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TN 127 DISCUSSION

Fatigue durability under wave action

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The Author's distribution of wave height (Fig. 1) requires the underlying long-term distribution of wave height to be exponential, which is equivalent to an exponent of unity in the two parameter Weibull distribution. This assumption has a measure of support from observations in open sea conditions but does not necessarily hold in coastal waters, and indeed some deviation from the exponential form has been observed in ocean wave records over the low wave height region which often contributes most to the total fatigue damage.

13. Practical *S–N* relationships exhibit a change in slope between the low and high cycle region which should strictly require the integration of damage intensity to be split into two or more regions.

14. The explicit derivation of total damage, as presented, relies upon the extension of the upper limits of integration from n_m and h_m to infinity since the contribution to total damage from high wave activity is assumed to be very small.[1] The same comment could be applied to the general solution, given at the end of the Note, when stress range is not a linear function of wave height which is certainly the case for structures subject to a significant drag component of load.[2]

15. Table 2 is in error and this leads to the apparent discrepancy between estimates of fatigue life, since the permissible number of stress cycles were calculated from the wave height value at the upper end of each class interval. If the mid-class height (i.e. 1·25 m, 3·75 m, etc.) is used, then $D_T = 1{\cdot}11$, and if the number of class intervals is increased to 30 then $D_T = 1{\cdot}01$, which is within 2% of the value from the gamma function integration method. In view of the above comments it would seem to the writers that the numerical approach is more flexible and to be recommended as being able to include non-linearities and discontinuities automatically.

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The above contribution, defining the area of applicability of the particular and general solutions developed in the Note, indicates the regions of wave action where corroboration of theory with practice may be expected.

17. The distribution of wave heights over a specified duration of time, described in Fig. 1, may be approximately derived from Weibull's long-term distribution of sea states together with Rayleigh's distribution of the individual wave heights within a particular sea state. Observations of ocean wave behaviour indicate sufficient corroboration to justify the use of this hypothesis in such domains.

18. Regions of large wave-height activity associated with rarity of such occurrence naturally permit the expedient of interchanging h_m with infinity. It is recognized that

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S–N relationships in practice generally exhibit a variation of slope with change in the permissible number of cycles of stress range. The gamma function integration was effected partly through this assumption of linearity. Non-linearity is however coped with in the general solution.

19. Table 2 was prepared intentionally as such, indicated by the staggered nature of the horizontal lining-up in the tabulation, in order to demonstrate the greatest error possible with the summation method, together with the tediousness of its procedure. It was not intended to show how close to convergence it could be manipulated to lead. This would require a knowledge of the actual convergent figure in the first place.

20. It is agreed, however, that the permissible number of stress range cycles calculated at mid-height of each stress range block, respectively, yields a total fatigue damage of 1·112 and consequently a fatigue durability of 90 years.

21. Finally, the following addenda to the discussion would appropriately illustrate the extent of applicability of the methods outlined in the Note.

22. With consideration given to directional intensity of wave action, frequency spectra of wave loading and dynamic resonant amplification response, together with stress concentration factors, etc., the gamma function integration solution affords a convenient means of assessment of fatigue durability at the design stage.

23. The general solution presented may be operated as a spectral analytic technique by individually arraying an appropriate series of waves of 'height—associated period', equivalent in effect to that of the expected applied frequency spectra of wave loading against the structure, amplified dynamically by the frequency response of the structure; due consideration being given to directional intensity of wave action. This, operated on by the appropriate stress concentration factor, would yield the required stress range response spectra, from which fatigue damage may be summed and fatigue durability subsequently deduced.

24. Alternatively, a series of waves of varying height and period may be employed, individually, through the entire gamut of frequency spectra, already described, to obtain the required spectral response of damage intensity for all wave directions and heights, which consequently summed leads to the evaluation of fatigue durability.

25. I have unfortunately not been able to obtain access to Payne[1] for study and comment.

References

1. PAYNE G. E. *A comparison of design methods for the fatigue of members in an offshore platform*. MSc thesis submitted to University of Manchester, March 1976.
2. TICKELL R. G. *et al.* Long-term wave loading on offshore structures, *Proc. Instn Civ. Engrs*, Part 2, 1976, **61**, March, 145–162.

Corrigendum

Proc. Instn Civ. Engrs, Part 1, 1976 .**60** .Feb., 149; *for* 'Panjaan' *read* 'Panjhan'.