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ERGONOMICS OF LABORATORY ROOMS – CASE STUDIES BASED ON THE GEOTECHNICAL LABORATORIES AT THE SILESIAN UNIVERSITY OF TECHNOLOGY

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Abstract
The paper is the first, introductory part to the description of an interdisciplinary research project in the modernization of laboratories at The Faculty of Civil Engineering, The Silesian University of Technology. The scope of the paper is to disseminate the current state of knowledge of ergonomics and issues involved in the technology of laboratory processes, describing the methodology of experiments carried out in geotechnical laboratories, their equipment and spatial requirements in view of the users – research staff. The course and results of the pre-design studies are presented in: PRE-DESIGN STUDIES ON THE EXAMPLE OF THE MODERNIZATION OF GEOTECHNICAL LABORATORIES

Streszczenie
Artykuł stanowi pierwszą, wprowadzającą część do opisu interdyscyplinarnego projektu badawczego związanego z modernizacją pomieszczeń laboratoryjnych na Wydziale Budownictwa Politechniki Śląskiej. Niniejszy tekst przybliża stan wiedzy i problematykę ergonomii związanej z technologią procesów laboratoryjnych, opisuje metodykę badań doświadczalnych realizowanych w pomieszczeniach laboratoriów geotechniki oraz wyposażenie i potrzeby przestrzenne z tym związane z punktu widzenia użytkowników – pracowników naukowych. Przebieg badań przedprojektowych oraz ich wyniki zostały zaprezentowane w artykule pt.: „BADANIA PRZEDPROJEKTOWE NA PRZYKŁADZIE PROJEKTU MODERNIZACJI LABORATORIÓW”.

Keywords: **Ergonomics; Laboratories; Laboratory process technology; Users' needs.**

1. INTRODUCTION: PURPOSE, RESEARCH METHODS AND STATE OF KNOWLEDGE

University laboratories are used for experiments on the level of teaching and research as well as development works, conducted by the staff. One of the most important stages in the development of university laboratories was the technological revolution in the 1970–1980s, spurring the advancement of modern industry, based on the quality of production. New

fields of industry emerged, dependent on the development of technology. In consequence, the dynamic evolution of industry and production technologies led to the development of the fields and directions of science, especially technical sciences. Technical universities began to educate specialists in the fields required by industry. Research and didactic laboratories well designed were essential in the teaching process.

The objective of this paper is to familiarise readers with the issues involving the design of laboratories in consideration of the complexity of laboratory process technologies and the spatial needs from the point of view of their users: research and teaching staff. The applied method of analysis was the case study – the investigation of the facilities (geotechnical laboratories) in view of the ergonomics criteria. The user (research and teaching staff member) is assumed to be an expert who has the practical knowledge of laboratory space and also serves the role of a provider of information [17].

The state of knowledge concerning the issues discussed in this paper refers to two thematic groups. The first group involves publications on the design of laboratory facilities, whereas, the second group are elaborations describing the research conducted in geotechnical laboratories.

1.1. Publications on the design of laboratories

In the last twenty years there were many publications describing and systematizing the issues involved in the design of university laboratories. In Poland, one of the first works was J. Charytonowicz's monograph [1], where the classification of modern laboratories was given, together with the description and presentation, in the form of projections of ergonomics and optimal solutions adjusted to organizational requirements and anthropometrical human needs. Also, D.J. Neumann [2] classified university laboratories in view of their equipment and the needs concerning the process of practical education. Nowadays in Poland many laboratory facilities are created for activities concerning the development of science, research and didactics. Such approach is justified, because the combination of the two processes renders excellent results, first and foremost, in the teaching process. In Western countries such facilities are labeled Research&Development. Their Polish equivalents are technology center, for example, New Technologies Centre at The Silesian University of Technology (Figs. 1-4). The developing and future model of the R&D laboratory facilities was described in DSc. dissertation [3]. The design of laboratory facilities was also discussed by D. Winnicka-Jasłowska in [4, 5].

1.2. Elaborations describing research in geotechnical laboratories

Many experimental works are conducted for the needs of Geotechnology, with the main focus on: identification of the type and condition of soils, designation of their mechanical properties: shear strength and deformation, as well as determination of other parameters essential for proper numerical modeling of the phenomena occurring in the ground exposed to the impact of: load, seismic shocks, or changes in humidity. To achieve these results suitable means are used, i.e. measuring equipment and research methods (tests on soil compacting by means of Proctor apparatus, designation of the grain-size distribution in cohesive soils by means of aerometric analysis, designation of the cohesion and internal friction angle in triaxial apparatus, and direct shear apparatus, and compressibility module in oedometers, Terzaghie's principle for a two-phase medium by carrying out the saturation of soil samples by means of the gravitation method and the back pressure method, etc.). The results of such tests have been described in: [6, 7, 8, 9, 10, 11, 12, 13, 14]. A more detailed description of complicated research procedures may be found in Jastrzębska and Kowalska [15, 16]. The specific nature of experimental tests has an impact on the division and furnishings of the laboratories where such tests are run.

2. METHODOLOGY OF STUDIES ON GEOTECHNICAL LABORATORY FACILITIES, THEIR EQUIPMENT AND ERGONOMIC SPATIAL NEEDS

The basic experimental procedure, irrespective of the type and level of studies, involves the following stages:

1. Preparation of the soil sample. Depending on the type of research, the tests involve: sample drying, watering, toasting, boiling, designation of a moisture content (the essential equipment are: weights and dryers); sample formation and measurements of its geometry (height, diameter, etc.), placement in the experimental chamber;
2. Performance of specific tests: sieve analysis, liquid limit in Cassagrande apparatus or by means of

Figure 1-4.
The building and the modern laboratory space; New Technologies Centre at The Silesian University of Technology, Gliwice, Poland (photos by Joanna Tymkiewicz)

cone-shaped penetrometers, soil compacting properties in Proctor apparatus, shearing force in triaxial apparatus or direct shear apparatus, compacting properties in oedometers, water- permeability;

3. Handwriting of results in the course of the process;
4. Designation of sample essential parameters after testing: a moisture content, geometry;
5. Preparation for the next class, i.e. reports from the tests after two weeks for BSc. courses or comprehensive reports in the form of geotechnical documentation at the end of the semester for MSc. courses.

The geotechnical laboratories are separately dedicated to designate the physical or mechanical properties of soils. Usually, the first stage of tests (concerning the physical properties of soils) is less time consuming and based on uncomplicated apparatuses (sets of sieves, Proctor's apparatus, Cassagrande apparatus, cone-shaped penetrometer) without electronics, and often manually handled. In such case specific tools are required, such as: small evaporators, knives, brushes, chisels, bowls, blades, mixers, etc.

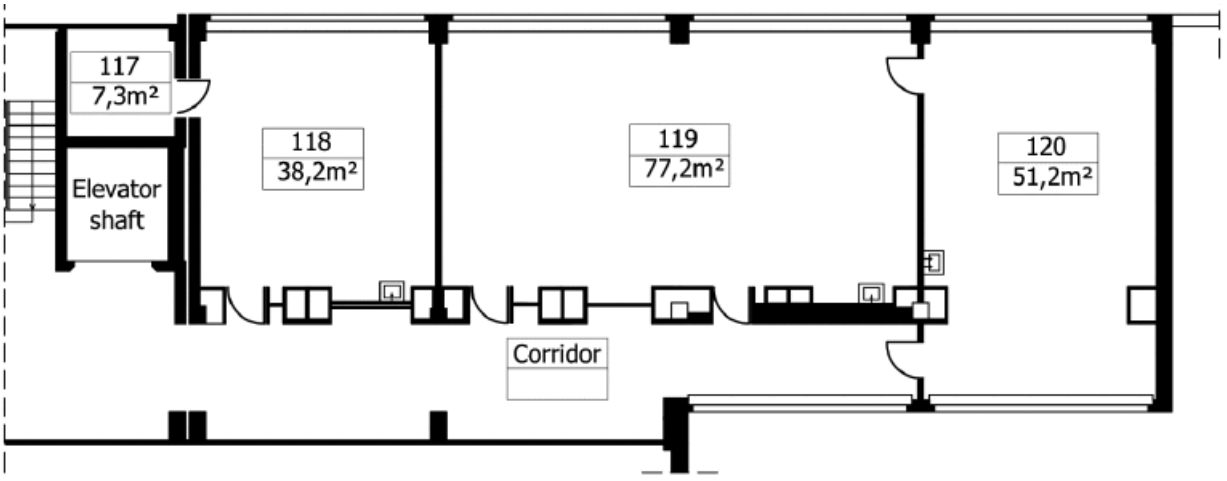

Figure 5.
Scheme of location of geotechnical laboratories (rooms 117L – 120L) at the Faculty of Civil Engineering

In turn, tests on the mechanical properties of soils require specific equipment (triaxial apparatus, direct shear apparatus, oedometers, permeability apparatus) which depends on many additional elements such as: sensors, computers, compressors, compensation vessels, control tables, under pressure pumps and other. At the same time, each of the research stands has its own requirements. For example, an oedometer should be insulated against vibrations, to prevent shocks. A triaxial apparatus requires a separate room with acoustic insulation from compressor that emits loud noise. It should also be stressed that it is necessary to maintain the ambient temperature, as its variations may disturb the operation and readings of precise sensors. Such state may only be achieved by the installation of air-conditioning in a given laboratory room.

The joint need of the determination of the physical and mechanical properties of soils is a direct access to water, vicinity of weights with diverse ranges and to dryers. At each step of the conducted experiment there is a need of repeatable hand washing and working boards cleaning (contact with soil) and the accessory equipment (knives, bowls, evaporators, chisels, etc.) Also, it is essential to carry out frequent measurements of the weight of samples: before tests, in the course of tests, and after tests, in their wet state and after drying.

The Department of Geotechnics and Roads at the Faculty of Civil Engineering, The Silesian University of Technology in Gliwice, houses eight laboratory facilities for geotechnical purposes. Two rooms are located in the cellars of the Laboratory of the Civil Engineering Faculty building, where large-size equipment is placed (destined for renovation and reuse) and oedometers dedicated only for research purposes. Other rooms (110L, 111L, 117L, 118L, 119L 120L) (Fig. 5) are located on the first floor of the same building, with two small rooms having a joint entry (110L i 111L) and functioning as "storage" of older or rarely used equipment.

Room 118L with the internal passage to smaller room 117L is used by the staff of the Department of Geotechnologies and Roads for advanced research on the mechanical properties of soils and supporting their physical properties. The small place is cramped with a number of large size of research apparatuses that require computer assistance. In the central part there is a working board which is a combination of cases and desks. The basic limitation of such arrangement is the lack of direct access to the water source. Also, keeping soil samples, small tools and the entire equipment necessary for the preparation and conduction of tests is cumbersome, random and ineffective. Several persons using room 118L are looking for something and simply clattering the board (so that things can be easily accessible). Moreover, there is no place for social needs. This is particularly inconvenient, especially when the tests should be continually supervised for many hours. It also happens that the staff have to "spend the night" in the laboratory. In the adjacent room 117L, with partially insulated door, there is a compressor that emits considerable noise.

The next two rooms 119L and 120L function as classrooms. In the first one – physical properties of soils are tested (for BSc. courses), in the second one, which is smaller – mechanical properties of soils (for MSc.

courses, English classes for BSc. courses and MSc. diploma students). It would seem that, in consideration of the size of apparatuses, the classes devoted to test on soils compressibility and resistance to the shearing force should be performed in a bigger room. However, this is not so as student groups dealing with the determination of the type and condition of soils are much more numerous (25-35 students) than the other groups (12-25 students). Both teaching rooms face the basic problem of the absence of direct access to the water source and crowded working stands. Even the number of chairs at the desks is often insufficient. It often happens that in the introductory stage students have to sit at working boards, which are higher than average desks and smaller people face problems with note-taking. The introductions often have a form of multi- media presentations supplied by notations on the teaching board. Usually, at the BSc. level two classes are devoted to a comprehensive discussion on future experiments, which students have to perform individually, but under the supervision of a teacher. In turn, for MSc. classes each meeting starts with the introduction in room 119L (which is equipped with a projector and traditional board) and, in the next stage, students move on to room 120L to perform appointed experiments (Figs. 6-7).

The specific nature of geotechnical laboratory classes, which are basically manual activities, requires frequent hand washing, boards cleaning, supporting tools and apparatuses clearing, as well as cleaning and ordering of the surroundings (for example, in the case of Proctor tests the beating of soil at a certain moisture content makes splashes). Likewise, the same needs come up in the process of research tests. Therefore, it is not important who performs the tests. Only in the case of teaching classes the range of tests and simplification methods are selected to make it possible for students to perform them during one class. For the BSc. courses the allotted time is 1,5 hours, whereas for the MSc. courses it is 4 hours. But, for research staff the time is unlimited. Their priority is the precision of the test, the level of detailed performance and the need of designating specific parameters and their mutual dependence. The tests are very time-consuming. Some of them may last even two to three months. Certainly, in such cases the load of work and physical presence in the laboratory is different, depending on the stage of research. Nonetheless, this is a demanding and long-term process. Thus, such ordinary matters as the comfort of chairs and possibility of heating up meals in the microwave seem to be important.

Figure 6.
Room 119L (Classroom) for examination of soil physical parameters: on the right side working tables with Cassagrande apparatuses; further, way to room; (photo by Joanna Tymkiewicz)

Figure 6.
Room 120L (Classroom) for examination of soil mechanical parameters: in the background triaxial test emplacement; (photo by Joanna Tymkiewicz)

4. RECAPITULATION OF THE NEEDS CONCERNING THE ERGONOMICS OF LABORATORY SPACES AND CONCLUSIONS

To sum up, in the ergonomic needs of geotechnical laboratories, the following issues should be considered:

- Number and vicinity of water sources,
- Next to the water source and dryers there should be a place for steam removers and other equipment,
- The working boards should be set in a manner that makes use of daylight and provision of proper artificial light,
- The furnishings should provide proper separation of small laboratory equipment and easy access to it;
- Movable furniture should be used, for example: between the rooms, or to facilitate the transport of soils with considerable weight;
- A social back up place should be provided for long-term research.

The above description indicates the complexity of research and work processes in geo-technology. The knowledge of laboratory process technologies enables the programming and devising a proper design project for the modernization of the laboratories. Without a strict cooperation of architects with direct users of the described facilities the definition of the project would be impossible. In the paper entitled: PRE-DESIGN STUDIES ON THE EXAMPLE OF MODENIZATION PROJECT OF GEOTECHNICAL LABORATORIES the stages of the pre-design studies were discussed for the project and its final results.

REFERENCES

[1] Charytonowicz J. (1994). Zasady kształtowania laboratoryjnych stanowisk pracy (Principles of shaping laboratory work stands). Monograph. Wrocław: Publishing House of Wrocław Technical University, (in Polish).

[2] Kliment S.A. (2003). Series Founder and Editor, Neuman D.J.; Building Type Basics for College and University Facilities. Canada: John Wiley&Sons.inc.

[3] Cieśla-Gałeczka K. (2012). Kształtowanie współczesnych funkcji nauki oraz ich rola w przestrzeni miejskiej. Wybrane obiekty (Shaping of modern functions of science and their role in city space. Selected objects). Ph.D. dissertation, supervised by N. Juzwa, Faculty of Architecture, The Silesian University of Technology. Gliwice (in Polish).

[4] Winnicka-Jasłowska D. (2012). Creating a functional and special program for a new building of the Faculty of the Biomedical Engineering, The Silesian University of Technology. *Architecture Civil Engineering Environment 5*(3), Gliwice.

[5] Winnicka-Jasłowska D. (2014). Ergonomic Solutions of Facilities and Laboratory Work-Stands at Universities. Programming of Ergonomic Technological Lines – Case Study, [in:] Universal access in human-computer interaction. 8th International Conference UAHCI 2014, held as part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014. Proceedings. Pt. 4, Design for all and accessibility practice, (eds.) Constantine Stephanidis, Margherita Antona. Cham: Springer, 2014, Lecture Notes in Computer Science 8516.

[6] Gryczmański M. (2009). State of the art in modelling of soil behaviour at small strains. *Architecture Civil Engineering Environment 2*(1), 61–80.

[7] Jastrzębska M., Łupieżowiec M., Uliniarz R., Jaroń A. (2014). Analysis of the vibration propagation in the subsoil, *Studia Geotechnica et Mechanical XXXVI*(3), 9–18.

[8] Jastrzębska M. (2010). Badania zachowania się gruntów spoistych poddanych obciążeniom cyklicznym w zakresie małych odkształceń (Investigations of the behaviour of cohesive soils subjected to cyclic loads in the area of small deformations). Scientific Journals of The Silesian University of Technology, Gliwice, Poland, 216 (in Polish).

[9] Jastrzębska M. (2002). Kalibrowanie i weryfikacja jednopowierzchniowego sprężysto-plastycznego modelu gruntu o silnie nieliniowym wzmocnieniu anizotropowym (Calibration and verification of a single surface elasto-plasic model for soil with strongly nonlinear anisotropic hardening law), PhD thesis, Department of Geotechnics, The Silesian University of Technology, Gliwice (in Polish).

[10] Jastrzębska M. (2010). The external and internal measurement effect on shear modulus distribution within cyclic small strains in triaxial studies on cohesive soil. Proc. International Conference on Experimental Mechanics ICEM14 Poitiers, France, *EDP Sciences*, *a*, 1–8.

[11] Kalinowska M., Jastrzębska M. (2014). Behaviour of cohesive soil subjected to low-frequency cyclic loading in strain-controlled tests, *Studia Geotechnica et Mechanica XXXVI*(3), 21–34.

[12] Kalinowska M. (2013). Określenie kryterium zniszczenia w gruntach spoistych poddanych wolnozmiennym obciążeniom cyklicznym (Determination of the destruction criterion for cohesive soils subjected to slow cyclic loads). MSc thesis supervised by M. Jastrzębska, Faculty of Civil Engineering, The Silesian University of Technology. Gliwice (in Polish).

[13] Konsek Sz., Walas M. (2010). Badania zachowania się gruntów spoistych poddanych obciążeniu cyklicznemu w aparacie trójosiowym oraz w aparacie bezpośredniego ścinania (Tests on the behaviour of cohesive soils subjected to cyclic loads by means of a triaxial apparatus and direct shear apparatus). MSc thesis supervised by M. Jastrzębska, Faculty of Civil Engineering, The Silesian University of Technology. Gliwice (in Polish).

[14] Kowalska M. (2009). Identyfikacja parametryczna modeli gruntów w zagadnieniach geotechniki (Parametric identification of soil models in geotechnical problems), PhD thesis, Department of Geotechnics, The Silesian University of Technology, Gliwice (in Polish).

[15] Jastrzębska M., Kowalska M. (2016). Triaxial tests on weak cohesive soils – some practical remarks (part 2). *Architecture Civil Engineering Environment 9*(3), 81–94.

[16] Kowalska M., Jastrzębska M. (2016). Triaxial tests on weak cohesive soils – some practical remarks (part 1). *Architecture Civil Engineering Environment 9*(3), 71–80.

[17] Krzyk P. (2013). Parametry wytrzymałościowe gruntów spoistych na podstawie badań w aparacie bezpośredniego ścinania i w aparacie trójosiowym (Strength parameters of cohesive soils on the grounds of direct shear apparatus and triaxial apparatus). MSc thesis supervised by M. Jastrzębska, Faculty of Civil Engineering, The Silesian University of Technology. Gliwice (in Polish).