NATIONAL BUREAU OF STANDARDS REPORT

8616

PERFORMANCE CHARACTERISTICS OF EXTERIOR WALLS

Progress Report for Period July 1 - December 31, 1964

by

James V. Ryan

Report to

Housing and Home Finance Agency
Federal Housing Administration
Washington, D. C.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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* NBS Group, Joint Institute for Laboratory Astrophysics at the University of Colorado.
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1. INTRODUCTION

The objectives of this project are to adopt or develop test methods and techniques for the measurement of the performance characteristics of exterior walls, and to provide representative values of those characteristics for typical walls. In the past, studies of building components have dwelt with one or a very few characteristics. This project is designed to study all the characteristics subject to measurement and to provide a basis for decisions as to which characteristics are of significance and what level of performance should be expected of a system intended for use as exterior walls. For this study, interest was confined to wall characteristics and systems as applicable to residential (houses or apartment buildings) construction.

2. PROJECT PLAN

The plan of the project called for (1) an analysis of the functions of exterior walls in order to develop a list of all characteristics and the selection of those subject to physical measurement, (2) review of existing test methods having potential applicability, (3) testing of representative samples by these methods, (4) development of additional test methods and apparatus as needed, (5) measurement of the performance characteristics of samples of representative wall systems by all the various methods, and (6) where possible, suggest limiting values for each of the significant wall performance characteristics subject to physical measurement.

3. ACTIVITIES

The activity described as (1) in the preceding section was completed except for any review that may be indicated as results are obtained in the rest of the study. Work was started under items (2), (3), and (4), in various Technical Sections of the Building Research Division.

3.1 Structural Stability and Water Permeability

3.1.1 Racking Test

Although ASTM Test Method E72 describes a standard racking test procedure, it is believed that a more realistic test procedure is desirable. Recent NBS studies of quarter scale models of masonry walls indicated that there is a significant increase in the racking strength when the upper and lower boundaries of a wall are subjected to relatively small vertical loads; such vertical forces would exist along the horizontal boundaries of load bearing walls.

A racking frame will be assembled and suitable spring-loaded yokes for applying the boundary forces will be fabricated.

3.1.2 Cracking Due to Static Loads

Cracking resulting from application of transverse loads (wind load test) and racking loads will be studied as a function of applied load, lateral deflections, and distortion under load. Cracks will have to be classified into several categories, such as cracks causing leakage, cracks which may be objectionable from standpoint of appearance, and cracks which may impair the structural integrity of the wall.

3.1.3 Dimensional Stability

Much of the cracking observed in structures is known to result from the use of a variety of dissimilar materials in a single structure. A procedure will be explored to measure possible distortion or warpage in exterior wall panels consisting of dissimilar materials subjected to severe thermal gradients.

3.1.4 Wind Load and Water Permeability Tests

The test chamber for these tests is completed and a sample wall panel has been constructed and placed in the chamber. The sample wall panel is a conventional wood frame with vinyl siding, 3/8-in. plywood sheathing, 2-in. fiber glass insulation, and 1/2-in. gypsum wall board. As a result of a preliminary test with this wall, modifications are being made to the air-supply system to increase its capacity. When these modifications are completed, a series of "shake down" tests will be made using the wall system described above. The testing procedures will be as outlined in the progress report for June 30, 1964.

3.2 Smoke Test (Fire Performance)

The desirability and usefulness of a small-scale laboratory test chamber for the evaluation of the smoke generation characteristics of materials under simulated building fire conditions was outlined in the previous progress report. During the past six months, the main effort has been directed toward establishing test requirements and procedures which would permit simple, reproducible and realistic smoke measurements. The following specific activities were undertaken:

1. The construction of a new smoke chamber of larger volume (7 times) and optical path length (3 times),

2. The design, construction and calibration of an air-cooled radiometer for establishing reproducible conditions of irradiance on the specimen surface, and

3. The evaluation of important test parameters such as the type and duration of the specimen exposure, and the orientation and length of the light path.

As a result of these tests, basic requirements for a suitable test method have been established, and the current NBS smoke measuring method incorporates the following features:

1. The specimen is exposed on, and generates smoke from, one surface only.

2. The specimen receives a controlled radiant exposure from an electrically powered furnace; hence no combustion air is required for, and no exhaust products are formed by, the heat source.

3. The method is suitable for radiant ignition (no pilot) or for pilot ignition (small gas pilot).

4. A sufficiently large chamber is used to prevent premature consumption of air, even when the chamber is entirely closed to prevent loss of smoke.

5. The photometer light path is vertical to reduce the recorded effects of smoke pulsing and stratification.

6. The results are reported in terms of optical density $\left[\log_{10}\left(\frac{100}{\%\ \text{Transmittance}}\right)\right]$ per unit path length since this is the most characteristic measure of smoke quantity and comparative obscuring power.

Future work includes plans (a) to compare the response of a blue- and a red-sensitive vacuum phototube with that of a visually corrected barrier layer cell, (b) to extend the measurements to a larger chamber, if necessary, and (c) to perform tests on a wide variety of surface finish materials with and without the use of a pilot flame.

3.3 Air and Water Vapor Transfer

During the past six months considerable progress has been made on developing design details and construction drawings for an apparatus for conducting tests on air and vapor transfer through exterior wall systems. A portion of the time was used in preparing a space adequate for housing the apparatus and its supporting equipment. The apparatus has been designed to provide two environmental chambers between which test specimens of exterior wall systems will be fixed. In this manner, the specimen will be exposed to spaces simulating those of both indoor and outdoor conditions.

The air infiltration will be measured by metering the air supply required to hold a constant pressure difference between the two spaces. After calibration of the chambers for air leakage through their walls, an accurate measurement of air infiltration through the test specimen can be made.

Instrumentation for measuring, and systems for producing and controlling, interior and exterior environmental conditions will be provided to study: (1) the presence of condensate at points within the wall structure, and (2) the removal of moisture from the air that has passed through the wall system as a means of determining the rate of vapor transfer.

Items which have been most actively engaged in during the past six months are:

1. Refinements in design of the apparatus:

   (a) Methods for prevention of air leakage and detailed design of the joints between the test frame and the two environmental chambers.

(b) Design of adequate observation ports and access doors including construction drawings for shop use.

(c) Remote instrumentation which must penetrate the chamber walls.

2. Renovation of the space in Building 14, Room SB101, for suitable housing of the apparatus.

3. Installation of an overhead monorail and trolley for lifting and turning the frame and test specimens.

4. Construction of the frame in which the test specimens are to be placed for testing. This arrangement for holding the test wall consists of a heavy metal frame member capable of supporting loads of several thousand pounds with very little deflection of the frame. The opening for the location of the specimen is 8 ft, 4 in. wide by 9 ft, 6 in. high. The opening is adequate to hold two 4-ft by 8-ft panels with joints at top and bottom to simulate ceiling and floor joints. The frame is supported from an overhead rail and trolley having a swivel attachment. The overhead suspension and attachments which have been installed allow the frame and specimen to be rotated, thus it can be easily removed from the apparatus, turned, and reinserted. By reversing the specimen, the apparatus can be simplified in that one chamber will provide heating and the other will provide cooling for all tests, so the environment in each chamber need not be varied over an unusually large range.

5. Construction of the chambers has just begun during the last three weeks of December. Approximately all of the materials and components, such as doors, windows, etc., are available or are on order. It is anticipated that work on the construction of the two chambers will continue through the months of January and February, 1965.

3.4 Weathering, Discoloration, Denting, etc.

Weathering of samples of Tedlar-coated aluminum siding and white, gray, brown, and beige factory-painted aluminum siding in carbon and

xenon arc weatherometers was continued. The samples have been exposed for 1,500 hours in the twin carbon arc machine and for 2,000 hours in the xenon arc machine. Small color changes have occurred as measured by a tristimulus colorimeter. A chemical colorimetric technique indicates a further degradation of the samples compared to 500 hours' exposure. Weathering tests have been started on a Tedlar-coated wood siding, a factory-painted galvanized steel siding, and a pigmented plastic siding.

Work has been started on the cleanability of the sidings. A slight modification of Federal Test Method Standard No. 141 is being used. Cleanability of these sidings will be determined on both new samples and sampled aged in the weatherometers.

Samples of additional commercial products have been obtained. These are Woodrock, a wood, asbestos fibers and cement product made by National Gypsum; Colorlok, a siding consisting of a pigmented polyester film bonded to Masonite board made by Masonite Corporation; and a pigmented plastic siding made by Bird and Son. Data on denting, cracking, abrasion resistance, weathering, etc. will be obtained on these materials.

3.5 Heat Transfer

The objective is to devise and evaluate a practical method of experimentally determining the transient thermal response parameters of exterior walls, useful for walls of composite (non-homogeneous) construction. It is feasible, in principle, to determine an effective thermal diffusivity for a wall consisting of one solid homogeneous material, but it is necessary to investigate whether a similar meaningful parameter can be established for non-homogeneous walls before attempting to develop a test method for its measurement. The investigation is being made, at this stage, entirely by mathematical means.

At the end of FY 1964, it had been found that the thermal response of a composite wall consisting of up to three layers of homogeneous but different materials, when subjected to an abrupt but constant step in temperature at one face, could not be represented by means of a simple or constant "effective diffusivity"--in short, that this particular method was not feasible. In recognition of the fact that walls normally are subjected to exterior temperature conditions which vary slowly rather than abruptly, and also have a moderate thermal resistance at the interior surface due to an air film, a tentative method was devised incorporating these conditions. The mathematical analytical

solution for the case of a three-layer composite wall (one layer can be an empty air space) has been completed, and coded for numerical computation. Six walls, representing a wide range of exterior wall constructions, have been selected for study to determine if a meaningful response parameter is feasible. The effect of a variation in the time period of the temperature cycle is also being investigated.

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