Computation of upper and lower connection of side frames of single side bulk carriers

The following note is extracted from the WP/S background document for UR S12 revision 4. This version of the UR was neither officially released, but is the basis for the requirements of the IACS Common Structural Rules for bulk carriers.
This note is related to the calculation of the longitudinals that support the lower and upper connecting brackets of the side shell frames in hopper and topside tanks.
The relevant requirements are provided in Ch 6, Sec 2, [3.4] of IACS CSR for bulk carriers.

The technical background document has been modified to adopt the symbols and notations of the Common structural rules for bulk carriers Chapter 6, Section 2, in order to facilitate the reading. For the meaning of the symbols not defined hereunder, please refer to the text of the Common Structural Rules.

Checking of section modulus of the longitudinals in Ch 6, Sec 2 [3.4.1]

The section modulus of the longitudinals is required to have sufficient bending strength to support the end fixing moment of the side frame about the intersection point of the sloping bulkhead and the side shell.
The end fixing moment of the side frame is that induced by the external sea pressure acting on the side frame (end brackets excluded) and the deflection and rotation of the end support due to the loading on the hopper and the double bottom.
The sea pressure loading on the end brackets is not included because the sea pressure loading on this and on the connecting structure of the hopper and topside tank are assumed to cancel.

The end fixing moment, M_{ef}, of the side frame about the intersection point of the sloping bulkhead and the side shell in Nm is given as:

$$M_{ef} = \alpha_T \cdot (p_S + p_W) \cdot s \cdot l^2 \qquad (1)$$

The end fixing moment, M_{ef}, gives rise to line loads on the connected side and sloping bulkhead stiffeners, q_{efi}, in N/m such that:

$$\frac{M_{ef}}{s} = \sum_i q_{efi} \cdot d_i \qquad (2)$$

The line load, q_{efi}, gives rise to plastic bending moments in the connected side and sloping bulkhead stiffeners, M_{ci}, in Nm given as:

$$M_{ci} = \frac{q_{efi}\ \ell_l^2}{16} \qquad (3)$$

Hence, assuming an allowable stress equal to yield, the section modulus requirement for a connected side or sloping bulkhead longitudinal in cm^3 becomes:

$$w_i = \frac{M_{ci}}{R_Y} \qquad (4)$$

Injecting the expression of M_{ci} from (4) into (3) and putting q_{efi} in (2), we obtain:

$$\sum_i w_i \cdot d_i = \frac{M_{ef} \cdot l_l^2}{16 \cdot s \cdot R_Y} = \alpha_T \cdot \frac{(p_S + p_W) \cdot l^2 \cdot l_l^2}{16 \cdot R_Y} \qquad (5)$$

The above expression allows the required section modulus of the connected longitudinals to be determined and is given under [3.4.1] of Common Structural Rules for bulk carriers, Chapter 6, Section 2.

Checking of connection area in Ch 6, Sec 2 [3.4.2]

The connecting force Q_{efi} in N is transferred through shear between the brackets and the longitudinals, with:

$$Q_{efi} = s \cdot q_{efi} \qquad (6)$$

Assuming an allowable shear stress equal to 0.5 R_Y, we have, with Ai in cm^2 the connection area between bracket and longitudinal:

$$\frac{R_{Ybkt}}{2} = \frac{10^{-2} \cdot Q_{efi}}{A_i} = \frac{10^{-2} \cdot s \cdot q_{efi}}{A_i} \qquad (7)$$

Injecting q_{efi} from (3) and (4) inside (7), we obtain:

$$A_i = [0.32] \cdot \frac{w_i \cdot s \cdot R_{Y\lg}}{l_l^2 \cdot R_{Ybkt}} \qquad (8)$$

The above expression provides the required connection area and is given with the coefficient 0.32 rounded up to 0.4 and introducing the material factors for bracket and stiffener to replace the yield strengths ratio, under [3.4.2] of Common Structural rules for bulk carriers, Chapter 6, Section 2.