Frank J. Gallo
Regis I. Campbell

SMALL RESIDENTIAL STRUCTURES

Construction Practices and Material Take Off Estimates

Professional Edition

Small Residential Structures

Construction Practices and Material Take Off Estimates

Professional Edition

Frank J. Gallo, M.S.C.E., P.E.
Cleveland State University
and
Regis I. Campbell, P.E.
Vice-President
Barber & Hoffman, Inc., Cleveland, Ohio

John Wiley & Sons
New York Chichester Brisbane Toronto Singapore

Library of Congress Cataloging in Publication Data:

Gallo, Frank J.
Small residential structures.

Bibliography: p.
Includes index.
1. House construction—Estimates. I.
Regis I. II. Title.
TH4812.G34 1984 692'.5 83-16847
ISBN 0-471-88359-X

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

This book is dedicated to

C. Merrill Barber

Professional Engineer and Architect

whose teaching and example have made many young engineers and architects, including the authors, aware of their responsibilities to society and to their professions.

Preface

This book was originally written to give contractors and tradespeople involved in the building industry some insight into the task of determining costs for constructing residential structures. It was intended to be used as a part of a continuing-education-type program that included videotaped lectures of the book's content.

As the book came together, the authors found that the inclusion of information on construction procedures, construction nomenclature, and so forth would make the book particularly useful to others. The resulting product now introduces construction as related to the assembly and the estimating of materials required to erect residential-type structures. The procedures discussed can very readily be adapted to the construction of small commercial structures as well.

We believe that this book will be useful to all individuals in the residential construction field. It is written to be easily understood by anyone having a basic knowledge of mathematics and simple trigonometry. Tables and charts are included to further simplify calculations.

This is not a "costing book," simply because we have found that construction costs vary tremendously throughout the country. As written, the material can be used in every area of the United States. References to published "costing" books that may be used are included for use when the builder is ready to put cost numbers into the estimate.

Small Residential Structures deals with the determining of quantities required as far as the following construction procedures are concerned:

1. Excavation and other earthwork operations.

2. Framing of floors, walls, and roofs.

3. Rough and final finishes needed.

4. Mechanical and electrical systems.

5. Decorating the finished structure.

The materials and procedures discussed have been used by us for many years. In addition, we have called on colleagues to aid us in presenting materials and methods that are truly up-to-date.

Frank J. Gallo
Regis I. Campbell

Acknowledgments

A book of this type needs a large number of "cooks" to make the "broth" come out clear and complete. The authors would not have been able to fulfill their ideas for this book without the help of many "cooks." Chief among these were

Harry G. Anderson, P.E., Office Manager, Barber & Hoffman, Inc., Cleveland, Ohio. Mr. Anderson was responsible for having the illustrations prepared by the Barber & Hoffman staff and also for much of the editing in parts of the text.

Albert Fishman, President, and **Leonard Nyman,** Chief Executive Officer, Drake Construction Co., Cleveland, Ohio. These men provided the impetus to getting the material for this book put down on paper. In addition, they were of tremendous help in developing the Wood Framing sections of the text.

James Hurst, P.E., formerly President, Evans & Associates, Inc., Cleveland, Ohio. Mr. Hurst was of enormous help in the developing of the chapter on Mechanical Systems.

To these, and to the many others who helped us to prepare this volume, we extend our sincerest thanks.

F.J.G.
R.I.C.

Contents

Chapter One Introduction and General Information 2

Introduction to Estimating Costs **3** Costs **6**
Basic Computations Needed in Estimating **8**
Qualifications of an Estimator **12** Forms Used by Estimators **12**

Chapter Two Earthwork Operations 16

Earthwork Computations **17** Earth Movement **19**
Excavating and Related Equipment **20**
Additional Earthwork Operations **21** Summary **25**

Chapter Three Foundation Work 28

Concrete Work **29** Concrete Blocks **34**
Brick Walls: Concrete and Burned Clay Elements **35**
Wall Exposures and Patterns **37** Masonry Piers **39** Steel Posts **40**
Wooden Posts **40** Post Note **40**

Chapter Four House Framing 42

Part I Floors 43 Floor-Supporting Structures **43**
Summary on Floor Framing **52**
Part II Walls and Partitions 54 Exterior Walls **54**
Estimating Procedures **57** Additional Framing Needed **58**
Sheathing (Covering) the Wall **59**
Part III Roofs and Ceilings 62 Ceilings **62** Roof Framing **62**
Roof Sheathing **69**

Chapter Five Roofing and Exterior Finish Materials 72

Roofing **73** Cornice and Gutter (Fascia) Boards **76**
Gutters and Downspouts **76** Windows **77** Exterior Doors **79**
Louvers **80** Exterior Wall Finishes **88**

Chapter Six Insulation and Interior Finishes 88

Insulation and Related Factors **89** Interior Finishes **91** Summary **98**

Chapter Seven Decorating 100

Exterior Painting and Staining **101** Interior Painting and Varnishing **102**
Interior Wall Coverings **104** Floor Coverings **108**

Chapter Eight Hardware 116

Rough Hardware **118** Finish Hardware **125**

Chapter Nine Mechanical Systems 138

Part I Plumbing 139 Water Distribution **140** Sewage Disposal **159**
Summary of Part I **165**
Part II Heating, Ventilating, and Air-Conditioning 170 Heating **170**
Economy Tips **171** Systems **171** Distribution System **180**
Humidity Control **181** Ventilation **182** Filtering **182** Cooling **182**
Special Installation Considerations **183**

Chapter Ten Basic Electrical 188

General Discussion **189** Procedure **190** Details to Be Noted **196**

Chapter Eleven Putting It All Together 202

Review of Construction Aspects Covered **203** Miscellaneous Materials **204**
Labor **210** Overhead and Profit **210** Summary **211**
Common Estimating Errors **212** Summary Sheets **214** Conclusion **215**
Epilogue **216**

Symbols and Abbreviations 217

Appendixes 220

A. Earthwork **221** B. Concrete Work **223** C. Lumber-Related Tables **225**
D. Finish-Related Tables **233**

Glossary 235

Bibliography 243

Index 245

Small Residential Structures

Professional Edition

Chapter One

Introduction and General Information

The purpose of this book is to show the student or the builder many of the factors that influence the cost of a residential structure. In addition, the authors will show how the cost of the structure can be estimated with reasonable accuracy. It is not our intent to make this a "costing book." Costs vary so greatly in different areas of the country that no one book can suit all the markets. This book illustrates typical ways to determine the kinds and quantities of the components needed for a residential structure. With these quantities and local cost figures, the estimator should be able to put together a reasonably accurate estimate of the total cost of a residential structure.

Introduction to Estimating Costs

Estimating costs of construction (even estimating costs of residential properties) is an involved process requiring the use of basic mathematics. In addition, knowledge of construction methods, materials of construction, and local sources of supplies is required in making accurate estimates.

An estimate represents a compilation of the materials needed and the approximate cost of constructing the project. The preparation of an estimate of construction costs is time consuming. In deciding whether or not to bid on a particular project, the estimator must consider the following questions:

Is adequate time available for preparing the estimate properly?

Is the type of work to be done within the scope and experience of the builder's firm?

Does the builder have the labor force, equipment, and knowledge to complete the job in question?

Does the builder's firm have access to the *subcontractors* the builder needs to fulfill the project requirements?

Does the estimator have reliable cost information for the type of work required on this project?

Will the estimate be based on results of previous projects, or will it be based on "costing books" only?

How will the undertaking of this project affect the firm's overall workload?

Can the contractor obtain the necessary *bonding* for the job (if required)?

Can the contractor obtain the required financing for the job?

It is important to establish the cost of a construction project as accurately as possible, because the inability to estimate costs effectively may well result in the failure of the contractor's business. This book will try to cover the costs that the residential builder will need to know to be able to handle most home and other small building projects.

In order to estimate construction costs accurately, one needs to know how to read and interpret *construction documents* (drawings and specifications) and also to be able to understand the principles of construction. The number and type of construction documents will vary with the scope of the project under review. In a typical residential structure, for example, the construction documents will include

1. The contract itself indicating general scope and cost of the project—to be signed by client (owner) and the builder.

2. Complete drawings of the project—minimum drawings required would be
(a) Plans of each separate level—scaled $\frac{1}{4}$ in. = 1 ft 0 in. typically.
(b) Elevations of all walls of the structure—most frequently scaled at $\frac{1}{8}$ in. = 1 ft 0 in.
(c) Cross section(s) of structure indicating basic construction and other details—scales used are $\frac{3}{8}$ in. = 1 ft 0 in., $\frac{1}{2}$ in. = 1 ft 0 in., $\frac{3}{4}$ in. = 1 ft 0 in., and larger.
(d) Drawings of special features of the structure.

3. Specifications—a written document (usually) that details requirements for the structure and will include type, grade, and quality of the materials and labor to be used. There are many sample specifications that can be used to develop the specifications for a particular structure. One widely used sample is the Guide Specifications of the American Institute of Architects. Another is published by the National Society of Professional Engineers.

With larger structures—usually commercial types—the construction documents may include items such as

1. Invitation to bid—publicizing the availability of the project for bidding purposes.

2. Proposal (or bid) form—standardized form on which the contractor is to submit his/her bid.

3. Bond forms required.

Other aids to the designer/builder are "how to" books that detail construction procedures, methods, and so forth. These are provided by many trade organizations such as The American Plywood Association, The Clay Institute, The Portland Cement Association, and so forth. One "bible" used frequently by the authors and others involved in architectural drafting is Ramsey and Sleeper's *Architectural Graphic Standards*.[1]

The ability to estimate and make rapid computations of adequate accuracy is a necessary requirement to being a successful estimator.

In addition to being able to read and understand working drawings and specifications, the estimator must be able to take off quantities of materials and labor needed. Estimates vary in complexity and degree of accuracy. The degree of accuracy needed depends upon the reason for making the estimate. The builder—or the firm's estimator—is best able to prepare whatever type of estimate is needed because he/she knows

1. The firm's resources, equipment, and labor force.

2. The results of previously built structures of a similar type.

3. That each firm can handle only a certain volume of business (the builder or estimator is in the best position to know at what volume the firm is presently operating).

In general, estimates can be broken down into two broad categories: approximate estimates, such as cost of a unit per square foot, cost per room, and so forth, and detailed estimates, such as cost per square foot of masonry wall or cost per board foot of lumber.

Obviously, the detailed estimate is the more accurate but requires a greater degree of skill and, of course, more time. The *material quantity take off* in a detailed estimate should always be developed according to the drawings and specifications for the job. The various sections of the material quantity take off should be kept separate and summarized individually. This will aid in effecting changes or locating errors at a later date. In addition, a recap or summary of each section, or trade, is required. Subsequent chapters will illustrate these summaries.

The material quantity take off should be completed in the same order in which the project will be built—in other words, in a building sequence that is logical for the structure being estimated. All take offs and calculations should be written neatly in pencil, with all totals shown on the extreme right side of the paper. In addition, all final calculations should be underlined. Some estimators use different colors for different types of work. It is important that the material quantity take off and the estimate be prepared accurately and carefully, without errors. Errors tend to result from misreading the specifications and from miscalculations. All work should be double-checked.

It should be noted that major items involved in the cost of a project are

Material quantity take off, counting and tabulating all the individual items and parts that compose the entire structure.

[1] Charles G. Ramsey and Harold R. Sleeper, *Architectural Graphic Standards* (New York: John Wiley & Sons, 1981).

Labor, the cost involved in building the structure according to the plans and specifications.

If the length of time for constructing the project is long, the person preparing the estimate must be aware that material and/or labor costs can escalate during the period of construction. This possibility should be considered before submitting the final cost bid for the project.

After figuring material and labor costs, the estimator must include other items to get a total cost for the project. Among these items are

Licenses and permits.

Equipment purchase or rental along with its fuel and maintenance costs.

Various overhead costs (such as main office expenses, executive and estimator costs, and secretarial office operating costs).

Insurances (such as Social Security and Workmen's Compensation).

Contingencies (risk).

Profit.

To be sure that no items are missed in the estimate, the estimator should use a checklist. Many good checklists are obtainable depending upon the project's size. Remember, use a checklist that permits listing the various operations in the order in which they are to be done on the project. See Figure 1-1 for a sample checklist.

Costs

The cost for any operation requires a knowledge of the costs of all types of construction materials involved in a building project, the cost of labor, a knowledge of up-to-date wage rates, and production rates of the workers on the job. Although much of this information is available in published cost books, it is much better for the estimator to maintain a good cost and production rate record of projects in which the estimator's firm has been involved. This information should be gathered from reports that show

1. The number of units completed.

2. The number of workers employed (by classification or skills).

3. The time required to complete each unit of the work involved.

4. A description of job conditions, climatic conditions, and any other conditions or factors that may have affected the production of labor and the progress of the project.

This information should be broken down into relatively short periods of time, such as days or weeks.

As mentioned previously, this book will not detail many cost factors. The authors will give the reader sources from which these costs can be obtained on a local basis. One publication that is usable in most areas of the country is the

SAMPLE CHECK LIST

Code	Category
1.00	GENERAL CONDITIONS
.10	Permits & Fees
.20	Field Administration
.21	Supervision
.22	Layout
.30	Temporary Utilities
.38	Temporary Drive
.50	Equipment
.52	Rental Equipment
.60	Clean-Up
2.00	SITEWORK
.13	Clearing & Grubbing
.22	Excavating & Backfilling
.60	Pavement & Walks
.61	Asphalt Paving
.80	Landscaping
3.00	CONCRETE WORK
.21	Wire Mesh
.30	Structural Concrete
.31	Footers & Pads
4.00	MASONRY
5.00	METALS
6.00	CARPENTRY
.10	Rough Carpentry
.13	Exterior Trim
.14	Wood Siding
.20	Interior Finish
.21	Millwork
.23	Wood Frames
.24	Wood Doors
.41	Cabinets
.42	Plastic Laminate Work
.50	Flooring
7.00	MOISTURE PROTECTION
.20	Insulation
.31	Asphalt
.52	Roll Roofing
.63	Gutters & Downspouts
8.00	DOORS & WINDOWS
.36	Overhead Doors
.52	Aluminum Windows
.70	HARDWARE & SPECIALTIES
.72	Door Operators
.80	Glass & Glazing
.86	Weatherstripping
9.00	FINISHES
.17	Stucco
.25	Drywall
.31	Ceramic Tile
.52	Acoustical Ceiling Tile
.66	Resilient Tile Flooring
.67	Rubber Base
.69	Carpeting
.91	Exterior Painting
.92	Interior Painting
.95	Wall Coverings
10.00	SPECIALTIES
.30	Fireplaces
.80	Toilet & Bath Accessories
11.00	EQUIPMENT
.93	Kitchen Appliances
15.00	MECHANICAL
.40	PLUMBING
.80	H.V.A.C.
.81	Ductwork
16.00	ELECTRICAL
.50	Light Fixtures

Figure 1-1. Sample checklist.

Engineering News-Record.[2] This reference is aimed mostly at heavy projects such as roads, bridges, and dams that are undertaken by commercial building contractors and civil engineers. For smaller projects, better results would be obtained from Robert S. Means costing books[3] and Frank R. Walker costing books.[4]

Another point that should be considered by the contractor is that many firms are organized to do a limited number of construction specialties, such as wood framing, concrete and/or masonry work, electrical wiring, and mechanical heating–ventilation–air-conditioning (HVAC). To complete a project, some or all of these specialties will be needed. If the contractor bidding on a project does not

[2] Weekly magazine published by the McGraw-Hill Publishing Company, New York.
[3] Robert S. Means, Inc., Kingston, Mass.
[4] Frank R. Walker, Publishers, Chicago.

have all of these specialties in his/her organization, it would be necessary to subcontract the missing items to specialists in these fields.

The contractor's estimator should become familiar with the material quantity take offs and unit costs of the subcontracting trades that will work on the contractor's project. This capability will gain the respect of the subcontractors. They will, hopefully, give better and more accurate bids for their parts of the project.

Basic Computations Needed in Estimating

One does not have to be an engineer or a mathematician to make accurate estimates, although basic background in figuring areas and volumes of triangular, rectangular, and circular shapes is needed. In addition, the use of a calculator will assure the estimator reasonably accurate computations. The accuracy used in estimating quantities is not required to be of a high order, however, since the materials involved usually cannot (and need not) be established with a high degree of precision during the early stages of the estimate.

The examples in this book have answers that are rounded off. To illustrate our experience in construction, many of the examples will be stated in feet, inches, and fractions since most carpenters, masons, and concrete workers use measuring devices that are graduated in this fashion. If the data are given in feet and inches, convert the data to tenths or hundredths of a foot and round off your answers to tenths or hundredths. Note that the accuracy of the estimate does not have to be any more accurate than to one tenth of the main units. We will also use consistent abbreviations for units. A listing of these will be found at the end of this book.

Example 1-1

Compute the volume of concrete in a footing that is 6 ft^2 and 16 in. thick (Figure 1-2). The volume is given as volume = width × length × thickness (depth).

Step 1: Change thickness to feet.

$T = \frac{16}{12} = \frac{4}{3}$ ft or 1.33 ft

Step 2: Compute volume in cubic feet.

$V = 6 \text{ ft} \times 6 \text{ ft} \times 1.33 \text{ ft}$

$= 47.88 \text{ ft}^3$ or 48 ft^3 rounded off

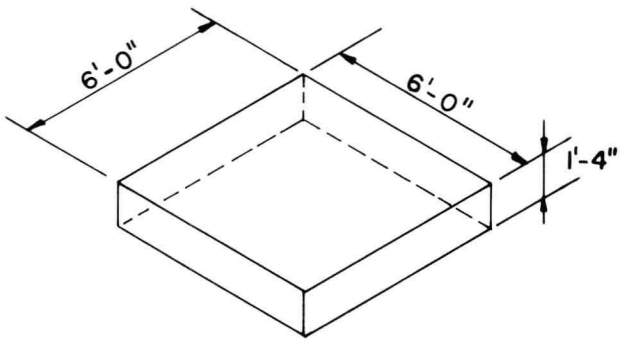

Figure 1-2.

The basic unit used in concrete work is cubic yards (yd^3). To convert the volume found in Step 2, the value must be divided by 27 ft^3/yd^3., since 27 ft^3 equals 1.0 yd^3.

Step 3: Convert 48 ft^3 to cubic yards.

$V = 48\ ft^3 \div 27\ ft^3/yd^3$

$= 1.78\ yd^3$

Answer: Round off to 1.8 yd^3

The precision of earthwork or concrete volumes seldom needs to be more precise than one decimal place as shown. To illustrate this, check into the following variation of Example 1-1.

Example 1-2

Because of tolerances in field work, the footing of Example 1-1 was formed with the following dimensions:

$W = 6$ ft $\frac{1}{2}$ in.

$L = 6$ ft 1 in.

What is the actual volume required?

Step 1: $V = W \times L \times T$

$= 6.04\ ft \times 6.08\ ft \times \frac{4}{3}\ ft$

$= 36.72 \times 1.33$

$V = 48.84\ ft^3$

Step 2: $V = 48.84\ ft^3 \div 27\ ft^3/yd^3$

$= 1.81\ yd^3$

Answer: Round off to 1.8 yd^3

In other words, minor variations in the dimensions may not affect the final usable answer.

In summary, be reasonably accurate in all calculations. Do not be concerned about decimal places beyond tenths. The answer cannot be any better than the field layout and measurements.

Example 1-3

Determine the area of a circle having a 12-ft diameter (Figure 1-3). (Radius is one half the diameter: 6 ft.)