

Instrumentation and Geotechnical Measurements on Submarine Contaminated Sediments

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Abstract – In this paper is briefly described an integrated system (hardware and software) for geotechnical measurement on submarine contaminated sediments, which permits to reduce the probability of human mistakes often made during manual operations and, to increase speed, accuracy, and productivity in laboratory tests. The software was developed in LabVIEW to permit the communication with different data acquisition platforms and to simplify an eventual software reconfiguration in the case of changes in laboratory procedures.

I. INTRODUCTION

In the last decades, growing attention has been paid to monitor the sea water quality and coast status; several studies have been carried out to propose new methods and sensors for both accurate measuring of environmental parameters and modelling and analyzing dynamic phenomena closely linked to marine pollution assessment [1]-[7]. At the same time, has become mandatory the need of a rational approach to environmental monitoring requiring the aggregation of data in distributed database able to store all information about each point of interest. All data must be traceable and should permit an efficient processing of such massive data.

The domain of interest for this work falls in the geotechnical characterization of the submarine polluted sediments to define the best strategy for the recovery of the territory. Obviously, this context, accurate measurements on submarine contaminated sediments are of great importance for reducing health risk and preserving the ecosystem. In particular, geotechnical laboratory tests permit to investigate the main mechanical properties of soils, such as compressibility and shear strength. The most common tests are: the Oedometer Test (OT), the Direct Shear Test (DST) and the Triaxial Test (TT) [8].

This paper deals with the development of a dedicated measurement system installed in a suitable geo-

mechanical laboratory, and the results of the experiments carried out on the polluted submarine clayey sediments of the Mar Piccolo in Taranto (South of Italy), shown in Fig. 1, one of the areas declared as “at high risk of environmental crisis” by the Italian government. As well known, this marine basin results highly contaminated, mainly due to heavy metals and organic pollutants carried out from all local industrial activities. The geotechnical investigation involved sediments up to about 20 m below the seafloor, along three vertical profiles in the most polluted area of the Mar Piccolo, facing an Italian Navy base [9], [10].

In the present paper, the implementation of an original automated hardware and software system is described. The system is composed by a purposely developed hardware and software suite of programs, able to acquire and process data coming from different tests for increasing speed and accuracy, reducing the risk of human mistakes and, more in general, to improve the productivity in geotechnical engineering laboratory tests.



Fig. 1 - Gulf of Taranto and the area of Mar Piccolo

The realized framework follows an approach already used by some of the authors in a previous work [11], and aims to overcome such limitations permitting researchers to apply new procedures, sharing results on different platforms giving the development of innovative algorithms to extract information from acquired data [12].

II. TEST PROCEDURES

As known, OT is a soil loading test useful to investigate compression and swelling (i.e. the relationship between effective stress and volumetric strain) or consolidation (i.e. the relationship between compression and seepage), on an undisturbed soil specimen placed in a loading machine. Two classes of test can be distinguished: stress-controlled loading and strain-controlled loading [13], [14]. The test procedure has been standardized in BS 1377-5 [15], and ASTM D2435 [16].

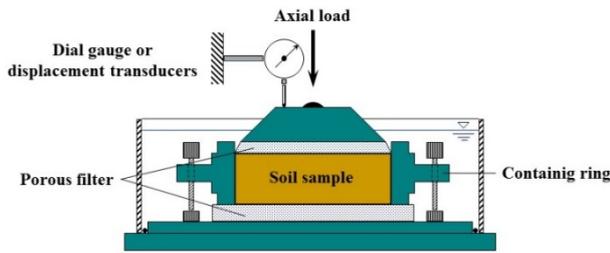


Fig. 2 – Oedometer Test apparatus

During the test period, the compression or the expansion of the specimen under the actual stress is measured by means of a Linear Displacement Transducer LDT, operating on the loading cap and firmly mounted on the machine (Fig. 2).

The DST apparatus is shown in Fig. 3, whereas test procedure is detailed in BS 1377-7 and BS 1377-8 [15] and in ASTM D3080 [17]. The specimen is placed in a metal box (shear box), with porous plates placed below and on top to allow free drainage. The shear force exhibited by the soil is then measured by a load cell, while the corresponding shear displacement together with the change in thickness of the specimen are measured by means of two LDTs, installed on the box and on the loading cap, respectively [13], [14].

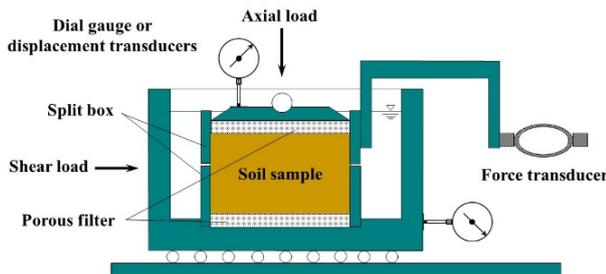


Fig. 3 - Direct shear box

The last test, TT, has the advantages that drainage conditions can be controlled, and pore water pressure measurements can be made [18]. Test procedure is reported in both ASTM and BS codes of practice [19]. The main features of the apparatus are shown in Fig. 4. The simplest TT has two phases that are isotropic compression and shearing. During the first one, the specimen is subjected to an all-round fluid pressure in the

cell and consolidation can take place in a drained test as the pore water could freely drain from the specimen to a volume gauge. The second one is performed until a condition of failure is reached [13], [14], [20], [21]. Five transducers are required to perform this test: two pressure transducers for cell and pore water pressure, a submersible load cell, a volume gauge to measure the volume variation of the specimen through an LDT, and another LDT to measure the axial deformation of the specimen.

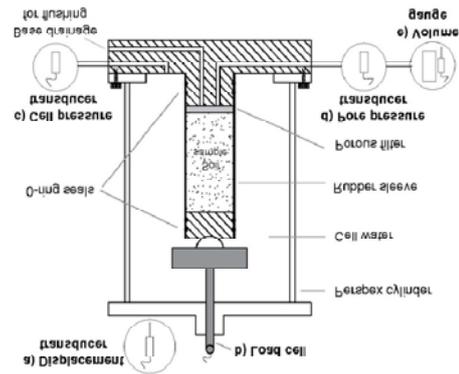


Fig. 4 - Triaxial apparatus

III. HARDWARE AND SOFTWARE OF THE NEW MEASUREMENT SYSTEM

The management software of the new measurement system was developed in LabVIEW® (by National Instruments Corp.), which permits to easily communicate with different platforms of data acquisition and to simplify both the software reconfiguration and the hardware replacement. It represents a helpful tool to manage several testbeds based of the use of instruments and data acquisition boards, ranging from remote sensing [22], [23] energy monitoring [24], up to automotive [25] or devices test and characterization [26], [27] only to make some examples.

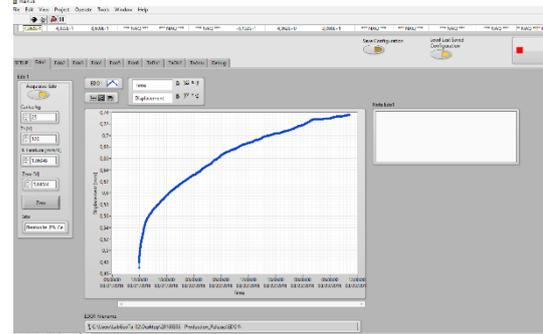


Fig. 5 - Screenshot of developed OT interface

In this specific work, it was chosen to comply the requirements made by the government to deepen the investigation of this polluted site. Normally, software solutions used in the geotechnical laboratories are commonly supplied by the same manufacturer of the data

acquisition hardware, obtaining a “closed” testing equipment. This approach makes the technicians strongly dependent on a specific vendor of hardware/software products and unable to develop their own solutions without large additional costs or time consumption.

Some graphical outputs of the OT and DST measurement systems are shown in Figs. 5 and 6 while the conceptual scheme of the whole measurement apparatus is depicted in Fig. 7.

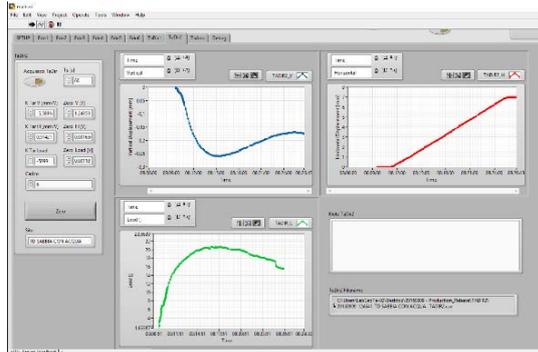


Fig. 6 - Screenshot of developed DST interface

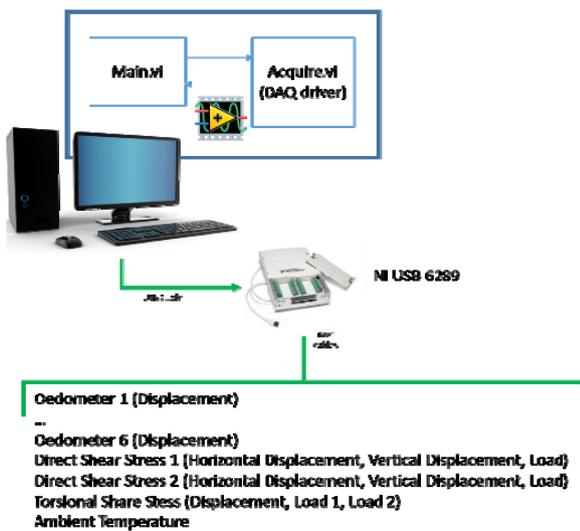


Fig. 7 - Conceptual scheme of the proposed system

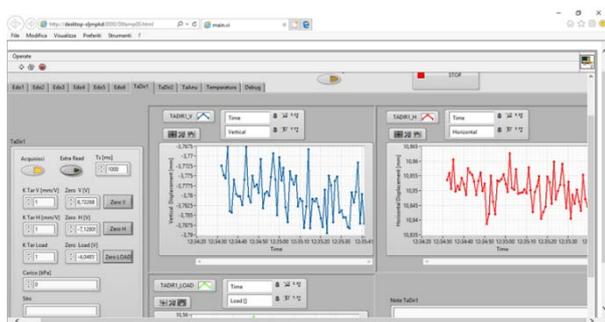


Fig. 8 - Remote management using an internet web browser

Moreover, one of the most interesting feature introduced by the proposed system is the remote test monitoring through networking techniques to minimize the operators' exposition to contaminants during the testing time. Then, different solutions have been developed ranging from the simple monitoring of the test by means of a common web-browser to the full control of the testing interface using web-based or built-in solutions (see Fig. 7). In this work, the main features of the system will be exhaustively described and the ensuing first geotechnical results will be reported as well.

IV. CONCLUSION AND FUTURE WORKS

The system here presented is part of a multidisciplinary survey comprising chemical and physical analysis aimed to recognize eventual pollution of groundwater or contamination of water resources using also environmental monitoring by image analysis [28][29].

The geotechnical models to be derived will be of use for the selection of the most sustainable options for the in-situ remediation.

High accuracy data acquisition with the proposed system is only a first goal of this interdisciplinary research program. Other tasks have to be addressed, in the next future, to build a decision support tool such the automatic identification of specific pattern features or profiles using appropriate data processing and algorithms.

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