GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Po 18

Date: June 15, 1976

Project Title: "Instructional Scientific Equipment ~~Program~~"

Project No: E-20-539

Project Director: Dr. J. S. Lai

Sponsor: National Science Foundation

Agreement Period: From 6/8/76 Until 5/31/78

Type Agreement: Grant No. SER76-13302

Amount:

$19,300	NSF
19,400	GIT (E-20-217)
$38,700	TOTAL

Reports Required: Final Report
Fiscal Report

Sponsor Contact Person (s):

Technical Matters

No letter

Contractual Matters
(thru OCA)

Instructional Scientific Equipment Program
National Science Foundation
Washington, D.C. 20550

Defense Priority Rating: None

Assigned to: Civil Engineering (School/Laboratory)

COPIES TO:

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- Project Code (GTRI)
- Other

CA–3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 8/11/78

Project Title: Instructional Scientific Equipment

Project No: E-20-539

Project Director: Dr. J. S. Lai

Sponsor: National Science Foundation

Effective Termination Date: 5/31/78

Clearance of Accounting Charges: 5/31/78

Grant/Contract Closeout Actions Remaining:

- _ Final Invoice and Closing Documents
- x Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ____________

Assigned to: Civil Engineering (School/Laboratory)

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Other ____________

CA–4 (3/76)

INSTRUCTIONAL SCIENTIFIC EQUIPMENT PROGRAM

PROJECT DIRECTOR'S FINAL REPORT

Proposal/Grant Number: SER 76-13302

submitted to

Instructional Scientific Equipment Program
Division of Higher Education in Science
National Science Foundation
Washington, D.C. 20550

from

James S. Lai
Project Director
School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

August 10, 1978

PROJECT DIRECTOR'S FINAL REPORT

PART A: Covering Letter

Proposal/Grant Number: SER 76-13302

The grant provided by NSF is to develop a mini-computer-based data acquisition and control instrumentation for improving teaching of the Materials and Geotechnical curriculum in the School of Civil Engineering at the Georgia Institute of Technology.

Teaching of laboratory classes in materials behavior in Civil Engineering have changed little in the last forty years. That is, the student spends an afternoon with clipboard and pencil recording data from a relatively simple test on a well characterized material sample. The data reduction and analysis is usually done sometime after the tests are performed. The students tend to lose the comprehension of the significance of the tests if a long delay occurs between the time of testing and the time of final data analysis. Manual methods of data collection also results in the student usually paying more attention to physically collecting the data rather than observing the physical responses of the specimen being tested. When testing a specimen using manual methods of data collection, irregularities in the test are often difficult to detect and correct during the test. Many experimental errors can be corrected during the test if the reduced results are available as the test progresses. In the manual method of data collection, a large portion of the effort put into the laboratory experiment is spent in reducing the data. When the student is required to do a large amount of repetitious data reduction, interest tends to be lost in not only the data, but also the entire area of material engineering.

The problems described above can be minimized by using a real-time data acquisition and control system. This approach will allow considerably more tests to be conducted, and permit the professor running the laboratory to discuss with the students immediately following the tests the significance of the results and any pertinent problems associated with the experiments.

Introducing a mini-computer-based data acquisition and control system into a material testing course has the potential of achieving the following purposes:

(1) Perform more interesting experiments and reduce the amount of manual data reduction.

(2) Obtain a good "feel" for materials behavior by being able to instantaneously observe the reduced experimental results.

(3) Acquire hands-on experience with modern mini-computer-based data processing equipment.

Incorporation of Automatic Data Acquisition and Control System (ADAC) into the Material Engineering curriculum in the School of Civil Engineering at Georgia Tech is being accomplished in two phases. In the first phase, the ADAC system is being used in the existing undergraduate Materials of Construction course and Physical Behavior of Soil and Rock course. A conventional FORTRAN IV computer course is a prerequisite of the Materials of Construction course. Therefore, the students can grasp the basic fundamentals of the ADAC system relatively quickly. In the second phase, an advanced senior technical elective and graduate course in materials technology and data acquisition will be introduced involving a more intensive use of the ADAC system. Further discussion of the implementation plan is presented in the accompanying paper entitled "Use of a Mini-Computer in Materials and Geotechnical Education".

Problems which have arisen in carrying out this project have been mainly the computer system itself. The INTERDATA 8/16 mini-computer system we have purchased under this project represents a new generation mini-computer which has better features in terms of system architecture, mass storage, speed and operation system. These features are very desirable for this project. Nevertheless, being a new product, there are some undetected "bugs" in the system. We have spent a considerable amount of time in the debugging.

In the original proposal for the project, a list of equipment based on the Digital Equipment Corporation's PDP-8 system was proposed. In the course of procuring the equipment, we decided to purchase the system from the Interdata Computer Products of their INTERDATA 8/16 system instead of the PDP-8 system. The decision was based on the fact that the INTERDATA 8/16 system not only meets all the minimum functional requirements as set forth in the original proposal, the system as a whole represents a much powerful operating system with many additional features which originally was thought to be too costly. For example, the computer has faster cycle time, the mass storage is a 10 kegabyte disk, instead of a flopy disk. We are convinced that with these added features, the original instructional goal can be better accomplished. The system configuration of the INTERDATA 8/16 system is described in the accompanying paper. Except this change, no other modifications were made during the life of the grant.

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COMPUTING IN CIVIL ENGINEERING

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USE OF A MINI-COMPUTER IN MATERIALS AND GEOTECHNICAL EDUCATION

by

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and

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Professor of Civil Engineering
Georgia Institute of Technology

ABSTRACT

The development of a mini-computer-based system is described for data acquisition and control for use in the Civil Engineering materials and geotechnical programs at the Georgia Institute of Technology. The basic concept of the system is presented as well as the hardware configuration and software requirements. The system is centered around a 16-bit mini-computer with 64 K core memory, hardware floating point processor and a 10 Mega byte disk. Peripheral equipment consist of a printer terminal, digital plotter, oscilloscopes, 32 channel digital/analog converter, and other digital and analog input/output control devices. The system can be operated using high level languages such as FORTRAN and BASIC.

A discussion is given of the implementation of the system for use as a teaching aid in materials and geotechnical laboratories. To illustrate the application of the system for educational purposes, examples are given illustrating the use for specific laboratory experiments in material testing. Illustrations are also given of the use of the computer system that has been integrated into the educational process as a problem solving tool.

Use of the automatic data acquisition and control system will allow considerably more tests to be conducted and permit the professor in charge of the laboratory time to discuss with the students, immediately following the tests, the significance of the test results and any pertinent problems associated with the experiments. Use of the system also gives the student hands-on experience with modern data acquisition and computation equipment.

INTRODUCTION

Use of a mini-computer-controlled instrumentation for data acquisition and experiment control has become increasingly popular for research and production controls involving large numbers of measurements and critical timing requirements. This trend will undoubtedly continue as the cost of mini-computer hardware continues to decrease, and as more engineers become familiar with mini-computers. Mini-computer control systems have been used in a number of civil engineering related applications in recent years. For example, mini-computer based monitoring and controlling systems have been used in transportation areas for traffic control, scheduling of bus and train operations. Computer systems have also been used in sanitary engineering for the control of sewage treatment plants, and other similar operations.

At the present time, civil engineering students usually use computers only to solve analytical problems. Students are taught to write computer programs in FORTRAN and BASIC language to solve specific numerical problems with interaction between the student and computer usually being minimal. This sequence is typical of a large digital computer system operated by a service organization such as a computer center. On the other hand, with a mini-computer the user can have direct interaction with the computer even when it is used for numerical problem solving applications. Because of the undoubtedly great future impact which mini-computers will have in civil engineering, students should get an introduction to the application and use of mini-computers while still in the school. The idea is not to teach a mini-computer course, this should be a part of the Computer Sciences curriculum. In civil engineering the purpose of introducing mini-computers in the educational process should be to demonstrate the applications of a mini-computer system for analytical computations, real time data processing, control of experiments and to demonstrate the basic configuration and operational function of each component of the mini-computer system.

A very appropriate environment to introduce a mini-computer system to civil engineering students is in materials and geotechnical testing laboratories associated traditional required undergraduate courses. Use of a mini-computer based data acquisition and control system in conjunction with conventional materials testing experiments can quite effectively show students the versatility and capability of a mini-computer system. Furthermore, a materials testing laboratory course using a mini-computer system for data acquisition, data processing and control of experiments can stimulate interest and greatly improve the effectiveness of the course. If with this introduction the student is sufficiently stimulated in the use of mini-computer systems, he can then enroll in formal mini-computer courses for in-depth training in this area.

Teaching of laboratory classes in materials behavior in civil engineering have changed little in the last forty years. That is, the student spends an afternoon with clipboard and pencil recording data from a relatively simple test on a well characterized material sample. The data reduction and analysis is usually done sometime after the tests are performed. The students tend to lose the comprehension of the significance of the tests if a long delay occurs between the time of testing and the time of final data analysis. Manual methods of data collection also results in the student usually paying more attention to physically collecting the data rather than observing the physical responses of the specimen being tested. When testing a specimen using manual methods of data collection, irregularities in the test are often difficult to detect and correct during the test. Many experimental errors can be corrected during the test if the reduced results are available as the test progresses. In the manual method of data collection, a large portion of the effort put into the laboratory experiment is spent in reducing the data. When the student is required to do a large amount of repetitious data reduction, interest tends to be lost in not only the data, but also the entire area of material engineering.

The problems described above can be minimized by using a real-time data acquisition and control system. This approach will allow considerably more tests to be conducted, and permit the professor running the laboratory to discuss with the students immediately following the tests the significance of the results and any pertinent problems associated with the experiments.

Introducing a mini-computer-based data acquisition and control system into a material testing course has the potential of achieving the following purposes:

(1) Perform more interesting experiments and reduce the amount of manual data reduction.

(2) Obtain a good "feel" for materials behavior by being able to instantaneously observe the reduced experimental results.

(3) Acquire hands-on experience with modern mini-computer-based data processing equipment.

SYSTEM CONFIGURATION

Figure 1 is a schematic of the hardware configuration of the Automatic Data Acquisition and Control System (ADAC). The system is centered around a 16-bit mini-computer (INTERDATA 8/16) having a 64-kilobyte core memory with a multi-tasking operating system that facilitates real-time task implementation using high level languages such as FORTRAN and BASIC. A 10-megabyte disk facility, which contains one fixed and one removable disk, is used for mass data storage. Cycle time for the core memory is typically about 750 nsec. To increase the speed for mathematical calculations, a hardware floating point processor is included in the computer. Peripheral equipment consists of a INTERDATA printer terminal, a ZETA digital plotter, a TEKTRONIX CRT, 32 channels analog-to-digital converter, 2 channels of digital-to-analog converter, and a contact closure and relay drive module for digital I/O control. Direct access is also available to the Rich Computer Center's CDC Cyber 74 System for use in the execution of computer programs which require a large amount of core memory.

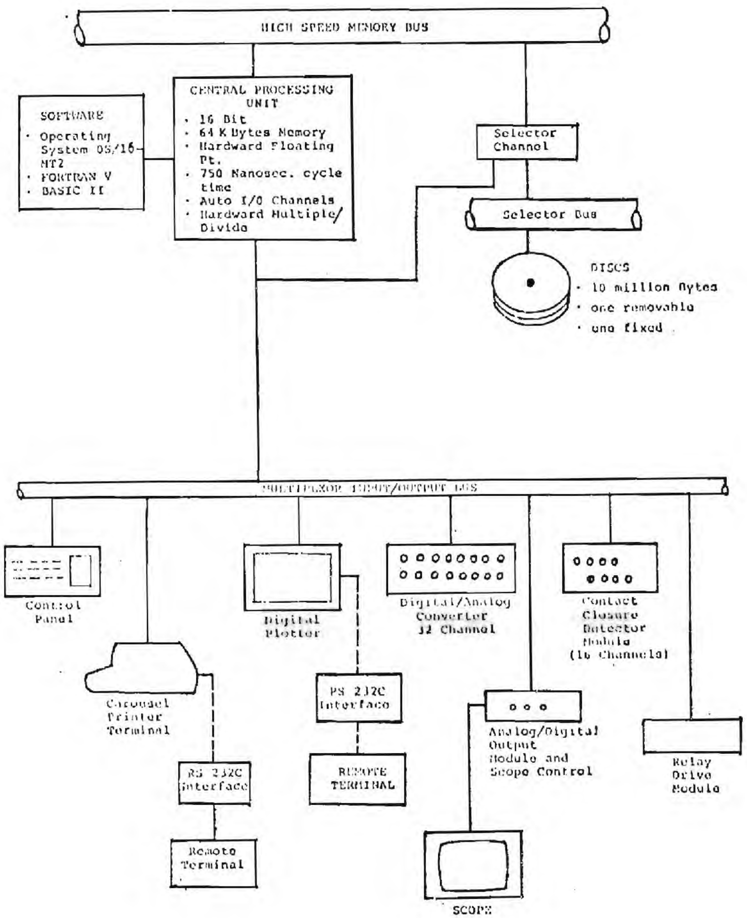

Figure 1. Automatic Data Acquisition and Control System (ADAC) Configuration.

IMPLEMENTATION OF ADACS IN MATERIALS ENGINEERING CURRICULUM

Incorporation of Automatic Data Acquisition and Control System (ADAC) into the Material Engineering curriculum in the School of Civil Engineering at Georgia Tech is being accomplished in two phases. In the first phase, the ADAC system is being used in the existing undergraduate Materials of Construction course and Physical Behavior of Soil and Rock course. A conventional FORTRAN IV computer course is a prerequisite of the Materials of Construction course. Therefore, the students can grasp the basic fundamentals of the ACAC system relatively quickly. In the second phase, an advanced senior technical elective and graduate course in materials technology and data acquisition will be introduced involving a more intensive use of the ADAC system.

Phase 1

The Materials of Construction course introduces the undergraduate students to the production and physical properties of civil engineering construction materials. The student receives each week three one-hour lectures, and participates in a three-hour laboratory. The laboratory work includes evaluating the properties of aggregates, hardened portland cement concrete, steel and aluminum in uniaxial tension and bending, wood and plastics. Also a portland cement concrete mix design is performed.

The Physical Behavior of Soil and Rock course covers the basic engineering properties of soil and rock. This course also consists each week of three one-hour lectures and one three-hour laboratory. Tests performed in the laboratory include Atterberg Limits, grain size, consolidation, unconfined compression and triaxial shear.

The intent of introducing the ADAC system in these two laboratories in conjunction with the conventional laboratory exercises is to demonstrate to the students the versatility and the capability of a minicomputer-based data processing system used in material testing experiments. By introducing the ADAC system in the laboratories after the students have gone through the drudgery of manual data collection and reduction, a great appreciation of the system and its tremendous capabilities will be gained. To stimulate interest and enthusiasm the ADAC system is being treated in as simple and straightforward a manner as possible. The coverage of the ADAC system is being limited to the operational function of the essential components of the system, and the overall system concept using a simple "flow chart" approach. The ADAC system is introduced simply as a "information transfer function" which converts the given input information into physical behavior and output decisions. In this context, this sophisticated system is no different than other types of transfer apparatus such as load cells, strain indicators and etc. When using the ADAC system in a specific experiment, the detailed use of the ADAC system including writing the data processing programs, setting up and operating the system during the test is performed by the laboratory instructor. Thus, the students can concentrate on observing the progress of the experiment and how the ADAC system interacts with the experiment.

Immediately after the completion of the experiment the instructor completely discusses the test results, their significance and then compares the results with similar materials. Disc storage in the computer is used to store material properties for typical materials from previous experiments. The uniaxial tension test and beam bending test in the Materials of Construction laboratory and the vacuum triaxial shear test performed on sand in the Soils laboratory are used to implement the ADAC system at this time. The implementation of ADAC system in the beam bending test and the triaxial shear test are subsequently given as examples.

Phase 2

In the existing Materials of Construction course a detailed study of advanced physical properties such as fatigue, creep, and failure under multi-stress states cannot be accomplished because of insufficient time. Therefore, an advanced materials course is being developed suitable for use as a senior elective or graduate level course which will fill this gap in the present curriculum. This course will consist each week of two one-hour lectures and a three-hour laboratory. Emphasis will be placed on introducing the student to physical material properties having practical civil engineering significance that have traditionally been neglected in the present curriculum. The ADAC system is being integrated into the laboratory to permit the student to learn in detail about the programming and operation of the system. The student will have the opportunity to use the system for data acquisition and data processing in several of the experiments being included in this new course. The laboratory experiment including the use of the ADAC system in the laboratory portion in this new course is summarized in Table 1 as follows:

Table 1. Outline for Advanced Physical Behavior Course Presently Being Developed

Laboratory Period	Content
1	Introduction to Operation of ADAC System, basic configuration, function of each component, capabilities.
2	Operation of ADAC System and other Electronic Instruments; simple data acquisition programming
3,4.	Demonstration of using ADAC System in basic tests: Elastic and Inelastic Behavior of Thin Walled Pressure Vessel. Measure Pressure Versus Strains, Determine Principal Strains, Principal Stresses, Elastic Modulus, Poisson's Ratio, Initial Yield, etc. Compare results with theory.

Table 1. Outline for Advanced Physical Behavior Course Presently Being Developed (continued)

Laboratory Period	Content
5	Creep and Stress Relaxation Test on Plastics - Use ADAC System for Data Acquisition and Processing. Use Curve Fit to Determine the Creep and Relaxation Functions
6, 7, 9	Student Select and Perform Term Projects
8	Fatigue Test of Asphalt Concrete and/or Portland Cement Concrete Beam Specimens
10	Oral Presentations of Student Projects and Discussion

FLEXURE TEST OF ALUMINUM BEAM

The purpose of this experiment is to determine experimentally the deflections and flexure strains of an aluminum beam under bending, and to compare the experimental results with the theoretical predictions of the deflections and strains under the same loading conditions. Figure 2 shows a schematic of the experimental set-up. An aluminum "I" beam, having a span length of 36 in. and depth of 6 in. is subjected to two point loads applied symmetrical with respect to the center of the span. The flexure strains at different depths in the section along the midspan are measured by strain gages and the midspan deflection is measured by a linear displacement transducer (LVDT). The magnitude of load applied to the beam is measured by a load cell. The analog signals from these transducers are conditioned and sent to the Analog to Digital Converter (ADC). The ADC then converts the analog signals into digital data at a predetermined sampling rate. The digital data is then processed by the computer and the resulting output sent to the digital plotter, printer, and CRT for graphical and numerical display. During the test the theoretical predictions of strains and deflections for the same loading condition are generated by the computer and output to the same devices for graphical comparison. The processed digital data is also stored in the disk for future use.

ADDITIONAL EXAMPLES

The second example of the use of the ADAC system is for the vacuum triaxial shear test in the Physical Behavior of Soil and Rock laboratory. The test is performed on a clean sand to evaluate the stress-strain characteristics under different confining stresses and to determine the shear strength. The confining pressure is applied to the specimen by means of a vacuum applied to the inside of the sample. Axial load is then applied. Load and axial deformation are measured using an electronic

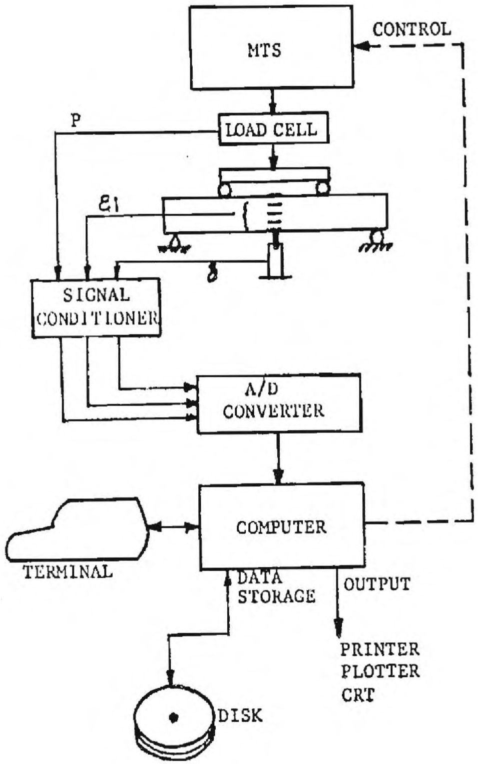

Figure 2. Flexure Test Set-Up.

load cell and displacement transducer (LVDT). The analog signals from these instruments are sent to the analog-to-digital converter (ADC) and changed into digital data at predetermined sampling rates. The stress-strain relationships, modulus of elasticity and Mohr failure envelope is plotted and displayed on the CRT for immediate viewing by the students. This data is compared with that for other sands having different physical characteristics.

The system has also been used by geotechnical graduate students to solve the problem of a laterally loaded pile. This gave the students the opportunity to physically see the components of the system, and learn how to operate and interact with a mini-computer.

CONCLUSION

The mini-computer has just been introduced to the civil engineering profession within the last ten years. This system offers unlimited uses in the area of data acquisition and reduction, process control and the solution of analytical problems. As time goes on the use of this type system will be gradually introduced into civil engineering curriculum throughout the country. This paper has described how a mini-computer is being used in Civil Engineering at the Georgia Institute of Technology to introduce students to its tremendous potential in data acquisition and process control in the area of materials engineering. The system in the future undoubtedly will be used in the Civil Engineering educational process in many additional applications.

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

SUMMARY OF COMPLETED PROJECT

Form Approved
OMB No. 99R0013

Please read instructions on reverse carefully before completing this form.

1. INSTITUTION AND ADDRESS		2. NSF PROGRAM	3. GRANT PERIOD
Georgia Institute of Technology Atlanta, Georgia 30332		Instructional Scientific Equipment Program	from 6/8/76 to 5/31/78
4. GRANT NUMBER	5. BUDGET DUR. (MOS)	6. PRINCIPAL INVESTIGATOR(S)	7. GRANTEE ACCOUNT NUMBER
SER 76-13302	24	James S. Lai	E-20-539

8. SUMMARY (Attach list of publications to form)

The purpose of this project is to develop a mini-computer based data acquisition and control instrumentations for use in the Civil Engineering materials and geotechnical programs at the Georgia Institute of Technology as an integral part of an improvement plan for the materials engineering curriculum in the School of Civil Engineering.

Introducing a mini-computer-based data acquisition and control system into a material testing course has the potential of achieving the following purposes:

(1) Perform more interesting experiments and reduce the amount of manual data reduction.
(2) Obtain a good "feel" for materials behavior by being able to instantaneously observe the reduced experimental results.
(3) Acquire hands-on experience with modern mini-computer-based data processing equipment.

The data acquisition system is centered around a 16-bit INTERDATA 8/16 Mini-Computer with 64 k core memory, hardware floating point processor and a 10 Megabyte disk. Peripheral equipment consists of a printer terminal, digital plotter, oscilloscope, 32 channel analogy/digital converter, and other digital and analog input/output devices. The system can be operated using high level languages such as FORTRAN and BASIC.

The system is currently in operation. Incorporation of the system into the materials testing laboratory is currently being implemented.

SIGNATURE OF PRINCIPAL INVESTIGATOR/ PROJECT DIRECTOR	TYPED OR PRINTED NAME	DATE
	James S. Lai	8/10/78

F Form 98A (5-76)

PUBLICATION

Lai, J. S., and Barksdale, R. D., "Use of a Mini-Computer in Materials and Geotechnical Education", Proceedings of the Conference on Computing in Civil Engineering, June 26-29, 1978, Atlanta, Georgia.