Concrete Mix Design, Quality Control and Specification

Fourth Edition

Ken W. Day
James Aldred
Barry Hudson

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A SPON PRESS BOOK

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Acknowledgements

Acknowledgements for this fourth edition are largely covered in the introduction but, as with the third edition, we do not wish earlier influences to be forgotten and so we repeat the acknowledgements of the second and third editions.

ACKNOWLEDGEMENTS TO THE THIRD EDITION

My third edition builds upon the shoulders of the work done for the first two, and I do not wish those I thanked then to be forgotten now. Therefore the acknowledgements in the second edition are reprinted in full following those for the current edition.

My company, Concrete Advice Pty Ltd, was sold in 2001 to Maricopa Readymix, my first U.S. client, at the instigation of Dave Hudder, at that time managing director of Maricopa. I have him to thank for his recognition of the value of ConAd in the United States and for providing me with the means to enjoy my semiretirement and to travel the world preaching my concepts.

Upon Dave leaving Maricopa, Concrete Advice was on-sold to Command Alkon. I was very pleased about this because ConAd is a perfect fit for a major, worldwide batching-system provider. I thank them for continuing my part-time consultancy until the end of 2004, even though I have had little influence on the new version of ConAd.

I will never forget the part played by Don Bain, technical manager of Maricopa, in all of this. It was he who recommended the initial purchase of the ConAd system to Dave Hudder back in early 2000, he who used ConAd to enable the expansion of Maricopa and build the U.S. reputation of ConAd, and he who left Maricopa for a time to help Command Alkon with initial marketing of ConAd. His written contribution to this text is appreciated, but it is negligible compared to his contribution to the reputation of the ConAd system.

Andrew Travers continues to labor prodigiously as CEO of ConAd. Its future now depends on him as he rushes around the world promoting and

installing it. Unfortunately he has been far too busy to write a section of this book, much as he wanted to, and much as it would have been appreciated. Perhaps he will write the next edition.

Two other stalwarts, having contributed greatly, are no longer able to do so. Dan Leacy, the Australian equivalent of Don Bain, unfortunately passed away at an early age, and Michael Shallard retired at an even earlier age after a severe illness, depriving the system of its major source of computer expertise. I shall remember them.

My e-mail directory overflows with large numbers of people substituting for my lack of field experience in recent years. Several names appear as contributing sections of the text: Dr Alex Leshchinsky and his father Dr Marat Lesinskij, Mark Mackenzie, Dr Norwood Harrison, Dr Grant Lukey, John Harrison, Tracy Goldsworthy, and Dr Joe Dewar, whose contribution to the previous edition is repeated here.

Contributions not so acknowledged, but nevertheless real, include Aulis Kappi, Charles Allen, James Aldred, Kevin Galvin, Lawrence Roberts, Richard Hall, Dr Celik Ozylidirim, Jay Lukkarila, Dr Steve Trost, also Barry and Tania Hudson for their magnificent forum on the website http://www.aggregateresearch.com. It should be emphasised that several of these do not agree with all that I have written, so any credit for the work is shared with them, but any blame is mine alone.

Justin Smyth (delphian@smythconsulting.net) operates my website (http://www.kenday.id.au) and has amended the free programs on that site.

ACKNOWLEDGEMENTS TO THE SECOND EDITION

There are three individuals without whom this book could not have happened and four more without whom it may have been very different. The first group comprises: O. Jan Masterman, technical director, Unit Construction Co., London in the 1950s, who somehow inspired and guided me to originate in my first two years of employment the greater part of the philosophy and concepts herein recorded; John J. Peyton, John Connell & Associates (now Connell Wagner), Melbourne, without whose encouragement I never would have started my company Concrete Advice Pty Ltd in 1973 and so the nascent control techniques never would have developed to fruition; John Wallis, formerly Singapore director of Raymond International (of Houston, Texas), without whom my Singapore venture would have foundered in 1980, leaving me without computerisation and without the broad international proving grounds for the mix design system.

The second group comprises John Fowler, who wrote the first computer program using my mix design methods, at a time when I had a firm opinion that mix design was partly an art and could never be computerised; D. A. Stewart, whose book *The Design and Placing of High Quality*

Concrete (Spon, 1951) was a first major influence; David C. Teychenné, who led where I have followed in specific surface mix design; and my son Peter, who transformed "ConAd" from an amateur spreadsheet into a professional computer program.

A third kind of indebtedness is to those who assisted in the actual production of the book. They have become too numerous to list all of them by name but Hasan Ay and Andrew Travers are especially thanked for their work on figures and tables.

Harold Vivian, Bryant Mather, Dr Alex Leshchinsky, and Dr Francois de Larrard are especially thanked for invaluable advice and contributions; Sandor Popovics for his published works and thought-provoking discussions; Joe Dewar, Bryant Mather, and John Peyton for their kind forewords; also Vincent Wallis on whom I have relied for an (often brutally) honest opinion over more than 30 years; and of course my wife, who has endured a great deal in the cause of concrete technology.

A new kind of indebtedness is to those individuals in my major client companies who have not only enabled my company (Concrete Advice Pty Ltd) to survive and prosper but have also contributed in no small measure to improvements in the system. They include Peter Denham and Dan Leacy of CSR Readymix, Paul Moses of Boral, and Mark Mackenzie of Alpha, South Africa.

The ConAd computer program has come a long way since the first edition and thanks are due to my staff at Concrete Advice. Michael Shallard and Lloyd Smiley wrote the latest program and Andrew Travers, now manager of the company, knows how to use it better than I.

Finally I must thank my younger son, John Day, now technical manager of Pioneer Malaysia, for using these techniques so effectively as to make the world's tallest building, Petronas Towers, the best example yet of low variability, high strength concrete.

Introduction

The rapidly changing scene in concrete technology necessitates this fourth edition. Obviously I am aware of these changes, but being retired from active participation in concrete production and control, I have brought in two carefully selected coauthors in addition to obtaining input from many people I consider to be leading experts in their fields.

The most fundamental change is the recognition that water to cement (w/c) ratio is not the best available criterion of quality and durability. This, combined with greenhouse gas and sustainability considerations, has caused cement replacement materials to be viewed in a new light. In the future, little, if any, concrete will be produced without at least one component of this large range of materials.

Diminishing availability of natural sand conforming to preconceived ideal gradings has opened up the field for crusher fines, creating a new imperative to better understand their production and use.

It is not surprising that higher strengths and higher heights of pumpability are available, or that self-compacting concrete is becoming popular—and there will always be new admixtures.

One consequence of the greatly expanded range of materials is that theoretical mix design has essentially become only a tool for the education of new entrants to the field. Practical mixes in use will be the result of feedback, adjustment, and trial and error—but the processes used to accomplish this will be very organised and precise rather than ad hoc.

Ideal quality control (MMCQC), on the other hand, will not change from the ideal described in previous editions. The difference here is that the principles (and practice) set out many times over the years are at last showing signs of universal acceptance, even in the United States. Concrete production must be controlled by the producer.

The specification of concrete will become detailed and precise for other than very routine use. However, it will be detailed and precise in terms of required properties and performance rather than constituents. A specification for a major project is likely to be negotiated and agreed upon rather than imposed. We can look forward to a time when every significant

producer will have a range of mixes with well-established properties from which a selection can be made.

Durability is a major topic; having discarded w/c ratio as the best criterion, a new criterion must be found. This needs to be in the form of a physical test because it must be applicable to a wide range of different formulations. Although we are concerned with durability for an extended life, a test at as early an age as possible is needed to form part of the QC process. Although strength can no longer be regarded as a criterion of durability, it retains its importance as a detector of change. A change point in strength is a change point in the mix quality and so may be the earliest way of detecting change in durability. However, having detected a change, its effect on durability cannot be established on strength grounds and a specific durability test is needed.

Ken W. Day
Nunawading, Australia

About the Authors

Ken W. Day is well known as the author of the first three editions of this book. He has worked continuously in concrete mix design and quality control since graduating in 1952, except for a short period in the 1960s as associate partner of Harris & Sutherland in the United Kingdom where he worked on battery precasting of concrete housing. His two most important developments have been multigrade, multivariable, cusum quality control and specific surface mix design. He worked initially in the United Kingdom, then Australia, before starting his own company, Concrete Advice Pty Ltd, in 1973. Day has lectured in 23 countries, leading to international use of his concepts, and received multiple international awards for his work, details of which can be read on his website, http://www.kenday.id.au. His company was sold to Command Alkon via Maricopa RMC in 2002 and his quality control (QC) program is now marketed as CommandQC, and is no longer under his control. However, a small program, "KensQC", is available on his website and enables new users to experience his techniques on their own data.

James Aldred has over 30 years of experience in the concrete industry in Australia, Asia, the Middle East, and the United Kingdom. His background includes technical director of an international admixtures company, manager of the High Performance Concrete Research Group at the National University of Singapore, technical manager of Taywood Engineering, and honorary research fellow at Imperial College. He was the independent verifier for the Burj Khalifa in Dubai, which is the world's tallest tower. Dr Aldred is currently technical director with AECOM and an adjunct associate professor at the University of New South Wales. Dr Aldred obtained his PhD from Curtin University (Australia). He is a fellow of the Institute of Engineers Australia, the American Concrete Institute, and the Institute of Concrete Technology, as well as being a LEED Accredited Professional. Dr Aldred has received the Award of Excellence from the Concrete Institute of Australia, an award for outstanding and sustained contributions to concrete technology by ACI International Conferences, and the prestigious George Stephenson Medal from Institute of Civil Engineers.

Barry Hudson has 30 years of experience in the construction materials industry. He currently holds dual roles in Heidelberg Cement, establishing and managing the Competence Center Materials for the TEAM Region (Africa, Northern Europe, Baltics, Benelux, the United Kingdom, and the Mediterranean Basin), an operational overview and best practice organisation that oversees 70 million tonnes of aggregates production and 17 million cubic metres of concrete. Along with this role, he is also director of aggregates for Norway, Sweden, and the Baltics.

Specialising in aggregates for concrete, Hudson has sat on various standards committees around the world as well as industry association representation. During his 11 years of experience in the United States, Hudson was involved with the International Center for Aggregates Research. He was also an integral part of Lafarge research efforts in concrete and aggregates.

Founder of Aggregate Research (http://www.aggregateresearch.com), Hudson has four patents based around concrete mix design and aggregates characterisations. He has been published 37 times and has given presentations on every continent. Hudson is recognised as a person who combines leading edge science with the serious practicalities of everyday production.

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