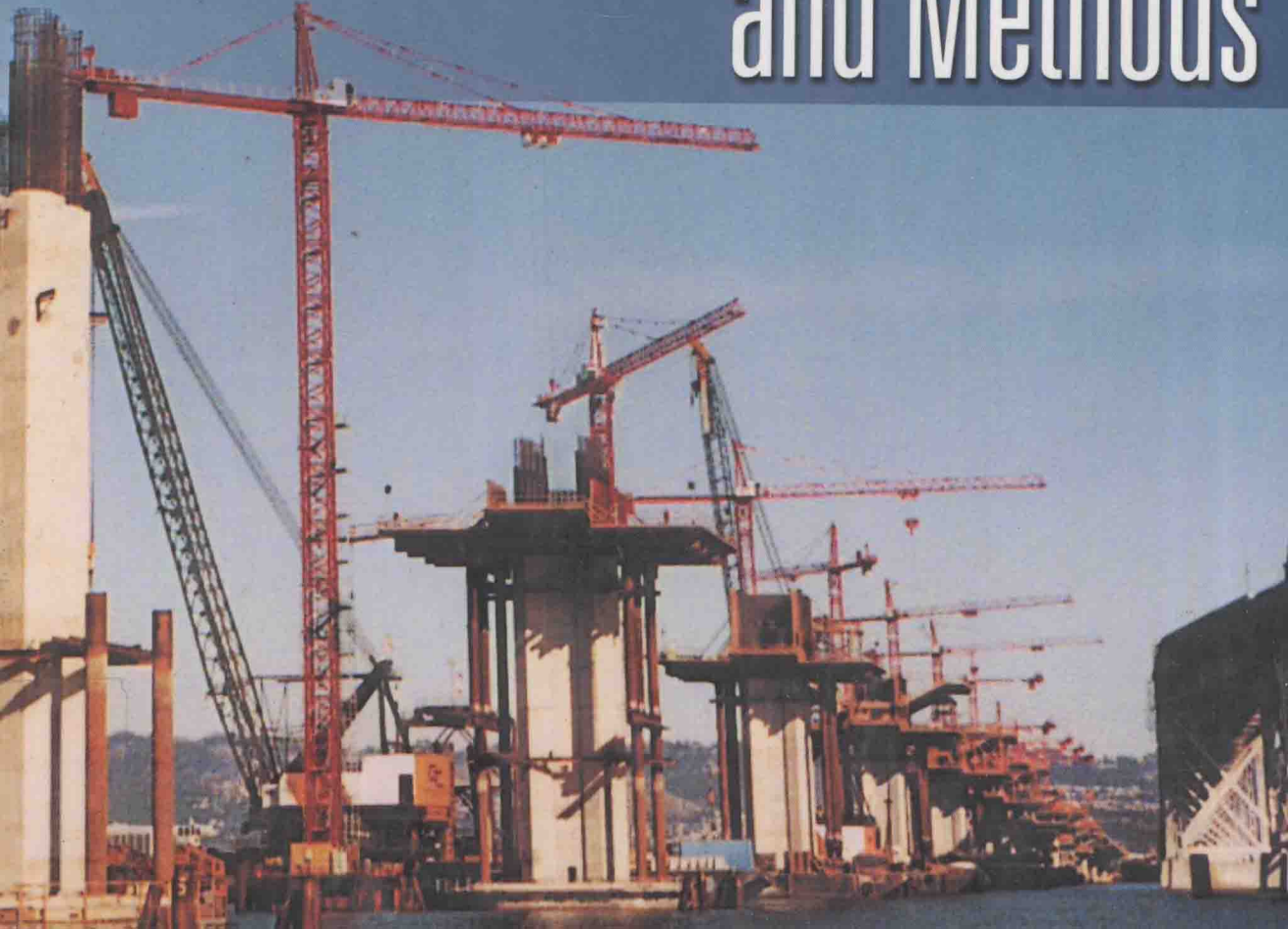
Construction Planning, Equipment, and Methods

Robert L. Peurifoy
Clifford J. Schexnayder
Aviad Shapira

Seventh Edition



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Construction Planning, Equipment, and Methods

Eliezer Shapira, a civil engineer, general contractor, and father of Aviad Shapira. As a father and most loving teacher it was he who sparked Aviad's passion for construction. Over the years, Eliezer and Cliff have also shared adventures at equipment shows in Europe and enjoyed many an interesting construction story. This book is therefore dedicated to Eliezer Shapira—a constructor who has taught both of us an appreciation for meeting the challenges of construction.

Cliff Schexnayder
Aviad Shapira

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ABOUT THE AUTHORS

R. L. Peurifoy (1902–1995), after serving as principal specialist in engineering education for the U.S. Office of Education during World War II, began teaching construction engineering at Texas A&M University in 1946. In the years that followed, Peurifoy led the transformation of the study of construction engineering into an academic discipline. In 1984 the Peurifoy Construction Research Award was instituted by the American Society of Civil Engineers upon recommendation of the Construction Research Council. This award was instituted to honor R. L. Peurifoy's exceptional leadership in construction education and research. The award recipients since the last edition of the book are:

2001 M. Dan Morris
2003 Jimmie W. Hinze, University of Florida
2004 David B. Ashley, University of California Merced
2005 Abraham Warszawski, Technion–Israel Institute of Technology

Clifford J. Schexnayder is an Eminent Scholar Emeritus at the Del E. Webb School of Construction, Arizona State University. He received his Ph.D. in Civil Engineering (Construction Engineering and Management) from Purdue University, and a Master's and Bachelor's in Civil Engineering from Georgia Institute of Technology. A construction engineer with over 35 years of practical experience, Dr. Schexnayder has worked with major heavy/highway construction contractors as field engineer, estimator, and corporate Chief Engineer.

As Chief Engineer he was the qualifying party for the company's Contractor's License and had direct line responsibility for the coordination and supervision of both the estimating and construction of projects. He provided management, administrative, and technical direction to the company's operations and represented the company in project meetings and negotiations.

Additionally, he served with the U.S. Army Corps of Engineers on active duty and in the reserves, retiring as a Colonel. His last assignment was as Executive Director, Directorate of Military Programs, Office of the Chief of Engineers, Washington, D.C.

He has taught construction equipment at Arizona State University, Louisiana Tech University, Purdue, Technion–Israel Institute of Technology, Universidad de Piura (Peru), the U.S. Air Force Academy, Universidad Tecnica Particuar de Loja (Equador), Virginia Polytechnic Institute and State University, and the U.S. Army Engineer School.

Dr. Schexnayder is a registered professional engineer in six states, as well as a member of the American Society of Civil Engineers. He served as chairman of the ASCE's Construction Division and on the task committee, which formed the ASCE Construction Institute. From 1997 to 2003 he served as chairman of the Transportation Research Board's Construction Section.

Aviad Shapira is an Associate Professor of Construction Engineering and Management in the Faculty of Civil and Environmental Engineering at the Technion–Israel Institute of Technology. He received his B.Sc., M.Sc., and D.Sc. degrees in Civil Engineering from the Technion. After completing his degrees, he spent one year as a post-doctoral fellow at the University of Illinois at Urbana–Champaign under a grant from the U.S. Air Force Civil Engineering Support Agency. In the 1990s he spent a year at the University of New Mexico in Albuquerque as the AGC Visiting Professor.

Dr. Shapira accrued his practical experience as a project engineer, project manager, and Chief Engineer in a general contracting firm prior to pursuing an academic career. During that period, he was in charge of the construction engineering for industrial, commercial, and public projects in Israel. His teaching, research, and consulting interests have taken him to construction projects around the world.

He has taught construction equipment and formwork design in Israel and the United States since 1985, and authored or co-authored the only texts addressing these subjects in Israel. His research has focused on formwork design and construction equipment for building construction. That work has covered equipment selection, operation, management, productivity, economics, and safety. He co-developed an innovative crane-mounted video camera that serves as an operator aid. This camera system has been used on most of the high-rise building projects built in Israel since 1998 and on several projects in Europe.

Dr. Shapira is a member of the American Society of Civil Engineers and the American Concrete Institute. He has been an active member of ACI Committee 347 Formwork for Concrete since 1997, and has also served on several ASCE and TRB construction equipment committees. Additionally, he is the Vice-Chair of Technical Committee 120 of the Standard Institution of Israel, which wrote the new Israeli formwork standard, first published in 1995 and revised in 1998.

PREFACE

With the coming of the railroads in the early 1800s there was a need to accomplish sizable grading operations. In Massachusetts, the building of the Western Railroad, which was completed in 1841, required the movement of approximately 6.8 million cubic yards of material. Men wielding pick and shovel accomplished most of the work, with horses and wagons used to move the material from the cuts to the fills. But a young man named William S. Otis, whose firm Carmichael, Fairbanks, and Otis held a grading contract with the Boston & Providence Railroad, developed a machine in 1834 commonly referred to as the "Yankee Geologist" by the English. It was the first steam shovel, and with it the age of mechanically driven construction equipment began.

The Bucyrus Company published a *Handbook of Steam Shovel Work, a Report by the Construction Service Company* in 1911. This publication is a collection of field studies performed in 1909 to analyze shovel production and delay factors. From this early treatise on time and motion applied to the utilization of steam shovels, it is clear that the engineers understood that production was tied to proper planning of the excavation and haulage.

Today, though we have entered the age of the laptop computer and the Internet, and can download data directly for our machines, there is an even greater need to properly plan equipment operations. A machine is only economical if used in the proper manner and in the environment for which it has the mechanical capabilities to engage. Technology improvements greatly enhance our ability to formulate equipment, planning, and construction decisions, but we must first have an understanding of machine capabilities and how to properly apply those capabilities to construction challenges.

This seventh edition follows in the tradition of the first six by providing the reader with fundamentals of machine selection and production estimating in a logical, simple, and concise format. With a grounding in these fundamentals, the constructor is prepared to evaluate those reams of computer-generated data and to develop programs that speed the decision process or that enable easy analysis of multiple options.

Significant changes have been made to this edition. Following a course plotted with the sixth edition, we have introduced more material applicable to building construction. This is particularly true in the chapters addressing cranes and concrete, which have been extensively rewritten, and the two new chapters on "Forming Systems" and "Planning for Building Construction." Today, formwork systems are construction equipment in very much the same manner as cranes and concrete pumps. The new "Forming Systems" chapter focuses on advanced modular and industrialized forming systems.

The chapters on "Compressed Air" and "Equipment for Pumping Water" have been combined because the concept of calculating friction losses is applied to both air and water in designing systems.

We have also found that in the five years since the last edition of *Construction Planning, Equipment, and Methods,* considerably more equipment manufacturers are placing their machine specifications and operation materials on the Internet. Machine data that we originally proposed to present on a CD with the book are now available over the Internet. Therefore Web resource information is provided at the end of every chapter of our text. In addition, Web-based exercises, which in some cases direct the student to specific machine information on the web, have been added to many of the chapters. When you see the website icon in the text margin, visit our website at *www.mhhe.com/peurifoy7e* for additional resources and exercises available on the World Wide Web.

All chapters have undergone revision, ranging from simple clarification to major modifications, depending on the need to improve organization and presentation of concepts. The pictures in all of the chapters have been updated to illustrate the latest equipment and methods, and more pictures of operating equipment have been used in this edition. Drawings have been added beside many of the figures so that the important features under consideration are clearly identified. Safety discussions are now presented in each of the chapters dealing with machine or formwork use.

The world of construction equipment is truly global, and we have tried to search globally for the latest ideas in machine application and technology. We have visited manufacturers and project sites in some 23 countries around the world in gathering the information presented in this edition.

This book enjoys wide use as a practical reference by the profession and as a college textbook. The use of examples to reinforce the concepts through application has been continued. Based on professional practice, we have tried to present standard formats for analyzing production. Many companies use such formats to avoid errors when estimating production during the fast-paced efforts required for bid preparation.

To enhance the value of the book as a college textbook, we have updated and expanded the number of problems at the close of each chapter. We have also included several problems that compel the student to learn using a step-by-step approach: these problems specifically request the solution for each step before moving on to reach a final solution. This approach focuses student learning by clearly defining the critical pieces of information necessary for problem solving. The solutions to some problems are included in the text at the end of the problem statements. Together with the examples, they facilitate learning and give students confidence that they can master the subjects presented.

We are deeply grateful to the many individuals and firms who have supplied information and illustrations. Two individuals are owed a particular debt of gratitude for their support and efforts. Prof. John Zaniewski, Director, Harley O. Staggers National Transportation Center, West Virginia University, has consistently provided assistance with the "Asphalt Mix Production and Placement" chapter, and Mr. R. R. Walker of Tidewater Construction Corporation has done the same for the "Piles and Pile-Driving Equipment" chapter. We would like to express our thanks for many useful comments and suggestions provided by the following reviewers:

David Arditi, *Illinois Institute of Technology*; Ibrahim A. Assakkaf, *University of Maryland*; Frank Atuahene, *South Dakota State University*; Marcia C. Belcher, *University of Akron*; Leonhard E. Bernold, *North Carolina State University*; Keith A. Bisharat, *Sacramento State University*; Carl Bovill, *University of Maryland*; Travis Chapin, *Bowling Green State University*; Jay Christofferson, *Brigham Young University*; Gregg R. Corley, *Clemson University*; Larry G. Crowley, *Auburn University*; Neil N. Eldin, *Texas A&M University*; William C. Epstein, *California Polytechnic State University, San Luis Obispo*; Sean P. Foley, *Northern Kentucky University*; David R. Fritchen, *Kansas State University*; Marvin C. Gabert, *Boise State University*; John Gambatese, *Oregon State University*; Jesus M. de la Garza, *Virginia Tech*; Sanjiv Gokhale, *Vanderbilt University*; Paul M. Goodrum, *University of Kentucky*; F. H. Griffs, *Brooklyn Institute of Technology*; Hanford Gross, *Washington University*; Carl Haas, *The University of Texas at Austin*; Dana Hobson, *Oklahoma State University*; Arpad Horvath, *University of California, Berkeley*; William Ibbs, *University of California, Berkeley*; Saeed Karshenas, *Marquette University*; Henry M. Koffman, *University of Southern California*; Walter Konon, *New Jersey Institute of Technology*; Thomas Mills, *Virginia Tech*; Keith R. Molenaar, *University of Colorado*; Michael L. Nobs, *Washington University in St. Louis*; David Riley, *The Pennsylvania State University*; Jeffrey S. Russell, *University of Wisconsin–Madison*; Richard C. Ryan, *University of Oklahoma*; Robert L. Schmitt, *University of Wisconsin–Platteville*; David N. Sillars, *Oregon State University*; Marlee Walton, *Oregon State University*

However, we take full responsibility for the material. Finally we wish to acknowledge the comments and suggestions for improvement received from persons using the book. We are all aware of how much our students help us to sharpen the subject presentation. Their questions and comments in the classroom have guided us in developing this revised book. For that and much more, we want to thank our students at the Air Force Academy, Arizona State University, Louisiana Tech, Purdue, Technion–Israel Institute of Technology, University of New Mexico, Virginia Tech, the Universidad de Piura, and the Universidad Technica Particuar de Loja, who have over the years contributed so much helpful advice for clarifying the subject matter.

Most importantly we express our sincere appreciation and love for our wives, Judy and Reuma, who typed chapters, proofread too many manuscripts, kept us healthy, and who otherwise got pushed farther into the exciting world of construction than they probably really wanted. Without their support this text would not be a reality.

We solicit comments on the edition.

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Haifa, Israel

Guided Tour

This book describes the fundamental concepts of machine utilization, which economically match machine capability to specific project construction requirements. The text contains over 300 photos and 300 additional drawings to describe equipment and construction methods. Illustrations and figures have been added to highlight important features.

FIGURE 9.7 Crawler-mounted hydraulic hoe.

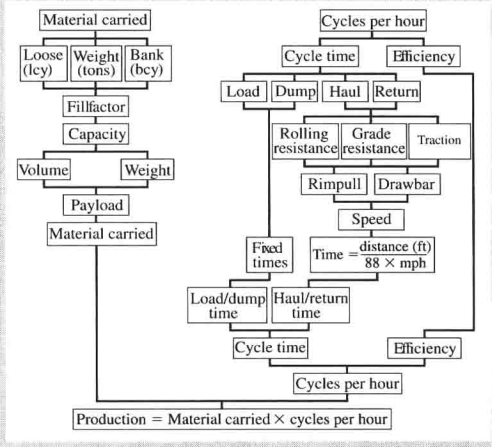

FIGURE 9.3 Excavator production process.

This seventh edition of *Construction Planning, Equipment, and Methods* presents the fundamentals of machine selection and production estimating in a **logical, simple, and concise format.**

Our text features more material applicable to **building construction.** See, for example, the chapters covering **cranes** and **concrete,** which have been extensively rewritten.

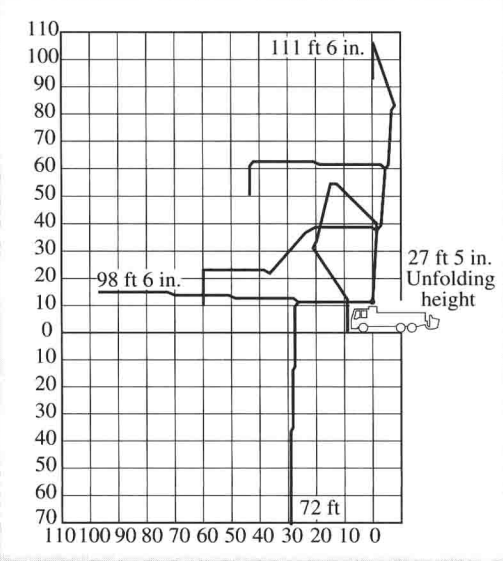

FIGURE 16.16 Truck-mounted boom and pump combination: (a) boom chart.

Guided Tour

Two new chapters, "Forming Systems" and "Planning for Building Construction," are introduced in this edition. The new chapter on forming focuses on advanced modular and industrialized forming systems.

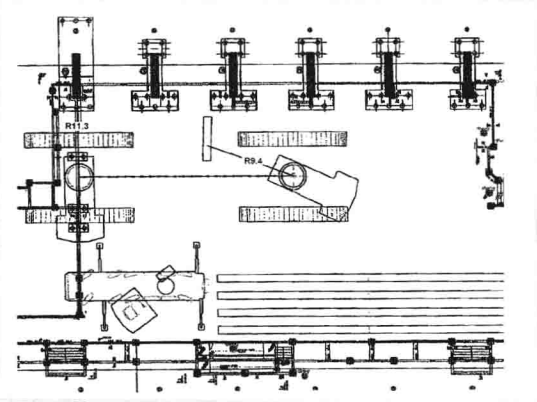

FIGURE 21.10 Lift plan for setting a concrete column.

(1)	Depth of hole:	(a) _____ ft face, (b) _____ ft drill		
(2)	Penetration rate:	_____ ft/min		
(3)	Drilling time:	_____ min	(1b)/(2)	
(4)	Change steel:	_____ min		
(5)	Blow hole:	_____ min		
(6)	Move to next hole:	_____ min		
(7)	Align steel:	_____ min		
(8)	Change bit:	_____ min		
(9)	Total time:	_____ min		
(10)	Operating rate:	_____ ft/min	(1b)/(9)	
(11)	Production efficiency:	_____ min/hr		
(12)	Hourly production:	_____ ft/hr	(11)×(10)	

FIGURE 12.16 Format for estimating drilling production.

We use **examples** to reinforce concepts and applications. Based on professional practice, our text presents **standard formats** for analyzing equipment production. Many companies use such formats to avoid errors when estimating production during the fast-paced efforts required for bid preparation.

Every chapter contains new and expanded **homework problems.** We have also included several problems requiring a **step-by-step approach,** which focuses student learning by clearly defining the critical pieces of information necessary for problem solving.

To purchase a new car it is necessary to borrow $18,550. The bank offers a 5-year loan at an interest rate of 4% compounded annually. If you make only one payment at the end of the loan period repaying the principal and interest, what is the total amount that must be paid back?

(a) What is the number of time periods (n) you should use in solving this problem? **(5)**

(b) What rate of interest (i), per period of time, should be used in solving this problem? **(4%)**

(c) Is the present single amount of money (P) known? (Yes, No) **(Yes)**

Guided Tour

Safety discussions are presented in every chapter covering machine and formwork use.

Operating and working around construction equipment and trucks is dangerous. A 6-ft-tall person within 70 ft of the right side of a 150 ton off-highway truck cannot be seen by the driver.

Web-based exercises have been added to many chapters to draw attention to the expanding volume of information available over the Internet. The computer monitor icon in the text margin will direct you to the text website (www.mhhe.com/peurifoy7e). In addition, extensive **Web resources** are provided at the end of every text chapter.

Visit the Caterpillar website and obtain the flywheel power (hp) rating for both a D6R and a D7R Series II track tractor. For these same tractors, check the blade specifications and determine the width (length) for both an "A" and an "S." Calculate the hp per foot of cutting edge ratio for all four conditions.

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