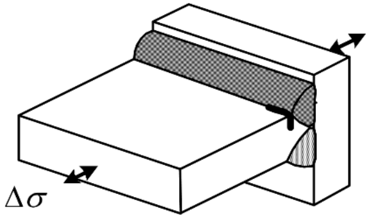
Fatigue-sensitive details



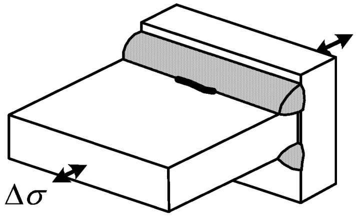
Detail categories

(extract from Annex J of EN 1999-1-3)

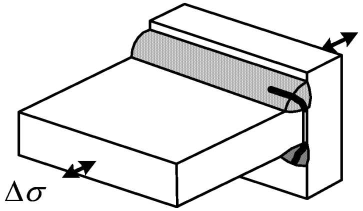
Detail (4a)
Type: 7.6
Category $\Delta\sigma$-m_1: **36-3,4**



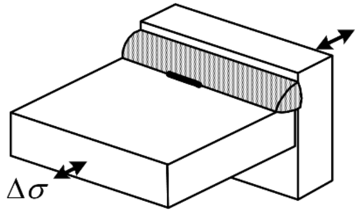
Detail (4b)
Type: 9.1
Category $\Delta\sigma$-m_1: **28-3,4**



Detail (4c)
Type: 9.2
Category $\Delta\sigma$-m_1: **25-3,4**



Detail (4d)
Type: 9.3
Category $\Delta\sigma$-m_1: **28-3,4**



Worked example using EN 1999-1-3

Fatigue verification based on cumulative damage (with γ_{Mf} = 1,1)

Detail	Detail type EN 1999-1-3	Detail category $\Delta\sigma$-m_1 (1G // 2G)	Cumulative damage $D_{L,d}$	
			1G - EN 1999-1-3	2G - EN 1999-1-3
(1)	1.4	71-7	0,0002	0,0002
(2a)	3.7	36-3,4	0,0585	0,0585
(2b)	3.8	23-3,4	0,6602	0,6602
(3a)	5.3	45-4,3	0,0080	0,0080
(3b)	17.1	- // 56-7	-	0,0006
(4a)	7.6	36-3,4	0,0585	0,0585
(4b)	9.1	28-3,4	0,2386	0,2386
(4c)	9.2	25-3,4	0,4283	0,4283
(4d)	9.3	12-3,4 // 28-3,4	**10,96**	0,2386

Worked example using EN 1999-1-3

Conclusion

1. Absence of fatigue verification for shear stress: no S-N curve for shear stresses given in EN 1999-1-3. (Possible to refer to the fatigue recommendations of the IIW.)

2. Fatigue checks are based on many assumptions and require interpretations, from the point of view of actions, that of the safety and also that of the resistance.

3. Passage from the 1st to the 2nd generation of EN 1999-1-3 results in generally more favourable verification results for this example.

Thank you!

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EN 1999-1-3: Structures susceptible to fatigue