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U. S. DEPARTMENT OF COMMERCE

BUILDING  
MATERIALS  
AND  
STRUCTURES

REPORT BMS1

Research on  
Building Materials and Structures  
for Use in Low-Cost Housing

by HUGH L. DRYDEN  
Bureau of Standards

JUL 20 1938



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NATIONAL  
BUREAU OF STANDARDS



JUL 16 1943

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The program of research on building materials and structures undertaken by the National Bureau of Standards is planned with the assistance of the following advisory committee designated by the Subcommittee on Design and Construction of the Central Housing Committee.

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The Forest Products Laboratory of the United States Department of Agriculture is cooperating with the National Bureau of Standards in studies of wood constructions.

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# BUILDING MATERIALS *and* STRUCTURES

REPORT BMS1

Research on  
Building Materials and Structures  
for Use in Low-Cost Housing

*by* HUGH L. DRYDEN



ISSUED JUNE 16, 1938

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly

## Foreword

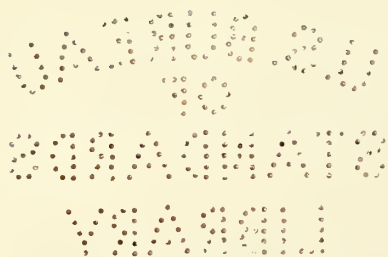
THE NATIONAL BUREAU OF STANDARDS begins herewith a new series of publications—Building Materials and Structures Reports. For many years the Bureau has developed test methods, made tests, and conducted research on building materials, such as cement, lime, brick, tile, and steel and has cooperated with various agencies in the formulation of specifications for such materials. The results of this work have been published in the Journal of Research, or in the trade journals, or are embodied in specifications of the Federal Government and of cooperating technical societies and industries.

A new approach has now been made to the problem of applying technical research in the building industry. This first report in the new series is intended to explain that approach. Acknowledgment is made to the Central Housing Committee, its various affiliated groups and cooperating individuals, for their invaluable advice and assistance.

The succeeding reports of the series will deal more particularly with the technical aspects, with test procedures, and results. They will be issued at irregular intervals as portions of the work are completed.

It is our hope that a wide use of the information and methods given in these reports will aid in reaching that goal of all housing interests—the provision of a satisfactory home at a cost within the means of those who are not adequately housed at present.

LYMAN J. BRIGGS, *Director.*



# Research on Building Materials and Structures for Use in Low-Cost Housing

by HUGH L. DRYDEN

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### I. INTRODUCTION

PROGRESS in every modern industry depends on technical research to improve old products and to develop new ones. The rapid development of faster and safer automobiles and airplanes is a direct consequence of reliance on research accompanied by freedom from stifling tradition. Railway trains have undergone a striking metamorphosis within the last few years because of the application of the results of technical research on new materials and methods of construction. To many thoughtful persons it appears that progress in the building industry can come only by the same route; in fact that the only hope of meeting the insistent demands of society for satisfactory houses within reach of millions of wage earners is through new materials and methods of construction made possible by research.

The housing agencies of the Government early recognized the need of research in answering the many technical questions confronting them and through the Central Housing Committee, its subcommittees, and affiliated groups, recommended the initiation of a research program with special reference to those materials and methods suitable for use in low-cost housing. The Congress included the sum of \$198,000 for such a program in the appropriation for the National Bureau of Standards for the fiscal year beginning July 1, 1937.

The program is being formulated with the

advice of representatives of the housing agencies of the Government. The Subcommittee on Design and Construction of the Central Housing Committee designated a special group to cooperate with the Bureau on this program of technical research. The group consists of Harold D. Hynds, chairman, C. W. Chamberlain of the Procurement Division, Pierre Blouke of the Home Owners' Loan Corporation, Walter Junge of the Federal Housing Administration, Charles E. Mayette of the Public Works Administration, Vincent B. Phelan of the National Bureau of Standards, George W. Trayer of the Forest Service, Capt. Elsmere J. Walters of the Quartermaster Corps of the War Department.

The conduct of the program is entrusted to a committee of Bureau division chiefs, P. H. Bates, H. C. Dickinson, H. L. Dryden, W. E. Emley, G. E. F. Lundell, A. S. McAllister, and H. S. Rawdon, under the chairmanship of H. L. Dryden, who is designated as coordinator of the program.

A research program is a means of achieving more quickly a wider experience than is possible in the slow process of service experience. Research is controlled, directed, and accelerated experience. So long as the quality and performance of a house must be judged by living in it for 25 or 50 years, the accumulation of experience is slow, and progress in improving houses and reducing their cost is correspondingly slow. Laboratory procedures and field

test methods must be developed for objectively determining all measurable features of performance. While the National Bureau of Standards may take the lead in conducting research for the industry and in establishing test methods, the full benefits of technical research cannot be realized until industry itself employs scientific and technical personnel and devotes some part of its resources to experimental development. There is no one house or appliance, and no single agency in industry or government, which will solve the problem of low-cost housing. By the cooperative effort of many groups, much can be accomplished.

The immediate need is for research directed toward the house as a whole rather than toward the individual materials of which the house is to be constructed. The manufacturers of building materials have in many instances utilized fully the resources of laboratories, but the objective has naturally been the promotion of the use of a single material or class of material. The building industry needs many more groups to assume responsibility for the house as a whole, develop and market complete houses, and stand back of the product. The program outlined in this report is intended to encourage these groups in the study of the complete house construction.

## II. OBJECTIVES

THE INTENT OF CONGRESS is expressed in the appropriation act as the "study of the properties and suitability of building materials with particular reference to their use in low-cost housing, including the construction of such experimental structures as may be necessary for this purpose. *Provided*, That no part of this program shall duplicate any work now being performed by the Forest Products Laboratory of the Department of Agriculture."

The opinions of the sponsors are expressed in the preliminary report on the program by the special group organized by the Subcommittee on Design and Construction of the Central Housing Committee, and in the 162 suggestions received from various agencies of the Government. According to this preliminary report, the sponsors believe that:

- (a) The results should be made available to the public.

- (b) The program should include—
  - (1) Materials, equipment, and methods already in use in low-cost housing.
  - (2) New materials and equipment, and new construction methods.
- (c) All available information from whatever source should be included in the reports.
- (d) Minimum technical requirements should be established for the elements of a low-cost house. These requirements would be of inestimable value to State and municipal officials.
- (e) The tests should insofar as possible be made under service conditions, and should include the effect of different materials in contact.
- (f) The effect of obsolete building codes in restricting the use of new constructions should be determined.
- (g) The useful life of each construction should be determined.

The investigation should, insofar as practicable, be so planned and carried out that these objectives will be attained.

The general objective may then be restated as follows:

*To furnish to Government agencies, the building industry, and the public technical information from every available source on the engineering properties of building materials as incorporated in the structural elements and equipment of a house, with particular reference to low-cost housing and including new materials, equipment, and methods of construction as well as those already in use.*

It should be noted that the Bureau will not consider the sociological and economic questions involved, the hygienic or esthetic questions, or the design of houses. We conceive it to be the function of the social planning agencies to answer the sociological and economic questions. Public-health authorities are already active in studying the hygienic questions, and the design of houses, including style and appeal to the public taste, lies within the field of the architect. When questions involving these matters arise, the recommendations of recognized authorities will be followed. The Bureau does not presume to endorse or critically evaluate recommendations on these questions, which are not within the scope of its activities.

## III. PROCEDURE

IT IS OBVIOUS that the objectives of the sponsors cannot be attained by investigations made only in a laboratory, although laboratory work

may contribute greatly to the final solution. Field surveys of existing houses and the erection of experimental houses for study and test under service conditions may be necessary for (d) the establishment of minimum technical requirements, (e) the testing under service conditions, (f) the effect of obsolete building codes, and in all probability, (g) the useful life of each construction.

Accelerated weathering tests made in a laboratory do not give results for many constructions which can be used to estimate the service life with reasonable accuracy. Such tests are, however, helpful because they indicate which constructions may be expected to give the longer service.

It appeared expedient for this investigation to consider a house as composed of *elements*, i. e., walls, partitions, floors, roof, plumbing, heating, etc., and to investigate each element. After determining satisfactory constructions for each element, there remains the problem of combining them to produce a satisfactory house. The combination of a particular wall with a particular roof, for example, might be prohibitive in cost, or be subject to corrosion which would shorten its life. However, it appears that the following advantages will result from the study of the elements of a house:

- (a) These data will be more useful to architects and engineers than data on the individual materials of which the elements are composed.
- (b) The cost of investigating elements will be very much less than the cost of investigating full-size houses and the data will be obtained in less time.
- (c) The results will approximate closely those obtained on complete full-size houses.
- (d) The effect of different materials in contact can be determined.
- (e) The data may indicate either that no radically new and different construction is likely to reduce the cost of a house appreciably or that some constructions costing much less than the usual constructions should be investigated further by erecting experimental houses and subjecting them to service conditions.

Insofar as possible, each element should be complete, i. e., a portion of a complete house ready for occupancy. For example, a wall element should be a duplicate of a portion of the wall for a house, one surface suitable for

exposure to the weather and the other having the finished surface for the inside of the house.

For this investigation the construction of an element is defined as the design, dimensions, materials, method or process of fabrication, and workmanship of the element. If any appreciable change is made in dimensions, materials, etc., the construction is considered different. For example, an 8-inch brick wall is one construction and the same wall plastered on one face is a different construction.

Representatives of the housing agencies of the Government believed that it was desirable to include in the program some problems involving combinations of elements. Some of these problems are durability, thermal insulation, ventilation, simplified practice, and commercial standardization of building materials. Therefore, it is proposed to study the condensation of moisture within walls, its effect on insulating materials, the corrosion of steel in walls, the preparation of steel for painting, and the adhesion of paint; the rain penetration of walls and calking materials for sealing joints to prevent the entrance of water and air; and the durability of building papers and boards by means of accelerated weathering tests.

#### IV. SCOPE

FORTUNATELY the program for the determination of the technical and engineering properties of the elements of a house does not depend to any great extent upon the number of rooms or their arrangement, the architectural effect, or the relation of the family units to each other, i. e., whether they are detached houses, row houses, or apartments in a multistoried building. Obviously, for each architectural plan problems may arise as, for example, the structural framework and the elevators for a six-story apartment building, which elements may not have been considered in the program. If satisfactory progress is to be made, it seems advisable to simplify the program at the risk of neglecting, for the present, some matters of fundamental importance.

The program will include elements suitable for detached houses, row houses, and low-cost apartment houses. It will include new as well as conventional constructions. Although all

problems relating to conventional constructions have not been solved, the investigation of such constructions will be limited to the data necessary for comparison with new constructions. A new construction is not necessarily a new material, but may be a change in the design, dimensions, method of fabrication, or workmanship of an old material.

To restrict the investigation to constructions and equipment suitable for a low-cost house, a maximum cost was fixed for each element after a study of the available information on this subject. These costs are sufficiently high to include constructions and equipment suitable for low-cost apartments in cities. The costs for detached suburban and rural houses should be considerably lower.

The sole purpose of the cost limitation is to restrict this investigation to constructions and equipment suitable for a low-cost house. For new constructions which are not widely used at present, the cost must eventually be much lower, when they reach mass production. If this investigation is to fulfill its objectives, the cost of the elements must be much lower than the maximum cost shown in table 1.

TABLE 1.—*Maximum cost of elements of a house to be studied*

[As of July 1937 in Washington, D. C.]

Structural elements	Maximum cost per square foot
Walls.....	\$0. 60
Partitions, not load bearing.....	. 35
Floors, including finish floor on upper face and ceiling (if any) on lower face.....	. 75
Roof, including weatherproofing on upper face and ceiling (if any) on lower face.....	. 60
Equipment	Maximum cost per family of four
Heating plant.....	\$400
Lighting.....	180
Kitchen equipment, including plumbing, refrigeration, and storage equipment.....	320
Bathroom equipment, including special finish walls and floor, plumbing and fixtures.....	400

It should be remembered that the cost of a house depends upon other factors besides the cost of the individual elements of the structure and its equipment. Thus the cost of the struc-

ture depends upon the size as well as on the cost per square foot of its elements, and the cost of the mechanical equipment depends upon the performance demanded. The lowest reasonable cost will be obtained with a structure of no larger size and having no more facilities than are required by standards of decency and health.

## V. COOPERATION WITH INDUSTRY

THE PROBLEM of obtaining satisfactory housing at a cost within reach of low-income groups is a complex one, even when attention is confined to the technical problems. Attack must be made on numerous specific problems relating to the several elements of a house, the results must be coordinated, and finally the problems relating to an assembly of the elements into a house or apartment building solved. It is probable that there is no unique solution, and that the solution appropriate for one section of the country may not be satisfactory for other sections.

The solution will probably not come from any single agency. It is believed that the solution will come most rapidly by encouraging large numbers of groups within the industry to attack the engineering problems, and by cooperating with them to improve their products, whatever the materials or methods of construction, provided the cost is low. If the Bureau should undertake to develop and sponsor new methods, its usefulness to other sponsors of new methods would be limited. Therefore, it seems better to mobilize the resources of the entire building industry, relying on industry to initiate new developments. The Bureau may then perform the function of a disinterested fact-finding agency as well as undertake research on basic problems confronting all the cooperating groups.

## VI. DETAILED PROGRAMS

THE DETAILS of the program are subject to change as the work progresses. The projects approved at the beginning of the program were as follows:

Structural properties of walls, partitions, roofs, floors.....	LC502A
Fire resistance of walls, partitions, roofs, floors.....	LC502C
Thermal insulation.....	LC502J
Moisture condensation.....	_____
Weathering of roofing materials.....	LC502G



Floor coverings.....	LC502F
Heating equipment.....	LC502L
Plumbing equipment.....	LC502E
Infiltration and ventilation.....	LC502K
Durability of fiber boards.....	LC502B
Corrosion of painted galvanized steel sheets...	LC502H
Rain penetration of masonry.....	LC502D
Calking materials.....	LC502I
Simplified practice recommendations for building materials.....	—
Commercial standards for building materials...	—

These projects, with three exceptions, are described in detail in mimeographed Letter Circulars identified by the symbols at the right in the preceding list, which may be obtained on request from the Bureau. Because of the intensive work on the important problem of moisture condensation at other laboratories, in particular at the Forest Products Laboratory and at the University of Minnesota, the work at the Bureau is of an exploratory nature to determine what study, if any, should be made. No Letter Circular has as yet been issued on this project, or on the last two listed.

## VII. NO "APPROVALS"

EACH REPORT in this series carries on its title page the following statement: "The National Bureau of Standards is a fact-finding organization; it does not 'approve' any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly." The Bureau determines technical facts, bases its reports so far as possible on objective tests in which the personal element is eliminated, and avoids the expression of opinions so far as is practicable. On the basis of tests at the Bureau *and other pertinent data*, several Government agencies set up approved lists of products or appliances, and through special cooperative arrangements a few nationally recognized organizations of con-

sumers and professional men are assisted in establishing such lists for certain special materials.

When nationally accepted standards are available, and there is reason for the Bureau to undertake the work, the Bureau can certify that a certain sample tested does or does not comply with the standard. It does not have the facilities to police an industry, to determine whether the manufacturing process is under satisfactory technical control, or to warrant that the sample tested is representative of the commercial product generally available. Even the proper identification of a given product sometimes offers considerable difficulty.

Reports in this series should not be construed as "approvals" for still another reason. To make the data available more promptly, the reports on the various properties will be issued as completed. Each report, therefore, will deal with one property or group of properties, for example the structural properties. Any agency giving approvals to constructions should also consider other properties, such as thermal insulation, durability, etc.

The Bureau does not have the facilities to undertake the testing of any and all materials for the public. It is the policy of the Bureau not to compete with commercial testing laboratories, and departmental regulations provide that the Bureau shall not make tests of materials and appliances for the general public if they can be made elsewhere. A Directory of Commercial Testing and College Research Laboratories is published as Miscellaneous Publication M125 of the National Bureau of Standards. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a cost of 15 cents.

WASHINGTON, April 21, 1938.

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The *National Bureau of Standards* was established by act of Congress, approved March 3, 1901, continuing the duties of the old Office of Standard Weights and Measures of the United States Coast and Geodetic Survey. In addition, new scientific functions were assigned to the new Bureau. Originally under the Treasury Department, the Bureau was transferred in 1903 to the Department of Commerce and Labor (now the United States Department of Commerce). It is charged with the development, construction, custody, and maintenance of reference and working standards, and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

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