Thornton highlights structural problems that have occurred because the effects of differential movements between different parts of a structure were ignored.

The final topic, *Structural creep analysis*, is covered by 13 papers that relate to many different types of structure or structural element. Emphasis is on the variety of numerical methods that have been developed for structural analysis, taking creep, shrinkage and cracking into account.

The book concludes with brief reports of some panel discussions that were held during the Symposium.

It covers the whole spectrum of interest on creep and shrinkage, from the fundamental mechanistic studies related to the structure of hardened cement paste,

through studies of the diverse parameters that influence the time-dependent deformations of concrete, to predictive equations that can be used by the designer and checked against real-life performance of the ultimate structure. There is thus something for everybody and it is in this regard that the volume is especially valuable, bringing practical needs to the notice of the laboratory worker and the significance of certain controlling parameters to the notice of the designer. The book is highly recommended to all engineers and concrete technologists who are interested in any aspect of time-dependent movements in concrete.

C. D. POMEROY

An investigation of the beam impact problem

G. Hughes and D. M. Speirs

Wexham Springs, Cement and Concrete Association, 1982. A4. Type-set, illustrated, paperback. pp. 117. ISBN 0 7210 1246 9. Technical Report 546 (publication 42.546). Price: £7.00.

This clear, comprehensive and self-sufficient document is the latest in the series of thorough reports on technical engineering problems for which the Cement and Concrete Association is well known.

The Report concentrates on transverse impact of a relatively rigid moving striker at mid-span of a stationary pin-ended reinforced concrete beam, a situation embodying many of the features of collisions with concrete structures in practice. The second section of the Report describes 92 impact tests whose results seem to agree remarkably well with the predictions of the extensive theoretical and numerical work of the first section.

The theoretical work emphasizes the importance of the mechanical properties of the contact zone. In the first theory presented, the striker collides with an immovable beam of infinite mass, so that deformation is entirely confined to the contact zone, with an assumed Hertzian (three-halves power) force-approach law. Simple explicit formulae are given for important quantities such as the peak contact force and the contact duration (for both an elastic contact zone with full restitution and a 'plastic' zone with none).

Impact with a beam is then treated as forced vibration of an elastic beam in its normal modes under the contact force concentrated at mid-span, leading (as in the classic textbook by Goldsmith) to a complex integral equation for the contact force as a function of time. An Appendix by R. Sym outlines the numerical solution procedure adopted and discusses its accuracy.

The theoretical predictions (of peak force, impact duration, energy etc.) are presented in dimensionless terms, as for example a proportion of the corresponding easily calculated result for infinite beam mass, and depend only upon two dimensionless input parameters: the 'mass ratio' (beam/striker) and the 'pulse ratio' [(duration of the collision with an infinite mass)/(period of first mode beam vibration)]. For pin-ended beams, comprehensive curves are given of theoretical predictions plotted against pulse ratio: for low pulse ratio, higher modes are excited significantly and maximum beam displacement occurs after contact ceases; for intermediate pulse ratios, only the first mode needs to be considered and maximum displacement occurs during the impact; for high pulse ratios, the impact lasts so long that the beam behaves in a 'quasi-static' manner. The numerical work allows development of some very useful approximate formulae for the range boundaries.

The theory covers cases where the beam remains elastic during the first impact, though it may yield later: the initial kinetic energy is not so high that a rigid-plastic bending analysis or a penetration analysis is appropriate. For lower pulse ratios, when a succession of impacts and free vibrations occur, bounds on the maximum beam displacement are derived (1) for a beam which remains elastic and (2) for a beam which yields in bending at mid-span after the first impact is over. Simply supported beams are then treated (their ends may lift off the supports) and the range of applicability of the theory is considered, with

'wave travel' solutions needed for very low pulse ratios.

Full details are given of the test set-up, the specimens, and end conditions (though not those on axial force), with full consideration of the accuracy of the instruments in recording short pulses. With five main types of beam, different striker masses (mass ratios 0.9, 1.4 and 2.4), and impact velocities between 2 and 8 m/s, pulse ratios between 0.02 and 0.65 were obtained by inserting various pads between striker and beam. Contact zone properties were measured in separate static and dynamic tests. These pulse ratios are mostly in the low range where higher vibration modes are excited.

Typical force-time histories show that the contact zone gave appreciable restitution but not full elasticity. Peak force and corresponding time agree remarkably well with theory, especially as the dynamic properties of a partially cracked beam must be rather uncertain (fully cracked stiffnesses were used in all calculations). Photographs of final crack patterns usually indicate bending yield at mid-span and demonstrate 'reverse bending' (top cracks near the supports) due to excitation of the third vibration mode. Maximum and residual displacements, converted to a corresponding first-mode energy, fall broadly within the theoretical limits, though a small correction for strain-rate effect on yield is advocated.

Other workers' test results are shown to conform with the beam-vibration theory, and an interesting practical problem of ship collision with an offshore concrete structure is treated by similar theory and numerical techniques.

In a report of such length it is always likely that some points can be gently queried. For example, several presumably smooth curves were apparently drawn with straight lines connecting the points plotted, obscuring the importance of genuine discontinuities revealed elsewhere. More explanation could be given of the 'yield ratio', the proportion of initial kinetic energy appearing as 'beam energy in the first mode, causing yield', later related to the energy absorbed by plastic hinge rotation at mid-span and so to the residual displacement. For impacts of long duration relative to the beam's fundamental period, the Report

predicts that the first normal mode of vibration is excited, rather than the beam deflecting slowly into the (very similar) shape for static load at mid-span. One wonders whether this conclusion is somehow related to the standard of accuracy adopted in the numerical procedure for deciding how many normal modes of vibration to consider.

Perhaps the most interesting question raised by the work is in what circumstances a beam will fail in shear during an impact (the ship-collision investigation is concerned with punching shear failure). The measured peak contact force was often ten, and sometimes as much as fifty, times the static mid-span force to cause yield in bending; the shear/moment ratio is much higher than for static loading. One would naively think the maximum shear force to be at mid-span and half the peak contact force, appreciably higher than the maximum shear force in any of the vibration modes - but although there was much diagonal cracking near mid-span, no beam failed in shear there. However, two beams failed in shear near a one-third-span point, presumably because of excitation of the third vibration mode.

There is evidently a difficulty in marrying the theory for the contact zone, at the top surface of the beam, with the vibration theory for a concentrated load at mid-span. None of the symmetrical modes gives any shear force at all at mid-span; for a concentrated load the theory is inevitably inaccurate on mid-span shear. But the contact force is not concentrated anyway, and it might be better to consider vibrations forced by a load spread over a short mid-span length, related to the width of the contact zone and the depth of the beam. Higher vibration modes would be excited even less than the authors predict, and there might be some prospect of relating predicted shear forces, just outside the loaded length or elsewhere, to the strength of the beam in shear on some suitable sloping failure surface.

But this is merely a suggestion for future work. The Report already represents a substantial and comprehensive contribution to the study of impact on concrete structures, and will be of interest and value to engineers and research workers concerned with collision problems.

C. T. MORLEY

Shorter notices

Cement research progress 1981

A survey of the literature on the science of cements published during 1981

Editor: J. Francis Young

Columbus (Ohio), American Ceramic Society, 1982. 280 x 215 mm. A4 type-written, paperback. pp. ix, 347. Price: US\$20 from American Ceramic Society Inc., 65 Ceramic Drive, Columbus, OH 43214, USA.

The American Ceramic Society and their Editor Professor Young are to be congratulated on the speed with which Cement Research Progress is published each year. This year's Review contains 347 pages, 13 separate chapters and 1242 references to papers published in 1981 and must be regarded as excellent value at \$20. The chapters and their authors are listed below:

- 1 Manufacture of structural cements
W. A. Klemm and L. J. Struble