SERI/TP-721-1327
UC CATEGORY: 59c

DESIGN AND ANALYSIS TOOL VALIDATION

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JULY 1981

FOR PRESENTATION AT THE
PASSIVE AND HYBRID SOLAR
ENERGY PROGRAM UPDATE
MAYFLOWER HOTEL
WASHINGTON, D.C.
9-12 AUGUST 1981

PREPARED UNDER TASK NO. 1053.00

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
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Prepared for the
U.S. Department of Energy
Contract No. EG-77-C-01-4042

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price:
Microfiche $3.00
Printed Copy $4.00

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CONTRACT NUMBER EG-77-C-01-4042

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PERIOD OF CONTRACT: Begin 10/1/80 End 10/1/81

OBJECTIVE

The Solar Energy Research Institute (SERI) is developing a procedure for the validation of Building Energy Analysis Simulation Codes (BEAS). These codes are being used increasingly in the building design process, both directly and as the basis for simplified design tools and guidelines. The importance of the validity of the BEAS in predicting building energy performance is obvious when one considers the money and energy that could be wasted by energy-inefficient designs. However, to date, little or no systematic effort has been made to ensure the validity of the various BEAS.

The validation work at SERI consists of three distinct parts: Comparative Study, Analytical Verification, and Empirical Validation (1,2,3,4). The procedures have been developed for the first two parts and have been implemented on a sampling of the major BEAS; results have shown major problems in one of the BEAS tested. Furthermore, when one building design was run using several of the BEAS, large differences were found in the predicted annual cooling and heating loads.

The empirical validation procedure has been developed, and five two-zone test cells have been constructed for validation; a summer validation run will take place as soon as the data acquisition system is completed. Additionally, a test validation exercise is now in progress using the low-cal house to fine-tune the empirical validation procedure and better define Class A monitoring data requirements.

BACKGROUND

The validation procedures developed thus far are limited to BEAS having time-steps on the order of one hour and using hourly values of radiation, ambient temperature, and other environmental data. The procedure is divided into three parts. In the first, Comparative Study, each BEAS analyzes the same buildings using the same sets of weather data. Building designs and weather data can be chosen to test the parameters having the greatest impact on building performance (1). This allows sampling of the many variable combinations that could occur in a real building before measured data are available. The technique is useful for finding large code errors that produce results that are consistently different from those of other codes or are counter-intuitive (1,2). However, this procedure gives little indication of the source of the discovered errors.

The second part of the validation procedure, Analytical Verification (2), is useful in diagnosing errors in heat-transfer mechanisms in the BEAS; it is used with the Comparative Study to locate and correct problems in specific mechanisms that are most important in building energy use (3,4).

The third phase of the validation procedure is Empirical Validation with carefully monitored test cells and buildings (4). Full-scale building data will be obtained from the Class A monitoring program for this purpose. Test-cell data will be collected from five two-zone cells already constructed at SERI.

SUMMARY OF ACCOMPLISHMENTS

Phases I and II of the Comparative Studies have been completed using DOE-2.1, BLAST-2MRT, BLAST-3.0, SUNCAT-2.4, DEROB-3, and DEROB-4. The derivation of analytical solutions has been completed, and all of the above computer programs have been run through the analytical verification procedure. Five two-zone test cells have been constructed and instrumented. The data acquisition and reduction system for these cells is about 99% complete. A co-heating procedure has been developed for deriving heat-loss coefficients suitable for input to the computer programs. Data requirement specifications for validation have been issued to the Class A Monitoring Program. The low-cal house and an NBS test building are being encoded for SUNCAT-2.4, DOE-2.1, and DEROB-4 in order to test the Class A Monitoring data specifications and the empirical validation procedure.

TECHNICAL ACCOMPLISHMENTS

Comparative Study, Phase I (1)

The study uncovered a major flaw in the solution technique of DEROB-3 (Figs. 1,2). As a result, the code author re-wrote the code entirely and issued a new code, DEROB-4. The study also showed some differences in hourly temperature profiles among SUNCAT-2.4, BLAST-2MRT, and DOE-2.1 (Fig. 1); however, annual heating and cooling load predictions agreed within ±5% (Fig. 2).

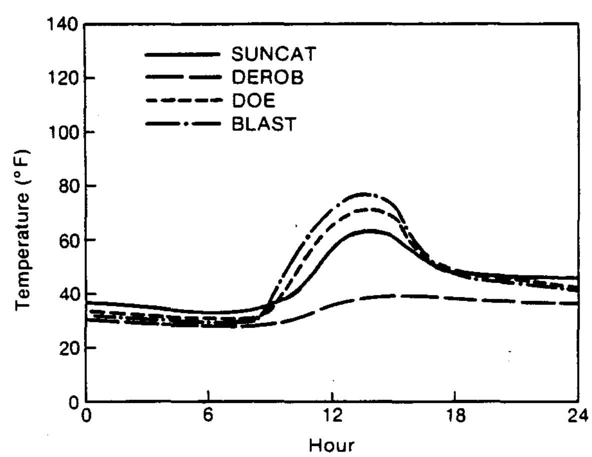

Figure 1. Himass Temperature Profiles (Jan. 21)

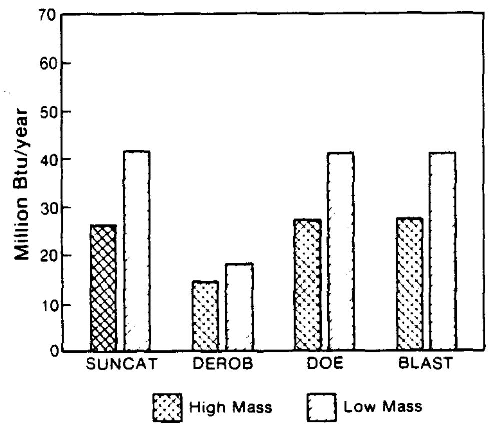

Figure 2. Cooling Loads: Phase I

Comparative Study, Phase II (2)

In Phase II, we investigated the effect of the temperature differences (noted among the codes in the Phase I study) on annual heating and cooling loads under differing variable mix conditions. The results showed considerable disagreement between the predicted annual heating and cooling loads for DOE-2.1, BLAST-3.0, SUNCAT-2.4, and DEROB-4 (Figs. 3,4). The study also showed the effect on the heating and cooling loads of an isotropic versus an anisotropic sky model. The differences were ±10%.

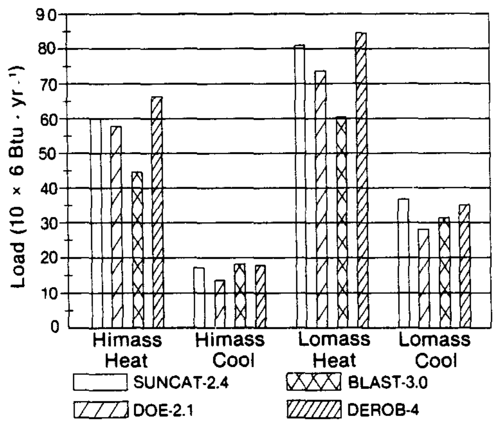

Figure 3. Madison, Wisconsin: Phase II

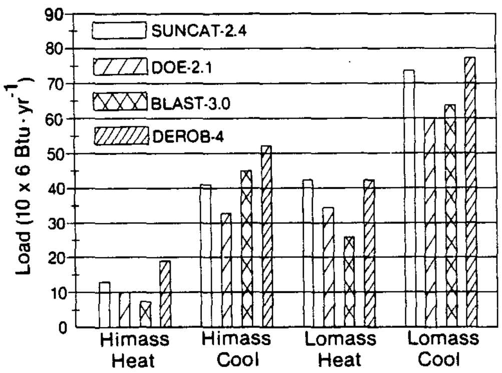

Figure 4. Albuquerque, New Mexico: Phase II

Analytic Verification (3,4)

This work produced a set of analytical solutions for testing key heat-transfer mechanisms in the codes. The selected mechanisms are

- steady-state and dynamic heat conduction and thermal storage of mass walls,
- glazing transmittance and conductance,
- heat load caused by infiltration, and
- response of mass walls to solar radiation.

In general, implementation of the Analytical Verification Technique on the four BEAS showed no apparent discrepancies. However, one of the BEAS, DEROB-3, showed a slower-than-expected response in internal temperature to a step-function change in external temperature. A similar slow response to solar radiation was also exhibited by this code. These slow responses are similar to what would be expected from models of buildings with higher thermal mass than that described in the input files of this code. As a result of the slow response, building designers might use less thermal mass in their building designs than correctly working BEAS would suggest. The problem in DEROB 3 was traced to the solution technique used in the code. When corrected, the thermal responses predicted by DEROB 3, as well as DEROB 4, agreed well with the expected results.

The Analytical Verification Technique also revealed differences between the BEAS in the effect of changes in infiltration rate on heating and cooling loads, and differences in the thermal characteristics that each BEAS contains for a variety of internally determined window models; for example, DEROB 4 includes substantially higher glass conductances than the other BEAS.

The results for the Comparative Study and the Analytical Verification Technique are generally consistent with each other.

Empirical Validation

Five test cells for validation have been constructed and instrumented with approximately 200 sensors per cell. Cell #1 is a two-zone cell consisting of a low-mass room adjacent to a high-mass room, both with a south window. Cell #2 is a south solar-receiving zone seperated from a north sink zone by a masonry wall. Cell #3 is the same as cell #2, except that the concrete wall is replaced by a water wall. Cell #4 is a single zone with a trombe wall, and cell #5 is a single zone with a water wall. As soon as the data acquisition system is completed, validation runs will be implemented for DOE-2.1, BLAST-3.0, SUNCAT-2.4, and DEROB-4 on the five test cells.

Validation using full-scale buildings will commence as soon as Class A data become available.

FUTURE ACTIVITIES

Project Activities

- Data acquisition hardware debugged: 8/81
- Summer validation runs completed on test cells: 9/81
- Summer data collected from test-cells: 8/81
- Low-cal house and NBS test-building validation runs completed: 8/81 (if data is available and complete)

- Final report issued for FY81, including validation data and procedure package for use by any code author: 10/81
- Harmonic analytical solutions: 11/81
- Winter validation tests: 12/81
- Full-scale-building validation tests (pending availability of Class A data): 3/82
- Validation tests by participating code authors: 6/82
- Commercial-building comparative studies: 7/82
- Design tool validation tests: 4/82

Post-Project Activities

Validation data and procedure kits will be issued to anyone wanting to validate a Passive/Hybrid computer program. This will increase confidence in the design-and-analysis tools used for designing passive/hybrid buildings.

EVALUATION

The primary means of evaluation will relate to the number of requests for the data-and-procedure package received from independent code authors and users for use in their validation efforts. This package will be ready for dissemination by 1 October 1981. To date we have received numerous requests for our published papers on the subject of validation, and numerous telephone inquiries concerning validation and use of the programs. We estimate that we have filled approximately 800 requests for copies of our papers, answered nearly 1000 telephone inquiries, and conducted several seminars on this work at the direct request of AS/ISES and ASHRAE.

PUBLICATIONS/REPORTS/REFERENCES

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