Proposal for Shear Force Correction in CSR BC Rules

1. Summary

1.1 CSR BC Rules stipulate that shear force (SF) correction should be applicable to non-homogeneous loading conditions. Furthermore, for the heavy ballast condition, IACS KC ID No. 453 says that the correction should be applicable only to the forward and aft bulkheads.

1.2 By the nature of the phenomenon of shear force correction, however, SF correction can be applicable to any loading conditions at any transverse bulkhead other than engine room front and collision bulkheads. This is confirmed by FE analysis in this paper.

1.3 Therefore it is proposed that the relevant KC should be modified to the effect that SF correction may be applicable to any loading conditions at any transverse bulkhead.

1.4 The revised definition of ε in Ch.5, Sec.1-2.2.2 is also proposed so that the shear stress with shear force correction can be properly calculated.

1.5 These proposals will contribute not only to the correctness in theory but also to simplification of the calculation of SF correction as the proposed method does not require distinction between "homogeneous loading condition" and "non-homogeneous loading condition".

2. Application of SF correction

2.1 The principle of SF correction is that when a double bottom is arranged as a grillage system (e.g. floors and girders arranged in double bottom) a portion of the double bottom load is transferred to the transverse bulkheads and the calculated shear force may be reduced.

2.2 To confirm the effect of the local forces at transverse bulkhead, FE analysis has been carried out for two cases. The first case (Case 1) is to prove the effect of SF correction at the transverse bulkhead between the loaded and empty holds for alternate load condition. The second case (Case 2) is to prove the effect of SF correction at the transverse bulkhead between empty holds for heavy ballast condition. In both cases, the following two sub-cases are considered:

a. Bottom floors and girders arranged in the model, which is expected to show the effect of the shear force correction.

b. Only floors arranged in the model (i.e. no girder), which is expected to show no effect of the shear force correction.

The cases considered are summarized in Table 1 and illustrated in Figs. 1 to 4. The FE models are made to show the effect of SF correction at the transverse bulkhead marked in blue in Figs. 2 and 4.

	T.BHD position considered	DB arrangement	Loading condition
Case 1a	Between loaded and empty holds	Girder + Floor	Alternate load
Case 1b		Floor only	
Case 2a	Between empty holds	Girder + Floor	Heavy ballast
Case 2b		Floor only	

Table 1

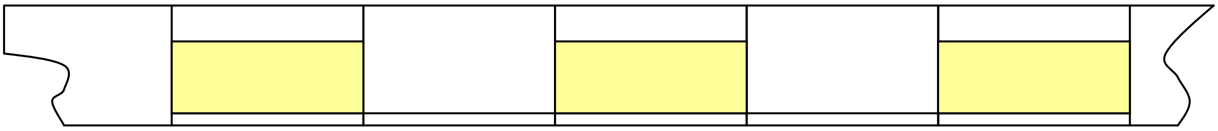

Fig.1 Alternate load condition

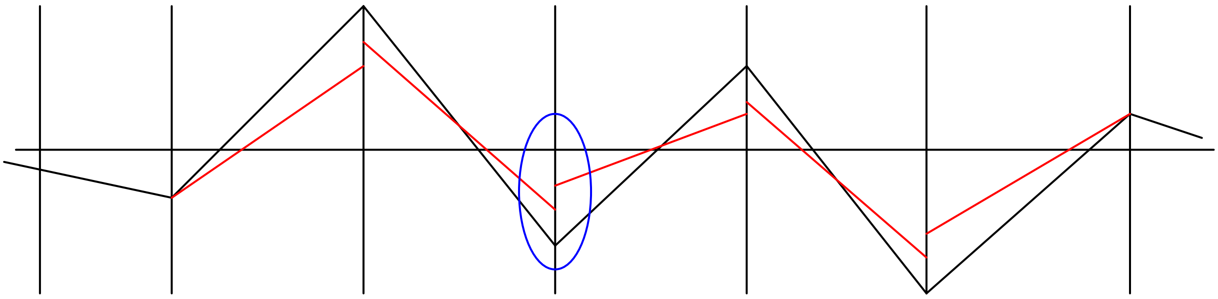

Fig.2 Expected SF distribution with/without SF correction
in way of T.BHD between loaded and empty holds marked in blue
(Alternate load condition)

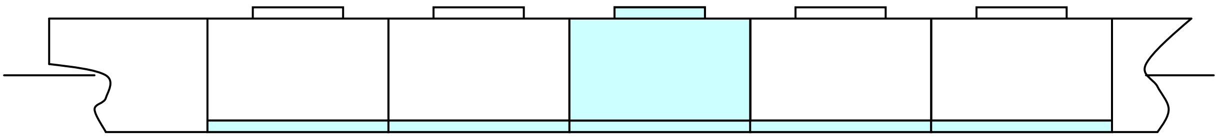

Fig.3 Heavy ballast condition

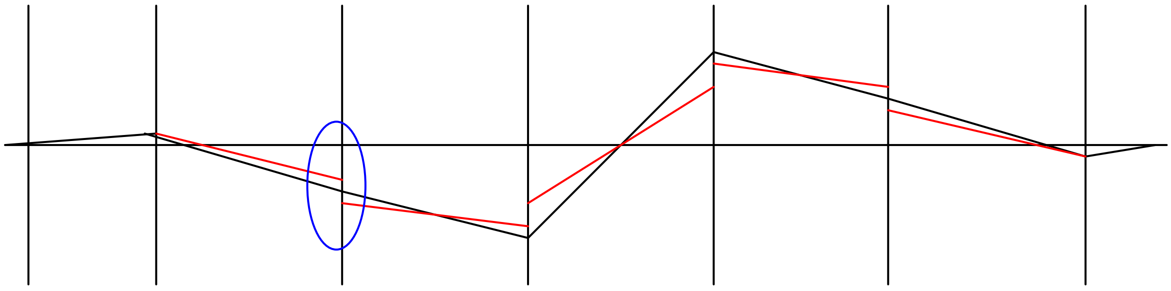

Fig.4 Expected SF distribution with/without SF correction
in way of T.BHD between empty holds marked in blue
(Heavy ballast condition)

2.3 The FE model and results of shear stress in way of T.BHD between loaded and empty holds (Alternate load condition: Case 1a and 1b) are shown in Figs. 5 to 8. From Fig. 8, the phenomena of shear force correction is observed, which corresponds to the area marked in blue in Fig.2.

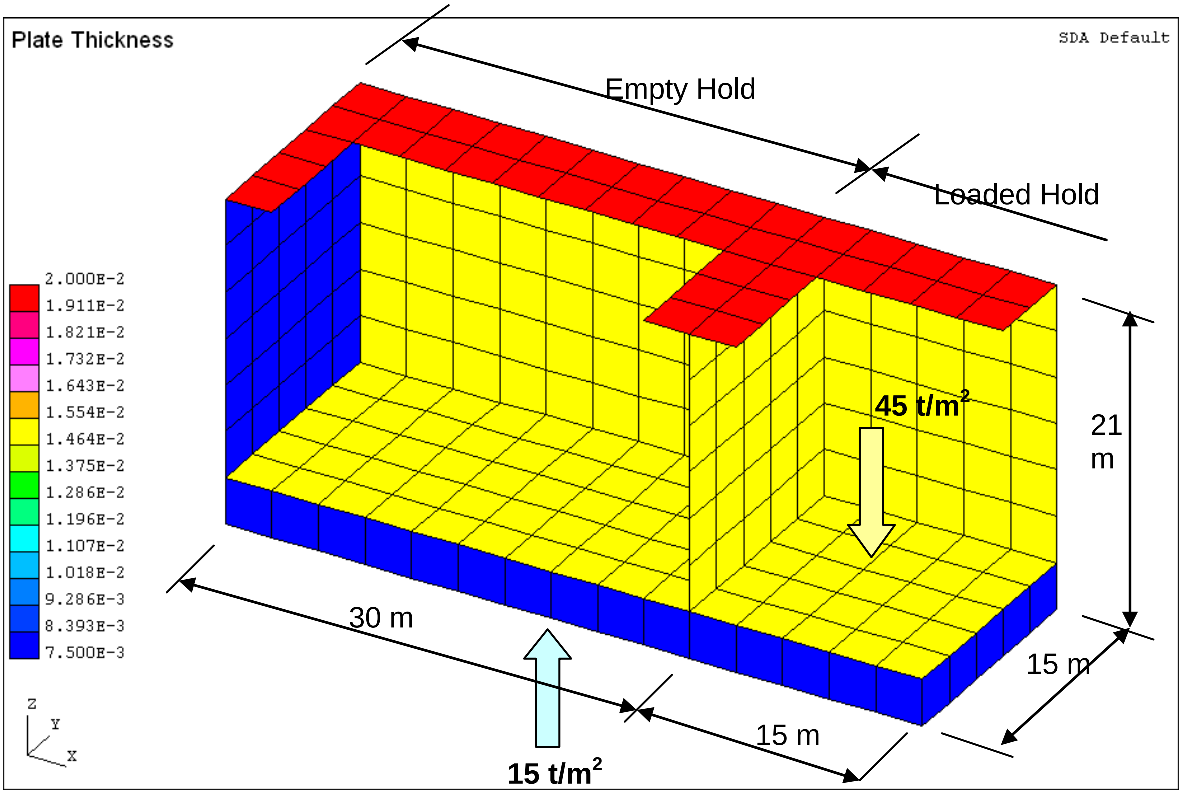

Fig.5 Cases 1a and 1b - Model and load in way of T.BHD between loaded and empty holds (Alternate load condition)

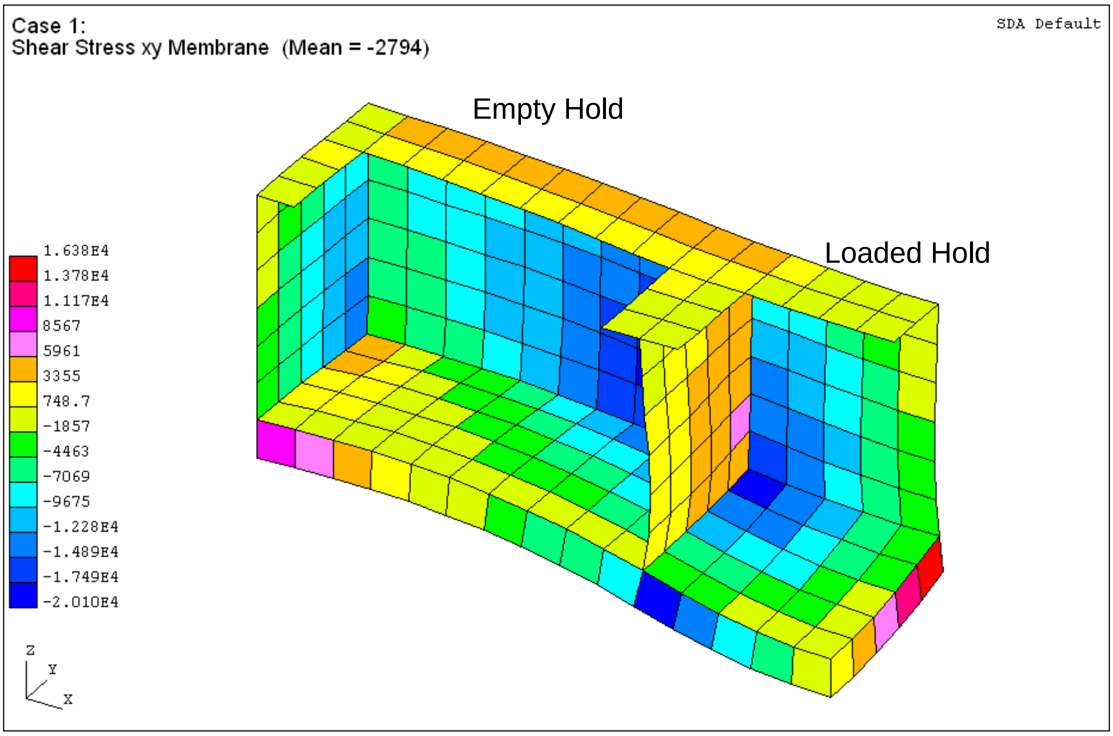

Fig.6 Case 1a – Deformation and shear stress of the model with girder and floor in way of T.BHD between loaded and empty holds (Alternate load condition)

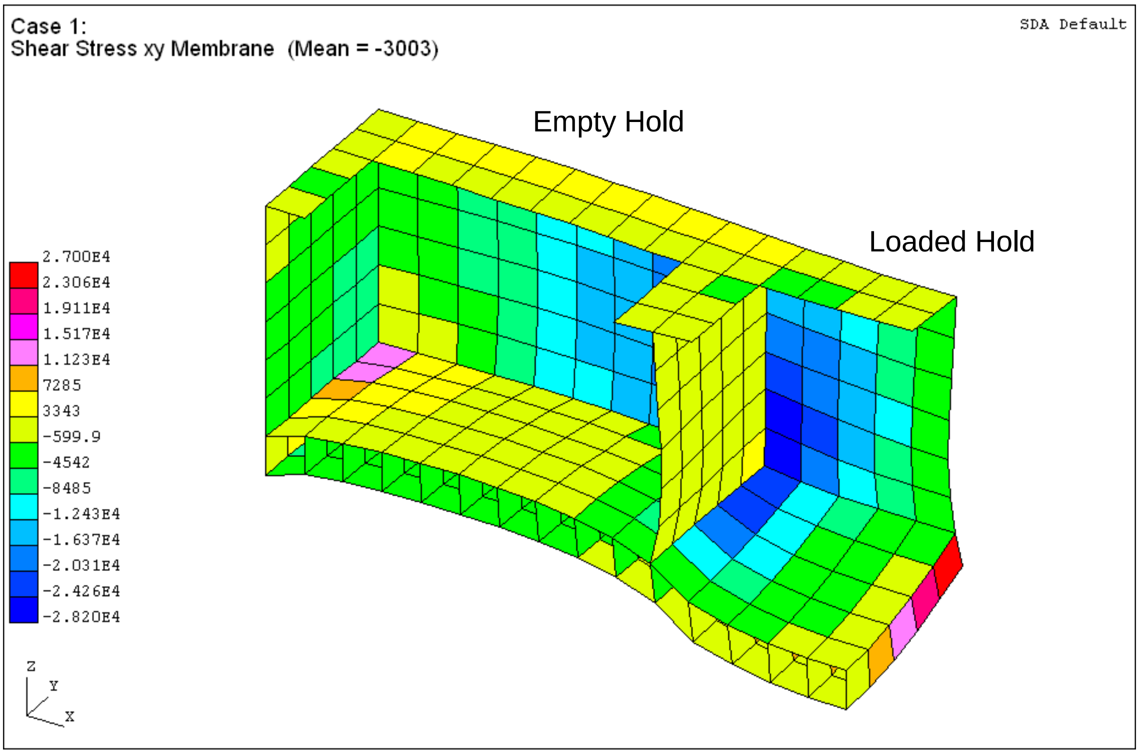

Fig.7 Case 1b – Deformation and shear stress of the model with floor only in way of T.BHD between loaded and empty holds (Alternate load condition)

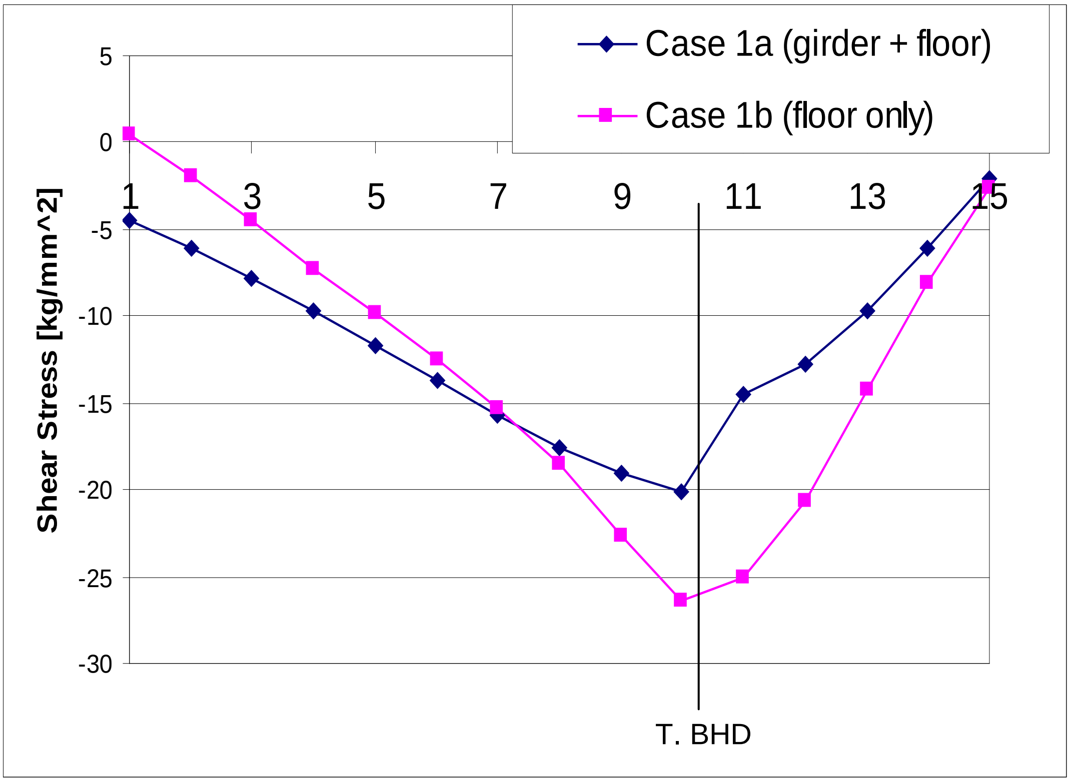

Fig.8 Cases 1a and 1b – Shear stress in the side shell around the neutral axis in way of T.BHD between loaded and empty holds (Alternate load condition)

2.4 The FE model and results of shear stress for T.BHD between empty holds (Heavy ballast condition: Case 2a and 2b) are shown in Figs. 9 to 12. From Fig. 12, even at the transverse bulkhead between empty holds, the phenomena of shear force correction is observed, which corresponds to the area marked in blue in Fig. 4.

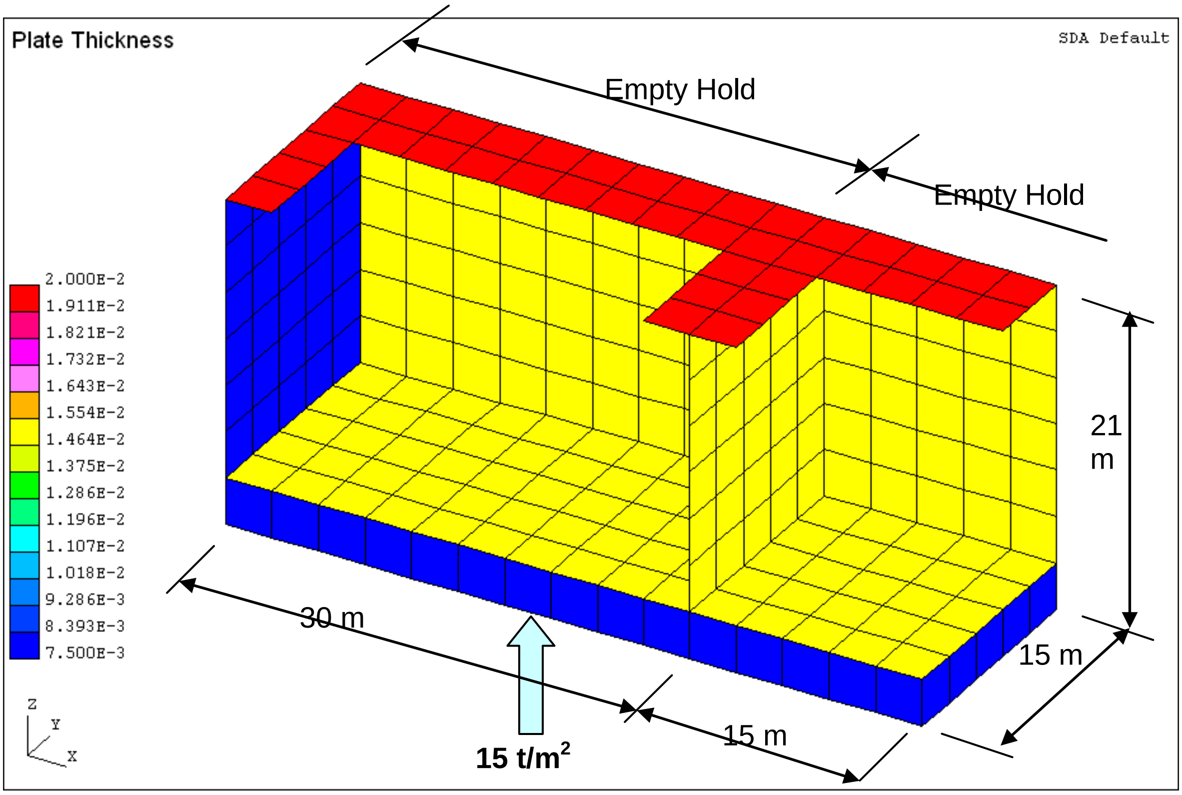

Fig.9 Cases 2a and 2b -Model and load in way of T.BHD between empty holds
(Alternate load condition)

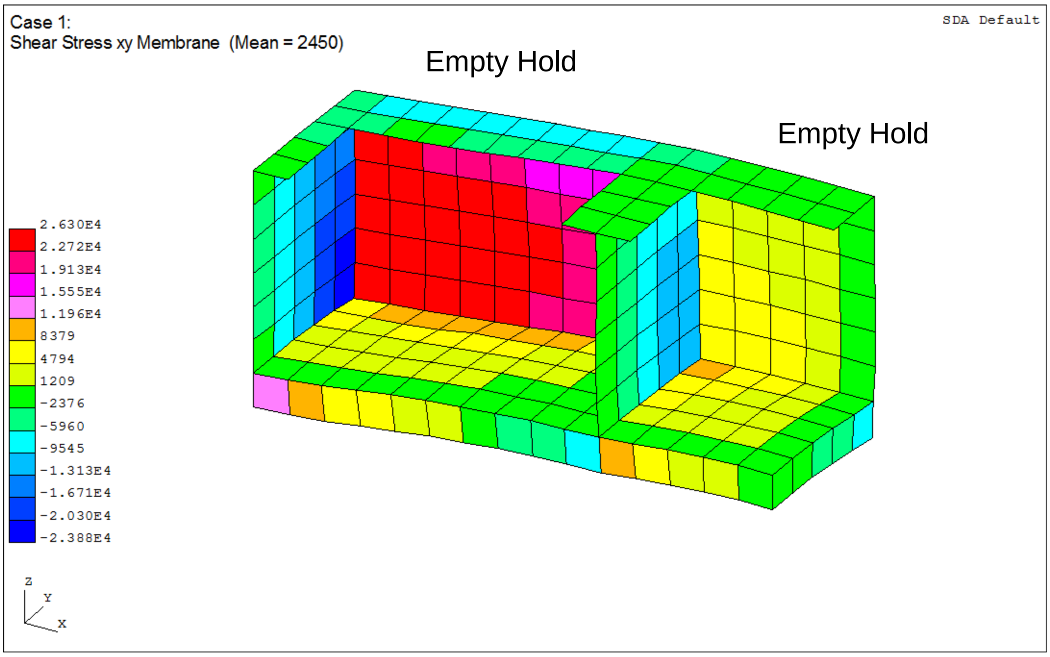

Fig.10 Case 2a – Deformation and shear stress of the model with girder and floor in way of T.BHD between empty holds
(Heavy ballast condition)

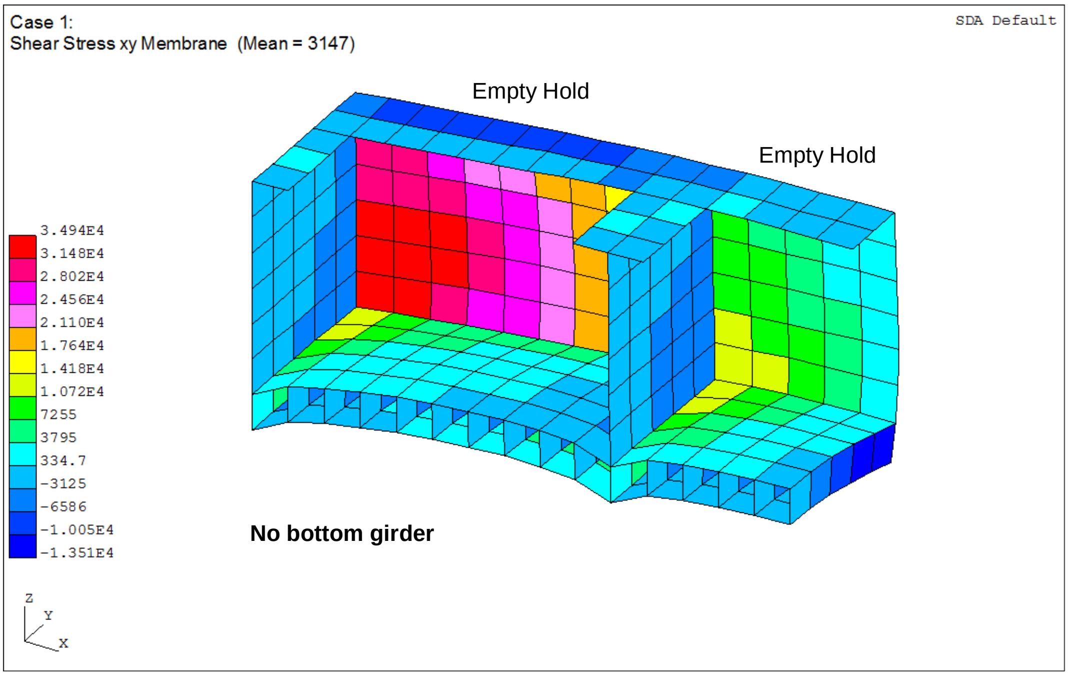

Fig.11 Case 2b – Deformation and shear stress of the model with floor only in way of T.BHD between empty holds
(Heavy ballast condition)

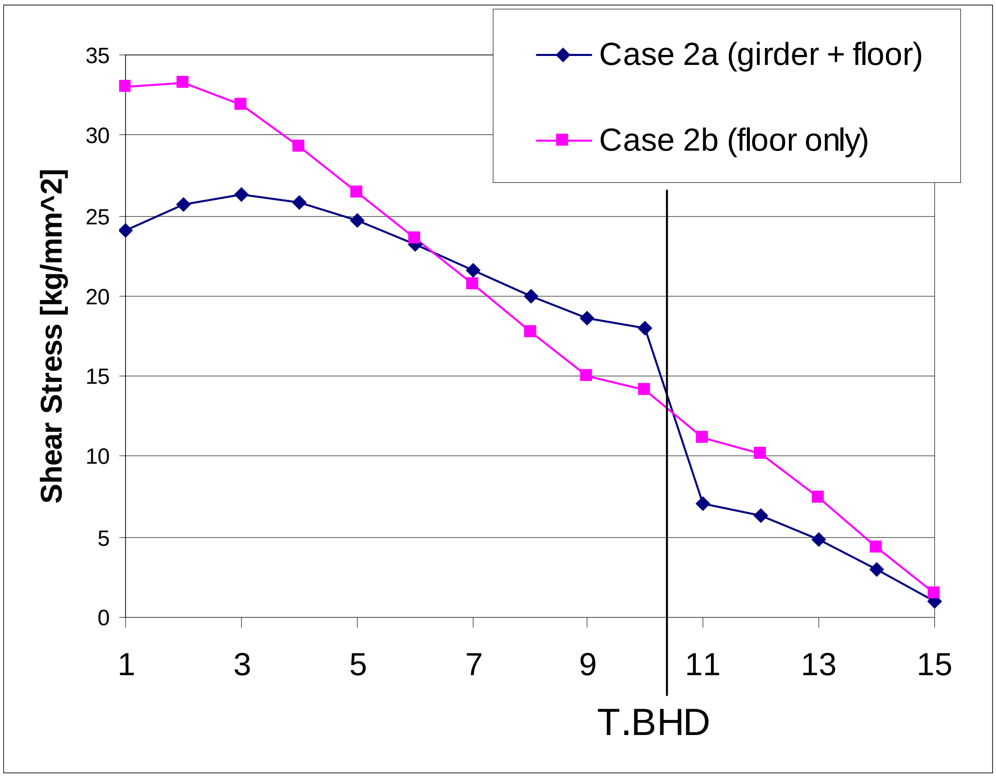

Fig.12 Cases 2a and 2b – Shear stress in the side shell around the neutral axis in way of T.BHD between empty holds
(Heavy ballast condition)

2.5 It is concluded that SF correction can be applicable to any loading conditions at any transverse bulkhead.

3. Definition of ε in Ch.5, Sec.1-2.2.2

3.1 It is noted that when the current SF correction is applied to aft and forward transverse bulkheads of the cargo hold considered where the aft and forward SF values have the same sign convention, it gives inappropriate SF values. The relevant cases are the following:

- Transverse bulkheads in the flooded hold for normal ballast condition.
- Transverse bulkheads not adjacent to ballast hold for heavy ballast condition, if the proposal in Paragraph 1.3 is adopted.

The latter case is shown as marked in blue in Fig.13. As can been seen, the lines representing SF values with and without SF correction is not crossed, which is inadequate in theory.

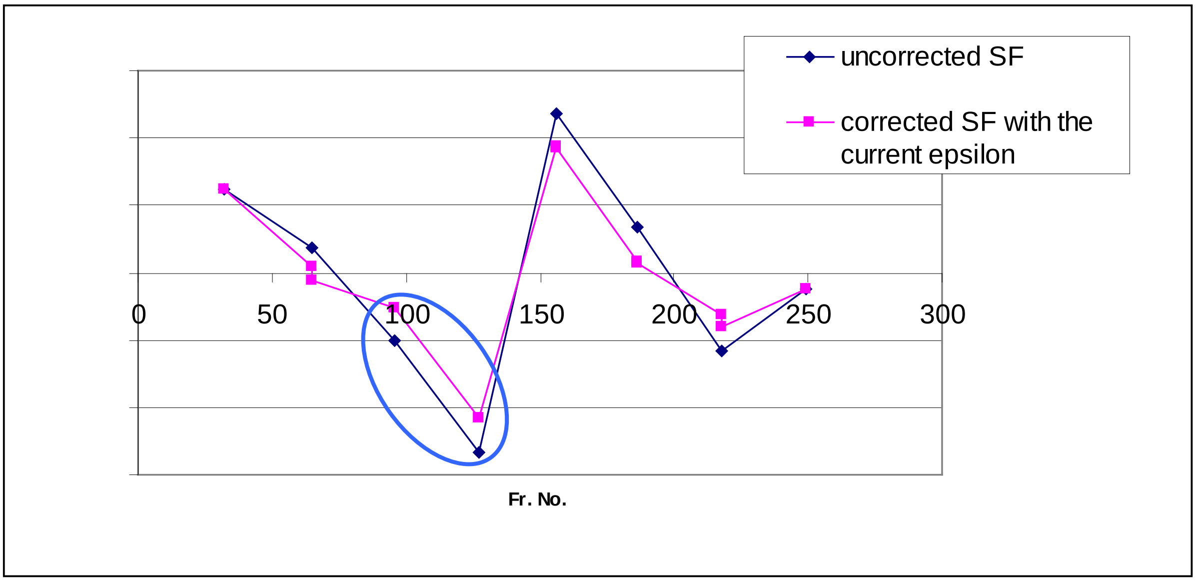

Fig.13 Shear force distribution with the current ε in CSR BC Rules for heavy ballast condition

3.2 The inappropriate SF correction is caused by the definition of ε in Ch.5, Sec.1-2.2.2 of the current CSR BC Rules. In Fig.13, as both of the sign conventions are negative, both values of ε (=sgn(Q_w)) are minus one (-1) and hence both SF values are corrected upward.

3.3 Consequently, the following new definition of ε is proposed. Fig.14 shows the SF with the proposed ε, which is adequate in theory.

$\varepsilon = \varepsilon_A$, at the aft transverse bulkhead in the cargo hold considered, or
ε_B, at the forward transverse bulkhead in the cargo hold considered.

Where:
$\varepsilon_A = \text{sgn}(Q_A - Q_B)$
$\varepsilon_B = -\varepsilon_A$
Q_A: Uncorrected SF at the aft transverse bulkhead in the cargo hold considered
Q_B: Uncorrected SF at the forward transverse bulkhead in the cargo hold considered

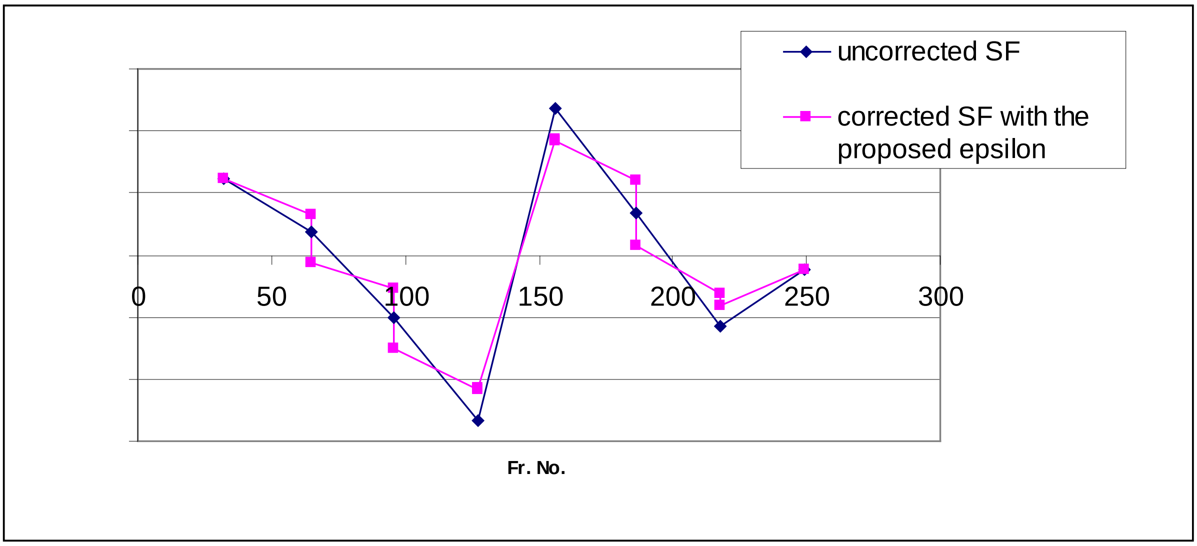

Fig.14 Shear force distribution with the proposed ε in CSR BC Rules
for heavy ballast condition

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