

Plasticity in reinforced concrete

W. F. Chen

New York etc., McGraw-Hill Book Company, 1982. 242 × 170 mm. Type-set, illustrated, hardback, pp. xvi, 474.
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A comprehensive work of almost 500 densely packed pages, on appreciably more than just plasticity theory for concrete structures, this is a thorough and wide-ranging compendium of possible constitutive laws governing non-linear material behaviour, cracking and failure for concrete, steel and bond, all expressed in mathematical terms suitable for incorporation into finite-element analyses of reinforced concrete structures by computer. Professor Chen confines himself to material behaviour which is independent of time, so that creep, shrinkage and diffusion problems (of heat or water) are excluded, as are dynamic problems and geometrical non-linearities leading to buckling. The book is thus entirely concerned with the proper formulation of mathematical models of non-linear material behaviour, for use in small-deflection analysis of structures under static load. Numerous examples of successful non-linear analysis are given, and the author is in expert command of literature and techniques (many of his own devising) in this rapidly developing and important field which he has led for many years.

Following introductory chapters on finite elements and the basic properties of concrete and steel, there follow chapters on linear-elastic brittle-fracture models of cracking in reinforced concrete, fracture of materials which are elastic but non-linear, failure criteria for concrete, elastic-perfectly-plastic models of the deformation of concrete, limit analysis of perfectly plastic structures, and elastic-work-hardening models for concrete incorporating cracking.

The tenor of the work is strongly mathematical – this book is not for those who are worried by indicial notation or tensors (to which a brief introduction is given). Practical illustrations are plentiful, and the aim is to develop constitutive models which facilitate rapid and accurate engineering calculations, but the book contains no computer coding and is largely devoted to formulating mathematical models for concrete and relating them properly to non-linear material behaviour in general.

The usual approach in each chapter is to describe constitutive laws, of the type under discussion, for materials in general, before their application to concrete is presented. Thus the chapter on non-linear elasticity covers at length the general laws governing Cauchy-type non-linear materials, hyperelastic (Green) materials and incremental (hypoelastic) non-linear materials, before going on to discuss proposed descriptions of concrete behaviour in these

terms. Similarly the chapter on elastic-perfectly-plastic models covers general topics such as convexity, normality, Drucker's stability postulate, non-associated flow rules and Prandtl-Reuss material, before presenting such yield criteria for concrete as the Mohr-Coulomb with tension cut-off. This approach has the great merit that the models for concrete are placed firmly in the context of non-linear material models in general, but it does not cater well for the reader only interested in concrete.

Incidentally the chapter on elastic-perfectly-plastic models has a very useful proof that only for associated flow-rules can one be certain that each boundary-value problem has a unique solution. One wonders, then, what is the value of any numerical solution found with a non-associated flow rule, if one must always worry that another (better?) solution may exist.

Perhaps the least comprehensive chapter in this scholarly work is the one on limit analysis of perfectly plastic structures. The upper- and lower-bound theorems are presented, as is the energy dissipation in a concentrated 'yield line' of deformation between rigid blocks, and there are applications to shear in brackets and in beams and to punching shear in slabs (all recent developments). The use of plastic theory with a non-zero tensile strength is advocated without enough discussion of ductility requirements, and there is little coverage of complex slab problems (perhaps old hat), torsion and distortion of box beams, optimization of reinforcement, or strain-capacity problems.

The final chapter is on numerical implementation of the elastic work-hardening-plastic and fracturing model which the author commends for concrete, with examples of analysis by this means of the split-cylinder test and various types of axisymmetric pressure vessel. In view of the marked lateral expansion which occurs in a uniaxial compression test, it is perhaps surprising that the strain criterion (Fig. 8.16) for 'fracture' in biaxial compression or tension should be much the same shape as the stress criterion, but the model evidently gives satisfactory results in practice.

The most difficult aspect of non-linear analysis of concrete is the proper modelling of the formation and propagation of cracks, which is accompanied by sudden release of stress from the crack faces and its redistribution to other parts of the structure. This is considered at length in Chapters 3 and 9. It is perhaps

a pity that, for example, Fig. 9.17, with its clear demonstration of load dropping off as cracks occur, does not come earlier in the book along with more discussion of such matters as unstable dynamic 'jumps' on cracking even in a deflection-controlled test, and uniqueness of numerical solution unless each individual crack is properly followed. On grounds of simplicity and adequate accuracy, Professor Chen currently advocates the 'smeared' approach to cracking, in which the material remains a continuum, but with an infinite number of infinitesimally narrow fissures over the relevant part of the finite

element. One cannot help feeling that we need a finite element capable of coping with discrete cracks in any direction (without too many nodes), so that fracture mechanics can be properly applied in the analysis of reinforced concrete.

Be that as it may in the long-term future, Professor Chen's book is a splendid detailed survey of current non-linear constitutive laws. It will perhaps not be required reading for designers of ordinary concrete structures, but anyone interested in finite-element analysis should certainly have it on his shelf.

C. T. MORLEY

Creep and shrinkage in concrete structures

Editors: Z. P. Bazant and F. H. Wittmann

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An International Symposium on Fundamental Research on Creep and Shrinkage of Concrete was held in September 1980 at the Swiss Federal Institute of Technology in Lausanne. In addition to a variety of papers of a purely research nature, ten invited lectures on selected topics were presented by authors drawn from Europe and North America. This volume consists of those invited contributions, some of which have been substantially revised and updated prior to publication.

The stated intention of the Symposium was, in the field of time-dependent deformations, to contribute to the closing of the gap between the typical materials science approach on the one hand and the methods developed by structural engineers on the other. To this end, the programme of the Symposium, and the invited contributions, were collected in three parts covering:

- (1) the general material properties relating to the microstructure and macrostructure of cement paste and concrete;
- (2) the measurement of creep and shrinkage, and mathematical modelling leading to constitutive equations;
- (3) the analysis of engineering structures and the observation of the effects of time-dependent movements in such structures.

It is by no means easy to link such a wide range of interests and it is inevitable that the assembly of contributions from ten different authors can do nothing to improve the continuity of treatment. It follows that this book is not a text-book but rather a series of expositions with strong research connections, providing a number of individual views of

topics throughout the intended range. Certainly, the structural engineer should not judge the contents from the title (and cover); he might well find that the coverage is both wider and more disjointed than he expected.

The first part of the book contains four chapters, one each for the contributions given by Professor J. F. Young (University of Illinois, USA), S. E. Pihlajaara (Technical Research Centre of Finland), Professor J. W. Dougill (Imperial College, University of London) and E. Cinlar (Northwestern University, USA). The first two authors give overviews of the detailed structure of hardened cement paste and of the movement of moisture through the pores. The other two authors deal with probabilistic aspects of deformations and the mechanics of concrete as a two-phase material. Both go beyond the straight description of existing knowledge and include theoretical concepts of a more novel kind. Not too much is said in any of these chapters about the relevance of the topics to the reality of creep and shrinkage, and the value of this first part of the book lies in the extension of an understanding of the structure and behaviour of concrete. This may well provide the necessary foundation for further developments of a more practical kind.

The middle part of the book contains chapters written by C. D. Pomeroy (Cement and Concrete Association), Professor F. H. Wittmann (Swiss Federal Institute of Technology, Lausanne), and Professor Z. P. Bazant (Northwestern University, USA). The contents cover a description of experimental methods for measuring creep and shrinkage, an exposition of the physical mechanisms that