COMPUTER CONTROLLED EXPERIMENTS

EXPERIENCES CONTROLEES PAR ORDINATEUR

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SYNOPSIS: A short conceptual history of computer application in geotechnical experiments is discussed. Technological progress nowadays renders the computer control of almost any type of geotechnical tests possible and opens the still relatively unexplored field of decision support systems in geotechnical engineering. Costs are, however, identified as the major factor controlling the diffusion of these systems.

Computers have been used in geotechnical experimentation at least for the past twenty years. In the beginning they were utilized mainly to reduce sampled data, but from the 1980s onwards the computer gradually became the main instrument for automatic logging and storage of experimental data; thus, substituting other electronic equipment previously used for these purposes.

Computer based data acquisition systems were first employed in labs and later extended to be also used in the field, once the problems of robust hardware and greater reliability were overcome. The state of the art report on "New developments in field and laboratory testing of soils" at the XI ICSMFE in San Fransisco (Jamiolkowski et al.,1985) formally sanctions the entry of the computer among equipment for geotechnical experimentation.

Computer flexibility is of great help in reducing the risk that the automation of data collection can turn the experimentation into a rather autonomous process which the operator might not fully control and understand. To avoid this, it is advisable to make acquisition system transparent (i.e. continuously providing values of collected data, plots of curves etc.) so that the operator can have everything under his immediate control. Other advantages of computerized data acquisition systems, besides the well-known ones of conventional automatic systems (such as reduction in personnel necessary for data acquisition and recording and the exemption of lab personnel during test performance), include:

- cost reduction, as computers are generally cheaper than other electronic equipment used for automatic data acquisition;
- time saving and simplification during data processing and plotting;
- greater flexibility to the requirements of the various tests and to optimize data acquisition as the measuring process is in progress (i.e. increasing the sampling rate in stages of greater interest, or when the measurements offer steep gradients).

The cost element has definitely been the crucial factor for the success of these systems. In those countries where the high and ever growing personnel cost has been matched by a significant reduction in the electronic equipment costs, the cost-benefit analysis has resulted favourable, explaining the wide spread use of these systems. For instance in Western Europe, in large labs with a high work-load, the cost of a computerized automatic data acquisition system tipically allows a saving in personnel of 50% to 100% of the cost of the actual system. In those countries where labour is cheap compared to the electronic parts and there is a scarce and expensive availability of electronic maintenance services, the economic balance is certainly different. This explains the scarce use of these systems.

The use of computers and electronics for data acquisition, however, is just the first level of the possibilities offered by these technologies. A second more recent stage is their application in the automatic control of tests. In this usage the system, besides acquiring the data, also compares them with a target, progressively updated by the computer itself, and sends a signal to the experimental equipment to control it. Therefore, it is necessary to have at disposal an experimental equipment that can be controlled by an electrical signal, and to add a digital to analog (D/A) converter in order to convert the digital signal into the control electrical signal of the machine.

This computer application stems originally from the requirements of lab research to control complex tests, difficult and laborious to be executed manually. From a technological point of view, components available today (16-20 bit converters with velocities up to several hundred MHz, advanced multiplexer cards, analogically and digitally controlled servovalves, etc) allow to carry out any kind of geotechnical test entirely controlled by computer. For example, actual laboratory possibilities range from automation of classification tests such as hydrometer tests (Nguyen and Paoloni, 1989) to sophisticated equipment such as resonant column (Mondini, 1987), or dynamic true triaxial machine

(Kitamura et al., 1989). These systems can turn out to be quite complex both in the hardware and in the software part, depending on the type of test or control required. Besides applications in research, the economic benefit achieved with this kind of systems is strongly conditioned by a number of factors, such as the market demand for the test in question, the cost of the control system and the saving in personnel or in work-time that can be achieved. With reference the above mentioned example on the automation of the resonant column test, the cost of a system able to automatically perform resonance and damping measurements is about 60.000-70.000 US$, with annual savings in personnel lower than 10% of the investment cost. On the other hand, the application of these systems may offer commercial organizations the possibility to provide tests which are otherwise available only within research organizations. The manual execution of a triaxial test following a complex stress path with the use of a classical Bishop and Wesley cell (Bishop and Wesley, 1975) requires the constant presence of an operator throughout the whole test. An automatic system such as the one described by Baldi (1991) and at the cost of 20.000 US$ allows to carry out the same test in a completely automatic fashion with a much greater capacity to stay on the desired stress path. How convenient it is to have an automatic equipment depends, therefore, mainly on the market demand that the system has to meet. For example, it is quite common that modern geotechnical centrifuges (Fioravante, 1992) or facilities for large 1 g models (Bauer et al., 1984) have computer controlled loading systems.

However, the demand of routine geotechnical tests demonstrate, even in the most advanced countries from a technological point of view, a great inertia and the tendency to favour traditional rather than innovative tests. This explains why computer controlled equipment is spreading so slowly within commercial organizations. At the present automatic systems for stress path controlled triaxial tests are certainly the most widely spread kind of laboratory equipment with automatic control. Among the equipment for in situ tests, some models of Self-Boring Pressuremeter today have a digital control for membrane expansion and loading and unloading cycles. In addition, in situ static loading tests on piles have began to use computer controlled hydraulic pumps. These permit to program loading ramps, duration of constant loading, and unloading and reloading cycles. Besides the obvious advantages of automation, the capacity of applying a rigourously constant force to the pile constitutes an important improvement respect to traditional equipment.

Actually, nowadays technology could allow to reach even higher levels of exploitation of the potential of computers. In particular, it is with no doubts technically possible to set up decision support systems (expert systems), which would be able not only to control the test, but also to decide or suggest autonomously the most adequate form of test execution in relation to the nature and the characteristics of the specimen and of the geotechnical problem that is being tackled. In practice it would be necessary to insert within the control system based on the computer not only the deterministic algorithms which fix the modes of application of the controlled quantities, but also the knowledge and the experience the operator has acquired and that allows him, given a specific situation, to choose the best technical and economical way to achieve the desired result. Many applications developed in other areas (Holsapple and Winston, 1987) ensure the feasibility of such a project, but its development is hindered by the high costs of this kind of systems (estimated to be around one or several hundreds of thousands of US dollars). At the present these costs don't seem to be bearable within a pure market logic, even in the area of research. It is only in the perspective of the precious aid that these systems can provide to personnel training, that such a high cost could be probably justified today.

It must be remembered, however, that the quality of the geotechnical experimentation on the whole depends more on other factors than on the automatic acquisition of data or on equipment fully controlled by a computer. For example, as far as lab experimentation is concerned, the quality of the in situ sampling, the ways of handling and storing the sample, the way the specimen is formed and the correct set up of the equipment, are certainly of much greater importance to obtain a high quality result. Within a global perspective for improving the quality of the geotechnical experimentation, these aspects should certainly to be considered as priorities, compared to those relating to the automatic data acquisition or to the automatic test control, despite the undeniable advantages they offer. In our opinion, therefore, efforts towards improvement should address mainly those aspects that fundamentally control the quality, rather than those regarding the application of computers, letting the latter's fortunes be decided autonomously by the economic laws of the market.

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