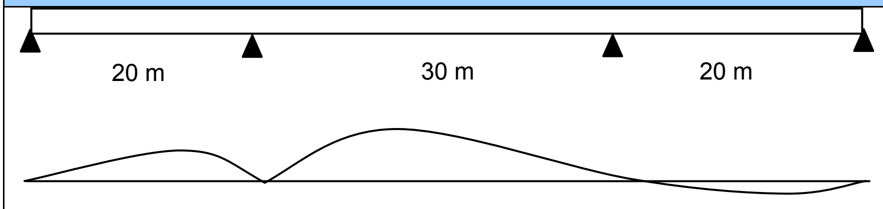
Worked example of fatigue assessment for a 3-span bridge

Assess the adequacy of the details at the bottom flange over an intermediate support for a composite highway bridge carrying a dual 2 lane road.

In the following text, references in [ ] are to BS EN 1993-2 and its NA, unless noted otherwise.

Span configuration and influence line for stress in flange at support



From an elastic global analysis:

Maximum stress in flange due to passage of FLM3 vehicle in lane 1: (compression) $+40\ \text{N/mm}^2$

Minimum stress in flange due to passage of FLM3 vehicle in lane 1: $-6\ \text{N/mm}^2$ (tension)

The influence line for lane 2 has a range that is 40% of that for lane 1

Reference stress range

$\Delta\sigma_p = |\sigma_{pmax} - \sigma_{pmin}| = 40 - -6 = 46$ [9.4.1(3)]

Damage equivalence factors

For damage effect of traffic, λ_1

Critical length of influence line at support section = mean of (20 and 30) = 25 m [9.5.2(2)]

$\lambda_1 = 1.78$ [Figure 9.5]

For traffic volume, λ_2

$$\lambda_2 = \frac{Q_{m1}}{Q_0}\left(\frac{N_{Obs}}{N_0}\right)^{1/5} \qquad [9.5.2(3)]$$

For the slow lane of an all-purpose dual carriageway road, $N_{Obs} = 1.5 \times 10^6$ [BS EN 1991-2, NA.2.23]

$Q_{m1} = 260$ kN [NA.2.39]

$$\lambda_2 = \frac{260}{480}\left(\frac{1.5}{0.5}\right)^{1/5} = 0.675$$

For design life, λ_3

For 120 year design life $\lambda_3 = \left(\frac{120}{100}\right)^{1/5} = 1.037$

For traffic in other lanes, λ_4

For the fast lane of an all-purpose dual carriageway road, $N_{Obs} = 1.0 \times 10^6$ [BS EN 1991-2, NA.2.23]

$$\lambda_4 = \left[1 + \frac{N_2}{N_1}\left(\frac{\eta_2 Q_{m2}}{\eta_1 Q_{m1}}\right)^5\right]^{1/5} = \left[1 + \frac{1.0}{1.5}\left(\frac{0.4 \times 260}{1.0 \times 260}\right)^5\right]^{1/5} = 1.001$$

Overall damage equivalence factor

$\lambda = \lambda_1\lambda_2\lambda_3\lambda_4 = 1.78 \times 0.675 \times 1.037 \times 1.001 = 1.25$

Maximum value of λ = 1.80 [Figure 9.6]

Hence λ = 1.25

Damage equivalent stress

$\gamma_{Ff}\Delta\sigma_{E2} = \gamma_{Ff}\, \lambda\phi_2\Delta\sigma_p$ [9.4.1(4)]

where γ_{Ff} = 1.0 [NA.2.35]

ϕ_2 = 1.0 [9.4.1(4)]

Hence $\gamma_{Ff}\Delta\sigma_{E2} = 1.25 \times 46 = 58$ N/mm^2

Design value of fatigue strength

Design value = $\dfrac{\Delta\sigma_c}{\gamma_{Mf}}$

The value of $\Delta\sigma_c$ depends on the detail category.

According to BS EN 1993-1-9, NA.2.5, the safe life method of assessment should be used and the value γ_{Ff} = 1.1; this value is confirmed by BS EN 1993-2, NA.2.36.

At the intermediate support there are bearing stiffeners attached to the flange by welds transverse to the flange. For the flange, the detail category is 80, according to detail 7 in Table 8.4 of BS EN 1993-1-9.

The bearings can either be attached to a bearing plate that is welded to the flange (using bolts in holes tapped into the bearing plate) or may simply be attached by bolting (with a non-welded tapered plate as necessary). For a bearing plate welded to the flange, the detail is detail 6 according to Table 8.5 and the category would be 40, for (say) a 45 mm thick plate attached to a 40 mm thick flange. For a bolted attachment the detail would be detail 10 according to Table 8.1 and the category would be 90.

Thus the design value of the fatigue strength is:

For the attachment of bearing stiffeners: $\dfrac{80}{1.1} = 73$ N/mm^2

For a welding bearing plate: $\dfrac{40}{1.1} = 36$ N/mm^2

For a bolted bearing attachment: $\dfrac{90}{1.1} = 82$ N/mm^2

Clearly, the fatigue life is adequate for a bearing attached by bolting, and for the welding of the bearing stiffeners to the flange, but not for the welding of a bearing plate to the underside of the flange.

The requirement to use a bolted attachment detail could have a significant effect on the detailing at the bearing.

Note that, in practice, the stress range in the weld attaching the bearing stiffener to the flange would also have to be verified (for the range of vertical force in the stiffener), as would the stress in the weld between the web and the flange (which is subject to combined longitudinal shear and vertical shear).