Introducing Building Energy Simulation Classes on the Web

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ABSTRACT

This paper reports the background, status, and current outcome of a collaborative European Union sponsored international project, which aims to promote computer modeling and simulation of energy in buildings by creating hypertext-based self-learning course material and publishing it on the World Wide Web.

INTRODUCTION

Computer modeling and simulation has become a very important technology for assisting engineers with their non-trivial task of designing/analyzing buildings and associated environmental systems such that the result is low energy consumption, good indoor conditions, and minimal impact on the environment in general. This fact is recognized by many engineering schools and, in several cases, the technology has been fully integrated in the curriculum (Clarke et al. 1994).

The World Wide Web is emerging as a powerful medium for dispersing and acquiring a wide range of information. For a variety of reasons—graphical attractiveness, low accessibility threshold level, and a flat learning curve—it seems to appeal to students and, therefore, it might prove to become an efficient platform for educational purposes. This paper describes the results of a project (Hensen et al. 1997) that aims to widely introduce building energy modeling and simulation classes by making hypertext courseware available on the Web.

BACKGROUND

The new democracies in Central and Eastern Europe (CEE) are characterized by an ongoing process of an overall transition toward a market economy. This restructuring process involves rapidly changing needs of the labor market. The areas where lack of skills and knowledge are enhanced by the previous centralized policy are quality control in engineering and global environmental management.

In the current context, we can see an increasing need for graduates who are fluent in the professional language and who are familiar with technical and economical approaches to these problems in CEE countries.

Furthermore, the global effort for integration of CEE countries into European structures underline the emphasis on compatibility and equivalence with European Union (EU) universities.

This paper originates from a project that aims to address these needs by restructuring the curricula of four higher education institutions in Slovakia and three higher education institutions in Bulgaria by the introduction of energy modeling and simulation courses using information technology.

The project (funded as a structural joint european project by the European Union TEMPUS program, a trans-European cooperation scheme for higher education) attempts to reach two major target groups. First, final year (or MSc) students in building or mechanical engineering in order to equip these students with the required skills and knowledge, before entering the competitive labor market. Second, a structure will be created, that enables the provision of continuing education for industry (in collaboration with industrial partners).

This three year project (1995 through 1998) is comprised of two main components: provision of necessary hardware for the CEE partners, and development, implementation, and integration of courseware. This paper focuses on the courseware component.

COURSEWARE

The goal to create integrated and interdisciplinary classes, and the aim to emphasize compatibility and equivalence with EU universities, led to the conclusion that the

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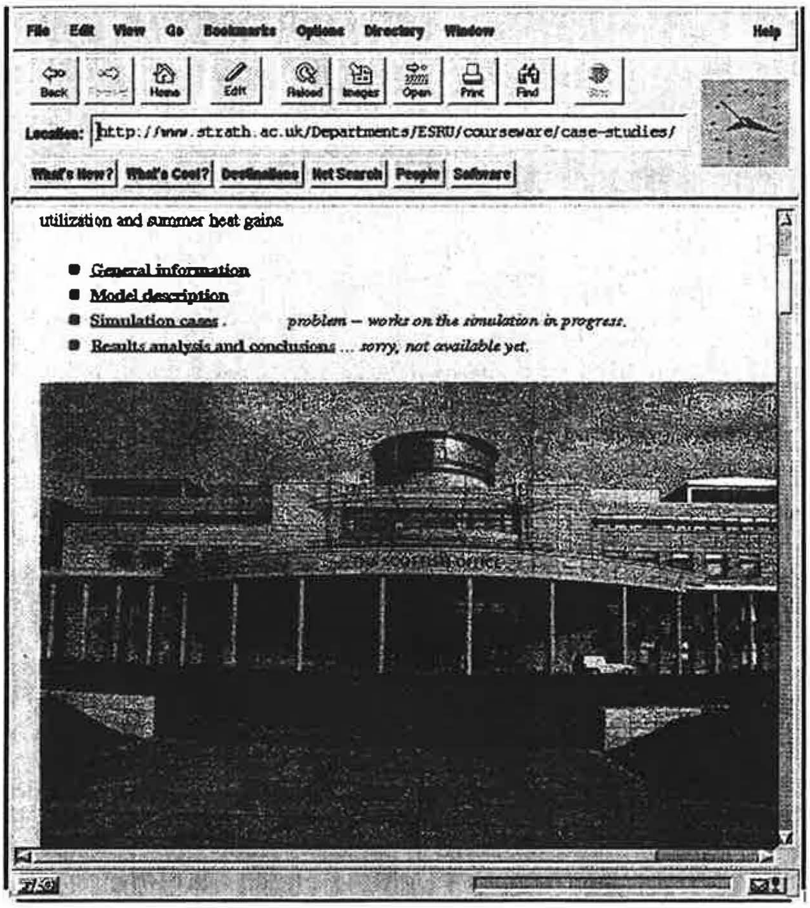

Figure 1 *Introduction to the case study regarding daylight utilization and summer heat gains in a Scottish office development.*

classes need an international dimension, and are, therefore, part of the English language.

The courseware is organized as (relatively) compact modular text with emphasis on graphical representations. The classes are prepared in hyper-text (HTML, hypertext markup language) and include computer aided learning features such as built-in exercises, assignments, and sample answers. This enables the material to be used in a self-learning mode. The compact and modular courseware structure allows for a significant portion of interdisciplinary material to be easily integrated. Furthermore, the courseware can be reorganized easily to suit additional purposes and target groups (i.e., continuing education for industry) or later to incorporate new developments in the field.

The courseware currently constitutes three common international classes. The idea is that eventually, about 95% of the material will be identical in the partner institutes, and about 5% will be specific to allow for special needs, such as national codes, local practices, and materials. So, by the end of the project, there will be a set of fully EU compatible and equivalent classes.

Currently, the courseware comprises the following three classes that are designed to be taken in chronological order:

Why should you use modeling and simulation for the design of buildings and environmental control systems?

This is a short introductory class that aims to generate interest and motivation for using the technology of computer modeling and simulation of energy in buildings.

Using a range of real case studies, students are given an overview of the main tasks involved in a simulation study:

—problem analysis and model creation;

—setting up and performing simulations;

—analyzing results and generating design knowledge.

Figures 1 and 2 are taken from two different case studies and illustrate the introduction and some simulation results, respectively.

Currently, (June 1997) the list of case studies comprises:

Case studies originating from ESRU:

- Daylight in a school in Modane, France;
- Daylight in a prestigious office in Edinburgh, Scotland;
- Summer overheating in offices in Glasgow, Scotland;
- Sunprotective or thermochromic glazing for a klinik in Germany;
- Wet central heating system modeling.

Case studies provided by others:

- Natural ventilation in a university building in Leicester, England;
- Retrofitting multifamily housing in Dolny Smokovec, Slovakia;
- Summer overheating of a conservatory in Stupava, Slovakia;
- Thermal bridges in panel system T06B constructions in Slovakia.

The various case studies aim to illustrate that simulation can be used to predict and assess energy consumption, load distributions, air and fluid flow rates, thermal and visual comfort, daylight distribution, and much more. Obviously, only a fraction of the building performance characteristics that can possibly be predicted using modeling and simulation are illustrated in the case studies regarding design aspects of offices, hospitals, multi-family housing, conservatories, HVAC systems, etc.

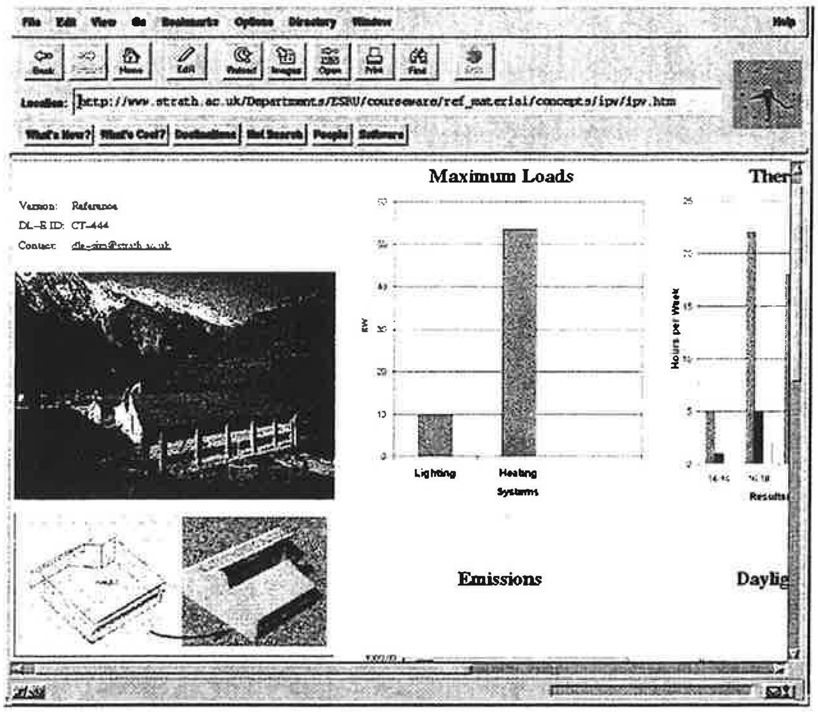

Figure 2 *Some results of the case study regarding daylight usage in a French school.*

The case study material (in each case comprising background, introduction, model and climate, simulation results, and conclusions) originates from various sources and covers a range of countries and a variety of modeling and simulation programs.

How can you practically use a real building energy modeling and simulation environment?

Once students are interested in the technology in general, they want to learn and use a real modeling and simulation system. Since you cannot learn how to use software unless you are specific about the program, this class is a practical training course for a particular software environment: the ESP-r system for building and plant energy simulation (ESRU 1996).

ESP-r is a dynamic thermal simulation environment for the analysis of energy and mass flows and environmental control systems within the built environment. ESP-r allows designers to assess the manner in which actual weather patterns, occupant interactions, design parameter changes, and control systems affect energy requirements and environmental states.

The "r" relates to the research and EU reference version. ESP-r is developed and distributed by a consortium, which is principally based at a university in Scotland, UK. This university continues to develop ESP-r and to support the needs of several research, educational, and commercial organizations in its application.

The practical training course is based on a series of hands-on exercises and assignments, which should be sent by e-mail to the supervisor. The purpose of the assignments is two-fold:

- in a training course or lecture/tutorial series, they enable the instructor to assess whether or not the training material is being absorbed effectively;
- for the student, they form a series of "real world" consultancy sub-tasks enabling them to check whether the training material is understood, while at the same time placing the ESP-r simulation tool in a realistic context.

The exercises are designed to progress ESP-r users from the category of novice to specialist over a period of time, which will depend on the individual's aptitude and stamina. The sets of exercises make the student familiar with the main features of the system from the elementary level to comprehensive system simulation:

Foundation Level Exercises

Preparatory

—Getting started on the workstation
—Configuring the workstation for ESP-r use
—Overview of ESP-r
—Exploring the in-built training exemplars

Basics of ESP-r

—Defining a problem to ESP-r - the basics
—Simulation - the basics
—Results analysis - the basics

Problem definition

—Problem definition - databases
—Problem definition - geometry
—Problem definition - constructions
—Problem description - operations
—Problem definition - inter-zone connections

Simulation and analysis

—Climate data and its analysis
—Control capabilities
—Simulation - advanced facilities
—Results analysis - additional facilities

Review

—Review of files and program modules
—Review of progress

Intermediate Level Exercises

Specific simulation facilities

—Shading and insolation analysis
—Mass flow analysis
—Plant and control modeling
—Lighting analysis

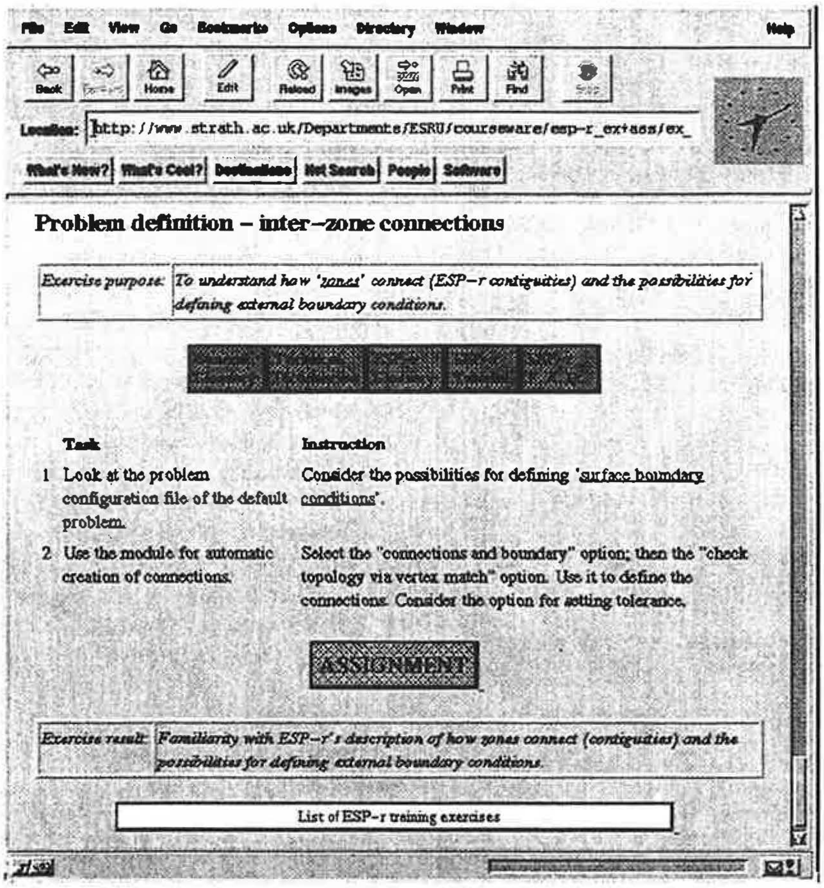

Figure 3 *Typical example of a training exercise description.*

Further simulation capabilities

—Other ESP-r facilities

—Upcoming ESP-r features

Expert Level Exercises

Advanced topics

—Making Models: CAD and Attribution

—Making Models: Fluid Flow, Plant and Control Networks

—Making Models: Enhanced Resolution

—Integrated Performance Appraisal Practical ESP-r model development

—Edit/ compile/ link test cycle

In addition to the above mentioned general case studies, there are also specific ESP-r training exemplars that are designed to illustrate selected features of modeling and simulation using ESP-r.

In order to be able to use and appreciate ESP-r, it is assumed that the student has access to a UNIX workstation and that a copy of the ESP-r software has been installed by the system manager.

For research and educational purposes, the university normally is able to offer a free system license. The restrictions imposed by the licence agreement primarily are that it is not allowed to undertake commercial work or pass copies to a third party.

How does building energy modeling and simulation actually work?

Some of the students may want to know more and will be interested in how modeling and simulation actually works.

The material in this module aims to give an understanding of the theoretical and operational principles underlying this new technology. In a series of elements outlined below, the class introduces the assumptions and limitations that underlie the methods currently used to appraise the energy performance of buildings and their associated environmental control systems. Particular attention is given to methods for representing and integrating building energy and mass transfer processes. The subjects are developed from basic principles, assuming limited knowledge of computers and application software. The associated exemplars are designed to demonstrate theoretical concepts introduced in the tutorial material, and to gain practical experience in using this new technology.

This class addresses the following subjects:

Part 1: Introduction

—Problem domain and scope Energy modeling techniques

Part 2: Modeling Building Energy Processes

—Heat and mass transfer through solids

—Heat and mass transfer by convection

—Heat and light transfer by radiation

—Energy transfer by electricity

Part 3: Modeling Building Energy Systems

—Building structure

—Auxiliary systems

—Control systems

—Occupants

—Outdoor environment Integration

Part 4: Simulation for Environmental Engineering

—Quality control

—Methodology

—Case studies

Part 5: Close

—Modeling and simulation context

—Conclusions

In total, the class has 17 sub-modules each comprised of a list of key concepts, an outline of the lecture structure, a

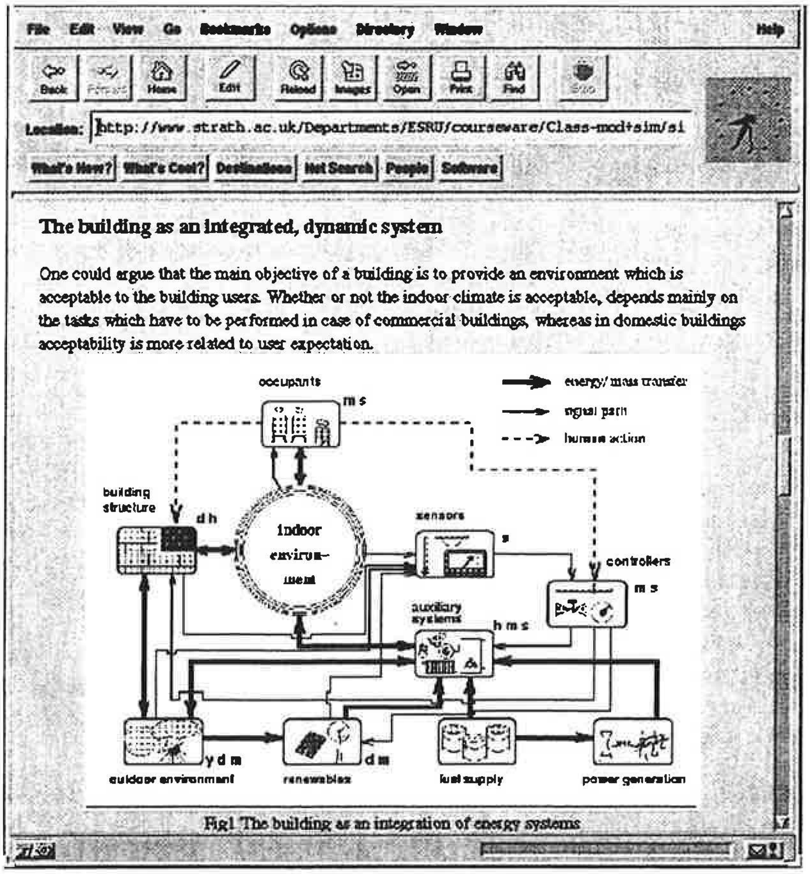

Figure 4 *Typical example from theory section showing the building as an integration of energy systems.*

summary, course material for studying by the student, and links to further reading material.

Each module ends with an assignment (plus some sample answers) that aims to link the theory to practice. As an example, the assignment following the sub-module on quality control reads:

> As a member of the design team you are using modeling and simulation to assess the relative performance of various fenestration options for a new multi-purpose building. The design is still in an early phase, and detailed information is not yet available. Discuss which error sources (internal or external) are likely to be more dominant in this situation, and suggest a procedure or approach that will reduce the impact of the error sources and advise the other team members which fenestration option will be best.

Both the introduction class and the theory class are very general in terms of modeling and simulation software. For reasons indicated above, only the practical class is specific in terms of a software product.

In developing the hypertext material, we started from existing material such as existing course notes, papers, articles, etc. This material was then transformed into HTML format, cross-links were established (for example from practical and theory sections to case studies), and where possible, links to other Web sites were introduced (for example, to a UNIX training site and to various building energy related sites).

At various locations in the text, students have access to additional information under a variety of topics. For example:

- a general glossary of terms related to modeling and simulation for environmental engineering;
- technical dictionaries listing terms commonly used in modeling and simulation of energy in buildings, currently in English - Bulgarian, English - Czech, English - Dutch, English - Portuguese, and English - Slovak;
- a collection of links to other World Wide Web sites providing information in the area of energy in buildings;
- various ESP-r specific materials, such as an ESP-r glossary of terms; an ESP-r tutorial; and an ESP-r "frequently asked questions" collection. In this way, there exists a number of classes that form study material, which is not restricted, as is the case in a normal (flat) text book, but will allow students to find more and more information by digging deeper into the Web material. Basically,

the assignments are designed and used to ensure a minimum level of studying. On completion of the three classes, students should appreciate the capabilities and limitations of the various methods for assessing the thermal behavior of buildings, including energy efficiency and indoor comfort. They should also:

1. Appreciate that environments result from complex interactions of many energy and mass transfer mechanisms.
2. Have a basic knowledge of how to apply computer modeling and simulation to address this complexity.
3. Understand the theoretical and operational principles of contemporary modeling programs.
4. Appreciate the limitations of current design support and performance evaluation tools and the issues to be addressed to bring about their improvement.
5. Possess practical skills in using the technology in an environmental engineering context.

IMPLEMENTATION

As indicated above, initial versions of the courseware have been developed. Currently, this constitutes about 12

Mbyte of HTML and image files. The courseware has been implemented on various Web servers for efficient access from the partner countries. (Access time and speed to and from CEE based universities tend to prohibit efficient student interaction.) The preferred Web location for global access is from the university in Scotland (ESRU 1997).

The information technology aspect of the courses allows self-learning, relatively easy maintenance of the course material, and, most importantly, it provides almost unlimited dissemination possibilities (anyone with internet access can access and use the course material).

This ensures that the project deliverables will be automatically dispersed to other universities and schools within and outside the countries involved, as well as to practitioners in the construction industry and elsewhere.

As part of the Tempus project, the material currently is being introduced in new and existing classes. Due to its modularity, the material can be incorporated into the curriculum either as complete classes or in bits and pieces, e.g., case studies, parts of theory, etc. The modules can be used for self-study or may be used as additional reading in other classes.

In the University of Strathclyde, the courseware has been fully integrated in two under-graduate classes and in one post-graduate module. The courseware also is used for continuing education purposes.

In order to assure successful implementation, each of the other partners also defined target groups with appropriate time schedules. For instance, in the case of the Slovak Technical University:

First year:

Post-graduate students were the first target group, in order to test the prepared newly introduced course content. The post-graduates form an integral part of the project, because they are considered as staff members and their updating and retraining will have a significant impact during the second and third year of the project. Integrated interdisciplinary courses were developed by restructuring existing MSc classes in Building Engineering and the introduction of three new courses by implementing them within the existing MSc degree curriculum.

Second year:

A limited group of final year students has been selected as the target group in this stage of the project, in order to enable a final check before introducing the new courses in the normal educational curriculum. Two existing final year classes (15 weeks each) on Energy Efficient Building Design and on Special Building Construction have been upgraded by introduction of simulation and modeling into the tutorial part of these existing courses.

Third year:

All final year students of the MSc in Building Engineering degree course in the normal curriculum. In this stage, continuing education courses for industry will be made available to enterprises and practice.

RESULTS

Successful completion of the project will provide the following results:

CEE participants:

Necessary hardware infrastructure for education (teaching/computer laboratories), software for education, updated and trained staff, training capacities for continuing education to be offered to industry, restructured existing courses, and introduced three new classes.

All participants:

Three EU compatible and equivalent courses, international links with other universities, and the courseware listed earlier.

It is too early to report on results in terms of increased/ decreased learning efficiency.

Current feed-back from students suggest that they appreciate the medium in which the material is presented. Early observations and experience suggests that, on average, students learn quicker and more independent; i.e., putting less demand on the supervisor/ teacher.

Although some students report "getting lost," most students are positive, especially regarding the appearance and richness of the material, which actually encourages students to dig deeper at the click of a (mouse) button.

CONCLUSIONS AND FUTURE WORK

One of the major outcomes of the project can be characterized as unlimited global dissemination potential of the courseware, that is being developed within the project.

As indicated above, the project is not finished yet, and it is our intention to continue development and improvement of the hypertext courseware once the Tempus project is completed. Development of this type of courseware is just starting. Many aspects need to be explored further. We therefore invite feed-back and appreciate any contributions.

Future work will involve comparison of this hypertext courseware to more traditional course notes and text books in terms of educational efficiency.

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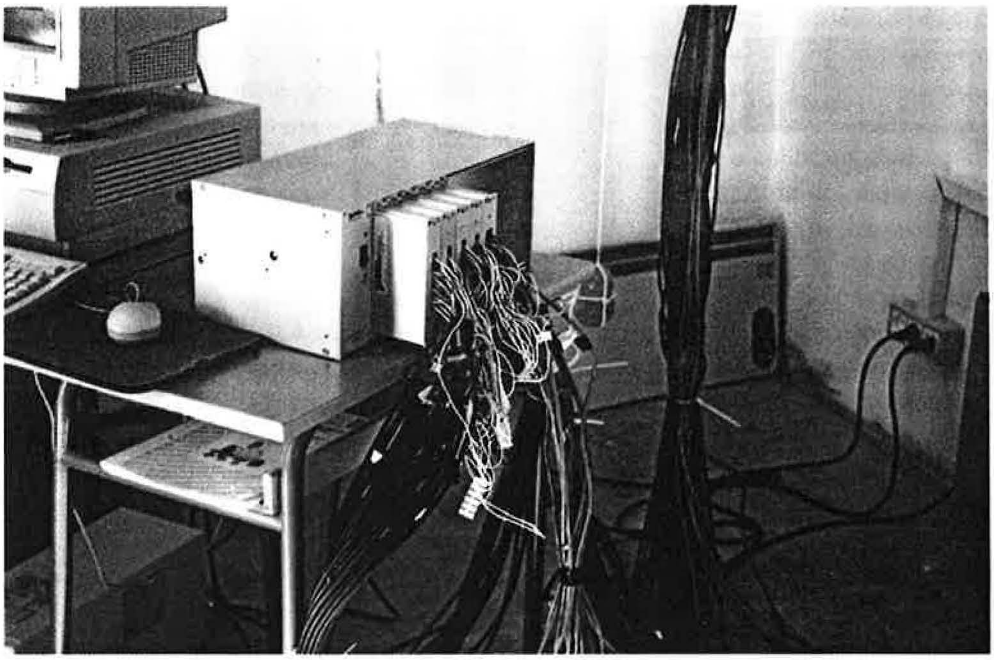

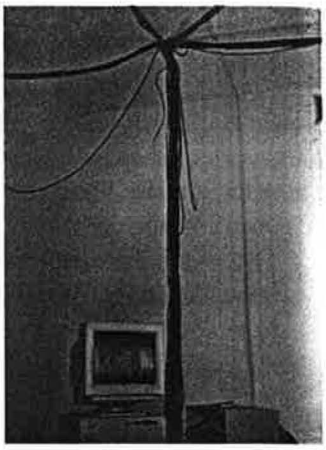

Figure 8, 9 - A sinistra: particolare dei collegamenti dei sensori con i moduli di condizionamento del sistema di acquisizione dati. In basso: il sistema di acquisizione dati

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RIASSUNTO - *ABSTRACT*

Stazione di prova a orientamento variabile
Un laboratorio mobile per lo studio e la sperimentazione del comportamento energetico dell'edificio

Viene descritta la stazione di prova ad orientamento variabile, costruita presso il Dipartimento di Meccanica dell'Università della Calabria. Consiste in un monolocale di dimensioni interne 4x4x3,2 m, poggiato sopra una piattaforma ruotante in acciaio, opportunamente strumentato in modo da monitorare il suo comportamento termico sia in condizioni invernali che estive.
Essa costituisce un laboratorio outdoor in scala reale per la verifica delle prestazioni di componenti edilizi e termotecnici e per la convalida sperimentale di modelli di calcolo nel campo dell'energetica dell'edificio.

Parole chiave: Stazione di prova - Sperimentazione - Energetica - Edifici

A testing station with changeable orientation
An outdoor laboratory for testing in the building energy field

A testing station with changeable orientation, built at Mechanical Engineering Department of the University of Calabria is described. It consists in a single room, internal size 4x4x3,2 m, mounted on a steel turntable, equipped with instruments for the monitoring of its winter and summer thermal behaviour.
The testing station is a real scale outdoor laboratory for the qualification of building construction components and the validation of calculation models.

Key words: Test station - Testing of building - Building energetics