Protection of concrete from cavitation damage

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In § 3 the Author has re-stated the classical theory that 'cavitation occurs when the local absolute pressure approaches the ambient vapour pressure of the water'. This may be correct in clean water in laboratory experiments, but, as Dr Chivers has emphasized,[3] cavitation is also dependent upon air pressures and the radii of any pre-existing bubbles in the water.

15. The Author, in his admirable CIRIA review of concrete erosion and cavitation,[1] briefly mentioned the role of dust particles in promoting cavitation, but he omitted all reference to the extremely important work of S. P. Kozirev, who carried out cavitation tests on brass specimens in water containing suspensions of 0·5% fine and medium sands.

16. Despite the BHRA translation,[4] Kozirev's important contribution to cavitation damage appears to be so little known to British civil engineers that its findings warrant repetition. These may be summarized as follows:

(*a*) air can be carried in moving streams of water in the form of small high-pressure bubbles attached to, or in crevices within, solid particles in suspension;

(*b*) although it may be relatively difficult to force air into solution in water or to draw it out of solution, a comparatively small drop in the ambient pressure will enlarge a bubble;

(*c*) on recompression downstream, such enlarged bubbles do not readily recompress or collapse, but their shape and number are easily changed;

(*d*) these changes are brought about by the local collapse of the bubble wall, giving rise to minute jets many times faster than the mean speed of the fluid and, on impact, to intense shock waves;

(*e*) these shock waves and the impact of solids in suspension moving in the jets transversely to the stream cause cavitation damage; in a stream moving at 50 m/s shock pressures of the order of 70 MN/m^2 are possible.

17. It is therefore incorrect to think of moving water and of solids in suspension in it 'abrading' concrete; the process of the erosion of concrete appears to be one of cavitation, in which the suspended solids content in natural water plays an important indirect part. It could well be that the form of the suspended solids, such as vesicular particles, is vital to the rate of erosion.

18. This conclusion has prompted CIRIA to consider a programme of research intended to revive an interest in the wet blasting of steelwork, recently completed work at the Paint Research Station having shown that the dry blasting of rust and millscale from steel substrates before applying protective coatings is not really effective in removing sulphate contamination. It may show that water lancing alone, with no abrasive added deliberately, also may be effective and more convenient to use.

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I am delighted that my note concerning some practical aspects of the protection of concrete from cavitation damage has provoked interest in the mechanism of both cavitation and cavitation damage.

20. The occurrence of cavitation is very much influenced by the free-air content

Paper published: *Proc. Instn Civ. Engrs*, 1971, **49** (May) 75–79.

of water (§ 7) and, in order to achieve comparable results in the present tests, care was taken to see that the laboratory water was fully aerated (by cascading) during recirculation. The water was not deliberately loaded with suspended matter but, nevertheless, carried particles (or 'nuclei') in suspension in the form of dust particles which were known to have fallen continuously on to the large areas of exposed water surface in the laboratory.

21. A great deal of evidence now indicates that cavities in liquids can collapse asymmetrically and produce water jets, especially when the collapse occurs near solid boundaries. Naudé and Ellis,[5] Benjamin and Ellis,[6] Brunton,[7] Gibson,[8] Hammitt,[9] and Worthington[10] have all obtained photographic evidence supporting such phenomena. Bowden and Brunton[11] have additionally demonstrated that minute water jets of very high velocity (1900 m/s) can stem from concave menisci. The formation of such microjets in collapsing cavities could explain the high impact pressures necessary to cause cavitation damage to resistant materials. (Collapse pressures of 10 000 atmospheres have been referred to by Benjamin and Ellis.[6])

22. Kozirev's[4] experiments, in which brass specimens were eroded by: (*a*) a combination of cavitation and suspended sand in water; and (*b*) sand suspended in water only, were indeed of interest. However, additional tests with cavitation but without suspended sand would have enabled the interpretation of the results to be more complete. Kozirev's tests were concerned with damage to brass and are consequently of indirect interest in the study of damage to concrete by cavitation. Nevertheless, it would be interesting to contrast the damage produced to concrete specimens by: (*a*) cavitation alone; and (*b*) cavitation with suspended sand in the water.

23. Concerning the research proposal to study the wet blasting of steelwork by clean water, it should be possible to assess the necessary water-droplet sizes and velocities from the extensive researches undertaken to reduce the impact erosion of aircraft and aero-engine components by rain. Measurements of the water-droplet velocities required for wet blasting of steelwork could certainly be made on the equipment developed for the determination of material resistance to rain erosion, wet-steam erosion, and allied phenomena.

24. Reverting to the problem of cavitation damage to concrete, a review of the occurrence of such damage to existing hydraulic structures of l'Electricité de France has recently been made by Destenay and Bernard.[12]

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