Discussion of Marr's paper

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CRITERIA FOR SETTLEMENT OF TANKS[a]

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The authors are to be commended for their work on the tolerable settlement of tanks. Since so many investigators have made recommendations for tolerable settlement, a comparison of the different criteria was badly needed.

Tank settlement data is, of course, always necessary to back up any new criterion that is proposed. Accordingly, the authors have presented in Fig. 6 a considerable amount of data on the non-planar edge settlement of tanks. In order to make a recommendation for non-planar edge settlement to limit the stress in tank walls, the authors have treated the wall as a beam and have used beam theory to correlate the amount of out-of-plane settlement to the stress level. The parameter K was used to indicate stress level in the walls and it was calculated from the following equation:

$$K = \frac{EH}{\sigma_f \ell^2} \quad \Delta S \qquad (1)$$

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[a] August, 1982, by W. Allen Marr, Jose A. Ramos and T. William Lambe (Proc. Paper 17261)

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where

ΔS = the out of plane settlement

H = tank height

σ_f = steel failure stress

E = Young's modulus

ℓ = distance between measuring points.

The authors have stated that yielding of the steel will occur at $K = 0.6$, strain hardening will occur at $K = 7$ and tensile failure will occur at $K = 55$.

This appears to be a theoretically correct and reasonable approach to assessing stress magnitude. However, looking at their results from a practical point of view there seems to be an unusual trend in the author's data which they have not addressed. In Fig. A the values of K that they have calculated are plotted against the distance between measuring points, ℓ, for each tank. This figure indicates that K-values tend to increase as the distance between measuring points decreases.

There does not seem to be any justification for this trend in the theory, however equation (1) does indicate that K is dependent on the term ℓ^2. It can be seen that as the value of ℓ decreases, the term

$$\frac{EH}{\sigma_f \ell^2}$$

increases considerably so that small errors in measuring or calculating ΔS are magnified in the value of K at small values of ℓ. The calculation of ΔS is not always simple because before calculating ΔS, a tilt plane must be found.

The writers of this discussion have done a simple calculation comparing possible values of K for tanks with E/σ_f = 800 and H = 20 m. It was assumed that the tanks tilted in a perfect plane (and thus had no extra stresses generated in the walls) but that inaccuracies in either the measurement or calculation of ΔS indicated that they had an out-of-plane settlement of only 0.5 or 1.0 cm. These magnitudes of errors seem possible considering the authors reported average edge settlements which were as great as 156 cm. The corresponding values of K calculated for several values of ℓ are shown below:

ℓ(m)	K when error in ΔS = 0.5 cm	K when error in ΔS = 1.0 cm
30	0.09	0.18
18	0.25	0.49
12	0.56	1.11
9	0.99	1.98
4.5	3.95	7.90

These calculated values of K, based on assuming a small error in ΔS, fit the trends found in the reported tank data (as shown in Fig. A) and seems to show that it is these errors that are dominating the data presented by the authors.

The authors go on further to recommend that tanks should be limited to having values of K no greater than 7. However, it appears that their data indicate that the value of K may not be reliably determined in practice. Thus, their criterion which is based on this, although theoretically correct, may not be the best to use.

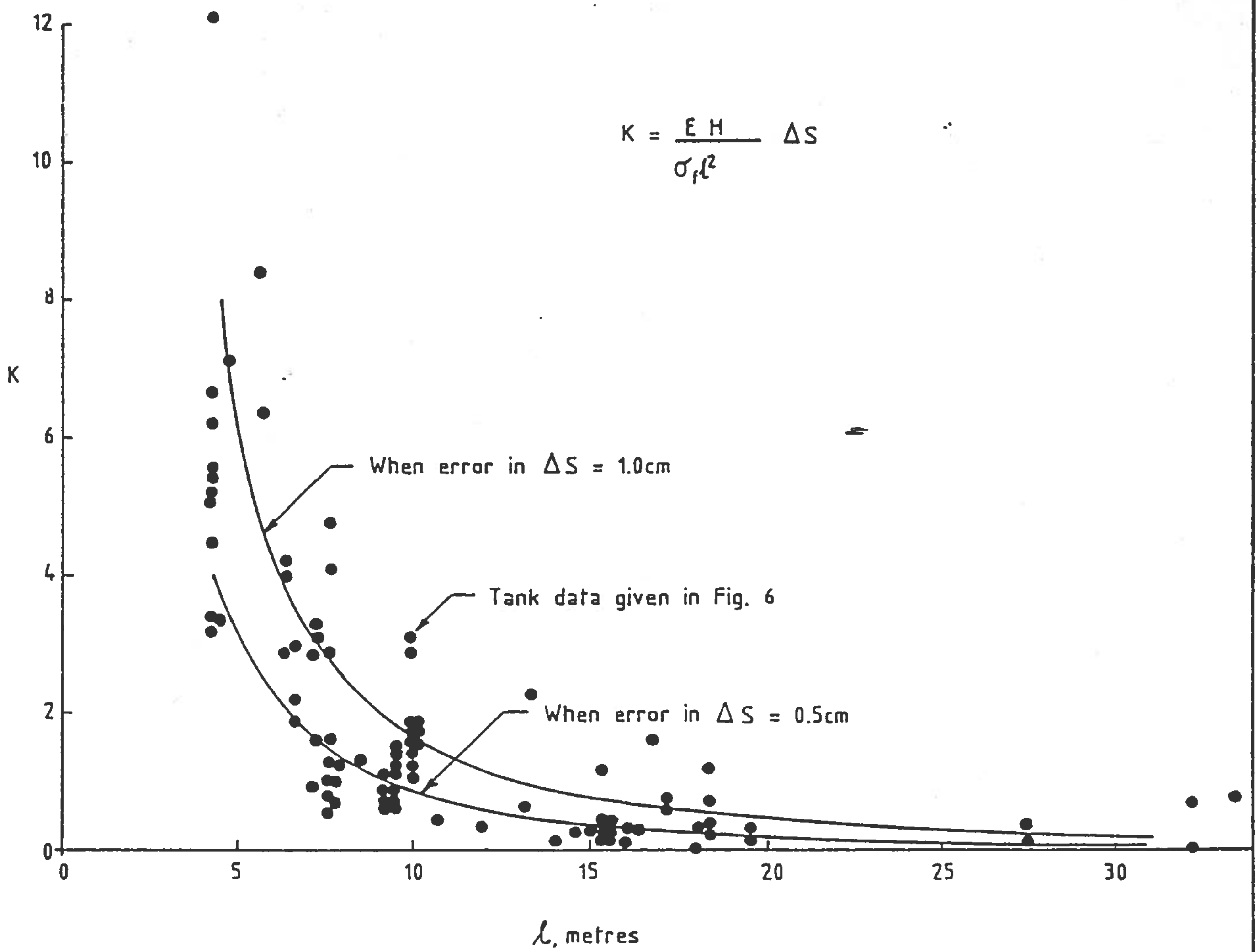

Fig. A : Values of K from tank data and from assuming errors in ΔS.

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