

FORMWORK FOR CONCRETE

by M. K. HURD

Prepared under the direction of
ACI COMMITTEE 347, FORMWORK FOR CONCRETE

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NOTE: This document has been superseded by SP-4 (eighth edition), and is available for informational purposes only.

This seventh edition has been revised to agree with "Guide to Formwork for Concrete (ACI 347-04)," which is reprinted in full in the appendix. Other revisions have been made for consistency with ACI documents undergoing revision since previous editions of this book were issued. Lumber design stresses and procedures have been updated to agree with the 2001 National Design Specification® issued by the National Forest and Paper Association.

7th Edition

Third Printing

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The drawings and examples in this book are based on typical designs and should not be used as working drawings or in place of making calculations for a particular job. They are intended to be helpful in the preparation of complete formwork plans which should be adapted to local conditions and conform with all applicable legal requirements. In no way is this book able to, or intended to, supplant the qualified designer or engineer to whom formwork should be entrusted.

Limitations of space and time make it impossible to show all of the methods, materials, and products available for formwork construction. Omission of any item therefore should not be regarded as a judgment that it is inferior or unsuitable.

FOREWORD TO THE SEVENTH EDITION

In the four decades since SP-4 made its first appearance, more than 120,000 copies have been printed and the book has become recognized as the “green bible” of the formwork industry. Formwork for Concrete has been and continues to be a cooperative effort supported by individuals and corporations, public agencies, and industry and professional associations. Much of the record of this cooperation will be found in the forewords to previous editions reprinted on the following pages. While it is not possible to list all participating individuals and organizations, we have listed the contributors of illustrations in a special section of the appendix and added footnotes to identify certain other contributions.

The seventh edition, as all previous editions, follows the most recent guidelines established by ACI Committee 347 and documented in the official committee report, now ACI 347-04, which is reprinted in full in the appendix. This new edition considers the effects of the weight and chemistry coefficients now provided by ACI 347 to determine lateral pressure for form design, and also reflects the latest changes in wood design recommendations of the National Forest and Paper Association. The recent recommendations of other ACI committees have also been considered in text revisions, as well as a number of formwork industry products and practices adopted since the last edition was published.

All drafts of revisions have been submitted for review and approval of ACI Committee 347, whose suggestions and advice have been most creatively constructive. Membership of the committee at the time of seventh edition approval included:

PERICLES C. STIVAROS

Chairman

Rodney D. Adams	David W. Johnston
Kenneth L. Berndt	Roger S. Johnston
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Ramon J. Cook	Harry B. Lancelot, III
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Jeffrey C. Erson	William R. Phillips
N. John Gardner	Douglas J. Schoonover
Samuel A. Greenberg	W. Thomas Scott
R. Kirk Gregory	Aviad Shapira
G.P. Jum Horst	Rolf A. Spahr
Mary K. Hurd	Kevin L. Wheeler

We are very grateful to the many committee members who shared their expertise and counsel during the preparation of the seventh edition, particularly to David Johnston, who chaired the committee during much of that period, and to Kevin Wheeler, long-time committee secretary.

M. K. Hurd
November 2004

FOREWORD TO THE SIXTH EDITION

At its March 1995 meeting, ACI Committee 347 voted to dedicate this new edition of *Formwork for Concrete* to the memory of

Peter D. Courtois and Victor F. Leabu who passed away during the time the book was in preparation. Both Peter and Vic were long-time committee members, former chairmen of the committee, and tremendously valuable contributors to the development of *Formwork for Concrete*. They are sadly missed now, and will be in the future.

Over a period of 32 years and some 100,000 copies, this book has come to be referred to as the "green bible" of the formwork industry. *Formwork for Concrete* has been and continues to be a cooperative effort supported by many individuals and industry organizations, as documented in the forewords to earlier editions included in the following pages. Illustrations contributed by many industry sources have been updated over the years, and acknowledgments for them continue to be recorded in the Appendix. Committee 347 member Randy Bordner prepared drawings for the revisions to Chapter 6 in this sixth edition. Harry Lancelot and his firm, Richmond Screw Anchor Company, contributed computer calculations for most of the revised design tables of Chapter 7.

As in the case of earlier editions, the drafts were submitted for review and approval of Committee 347. Membership at the time the draft of the sixth edition was completed included:

SAMUEL A. GREENBERG, Chairman

ROBERT R. ANDERSON	HARRY B. LANCELOT, III
J. DANILO ARZENO	DAVID T. LASHGARI
IRWIN J. BENSON	VICTOR F. LEABU
RANDOLPH H. BORDNER	H. S. LEW
DAN H. CALDWELL	ANTONIO LIMBARDO
RAMON J. COOK	W. ROBERT LITTLE
DAVID S. CRAWFORD	ROBERT G. McCRACKEN
WILLIAM A. DORTCH	JOHN R. PAINE
JEFFREY C. ERSON	RUSSELL B. PECK
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ROGER S. JOHNSTON	LAURENCE E. SVAB
DOV KAMINETZKY	ERNEST E. TROLIO
KYUNG H. KIM	KEVIN L. WHEELER

JIM L. WILLIAMS

As always, we are extremely grateful to the many committee members who have shared their expertise through advice and counsel during the long period of work on this sixth edition.

M. K. HURD
April 1995

FOREWORD TO THE FIFTH EDITION

In the more than 26 years that this book has been in print it has come to be recognized as a standard reference, used as a textbook, and frequently referred to as the "green bible" of the industry. All this has come about as a result of ongoing cooperation and contributions by individuals and corporations, public agencies, and industry and professional associations. The fifth edition continues that tradition and benefits from the review and guidance of ACI Committee 347.

While it is impossible to list all participating individuals and organizations, we have listed the contributors of photographs in a special section in the appendix. In addition we must acknowledge the work of several major contributors. Lewis H. Tuthill provided valuable suggestions and contributions to the revision of Chapters 13 and 14. Dan Litt, a former member of ACI Committee 347, provided text, photos, and resource information for the major revision of the slipforming section in Chapter 15. Bob Opie, also a former member of Committee 347, contributed a new planning example for Chapter 3 as well as illustrations and critical review for other parts of the book. Dov Kaminetzky and the firm of Feld, Kaminetzky & Coher contributed computer time for recalculation of the lumbe design tables in Chapter 7, with work performed by Joe Tang of that firm. We also remember the ongoing support of the late Paul Sommers.

As in the case of earlier revisions, the drafts were submitted for review and approval of ACI Committee 347. Membership at the time of fifth edition approval included the following:

RANDY BORDNER, Chairman

ROBERT R. ANDERSON	ROGER S. JOHNSTON
IRWIN J. BENSON	DOV KAMINETZKY
LEON BIALKOWSKI	HARRY B. LANCELOT, II
RAMON J. COOK	VICTOR F. LEABU
PETER D. COURTOIS	H. S. LEW
DAVID S. CRAWFORD	W. ROBERT LITTLE
NOEL J. GARDNER	JOHN R. PAINE, JR
SAMUEL A. GREENBERG	WILLIAM R. PHILLIPS
R. KIRK GREGORY	PAUL H. SOMMER
MARY K. HURD	W. THOMAS SCOTT

We are indebted to the entire committee for help in making this fifth edition possible, particularly to Chairman Bordner and to the former chairman, Roger Johnston.

November 1989

M.K. Hurd

To maintain continuity of records regarding past participation and contributions to this book, the ACI 347 roster at the time the fourth edition was issued in 1979 is reprinted below.

PETER D. COURTOIS, Chairman

ROBERT R. ANDERSON	VICTOR F. LEABU
IRWIN J. BENSON	H. S. LEW
THOMAS J. CROWLEY	ROBERT S. OPI
NOEL J. GARDNER	JOHN R. PAINE, JR
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DOV KAMINETZKY	FRANKLIN SALE
DENNIS J. KEARNEY	PAUL H. SOMMER
HARRY B. LANCELOT, III	WILLIAM R. WAUG

FOREWORD TO THE FOURTH EDITION

In the decade and a half since *Formwork for Concrete* made its first appearance, it has become the familiar "green bible" of the formwork industry. We hope that this new book will maintain the reputation established by past editions, and prove to be an even more helpful reference because of the extensive revisions which have been introduced.

Although budget limitations precluded making all of the changes that might have been desirable, we were able to direct substantial effort toward changes to make the book consistent with the new ACI formwork standard, ACI 347-78, which contains several important revisions having a bearing on formwork safety. To a lesser extent, the revised book also reflects provisions of ACI standards 309-72 for consolidation of concrete; 313-77, on bins and silos; 316-74, construction of pavements; and ACI 318-77, "Building Code Requirements for Reinforced Concrete." Consideration is also given to revised recommendations of ACI Committee 306 for cold weather concreting.

In addition, all design tables and examples have been revised as required by the reductions in working stresses for horizontal shear and the changed provisions for simple column design (applicable to wood shores), issued in the 1977 "National Design Specification for Stress Grade Lumber." Aside from complying with changes in these fundamental references, major changes have been made to update Chapter 4—Materials, Accessories, and Proprietary Products, and Chapter 10—Using the Forms. The chapter on architectural concrete formwork has been modernized and expanded substantially, to reflect new construction materials and practices as well as recommendations of ACI Committee 303, Architectural Concrete. Other chapters have much new information and many new pictures. Reference lists have been increased, and the appendix expanded to include Subpart Q (concrete forms and shoring) of the OSHA regulations and ACI 318-77 Code and Commentary provisions for formwork.

Of particular significance are the methods presented in Chapters 5 and 6 for the analysis of loads and the planning of shoring and reshoring for multistory structures. These passages were developed in response to the specific request by Committee 347 that we show how to implement the basic recommendations outlined in ACI 347-78, Section 2.5.3.

As in the case of earlier editions of this book, all drafts of revisions were submitted for review and approval of ACI Committee 347, whose suggestions and advice have been most creatively constructive. Members of ACI Committee 303 also contributed helpful suggestions for Chapter 11. *Formwork for Concrete* is the fruit of extensive cooperation involving not only the present committee members whose names appear on the title page, but also all of the past members of the committee. It therefore seems appropriate to reprint the forewords to previous editions so that the names of those many other devoted ACI members are not lost to posterity.

March 1979

M. K. Hurd

FOREWORD TO THE THIRD EDITION

Even though it was evident in 1968 when the revised second edition of this work was being prepared that changes in United States lumber standards were in the offing, resolution of the controversial changes by the lumber industry did not come soon enough to get the results into our second edition. Not until late in 1970 was the new PS 20-70 "Voluntary Product Standard for Softwood Lumber" formally adopted, and many months later lumber began coming into the market manufactured to the new dimensions specified in that standard. This third edition of *Formwork for Concrete* has been completely revised to reflect changes in the lumber standard, and to make use of the most recent (1971) working stress values for lumber recommended by the National Forest Products Association. All design examples, design tables, and design data for lumber have been revised to conform to the new dimensions and stresses. The design tables of Chapter 7 have been expanded to cover four different strengths of lumber, rather than two as in earlier editions. Additional minor changes include the updating of numerous referenced documents.

Revisions have been reviewed by ACI Committee 347, whose continuing cooperation is greatly appreciated. Committee membership at the time these revisions were completed included:

VICTOR F. LEABU
Chairman

ROBERT R. ANDERSON
MARTIN W. BOLL
PETER D. COURTOIS
THOMAS J. CROWLEY
JACOB FELD
DAVID E. FLEMING

JOHN A. GUSTAFSON
ROGER S. JOHNSTON
ROY H. OLSEN
CHARLES F. PECK
PAUL H. SOMMERS
WILLIAM R. WAUGH

Peter D. Courtois again served as chairman of the subcommittee directly responsible for reviewing revisions. Computer calculations for the new design tables were contributed by William Phillips and by Superior Concrete Accessories, Inc.

Detroit
April 1973

M. K. Hurd

FOREWORD TO THE SECOND EDITION

The first edition of *Formwork for Concrete* appeared in 1963, at the same time that the first ACI Formwork Standard, ACI 347-63, was adopted. The book was written as a how-to-do-it manual for form designers, contractors, engineers, and architects, following guidelines established by Committee 347 (formerly designated Committee 622) in the Standard. In July of 1968, a revised "Recommended Practice for Concrete Formwork, ACI 347-68" was adopted and this second revised edition has been prepared to take cognizance of changes in the Committee 347 recommendations. Retaining the freely illustrated format of the first edition, *Formwork for Concrete* continues to emphasize safety, efficiency, and economy in

planning and building formwork. Completely new tables of the sectional properties of plywood and new design tables for plywood form members have been substituted because of changes in product standards for softwood plywood made since the first edition was released.

Revisions for the book were reviewed and approved by Committee 347, in much the same manner that the original draft of the book was reviewed, and the cooperation of this highly capable group is greatly appreciated. Committee membership during the review process included:

WILLIAM R. WAUGH
Chairman

MARTIN W. BOLL
GEORGE F. BOWDEN
PETER D. COURTOIS
L. B. CROSSING
THOMAS J. CROWLEY
WILLIAM R. DAVIS, JR.
JACOB FELD
DAVID E. FLEMING

ROY H. OLSEN
EDWARD J. O'REILLY
JOSEPH R. PROCTOR, JR.
PAUL F. RICE
LYNN M. ROSS
HARRY L. SCOGGIN
WILLIAM H. WOLF
GEORGE J. ZIVERTS

VICTOR F. LEABU

Peter D. Courtois was chairman of the subcommittee guiding revision of the book, and Joseph R. Proctor, Jr. headed the subcommittee which originated the new draft of the Formwork Standard.

Detroit
April 1969

M. K. Hurd

FOREWORD TO THE FIRST EDITION

Born of a concern for improving the safety and quality of formwork for concrete construction, ACI Committee 622 (since redesignated Committee 347) was organized in 1955. With the basic goal of developing a specification for the design and construction of formwork, the committee first published results of its studies of lateral pressure on formwork and of existing form construction practices. Under the leadership of Harry Ellsberg, the committee culminated 5 years of work with the publication in March, 1961, of a recommended practice for formwork. That report, with subsequent revisions, has been adopted this year as an ACI standard.

When the major committee report was completed, it was recognized that much more must be said to provide a how-to-do-it manual useful to form designers, contractors, engineers and architects. It was then that the American Concrete Institute decided to undertake the preparation of such a formwork manual, following the guide-lines established by the

committee report, and under the continuing direction of the committee's formwork authorities.

The entire preparation of this volume has been an exercise in cooperation of the highest order. The Concrete Reinforcing Steel Institute, which had previously contemplated publication of a similar work, turned over its file of information. The Portland Cement Association permitted use of material previously issued in its booklet on forms for architectural concrete. Other trade associations, together with the producers and suppliers of forms, formwork materials, and accessories, contributed generously of information regarding their products and specialties. Form builders, form designers, architects, and engineers shared experience and opinion in discussions which have contributed much to the preparation of this book. Information has also been derived from existing books and periodicals, many of which are cited in the text. The ACI staff offered continuing support in many ways. It is impossible to specifically acknowledge all contributions, but credits for direct contribution of illustrations are listed at the close of the text.

The book has benefitted greatly from the guidance and fine cooperation of Committee 622. A special editorial subcommittee was appointed to shoulder major responsibility for reviewing the manuscript during its preparation. This group included Paul Barton, Harry Ellsberg, Robert C. Johnson, V. F. Leabu, Paul Rice, and O. G. Sharrar. All members of Committee 622 were given the opportunity to review the complete manuscript; many were tireless in their response with constructive suggestions and criticism. Joseph R. Proctor, who assumed chairmanship of the committee early in 1961, was particularly helpful in organizing the talents and energies of the committee in support of the project, and both Chairman Proctor and P. R. Stratton made substantial direct contributions to preparation of the manuscript.

Detroit
March 1963

M. K. H.

Complete membership of ACI Committee 622 at the time of approval of the first edition was as follows:

JOSEPH R. PROCTOR
Chairman

JOHN H. BANKER
PAUL S. BARTON
F. H. BEINHAEUER
H. P. CERUTTI
N. L. DOE
HARRY ELLSBERG
JACOB FELD
DAVID E. FLEMING
VANCE J. GRAY

ROBERT C. JOHNSON
VICTOR F. LEABU
DONALD R. PEIRCE
A. H. PILLING
PAUL F. RICE
O. G. SHARRAR
P. R. STRATTON
WILLIAM R. WAUGH
WILLIAM H. WOLF

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I: INTRODUCTION

FORMWORK DEVELOPMENT has paralleled the growth of concrete construction throughout the twentieth century. As concrete has come of age, and has been assigned increasingly significant structural tasks, form builders have had to keep pace. The increasing acceptance of concrete as an architectural medium today presents the form builder a new range of problems in the development of appropriate sheathing materials and maintenance of rigid tolerances.

Lumber was once the predominant form material, but developments in the use of plywood, metal, plastics, and other materials, together with the increasing use of specialized accessories have changed the picture. Form designers and builders must keep abreast

of advancing technology in other materials fields in order to develop creative innovations required to maintain quality and economy in the face of new formwork challenges.

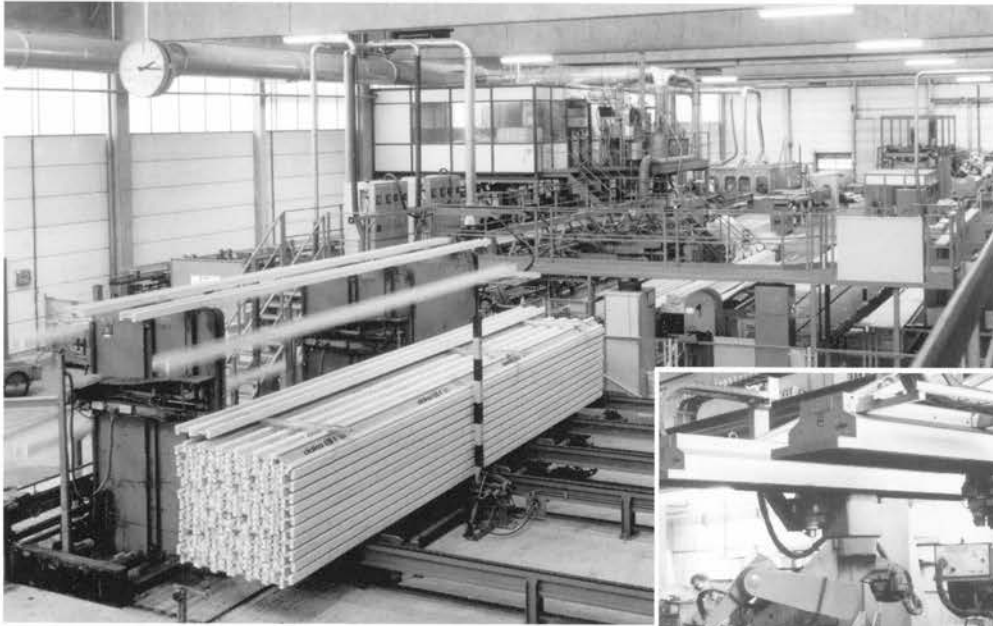
Formwork was formerly built in place, used once, and wrecked. Because of high labor costs in the United States, the trend today is toward increasing prefabrication, assembly in large units, erection by mechanical means such as "flying" forms into place by crane, and continuing reuse of the forms. These developments are in harmony with the increasing mechanization of production in other fields.

Not all of the important ideas are new, however. As early as 1908, members of the American Concrete

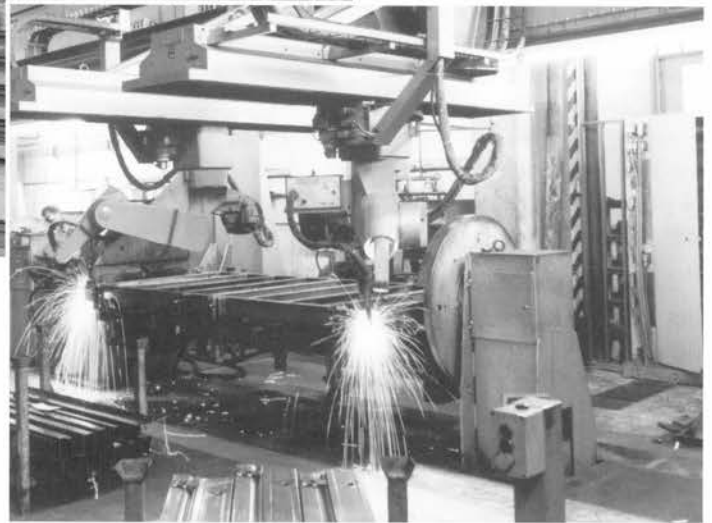
1-1 Turn-of-the-century techniques in form building shown in this photo of work at the Cincinnati Zoo. Concentration of workmen and tools high in the structure is representative of the built-in-place technique that has been supplanted today in large degree by prefabrication.



FORMWORK FOR CONCRETE



1-2 Automated construction lines are common for formwork production, just as for other industrial assembly work. Welding robots are shown fabricating metal frames used for heavy panels. The upper picture shows fabrication of wood I-beam form supports. In an alternative approach to efficient fabrication, components of job-built forms are precut and shipped to the job site for assembly (see Figure 3-2).



Institute (then called the National Association of Cement Users) were debating the relative merits of wood and steel formwork at their annual convention. At the same meeting they heard a colleague proclaim the advantages of modular panel forming that could be adapted for most any job, had its own connecting hardware, and was good for extensive reuse. By 1910, steel forms for paving were being produced commercially and used in the field (Figure 1-3). Steel forms for underground structures were marketed even earlier. Continuing refinement of basic ideas like these represents another area of formwork progress.

There are wide variations in details of forming practice from one country to another, and likewise considerable variation locally from one region of the United States to another. It was earlier hoped that this book could be made international in scope, matching the international character of the American Concrete Institute. However, such a task proved too formidable to undertake. Although the information presented has been drawn from many sources worldwide, this volume is intended for application primarily in the United States. Suggestions for formwork economy have been based on conditions in industrialized countries. In areas where labor costs are low in rela-

tion to the price of construction materials, many of these ideas will not have the same validity.

Whether form building is an art or a science remains an open question; the best answer probably is that it combines important elements of both. There is certainly no substitute for the skill and sense of "know-how" that come with experience. Yet many engineering principles can be brought to bear—improving the safety, quality, and economy of formwork.

One objective of this book is to make available in convenient, concise form much of the available existing knowledge that will be useful in planning, constructing, and using formwork. In no way will it supplant the experienced form designer or builder; it can, however, give him considerable help by bringing together a multitude of properties, design data, and construction suggestions for convenient reference in a single volume. For the architect-engineer, it offers an improved opportunity for masterly execution of detail in concrete through a better understanding of the problems and possibilities in form building. For the novice, the book will serve as an introduction to many common forming practices, explaining basic principles of design and encouraging a rational rather than rule-of-thumb approach.