IIIa 6

Notes on the Method of Expression of Allowable Unit Stress as determined by the Pulsation or Reversal of the Stresses.

Angaben über die Methode des Ausdrucks einer zulässigen Spannung, die durch Schwingung oder Wechsel im Vorzeichen der Spannungen bestimmt ist.

Notes sur la méthode d'expression de la contrainte admissible déterminée à partir de la pulsation ou de l'alternance des efforts appliqués.

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In standard American specifications for riveted bridges, a reduction of allowable unit stress has been prescribed in the case of reversed stresses, but not in the case of pulsating stresses (fluctuating but without change of sign).

However, the committee assembled by the American Welding Society to prepare a specification for welded bridges (issued 1936), decided from the available data, largely the published reports of Professors *Graf* and *Schaechterle,* to make a reduction in the allowable unit stress on certain types of welded joints for stresses pulsating through considerable range, as well as for those actually reversing.

These notes do not discuss the actual values selected for allowable unit stress under various conditions, but only the manner of their expression. As most of the important members of any bridge, and their connections, are subject to pulsating stress, it is important to keep to a minimum the arithmetical labor involved in carrying out any prescribed rules.

The previous American specifications applicable, as noted above, in the case of reversed stresses only, require the calculation from the minimum and maximum total stresses of a third or hypothetical stress, greater than the maximum, to which the normal unit stress is applied, thus giving an increase of required area. An identical method is, for geometrical reasons, not possible of employment when reduction of unit stress is to be made for pulsation as well as for reversal.

The official German method ("gamma method") is similar to the foregoing, and requires the calculation from the maximum and minimum total stresses of a multiplier "gamma" to be applied to the maximum stress.

Each of these methods introduces an auxiliary step, the calculation of a modified or hypothetical maximum stress, before proceeding to the determination of the required area. The method adopted by the American Welding Society eliminates the preliminary step and yields the required area by the direct application of a simple formula, the derivation of which will now be given.

Let the line A B C be a graph of permissible unit stresses, plotted so that any minimum is an abscissa and the corresponding maximum is the corresponding ordinate. Thus at A, min = max, and the ordinate S_{-1} is the unit stress selected on the basis of the test data to be permitted in the case of full reversal. So at B, min = 0, and the ordinate S_0 is the unit stress selected to be permitted in the case of pulsation from zero.

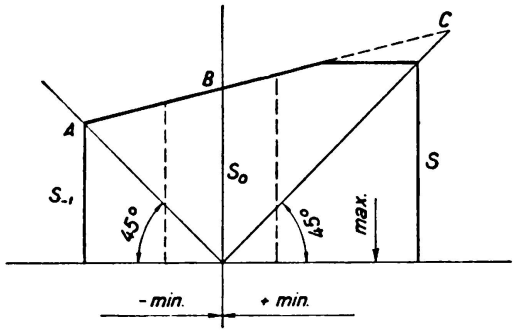

Fig. 1.

For all practical purposes, A B C may be taken as a straight line. It is undesirable to complicate design requirements by introducing any other form of variation, considering how small the percentages of error, even if they could be definitely known, must be.

The full range of the line B C is not utilizable, because the values of maximum unit stress increase beyond the value S which has been established for static conditions (max = min). The sloping line must therefore be neglected above its intersection with a horizontal through the value S.

Consider now a bridge part which undergoes some other degree of reversal than complete reversal, or some other degree of pulsation than return to zero, as indicated by dotted ordinates in the sketch. For this member the unknown "max" and "min" permissible unit stresses are of course proportional to the known "Max" and "Min" or calculated total stresses.

Then:

$$\text{max.} = S_0 + \frac{S_0 - S_{-1}}{S_{-1}} \text{min.} \tag{1}$$

$$= S_0 + \varnothing \cdot \text{min.},$$

"$\varnothing$" being the slope of the line A B $= \dfrac{S_0 - S_{-1}}{S_{-1}}$.

$$\text{Required area A} = \frac{\text{Max.}}{\text{max.}} = \frac{\text{Max.}}{S_0 + \varnothing \cdot \text{min.}} = \frac{\text{Max.}}{S_0 + \varnothing \cdot \dfrac{\text{Min.}}{\text{A}}}$$

$$\text{A} \cdot S_0 + \varnothing \cdot \text{Min.} = \text{Max.}$$

$$\text{A} = \frac{\text{Max.} - \varnothing \cdot \text{Min.}}{S_0} \tag{2}$$

This, then, is the form in which the specification is cast. For each particular type of stress or type of joint, the committee has selected a permissible value of S_0 and a value of S_{-1}. From these, by Eq. (1), $\varnothing$ is derived and then Equation (2) is written into the specification. The designer, having from the prescribed loding calculated "Max" and "Min" derives his area "A" in the simplest possible fashion.

In the future, as further test results become available, and as for other reasons the necessary factors of safety are re-considered, future committees may modify "S_0" or "S_{-1}", or both. The form of the several formulas need not be disturbed, and a simple modification of "$\varnothing$" or "S_0", or both, will embody the desired change or changes.

As an example the American Welding Society specification for the area of fillet welds is:

$$\text{Area} = \frac{\text{Max.} - \frac{1}{2}\,\text{Min.}}{7200} \text{ but not less than } \frac{\text{Max.}}{9600}.$$

(The second expression embodies the portion of the foregoing diagram in which the sloping line is replaced by the horizontal line through the ordinate "S".)

Example 1. Max. $= +\ 80000$ Min. $= -\ 80000$

$$A = \frac{80\,000 + 40\,000}{7200} = 16.7 \text{ sq. in.}$$

Example 2. Max. $= +\ 80000$ Min. $= -\ 40000$

$$A = \frac{80\,000 + 20\,000}{7200} = 13.9 \text{ sq. in.}$$

Example 3. Max. $= +\ 80000$ Min. $= 0$

$$A = \frac{80\,000}{7200} = 11.1 \text{ sq. in.}$$

Example 4. Max. $= +\ 80000$ Min. $= +\ 16000$

$$A = \frac{80\,000 - 8000}{7200} = 10.0 \text{ sq. in.}$$

$$\text{but not less than } \frac{80\,000}{9600} = 8.33 \text{ sq. in.}$$

Example 5. Max. $= +\ 80000$ Min. $= +\ 64000$

$$A = \frac{80\,000 - 32\,000}{7200} = 6.67 \text{ sq. in.}$$

$$\text{but not less than } \frac{80\,000}{9600} = 8.33 \text{ sq. in.}$$